Appendices

Appendix A

Glossary of terms used for the coho and Chinook salmon population models

Appendix A. Glossary of terms used for the coho and Chinook salmon population models.

Terms	Definitions
Beverton-Holt model	Stock-production model that the user may select within the population dynamics models. It is a model commonly used in management of Pacific salmon, based on Beverton and Holt (1957). This model allows production to increase until reaching a certain stock level; above this stock level, production remains constant, at the limit defined by the carrying capacity, K. The population dynamics models allow the user to choose between two versions: Version 1 is the "original" form; Version 2 is a form that allows production to approach carrying capacity at a faster rate (i.e., it allows a steeper curve).
Carrying capacity, K	A density-dependent term used in stock-production models that represents the population size limit for a given life-stage. This term represents density-dependent factors such as spawning gravel area, or abundance of over-wintering refugia.
Cohort	Members of a life-stage that were spawned in the same year.
Density-dependent	Factors affecting the population that are dependent on the population size, such as habitat area.
Density-independent	Factors affecting the population regardless of population size, such as temperature, disease, or stranding.
Hockey stick model	A stock-production model that is a piece-wise linear function with a slope of r for the density-independent phase, and with a slope of zero for the density-dependent phase (once reaching carrying capacity) (Barrowman and Myers 2000).
Rate of population increase, *r*	An input parameter needed in stock-production models. It is a density-independent term that represents the net effect of births and/or deaths, resulting from factors such as fecundity, or dependence of egg survival on spawning gravel quality. Depending on the life-stage of interest and the stock-production model selected, the input parameter *r* represents the fraction of adults spawning, fecundity, or density-independent survival rate.
Linear model	A stock-production model that the user may select within the population dynamics models. This stock-production model assumes a linear relationship between two life-stages, where *r* is the slope of the line.
Life-stage	Temporal stages (or intervals) of a fish's life that have distinct anatomical, physiological, and/or functional characteristics that contribute to potential differences in use of the environment.

Life-step	Interval between a production and stock life-stage (i.e., adult to female spawner)
Production	Output from a stock-production model at a particular life-step.
Stock	Input value required by the stock-production models. It is the first required value entered into the population dynamics model spreadsheets; for example, stock would be the number of fry, for a fry-to-juvenile step.
Stock-production model	Relates the number of individuals P in some cohort at one development stage, as a function (F) of the number of individuals S in that cohort at an earlier development stage: $P = F(S)$. The population dynamics models allow the user to choose from the following four stock-production models: (1) Linear (2) Hockey stick, (3) Beverton-Holt 1 (Beverton and Holt 1957), 4) Beverton-Holt 2, and (5) Superimposition.
Superimposition model	A stock-production model that the user may select within the population dynamics models. The values for this model are based on fecundity, suitable spawning gravel area, and average redd size. This model is used to estimate the number of deposited eggs based on the number of female spawners.

Appendix B

Coho salmon population dynamics model parameters and values under current conditions in the Mill Creek Study Area.

Appendix B. Coho salmon population dynamics model parameters and values under current conditions in the Mill Creek Study Area.

Sub reach	Life-stage	Parameter	Value	Source	Comments
Initial population size	**Returning adults to mainstem Mill Creek as female spawners**	Sex ratio (females to males)	1:1	Howard and McLeod (2005a)	Approximately 1:1 sex ratio based on spawning survey data
		Pre-spawning survival	1.0	Assumption	Assumed pre-spawning survival was typically high
		Proportion of female spawners to the West Branch	0.5	Howard and McLeod (2005a)	Proportion of female spawners default based on spawning survey results; assumes one female per redd.
		Proportion of female spawners to the East Fork	0.5	Howard and McLeod (2005a)	Proportion of female spawners default based on spawning survey results (Howard and McLeod 2005); assumes one female per redd.
West Branch sub reach	**Female spawner to deposited eggs**	Suitable spawning gravel area	3,010 m^2	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Based on densities of observed spawners and reconnaissance-level mapping of West Branch, 2005 field visit.
		Mean redd area	2.8 m^2	Burner (1951)	Mean redd area based on literature
		Fecundity	2,300	Rowdy Creek Hatchery (1998, unpubl. data)	Assumed fecundity of 2,300 eggs/female based on Rowdy Creek Hatchery data (1993 to 1998)
	Deposited eggs to emergent fry	Survival rate	0.5	Assumption	Assumed to be 0.5, conservative estimate given likely high gravel quality in West Branch (Waldvogel 2005).
	Emergent fry to early summer 0+	Maximum fry density	2.5 fish/m^2	C. Howard (2006, unpublished data)	These data were used to form a product of 25,000 fish, the estimated carrying capacity based on graphical analysis of 0+juveniles versus emergent fry.
		Suitable habitat area	10,000 m^2		
		Density-independent survival rate	0.8	Howard and McLeod (2005b)	Density-independent survival rate assumed high; potential losses due to disease and predation.
	Early summer 0+ fry to late summer 0+	Density-independent survival rate	0.8	C. Howard (2006, unpubl. data)	Density-independent survival rate based on potential losses due to stranding.
	Late summer 0+ to spring 1+ smolts	Maximum juvenile density	0.35	Howard and McLeod (2005b)	Product used to match carrying capacity determined from graphical analysis of 1+ smolts versus 0+ juveniles.
		Suitable habitat area	15,800 m^2		
		Density-independent survival rate	0.8	Assumption	Assumed density-independent survival to be high; majority of winter mortality is likely due to density-dependent effects which happen during peak flow events.
East fork sub reach	**Female spawner to deposited eggs**	Suitable spawning gravel area	3,340 m^2	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Based on densities of observed spawners and reconnaissance-level mapping of East Fork, 2005 field visit.

Sub reach	Life-stage	Parameter	Value	Source	Comments
		Mean redd area	2.8 m^2	Burner (1951)	Mean redd area based on literature
		Fecundity	2,300	Rowdy Creek Hatchery (1998, unpubl. data)	Assumed fecundity of 2,300 eggs/female based on Rowdy Creek Hatchery data (1993 to 1998)
	Deposited eggs to emergent fry	Survival rate	0.1	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Assumed to be 0.1, estimate based on likely low gravel quality in East Fork, based on ocular estimate from field visit.
	Emergent fry to early summer 0+	Maximum fry density	0.51 fish/m^2	C. Howard (2006, unpubl. data)	Product of density and area to match the estimated carrying capacity from graphical analysis of 0+ versus expected emergent fry.
		Suitable habitat area	23,700 m^2		
		Density-independent survival rate	0.8	Howard and McLeod (2005a, 2005b)	Density-independent survival rate assumed high; potential losses due to disease and predation.
	Early summer 0+ to late summer 0+	Density-independent survival rate	0.9	Assumption	Density-independent survival rate assumed to be high; summer mortality assumed to be low.
	Late summer 0+ to 1+spring smolts	Maximum juvenile density	0.1 fish/m^2	C. Howard (2006, unpubl. data)	Product matches carrying capacity determined from time series of 1+ trapping estimates, highest estimates.
		Suitable habitat area	23,700 m^2		
		Density-independent survival rate	0.8	Assumption	Professional judgment.
Downstream of West Branch and North Fork	**Migrant emergent fry from upstream to adults produced from emergent fry**	Density-independent survival rate	0.0001	Assumption	
	Migrant early summer 0+ from upstream to adults produced from migrant early summer 0+	Density-independent survival rate	0.001	Assumption	
	Migrant late summer 0+ juveniles from upstream to adults produced from late summer 0+ juveniles	Density-independent survival rate	0.005	Assumption	
	Spring 1+ smolts from upstream to adults produced from spring 1+	Density-independent survival rate	0.032	Chris Howard (2006, unpubl. data)	Survival based on ratio of returning adults to the estimate of smolts (from both branches/forks) two years prior, adults returning from WY 1997 to 2004.

Sub reach	Life-stage	Parameter	Value	Source	Comments
	smolts				

Appendix C

Chinook salmon population dynamics model parameters and values under current conditions in the Mill Creek Study Area.

Appendix C. Fall Chinook salmon population dynamics model parameters and values under current conditions in the Mill Creek Study Area.

Sub reach	Life-stage	Parameter	Value	Source	Comments
Initial population size	**Returning adults to mainstem Mill Creek to total female spawners**	Proportion of females	0.5	Waldvogel (2005)	Based on observed sex ratio of 1.1 to 1 (females to males) in the West Branch of Mill Creek, 1980 to 2002.
		Pre-spawning survival	0.8	Assumption	Pre-spawning survival assumed high, since Mill Creek is relatively low in the Smith River watershed.
		Proportion of female spawners to the West Branch	0.5	C. Howard (2006, unpubl. data)	Average fraction of spawner based on data from WY 1995 to 2005.
		Proportion of female spawners to the East Fork	0.5		
West Branch sub reach	**Female spawner to deposited eggs**	Suitable spawning gravel area	4840 m^2	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Based on densities of observed spawners and reconnaissance-level mapping of West Branch, 2005 field visit.
		Mean redd area	4.5 m^2	Burner (1951)	Mean redd area based on literature.
		Fecundity	3,900	Rowdy Creek Hatchery (1998, unpubl. data)	Assumed fecundity of 3,900 eggs/female based on Rowdy Creek Fish Hatchery data from WY 1994 to 1998.
	Deposited eggs to emergent fry	Survival rate	0.5	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Based on visual assessment of gravel quality observed during field reconnaissance visit in 2005.
	Emergent fry to 0+ smolts (> 55 mm)	Maximum fry density	0.6 fish/m^2	C. Howard (2006, unpubl. data)	Density and suitable habitat area parameterized to produce 6,000 0+ smolts, carrying capacity determined from graph of 0+ smolts versus emergent fry.
		Suitable habitat area	10,000 m^2		
		Density-independent survival rate	0.8	Assumption	Density-independent survival assumed to be high; mortality primarily due to density-dependent effects.
East Fork sub reach	**Female spawner to deposited eggs**	Suitable spawning gravel area	5360 m^2	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Based on densities of observed spawners and reconnaissance-level mapping of West Branch, 2005 field visit.
		Mean redd area	4.5 m^2	Burner (1951)	Mean redd area based on literature.
		Fecundity	3,900	Rowdy Creek Hatchery (1998, unpubl. data)	Assumed fecundity of 3,900 eggs/female based on Rowdy Creek Fish Hatchery data from WY 1994 to 1998.

Sub reach	Life-stage	Parameter	Value	Source	Comments
	Deposited eggs to emergent fry	Survival rate	0.1	Field reconnaissance data (Stillwater Sciences 2005, unpubl. data)	Based on visual assessment of gravel quality observed during field reconnaissance visit in 2005.
	Emergent fry to 0+ smolts (> 55 mm)	Maximum fry density	0.5 fish/m^2	C. Howard (2006, unpubl. data)	Density and suitable habitat area parameterized to produce 5,000 0+ smolts, carrying capacity determined from graph of 0+ smolts versus emergent fry.
		Suitable habitat area	10,000 m^2		
		Density-independent survival rate	0.8	Assumption	Density-independent survival assumed to be high; mortality primarily due to density-dependent effects.
Below West Branch and East Fork	**Migrant emergent fry from upstream to returning adults**	Density-independent survival rate	0.0001	Assumption	Survival assumed to be low.
	0+ smolts from upstream to returning adults	Density-independent survival rate	0.024	C. Howard (2006, unpubl. data)	Based on the ratio of 3-year old returning adults to number of 0+ smolts (>55 mm FL).

Appendix D

Model sensitivity analyses, coho salmon population model, Mill Creek.

Appendix D. Model sensitivity analyses, coho salmon population model, Mill Creek.

Table D-1. Based on current conditions.

Relation	Parameter	Parameter values					One-step responses					Steady-state responses				
Adults returning to Mill Creek to total female spawners	Proportion of Females	0 25	0 38	0 50	0 67	1 00	318	331	337	339	344	317	331	337	339	344
	Pre-spawning survival	0 50	0 75	1 00	1 33	2 00	318	331	337	339	344	317	331	337	339	344
Total female spawners to West Branch female spawners	Proportion of Spawners to West Branch	0 25	0 38	0 50	0 67	1 00	334	335	337	331	240	334	335	337	331	236
West Branch female spawners to deposited eggs	Suitable spawning gravel area (m²)	1505	2258	3010	4012	6020	336	337	337	337	337	336	337	337	337	337
	Mean redd area (m²)	1 40	2 10	2 80	3 73	5 60	337	337	337	337	336	337	337	337	337	336
	Fecundity (#eggs/female)	1150	1725	2300	3066	4600	333	335	337	339	344	333	335	337	339	344
West Branch, Deposited eggs to emergent fry	Density-independent survival	0 25	0 38	0 50	0 67	1 00	333	335	337	339	344	333	335	337	339	344
West Branch, Emergent fry to early summer 0+	Suitable habitat area (m²)	5000	7500	10000	13330	20000	298	317	337	363	414	297	317	337	363	416
	Density (fish/m²)	1 25	1 88	2 50	3 33	5 00	298	317	337	363	414	297	317	337	363	416
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	333	335	337	339	339	333	335	337	339	339
West Branch, Early summer 0+ to late summer 0+	Density-independent survival	0 40	0 60	0 80	1 07	1 60	297	317	337	357	357	296	316	337	357	357
West Branch, Late summer 0+ to spring 1+ smolts	Suitable habitat area (m²)	7900	11850	15800	21061	31600	262	299	337	387	486	257	299	337	388	490
	Density (fish/m²)	0 18	0 26	0 35	0 47	0 70	262	299	337	387	486	257	299	337	388	490
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	297	317	337	357	357	296	316	337	357	357
East Fork female spawners to deposited eggs	Suitable spawning gravel area (m²)	1670	2505	3340	4452	6680	337	337	337	337	337	337	337	337	337	337
	Mean redd area (m²)	1 40	2 10	2 80	3 73	5 60	337	337	337	337	337	337	337	337	337	337
	Fecundity (#eggs/female)	1150	1725	2300	3066	4600	321	332	337	337	338	319	332	337	337	338
East Fork, Deposited eggs to emergent fry	Density-independent survival	0 05	0 08	0 10	0 13	0 20	321	332	337	337	338	319	332	337	337	338
East Fork, Emergent fry to early summer 0+	Suitable habitat area (m²)	11850	17775	23700	31592	47400	318	327	337	344	344	318	327	337	345	345
	Density (fish/m²)	0 26	0 38	0 51	0 68	1 02	318	327	337	344	344	318	327	337	345	345
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	321	332	337	337	337	319	332	337	337	337
East Fork, Early summer 0+ to late summer 0+	Density-independent survival	0 40	0 60	0 80	1 07	1 60	317	327	337	346	346	317	327	337	347	347
East Fork, Late summer 0+ to spring 1+ smolts	Suitable habitat area (m²)	11850	17775	23700	31592	47400	305	321	337	358	401	304	320	337	359	402
	Density (fish/m²)	0 05	0 08	0 10	0 13	0 20	305	321	337	358	401	304	320	337	359	402
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	317	327	337	346	346	317	327	337	347	347
Below West Branch and East Fork, Migrant emergent fry from upstream to adults produced from emergent fry	Density-independent survival	0 0001	0 0001	0 0001	0 0001	0 0002	334	336	337	338	342	334	336	337	338	342
Below West Branch and East Fork, Migrant early summer 0+ from upstream to adults produced from migrant early summer 0+	Density-independent survival	0 0005	0 0008	0 0010	0 0013	0 0020	337	337	337	337	337	337	337	337	337	337
Below West Branch and East Fork, Migrant late summer 0+ juveniles from upstream to adults produced from late summer 0+ juveniles	Density-independent survival	0 0025	0 0038	0 0050	0 0067	0 0100	297	317	337	363	416	296	317	337	364	418
Below West Branch and East Fork, Spring 1+ smolts from upstream to adults produced from spring 1+ smolts	Density-independent survival	0 02	0 02	0 03	0 04	0 06	210	274	337	421	590	196	271	337	423	595

Appendix D. Model sensitivity analyses, coho salmon population model, Mill Creek.

Table D-2. Based on revised marine conditions (survival from 1+ smolt to adult of 0.006).

Relation	Parameter	Parameter values					One-step responses					Steady-state responses				
Adults returning to Mill Creek to total female spawners	Proportion of Females	0 25	0 38	0 50	0 67	1 00	29	42	55	71	101	0	0	55	109	125
	Pre-spawning survival	0 50	0 75	1 00	1 33	2 00	29	42	55	71	101	0	0	55	109	125
Total female spawners to West Branch female spawners	Proportion of Spawners to West Branch	0 25	0 38	0 50	0 67	1 00	38	47	55	64	83	0	0	55	97	87
West Branch female spawners to deposited eggs	Suitable spawning gravel area (m²)	1440	2160	2880	3839	5760	54	54	55	55	55	50	53	55	56	57
	Mean redd area (m²)	1 40	2 10	2 80	3 73	5 60	55	55	55	54	54	57	56	55	53	50
	Fecundity (#eggs/female)	1150	1725	2300	3066	4600	33	45	55	68	94	0	0	55	103	105
West Branch, Deposited eggs to emergent fry	Density-independent survival	0 25	0 38	0 50	0 67	1 00	33	45	55	68	94	0	0	55	103	105
West Branch, Emergent fry to early summer 0+	Suitable habitat area (m²)	5000	7500	10000	13330	20000	55	55	55	55	55	55	55	55	55	55
	Density (fish/m²)	1 25	1 88	2 50	3 33	5 00	55	55	55	55	55	55	55	55	55	55
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	33	45	55	64	64	0	0	55	103	103
West Branch, Early summer 0+ to late summer 0+	Density-independent survival	0 40	0 60	0 80	1 07	1 60	33	45	55	64	64	0	0	55	126	126
West Branch, Late summer 0+ to spring 1+ smolts	Suitable habitat area (m²)	7900	11850	15800	21061	31600	52	53	55	56	57	29	42	55	70	96
	Density (fish/m²)	0 18	0 26	0 35	0 47	0 70	52	53	55	56	57	29	42	55	70	96
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	33	45	55	64	64	0	0	55	126	126
East Fork female spawners to deposited eggs	Suitable spawning gravel area (m²)	1200	1800	2400	3199	4800	54	54	55	55	55	53	54	55	55	55
	Mean redd area (m²)	1 40	2 10	2 80	3 73	5 60	55	55	55	54	54	55	55	55	54	53
	Fecundity (#eggs/female)	1150	1725	2300	3066	4600	50	52	55	58	63	0	39	55	87	123
East Fork, Deposited eggs to emergent fry	Density-independent survival	0 05	0 08	0 10	0 13	0 20	50	52	55	58	63	0	39	55	87	123
East Fork, Emergent fry to early summer 0+	Suitable habitat area (m²)	11850	17775	23700	31592	47400	55	55	55	55	55	55	55	55	55	55
	Density (fish/m²)	0 26	0 38	0 51	0 68	1 02	55	55	55	55	55	55	55	55	55	55
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	50	52	55	57	57	0	39	55	79	79
East Fork, Early summer 0+ to late summer 0+	Density-independent survival	0 40	0 60	0 80	1 07	1 60	50	52	55	57	57	0	39	55	79	79
East Fork, Late summer 0+ to spring 1+ smolts	Suitable habitat area (m²)	11850	17775	23700	31592	47400	54	55	55	55	55	52	55	55	55	55
	Density (fish/m²)	0 05	0 08	0 10	0 13	0 20	54	55	55	55	55	52	55	55	55	55
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	50	52	55	57	57	0	39	55	79	79
Below West Branch and East Fork, Migrant emergent fry from upstream to adults produced from emergent fry	Density-independent survival	0 0001	0 0001	0 0001	0 0001	0 0002	55	55	55	55	55	55	55	55	55	55
Below West Branch and East Fork, Migrant early summer 0+ from upstream to adults produced from migrant early summer 0+	Density-independent survival	0 0005	0 0008	0 0010	0 0013	0 0020	55	55	55	55	55	55	55	55	55	55
Below West Branch and East Fork, Migrant late summer 0+ juveniles from upstream to adults produced from late summer 0+ juveniles	Density-independent survival	0 0025	0 0038	0 0050	0 0067	0 0100	49	52	55	59	66	42	44	55	125	180
Below West Branch and East Fork, Spring 1+ smolts from upstream to adults produced from spring 1+ smolts	Density-independent survival	0 00	0 00	0 01	0 01	0 01	33	44	55	69	97	0	0	55	121	158

Appendix E

Model sensitivity analysis, Chinook salmon population model, Mill Creek (based on current conditions).

Appendix E. Model sensitivity analysis, Chinook salmon population model, Mill Creek (based on current conditions).

Relation	Parameter	Parameter values					One-step responses					Steady-state responses				
Adults returning to Mill Creek to total female spawners	Proportion of Females	0 26	0 39	0 52	0 70	1 05	270	273	276	281	289	270	273	276	281	290
	Pre-spawning survival	0 50	0 75	1 00	1 33	2 00	270	273	276	281	289	270	273	276	281	290
Total female spawners to West Branch female spawners	Proportion of Spawners to West Branch	0 25	0 38	0 50	0 67	1 00	273	275	276	278	279	273	275	276	278	280
West Branch female spawners to deposited eggs	Suitable spawning gravel area (m^2)	2420	3630	4840	6452	9680	276	276	276	276	276	276	276	276	276	276
	Mean redd area (m^2)	2 25	3 38	4 50	6 00	9 00	276	276	276	276	276	276	276	276	276	276
	Fecundity (#eggs/female)	1950	2925	3900	5199	7800	271	274	276	280	288	271	274	276	280	289
West Branch, Deposited eggs to emergent fry	Density-independent survival	0 25	0 38	0 50	0 67	1 00	271	274	276	280	288	271	274	276	280	289
West Branch, Emergent fry to 0+ smolts	Suitable habitat area (m^2)	5000	7500	10000	13330	20000	205	241	276	324	420	201	239	276	327	427
	Density (fish/m^2)	0 30	0 45	0 60	0 80	1 20	205	241	276	324	420	201	239	276	327	427
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	271	274	276	279	279	271	274	276	279	279
East Fork female spawners to deposited eggs	Suitable spawning gravel area (m^2)	2680	4020	5360	7145	10720	276	276	276	276	276	276	276	276	276	276
	Mean redd area (m^2)	2 25	3 38	4 50	6 00	9 00	276	276	276	276	276	276	276	276	276	276
	Fecundity (#eggs/female)	1950	2925	3900	5199	7800	275	276	276	277	279	275	276	276	277	279
East Fork, Deposited eggs to emergent fry	Density-independent survival	0 05	0 08	0 10	0 13	0 20	275	276	276	277	279	275	276	276	277	279
East Fork, Emergent fry to 0+ smolts	Suitable habitat area (m^2)	5000	7500	10000	13330	20000	217	247	276	316	396	214	245	276	318	402
	Density (fish/m^2)	0 25	0 38	0 50	0 67	1 00	217	247	276	316	396	214	245	276	318	402
	Density-independent survival	0 40	0 60	0 80	1 07	1 60	275	276	276	277	277	275	276	276	277	277
Below West Branch and East Fork, Migrant emergent fry from upstream to returning adult	Ocean survival	0 0001	0 0001	0 0001	0 0001	0 0002	270	273	276	281	289	270	273	276	281	290
Below West Branch and East Fork, 0+ smolts from upstream to returning adult	Ocean survival	0 01	0 02	0 02	0 03	0 05	144	210	276	364	540	138	207	276	369	554

From: Staples, Rose
Sent: Monday, October 10, 2011 5:03 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: Don Pedro RWG Meeting Reference - Mill Creek Model link Not Working- Have Uploaded to Website

I understand several of you experienced problems downloading the document using the "Mill Creek Model" link I forwarded earlier today. I was able to download a copy—and have now uploaded it to the Don Pedro Relicensing website (www.donpedro-relicensing.com) under the ANNOUNCEMENT tab. Thank you.

ROSE STAPLES
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Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Thursday, October 13, 2011 7:22 PM
To: 'Alves, Jim - City of Modesto'; 'Anderson, Craig - USFWS'; 'Asay, Lynette - N-R'; 'Aud, John - SCERD'; 'Barnes, James - BLM'; 'Barnes, Peter - SWRCB'; 'Beuttler, John - CSPA'; 'Blake, Martin'; 'Bond, Jack - City of Modesto'; 'Boucher, Allison - TRC'; 'Boucher, Dave - Allison - TRC'; 'Bowes, Stephen - NPS'; 'Bowman, Art - CWRMP'; 'Brenneman, Beth - BLM'; 'Brewer, Doug - TetraTech'; 'Brochini, Anthony - SSMN'; 'Brochini, Tony - NPS'; 'Buckley, John - CSERC'; 'Buckley, Mark'; 'Burley, Silvia-CVMT'; 'Burt, Charles - CalPoly'; 'Cadagan, Jerry'; 'Carlin, Michael - SFPUC'; 'Catlett, Kelly - FOR'; 'Charles, Cindy - GWWF'; 'Cismowski, Gail - SWRCB'; 'Costa, Jan - Chicken Ranch'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob - TBMWI'; 'Cranston, Peggy - BLM'; 'Cremeen, Rebecca - CSERC'; 'Day, Kevin - TBMI'; 'Day, P - MF'; 'Denean - BVR'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne - OHP'; 'Dowd, Maggie-SNF'; 'Drekmeier, Peter - TRT'; 'Edmondson, Steve - NOAA'; 'Eicher, James - BLM'; 'Fety, Lauren - BLM'; 'Findley, Timothy - Hanson Bridgett'; 'Freeman, Beau - CalPoly'; 'Fuller, Reba - TMTC'; 'Furman, Donn W - SFPUC'; 'Ganteinbein, Julie - Water-Power Law Grp'; 'Giglio, Deborah - USFWS'; 'Goode, Ron - NFMT'; 'Gorman, Elaine - YSC'; 'Grader, Zeke'; 'Gutierrez, Monica - NOAA-NMFS'; 'Hackamack, Robert'; 'Hastreiter, James L - FERC'; 'Hatch, Jenny - CT'; 'Hayat, Zahra - MF'; 'Hayden, Ann'; 'Hellam, Anita - HH'; 'Heyne, Tim - CDFG'; 'Holden, James '; 'Holm, Lisa'; 'Horn, Jeff - BLM'; 'Horn, Tini'; 'Hudelson, Bill - StanislausFoodProducts'; 'Hughes, Noah'; 'Hughes, Robert - CDFG'; 'Hume, Noah - Stillwater'; 'Jackman, Jerry '; 'Jackson, Zac - USFWS'; 'Jennings, William - CSPA'; 'Jensen, Art - BAWSCA'; 'Jensen, Laura - TNC'; 'Johannis, Mary'; 'Johnson, Brian - CalTrout'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn - NOAA-MNFS'; 'Kinney, Teresa'; 'Koepele, Patrick - TRT'; 'Kordella, Lesley - FERC'; 'Lein, Joseph'; 'Levin, Ellen - SFPUC'; 'Lewis-Reggie-PRCI'; 'Linkard, David - TRT /RH'; 'Looker, Mark - LCC'; Loy, Carin; 'Lwenya, Roselynn, BVR'; 'Lyons, Bill - MR'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul '; 'Marshall, Mike - RHH'; 'Martin, Michael - MFFC'; 'Martin, Ramon - USFWS'; 'Mathiesen, Lloyd - CRRMW'; 'McDaniel, Dan - CDWA'; 'McDevitt, Ray - BAWSCA'; 'McDonnell, Marty - SMRT'; 'McLain, Jeffrey - NOAA-NMFS'; 'Means, Julie - CDFG'; 'Mills, John - TUD'; 'Morningstar Pope, Rhonda - BVR'; 'Motola, Mary - PRCI'; 'O'Brien, Jennifer - CDFG'; 'Orvis, Tom - SCFB'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane - Cardno'; 'Pavich, Steve-Cardno'; 'Pinhey, Nick - City of Modesto'; 'Pool, Richard'; 'Porter, Ruth - RHH'; 'Powell, Melissa - CRRMW'; 'Puccini, Stephen - CDFG'; 'Raeder, Jessie - TRT'; 'Ramirez, Tim - SFPUC'; 'Rea, Maria - NOAA-NMFS'; 'Reed, Rhonda - NOAA-NMFS'; 'Richardson, Kevin - USACE'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O - N-R'; 'Roos-Collins, Richard - Water-Power Law Grp for NHI'; 'Roseman, Jesse'; 'Rothert, Steve - AR'; 'Sander, Max - TNC'; 'Sandkulla, Nicole - BAWSCA'; 'Saunders, Jenan'; 'Schutte, Allison - HB'; 'Sears, William - SFPUC'; 'Shipley, Robert'; 'Shumway, Vern - SNF'; 'Shutes, Chris - CSPA'; 'Sill, Todd'; 'Slay, Ronn - CNRF/AIC'; 'Smith, Jim - MPM'; Staples, Rose; 'Steindorf, Dave - AW'; 'Steiner, Dan'; 'Stone, Vicki -TBMI'; 'Stork, Ron - FOR'; 'Stratton, Susan - CA SHPO'; 'Taylor, Mary Jane - CDFG'; 'Terpstra, Thomas'; 'TeVelde, George A '; 'Thompson, Larry - NOAA-MNFS'; 'Vasquez, Sandy '; 'Verkuil, Colette - TRT/MF'; 'Vierra, Chris'; 'Villalabos, Ruben'; 'Walters, Eric - MF';

'Wantuck, Rick - NOAA-NMFS'; 'Welch, Steve - ARTA'; 'Wesselman, Eric - TRT'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas - RHH'; 'Wilcox, Scott - Stillwater'; 'Williamson, Harry (NPS)'; 'Willy, Alison - FWS'; 'Wilson, Bryan - MF'; 'Winchell, Frank - FERC'; 'Wood, Dave - FR'; 'Wooster, John -NOAA'; 'Workman, Michelle - USFWS'; 'Yoshiyama, Ron'; 'Zipser, Wayne - SCFB'

Subject: Don Pedro Study Plans - Most Recent Versions - Status of Uploading

An Updated Study Plan with the most recent versions of the Don Pedro Project study plans will be uploaded to the Don Pedro Project relicensing website tomorrow—and I will notify you when that has been done—and the location of the document. Thank you.

ROSE STAPLES
CPS CAP

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From: Staples, Rose
Sent: Friday, October 14, 2011 1:42 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: Don Pedro Updated Study Plan Is Now Available on Website

Today we have e-filed with FERC an UPDATED STUDY PLAN, which consists of a set of CLEAN Study Plans (Appendix A) and a set of the REDLINE Study Plans (Appendix B). We have also uploaded a copy of the filing to the relicensing website. You will note that these files are in a .pdf format—but we will also be uploading, by the end of the day, a set of the CLEAN Study Plans in WORD format.

You will also note a different look to the DOCUMENTS section of the website. We have "collapsed" all the individual files so when you access the Document sections, only the major section headings appear. To locate the Updated Study Plan, you will click on STUDIES, which will open three sub-headings (Proposed Study Plan, RWG Study Plan Development, and the new Updated Study Plan). Click on CONTENT: UPDATED STUDY PLAN, and the two Updated Study Plan file names should pop. If not, please let me know.

Thank you!

ROSE STAPLES
CPS CAP

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Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Tuesday, October 18, 2011 6:48 PM
To: 'Peter Barnes'
Cc: Loy, Carin
Subject: Copy of Report Referenced
Attachments: TID-MID_1992_Lower Tuolumne Predator Abundance Report.pdf

Carin Loy has provided the attached report, in response to your query of Monday, October 17th. I will also be uploading the document to the relicensing website, under INTRODUCTION/ANNOUNCEMENTS.

In regards to your question regarding verification of the due date for comments on the Proposed Study Plan, originally stated by FERC as Sunday, October 23, I have my query out to them, outlining the Monday, October 24 due date (and the reasoning for same), and the effect of that date on the filing date of the Revised Study Plan, which would then be Wednesday, November 23. I will do another query today, and advise you as soon as a response is received.

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From: Peter Barnes [mailto:PBarnes@waterboards.ca.gov]
Sent: Tuesday, October 18, 2011 3:31 PM
To: Loy, Carin
Subject: RE: Don Pedro Relicensing Reference

Thank you. Were you ever able to determine the correct date by which comments need to be submitted?

Sincerely,

Peter Barnes
Engineering Geologist
Division of Water Rights
State Water Resources Control Board
Phone: (916) 445-9989
Email: pbarnes@waterboards.ca.gov
>>> "Loy, Carin" <Carin.Loy@hdrinc.com> 10/17/2011 4:43 PM >>>
Hi Peter,
We will scan the document and send it to you tomorrow.

Regards,
Carin Loy

From: Peter Barnes [PBarnes@waterboards.ca.gov]
Sent: Monday, October 17, 2011 3:06 PM
To: Loy, Carin; Staples, Rose
Subject: Don Pedro Relicensing Reference

Do you know where I could find a copy of the following study referenced below. It has been referenced a number of times in the proposed study plans. Thank you.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 1992. Lower Tuolumne River Predation Study Report. Appendix 22 to Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 39 of the License for the Don Pedro Project, No. 2299 Vol. VII. Prepared by T. Ford, Turlock and Modesto Irrigation Districts and EA Engineering, Science, and Technology, Lafayette, California.

Sincerely,

Peter Barnes
Engineering Geologist
Division of Water Rights
State Water Resources Control Board
Phone: (916) 445-9989
Email: pbarnes@waterboards.ca.gov

From: Staples, Rose
Sent: Tuesday, October 18, 2011 8:09 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: 1992 Report Reference Uploaded to Don Pedro Relicensing Website

We have been asked for a copy of the 1992 report referenced in several of the Don Pedro Project proposed study plans:

LOWER TUOLUMNE RIVER
PREDATION STUDY REPORT

A copy has just been uploaded to the Don Pedro Project Relicensing Website Announcement Page (accessed via the INTRODUCTION tab).

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DON PEDRO PROJECT
FISHERIES STUDY REPORT
FERC ARTICLE 39, PROJECT NO. 2299

APPENDIX 22

LOWER TUOLUMNE RIVER PREDATION STUDY REPORT

Prepared for

Turlock Irrigation District
333 E. Canal Drive
Turlock, California 95381

Modesto Irrigation District
1231 11th Street
Modesto, California 95342

Prepared by

EA Engineering, Science, and Technology
41 Lafayette Circle
Lafayette, California 94549

5 February 1992

EXECUTIVE SUMMARY

The purpose of this report is to estimate the abundance of predator species in the lower Tuolumne River and to estimate the predation rates of those resident piscivores. Predation of juvenile chinook salmon is a potentially major source of mortality in the lower Tuolumne River. As measured in other freshwater streams, piscivores may remove 55 percent to 85 percent of the juvenile salmon population. There are a variety of potential influences to the degree of predation (e.g., streamflow, turbidity, predator population size and density, habitat availability, cover/refuge availability, and others).

The lower Tuolumne River was categorized into two general strata; Stratum 1 (RM 25-52) consisted of alternating riffle and run-pool habitats (with occasional deep and/or wide pools, termed "special run-pools"), while Stratum 2 (RM 0-25) is almost uniformly run-pool. Replicated study sites in Stratum 1 consisted of three riffle, three special run-pool, and five run-pool habitats, while Stratum 2 study sites replicated four run-pool habitats. To estimate bass population abundance, sites were electrofished and "captured" fish were identified and systematically marked for mark-recapture population studies. Several methods of estimating abundance were utilized, and are detailed in the text. Predatory rates were assessed by irrigation of predatory bass stomachs, and subsequent stomach contents identification and analysis. Concurrently-collected water samples were analyzed for turbidity, because turbidity plays a role in the predation efficiency of bass.

Population estimates for largemouth bass ranged from 1-139 fish per acre of stream surface (6-758 fish per mile of river shoreline) and from 1-16 fish per acre (2-158 fish per shoreline mile) for smallmouth bass. These ranges are approximates in light of the assumptions used in the population estimation methods. Bass predation rates averaged from zero to 3.62 chinook salmon ingested per day (assuming a slow rate of digestion) or from zero to 5.31 salmon ingested per day (assuming a faster digestion rate).

CONTENTS

1. INTRODUCTION

A study of predation on juvenile chinook salmon by predatory fishes was conducted on the Tuolumne River in the spring of 1990. Its goals were (1) to estimate the total number of the different predator species in the river and (2) to estimate the rate of predation by the major predators on juvenile salmon. This study was prompted by a study carried out in 1987 by CDFG in which almost 70 percent of 90,000 coded-wire-tagged juvenile chinook salmon released just below La Grange Dam died in the three days it took them to travel downstream to the San Joaquin River confluence (Preliminary Summary Smolt Survival Index Study, Appendix 25). Water temperatures were considered optimal during this period for outmigrating juvenile salmon, leaving predation the most plausible explanation for the high mortality. This study was conducted to test whether the number of predators and the rates of consumption were high enough to explain some or all of this mortality.

In spring 1989, a pilot predation study (Attachment A) was undertaken to get preliminary estimates of predator densities and consumption rates and the variances of the estimates, in order to determine the level of effort needed to complete the full study. The results of the pilot study led to some important methodological improvements for the full study. Among the changes were use of an electrofishing boat to permit the sampling of deeper habitat types and use of a multiple mark-recapture method for population estimates.

Analyses of these data are still in progress. This report includes preliminary results, with a brief discussion.

2. METHODS

2.1 RIVER STRATIFICATION

The lower section of the Tuolumne River, where the study areas are located, extends from La Grange Dam at river mile (RM) 52.2 to its confluence with the San Joaquin River (RM 0.0). This portion of the river is a meandering, low-gradient stream that flows through agricultural and urban environments.

The lower Tuolumne River was divided into two strata. Stratum 1, the upper half of the river (RM 25-52) has alternating riffle and run-pool habitats. Stratum 2, the lower half of the river (RM 0-25) is almost uniformly run-pool (see Figure 1).

Stratum 1 was further sub-stratified into three predominant habitat types: riffles, run-pools, and special run-pools. ("Special run-pool" designates an area of the river that is especially deep and/or wide, resulting in conditions that are more lake-like than stream-like. These areas are generally the result of in-river gravel mining.) The stratification was based on 1986 aerial photos and on riffle

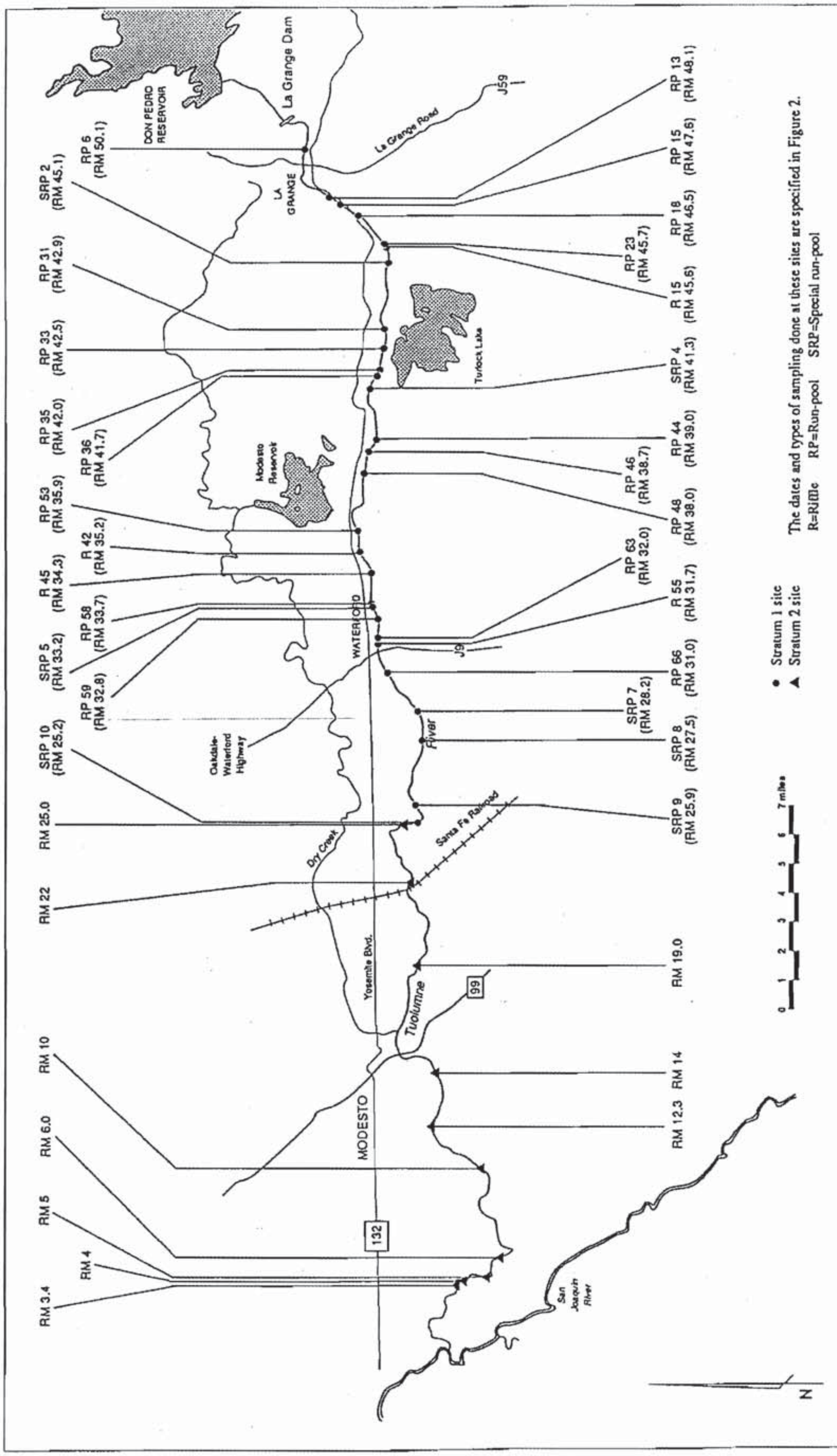


Figure 1. Locations of predator censuses and predation rate sampling, January - May 1990.

designations made by CDFG and TID/MID in the early 1980s. The stratification designations were checked by ground-truthing a subsample of habitat units.

2.2 PREDATOR POPULATION ESTIMATE SAMPLING

2.2.1 Field Data Collection

In Stratum 1, replicate study sites were selected at random from the three habitat types. Three riffles, three special run-pools, and five run-pool sites were selected. A larger number of run-pool sites were selected because they appear to have greater variability in depth, available cover, and flow characteristics than do riffles or special run-pools. In Stratum 2, four run-pool sites were selected randomly by river mile. If a site in Stratum 2 proved inaccessible, it was discarded and another random selection was made. Separate study sites were selected for the predator population estimate and predation rate parts of the study to minimize the stress on the fish in the population sites.

Except when habitat units were prohibitively large, study sites encompassed entire habitat units; i.e., the study site boundaries were the natural boundaries of the habitat unit. When habitat units were too long to be worked as a whole (as with some of the special run-pools), only a portion of the unit was sampled. In these cases, boundaries were defined by clear breaks in habitat within the unit, e.g., channel constrictions and/or vegetative cover breaks.

Because of limited depth and/or poor boat accessibility, the run-pools in Stratum 2 (below Charles Road [RM 24.9]) and all of the riffles were sampled using a 3,500-watt generator in a barge shocker. The run-pools and special run-pools in Stratum 1 were sampled using a boat shocker equipped with a 5,000-watt generator. All of the run-pools and special run-pools were sampled at night to increase capture rates. Run-pools and special run-pools were not blocked to prevent migration, because bass are territorial and do not move far from their territories.

A multiple mark-recapture method (Schnabel census) for estimating numbers of fish was used (Seber 1982). A site was electrofished, and all predators were collected. All predators large enough to consume juvenile salmon ($\geq$ 100 mm) were anesthetized with MS-222, weighed, measured, and tagged with individually numbered Floy tags. The fish were redistributed throughout the study site.

The run-pools and special run-pools were sampled approximately every fifth day for a total of four or five times in the course of the study (Figure 2). Care was taken to ensure that for a given site, the electrofishing effort and the area sampled remained equal for every sampling run. The tag numbers of recaptured fish were recorded, and all newly captured fish were given tags. The lengths and weights of all new fish were recorded. Again, all fish were returned to the site. On the final run, fish weights and lengths were recorded and recaptures were noted, but no new tags were attached.

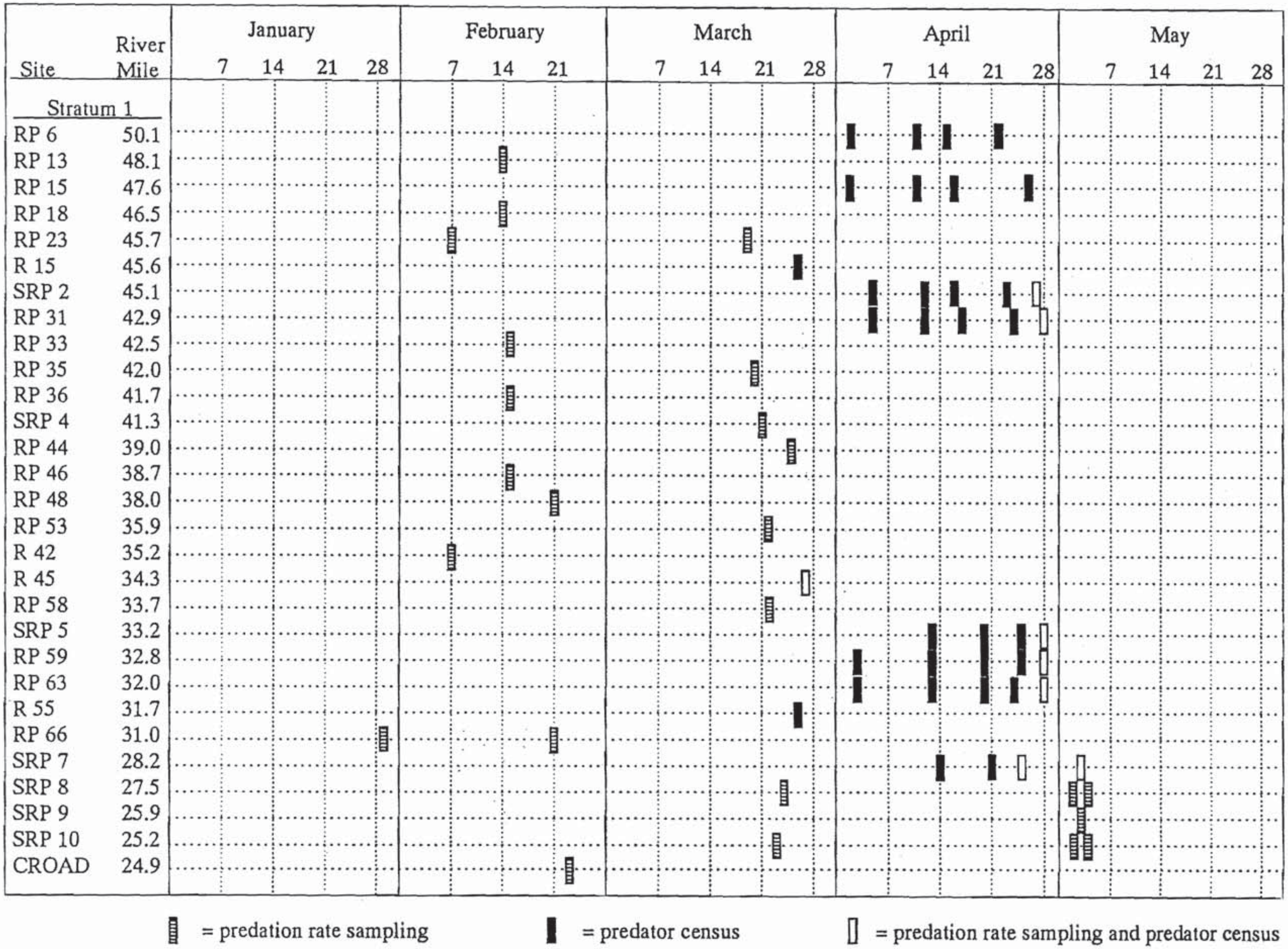


Figure 2. Dates of predation rate sampling and predator censuses in two strata of the lower Tuolumne River, January - May 1990.

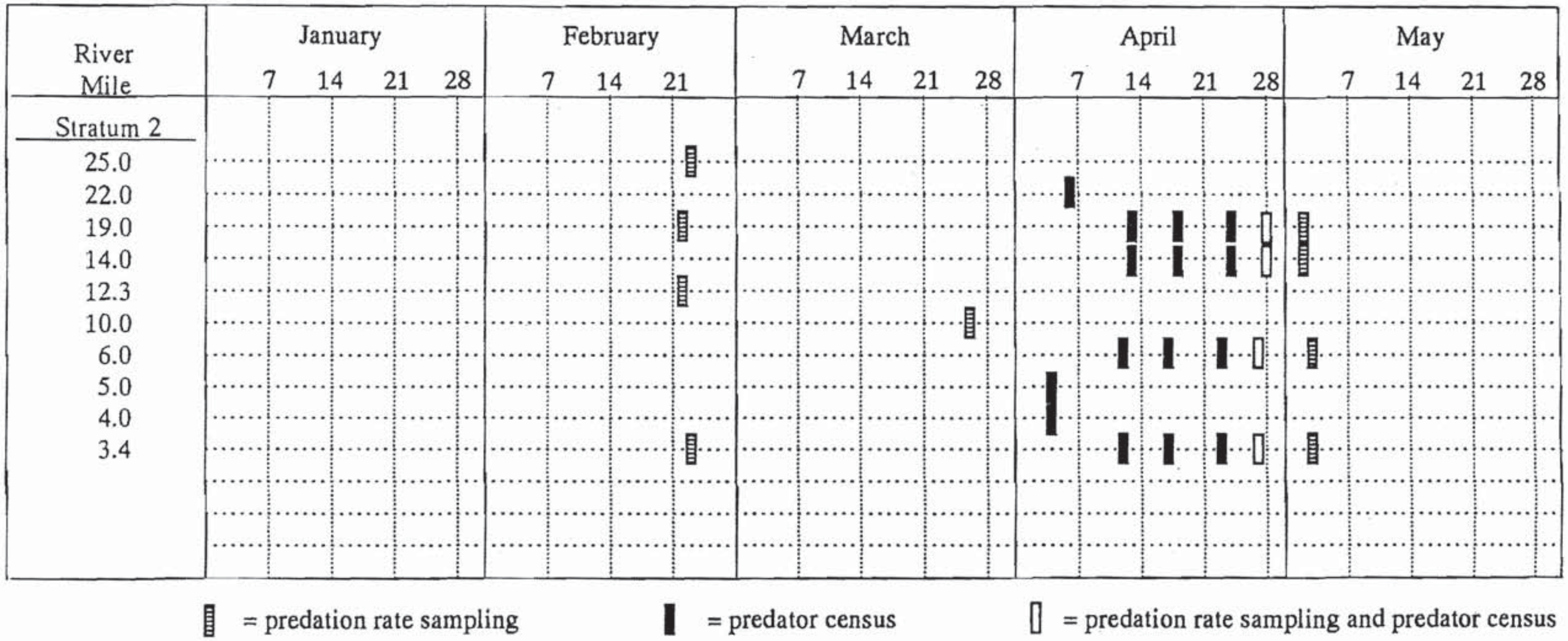


Figure 2 (cont.)

A different sampling method was used in the three riffles in Stratum 1 that were selected for population estimate sites. Because access to these sites was easier and it was feasible to put up blocking nets at both ends of the riffles, they were sampled using a three-pass reduction method for estimating populations (Seber 1982). This method yielded population estimates without repeated site visits. These riffles (R15, R45, and R55) were sampled on 26-27 March 1990 (Figure 2).

2.2.2 Data Analysis

The mark-recapture data have been analyzed with statistical models to get estimates of predator abundances in each study site. These population estimates are used to estimate, for each habitat type, average predator species population numbers, per unit "bank distance" and per acre of water surface. (Habitat bank distance is defined as the total riverbank distance included in a habitat type unit. For example, one river mile will have at least 2 miles of riverbank available as habitat, and there may be considerably more, depending on bank complexity.) Bank distance is an appropriate measure of habitat availability for species, such as largemouth bass and smallmouth bass, which set up territories near banks. The water surface area is more appropriate for species, like squawfish, that do not utilize the banks as extensively. The final habitat-type estimates are being extrapolated to estimate predator densities for the river as a whole.

The information on predator densities will be used in conjunction with predation rates (Section 2.3) to estimate total potential chinook salmon losses due to predation.

2.2.3 Population Models

In most cases, recaptures were sufficient to use an unmodified Schnabel census model, which estimates capture probabilities separately for each sampling run (Model 1 below). In some cases recapture rates were too low to estimate capture probabilities separately for each run, and a model which assumes equal capture probabilities for all runs was used (Model 2 below). At one site, low recaptures necessitated using a model which estimates the capture probability by pooling recapture data with those from a morphologically similar site (Model 3 below). These models all assume one population in a site, in which all fish for a given sampling run have an equal probability of capture. In addition, all three models assume that there is no immigration or outmigration between sampling runs. A general description of the models and their assumptions follows:

Model 1: Capture Probabilities Different, One Sample Site

If enough tagged fish were recaptured in all sampling runs at a given site, a model making no assumptions about consistency of capture probabilities between sampling runs was used: predator abundance is estimated by solving iteratively for N in Equation 1:

$$N = \frac{m}{1 - \prod_i (1-P_i)} \qquad (1)$$

where N is the population size, m is the number of distinct fish captured, and $P_i = n_i/N$ (n_i is the number of captured fish in sample i). The i-th capture probability is estimated as P_i (Equation 1 corresponds to Equation 4.4 in Seber 1982).

The variance of the estimate of $N(\hat{N})$ is obtained, following maximum likelihood theory, as:

$$\mathrm{var}(\hat{N}) = [\,(\hat{N}-m)^{-1} - \hat{N}^{-1} - \Sigma_i\, n_i \{\,(\hat{N}-n_i)\,\hat{N}\,\}^{-1}\,]^{-1} \qquad (2)$$

This formula is equivalent to the variance estimate listed in Cormack (1979), even though the derivations are different.

Model 2: Capture Probabilities Equal Within a Sampling Site

If too few tagged fish were recaptured in a sampling run at a given site, it was not possible to estimate the capture probabilities separately, and a simpler model was used. This model is based on the assumption that probabilities of capture are equal for all sampling runs. The abundance is estimated by solving iteratively for N in the following equation:

$$N = \frac{m}{1 - (1-P)^s} \qquad (3)$$

where N is the population size, m is the number of distinct fish captured, s is the number of samples taken and $P = n/(sN)$ (n is the sum of captured fish over all samples, whether newly captured or recaptured). P is the estimated capture probability (Equation 3 corresponds to Equation 6 in Cormack 1979).

The variance of the estimate of N is obtained, following maximum-likelihood theory, as:

$$\mathrm{var}(\hat{N}) = [\,(\hat{N}-m)^{-1} - \hat{N}^{-1} - n\,\{\,(\hat{N}s-n)\,\hat{N}\,\}^{-1}\,]^{-1} \qquad (4)$$

While equation (4) is functionally different from equation (2), it gives an almost identical variance, which agrees with observations made by Cormack (1979).

Model 3: Capture Probabilities Equal, Multiple Sample Sites

In one case, too few fish were recaptured at a site to estimate capture probability, even assuming equal probabilities among sampling runs. In such a case, if the sample site is taken to be similar to another site with adequate recapture, it is possible to pool capture information from both sites and to estimate the capture probability for the site with low recaptures. This approach assumes that the capture probabilities are equal both for all samples and for both sites. Estimates of abundance are obtained by solving for the N_i in the following equations:

$$N_i = \frac{m_i}{1 - (1-P)^{s_i}}, \ i=1, 2, \ldots r \tag{5}$$

where N_i is the population size at the i-th site, m_i is the number of unique fish captured at site i, s_i is the number of samples taken at site i, and $P = n/(\Sigma_i s_i N_i)$ (n is the sum of captured fish over sites and samples, both new captures and recaptures). P, again, is the estimated capture probability.

The variances of the estimates of N_i are obtained following maximum likelihood theory:

$$\text{var}(\hat{N}_i) = D_i^{-1} [1 + (D_i d)^{-1} w_i^2] \tag{6}$$

where $D_i = (\hat{N}_i - m_i)^{-1} - \hat{N}^{-1}$, $w_i = s_i/(1-p)$, and $d = nP^{-2} - (1-P)^{-2}(n - \Sigma_i s_i \hat{N}_i) - \Sigma_i D_i^{-1} w_i^2$.

2.3 PREDATION RATE SAMPLING

2.3.1 Field Collection

Study sites were selected in Strata 1 and 2 as described for predator population sampling in Section 2.2.1. Separate sites were selected for predation rate sampling to minimize stress on the fish at the population sampling sites.

Again, all three riffles, in Stratum 1, and the run-pools, in Stratum 2 (RM 25 and below), were sampled using a 3,500-watt generator in a barge shocker. The run-pools and special run-pools in Stratum 1 were sampled with a boat shocker equipped with a 5,000-watt generator.

The predation rate sites were sampled in a single electrofishing pass. All predators large enough to consume juvenile salmon were collected. Predators were anesthetized with MS-222, weighed, and measured, and their stomachs were pumped to yield stomach contents (fish of species whose stomachs cannot be pumped were sacrificed). The stomach contents were put into Whirl-Pak bags that were labeled with site, date, and fish identification number and preserved in 80 percent ethanol for later inspection. Fish were released into the study site.

Predation sampling began in late January and was carried out in February and March (see Figure 2). The first predation rate sampling of run-pools (at eight sites over approximately 10 days in February), was done during daylight hours. However, night electrofishing, done for the predator census, proved to be much more effective at capturing predatory fish, and subsequent predation rate sampling was all done at night.

In both the riffles (one-day predation census sampling) and the run-pool and special run-pool predator census sites, samples of prey were collected from the stomachs of predatory fish in the last predator census population sample, since no further marking was to be done, and the sites were not to be revisited. The riffle samples were collected in the last week of March; the run-pool and special run-pool samples in late April (see Figure 2).

The final predation rate sampling, carried out in run-pools and special run-pools during the first week of May, was timed to coincide with a pulse flow (a temporary increase in river discharge that had been jointly arranged between TID/MID, the California Department of Fish and Game (CDFG), and the United States Fish and Wildlife Service (USFWS), for a smolt survival study by CDFG) (TID/MID 1986). The pulse flow began on 29 April and was decreased gradually starting on 4 May. Coincident with the pulse flow, CDFG released 93,600 salmon smolts at La Grange. All of these fish were implanted with coded wire tags. The purpose of this sampling was to try to estimate predation rates during this highly concentrated juvenile outmigration.

Turbidity Sampling

Water turbidity samples were taken in a period prior to the pulse flow and during the pulse flow to assess the effects of turbidity on predation and, in particular, to see if the pulse flow increased turbidity sufficiently to reduce predation rates. On each day of sampling, 8-10 samples were taken at approximately 5-mile intervals along the river, from Basso Bridge (5 miles below La Grange Dam, [RM 47.5]) to McCleskey Ranch (5 miles above the mouth of the Tuolumne River, [RM 6.0]); occasionally access to the regular sampling sites was restricted, and alternative sites were chosen in the vicinity.

In general, three samples were collected at each site from approximately the middle depth of the water column as far out from shore as possible. Samples were collected in glass vials and stored on ice for transportation back to the laboratory. The samples were left on ice until they could be processed, to retard any algal growth or decomposition that might affect their turbidity. As soon as possible, samples were measured for turbidity in nephelometric turbidity units (NTU), using standard procedures, on a Turner Designs Model 40-100 nephelometer. Five individual readings were taken on each vial, for a total of 15 readings per sample site. The average of these 15 values was used in the turbidity analysis for comparisons between sites and dates.

2.3.2 Data Analysis

The stomach sample contents were analyzed to determine what, and how much, each predator had consumed. The contents were removed from the field samples and inspected to identify the prey organism(s). When possible, the standard lengths (from tip of snout to end of spine) of fish prey were measured. Total lengths (or carapace lengths of crayfish) were measured. In both cases an estimate was made of the percentage of the prey organism digested. This was done to aid in estimating digestion rates/gut evacuation rates and to calibrate the expected accuracy of prey organism identification: positive identification of fish could be made if the degree of digestion was less than 25 percent, and less reliably if digestion was between 25 and 75 percent. Identification could not be made if the fish was more than 75 percent digested.

Macroinvertebrates recovered from the samples were noted and saved, but not counted or identified. Other occasional prey items (e.g., amphibians, reptiles) were noted, but not included for purposes of predation rate assessment.

An analysis is being carried out to estimate predation rates based on the amount of predation by the major predator species on the most commonly utilized prey species. The data will be divided by strata and by date of collection: either base flow or pulse flow. It may be necessary, to group sites and/or sampling dates. Care will be taken to make sure that sites or sampling dates are not grouped if significant temporal or spatial trends in the data are noticed.

The stomach samples collected during the pulse flow were screened with a magnet during analysis for coded wire tags, either implanted in prey fish or loose in the sample.

3. RESULTS

3.1 PREDATOR POPULATION ESTIMATES

The predator population estimates for each study site are summarized in Table 1. Estimates for largemouth bass in the run-pools in Stratum 1 range from 29 to 150 largemouth bass per site: 29 in RP 15, 79 in RP59, 99 in RP6, and 150 in RP31. Estimates of largemouth bass in special run-pools in Stratum 1 ranged from 133 to 181 for the sites studied. The models estimated 133 fish in SRP 7, 135 in SRP 5, and 181 in SRP 2. The estimates in the Stratum 2 sites were smaller than those in Stratum 1. There were 25 largemouth bass estimated at RM 19, 21 at RM 14, 11 at RM 6, and 17 at RM 3.4.

At most sites, smallmouth bass densities were too low to obtain reliable population estimates. The exceptions to this were RP6 ($\hat{N}$ = 29), SRP5 ($\hat{N}$ = 23), and SRP7 ($\hat{N}$ = 9). Of the three riffles

TABLE 1 POPULATION ESTIMATES FOR LARGEMOUTH BASS AND SMALLMOUTH BASS BY STUDY SITE, LOWER TUOLUMNE RIVER

	Largemouth Bass					
	Predator Abundance	SE	Site Area (acres)	Site Bank Distance (feet)[a]	Abundance per Acre	Abundance per Bank Mile[a]
Stratum 1						
RP6	99[b]	92	3.4	1808	2 - 56	20 - 558
RP15	29[c]	25	4.4	3763	1 - 12	6 - 76
RP31	150[b]	141	2.1	2028	4 - 139	23 - 758
RP59	79[b]	24	2.4	1782	23 - 43	163 - 305
SRP2	181[b]	31	6.8	6666	22 - 31	119 - 168
SRP5	135[b]	27	8.7	4445	12 - 19	128 - 192
SRP7	133[b]	19	15.0	6278	8 - 10	96 - 128
Stratum 2						
RM 19	25[d]	17	2.3	1770	3 - 18	24 - 125
RM 14	21[c]	12	2.0	1519	5 - 17	31 - 115
RM 6	11[b]	3	2.9	2121	3 - 5	20 - 35
RM 3.4	17[b]	9	3.7	2546	2 - 7	17 - 54
	Smallmouth Bass					
Stratum 1						
RP6	29[c]	25	3.4	1808	1 - 16	12 - 158
SRP5	23[c]	19	8.7	4445	0 - 5	5 - 50
SRP7	9[c]	7	15.0	6278	0 - 1	2 - 13

a Equals the distance of bank on both sides of the sites *and around islands.*
b Model 1 used for abundance estimate
c Model 2 used for abundance estimate
d Model 3 used for abundance estimate

that were sampled for predator population estimates, only one, R45, contained a predator, a 199-mm smallmouth bass.

For largemouth bass, Model 1 was used at 8 sites and Model 2 at 2 sites. Model 3 (in which capture probability data from one site are applied to another site in which capture information is too low to estimate capture probability independently) was used in only one case, for the estimation of largemouth bass population, at RM 19, for which recapture data were pooled with those from RM 14.

For the three sites for which there were smallmouth bass recapture data, Model 2 was used to estimate populations.

The areas included in each of the run-pools and special run-pools and the bank distances in each study site were calculated from the Tuolumne River GIS database (see Attachment D). Measurements for each site are included in Table 1. Using these areas and bank distances, population estimates for each study site were extrapolated to produce estimates of the largemouth bass population in the entire lower river. The numbers of smallmouth bass in the study sites were insufficient to provide reliable extrapolations for the whole river.

Two estimates for each habitat type and for the total were calculated (see Table 2). The first estimates were calculated based on the area of the study sites sampled, and the second estimates were based on the bank distances contained in the study sites. The area-based estimates are 5,230 largemouth bass in the Stratum 1 run-pools, 2,621 in the Stratum 1 special run-pools, and 2,279 in Stratum Two. The area-based estimate for the whole river is 10,130 largemouth bass with a combined standard error of 2,391. The estimates based on bank distances are 6,822 in Stratum 1 run-pools, 2,115 in Stratum 1 special run-pools, and 2,137 in Stratum 2. The distance-based total estimate is 11,074 with a combined standard error of 1,938.

3.2 PREDATION RATE ESTIMATES

For this report, evaluation of predation rates has been restricted to predation by the two most significant piscine predators: largemouth bass and smallmouth bass, and to their predation on juvenile chinook salmon. All of the run-pool data for Stratum 1 have been grouped together. The same is true of the special run-pool data in Stratum 1. Data from all the sites in Stratum 2 were grouped, since they are all run-pool habitat. In all cases the data have been grouped by date of field collection: (1) early predation--samples collected between late January and late March; (2) pre-pulse-flow predation--samples taken in late April, just prior to the pulse flow (these samples were taken on the last sampling runs in the predator population sites and will henceforth be refered to as pre-pulse samples); and (3) pulse-flow predation, samples taken during the pulse flow. Sampling during the pulse flow was restricted to Stratum 2 and to special run-pools in Stratum 1.

TABLE 2 BLACK BASS POPULATION ESTIMATES, LOWER TUOLUMNE RIVER

	Abundance (based on area)	Standard Error	Abundance (based on bank distance)	Standard Error
Stratum 1				
Run-Pools	5,230	2,121	6,822	1,862
Special Run-Pools	2,621	758	2,115	236
Stratum 2	2,279	802	2,137	481
Totals	10,130	2,391	11,074	1,938

3.2.1 Predation Ratios

Predation rates are calculated in two steps. The first is to calculate a predation ratio (by species, habitat type, and sampling time), which is the average number of prey fish per predator sampled. For example, during the early sampling in run-pools of Stratum 1, 26 largemouth bass were caught, of which two had a total of 4 juvenile chinook salmon in their stomachs; in this case, 4 salmon in 26 largemouth bass (4/26) = 0.15. The 95 percent lower and upper confidence intervals for this ratio (assuming that the data are Poisson-distributed) are 0.04 and 0.38 (Johnson and Kotz 1969). All predation ratios are calculated similarly and are summarized in Table 3, along with the upper and lower 95 percent confidence intervals.

Early Sampling

In the run-pools in Stratum 1 during the early samplings, 18 smallmouth bass were caught with a total of 3 salmon in their stomachs. The predation ratio was 0.17. In the same sites, 26 largemouth bass had consumed 4 salmon. This predation ratio was 0.15. No predation by either largemouth or smallmouth bass was documented in the special run-pools during the early samplings, nor was any predation documented in any of the Stratum 2 sites during early sampling. Only one predator was found in the three Stratum 1 riffles sampled, a 199-mm smallmouth bass whose stomach contained no salmon.

Pre-pulse Sampling

During pre-pulse sampling, no predation was documented in Stratum 1 run-pools. Out of 60 largemouth bass in special run-pools whose stomachs were pumped during the pre-pulse sampling, only 2 salmon were found, for a predation ratio of 0.03. Predation by smallmouth bass was not detected in these sites at this time.

In Stratum 2 during the pre-pulse period, no predation by largemouth bass was documented; the smallmouth bass predation ratio was 0.17.

Pulse Flow Sampling

The Stratum 1 run-pools were not sampled during the pulse flow. In the special run-pools 88 salmon were found in the stomach samples of 134 largemouth bass, for a predation ratio of 0.66. Only 9 smallmouth bass were caught in the special run-pools during the pulse flows, but they had consumed 15 salmon; the predation ratio was 1.67 .

TABLE 3 SUMMARY OF PREDATION RATE STUDY DATA, LOWER TUOLUMNE RIVER, JANUARY-MAY 1990

Stratum	Species[b]	Site Type[c]	Sample Time[d]	Predators Captured	Predators with Salmon in Stomach	Predators w/o Salmon in Stomach	Largest Number of Salmon in One Predator	Total Salmon Prey	Average Consumption Per Predator	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Average Predation Rate[a]: Low Digestion Rate	Average Predation Rate[a]: High Digestion Rate
1	LMB	RP	Early	26	2	24	3	4	0.15	0.04	0.38	0.24	0.36
1	SMB	RP	Early	18	1	17	3	3	0.17	0.03	0.47	0.35	0.51
1	LMB	RP	Pre-pulse	7	0	7	0	0	0	-	-	-	-
1	SMB	RP	Pre-pulse	9	0	9	0	0	0	-	-	-	-
1	LMB	SRP	Early	58	0	58	0	0	0	-	-	-	-
1	SMB	SRP	Early	1	0	1	0	0	0	-	-	-	-
1	LMB	SRP	Pre-pulse	60	2	58	1	2	0.03	0.004	0.11	0.05	0.07
1	SMB	SRP	Pre-pulse	1	0	1	0	0	0	-	-	-	-
1	LMB	SRP	Pulse Flow	134	40	94	9	88	0.66	0.53	0.82	1.06	1.57
1	SMB	SRP	Pulse Flow	9	5	4	5	15	1.67	0.93	2.74	3.62	5.31
2	LMB	RP	Early	13	0	13	0	0	0	-	-	-	-
2	SMB	RP	Early	13	0	13	0	0	0	-	-	-	-
2	LMB	RP	Pre-pulse	9	0	9	0	0	0	-	-	-	-
2	SMB	RP	Pre-pulse	6	1	5	1	1	0.17	0.004	0.89	0.35	0.51
2	LMB	RP	Pulse Flow	18	0	18	0	0	0	-	-	-	-
2	SMB	RP	Pulse Flow	9	1	8	1	1	0.11	0.003	0.62	0.24	0.35

a. Chinook salmon consumed per predator per day; low digestion rate, 15 hours for largemouth bass, 11 hours for smallmouth bass; high digestion rate 10 hours for largemouth bass, 7.5 hours for smallmouth bass.

b. LMB, largemouth bass; SMB, smallmouth bass.

c. RP, run-pool; SRP, special run-pool.

d. Early sampling was done from 29 January to 27 March; Pre-pulse from 25 April to 28 April; Pulse Flow from 2 May to 4 May.

In Stratum 2, no predation by largemouth bass was seen during the pulse flow. The predation ratio for smallmouth bass was 0.11.

Figures 3 through 8 give length-frequency histograms for all largemouth and smallmouth bass sampled for predation rate. The length frequencies of fish that had consumed salmon are indicated in the histograms.

3.2.2 Gastric Evacuation and Predation Rate

The second step in calculating a predation rate (on a daily average basis) is to adjust the predation ratio with the gastric evacuation time for the food items. Gastric evacuation rates are affected by several factors, including predator and prey species (Beyer and Burley 1988), predator size (Swenson and Smith 1973), size and type of meal (Fange and Grove 1979), and water temperature (Hunt 1960; Seaburg and Moyle 1964; Molnar et al. 1967; Lewis et al. 1974). Lewis et al. found that for largemouth bass between 200 and 400 g held at 18 C (64 F), 30 hours was required for complete emptying of the stomach. Seaburg and Moyle (1964) found that largemouth bass held at 64-74 F (17.8-23.3 C) took 7 hours to reduce volume in their stomachs by 36 percent. Beyer and Burley (1988) concluded that evacuation rates for smallmouth bass are faster than for largemouth bass, and are in the range of 23 hours for a 200 mm fish to digest 5 grams of prey.

For our study, an estimate is also needed for the time it takes for the salmon prey to become unrecognizable in a stomach sample. Based on the literature and field observations, we estimate that 10-15 hours are required before chinook salmon juveniles become unrecognizable in the stomachs of largemouth bass at the temperatures during the pulse flow (approximately 17 C). For smallmouth bass, assuming that 25 percent less time is required, 7.5-11 hours are probably sufficient to render prey fish unrecognizable. With these gastric evacuation rates, it is possible to estimate the average number of salmon caught per predator per day ($\hat{f}$) by solving equation 8:

$$\hat{f} = \hat{\lambda}/d \qquad (8)$$

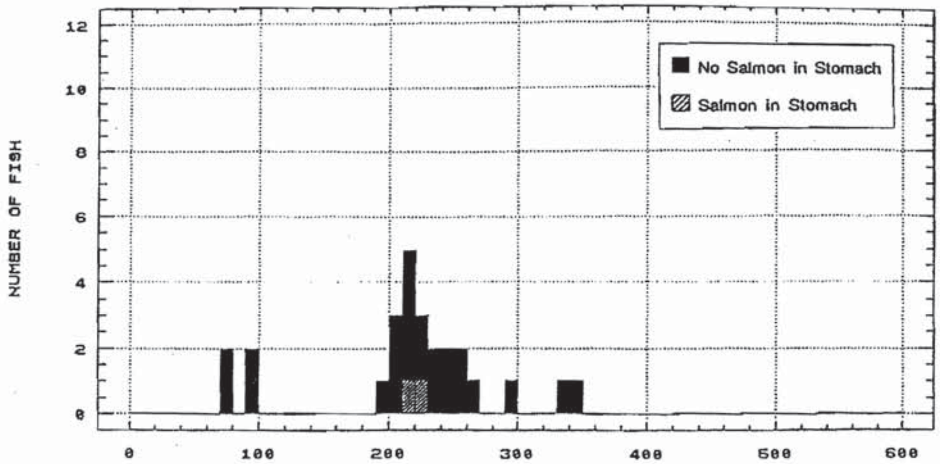
where $\hat{\lambda}$ is the average number of fish recognizable as salmon present in a predator's stomach, and d is the fraction of a day required to render a salmon unrecognizable.

For example, the predation ratio for largemouth bass in Stratum 1 run-pools during early sampling was 0.15. If 10 hours (0.42 days) is the evacuation time, the average predation rate, $\hat{f}$, is :

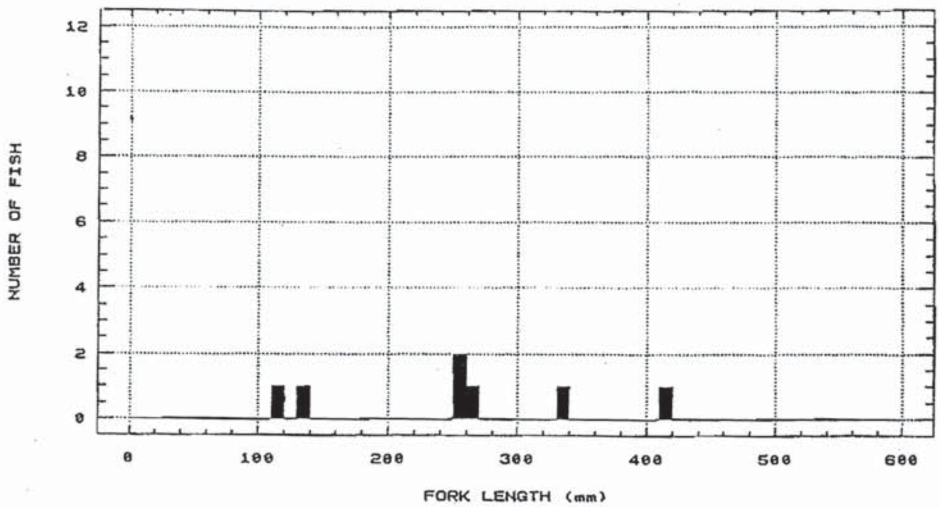
$$\hat{f} = 0.15/0.42 = 0.36 \text{ salmon per predator per day.}$$

Table 3 includes the ranges of average predation rates for largemouth and smallmouth bass by habitat types and times. During early sampling, predation rates for largemouth bass in Stratum 1

a. Early



b. Pre - Pulse Flow



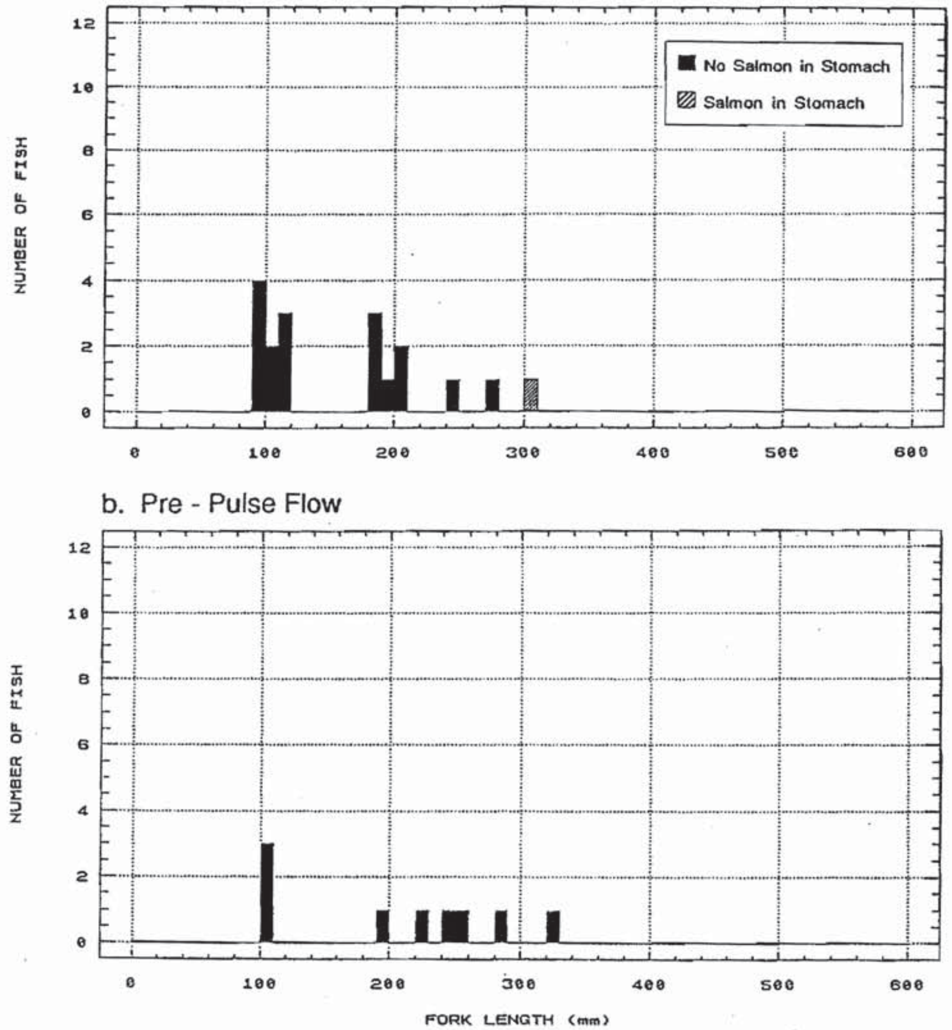
c. Pulse Flow

Run-pools were not sampled during the pulse flow.

Figure 3. Length frequencies of largemouth bass collected in Stratum 1 run-pools during predation rate studies, lower Tuolumne River, 1990.

a. Early

b. Pre - Pulse Flow



c. Pulse Flow

Run-pools were not sampled during the pulse flow.

Figure 4. Length frequencies of smallmouth bass collected in Stratum 1 run-pools during predation rate studies, lower Tuolumne River, 1990.

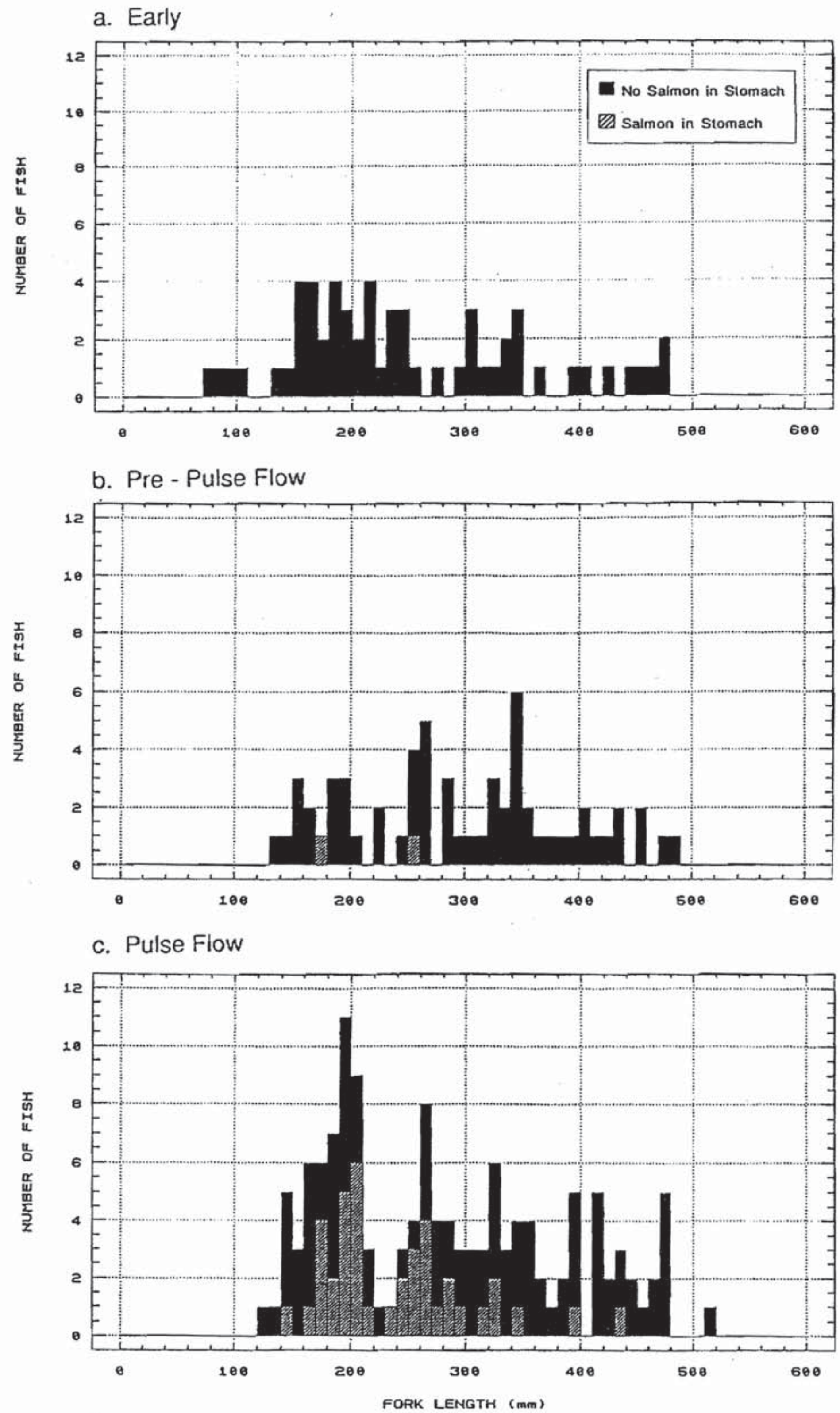


Figure 5. Length frequencies of largemouth bass collected in Stratum 1 special run-pools during predation rate studies, lower Tuolumne River, 1990.

a. Early

Only one predator caught; no histogram produced.

b. Pre - Pulse Flow

Only one predator caught; no histogram produced.

c. Pulse Flow

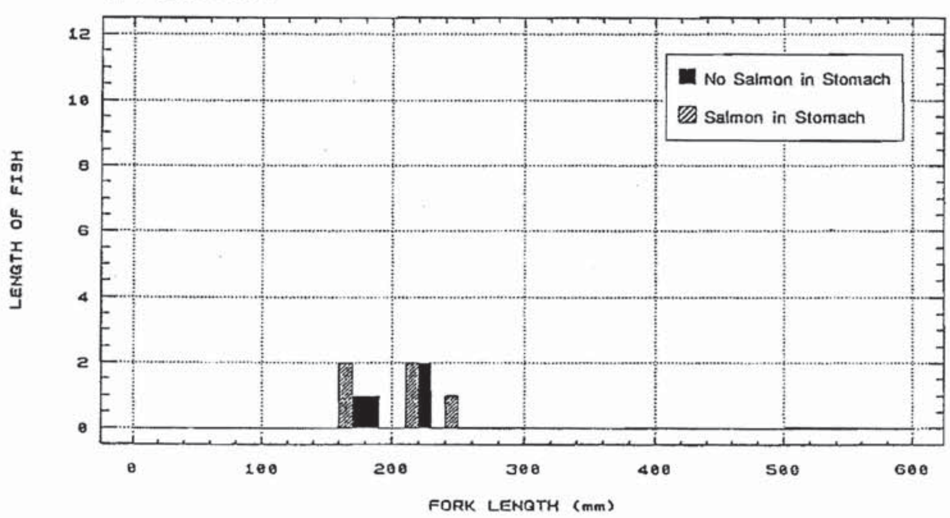


Figure 6. Length frequencies of smallmouth bass collected in Stratum 1 special run-pools during predation rate studies, lower Tuolumne River, 1990.

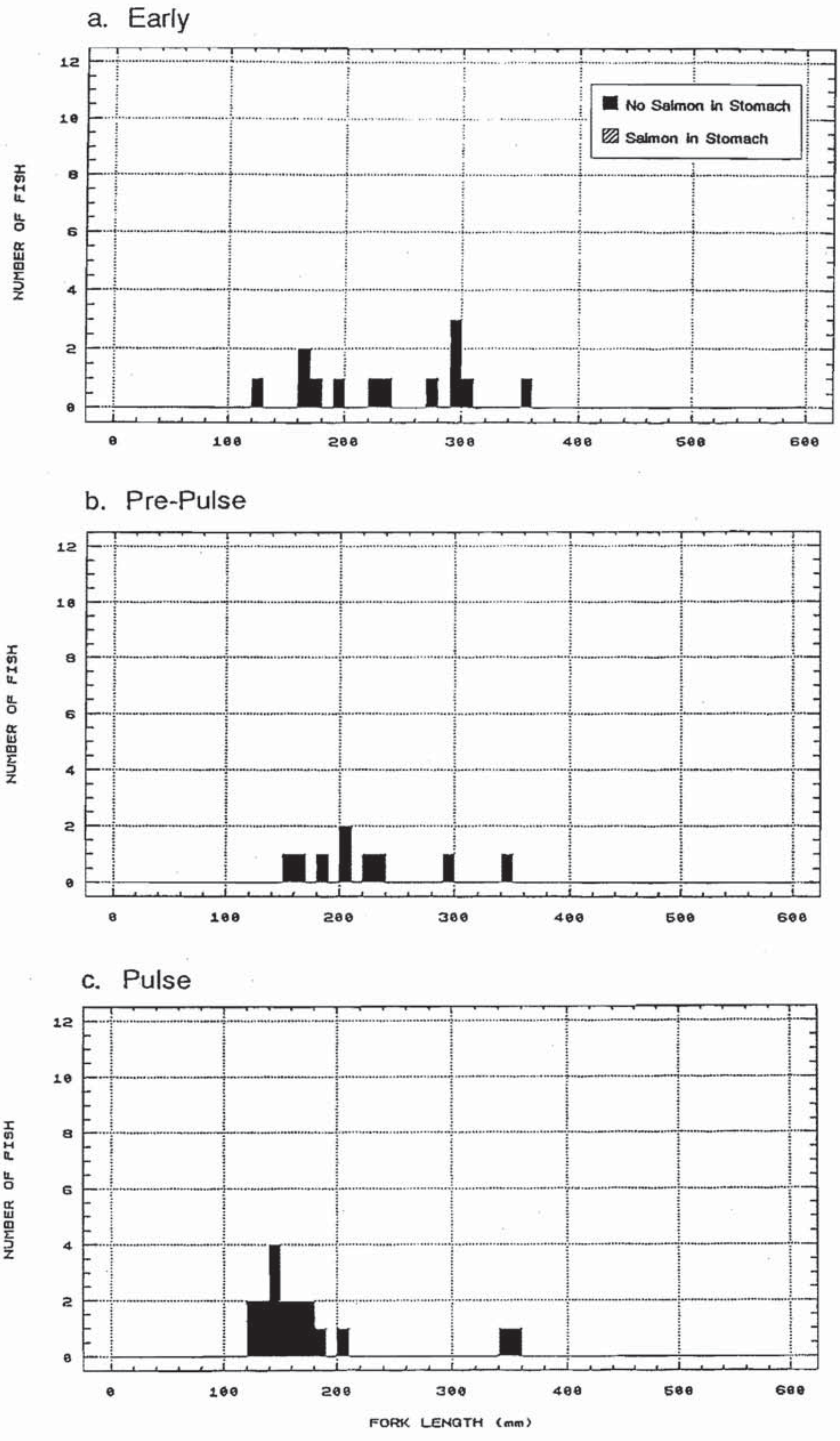


Figure 7. Length frequencies of largemouth bass collected in Stratum 2 run-pools during predation rate studies, lower Tuolumne River, 1990.

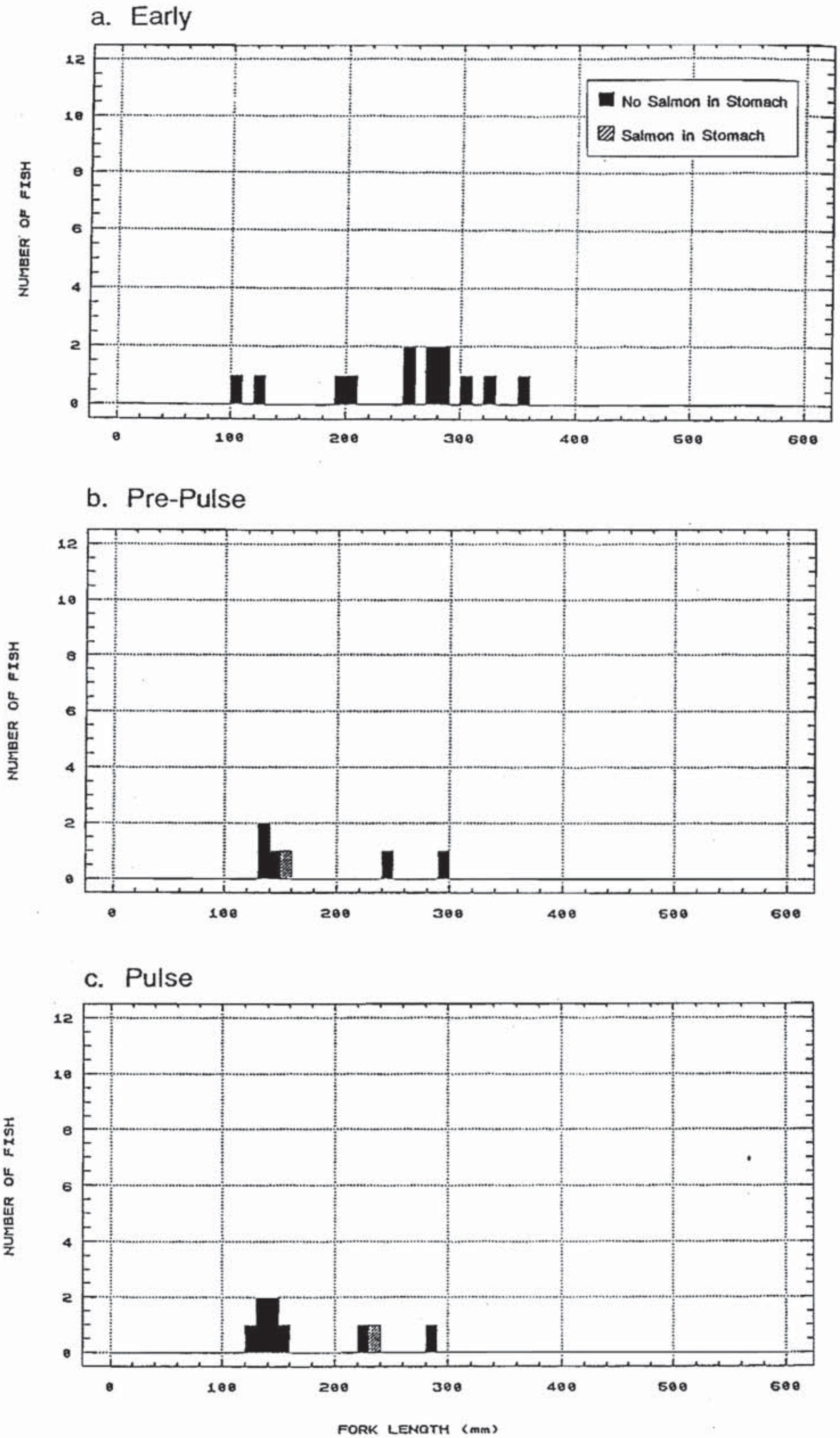


Figure 8. Length frequencies of smallmouth bass collected in Stratum 2 run-pools during predation rate studies, lower Tuolumne River, 1990.

run-pools ranged from 0.24 to 0.36 salmon per predator per day. Predation by smallmouth bass in the same sites and times was 0.35 to 0.51 salmon per predator per day. At the same times, predation by either of these predators on salmon in the special run-pools and in all of Stratum 2 was not detected.

During the pre-pulse sampling, neither largemouth nor smallmouth bass were detected preying on salmon in Stratum 1 run-pools. Predation by largemouth bass in special run-pools occurred at a very low rate (0.05-0.07 salmon per predator per day), and smallmouth bass predation was not detected. At this time in Stratum 2, largemouth bass predation was not detected, but smallmouth predation had increased (from undetected during early sampling) to 0.35-0.51 salmon per predator per day.

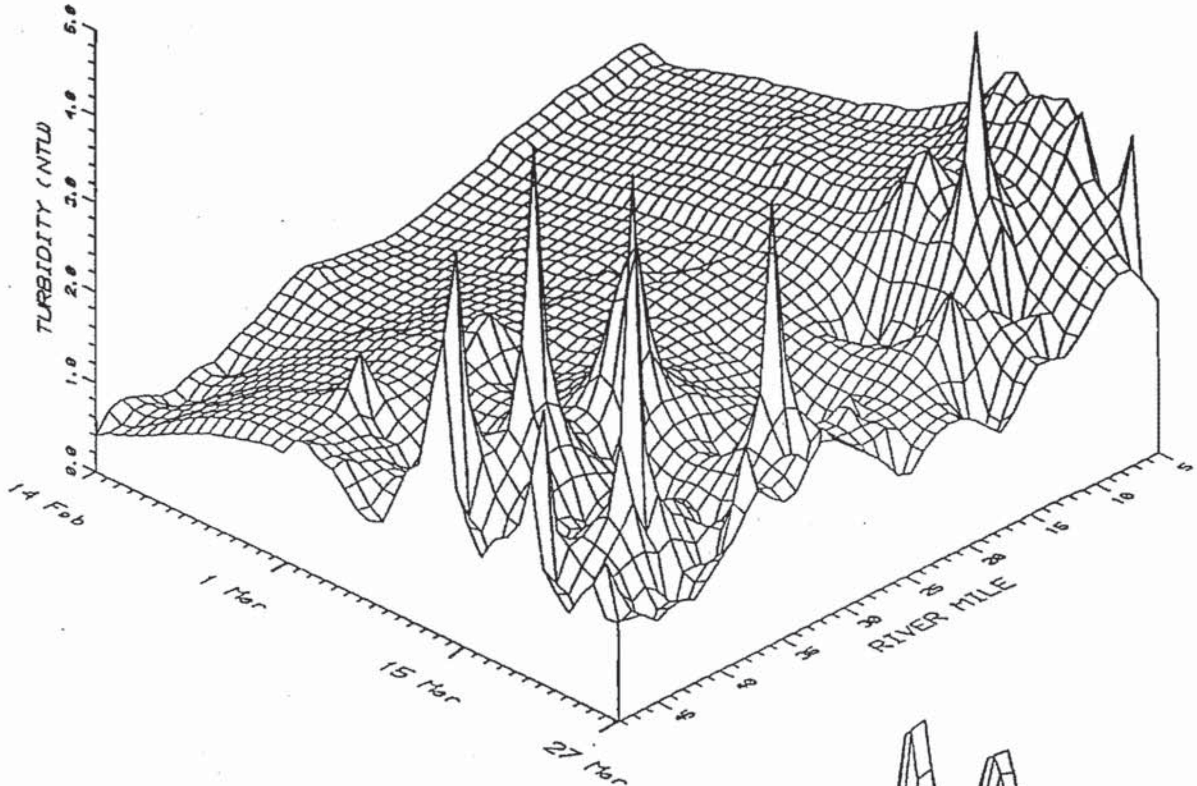
During the pulse flow, average predation by largemouth bass increased to 1.1-1.6, and smallmouth bass average predation to 3.6-5.3 salmon per predator per day in the special run-pools of Stratum 1. Largemouth bass predation in Stratum 2 was still not detected, and the smallmouth rate remained about the same as during the pre-pulse period: 0.24-0.35.

3.3 TURBIDITY: EFFECTS OF PULSE FLOW AND EFFECTS ON PREDATION

The data collected during the water turbidity sampling is summarized in Figure 9. (Attachment B shows longitudinal profiles of turbidity on representative dates of sampling. Attachment C shows the changes in turbidity over time at the given locations or areas.) In general, turbidity increases downstream. This is an expected phenomenon: the relatively clear water from the upstream reservoirs continually gathers more suspended sediment as it moves downstream. Agricultural return flows also contribute to the turbidity increases downstream. The spikes in turbidity in late March were of unknown origin, but they appeared to take about 5 days to move through the river and they were attenuated in the process (see Attachment B).

The effects of the pulse flow in late April and early May on the water turbidity are clearly visible in the figures. The turbidity pulse was slight in the river above Turlock Lake State Recreation Area (see Attachment C), and became more pronounced the farther downstream it traveled. The turbidity peak appeared to reach its highest level during the pulse flow, around the Modesto area (about 5.5 NTU at Riverdale Park [RM 12.3]) and was attenuated somewhat below there.

The turbidity in the area of the special run-pools between run-pool 66 (RM 31) and RM 25 peaked at about 2.5 NTU during the pulse flow. Comparing this turbidity with the predation rate data for the special run-pools during the pulse flow, it is clear the turbidity pulse that accompanies a pulse flow of this magnitude is not enough to impair the success of sight-feeding predators. Turbidity would have to be artificially increased to reduce predation during a pulse flow.



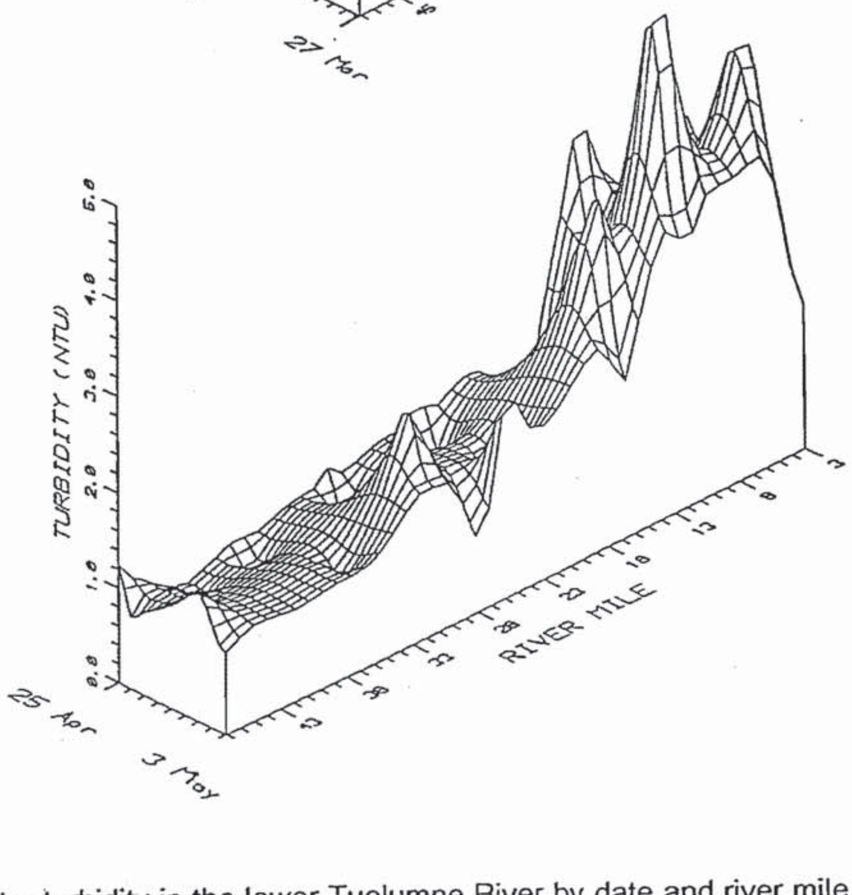


Figure 9. Water turbidity in the lower Tuolumne River by date and river mile for a period before and during the pulse flows, spring 1990.

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ATTACHMENT A:

PILOT STUDY REPORT: PREDATION BY PISCIVOROUS FISH IN THE TUOLUMNE RIVER, 1989

ATTACHMENT A: PILOT STUDY REPORT: PREDATION BY PISCIVOROUS FISH IN THE LOWER TUOLUMNE RIVER

A.1 INTRODUCTION

Predation has been implicated as a significant mortality factor for juvenile salmon (Foerster and Ricker 1941; Johnson 1965; Neave 1953; Peterman 1978; Poe and Rieman 1988; Ricker 1941, 1962). Salmon fry and smolts are subject to a variety of predators, including fish, birds, and mammals (Alexander 1979). Some studies indicate that as much as 55-85 percent of juvenile salmon (fry or smolts) can be removed by piscivorous fish in freshwater streams (Foerster 1968; Hunter 1959; Neave 1953). Piscivorous predation is an important component of chinook fry and smolt mortality, and is thus an important management concern. The pilot predation study was carried out to assess piscivorous fish predation in the Tuolumne River.

The level of predation on juvenile salmon is a function of several factors, which include predator density and prey density. In some situations the percentage mortality from predation actually decreases as salmon fry numbers increase (Hunter 1959; Neave 1953). Other data, however, do not show this "swamping effect" on predators caused by large prey populations (Neave 1953). In a review of the data from some previous experiments, Peterman (1978) concluded that because predators are often not saturated, one must determine how predation mortality varies with prey density in order to evaluate the effectiveness of salmon management programs.

Other factors that influence the level of predation include water flow, turbidity, cover, hatchery releases, size of predator, and water temperature. At low flows, salmon fry and smolts would be concentrated in a smaller area and therefore more susceptible to predation. The amount of cover would affect the vulnerability of salmon juveniles to predation. Turbidity is one aspect of cover, and at high turbidity levels, juvenile salmonids become less susceptible to predation by sight-feeding predators. High mortality of juvenile salmon has been reported for hatchery-released salmon (Buchanan et al. 1981). The size and type of prey has been shown to vary with the size of the predator: for example, Moyle and Li (1979) noted a transition in the diet of Sacramento squawfish from primarily insects to crayfish and fish at approximately 200 mm Standard Length. Water temperature may affect the structure of a predator population by regulating the abundance and size availability of prey (Adams et al. 1982).

The impact of predation on salmon fry and smolts by piscivorous predators in the Tuolumne River is not known, but in other areas these predators have been shown to cause significant mortality of chinook smolts (Poe and Rieman 1988). Frequently implicated predators on rearing and emigrating chinook salmon include squawfish (*Ptychocheilus* spp.), sculpins (*Cottus* spp.), smallmouth bass (*Micropterus dolomieui*), largemouth bass (*Micropterus salmoides*), rainbow trout (*Oncorhyncus mykiss*) and coho salmon (*Oncorhynchus kisutch*) (Patten 1971; Meacham and Clark 1979; Buchanan et al 1981; Poe and Rieman 1988). Although squawfish (*Ptychocheilus* spp.) have often been implicated as predators on salmon (Borgeson 1979; Jeppson and Platts

1959; Palmer et al. 1986; Poe and Rieman 1988; Steigenberger and Larkin 1974; Thompson 1959), other researchers have argued that squawfish are only a significant problem under unusual circumstances; e.g., below dams, near diversion facilities, and on hatchery-produced fish (Buchanan et al. 1981).

The three main objectives of the Tuolumne River pilot predation study were to obtain preliminary data on (1) the piscivorous predator population (species, abundance), (2) the rates of predation, and (3) the variability inherent in sites, timing of surveys, and numbers of fish examined. The preliminary data will permit the development of a comprehensive study plan which can be implemented in a future study for evaluating the species, numbers, and sizes of fish that prey on chinook salmon and the rates of predation through the rearing and emigration period. These data, combined with an estimate of fry/smolt production and density, can be used to evaluate the impact of piscivorous fish predation on chinook salmon juveniles in the Tuolumne River.

The pilot predation study was conducted in the lower Tuolumne River, below La Grange dam. The Tuolumne River Summer Flow Study Report (Appendix 27) was used to provide some additional preliminary information on fish species composition and distribution.

A.2 METHODS

Predation field studies were conducted during the months of April and May 1989 to coincide with the greatest potential chinook smolt outmigration. Nine sampling sites were randomly selected in the lower Tuolumne River (Figure A-1).

Electrofishing gear and gill nets were used to capture fish. Electrofishing gear alone was used to capture fish for estimating predation rates in the three sampling periods between April 11 and May 2. During this period, population estimates were not attempted.

A combination of electrofishing and gill netting was used at the Zanker site (RM 46.4) on 17 May for a capture-reduction estimate of predator abundances and predation-rate sampling. On 18 May a similar capture-reduction estimate was attempted at the McCleskey Farm (RM 6.0) site, but the gill nets clogged quickly with floating debris, and a capture-reduction population estimate could not be obtained. Table A-1 lists the locations of sampling sites and dates.

The electrofishing gear consisted of a gasoline-powered DC generator with three anodes mounted on a tow barge. In the predation-rate efforts, one electrofishing pass was completed at each sampling site on each sampling date. For the predator abundance sampling at the Zanker Farm (RM 46.4) site, a three-pass capture-reduction technique was used.

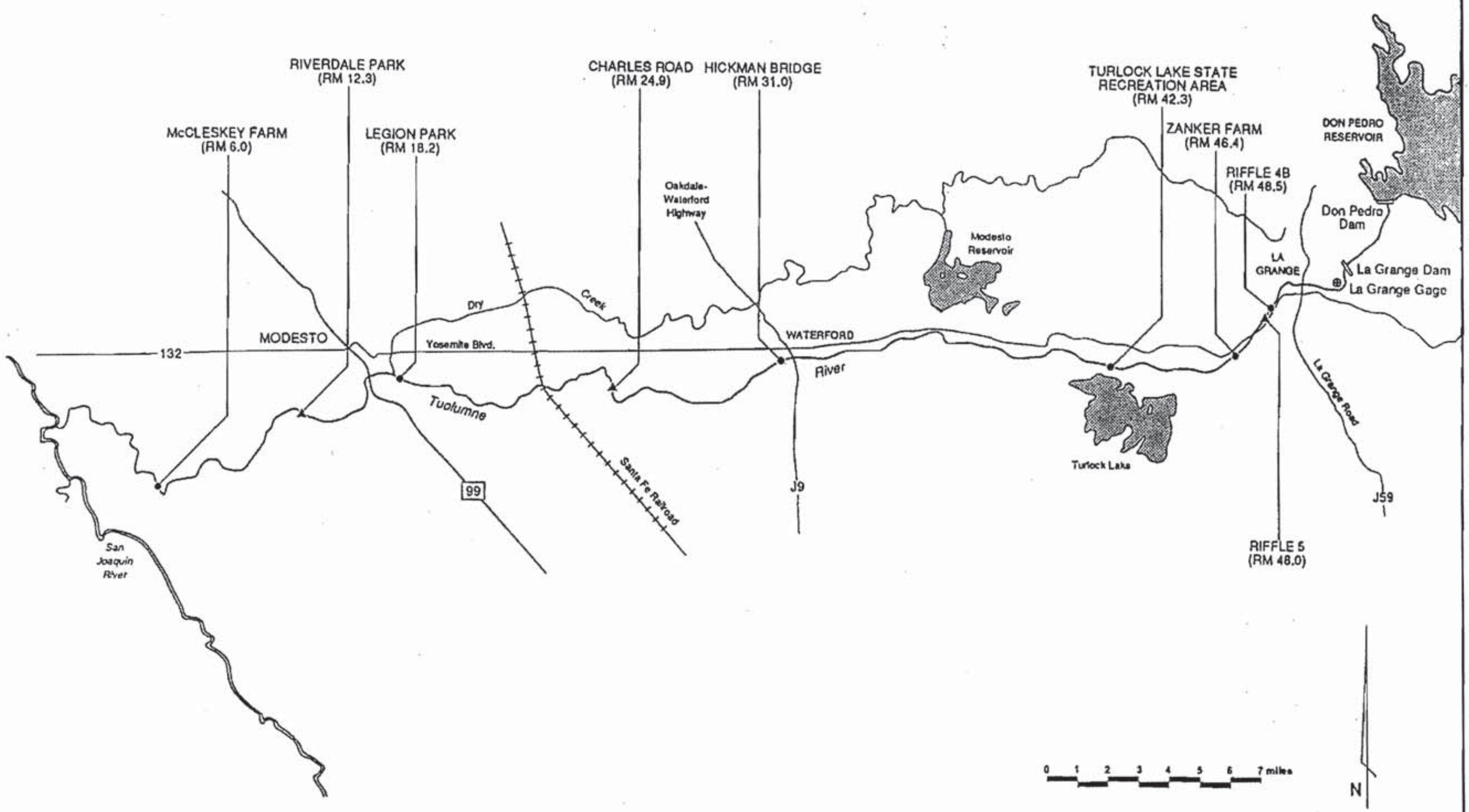

Figure A-1 Nine predation study sites sampled in the lower Tuolumne River, below La Grange Dam, 1989.

TABLE A-1 SITES SAMPLED ALONG THE TUOLUMNE RIVER TO GATHER DATA ON PREDATOR POPULATIONS AND PREDATION RATES, APRIL-MAY 1989

		Date			
Site	River Mile	Wk1	Wk2	Wk3	Wk5
Riffle 4B	48.5	11-Apr	18-Apr	29-Apr	
Riffle 5	48			30-Apr	
Zanker Farm	46.4				17-May
Turlock State Lake Recreation Area	42	12-Apr	18-Apr	30-Apr	
Hickman Bridge	31		19-Apr	1-May	
Charles Road	24.9			1-May	
Legion Park	18.2			1-May	
Riverdale Park	12.3		20-Apr	2-May	
McCleskey Farm	6	13-Apr	20-Apr	2-May	

A.2.1 PREDATION RATE

During each electrofishing pass, all fish of piscivorous species captured were placed into live wells for stomach pumping. Before its stomach was pumped, each fish was measured to Fork Length (mm) and weighed (g). Once the stomachs were pumped, the fish were put back into live wells to ensure their recovery and subsequently returned to the river.

A.2.1.1 Stomach Sample Collection

All predators captured were examined for the presence of juvenile chinook salmon in their stomachs. Stomachs were pumped by holding the fish in a vertical position, head down, and injecting water into the fish's stomach, which forced the fish to regurgitate the food items. All food items were placed in sealed containers in an 80 percent alcohol solution. In some fish (e.g., some squawfish and catfish), stomach pumping was not completely effective. In these cases the fish were sacrificed, and the entire stomach was removed and placed in a sealed container containing an 80 percent alcohol solution. All stomach samples were taken to the EA laboratory for examination.

A.2.1.2 Processing of Laboratory Samples

All preserved stomach samples were processed at the EA laboratory. The numbers of salmon and crayfish were enumerated for each sample. Other aquatic invertebrates were not identified, but the samples were re-preserved for future processing.

A.2.1.3 Analysis of Fry Counts From Stomach Samples

Although counts were made for a given species by date and location, these numbers were generally too small to be of much use at that level. Thus, it was most reasonable to pool the counts over dates and over the upper half and the lower half of the Tuolumne River. These data are presented as "upper stratum" and "lower stratum" data. The upper stratum of the river, river miles (RM) 25-52), contains all the riffle areas and included the following sites for this study: Riffle 4B (RM 48.5), Riffle 5 (RM 48.0), Zanker Farm (RM 46.4), Turlock State Lake Recreation Area (RM 42.3), and Hickman Bridge (RM 31.0). All other sites were included in the lower stratum of the river (RM 1-25), where the habitat consists mainly of run-pools. At this level of analysis, the preliminary data were quite useful.

Because many, if not most, potential predators caught had no fry in their stomachs, it was thought reasonable to assume a Poisson distribution for the number of fry in the stomachs of fish caught. It was also assumed that the numbers of fish in the stomachs of different fish were independent.

A.2.1.4 Gastric Evacuation Time

To estimate the number of prey items eaten per predator per day from the number of fry found in predators' stomachs, an estimate of the gastric evacuation time is needed. The gastric evacuation time is the time it takes an ingested food item to become unidentifiable through digestion by the predator. A review of the literature was carried out to determine, as far as possible, evacuation rates for salmon young for the predator species and environmental conditions involved.

A.2.2 PREDATOR ABUNDANCE

A.2.2.1 Capture-Reduction Technique

The capture-reduction technique for estimating the density of predatory fish (used at the Zanker Farm (RM 46.4) site on May 17) involved blocking (with 1/4-inch-mesh gill nets) the upper and lower ends of a river section approximately 80 meters in length and driving fish (with an electroshocker powered by a gasoline-powered electric generator on a tote barge) into a series of size-graded gill nets located at the upper end of the section (Figure A-2). Fish were removed from the gill nets immediately after each pass and kept in live wells. This procedure was repeated until the reduction of captures on sequential passes was sufficient to estimate the population size. The stomachs of all predatory fish species were pumped and preserved for later analysis. All fish were then returned to the river. Water temperature and electrical conductivity were recorded on each data sheet. The capture-reduction technique was attempted at the McCleskey Farm (RM 6.0) site, but it was not completed, because the blocking nets very quickly became clogged with suspended organic matter.

A.3 RESULTS

A.3.1 PREDATION RATES

A.3.1.1 Predation on Chinook Juveniles

Twelve potential chinook salmon predator species (two of which are native species) were captured during the pilot study. The numbers of potential predators collected at the various sites in the upper and lower strata and examined for stomach contents are presented in Tables A-2 and A-3.

Of the fish of 12 species examined, only five smallmouth bass (9 percent of all smallmouth bass captured in the two strata) and two largemouth bass (4 percent) were found to contain chinook fry

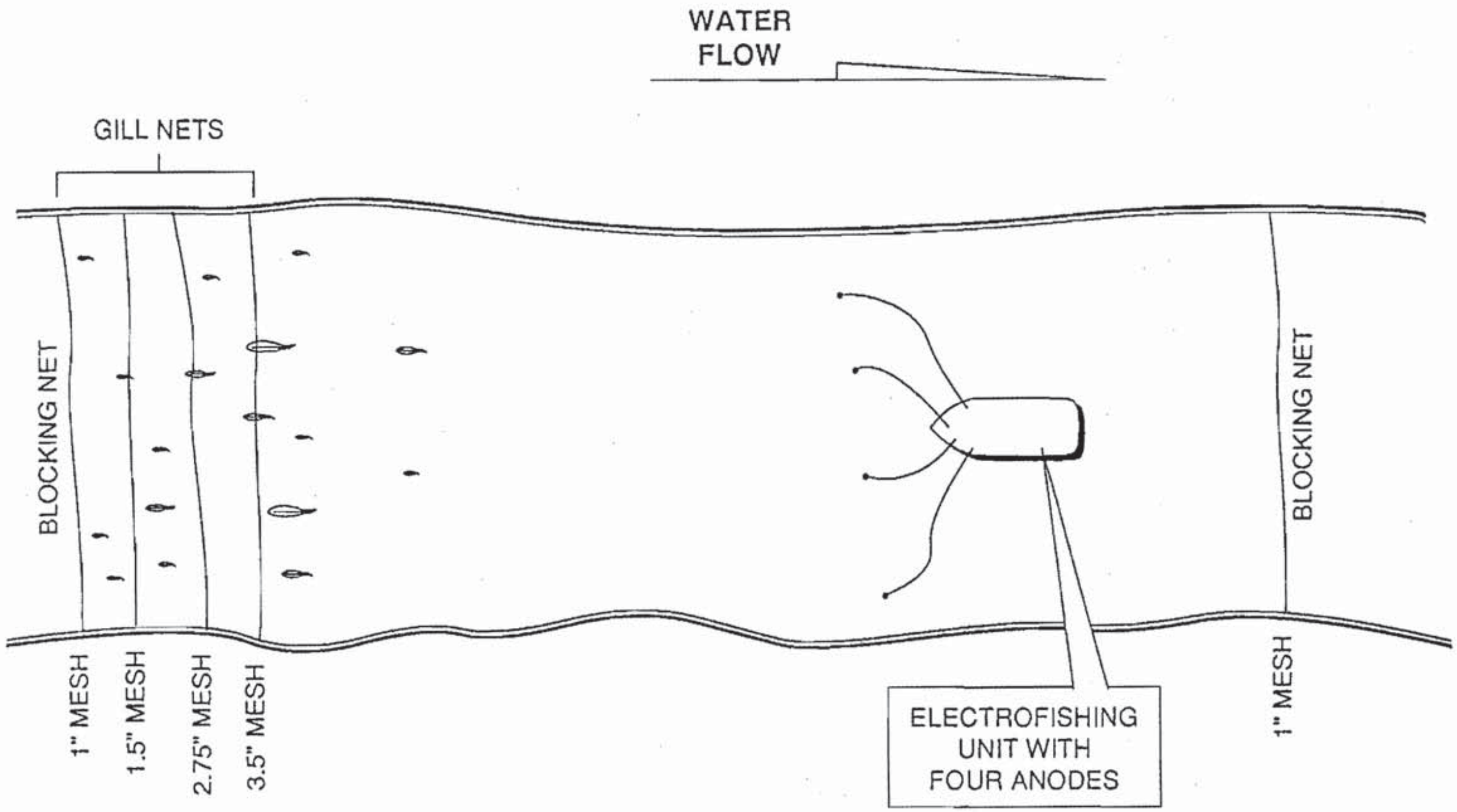

Figure A-2 Capture-reduction technique used to estimate fish populations at the Zanker Farm site and attempted at the McCleskey Farm site

TABLE A-2 NUMBERS OF POTENTIAL PREDATORS EXAMINED FOR CHINOOK SALMON IN STOMACHS AT UPPER-SECTION SITES, APRIL-MAY 1989

	Site					
Species (N=native species)	R4B	R5	Zanker	TLSRA	Hickman	All
Smallmouth bass (*Micropterus dolomieui*)	4	0	5	7	14	30
Largemouth bass (*Micropterus salmoides*)	1	1	14	2	2	20
Striped bass (*Morone saxatilus*)	0	0	0	0	0	0
Bluegill (*Lepomis macrochirus*)	2	1	1	3	7	14
Redear sunfish (*Lepomis microlophus*)	0	0	7	5	1	13
Green sunfish (*Lepomis cyanellus*)	4	0	4	2	4	14
Warmouth (*Lepomis gulosus*)	0	0	0	1	0	1
Channel catfish (*Ictalurus punctatus*)	0	0	0	0	0	0
White catfish (*Ictalurus catus*)	0	0	0	0	6	6
Brown bullhead (*Ictalurus nebulosus*)	5	0	0	9	9	23
Sacramento squawfish (N) (*Ptychocheilus grandis*)	6	0	0	42	20	68
Riffle sculpin (N) (*Cottus asper*)	1	0	0	0	0	1
Total	23	2	31	71	63	190

TABLE A-3 NUMBERS OF POTENTIAL PREDATORS EXAMINED FOR CHINOOK SALMON IN STOMACHS AT LOWER-SECTION SITES, APRIL-MAY 1989

	Site				
Species (N=Native)	Charles Road	Legion Park	Riverdale Park	McCleskey Farm	All
Smallmouth bass	1	0	10	17	28
Largemouth bass	3	4	18	11	36
Striped bass	0	0	0	8	8
Bluegill	2	9	8	8	27
Redear sunfish	0	1	6	10	17
Green sunfish	1	0	7	12	20
Warmouth	0	0	0	0	0
Channel catfish	0	0	0	11	11
White catfish	1	1	3	13	18
Brown bullhead	1	0	0	0	1
Sacramento squawfish (N)	0	0	0	0	0
Riffle sculpin (N)	0	0	0	0	0
Total	9	15	52	90	166

or smolts in their stomachs. These seven fish constituted 3.7 percent of the 190 predatory fish examined in the upper stratum. All of these fish were collected in the upper stratum of the river; no predation on salmon was found in the 149 fish examined in the lower stratum. The five smallmouth bass ranged in fork length from 168 to 267 mm and in weight from 60 to 280 g. The median fork length (253 mm) of the five smallmouth bass with salmon present in their stomachs was significantly higher ($P < 0.05$) than the median fork length (166 mm) of the 53 smallmouth bass without salmon (Figure A-3). The weight-length relationship of smallmouth bass examined is presented in Figure A-4. The two largemouth bass with salmon in their stomachs were 160 and 222 mm in fork length and 55 and 170 g in weight, respectively. There was no significant difference ($P > 0.05$) between the median fork length of largemouth bass with salmon present (191 mm, n=2) and salmon absent (202 mm, n=54) in their stomachs (Figure A-5). The weight-length relationship for largemouth bass examined is presented in Figure A-6.

A summary of the stomach content data is provided below:

	Number Examined	Number with Salmon	Number of Salmon
Smallmouth bass			
Upper Stratum	30	5	10
Lower Stratum	28	0	0
Total	58	5	10
Largemouth bass			
Upper Stratum	20	0	0
Lower Stratum	36	2	3
Total	56	2	3

The numbers of predators containing salmon by date and site and the numbers of salmon found in their stomachs are presented in Table A-4.

The weight-length relationships for all other species examined are presented in the section on predation on crayfish.

Daily predation rates were estimated in two steps. First, the predation ratio (by species) was calculated by dividing the total number of fry in the stomachs of predators by the number of predators captured. In the upper stratum sites of the Tuolumne River, 10 chinook salmon smolts were found in the stomachs of the 30 smallmouth bass examined. The estimated predation ratio was 10/30, or 0.33. The lower and upper 95 percent confidence intervals, assuming a Poisson distribution for the estimate, are 0.16 and 0.61 (Johnson and Kotz 1969). The predation ratio for largemouth bass, in the upper section, based on the presence of three young salmon in the stomachs of 20 bass, was 3/20 or about 0.15.

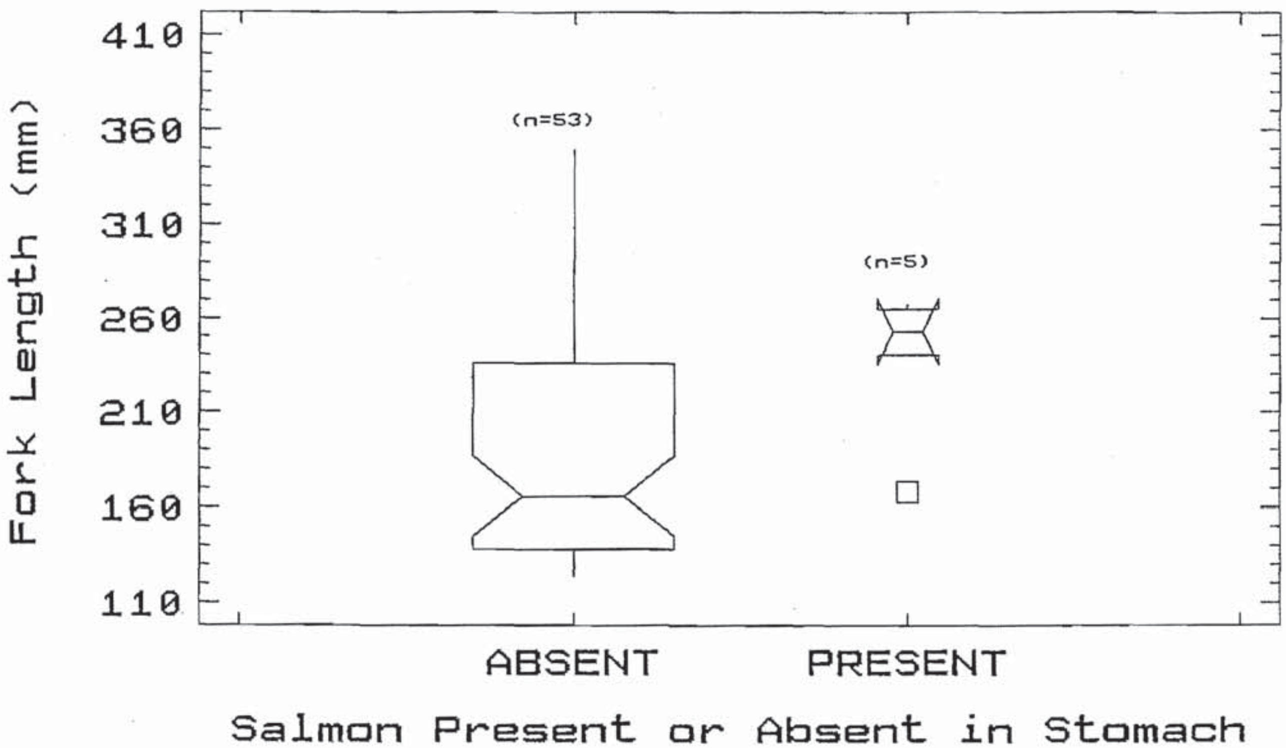

Figure A-3 Notched box-and-whisker plot of the fork length of smallmouth bass with and without salmon in stomach contents.

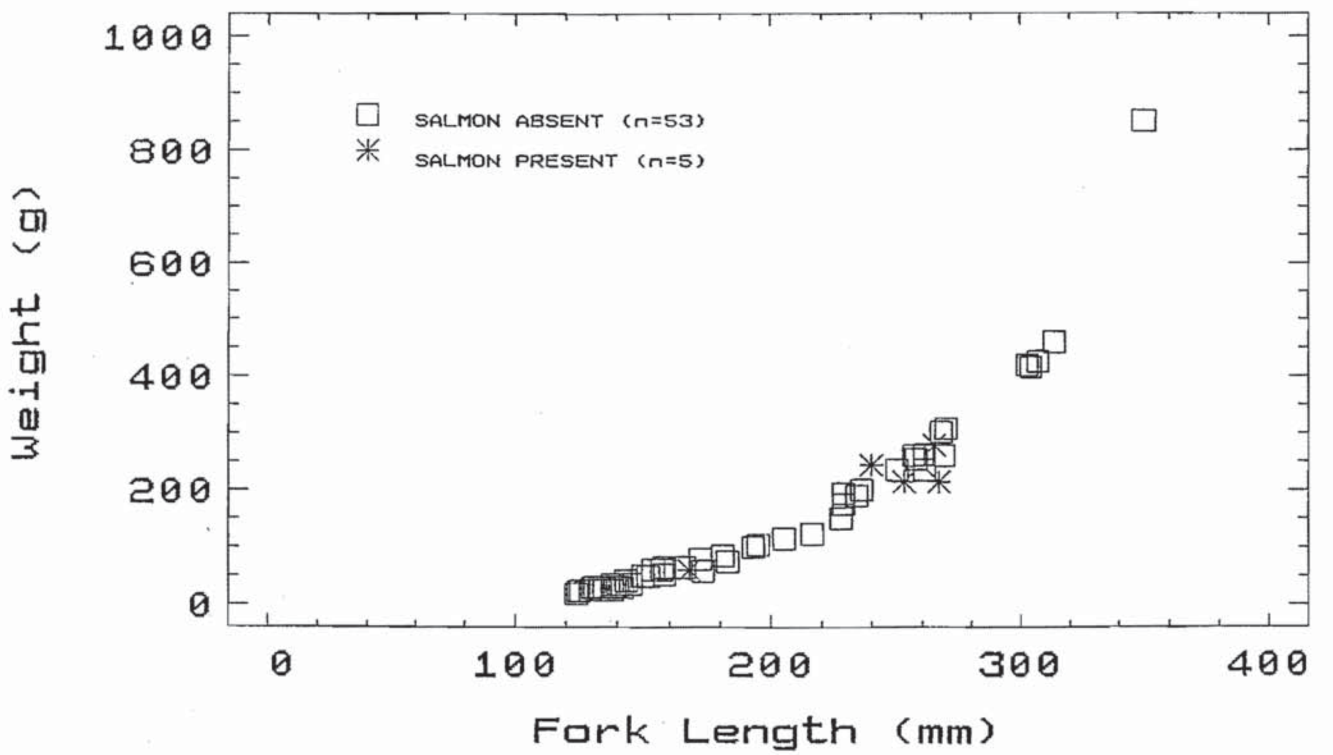

Figure A-4 Weight-length relationship of smallmouth bass with and without salmon in stomach contents.

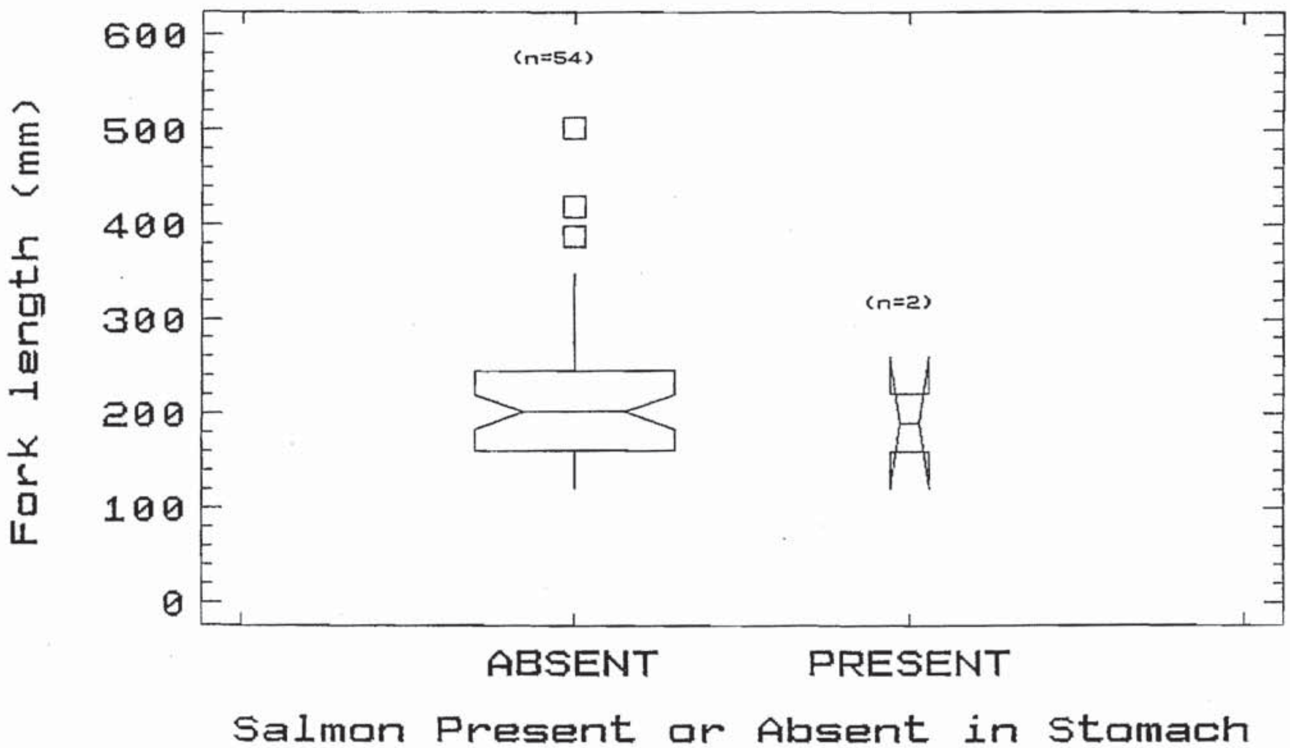

Figure A-5 Notched box-and-whisker plots of the fork length of largemouth bass with and without salmon in stomach contents.

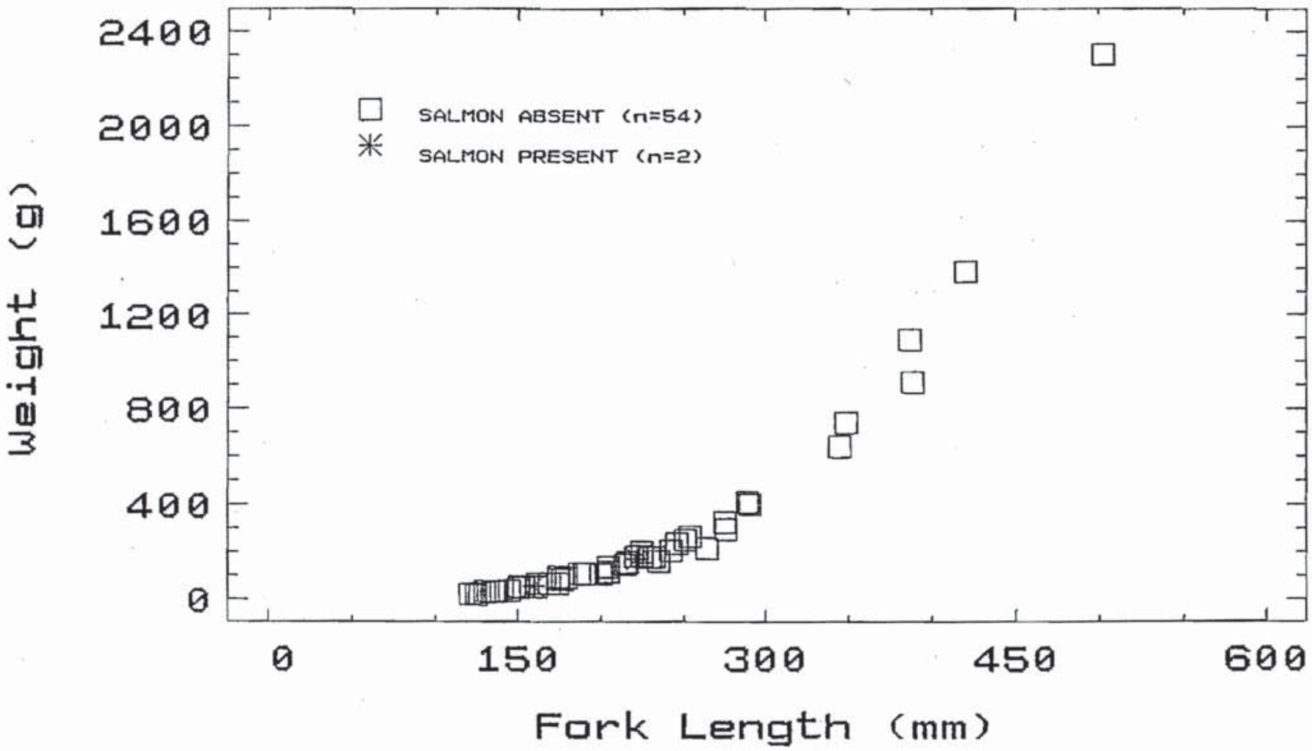

Figure A-6 Weight-length relationship of largemouth bass with and without salmon in stomach contents.

TABLE A-4 NUMBER OF PREDATORS WHICH CONTAINED SALMON, BY SAMPLING DATE AND SITE, UPPER SECTION OF THE LOWER TUOLUMNE RIVER, APRIL-MAY 1989

Species	Number with Salmon	Number of Salmon	Sampling Date	Sampling Site
Smallmouth bass	1	2	19-Apr	TLSRA
Largemouth bass	1	1	19-Apr	HICKM
Smallmouth bass	2	4	19-Apr	HICKM
Smallmouth bass	2	4	30-Apr	TLSRA
Largemouth bass	1	2	17-May	ZANKE

The second step in calculating the daily predation rate was to adjust the predation ratio with the gastric evacuation time for the food items. Many factors affect gastric evacuation time, including predator and prey species (Beyer and Burley 1988), predator size (Swenson and Smith 1973; Jobling et al. 1977), size and type of meal (Fange and Grove 1979), and water temperature (Molnar et al. 1967; Durbin and Durbin 1980). Steigenberger and Larkin (1974) found that squawfish held at 10-12 degrees Celsius showed an evacuation time for sockeye salmon (*Oncorhynchus nerka*) smolts of 7.1 hours. They found that most squawfish cleared their stomach contents in about 24 hours, and that half had done so between 12 and 18 hours. These researchers also found that the evacuation times for squawfish that were force-fed rainbow trout decreased with water temperature, from 20 hours at 4-6 C to 2-2.5 hours at 24 C. They concluded that evacuation times decreased with increasing temperature, increased with larger weights of food, and did not differ with the size of the predator fish. Beyer and Burley (1988) found that evacuation times for smallmouth bass decreased with increases in water temperature, food weight, and predator weight. The gastric evacuation times for fingerling bass as prey may be similar for related predator species: 48-72 hours for smallmouth bass, as compared to 48-84 hours for largemouth bass (Lane and Jackson 1969). It should be kept in mind that smallmouth bass prefer colder and faster-moving water (Ferguson 1958; Scott and Crossman 1973) and may therefore have different metabolisms and evacuation times. Beyer and Burley (1988) concluded that smallmouth bass evacuation times were faster than those for largemouth bass and that evacuation time was between 3 and 78 hours over the range of variables tested (temperature, predator weight, prey weight, etc.). Because evacuation time estimates vary so much with the several factors involved, the results are presented over a range of evacuation times. If f is the average number of fry caught by the predator per day, and d is the average number of days that fry evidence remains in the stomach, then fd is the average number of salmon present in the fish's stomach, estimated as $\hat{\lambda}$. Assuming that d is known, we estimate f by

$$\hat{f} = \hat{\lambda} / d$$

If the the evacuation time = 24 hours (d=1) then $\hat{f} = \hat{\lambda}$. In the above smallmouth bass example, the number of prey items eaten per day per smallmouth bass is equal to 0.33. If the gastric evacuation time is only 12 hours (d=0.5) then the number of prey items eaten per smallmouth bass per day is equal to 0.33/0.5, or 0.66.

Assuming an evacuation time of 18 hours (d=0.75) for both smallmouth bass and largemouth bass, the estimated rate of predation for smallmouth bass, 0.44, was over twice as high as that estimated for largemouth bass, 0.20. The estimated numbers of salmon eaten per predator per day, for the expected range of evacuation times for smallmouth bass and largemouth bass, are shown in Figure A-7.

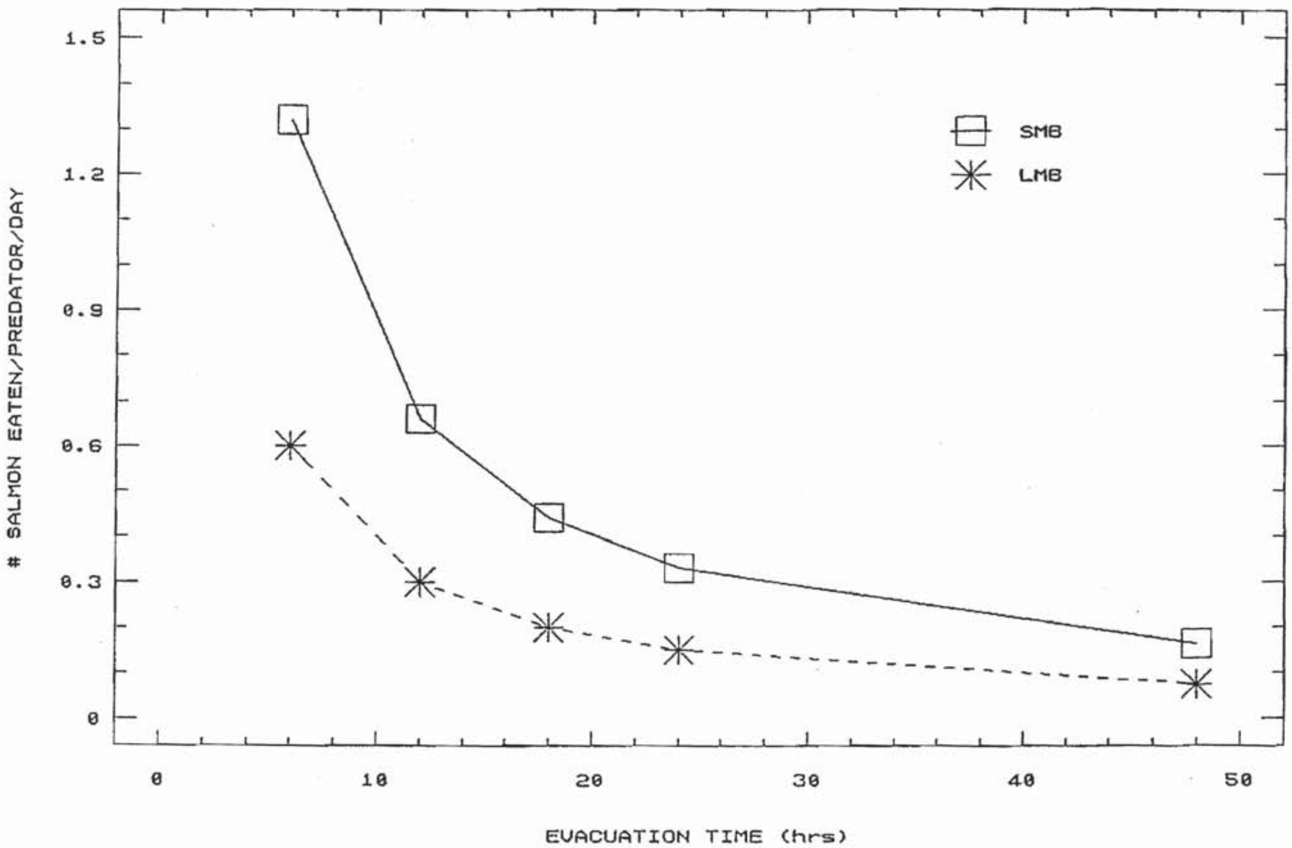

Figure A-7 Estimated numbers of salmon eaten per predator (LMB, SMB) per day, for various possible evacuation times.

A.3.1.2 Predation on Crayfish

Daily predation rates on crayfish by predatory fish were calculated in the same manner as the predation rates on chinook juveniles. Of the 190 fish examined in the upper stratum, 17 percent had crayfish in their stomachs; of the 160 fish examined in the lower stratum, 33 percent had crayfish in their stomachs. Crayfish were found in the stomachs of all predatory species except redear sunfish, warmouth, and riffle sculpin. (It should be noted that only one warmouth and one riffle sculpin were captured and examined.) A summary of the stomach data relating to the occurrence of crayfish in predator stomachs is presented in Table A-5. In the upper stratum of the river, squawfish (0.64), brown bullhead (0.60), white catfish (0.66), and smallmouth bass (0.60) had the highest estimated predation ratios. In the lower stratum- channel catfish (1.09), striped bass (0.78), and largemouth bass (0.78) had the highest daily predation ratios for crayfish. The daily rates of predation by predator species in the upper and lower strata, assuming a gastric evacuation time of 24 hours (d=1), are shown in Figures A-8 and A-9.

A.3.1.3 Predator Densities

Seven of the 12 potential predatory species were collected at the Zanker Farm (RM 46.4) site on 17 May. Centrarchids constituted the most abundant family of fish in the electrofished section, and bluegill were the most abundant of these. The population estimates and 95 percent confidence intervals for the potential predatory species species captured at the Zanker Farm site were the following:

Species (N=Native)	Population Estimate	Interval Lower	Interval Upper
Smallmouth bass	5	5	6
Largemouth bass	18	16	25
Bluegill	95	67	135
Redear sunfish	62	58	69
Green sunfish	34	23	63
Brown bullhead	11	10	16
Sacramento squawfish (N)	7	7	9

A.4 DISCUSSION

Of the 12 potential predatory species examined, only two, smallmouth and largemouth bass, were found to contain chinook juveniles. Of the smallmouth bass examined, 8.6 percent contained one or more chinook salmon juveniles. Palmer et al. (1986) reported that of 1,683 smallmouth bass examined from John Day reservoir, 1.8 percent contained a chinook juvenile. In that study, the

TABLE A-5 NUMBERS OF PREDATORY FISH AND CRAYFISH PREDATION NUMBERS IN THE UPPER (U) AND LOWER (L) SECTIONS OF THE LOWER TUOLUMNE RIVER, APRIL-MAY 1989

	Predatory Fish					
	Number Examined		Number Containing Crayfish		Number of Crayfish	
Species (N=Native)	U	L	U	L	U	L
Smallmouth bass	30	28	7	9	9	10
Largemouth bass	20	36	2	18	3	22
Striped bass	0	8	0	4	0	6
Bluegill	14	27	0	2	0	2
Redear sunfish	13	17	0	0	0	0
Green sunfish	14	20	1	9	2	9
Warmouth	1	0	0	0	0	0
Channel catfish	0	11	0	9	0	12
White catfish	6	13	2	3	2	4
Brown bullhead	23	1	6	0	7	0
Sacramento squawfish (N)	68	0	15	0	22	0
Riffle sculpin (N)	1	0	0	0	0	0
Total	190	166	33	54	45	65
Total	356		87		110	

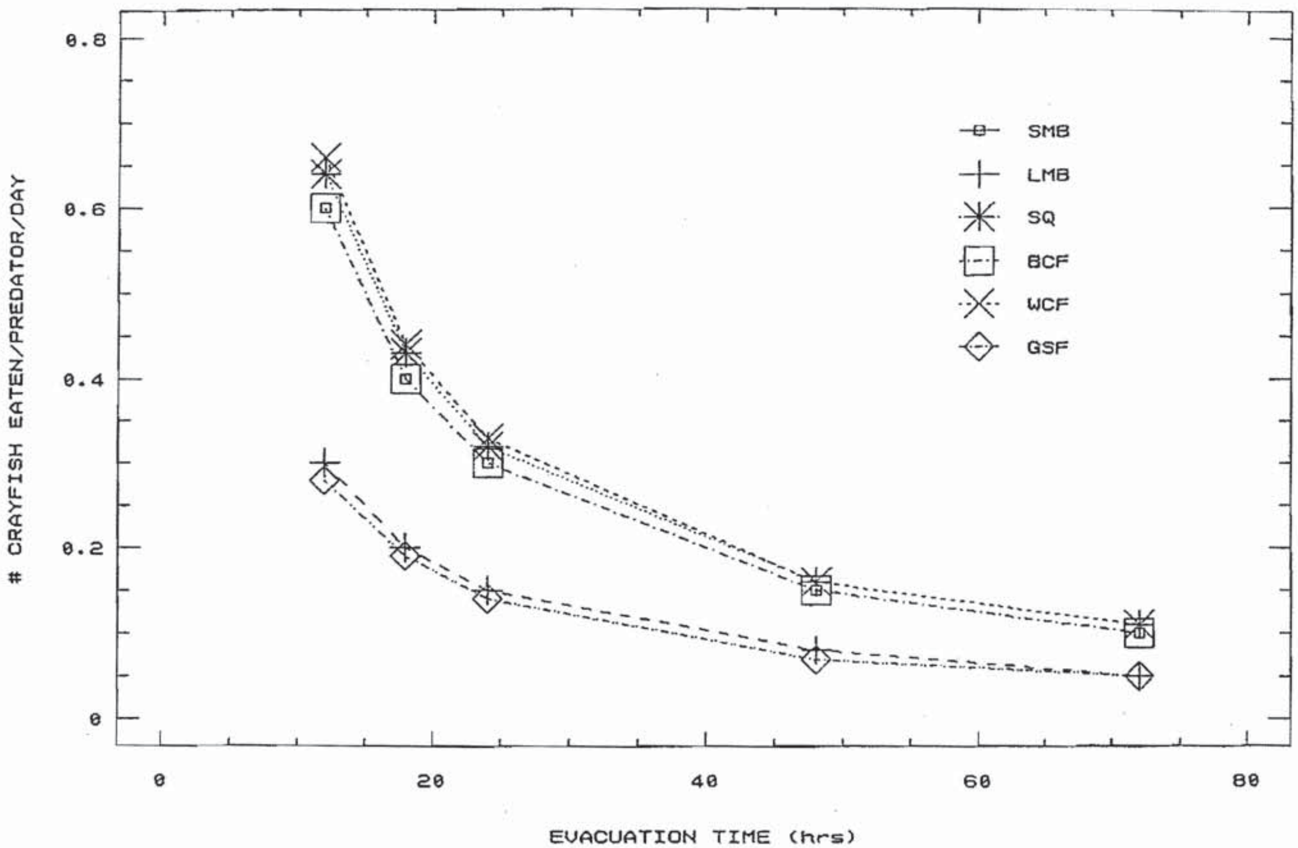

Figure A-8 Estimated numbers of crayfish eaten in the upper river section per predator per day, for various evacuation times.

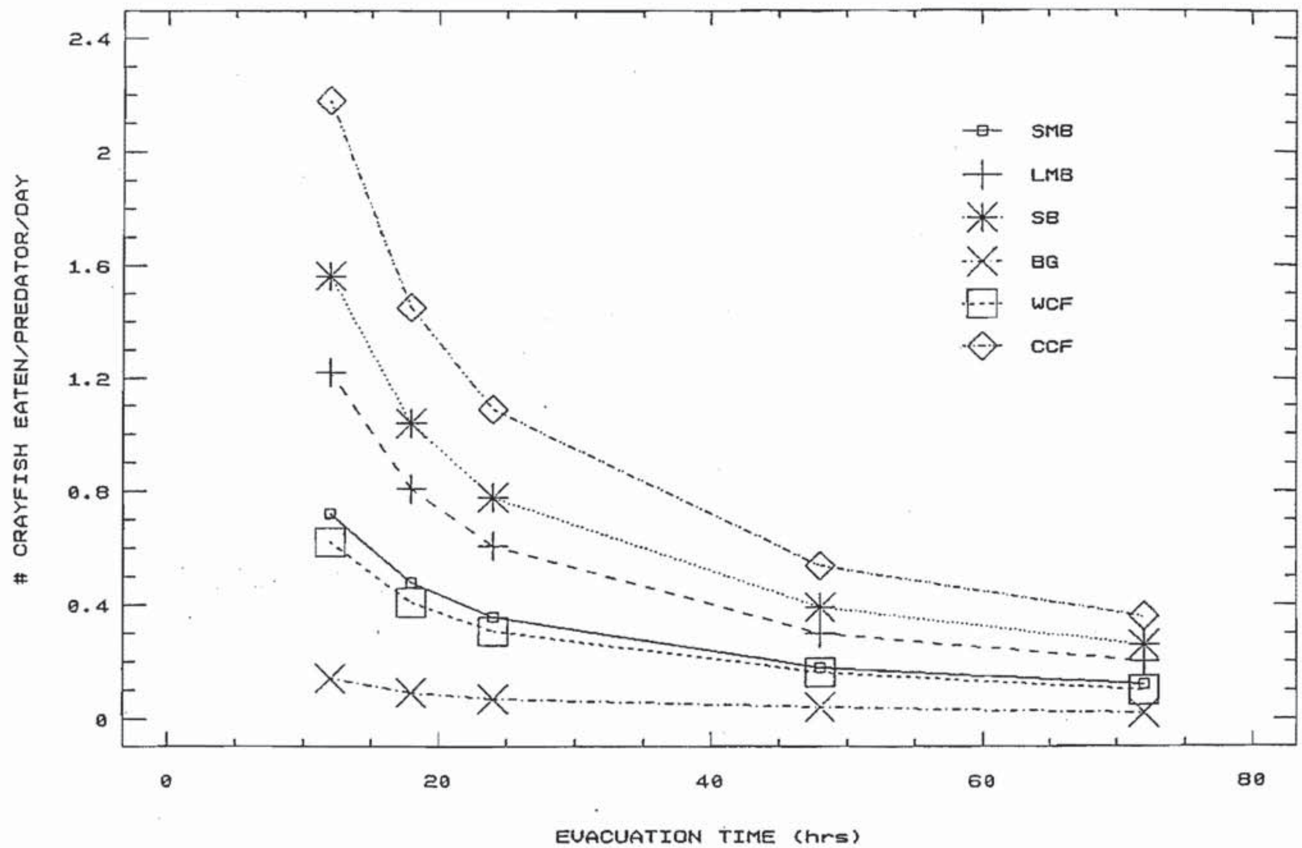

Figure A-9 Estimated numbers of crayfish eaten in the lower river section per predator per day, for various evacuation times.

smallest smallmouth bass found to have ingested a salmonid was 94 mm in fork length; in this study, the smallest was 168 mm long.

Of the 68 Sacramento squawfish examined in this study, none contained chinook salmon in their stomachs. Palmer et al. (1986) found that 19 percent of the northern squawfish examined from John Day Reservoir contained chinook juveniles; of these, the smallest northern squawfish found to have consumed a fish of any species was 113 mm in fork length, while the smallest that contained a salmonid was 256 mm long. The range in fork lengths of Sacramento squawfish in the lower Tuolumne River was from 112 to 625 mm.

Smallmouth bass are suited to cooler and faster-flowing water than largemouth bass. It was expected that more smallmouth bass would be collected in the upper stratum and more largemouth bass in the lower stratum of the river. In the upper stratum (assuming that evacuation rates are the same for the two species), smallmouth bass preyed at approximately twice the rate of largemouth bass on both chinook juveniles and crayfish (see Figures A-7 and A-8). In the lower stratum, largemouth bass showed a higher predation rate on crayfish than did smallmouth bass (Figure A-9). For both species however, the rate of predation on crayfish was greater in the lower stratum than in the upper section: overall, twice as high. The variability in predation rates on both salmon and crayfish in the upper and lower strata of the lower Tuolumne River indicate that an estimate of the entire invertebrate food base at different sites along the river would be very useful in understanding predation.

This pilot study was conducted over a relatively short period, approximately one month. Salmon juveniles are generally present in the system from as early as January to as late as June, and predation can occur over this entire time period. The amount of predation and the times of predation depend in part on the seasonal movements of the predators. For example, Sacramento squawfish may migrate upstream to spawn in the spring, and they may pose more of a threat of predation then than earlier in the year.

One problem encountered during the study was obtaining population estimates with the available gear. A capture-reduction method was satisfactory when used in a shallow (<3.5 feet deep) reach of the river. When water depth increases, a tote barge electrofisher is less effective. In addition, it is difficult to keep debris out of the nets in deeper water, especially in the lower strata of the river where there are high levels of organic debris. For these reasons, the use of a boat electrofisher and a multiple-mark-recapture population estimation procedure (e.g., Jolly-Seber, Schnabel Census [Seber 1982]) is recommended for the censusing of predators.

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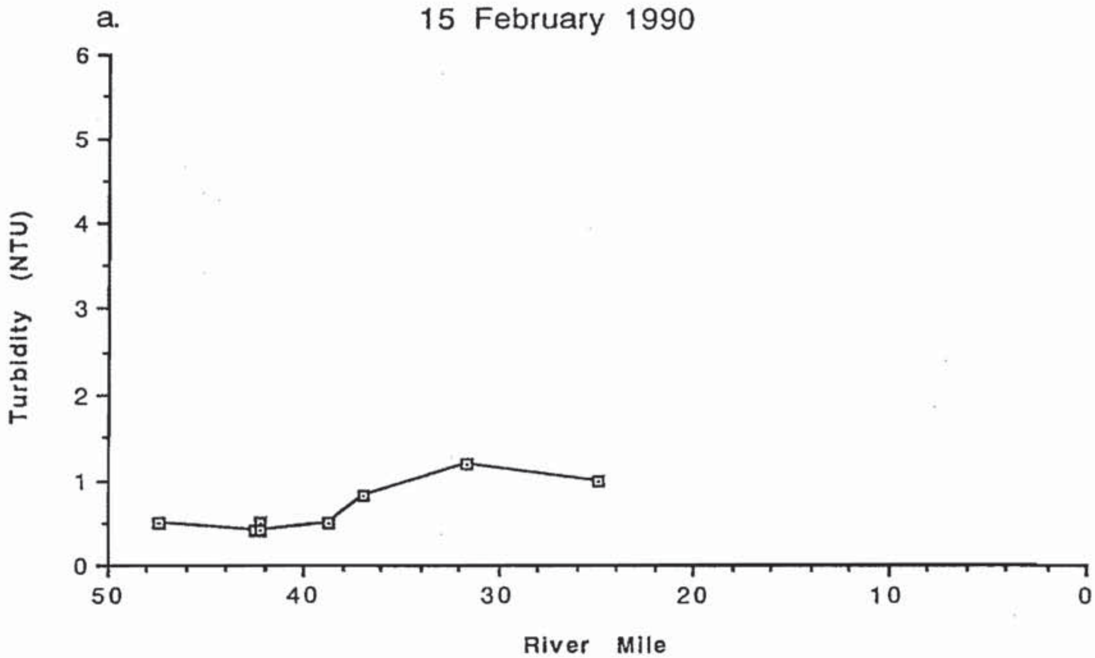
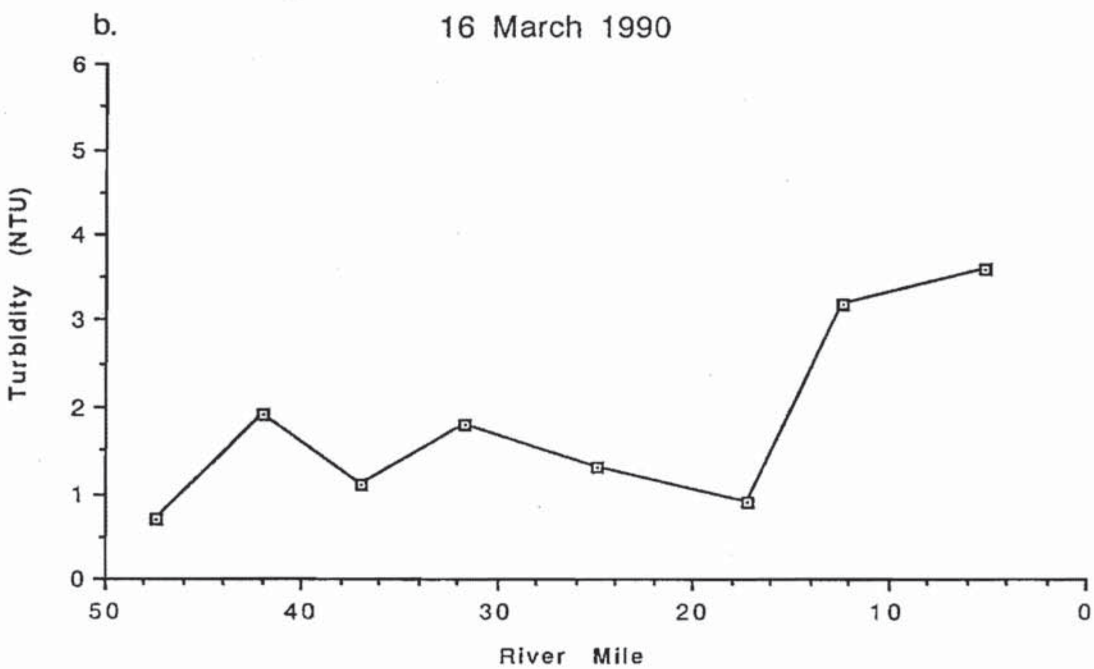
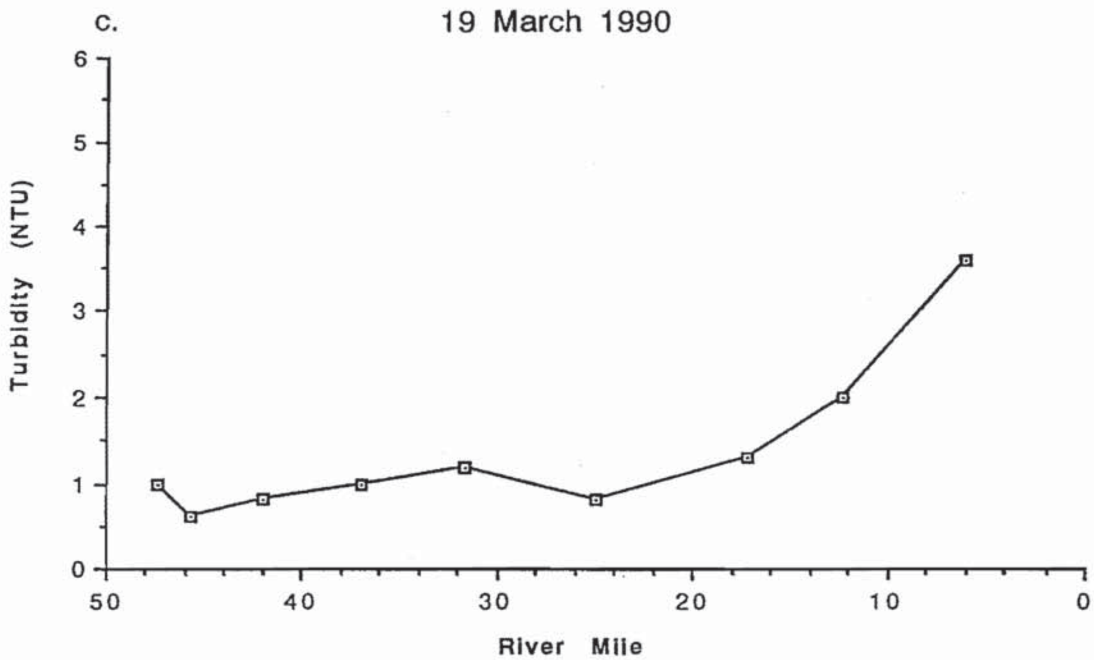
ATTACHMENT B:

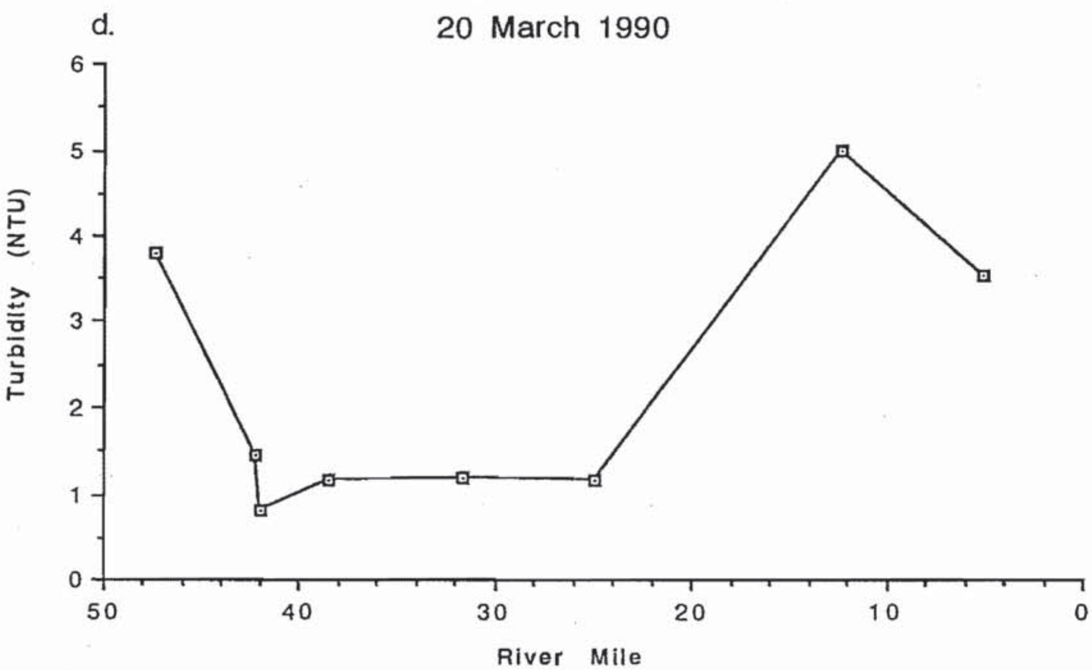
LONGITUDINAL PLOTS OF TURBIDITY, BASED ON GRAB SAMPLES, IN THE LOWER TUOLUMNE RIVER, BASSO BRIDGE TO MCCLESKEY RANCH, FEBRUARY-MAY 1990

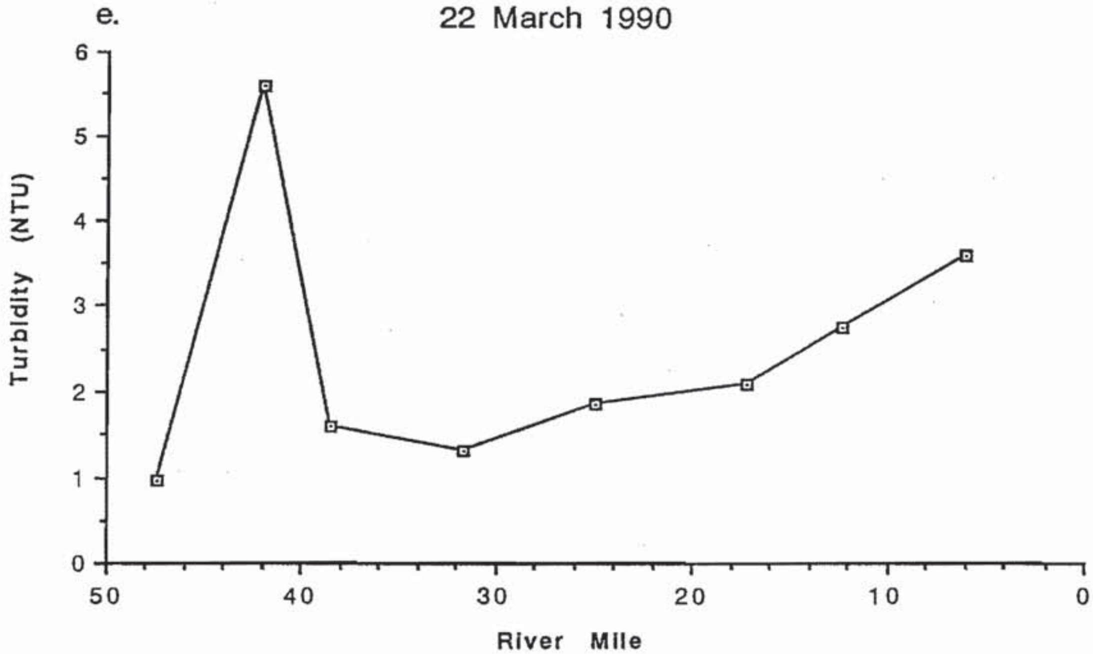
These are longitudinal turbidity plots on specified dates. Turbidity is plotted in Nephelometric Turbidity Units (NTU) (see methods in Section 2.3.1). Note the pulse of turbidity that starts on 20 March and moves through the river over the next five days.

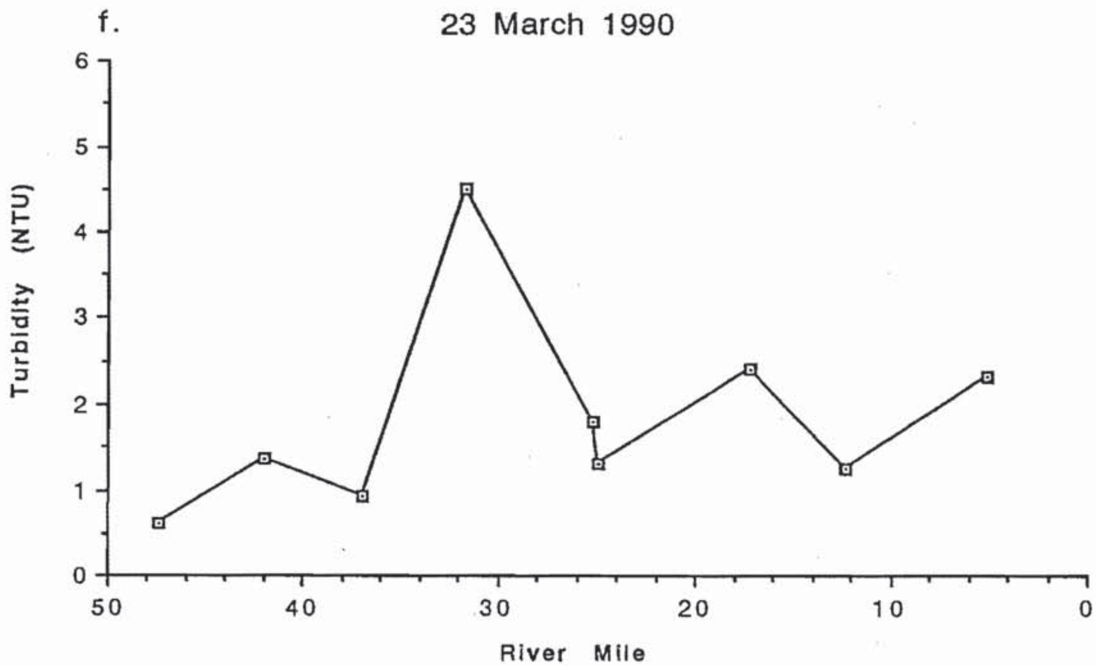

a.
15 February 1990
Turbidity (NTU)
6
5
4
3
2
1
0
50
40
30
20
10
0
River Mile

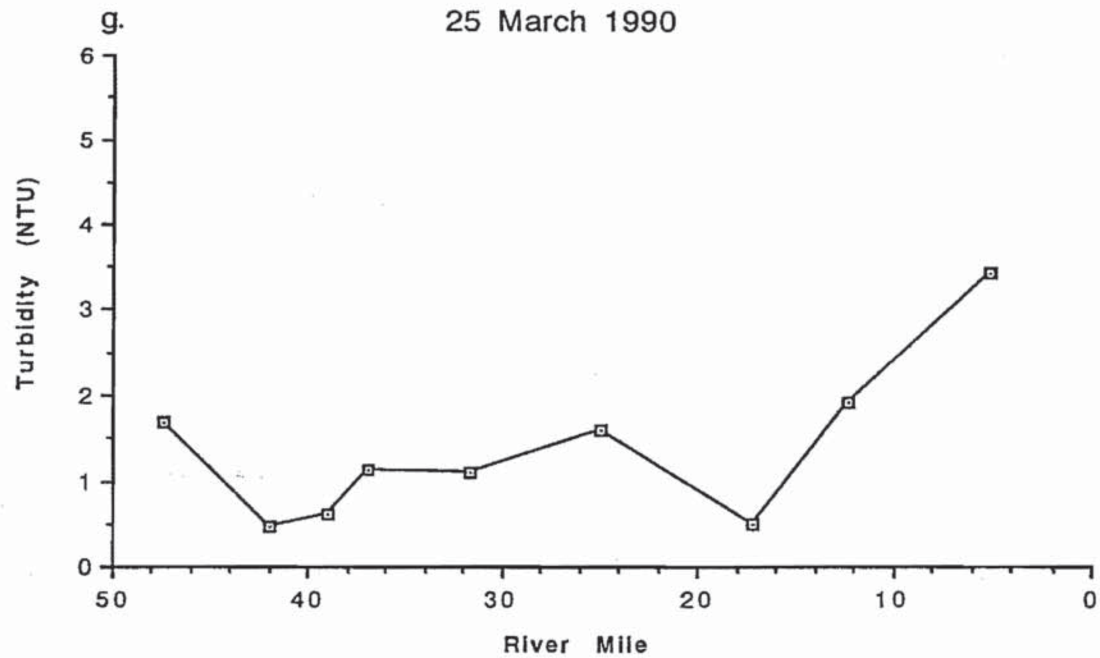

b.
16 March 1990
Turbidity (NTU)
6
5
4
3
2
1
0
50
40
30
20
10
0
River Mile

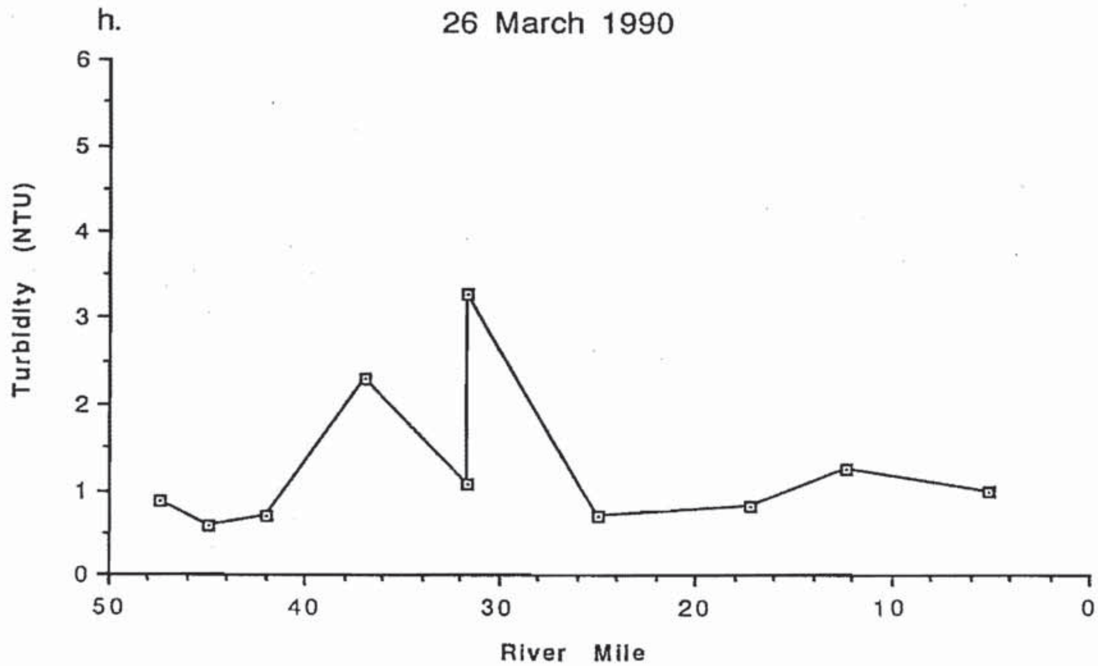

c.
19 March 1990
Turbidity (NTU)
6
5
4
3
2
1
0
50
40
30
20
10
0
River Mile

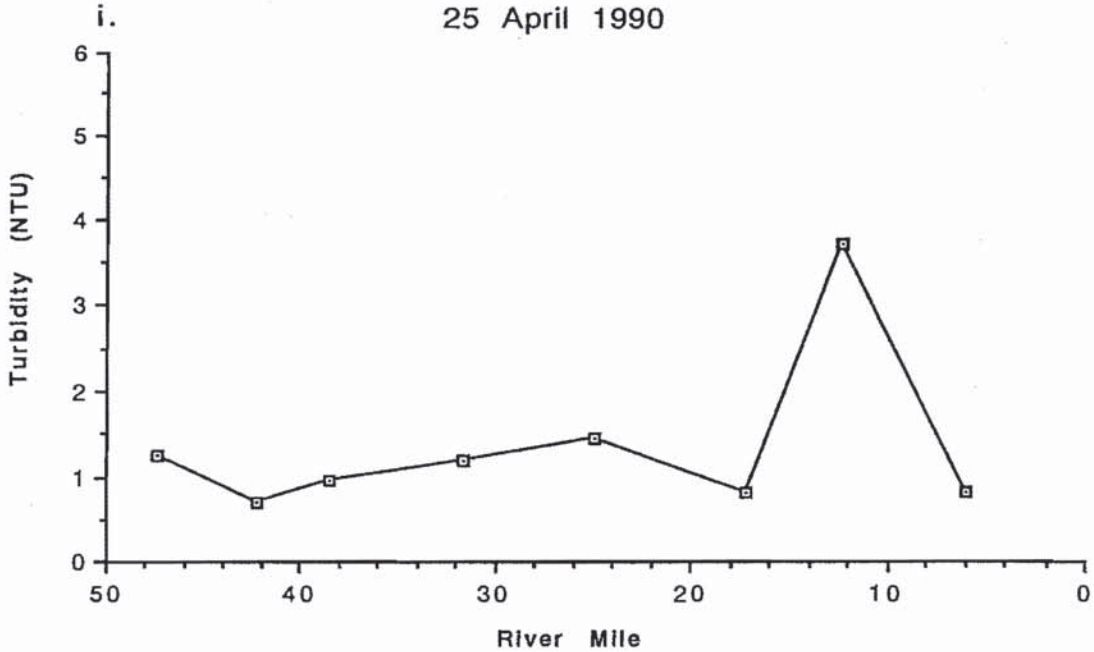

d.
20 March 1990
Turbidity (NTU)
6
5
4
3
2
1
0
50
40
30
20
10
0
River Mile

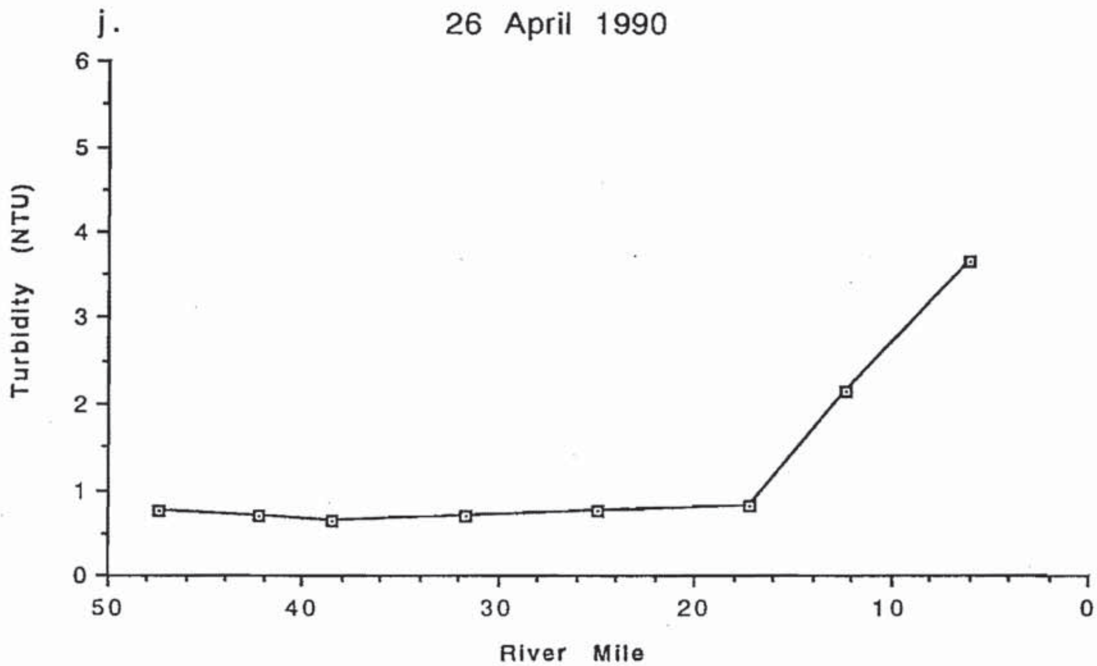

e.
22 March 1990
Turbidity (NTU)
0
1
2
3
4
5
6
50
40
30
20
10
0
River Mile

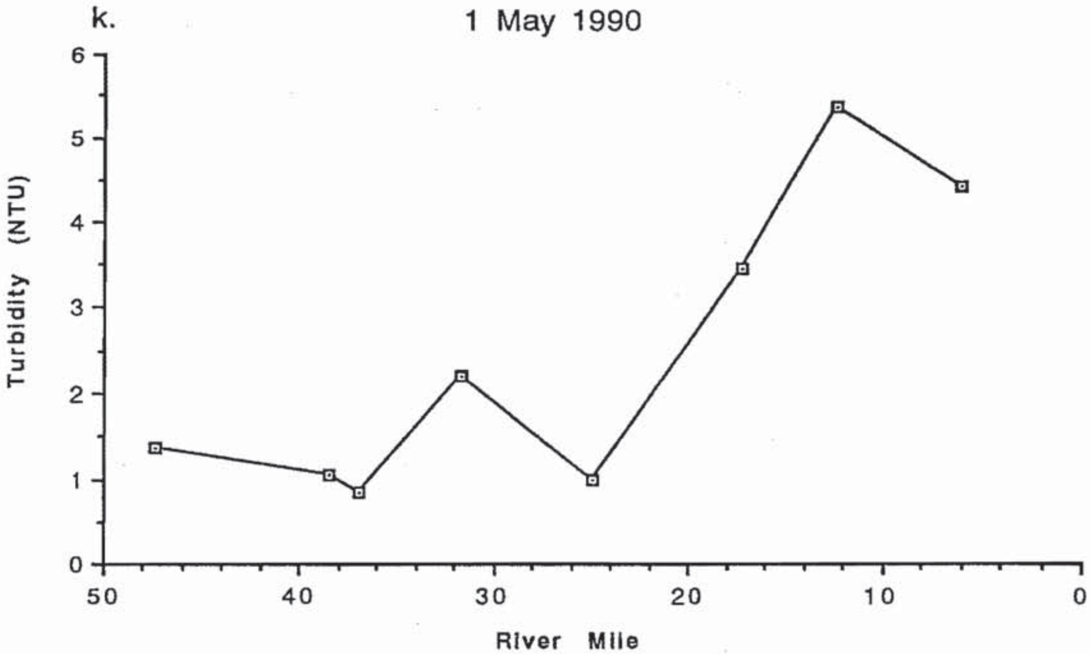

f.
23 March 1990
Turbidity (NTU)
0
1
2
3
4
5
6
50
40
30
20
10
0
River Mile

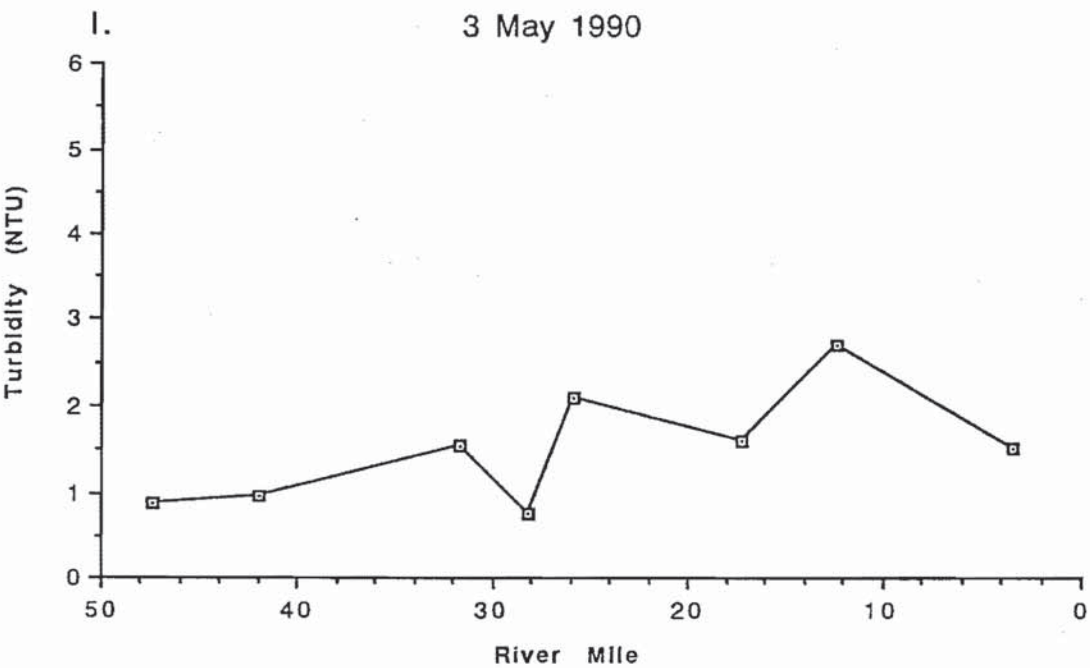

g.
25 March 1990
Turbidity (NTU)
River Mile
6
5
4
3
2
1
0
50
40
30
20
10
0


h.
26 March 1990
Turbidity (NTU)
River Mile
6
5
4
3
2
1
0
50
40
30
20
10
0


i.
25 April 1990
Turbidity (NTU)
River Mile
0
1
2
3
4
5
6
50
40
30
20
10
0


j.
26 April 1990
Turbidity (NTU)
River Mile
0
1
2
3
4
5
6
50
40
30
20
10
0


k.
1 May 1990
Turbidity (NTU)
River Mile
6
5
4
3
2
1
0
50
40
30
20
10
0

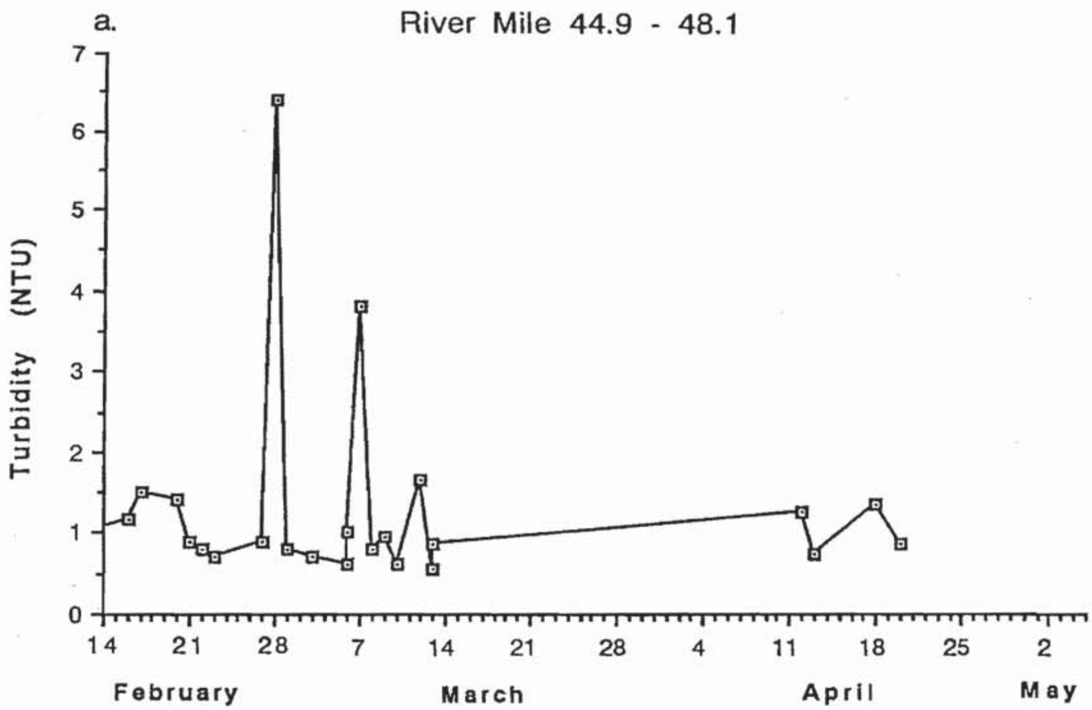

l.
3 May 1990
Turbidity (NTU)
River Mile
6
5
4
3
2
1
0
50
40
30
20
10
0

ATTACHMENT C:

TIME SERIES OF TURBIDITIES, BASED ON GRAB SAMPLES, AT VARIOUS LOCATIONS IN THE LOWER TUOLUMNE RIVER, 1990

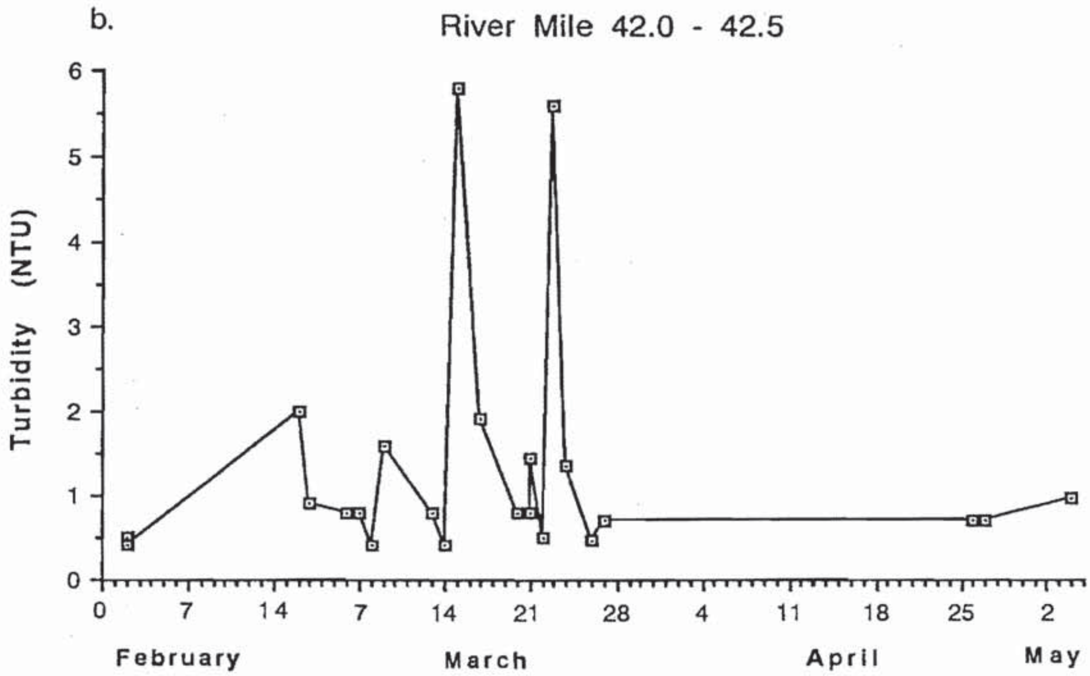
These graphs plot the changes in water turbidity with time at the specified locations or areas. Turbidity is plotted in Nephelometric Turbidity Units (NTU) (see methods in Section 2.3.1). Often several locations are included in a single plot. This was done because during the field collection it was sometimes necessary to replace a standard site with one near by.

a.



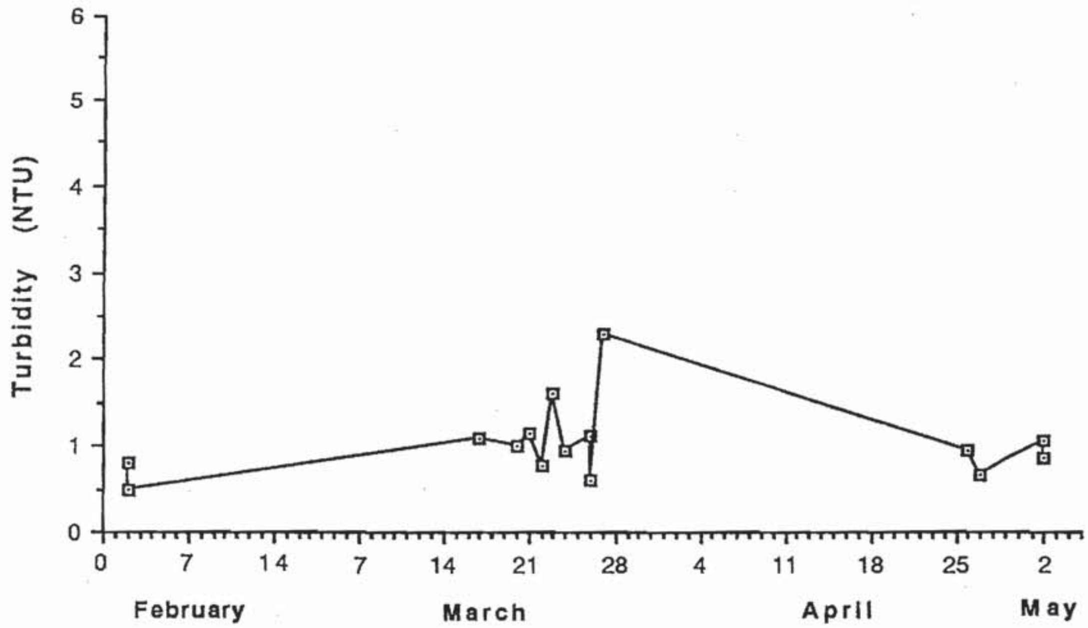
River Mile 44.9 - 48.1
Turbidity (NTU)
0
1
2
3
4
5
6
7
14
21
28
7
14
21
28
4
11
18
25
2
February
March
April
May

b.

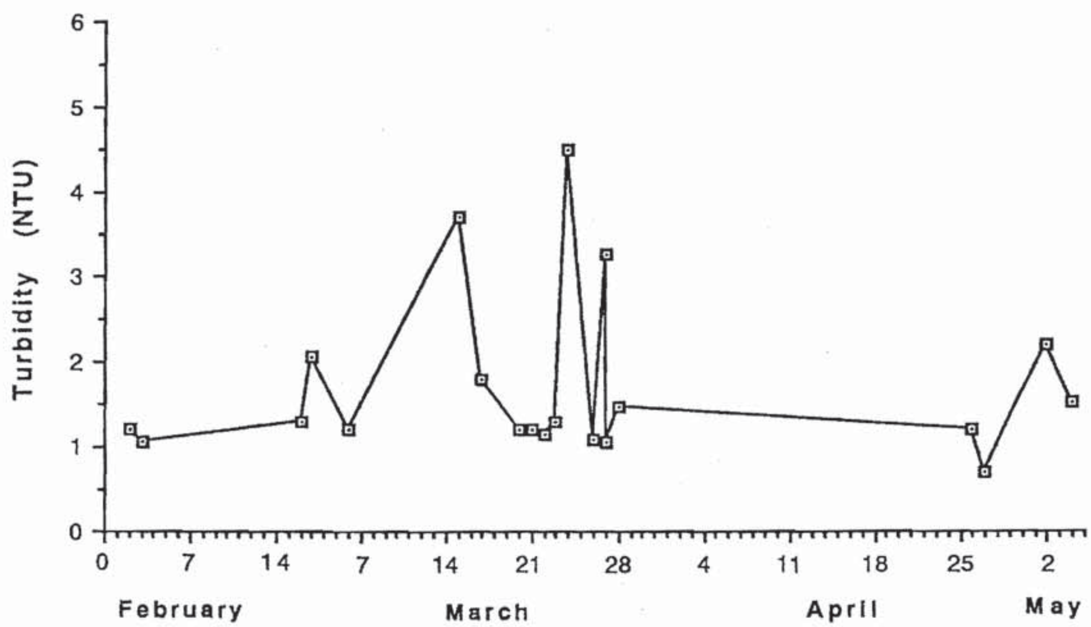


River Mile 42.0 - 42.5
Turbidity (NTU)
0
1
2
3
4
5
6
0
7
14
7
14
21
28
4
11
18
25
2
February
March
April
May

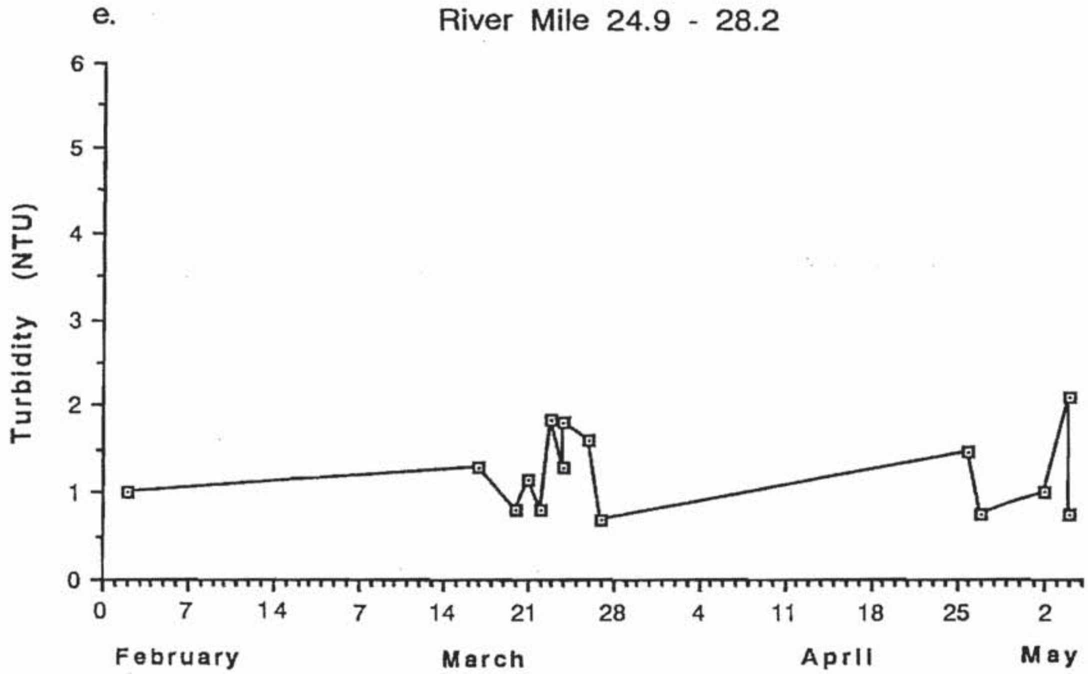
c. River Mile 37.0 - 39.0



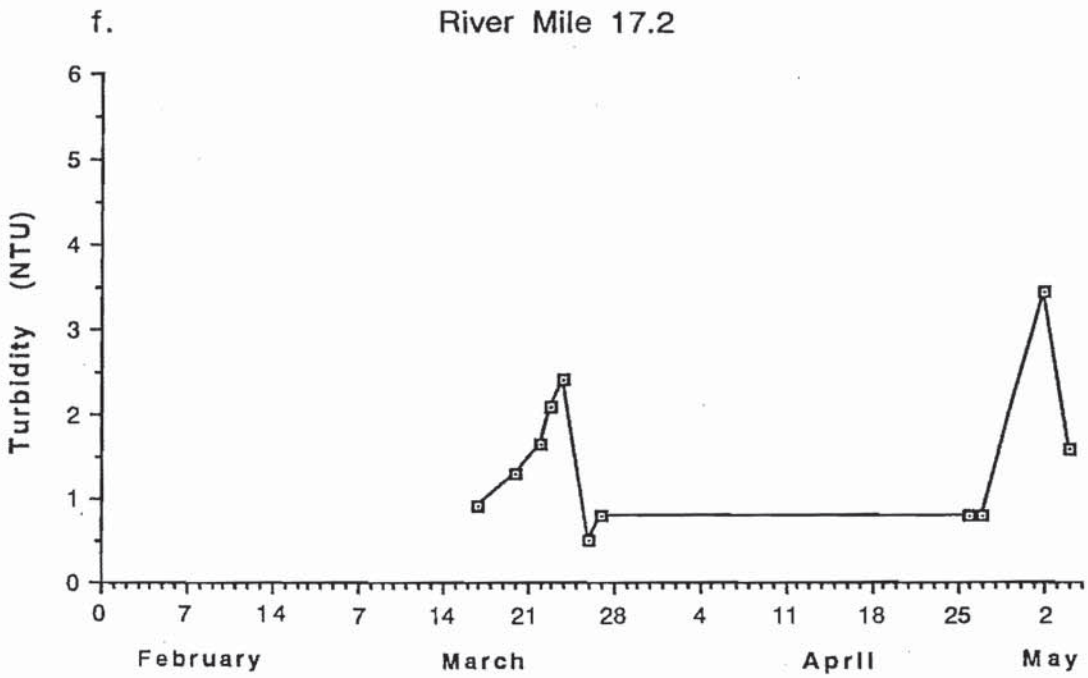
d. River Mile 31.0 - 34.3

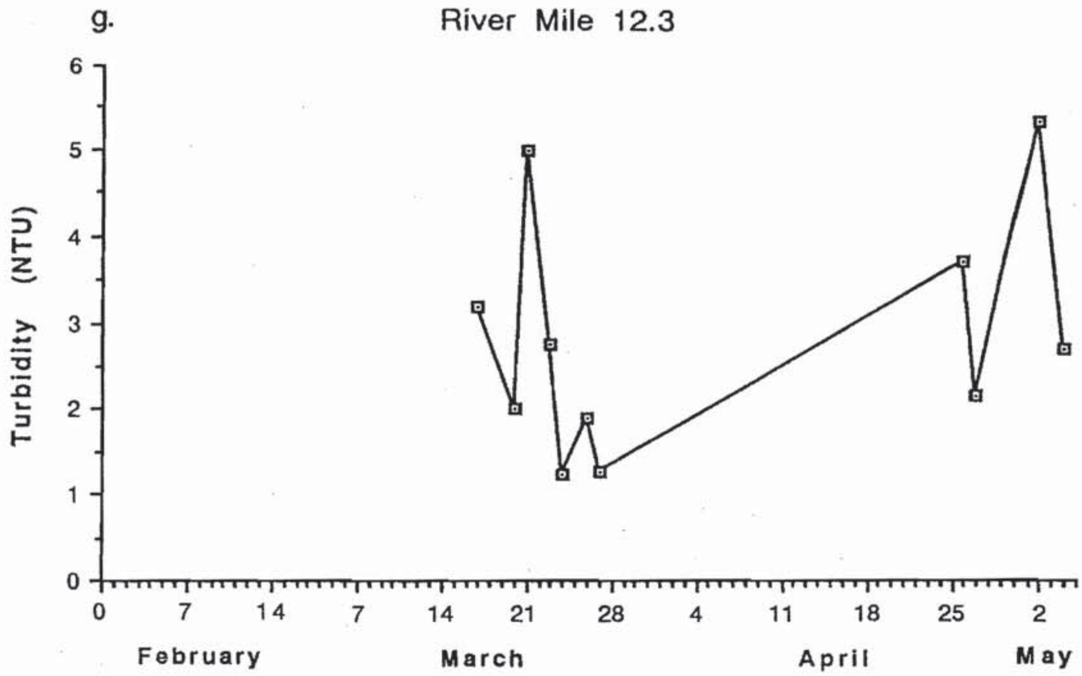


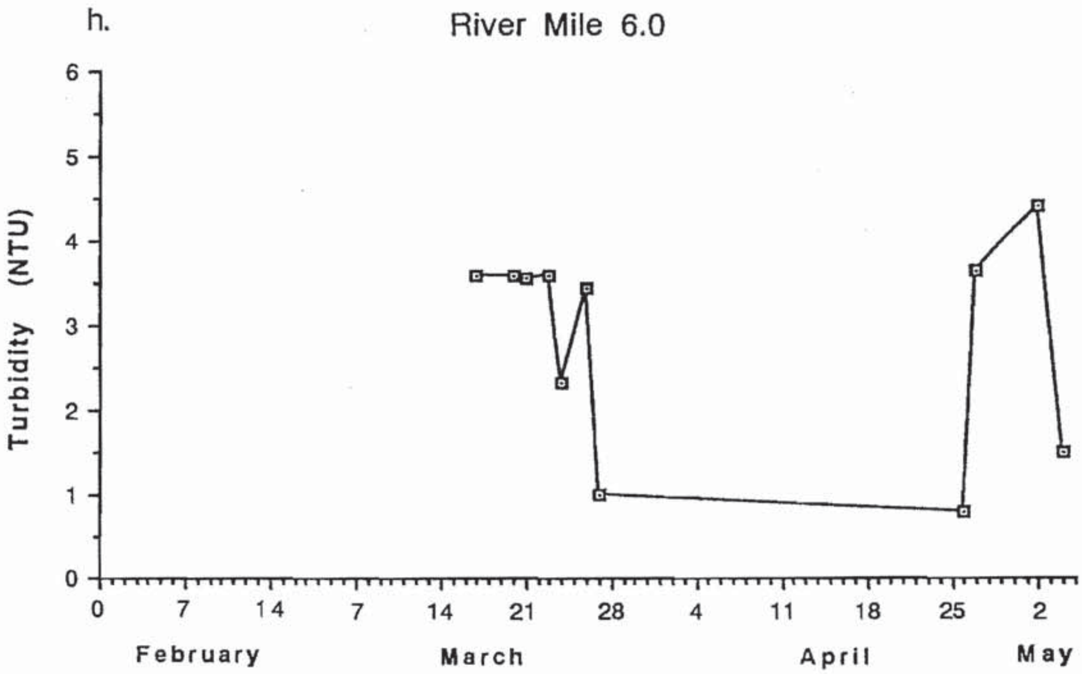
e.


River Mile 24.9 - 28.2
Turbidity (NTU)
0
1
2
3
4
5
6
0 7 14 7 14 21 28 4 11 18 25 2
February
March
April
May

f.


River Mile 17.2
Turbidity (NTU)
0
1
2
3
4
5
6
0 7 14 7 14 21 28 4 11 18 25 2
February
March
April
May


g.
River Mile 12.3
Turbidity (NTU)
0
1
2
3
4
5
6
0
7
14
7
14
21
28
4
11
18
25
2
February
March
April
May


h.
River Mile 6.0
Turbidity (NTU)
0
1
2
3
4
5
6
0
7
14
7
14
21
28
4
11
18
25
2
February
March
April
May

ATTACHMENT D:

GIS METHODS FOR TUOLUMNE RIVER MAP

ATTACHMENT D: GIS METHODS FOR TUOLUMNE RIVER MAP

Creation of a geographic information system (GIS) map layer (or coverage) for the channel features of the Tuolumne River involved the following tasks: (1) obtaining aerial photographs of the river channel at appropriate scales, dates, and times to show flow levels of interest, (2) using aerotriangulation to identify control points for the photographs and register them to a coordinate system, (3) using photogrammetric techniques to compile coordinates for the map of the river itself, and (4) using an error-checking procedure to verify that the map features were as complete and as correct as possible. The resulting GIS database can be used to produce maps of the river features at various scales, or it can also be used in analyses of the river where the location, areal extent, or interrelationship of river features are important.

D.1 AERIAL PHOTOGRAPHY

Aerial photographs were obtained that cover various portions of the river between 1986 and 1991 at different flow levels (Table B-1). Photographs taken between 1986 and 1990 were printed at relatively large scales (1:2,160, 1:2,400, 1:4,800) with color film. These photographs were taken in conjunction with EA's superimposition studies in order to map riffle areas with enough detail to capture salmon redd information for a census. The photographs do not contain either complete coverage of the river or the 60 percent overlap required for stereo compilation of the "wetted perimeter" of the river (the shoreline, or water's edge), so they could not be used to create an accurate base map. However, they were useful in adding wetted perimeters at higher flow levels to a base map created photogrammetrically.

Two sets of photographs were made in 1991 at 1:24,000 scale, which cover the Tuolumne River from La Grange Dam to its confluence with the San Joaquin River. The first set was made on 19 January, using black and white film, at an estimated release from La Grange Dam of 100 cfs. These black and white photographs, representing a low flow level, were used as the primary base for mapping.

The second set of photographs was made on 20 May with color infrared film. These photographs will be used to study the riparian vegetation and to provide the wetted perimeter at 550 cfs.

TABLE D-1 AERIAL PHOTOGRAPHY

Average Daily Flows at La Grange Dam	Date	Notes	Photo Series	Scale	Film Type	Stereo (yes or no)	Coverage
100 cfs	11-09-88	negatives only	KAVP 3412	1:2160	color	no	Riffle areas only
105 cfs	11-19-88	negatives only	KAVP 3421	1:2400	color	no	Riffle areas only
89 cfs	11-30-88	negatives only	KAVP 3430	1:2160	color	no	Riffle areas only
91 cfs	01-11-89	negatives	KAVP 3448	1:2160	color	no	Riffle areas only
93 cfs	01-15-89	negatives	KAVP 3457	1:2160	color	no	Riffle areas only
____	11-18-89	w/ control	KAVP 3696	1:2160	color	no	Riffle areas only
____	01-03-90	prints	KAVP 3727	1:2160	color	no	Riffle areas only
231 cfs	11-26-86	w/ control	AV 2992	1:2400	color	no	Upper half of river
226 cfs	02-25-87	w/ control	AV 3035	1:4800	color	no	Lower half of river
96 cfs	01-19-91	w/ control	AV 3988	1:24000	black & white	yes	La Grange Dam to San Joaquin
622 cfs	05-20-91	w/ control	AV 4056	1:24000	color infrared	yes	La Grange Dam to San Joaquin

D.2 AEROTRIANGULATION

Control for the 1:24,000 scale river map was obtained from USGS 7.5-minute quadrangle maps in the following fashion: as many individual features, such as road intersections or buildings, as possible were located on both the 19 January 1991 photographs and the USGS quadrangles. X, Y, and Z coordinates for these initial control points were determined from the quadrangles and assigned to the corresponding points on the photographs. Next, additional control points were calculated through aerotriangulation, a process that constructs a mathematical model to represent geometric relationships between object space, perspective photo centers, and photographic images. All image points were measured in a comparator and represented by coordinates on the image. These coordinates, along with camera and ground control information, were manipulated using numerical techniques. The output of these computations consisted of the ground coordinates and elevations of additional points on the photographs, elements of exterior orientation of each photograph, and the measures of reliability of calculated coordinates. Two additional types of control points were identified through aerotriangulation, those for which only X and Y coordinates and those for which only Z coordinates were known. The process was carried out to provide a minimum of six control points for each photograph. The control points established for each photographic model were then used in the stereo compilation process to collect coordinate values for the river features.

D.3 STEREO COMPILATION

Each pair of photographs, with control points identified, was placed in a Zeiss C120 stereo compiler. This machine is used to create a planimetrically correct base map from aerial photographs viewed in stereo, because it can correct for changes in altitude between photographs and tip and tilt within photographs as well as for vertical relief on the ground. The machine operator first orients the photographs with respect to one another, bringing the area of overlap of the adjacent photographs into a virtual 3-dimensional image. Next, he orients the 3-dimensional mathematical model to the ground control points on the photographs. He then traces the river features, collecting X, Y, and Z coordinates for each point compiled; these coordinates are read into a file that will eventually be used in the geographic information system. Four types of lines were compiled into the Tuolumne River file: (1) Wetted Perimeter - the line that represents the water/land interface, either at the river bank or around an island; (2) Historical Bank - the line delineating the formerly active floodplain; (3) Coincident Line - any line that represents both the current wetted perimeter and the historical bank; and (4) Feature Line - the line that separates either within-stream underwater features, such as the border between a riffle and a run-pool or between-bank features such as unvegetated and vegetated bars (see Figure B-1). EA provided a large-scale photomosaic of the Tuolumne River, with all riffles and run-pools identified. The stereo compiler operator used the photomosaic as an aid to interpret river features, but recorded all lines as he saw them on the 1:24,000-scale photographs.

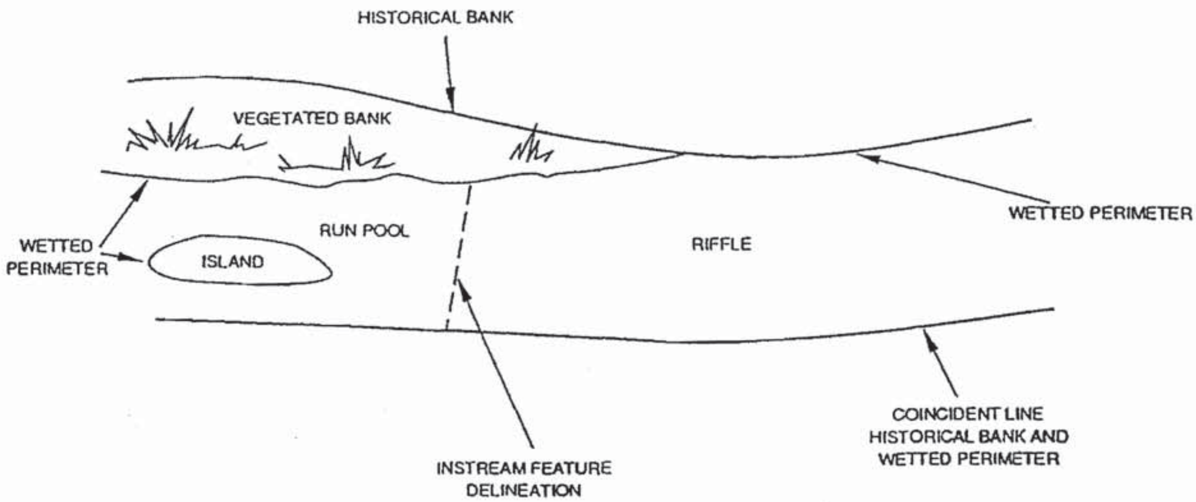


Figure D-1 Example of line and polygon classification.

D.4 TRANSLATION TO ARC/INFO

The data were translated into ARC/INFO format with a standard conversion program, and the resulting data file was processed in the ESRI ARC/INFO geographic information system. The Tuolumne River coverage contains both line and polygon attributes for all channel features, as well as the inherent geographic relationships between and among features. Each line, for example, has a length attribute and an identification code to identify its line type (wetted perimeter, historical bank, coincident line, or channel feature delimiter). Each line is also related to the polygons it delineates, having a unique polygon to its left and one to its right. Each polygon has an identification number and a type attribute (e.g,. Riffle, Run-Pool, Vegetated Island) and is bounded by lines whose types can be identified. Table B-2 is a data dictionary for the line codes and polygon attributes for the river map.

D.5 VERIFICATION OF THE GIS MAP LAYER

The locations and identifications of all channel features within the GIS coverage were verified by plotting the river map at photo scale and comparing the plotted lines to the photographs. A map of the Tuolumne River with both color-coded lines (representing line type codes) and labeled polygons was generated. This plot was compared to the large-scale aerial photographs by EA field personnel who are knowledgeable about the river and who also understand and have experience with aerial photography. Both the linework and the polygon attribute codes were verified, changes were noted, and corrections were made to the digital data file. The final GIS coverage contains linework and feature identifications that are both complete and correct.

D.6 ADDITION OF 225-CFS DATA

Channel features and wetted surface area of parts of the river at a flow of 225 cfs was prepared by digitizing two sets of photographs. The 26 November 1986 color photographs cover Stratum 1 of the river, from river mile 25 to La Grange Dam, at 1:2,400 scale. Stratum 2, the reach from the confluence with the San Joaquin River to river mile 25, was mapped for this flow level from 1:4,800 scale photographs made on 25 February 1987. Actual discharge varies along the river: gaging stations located along the river reported the following flow levels:

TABLE D-2 DATA DICTIONARY FOR THE TUOLUMNE RIVER BASE MAP

Historic Bank: (Line)

ID: **999**

—Where the historic bank is naturally formed, digitize the top of the bank;

—Where the historic bank has been artificially constructed (i.e. riprap, levee, dyke) digitize the bottom of the bank (in some cases this may be the water's edge);

—(By definition, all other polygons, lines, or points describing river attributes will be within or be bounded by the river's historic banks)

100 Wetted Perimeter: (Line)

ID: **100 WP**

—This line will define the wetted perimeter (shoreline) of the river when flows are 100 cfs;

—This line will also constitute the wetted perimeters (shorelines) of all instream features (gravel bars, islands, sand bars)

Coincident Historic Banks and Wetted Perimeter: (Line)

ID: **199**

—This line code should be used when the historic bank is the same as the wetted perimeter

Vegetated Bank: (Polygon)

ID: **VB**

—Exposed areas of established vegetation which exist between the historic bank and the wetted perimeter

Unvegetated Bank: (Polygon)

ID: **UVB**

—Exposed areas with no established vegetation that are found between the historic bank and the wetted perimeter

Bedrock Outcroppings: (Polygon)

ID: **BRO**

—These areas consist of exposed bedrock either on the banks or in midstream; (most of these areas are in the upstream section of the river)

Riffle: (Polygon)

ID: **R or R#**

—Area of higher stream gradient, fast-moving and in many cases turbulent flow, constrictions in the channel, gravel bed bottoms, and, in some cases, evidence of salmon spawning nests;

—(Some downstream riffles do not have numbers associated with them)

Run Pool: (Polygon)

ID: **RP or RP#**

—Areas of laminar (smooth, untubulent) flow over an even bottom

Special Run Pool: (Polygon)

ID: **SRP or SRP#**

—Areas similar to run pools except that they are larger and often deeper and have slow-moving water with little or no distinguishable current. (Most of these areas represent modification of the stream bed by gravel excavation)

Bedrock Chute: (Polygon)

ID: **BRC**

—Areas characterized by a riverbed consisting of exposed bedrock, large boulders, concrete slabs, and/or concrete pilings

Saturated Lowland: (Polygon)

ID: **SL**

—Areas with soil which is habitually saturated, but which are dominated by terrestrial vegetation rather than aquatic vegetation;

—Often characterized by low slope

__Vegetated Island:__ (Polygon)

ID: **VI**

—Exposed areas of established vegetation with the wetted perimeter defining the banks

__Unvegetated Island:__ (Polygon)

ID: **UVI**

—Exposed areas with no established vegetation which exist within the wetted perimeter

ID: **BD** = Beaver Dam

ID: **BF** = Bridge Foundation

ID: **SI** = Stream Inlet

ID: **BLDG** = Building

ID: **TR** = Tailrace

ID: **SC** = Side Channel

	26 NOV 1986	25 FEB 1987	19 JAN 1991	20 MAY 1991
Stratum 1				
La Grange Dam	231 cfs	226 cfs	96 cfs	622 cfs
Hickman Bridge	633 cfs	296 cfs	139 cfs	---
Stratum 2				
9th St. Bridge	1,010 cfs	355 cfs	159 cfs	667 cfs
(Dry Creek	16 cfs	13 cfs	0 cfs)	---

The two sets of photographs were compared to the 100-cfs base map and the 1:24,000 scale photographs by EA personnel knowledgeable about the river. Areas where the wetted surface of the river changed between the 100-cfs and 225-cfs flow levels were identified; the new river perimeter was delineated on aerial photographs; and new polygons were classified, using the assumption that a river feature extends from bank to bank (see Figure B-2). If the water level rose enough to cover an island that had been surrounded by a run-pool, the new area would become part of that run-pool; similarly, if the dry area adjacent to a riffle at 100 cfs was inundated at 225 cfs, the new area would be classified as part of the riffle at 225 cfs.

The wetted perimeter for the 225-cfs flow level was added to the existing 100-cfs coverage using one of two methods. If a photograph contained at least four control points that were outside the extent of the new river features, the lines were digitized in ARC/INFO directly from the photograph. The 225-cfs wetted- perimeter lines thus created were then copied directly into the 100-cfs river coverage.

If the control for a given photograph was insufficient, the lines were manually transferred to a 1:24,000 scale base map of the 100-cfs wetted perimeter and channel features, that map was placed on a tablet, and the 225-cfs lines were digitized directly into the 100-cfs river coverage.

In either case, the 225-cfs and 100-cfs wetted-perimeter lines were then plotted together at photo scale (1:4,800) for verification. Any areas where the transformation from photographic coordinates failed were edited either by shifting and rotating lines to approximate their correct positions or by transferring them to a base map and digitizing them. All linework and feature identifications were carefully checked, errors were identified, and changes were made to the GIS coverage.

The final GIS coverage indicates wetted perimeters for both the 100-cfs and the 225-cfs levels of flow. Polygons are identified for both levels of flow (for example, an area that changed from vegetated bar to riffle at the higher water level is coded as VB for the 100-cfs flow level and as R for the 225-cfs flow level). A complete river map for either the 100-cfs or the 225-flow level can be created from this coverage by plotting the attributes associated with the particular level of flow.

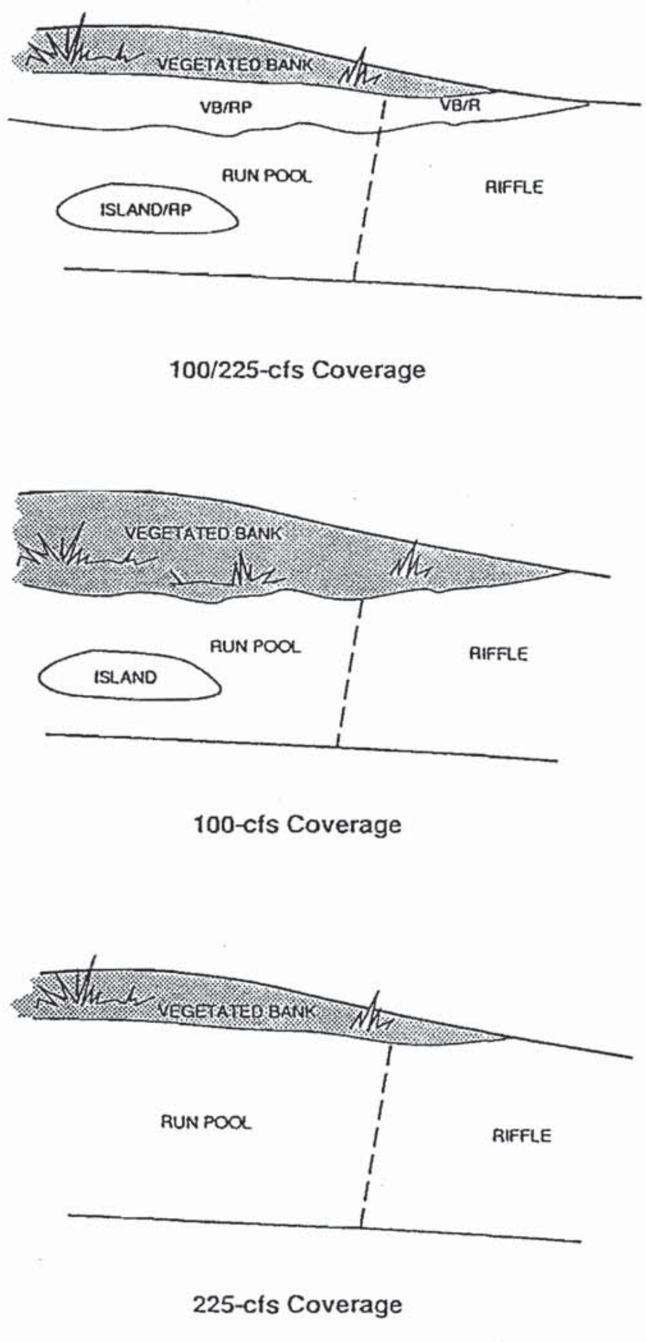


Figure D-2 Line and polygon classifications at two different flow levels.

A new coverage can be created for either flow by eliminating all lines that separate polygons on the basis of flow alone. For example, lines that are necessary for the 100-cfs coverage but do not exist in the 225-cfs coverage would be retained in the former and eliminated from the lattter. The line in Figure B-2 that separates vegetated bank from riffle at 100 cfs, where the area changed from vegetated bank to riffle at 225 cfs, is an example of this. That line must be included in the 100-cfs coverage, because there it separates two different polygon types, but it should not be included in the 225-cfs coverage, because there it would separate the parts of a single riffle.

From: Staples, Rose
Sent: Wednesday, October 19, 2011 4:47 PM
To: 'Alves, Jim - City of Modesto'; 'Anderson, Craig - USFWS'; 'Asay, Lynette - N-R'; 'Aud, John - SCERD'; 'Barnes, James - BLM'; 'Barnes, Peter - SWRCB'; 'Beuttler, John - CSPA'; 'Blake, Martin'; 'Bond, Jack - City of Modesto'; 'Boucher, Allison - TRC'; 'Boucher, Dave - Allison - TRC'; 'Bowes, Stephen - NPS'; 'Bowman, Art - CWRMP'; 'Brenneman, Beth - BLM'; 'Brewer, Doug - TetraTech'; 'Brochini, Anthony - SSMN'; 'Brochini, Tony - NPS'; 'Buckley, John - CSERC'; 'Buckley, Mark'; 'Burley, Silvia-CVMT'; 'Burt, Charles - CalPoly'; 'Cadagan, Jerry'; 'Carlin, Michael - SFPUC'; 'Catlett, Kelly - FOR'; 'Charles, Cindy - GWWF'; 'Cismowski, Gail - SWRCB'; 'Costa, Jan - Chicken Ranch'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob - TBMWI'; 'Cranston, Peggy - BLM'; 'Cremeen, Rebecca - CSERC'; 'Day, Kevin - TBMI'; 'Day, P - MF'; 'Denean - BVR'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne - OHP'; 'Dowd, Maggie-SNF'; 'Drekmeier, Peter - TRT'; 'Edmondson, Steve - NOAA'; 'Eicher, James - BLM'; 'Fety, Lauren - BLM'; 'Findley, Timothy - Hanson Bridgett'; 'Freeman, Beau - CalPoly'; 'Fuller, Reba - TMTC'; 'Furman, Donn W - SFPUC'; 'Ganteinbein, Julie - Water-Power Law Grp'; 'Giglio, Deborah - USFWS'; 'Goode, Ron - NFMT'; 'Gorman, Elaine - YSC'; 'Grader, Zeke'; 'Gutierrez, Monica - NOAA-NMFS'; 'Hackamack, Robert'; 'Hastreiter, James L - FERC'; 'Hatch, Jenny - CT'; 'Hayat, Zahra - MF'; 'Hayden, Ann'; 'Hellam, Anita - HH'; 'Heyne, Tim - CDFG'; 'Holden, James '; 'Holm, Lisa'; 'Horn, Jeff - BLM'; 'Horn, Tini'; 'Hudelson, Bill - StanislausFoodProducts'; 'Hughes, Noah'; 'Hughes, Robert - CDFG'; 'Hume, Noah - Stillwater'; 'Jackman, Jerry '; 'Jackson, Zac - USFWS'; 'Jennings, William - CSPA'; 'Jensen, Art - BAWSCA'; 'Jensen, Laura - TNC'; 'Johannis, Mary'; 'Johnson, Brian - CalTrout'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn - NOAA-MNFS'; 'Kinney, Teresa'; 'Koepele, Patrick - TRT'; 'Kordella, Lesley - FERC'; 'Lein, Joseph'; 'Levin, Ellen - SFPUC'; 'Lewis-Reggie-PRCI'; 'Linkard, David - TRT /RH'; 'Looker, Mark - LCC'; Loy, Carin; 'Lwenya, Roselynn, BVR'; 'Lyons, Bill - MR'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul '; 'Marshall, Mike - RHH'; 'Martin, Michael - MFFC'; 'Martin, Ramon - USFWS'; 'Mathiesen, Lloyd - CRRMW'; 'McDaniel, Dan - CDWA'; 'McDevitt, Ray - BAWSCA'; 'McDonnell, Marty - SMRT'; 'McLain, Jeffrey - NOAA-NMFS'; 'Means, Julie - CDFG'; 'Mills, John - TUD'; 'Morningstar Pope, Rhonda - BVR'; 'Motola, Mary - PRCI'; 'O'Brien, Jennifer - CDFG'; 'Orvis, Tom - SCFB'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane - Cardno'; 'Pavich, Steve-Cardno'; 'Pinhey, Nick - City of Modesto'; 'Pool, Richard'; 'Porter, Ruth - RHH'; 'Powell, Melissa - CRRMW'; 'Puccini, Stephen - CDFG'; 'Raeder, Jessie - TRT'; 'Ramirez, Tim - SFPUC'; 'Rea, Maria - NOAA-NMFS'; 'Reed, Rhonda - NOAA-NMFS'; 'Richardson, Kevin - USACE'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O - N-R'; 'Roos-Collins, Richard - Water-Power Law Grp for NHI'; 'Roseman, Jesse'; 'Rothert, Steve - AR'; 'Sander, Max - TNC'; 'Sandkulla, Nicole - BAWSCA'; 'Saunders, Jenan'; 'Schutte, Allison - HB'; 'Sears, William - SFPUC'; 'Shipley, Robert'; 'Shumway, Vern - SNF'; 'Shutes, Chris - CSPA'; 'Sill, Todd'; 'Slay, Ronn - CNRF/AIC'; 'Smith, Jim - MPM'; Staples, Rose; 'Steindorf, Dave - AW'; 'Steiner, Dan'; 'Stone, Vicki -TBMI'; 'Stork, Ron - FOR'; 'Stratton, Susan - CA SHPO'; 'Taylor, Mary Jane - CDFG'; 'Terpstra, Thomas'; 'TeVelde, George A '; 'Thompson, Larry - NOAA-MNFS'; 'Vasquez, Sandy '; 'Verkuil, Colette - TRT/MF'; 'Vierra, Chris'; 'Villalabos, Ruben'; 'Walters, Eric - MF';

'Wantuck, Rick - NOAA-NMFS'; 'Welch, Steve - ARTA'; 'Wesselman, Eric - TRT'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas - RHH'; 'Wilcox, Scott - Stillwater'; 'Williamson, Harry (NPS)'; 'Willy, Alison - FWS'; 'Wilson, Bryan - MF'; 'Winchell, Frank - FERC'; 'Wood, Dave - FR'; 'Wooster, John -NOAA'; 'Workman, Michelle - USFWS'; 'Yoshiyama, Ron'; 'Zipser, Wayne - SCFB'

Subject: Due Date Confirmation for Comments on Don Pedro Proposed Study Plan: Monday, October 24

With the FERC filing deadline for comments on the Don Pedro Project's *Proposed Study Plan* falling on a Sunday (October 23), we sought clarification from FERC as to the actual deadline—and its effect on the filing of the *Revised Study Plan.* I received confirmation today from Jim Hastreiter that the comments filing date would slide over one day to Monday, October 24th.

The deadline for the filing of the *Revised Study Plan, which is to be 30 days after the original filing date (October 23) for comments, would then be Tuesday, November 22.*

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From: Staples, Rose
Sent: Thursday, October 20, 2011 6:04 PM
To: 'Porter, Ruth M.'; Devine, John
Cc: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas P.; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: RE: Don Pedro Updated Study Plan Is Now Available on Website

Ruth, thank you for your query. The October 14, 2011 e-filing with FERC of the Don Pedro UPDATED STUDY PLAN document can be accessed on FERC's E-Library at P-2299-000. The link (second highlight) below should take you directly to the document. The document is also available on the Don Pedro Relicensing website, in the DOCUMENTS/STUDIES section.

Acceptance for Filing

The FERC Office of the Secretary has accepted the following electronic submission for filing (Acceptance for filing does not constitute approval of any application or self-certifying notice):

-Accession No.: 201110145077
-Docket(s) No.: P-2299-000
-Filed By: Turlock Irrigation District and Modesto Irrigation District -Signed By: Robert Nees -Filing Type: ILP Initial or Updated Study Report -Filing Desc: ILP Updated Study Plan of Turlock Irrigation District and Modesto Irrigation District under P-2299, Don Pedro Project.
-Submission Date/Time: 10/14/2011 12:50:20 PM -Filed Date: 10/14/2011 12:50:20 PM

Your submission is now part of the record for the above Docket(s) and available in FERC's eLibrary system at:
http://elibrary.ferc.gov/idmws/file_list.asp?accession_num=20111014-5077

If you would like to receive e-mail notification when additional documents are added to the above docket(s), you can eSubscribe by docket at:
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From: Porter, Ruth M. [mailto:ruth.porter@hoganlovells.com]
Sent: Thursday, October 20, 2011 5:09 PM
To: Devine, John
Cc: Staples, Rose; Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail -

SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan - CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas P.; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB
Subject: RE: Don Pedro Updated Study Plan Is Now Available on Website

John,

There is no record of this filing in FERC Docket No. P-2299-075 on October 13th (the date of the transmittal letter) or October 14th (the date of the e-mail below). Can you please confirm that this was filed with the Commission?

Ruth Porter

Counsel for Restore Hetch Hetchy

From: Staples, Rose [mailto:Rose.Staples@hdrinc.com]
Sent: Friday, October 14, 2011 1:42 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry;

Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan - CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth M.; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas P.; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB
Subject: Don Pedro Updated Study Plan Is Now Available on Website

Today we have e-filed with FERC an UPDATED STUDY PLAN, which consists of a set of CLEAN Study Plans (Appendix A) and a set of the REDLINE Study Plans (Appendix B). We have also uploaded a copy of the filing to the relicensing website. You will note that these files are in a .pdf format—but we will also be uploading, by the end of the day, a set of the CLEAN Study Plans in WORD format.

You will also note a different look to the DOCUMENTS section of the website. We have “collapsed” all the individual files so when you access the Document sections, only the major section headings appear. To locate the Updated Study Plan, you will click on STUDIES, which will open three sub-headings (Proposed Study Plan, RWG Study Plan Development, and the new Updated Study Plan). Click on CONTENT: UPDATED STUDY PLAN, and the two Updated Study Plan file names should pop. If not, please let me know.

Thank you!

ROSE STAPLES
CPS CAP

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

About Hogan Lovells
Hogan Lovells is an international legal practice that includes Hogan Lovells US LLP and Hogan Lovells International LLP. For more information, see www.hoganlovells.com.

From: Staples, Rose
Sent: Monday, October 31, 2011 6:51 PM
To: 'Alves, Jim - City of Modesto'; 'Anderson, Craig - USFWS'; 'Asay, Lynette - N-R'; 'Aud, John - SCERD'; 'Barnes, James - BLM'; 'Barnes, Peter - SWRCB'; 'Beuttler, John - CSPA'; 'Blake, Martin'; 'Bond, Jack - City of Modesto'; 'Boucher, Allison - TRC'; 'Boucher, Dave - Allison - TRC'; 'Bowes, Stephen - NPS'; 'Bowman, Art - CWRMP'; 'Brenneman, Beth - BLM'; 'Brewer, Doug - TetraTech'; 'Brochini, Anthony - SSMN'; 'Brochini, Tony - NPS'; 'Buckley, John - CSERC'; 'Buckley, Mark'; 'Burley, Silvia-CVMT'; 'Burt, Charles - CalPoly'; 'Cadagan, Jerry'; 'Carlin, Michael - SFPUC'; 'Catlett, Kelly - FOR'; 'Charles, Cindy - GWWF'; 'Cismowski, Gail - SWRCB'; 'Costa, Jan - Chicken Ranch'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob - TBMWI'; 'Cranston, Peggy - BLM'; 'Cremeen, Rebecca - CSERC'; 'Day, Kevin - TBMI'; 'Day, P - MF'; 'Denean - BVR'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne - OHP'; 'Dowd, Maggie-SNF'; 'Drekmeier, Peter - TRT'; 'Edmondson, Steve - NOAA'; 'Eicher, James - BLM'; 'Fety, Lauren - BLM'; 'Findley, Timothy - Hanson Bridgett'; 'Freeman, Beau - CalPoly'; 'Fuller, Reba - TMTC'; 'Furman, Donn W - SFPUC'; 'Ganteinbein, Julie - Water-Power Law Grp'; 'Giglio, Deborah - USFWS'; 'Goode, Ron - NFMT'; 'Gorman, Elaine - YSC'; 'Grader, Zeke'; 'Gutierrez, Monica - NOAA-NMFS'; 'Hackamack, Robert'; 'Hastreiter, James L - FERC'; 'Hatch, Jenny - CT'; 'Hayat, Zahra - MF'; 'Hayden, Ann'; 'Hellam, Anita - HH'; 'Heyne, Tim - CDFG'; 'Holden, James '; 'Holm, Lisa'; 'Horn, Jeff - BLM'; 'Horn, Tini'; 'Hudelson, Bill - StanislausFoodProducts'; 'Hughes, Noah'; 'Hughes, Robert - CDFG'; 'Hume, Noah - Stillwater'; 'Jackman, Jerry '; 'Jackson, Zac - USFWS'; 'Jennings, William - CSPA'; 'Jensen, Art - BAWSCA'; 'Jensen, Laura - TNC'; 'Johannis, Mary'; 'Johnson, Brian - CalTrout'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn - NOAA-MNFS'; 'Kinney, Teresa'; 'Koepele, Patrick - TRT'; 'Kordella, Lesley - FERC'; 'Lein, Joseph'; 'Levin, Ellen - SFPUC'; 'Lewis-Reggie-PRCI'; 'Linkard, David - TRT /RH'; 'Looker, Mark - LCC'; Loy, Carin; 'Lwenya, Roselynn, BVR'; 'Lyons, Bill - MR'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul '; 'Marshall, Mike - RHH'; 'Martin, Michael - MFFC'; 'Martin, Ramon - USFWS'; 'Mathiesen, Lloyd - CRRMW'; 'McDaniel, Dan - CDWA'; 'McDevitt, Ray - BAWSCA'; 'McDonnell, Marty - SMRT'; 'McLain, Jeffrey - NOAA-NMFS'; 'Means, Julie - CDFG'; 'Mills, John - TUD'; 'Morningstar Pope, Rhonda - BVR'; 'Motola, Mary - PRCI'; 'O'Brien, Jennifer - CDFG'; 'Orvis, Tom - SCFB'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane - Cardno'; 'Pavich, Steve-Cardno'; 'Pinhey, Nick - City of Modesto'; 'Pool, Richard'; 'Porter, Ruth - RHH'; 'Powell, Melissa - CRRMW'; 'Puccini, Stephen - CDFG'; 'Raeder, Jessie - TRT'; 'Ramirez, Tim - SFPUC'; 'Rea, Maria - NOAA-NMFS'; 'Reed, Rhonda - NOAA-NMFS'; 'Richardson, Kevin - USACE'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O - N-R'; 'Roos-Collins, Richard - Water-Power Law Grp for NHI'; 'Roseman, Jesse'; 'Rothert, Steve - AR'; 'Sander, Max - TNC'; 'Sandkulla, Nicole - BAWSCA'; 'Saunders, Jenan'; 'Schutte, Allison - HB'; 'Sears, William - SFPUC'; 'Shipley, Robert'; 'Shumway, Vern - SNF'; 'Shutes, Chris - CSPA'; 'Sill, Todd'; 'Slay, Ronn - CNRF/AIC'; 'Smith, Jim - MPM'; Staples, Rose; 'Steindorf, Dave - AW'; 'Steiner, Dan'; 'Stone, Vicki -TBMI'; 'Stork, Ron - FOR'; 'Stratton, Susan - CA SHPO'; 'Taylor, Mary Jane - CDFG'; 'Terpstra, Thomas'; 'TeVelde, George A '; 'Thompson, Larry - NOAA-MNFS'; 'Vasquez, Sandy '; 'Verkuil, Colette - TRT/MF'; 'Vierra, Chris'; 'Villalabos, Ruben'; 'Walters, Eric - MF';

'Wantuck, Rick - NOAA-NMFS'; 'Welch, Steve - ARTA'; 'Wesselman, Eric - TRT'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas - RHH'; 'Wilcox, Scott - Stillwater'; 'Williamson, Harry (NPS)'; 'Willy, Alison - FWS'; 'Wilson, Bryan - MF'; 'Winchell, Frank - FERC'; 'Wood, Dave - FR'; 'Wooster, John -NOAA'; 'Workman, Michelle - USFWS'; 'Yoshiyama, Ron'; 'Zipser, Wayne - SCFB'

Subject: Conf Call ONLY Don Pedro Water & Aquatic; No meeting or conf call Recreation, Cultural & Terrestrial this week

There will be no Resource Work Group meetings this week. These meetings were originally scheduled for November 3 (Water & Aquatic; Terrestrial) and November 4 (Recreation; Cultural). The number and scope of the comments received requires that we spend the limited time available addressing comments, revising study plans, and finalizing the Revised Study Plan document for submittal to FERC on November 22. The Districts appreciate the substantial commitment of time and the effort made by all the relicensing participants that have been engaged in the process. The prior meetings and comments have materially improved the study plans.

There were a significant number of detailed comments on study plans covering the **Water& Aquatic Resource area**. The Districts believe a conference call to discuss several of these studies may be beneficial. The Districts are proposing to conduct a conference call on Thursday, November 3 from 2 PM to 5 PM Pacific time. The call-in number is provided below.

The Districts look forward to continuing the excellent dialogue that has taken place over the last several months as we move forward with the relicensing of Don Pedro.

Call-in Number 866-994-6437
Conference Code 5424697994

ROSE STAPLES
CPS CAP

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Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Thursday, November 03, 2011 10:46 AM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

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Subject: Info Regarding Today's Don Pedro Water & Aquatic RWG Conference Call

In regards to this afternoon's Don Pedro Relicensing **Water & Aquatic RWG Conference Call**, there is no set agenda--and the call may not last the full three hours. From the Districts' perspective, we do have a few questions/clarifications that we would like to go over. And if any of the Relicensing Participants have further questions or items to clarify, we could also cover those items. We appreciate all the effort that went into preparing the comments. The Districts are busy preparing their Revised Study Plan which must be filed with FERC on Tuesday, November 22. We have slotted three hours for today's call, not knowing what parties might want to cover; it may take considerably less time than that, so we would ask that you please plan to join the call promptly at 2 PM. Thank you.

Thursday, November 3 – 2:00 p.m. Pacific
Call-in Number 866-994-6437
Conference Code 5424697994

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From: Staples, Rose
Sent: Tuesday, November 22, 2011 5:59 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: Don Pedro Revised Study Plan document e-filed with FERC today

TID-MID Don Pedro Project FERC No. 2299-75's ***Revised Study Plan*** document was e-filed with FERC today, with Attachment D-3 going in CD form via Express Mail.

A copy of the document filed (cover letter, RSP, Appendices A-C, and Appendix D-minus Attachment D-3 due to size) is available on FERC's E-Library at www.ferc.gov (docket #2299-75).

An announcement of the e-filing has also been placed on the Relicensing website at www.donpedro-relicensing.com (INTRODUCTION tab/Announcement section in upper right corner). A copy of this document was attached to the announcement. And for reference in the future, a copy will also be uploaded, within a few days, to the DOCUMENTS/STUDIES section of the website.

Announcements

Revised Study Plan filed with FERC today! NEW

by Rose Staples

Please note that ***Attachment 3 to Appendix D***, which is the Tuolumne Stream and Reservoir Water Temperature Data (in CD form) is 75 MB as a zip file, which is why we have not tried to electronically file it—or upload it to the website. If you are interesting in receiving a copy of this data, please email me at Rose.Staples@hdrinc.com with your mailing address and quantity of CDs wanted—and we will mail you them to you.

Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Friday, December 09, 2011 5:36 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Goode, Ron - NFMT; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: Forwarding of CCSF Socioeconomic Study Plan as Requested by Donn Furman

Attachments: CCSF Socioeconomic Study Plan.pdf

I am forwarding to you a copy of the CCSF Socioeconomic Study Plan filed with FERC yesterday, as requested by Donn Furman (see email below). Thank you.

ROSE STAPLES
CAP-OM

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From: Donn.W.Furman@sfgov.org [mailto:Donn.W.Furman@sfgov.org]
Sent: Friday, December 09, 2011 4:09 PM
To: Staples, Rose
Cc: Devine, John
Subject: Re: FW: Don Pedro RPCL Email Group

Rose-

Please forward the attached document to the email list for the Don Pedro Relicensing Participants. Thanks.

Donn W. Furman

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CITY AND COUNTY OF SAN FRANCISCO

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December 8, 2011

Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington DC 20426

Re: *Turlock Irrigation District and Modesto Irrigation District*, Project No. 2299-075
Don Pedro Project CCSF Socioeconomics Study Plan

Dear Secretary Bose:

The City and County of San Francisco ("CCSF" or "San Francisco") respectfully submits for the Commission's information, its proposed Socioeconomics Study Plan – San Francisco Bay Area, consistent with the findings of the Commission's Scoping Document 2 ("SD2") issued July 25, 2011. SD2 presented a list of issues to be addressed in the Environmental Impact Statement for the Don Pedro Project relicensing. This list included the socioeconomic impacts on the people dependent upon the water delivery system owned and operated by CCSF should additional water be required for environmental mitigation at the project. The attached Study Plan directly addresses this issue and will assist the Commission in developing an adequate record to assess the direct impacts of any modification in project operations on the ability of CCSF to provide the water necessary to protect the jobs and living conditions of nearly 2.5 million people living in the San Francisco Bay Area.

This study will assess the effects of potential changes in Don Pedro Project operations on the economic well-being of the residents, businesses, workers, and community organizations in the Bay Area. Economic well-being and welfare will also be evaluated through case studies detailing what changes in water availability would mean to various classes of consumers, such as families, small businesses, and large employers. The study plan methodologies proposed are consistent with, and will expand upon, information filed by CCSF in the 2009 Administrative Law Judge proceeding before the Commission on the Don Pedro Project.

The importance of this study and its results cannot be overestimated in the decision making process that lies before the Commission. Determinations by the Commission on what will be included in a new Don Pedro Project license have the potential to affect the lives of millions of people for decades to come. The new license must be based on a complete record that includes the potential direct impacts to the people served by CCSF. The results of the proposed Socioeconomics Study Plan are critical for the new license to be consistent with the Federal Power Act's requirement that the project adopted be best adapted to the public interest and a comprehensive plan for, among other things, beneficial public uses including water supply.

On November 22, 2011, Turlock Irrigation District and Modesto Irrigation District ("Districts"), co-licensees for the Don Pedro Project, filed their Revised Study Plan for the relicensing effort. The socioeconomic study plan included in that filing focused on the baseline economic values and benefits supported by the Project in the region. As the Districts stated in that same filing, consumers who rely on CCSF water supply may be significantly impacted by potential reductions in water supply that could result from relicensing of the Project. The Districts' filing also indicated that CCSF would be conducting an independent assessment of socioeconomic impacts to San Francisco and its Bay Area consumers, given its intimate knowledge of the role a reliable water supply plays in the Bay area. The attached Socioeconomics Study Plan – San Francisco Bay Area is consistent with that understanding as previously presented to the Commission.

CCSF is filing this Socioeconomics Study Plan, so that the Commission is aware of CCSF's study effort, and to facilitate evaluation by, and comments from, the participants in the relicensing of the Don Pedro Project. CCSF believes that this level of transparency and willingness to consider all comments on the elements of this study should ensure that the results will be of significant value to the Commission in this proceeding, as it moves forward to develop a license that truly balances all the issues related to the Don Pedro Project, including the water supply for the San Francisco Bay Area.

Very truly yours,

DENNIS J. HERRERA
City Attorney

/s/ Donn W. Furman

Donn W. Furman
Deputy City Attorney

cc: FERC Service List
Don Pedro Project email list
Jim Hastreiter, FERC

STUDY PLAN

CITY AND COUNTY OF SAN FRANCISCO PUBLIC UTILITIES COMMISSION

DON PEDRO HYDROELECTRIC PROJECT FERC NO. 2299

Socioeconomics Study Plan – San Francisco Bay Area

December 2011

The City and County of San Francisco ("CCSF" or "San Francisco"), through the San Francisco Public Utilities Commission ("SFPUC"), owns and operates a regional water system that serves nearly 2.5 million people primarily in San Francisco and the south San Francisco bay region ("Regional Water System"). In addition to serving residents and businesses in the CCSF, the SFPUC provides water to thirty cities, water agencies and other water users that comprise its 26 wholesale customers in San Mateo, Santa Clara and Alameda Counties. Some of these wholesale customers are totally dependent on the Regional Water System for water; all are dependent on the Regional Water System for a significant portion of their water needs. The wholesale customers that depend on purchases of wholesale water from San Francisco are member agencies of the Bay Area Water Supply and Conservation Agency ("BAWSCA"). The Regional Water System transports water across the state from the Sierra Nevada to the Bay Area almost entirely by gravity. The water conveyance system extends about 167 miles from Yosemite National Park to San Francisco, and develops water supply from three principal areas: the Tuolumne River watershed, Alameda Creek watershed, and several smaller watersheds in the San Francisco Peninsula. In 2008, the SFPUC adopted level of service goals to meet customer needs. Those level of service goals included meeting a demand of 265 mgd in normal and wet years, of which about 85% is from the Tuolumne River Watershed and about 15% is from the combined Alameda and Peninsula watersheds. This level of service goal is based on historic deliveries in normal and wet years. The demand for water deliveries from the Regional Water System can vary widely from year to year depending on climate, economic conditions, conservation measures, voluntary or mandatory rationing, and other factors.

The Don Pedro Project is located downstream from San Francisco’s Hetch Hetchy System. When the Don Pedro Project was being developed, CCSF agreed to pay for most of the cost of the dam and reservoir in return for creation of a water bank account in the Don Pedro Reservoir. Under the Fourth Agreement between the Districts and CCSF, San Francisco receives water bank account credits when the calculated daily natural flow at La Grange exceeds the Districts’ senior Tuolumne River water rights entitlements. These credits allow San Francisco at other times to divert water at its upstream storage reservoirs for municipal water supply in the Bay Area that it would otherwise have to release to meet District entitlements.

The economic benefits of the Don Pedro Project are enjoyed by the MID and TID service areas, the San Joaquin Central Valley region, and extend to the San Francisco Bay Area through the benefits of Project facilities to CCSF under the Fourth Agreement. The Bay Area's interest in these proceedings is in part to assure that water supply issues and resulting economic and social impacts are fully understood and appropriately balanced in any new license issued to the Districts for the Don Pedro Project.

As discussed in the Proposed Socioeconomic Study Plan filed by the Districts on July 25, 2011, the San Francisco Bay Area is a necessary part of the Socioeconomic Study Plan Area for the Don Pedro Project. *See* MID/TID Proposed Study Plan W&AR-15, p. 8. As also acknowledged in that plan, *id.*, p. 6, CCSF is uniquely qualified to analyze the socioeconomic impact of any changes in Project operations on the Bay Area having conducted just such analyses in other public forums. CCSF therefore submits the instant study plan of Bay Area socioeconomic impacts for the record in this proceeding.

1.0 PROJECT NEXUS

Changes to Project operations may have significant economic impacts in the San Francisco Bay Area. Don Pedro Reservoir provides up to 570,000 acre-feet ("AF") of credits to CCSF that can be used in its management of the Hetch Hetchy water system. Although water stored in the Don Pedro Reservoir does not belong to, and is not delivered to Bay Area water customers, those credits enable CCSF to deliver water reliably from the Hetch Hetchy System to customers in the San Francisco Bay Area.

San Francisco Bay Area water supply impacts have been a central issue with respect to the Don Pedro Project since it was originally licensed. As Scoping Document 2 acknowledges (at 30-1), the need to assure Bay Area water supply was the primary reason that the City and County of San Francisco helped finance the original construction of the Don Pedro Project. *See also Turlock Irrigation Dist.*, 76 FERC ¶ 61,117, at 61,606-607 (1996). The Commission has previously and repeatedly recognized that changes in the operation of the Don Pedro Project could have significant and potentially devastating impacts on the millions of people who live and work in the San Francisco Bay Area. Accordingly, it is crucial that the Bay Area water supply and socioeconomic impacts of any potential modification of the existing flow regime are studied as part of the pre-application and scoping processes for this relicensing, to assure that the Commission has an adequate record on which to establish appropriate terms and conditions, consistent with its Federal Power Act obligation to issue only a license that is best adapted to serve the public interest (16 U.S.C. § 808(a)(2)), and "best adapted to a comprehensive plan for improving or developing a waterway" (16 U.S.C. § 803(a)(1)).

2.0 RESOURCE MANAGEMENT GOALS OF AGENCIES WITH RESPONSIBILITY FOR THE RESOURCE TO BE STUDIED

Social and economic impacts of changes in available water supply to the San Francisco Bay Area has been a significant concern of the CCSF for decades. The CCSF has developed operational objectives and water system management goals to reduce the potential for water shortages that impact the social and economic welfare of millions of people in the San Francisco Bay Area. In recent years, CCSF has adopted defined resource management goals and objectives specific to this resource area, including a "water first" operation and a rationing objective of no greater than 20 percent water shortage in any one year of a drought.

CCSF's Water First Policy gives priority to the production of water supply over the production of hydropower generation in the operation of the Hetch Hetchy system. The Water First Policy was adopted in California in 2002 as part of the Wholesale Regional Water System Security and Reliability Act (Assembly Bill No. 1823), but has been the operational practice of the SFPUC since 1993 (CCSF 2008). The Water First Policy was also enacted into San Francisco's Charter by San Francisco voters in 2002.

In 2008, the SFPUC adopted levels of service goals when approving its Water System Improvement Project. The overall goals include maintaining a high quality and gravity-driven system, increasing delivery reliability, meeting customer water supply needs, and enhancing sustainability. In recognition that under current conditions, CCSF and its customers are vulnerable to shortages greater than 20 percent, the SFPUC adopted a level of service goal of rationing no greater than 20 percent of system deliveries during any year of a multi-year drought. The SFPUC has developed a water supply program to meets it rationing goals, and implementation of this program is currently underway as part of SFPUC's Water System Improvement Program. It should be noted that to meet these system-wide rationing goals of no greater than 20 percent shortage wholesale customers within the SFPUC's service area may incur shortages greater than 20 percent. A 20 percent system-wide shortage will not result in a uniform 20 percent shortage for all Regional Water System retail and wholesale customers.

3.0 STUDY GOALS AND OBJECTIVES

The primary objective of the study is to assess the effects of changes in Project operations on the economic well-being of the residents, businesses, workers and community organizations in the Bay Area. Economic well-being is broadly defined in the study and includes measures relevant to the use of water by businesses and households in the region. Measures of economic welfare used in the study reflect the diversity of water uses in the San Francisco Bay Area, and can include measures such as employment, sales, value added, income and economic surplus concepts like consumer willingness to pay (a measure of quality of life), and profit. Due to the sheer variety of the types of water users, an appropriate method for evaluating impacts to the Bay area water users is through a series of case studies. This approach, tailored to CCSF's specific circumstances, will detail what changes in water availability would mean to various types of customers, such as single-family residential, multi-family residential, and the wide variety of commercial and industrial customers.

The study will consider the socioeconomic effects of altering the reliability of Hetch Hetchy water supplies. The SFPUC has previously evaluated and continues to evaluate the use of alternative water supplies. In its recent planning studies, and as part of the Water System Improvement Program, these evaluations have included consideration of alternative water supplies in meeting dry-year needs and future demand in the service area. The CCSF will include relevant existing information from these studies in the socioeconomics study. While alternative supplies may be considered, it is important to note that a range of water management options have already been implemented in the Bay Area, and others have been identified for use in meeting future water needs and providing increased water supply reliability if there were no change in the operation of the Project. These management options include additional water conservation programs and alternative investments in water supplies. If additional management alternatives must be considered as a way to replace water supplies lost as a consequence of instream flow requirements, CCSF, consistent with its previous assessments of alternative water supplies, will incorporate these prior commitments that agencies are planning to make and consider the feasibility, cost and environmental consequences of implementing such alternatives.

The study will consider how changes in the reliability of Hetch Hetchy water supplies could limit future growth in the San Francisco Bay Area since BAWSCA already projects demand will outstrip supply in some of its members' service territories within a decade and for the whole by 2035 – even assuming no incremental instream flow requirements for Don Pedro beyond those existing in the baseline.

4.0 EXISTING INFORMATION AND NEED FOR ADDITIONAL INFORMATION

As noted, the SFPUC provides water to nearly 2.5 million people. This figure includes the SFPUC's retail water delivery service within the City and County of San Francisco to over 147,800 residential accounts and 21,600 non-residential accounts. Over 800,000 people live within CCSF, and workers who commute into the city increase CCSF's daytime population to close to 1 million. In addition, over 15.9 million people visited San Francisco in 2010.

The SFPUC also provides wholesale water to BAWSCA members, which include 24 cities and public water districts and two private water suppliers (Stanford University and California Water Service Company) in parts of Alameda, Santa Clara and San Mateo Counties. Member agencies of BAWSCA serve a population of nearly 1.7 million people, with over 370,000 residential accounts, 5,500 industrial accounts and 25,800 commercial accounts. Like San Francisco, a sizable workforce commutes into the communities served by these agencies. CCSF accounts for roughly two-thirds of the water delivered by the BAWSCA agencies.

Water delivered to the San Francisco Bay Area by CCSF serves many types of consumers. The socioeconomic study will distinguish among categories of uses, develop appropriate economic impacts measures for each sector, and measure outcomes resulting from a range of potential changes in Project operation that may affect CCSF water supplies.

4.1 The Demand for Water in the San Francisco Bay Area

4.1.1 Residential Use

The majority of water delivered by the Hetch Hetchy System is used by households. Residential per capita usage in both the CCSF retail and wholesale service areas is already significantly lower than in other regions in California. Water conservation has been a priority in the Bay Area for decades, and measures have been enacted to reduce water use across all sectors of the economy. For example, residential water use in CCSF has been limited by plumbing codes that require the installation of efficient appliances and outdoor irrigation systems. As a result, CCSF has some of the lowest levels of residential water use in the State. Current residential per capita use in San Francisco is about 50 gallons per capita per day. Residential water use in the BAWSCA service territory has also been significantly reduced as a result of conservation efforts, code requirements, economic incentives and limitations on water service. In 2009-2010, residential consumption among the BAWSCA agencies (excluding Stanford) was 78 gallons per capita per day (gpcpd), which is 25 percent below the pre-drought period of 1986-1987 and 32% below the level of 115 gpcpd in 1975-1976, in spite of continued population growth.

To implement their water conservation programs and facilitate other aspects of their operations, the SFPUC and BAWSCA collect extensive information on single- and multi-family residential water use in their service territories. This information is detailed in the SFPUC's 2010 Urban Water Management Plan and in the BAWSCA's 2009-2010 Annual Survey of its member agencies. The data contained in these studies will be the foundation of the residential analysis in the socioeconomic study.

To characterize the economic impact of water shortages on various types of residential customers in the Bay Area, it may be possible to combine and analyze existing information in new ways. In particular, CCSF will analyze data on residential water consumption to determine the responsiveness of demand to changes in price (i.e., the price elasticity of demand). Price elasticity is a basic element of calculating willingness to pay, which is a measure of the changes in the quality of life resulting from disruptions in water service.

Price elasticity will be identified by examining the actual water use choices of households and businesses across the Bay Area through the use of an econometric model of water demand. The econometric model isolates the influence of price on consumption by controlling for exogenous factors such as fluctuations in economic conditions and weather.

4.1.2 Commercial & Industrial Use

The area served by the Regional Water System is one of the largest centers of employment and economic activity in the United States. There are over 1.6 million jobs located in the SFPUC service territory. Firms in the service area produce over $280 billion in goods and services each year. As a result of the Mediterranean climate of the San Francisco Bay Area, economic activity in the region is largely dependent on a reliable supply of imported water.

The SFPUC and BAWSCA collect information on commercial and industrial water use in their service territories. Both agencies have studied patterns of water use by businesses, and have gathered information from their business customers on how they would cope with various levels of rationing (SFPUC, 2007).

Similar to the residential sector, it is necessary to gather information on the price elasticity of commercial and industrial demand. One source of information on price elasticities for these sectors is the academic literature (see, for example, Brozovic et al., 2007; Berkman and Sunding, 2008). There have been numerous studies examining price responsiveness in various industries, and the socioeconomic study will use this research to calibrate demands for various sectors. The study will control for the mix of industries by using data from the Bureau of Economic Analysis.

The study will also present the results of original research on commercial and industrial price elasticity using econometric methods similar to those described in the section on residential demand. Data will be gathered and used to estimate the parameters of a panel model. The results will be compared to the price elasticities found in the academic literature.

Reducing the amount of water available to commercial and industrial customers has the potential to reduce levels of output and jobs, particularly for rationing levels in excess of 20 percent. The socioeconomic study will address this important question in two ways. First, the socioeconomic study will present the results of original research on the relationship between economic output, jobs and water availability. Again, the likely approach will be to estimate the parameters of a panel model using year and location-fixed effects to control for unobservable factors. The results of this econometric modeling will be compared to those contained in the study of McLeod (1994), who estimated elasticities of output and jobs for various types of businesses in response to changes in water availability.

4.1.3 Demand Growth and Land Use Projections

The economy of the Bay Area is one of the most dynamic in the nation, and includes some of the country's most innovative and important businesses. Owing to factors including a strong economic base, several premier research universities, and temperate climate, the Bay Area is expected to grow in the coming decades. This population growth will affect the demand for reliable water supplies and place even more pressure on existing systems. BAWSCA reports that the number of people residing in its service territory is estimated to grow by approximately 300,000 persons, or 18 percent, by 2035.

The socioeconomic study will include a statistical analysis of per capita residential water demand, coupled with population and land use projections to 2035. One possible source of projected future conditions is the Association of Bay Area Governments (ABAG). ABAG land use projections detail expected changes in population, residential densities, and commercial and industrial development to 2035. By linking the residential demand model described above with the ABAG projections, it would be possible to fully characterize sectoral water demands out to the end of the ABAG planning period, taking into account changes in water rates, housing vintage, population densities, conservation programs and other factors. To the extent that wholesale customers use planning data and assumptions that are different than ABAG's, adjustments may be made to future conditions so that they best reflect expected growth in the service area.

4.2 The Supply of Water in the San Francisco Bay Area

The water system of the San Francisco Bay Area is a complex mix of infrastructure, water sources and institutions for the pricing and allocation of scarce water resources. This socioeconomic impact study will reflect these conditions in its calculation of the economic impacts of changes in Project operations.

4.2.1 Water Shortage Quantities and Allocation

To understand the economic effects of changes in Project operation, it is necessary to translate changes in Hetch Hetchy supplies into changes in end use. This translation has several elements: how shortfalls in delivery of Hetch Hetchy water are allocated among San Francisco and the wholesale customers, and how shortages are allocated among BAWSCA agencies. Mandatory reductions in end use that remain after the application of other water supplies used by the wholesale customers will be evaluated according to the methods described in the previous section.

4.2.2 Other Water Supply

Water agencies in the San Francisco Bay Area have access to a number of other water sources. These sources vary among agencies, and include local surface and groundwater supplies, Delta imports received from the State Water Project, banked groundwater from inside and outside the region, water transfers, recycled water and desalination. These water supplies are used today to meet existing demand. The availability of these water supply sources vary in their ability to meet additional needs reliably.

SFPUC and BAWSCA agencies have already developed information on the cost, feasibility and quantity of water available from potential alternative sources through various planning efforts including the Water System Improvement Program. BAWSCA's Long Term Reliable Water Supply Strategy Phase I Scoping Report details information on a wide range of potential supplies that may be developed at some point in the future. The study will start with this list and develop information on the costs of implementing other projects. The socioeconomic analysis will consider the feasibility, environmental impacts and additional burden on ratepayers resulting from the construction of such water supply projects necessary to address water shortages caused by instream flow requirements imposed on the Project.

4.3 Water Shortages and Lost Utility Revenues

In general, when water utilities are forced to reduce sales during periods of water shortage, they take in less revenue but also spend less on variable costs. If the marginal water rate exceeds variable cost, which is nearly always the case, then a mandatory reduction in sales creates a need to cover fixed costs by some means, either by increasing water rates or depleting reserves. In the Bay Area agencies benefit from the Regional Water System moving very high quality water by gravity; both treatment and energy costs are far lower than typical water utilities. As a result, variable costs of water service are relatively low in this service area. Lost revenues above variable costs are thus expected to be large, and should be included in the calculation of lost economic welfare.

5.0 STUDY METHODS AND ANALYSIS

5.1 Study Area

The primary study area for the socioeconomic study includes the City and County of San Francisco, and the service territories of the 26 BAWSCA members (see attached map). The study will also consider indirect economic impacts experienced by the State of California as a result of changes in economic activity within the San Francisco Bay Area resulting from changes in water supply availability.

5.2 General Concepts

The following general concepts will apply to the study:

- Water is essential to the quality of life and to economic activity. Disruptions in water supply have the potential to adversely impact individual consumers, job holders, businesses and governments.
- The study will quantify expected economic impacts of potential changes in Project operation affecting CCSF water supplies.
- Impacts will be measured from a variety of perspectives, including jobs, consumer welfare, economic activity and value added.
- Impacts will be described for a set of defined cases drawn from across the main sectors of demand.
- Primary sources of data will be preferred, and the study will clearly identify sources of data and other information.

5.3 Study Methods

The socioeconomic study will calculate changes in economic outcomes resulting from potential changes in the operation of the Project that may affect the Regional Water System and San Francisco Bay Area water supplies. Impacts will be measured in terms of economic surplus (i.e., consumer and producer surplus), economic activity and employment.

Changes in the availability of water can have significant consequences for urban economies and available life choices. Water is an essential input to many production processes, and mandatory conservation has been shown to affect the level of economic activity in water-short regions, and also to affect the pace of job creation. In addition to commercial and industrial impacts, mandatory conservation imposed on residential consumers can affect the quality of life as households lose access to water for outdoor irrigation, and in severe cases may even lack adequate water for some normal indoor uses such as daily bathing, clothes washing and the like.

5.3.1 Water balances

The socioeconomic study calculates impacts resulting from changes in end use and changes in the cost of alternative water supplies. The analysis starts with reductions in delivery of Hetch Hetchy water supplies and then allocates the shortage across CCSF and the BAWSCA member agencies. Changes in end use are calculated as the change in the SFPUC deliveries minus the increase in water available from other supply sources planned and financed for this purpose.

5.3.2 Consumer impacts

Consumer surplus is the theoretically correct measure of residential impacts of more frequent water shortages. Consumer surplus is defined as the difference between market price and the amount that consumers are actually willing to pay for a commodity. Economists frequently describe consumer surplus as the area underneath a demand curve and above market price. Consumer surplus can be used to capture the impacts of both incremental water shortages resulting from instream flow requirements, and expenditures on any feasible alternative water supplies that could be used to maintain consumption at close to baseline levels.

Consumer surplus measures the amount that households would be willing to pay to avoid residential water shortages. It is measured in terms of money, and reflects the diminution in the quality of life resulting from mandatory cutbacks in water service. For a given degree of rationing, consumer surplus loss is usually smaller for outdoor use than indoor use. The reason is that indoor uses such as bathing, cooking, dishwashing, clothes washing and the like are central to the quality of life, and to meeting basic human needs such as drinking water and personal hygiene. Outdoor use is valued by consumers, but will typically be curtailed before they will cut back significantly on indoor use. This socioeconomic study will develop estimates of the price elasticity of demand for the SFPUC service area as a means to gauge the economic significance of residential water supply losses. The study will also provide example cases in which the effects of water supply loss are described for a typical family.

5.3.3 Business impacts

The San Francisco Bay Area is home to a wide variety of industries. Water is an essential input in the economy, and the socioeconomic study will examine the implications of commercial and industrial water shortages. Impacts will be quantified using a variety of metrics, including producer surplus, economic activity and employment. The effects on a typical business resulting from water supply loss will be described.

Producer surplus is roughly equivalent to profit, and is the theoretical equivalent of consumer surplus used to measure outcomes in the residential sector. Profit can be affected by water shortages as firms adjust to rationing by investing in conservation devices, substituting for water when possible in production processes, and reducing operations in the face of significant shortages.

Employment is an important measure of economic activity, particularly in environments like the one at present where the economy is operating under conditions of an excess supply of labor. The job losses resulting from water shortages are closely related to changes in economic output.

While producer surplus is the theoretically preferred welfare measure to use in a cost-benefit setting, it falls short in other ways. For example, producer surplus is distinct from sales, which is a measure of the total economic activity of a sector. The study thus will also examine the impact of water shortages on regional sales and business net income as a way of capturing regional economic impacts.

Economic outcomes will also be expressed in terms of changes in output and employment. These changes include direct, indirect and induced impacts, the latter two categories including impacts that result from economic "ripple" effects including changes in spending by businesses and residents. Indirect and induced effects of changes in Project operations will be calculated using the IMPLAN modeling system which is based on a system of regional accounts and spending patterns.

5.3.4 Lost utility revenues

Lost consumer and producer surplus does not completely describe the economic welfare losses resulting from water shortages. It is also necessary to consider the need for affected water utilities to raise additional revenues as a result of lost sales. For nearly all water utilities, the majority of costs are fixed costs, meaning that they are unrelated to the amount of water sales. Fixed costs include the costs of infrastructure, treatment plants and the like. Marginal costs of water service are those costs that vary with the level of water sales. These costs include expenditures on chemicals and energy.

6.0 SCHEDULE

CCSF would work within the milestones of the ILP as follows:

First Study	Summer 2012
Initial Study Report	12/21/12

7.0 CONSISTENCY OF METHODOLOGY WITH GENERALLY ACCEPTED SCIENTIFIC PRACTICES

The methods described in this study plan are consistent with accepted practices in economics and public finance.

8.0 DELIVERABLES

Three written deliverables and at least two workshops are anticipated. The first written deliverable would be a detailed outline of the proposed project, including data requirements, model specification, and impact measures. The first workshop would present the first written deliverable to relicensing participants and the public and provide opportunity for discussion and comment. The second written deliverable would be a draft report. The third written deliverable would be a final report. The second workshop is a presentation to relicensing participants and the public following completion of the draft study. There will be an opportunity for additional workshops as necessary.

9.0 LEVEL OF EFFORT AND COST

The cost of the proposed study is between $150,000 and $250,000.

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From: Staples, Rose
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Subject: FERC Study Plan Determination for Don Pedro Project Relicensing Issued Today

FERC has issued its Study Plan Determination for the Don Pedro Project Relicensing. A copy of the document is available on FERC's E-Library, under docket P-2299-075. It has also been uploaded to the relicensing website at www.donpedro-relicensing.com, both as an attachment to the Announcement under the INTRODUCTION section and also in the Studies section of the Documents tab. If you have any problems accessing the document, please let me know. Thank you.

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Rick - NOAA-NMFS'; 'Welch, Steve - ARTA'; 'Wesselman, Eric - TRT'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas - RHH'; 'Wilcox, Scott - Stillwater'; 'Williamson, Harry (NPS)'; 'Willy, Alison - FWS'; 'Wilson, Bryan - MF'; 'Winchell, Frank - FERC'; 'Wood, Dave - FR'; 'Wooster, John -NOAA'; 'Workman, Michelle - USFWS'; 'Yoshiyama, Ron'; 'Zipser, Wayne - SCFB'

Subject: Don Pedro Relicensing: Study W&AR-5 Workshop 1 Materials Available on CD

During the November 4, 2011 Resource Work Group Meeting discussion of *Study W&AR-5 – Salmonid Populations Information Integration*, the Districts indicated they would provide the Relicensing Participants with an initial set of relevant information prior to the Study's first planned Workshop in April, 2012.

Materials for Study W&AR-5's Workshop 1 are now available. Due to the volume of information, materials for this first workshop are available on CD. Please contact me at rose.staples@hdrinc.com (or call 207.239.3857) if you would like a copy mailed to you.

Thank you.

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January 17, 2012

TO: Don Pedro Project Relicensing Participants

FROM: Turlock Irrigation District/Modesto Irrigation District

SUBJECT: FERC Project No. 2299
Study W&AR-5 – Salmonid Populations Information Integration
Preliminary Workshop 1 Materials

During the November 4, 2011, Resource Work Group Meeting discussion of *Study W&AR-5 – Salmonid Populations Information Integration*, the Districts indicated they would provide the Relicensing Participants with an initial set of relevant information prior to the Study's first planned Workshop in April 2012.

Enclosed please find a CD containing the references that were cited in the Pre-Application Document (PAD). Also included is a list of the references provided on the CD. These references provide information on factors affecting salmonid populations in the lower Tuolumne River. General salmonid life history references, as well as Tuolumne River specific information are included. The Districts would like to emphasize that the attached reference set is intended as an initial background survey of available information and some, or portions of some, of these references may not ultimately be required to be included in the final study report. In the course of this study, the reference list will be revised and/or supplemented as required in advance of the initial or subsequent workshops. Also, additional data resources will be reviewed and incorporated, if needed.

Enclosures

STUDY W&AR-5
SALMONID POPULATIONS INFORMATION INTEGRATION
PRELIMINARY WORKSHOP 1 MATERIALS
REFERENCES CITED IN THE DON PEDRO PROJECT
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Appendix 1: Population model documentation. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 2: Stock recruitment analysis of the population dynamics of San Joaquin River system Chinook salmon. Prepared by EA Engineering, Science and Technology. February 1992

Appendix 3: Tuolumne River salmon spawning surveys 1971-1988. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 4: Instream flow data processing Tuolumne River, California. Prepared by Robert E. Meyer Consultants, Inc. August 1984

Appendix 5: Analysis of 1981 lower Tuolumne River IFIM data. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 6: Lower Tuolumne River spawning gravel availability and superimposition report. Prepared by EA Engineering, Science and Technology. February 1992

Appendix 7: Lower Tuolumne River Chinook salmon redd excavation report. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 8: Lower Tuolumne River spawning gravel studies report. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 9: Spawning gravel cleaning methodologies. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 10: 1987 juvenile Chinook salmon mark-recapture study. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 11: An evaluation of the effect of gravel ripping on redd distribution in the Lower Tuolumne River. Prepared by EA Engineering, Science and Technology. November 1991

Appendix 12: Data results: Seining of juvenile Chinook salmon in the Tuolumne, San Joaquin and Stanislaus Rivers, 1986-1989. Prepared by EA Engineering, Science and Technology. August 1991

Appendix 13: Preliminary juvenile salmon study: Report on sampling of Chinook salmon fry and smolts by fyke net and seine in the Lower Tuolumne River 1973-1986. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 14: Tuolumne River fluctuation flow study report. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 15: Tuolumne River fluctuation flow study plan: Draft. Prepared by EA Engineering, Science and Technology. February 1992
Appendix 16: Aquatic invertebrate studies report. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 17: Preliminary Tuolumne River water temperature report. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 18: Lower Tuolumne River instream temperature model documentation: Description and calibration. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 19: Modeled effects of La Grange releases on instream temperatures in the Lower Tuolumne River. Prepared by EA Engineering, Science and Technology. September 1991
Appendix 20: Juvenile salmon pilot temperature observation experiments. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 21: Possible effects of high water temperature on migrating Chinook salmon (Oncorhynchus tshawytscha) smolts in the San Joaquin River System. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 22: Lower Tuolumne River predation study report. Prepared by EA Engineering, Science and Technology. February 1992
Appendix 23: Effects of turbidity on bass predation efficiency. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 24: Effects of introduced species of fish in the San Joaquin River system. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 25: Preliminary summary smolt survival index study. Prepared by Loudermilk, Fjelstad, Neillands, Wingett, Della Valle, Presher and Traylor, California Department of Fish and Game. July 1987
Appendix 26: Export mortality fraction submodel. Prepared by EA Engineering, Science and Technology. February 1992
Appendix 27: Tuolumne River summer flow study report 1988-1990. Prepared by EA Engineering, Science and Technology. November 1991
Appendix 28: Tuolumne River summer flow invertebrate study. Prepared by EA Engineering, Science and Technology. November 1991

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Report 1996-5: Stock-recruitment analysis report. Prepared by EA Engineering, Science and Technology. March 1997
Report 1996-6: Redd superimposition report. Prepared by EA Engineering, Science and Technology. March 1997
Report 1996-7: Redd excavation report. Prepared by EA Engineering, Science and Technology. March 1997

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From: Staples, Rose
Sent: Friday, January 20, 2012 2:46 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas - RHH; Wilcox, Scott -

Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: : Don Pedro Draft Study Plans – Sturgeon, Riparian, and O.myskiss Scale Studies

Don Pedro Relicensing Participants,

Following discussions of the Revised Study Plan (RSP) and in response to relicensing participant requests, the Districts agreed to develop three additional study plans:

W&AR 18 – Sturgeon Study
W&AR 19 – Lower Tuolumne Riparian Information and Synthesis Study
W&AR 20 – Oncorhynchus mykiss Scale Collection and Age Determination Study

Pursuant to the Study Plan Determination issued by FERC on December 22, 2011, the Districts are providing drafts of these three study plans for your review. These three studies can be downloaded from the Don Pedro Relicensing Website at donpedro-relicensing.com. In the row of banner headings across the top, please click on DOCUMENTS, then scroll down and select STUDIES under "Documents Now Available." Then you will need to scroll down again, under STUDIES, until you reach WATER-AQUATIC RWG (3). Click on that and you should see the three study plan drafts. Any problems accessing, please let me know.

Following the 30-day review period, the Districts will respond to comments received and file the study plans with FERC within 60 days of the Study Determination.

Please provide comments directly to the Districts via email to Rose.Staples@hdrinc.com (or Fax 207-775-1742) no later than February 20, 2012.

Thank you.

ROSE STAPLES
CAP-OM

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Executive Assistant, Hydropower Services

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TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT
FERC NO. 2299
WATER AND AQUATIC RESOURCES WORK GROUP

Study Plan W&AR-18
Sturgeon Study Plan
January 2012

Related Study Request: SWRCB-11

1.0 Project Nexus

The continued operation and maintenance (O&M) of the Don Pedro Project (Project) may contribute to cumulative effects on habitat availability for in-river life stages of the southern Distinct Population Segment (DPS) green sturgeon (*Acipenser medirostris*) and the potential for green sturgeon to occur in the lower Tuolumne River.

2.0 Resource Agency Management Goals

The Districts believe that four agencies have resource management goals related to the southern DPS green sturgeon and/or their habitat: (1) U.S. Department of Interior, Fish and Wildlife Service (USFWS); (2) United States Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS); (3) California Department of Fish and Game (CDFG); and 4) State Water Resources Control Board, Division of Water Rights (SWRCB).

Green sturgeon was considered in the 1995 Sacramento-San Joaquin Delta Native Fishes Recovery Plan (USFWS 1995). This plan identifies a primary restoration (recovery) objective of a minimum population of 1,000 fish over 1 meter (39 inches) total length each year, including 500 females over 1.3 meters (51 inches) total length (minimum size at maturity), during the spawning period (presumably March-July) when spawners are present in the estuary and the Sacramento River. A broad goal of the USFWS (2001) Anadromous Fish Restoration Program (AFRP), as stated in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to double the long-term production of anadromous fish in California's Central Valley rivers and streams. Although no specific objectives have been established for the Tuolumne River, broader objectives relating to green sturgeon to support the long-term goal for the Central Valley include: (1) improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat; (2) improve survival rates by reducing or eliminating entrainment of juveniles at diversions; (3) improve the opportunity for adult fish to reach spawning habitats in a timely manner; (4) collect fish population, health, and habitat data to facilitate evaluation of restoration actions; (5) integrate habitat restoration efforts with harvest and hatchery management; and (6) involve partners in the implementation and evaluation of restoration actions.

NMFS has developed Resource Management Goals and Objectives for species listed under the Endangered Species Act (ESA) (16 U.S.C. §1531 et seq.), as well as anadromous species that are not currently listed but may require listing in the future. The southern DPS green sturgeon was federally listed as threatened under the Endangered Species Act in 2006. Critical habitat was designated for the southern DPS in 2008. Although the Tuolumne River is not currently designated as critical habitat for the southern DPS green sturgeon, critical habitat is designated to include the Sacramento-San Joaquin Delta including all waterways up to the elevation of mean higher high water within the area defined in California Water Code Section 12220, except for specific excluded areas as described in (NMFS 2009).

CDFG's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFG's resource management goals, as summarized in restoration planning documents such as "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993), are to restore and protect California's aquatic ecosystems that support fish and wildlife, and to protect threatened and endangered species under California Fish and Game Code (Sections 6920–6924).

SWRCB has responsibility under the federal Clean Water Act (33 U.S.C. §11251–1357) to preserve and maintain the chemical, physical and biological integrity of the State's waters and to protect water quality and the beneficial uses of stream reaches consistent with Section 401 of the federal Clean Water Act, the Regional Water Quality Control Board Basin Plans, State Water Board regulations, the California Environmental Quality Act, and any other applicable state law.

3.0 Study Goals

The goal of this study is to conduct a literature review and synthesize applicable studies and reports on green sturgeon life history and habitat requirements in the Central Valley and San Joaquin Basin, and evaluate the potential for green sturgeon to be affected by Project operations. Study objectives are to:

- collect and summarize available information on green sturgeon distribution in order to characterize green sturgeon habitat requirements,
- evaluate potential habitat availability for in river life stages of green sturgeon in the lower Tuolumne River, and
- identify if there are Project-related factors that are potentially limiting the availability of green sturgeon habitat in the Tuolumne River.

4.0 Existing Information and Need for Additional Information

Green sturgeon life history requirements, distribution, and abundance information in the Sacramento-San Joaquin basin has been reported in several publications (e.g., Beamesderfer et al. 2004, Reclamation 2008, Adams et al. 2002). However, there are no data documenting the presence of green sturgeon in the San Joaquin or Tuolumne rivers. Similarly, there is little information regarding the potential to provide suitable habitat for this species within the San Joaquin River watershed. At the request of Relicensing Participants, a literature review will be conducted to provide a summary and synthesis of available publications and other sources of information on green sturgeon habitat. The study will attempt to identify factors affecting the potential green sturgeon habitat in the Tuolumne River and lower San Joaquin rivers.

5.0 Study Methods

The State Water Board requested the Districts perform a literature review and synthesis of available studies and reports to determine the impacts of the Project upon green sturgeon habitat in the Lower Tuolumne River. The Districts will review and synthesize information on green sturgeon distribution in order to characterize green sturgeon habitat requirements, and evaluate potential habitat availability in the lower Tuolumne River. No field studies will be conducted; the Districts will rely upon previously conducted studies and ongoing fisheries data collection and monitoring activities in the study area.

5.1 Study Area

The study area includes the Tuolumne River from the La Grange Dam (RM 52) downstream to the confluence with the San Joaquin River (RM 0).

5.2 General Concepts

The following general concepts apply to the study:

- The goal of this review is to characterize conditions and identify any Project related effects on those conditions in the study area as they relate to the potential availability of green sturgeon habitat through a focused examination of the available literature.
- The review will synthesize *findings* specific to the study area or green sturgeon habitat characteristics.
- Primary literature sources are preferred and secondary sources are rarely cited. If a secondary or tertiary source is cited, it will be clearly identified as such.

5.3 Study Methods

The study methods will consist of the three steps described below.

Step 1 – Data Compilation. Information from previously conducted studies on green sturgeon habitat, ecological needs and related conditions will be compiled. Attachment A provides a preliminary list of references to be reviewed. Subsequent literature review (Step 2) will focus on studies in Attachment A conducted on green sturgeon habitat and ecological needs in the Sacramento-San Joaquin basin. The highest priority will be given to data and reports specific to the Tuolumne River, then to data and reports related to the San Joaquin and its major tributaries. Information from these studies will be compiled and supplemented with relevant biological, hydrologic, physical habitat, and water quality data information in the study area. Information from broader sources may be used to address specific data or information gaps identified as part of this process. Relicensing participants will be encouraged to provide additional relevant information for the study.

Step 2 – Perform Analysis. The proposed study will compare information on habitat conditions in the study area with green sturgeon ecological and habitat requirements to identify potential Project related effects on green sturgeon habitat. Physical habitat attributes (e.g., temperature, substrate, depth, and velocity) observed in the lower Tuolumne and San Joaquin Rivers will be compared with green sturgeon habitat requirements to identify relative suitability. For example, water temperature criteria summarized by Van Eenennaam et al. (2005) will be compared to observed temperatures in the lower Tuolumne and San Joaquin rivers to assess habitat suitability for spawning and rearing life stages of green sturgeon. Analyses will be conducted for each in-river life history stage to gain an understanding of the potential for the Tuolumne River in its current condition to provide suitable habitat for green sturgeon. The study will provide an assessment of factors affecting habitat suitability for each life stage and an indication of the level of certainty associated with these conclusions.

Step 3 – Prepare Report. The Districts will prepare a report that includes the following sections: (1) Study Goals and Objectives; (2) Methods and Analysis; (3) Results; (4) Discussion; and (5) Conclusions. The report for this study will be a synthesis of existing information, and will provide an assessment of habitat suitability for green sturgeon in the Tuolumne River.

6.0 Schedule

The Districts anticipate the schedule to complete the study proposal as follows:

- Existing Data Compilation (Step 1)...February – March 2012
- Analysis and Synthesis (Step 2) ....March – May 2012
- Report Preparation (Step 3) ....May – June 2012
- Report Issuance ....July 2012

7.0 Consistency of Methodology with Generally Accepted Scientific Practices

Review and analysis of existing literature and other information sources is an important and well accepted step in scientific practices.

8.0 Deliverables

The Districts will prepare a final study report, which will document the methodology and results of the study.

9.0 Level of Effort and Cost

The Districts estimate that the cost to complete this study is $39,000.

10.0 References

Adams, P.B., C.B. Grimes, J.E. Hightower, S.T. Lindley, and M.L. Moser. 2002. Status review for the North American green sturgeon (*Acipenser medirostris*). National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California.

Beamesderfer, R., M. Simpson, G. Kopp, J. Inman, A. Fuller, and D. Demko. 2004. Historical and current information on green sturgeon occurrence in the Sacramento and San Joaquin rivers and tributaries. Prepared for State Water Contractors. S.P. Cramer and Associates, Oakdale, California.

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Van Eenennaam, J.P., J. Linares-Casenave, X. Deng, and S.I. Doroshov. 2005. Effect of incubation temperature on green sturgeon embryos, (*Acipenser medirostris*). Environmental Biology of Fishes. 72:145-154.

Attachment A

Study W&AR-18 Sturgeon Study
Preliminary Literature Sources for Review

Adams, P. B., C. B. Grimes, S. T. Lindley, and M. L. Moser. 2002. Status review for North American green sturgeon, *Acipenser medirostris*. NOAA, National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, CA. 50 p.

Allen, P. J. and J. J. Cech. 2007. Age/size effects on juvenile green sturgeon, *Acipenser medirostris*, oxygen consumption, growth, and osmoregulation in saline environments. Environmental Biology of Fishes 79:211-229.

Benson, R. L., S. Turo, and B. W. McCovey Jr. 2007. Migration and movement patterns of green sturgeon (*Acipenser medirostris*) in the Klamath and Trinity rivers, California, USA. Environmental Biology of Fishes 79:269-279.

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National Marine Fisheries Service (NMFS). 2009b. Final Rule to Designate Critical Habitat for the Threatened Southern Distinct Population Segment of North American Green Sturgeon.

Van Eenennaam, J.P., J. Linares-Casenave, X. Deng, and S.I. Doroshov. 2005. Effect of incubation temperature on green sturgeon embryos, (*Acipenser medirostris*). Environmental Biology of Fishes. 72:145-154.

TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT
FERC NO. 2299
WATER AND AQUATIC RESOURCES WORK GROUP

Study Plan W&AR-19
Lower Tuolumne River Riparian Information and Synthesis Study
January 2012

Related Study Requests: AR-15, BLM-09, SWRCB-03

1.0 Project Nexus

The continued operation and maintenance (O&M) of the Don Pedro Project (Project) may contribute to cumulative effects on the distribution, extent, composition, and structure of riparian vegetation downstream of La Grange Dam.

2.0 Resource Agency Management Goals

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) believe that four agencies may have resource management goals related to riparian vegetation along the Lower Tuolumne River: (1) U.S. Department of Interior, Fish and Wildlife Service (USFWS); (2) California Department of Fish and Game (CDFG); (3) the California Department of Water Resources (DWR); and (4) State Water Resources Control Board, Division of Water Rights (SWRCB).

The USFWS (2001) identified restoration and protection of riparian habitat as a high priority action for the Tuolumne River in the final restoration plan for the anadromous fish restoration program (Action 2; page 84).

CDFG's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. There are two management documents published by CDFG which include goals to protect and improve riparian vegetation within the Central Valley (CDFG 1993, 2007). In the California wildlife action plan, CDFG (1993) places a high priority on development of a comprehensive plan that addresses habitat improvements, including riparian habitat, along the San Joaquin River in order to re-establish anadromous fisheries below Friant Dam. Additionally, the California Advisory Committee on Salmon and Steelhead Trout (CACSST 1988), created in consultation with and directed to report to CDFG and the state legislature, recommended state-wide improved enforcement of Streambed Alteration Agreements to better protect riparian habitat and recommended that the State Legislature develop an incentive program to support protection and restoration of the riparian zone.

Outside of the lower Tuolumne River corridor, restoration and protection of riparian habitat in the Bay-Delta watershed is consistent with stated goals of the California Department of Water Resources, the lead agency for the CALFED program. The Ecological Restoration Program of CALFED includes multiple goals for restoration and protection of riparian vegetation and habitat, and for supporting ecological processes in the Central Valley (DWR 2000).

SWRCB has responsibility under the federal Clean Water Act (33 U.S.C. §11251–1357) to preserve and maintain the chemical, physical and biological integrity of the State's waters and to protect water quality and the beneficial uses of stream reaches consistent with Section 401 of the federal Clean Water Act, the Regional Water Quality Control Board Basin Plans, State Water Board regulations, the California Environmental Quality Act, and any other applicable state law.

3.0 Study Goals

The goal of this study is to review, summarize and report information describing the condition of the riparian resources and habitats associated with the Tuolumne River downstream of La Grange dam. Objectives in meeting this goal include:

- collect and summarize available existing information to characterize potential cumulative effects of the Project upon riparian vegetation along the lower Tuolumne River,
- provide a summary and synthesis of literature and other sources used in this study to characterize riparian habitat condition in the study area, and
- identify factors potentially affecting riparian resources and habitats in the study area.

4.0 Existing Information and Need for Review and Synthesis

As stated in the PAD (Section 6.1.6 Riparian, Wetlands, and Littoral Habitats), the Project may contribute to cumulative effects on riparian resources downstream of La Grange Dam by modifying the hydrologic and fluvial processes that influence the establishment, survival, and succession of riparian vegetation. For example, McBain & Trush (2000) suggest opportunities might exist to revise U.S. Army Corps of Engineers flood control operations of Don Pedro Reservoir in order to partially restore fluvial processes that support a more dynamic riparian system and improved habitat. Studies of the Tuolumne River (e.g., McBain & Trush 2000, Stella et al. 2006, Stillwater Sciences 2006) as well as broader studies (Anderson et al. 2006, Arthington et al. 2006, Bendix 1999, Lytle and Merritt 2004, Merritt and Cooper 2000, Rood et al. 1995, Rood et al. 2005, Shafroth et al. 2002) have examined linkages between river hydrographs and riparian vegetation. Other factors affecting riparian landscapes include predicted changes in snowpack and the snowmelt hydrograph (Young et al. 2009; Stromberg et al. 2010) and land use changes. At the request of Relicensing Participants, this study will provide a summary and synthesis of these literature and other sources indentified during this study.

5.0 Study Area and Study Methods

5.1 Study Area

The study area includes the Tuolumne River from the La Grange Dam (RM 52) downstream to its confluence with the San Joaquin (RM 0).

5.2 General Concepts

The following general concepts apply to the study:

- The goal of this review is to summarize factors affecting riparian ecology in the Tuolumne and San Joaquin rivers through a focused examination of the available literature.
- The review will synthesize *findings* specific to the study area.
- Primary sources are preferred and secondary sources are rarely cited. If a secondary or tertiary source is cited, it is clearly identified as such.

5.3 Study Methods

The riparian vegetation study will be accomplished in three steps.

Step 1 – Data Compilation. Source documents will include peer-reviewed literature and reports that address riparian vegetation specific to the study area as well as other sources describing factors (e.g., flow regulation, land use, climate change, and invasive species) that may impact riparian processes and the distribution of riparian vegetation in general. Attachment A provides a preliminary list of references to be reviewed. Subsequent literature review (Step 2) will focus on studies in Attachment A.

Step 2 – Information Review. Documents describing current riparian community structure, composition, and distribution (patch size, connectivity, and floodplain lateral extent) will be reviewed. Linkages between Tuolumne River riparian vegetation dynamics (including creation of fluvial/riparian surfaces, riparian vegetation recruitment, survival, and succession), hydrology (including the frequency and intensity of scouring flows, the spring snow melt hydrograph, and summer low flow conditions), and geomorphology (including fine and coarse sediment supplies and transport) will be assessed. Factors (e.g., hydrologic and geomorphic processes, land use management, invasive species) affecting current riparian conditions in the study area will be reviewed and synthesized. The literature review may include findings of studies in the lower San Joaquin as well as other lowland Central Valley rivers.

Step 3 – Prepare Report. The report will summarize points relevant to evaluating potential cumulative effects of the Project on riparian vegetation in the study area. The report will include the following sections: (1) Study Goals and Objectives; (2) Information sources, assessment methods and analysis; (3) Findings and Discussion; and (5) Conclusions.

6.0 Schedule

The Districts anticipate the schedule to complete the study as follows.

- Data Compilation (Step 1) .... February 2012
- Information Review (Step 2) ....February 2012–March 2012
- Report Preparation (Step 3) ....March 2012–May 2012
- Report Issuance (Step 3)..July 2012

7.0 Consistency of Methodology With Generally Accepted Scientific Practices

Review and analysis of existing literature and other information sources is an important and well accepted step in scientific practices.

8.0 Deliverables

The Districts will prepare a report which will document the methodology, literature sources, and findings of the study.

9.0 Level of Effort and Cost

The Districts estimate that the cost to complete this study is $38,000.

10.0 Literature Cited

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Attachment A

Study W&AR-19 Lower Tuolumne River Riparian Information and Synthesis Study Preliminary Literature Sources for Review

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TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT
FERC NO. 2299
WATER AND AQUATIC RESOURCES WORK GROUP

Study Plan W&AR-20
***Oncorhynchus mykiss* Scale Collection and Age Determination Study Plan**
January 2012

Related Study Request: USFWS-10

1.0 Project Nexus

The continued operation and maintenance (O&M) of the Don Pedro Project (Project) may contribute to cumulative effects on salmonid fish habitat in the Tuolumne River downstream of La Grange Dam. These environmental effects include changes in the quality and quantity of physical habitat available for *Oncorhynchus mykiss (O. mykiss*), thereby potentially affecting populations in the lower Tuolumne River.

2.0 Resource Agency Management Goals

The Districts believe that four agencies have resource management goals related to the *O. mykiss* and/or their habitat: (1) U.S. Department of Interior, Fish and Wildlife Service (USFWS); (2) California Department of Fish and Game (CDFG), (3) National Marine Fisheries Service (NMFS), and (4) State Water Resources Control Board, Division of Water Rights (SWRCB).

A broad goal of the USFWS (2001) Anadromous Fish Restoration Program (AFRP), as stated in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to double the long-term production of anadromous fish in California's Central Valley rivers and streams. Although no specific objectives have been established for the Tuolumne River, broader objectives of this long-term goal for the Central Valley include: (1) improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat; (2) improve survival rates by reducing or eliminating entrainment of juveniles at diversions; (3) improve the opportunity for adult fish to reach spawning habitats in a timely manner; (4) collect fish population, health, and habitat data to facilitate evaluation of restoration actions; (5) integrate habitat restoration efforts with harvest and hatchery management; and (6) involve partners in the implementation and evaluation of restoration actions.

NMFS has developed Resource Management Goals and Objectives for species listed under the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 et seq.) and the Endangered Species Act (ESA) (16 U.S.C. §1531 et seq.), as well as anadromous species that are not currently listed but may require listing in the future. Although NMFS' (2009) Public Draft Recovery Plan for Sacramento River Winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and Central Valley steelhead (Draft Recovery Plan) outlines the framework for the recovery of ESA-listed species and populations in California's Central Valley, including the Tuolumne River, this plan has not been adopted by FERC as a comprehensive plan (FERC 2011).

CDFG's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFG's resource management goals, as summarized in restoration planning documents such as "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993), are to restore and protect California's aquatic ecosystems that support fish and wildlife, and to protect threatened and endangered species under California Fish and Game Code (Sections 6920–6924).

SWRCB has responsibility under the federal Clean Water Act (33 U.S.C. §11251–1357) to preserve and maintain the chemical, physical and biological integrity of the State's waters and to protect water quality and the beneficial uses of stream reaches consistent with Section 401 of the federal Clean Water Act, the Regional Water Quality Control Board Basin Plans, State Water Board regulations, the California Environmental Quality Act, and any other applicable state law.

3.0 Study Goals

The goal of this study is to determine the age-length relationship of *O. mykiss* in the Tuolumne River. Objectives in meeting this goal include:

- Collect, preserve, and analyze *O. mykiss* scales to determine ages of individual fish, and
- Develop an age to the length relationship for the sampled *O. mykiss*.

4.0 Existing Information and Need for Additional Information

As part of the interrelated *Oncorhynchus mykiss* Population Study (Study Plan W&AR-10), the Districts have agreed to incorporate fish age and growth analyses into the development of population models, relying primarily upon length frequency analysis (e.g., MacDonald and Pitcher 1979) of *O. mykiss* observed in recent snorkel surveys collected in the past several years (e.g., Stillwater Sciences 2011). At the request of Relicensing Participants, the Districts also agreed to collect scales from *O. mykiss* in the lower Tuolumne River, downstream of La Grange Dam to refine age composition and growth estimates. The age-length relationship results of this study will allow *O. mykiss* length data collected from the Tuolumne River during the past several years to be applied in developing representative age structure as part of population modeling in the interrelated *Oncorhynchus mykiss* Population Study (Study Plan W&AR-10).

5.0 Study Methods

5.1 Study Area

The study area includes the Tuolumne River from the La Grange Dam (RM 52) downstream to Robert's Ferry Bridge (RM 39.5), which is the section of the lower Tuolumne River typically inhabited by *O. mykiss*.

5.2 General Concepts

The following general concepts apply to the study:

- Personal safety is an important consideration of each fieldwork team. The Districts and their consultants will perform the study in a safe manner; areas considered unsafe in the judgment of field teams will not be surveyed.
- The Districts will make a good faith effort to obtain permission in advance of performance of the study to access private property where needed. Field crews may make minor modifications in the field to adjust to and to accommodate actual field conditions and unforeseeable events. Any modifications made will be documented and reported in the draft study reports.

5.3 Study Methods

The study method will consist of the following four steps.

Step 1 – Study Design and Permitting. *O. mykiss* will be collected from pool and riffle-tail habitats by angling or other potentially more efficient methods to be determined as part of the ESA Section 10 and Scientific Collection Permitting processes. Length data and scale samples will be obtained from up to 75 fish using 15 individuals per 100 mm size-group (i.e., 50-50 mm, 150-250 mm, 250–350 mm, etc) encountered during sampling.

Because initiation and completion of the study, as described in this Plan, is contingent on permit approval by NMFS and CDFG, permit inquiries and requests will be made in February 2012, in advance of study initiation. The Districts will make a good faith effort to modify the study design to comply with permit conditions and proceed with the study, if possible. In the event permits are not granted or an insufficient number of individuals are captured, the Districts will reevaluate alternative approaches to developing age at length and age structure information as part of the interrelated salmonid studies (e.g.,W&AR-5, W&AR-6 and W&AR-10).

Step 2 – Field Sampling. Juvenile and adult *O. mykiss* will be captured in the Tuolumne River at selected locations from RM 52 (La Grange Dam) downstream to approximately RM 39.5 (Roberts Ferry Bridge), which is the portion of the river where *O. mykiss* have been historically observed (Stillwater Sciences 2011).

The survey crew will record the location (GPS coordinates), habitat type, and length of each captured *O. mykiss*. Fish will be transferred to a measurement cradle and data recorded for all fish meeting the required length criterion, including fork length (FL, mm), total length (TL, mm), and general condition. If possible, the sex of each fish will be determined, and any marks that would aid in determining hatchery vs. wild origin (e.g., adipose fin clip) will be noted.

Scales will be removed from the region between the posterior end of the dorsal fin and the lateral line on the left side, roughly two scale rows above the lateral line. Prior to scale removal, mucous and debris will be cleaned from the sampling location for ease in scale processing. Scales will be removed by scraping a dull knife from the anterior to posterior of the sample area (Figure 1). Approximately 10 scales will be removed per fish.

All collected scales from individual fish will be placed on a square of “Rite in the Rain” paper. The paper will be folded over the blade and pinched to remove the scales. The folded paper will be immediately inserted into an envelope. Each individual envelope will be clearly labeled with species, site location, fork length, weight, date, condition, and any other applicable information.

All envelopes will be pressed flat to reduce scale curling and increase analytical accuracy. Only one envelope will be used for each fish. Knives will then be thoroughly cleaned with ethanol to prevent cross-contamination of scale samples.

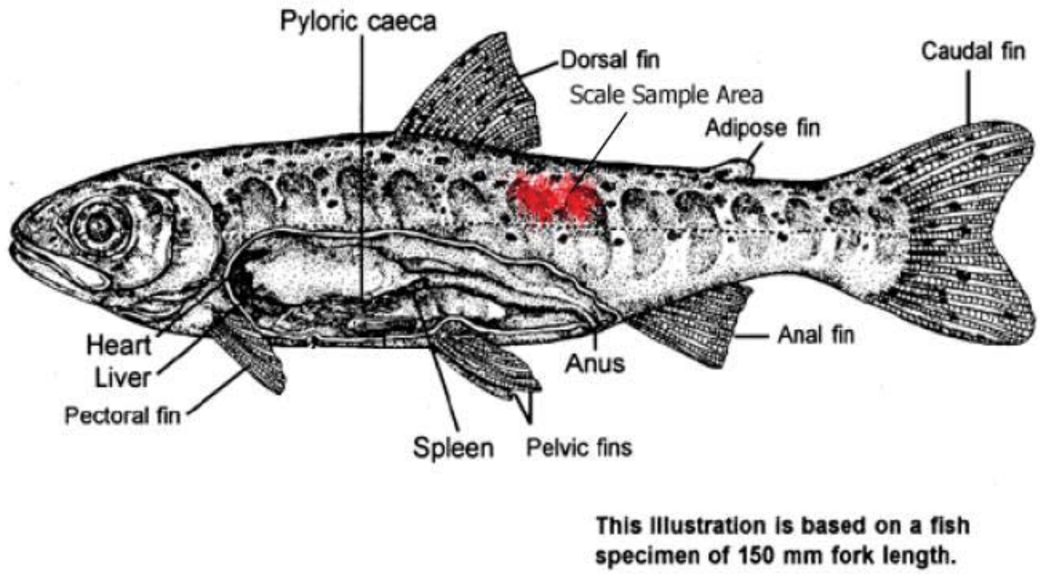

Figure 1. Fish schematic showing area (red) where scale sample will be taken from fish (modified from Columbia Basin Fish and Wildlife Authority. 1999).

<u>Step 3 – Analysis</u>. Scales will be prepared by qualified staff according to standard procedures (Drummond 1966). Scales will be transferred from the envelopes onto a glass slide. The best scales will be arranged towards the top of the slide, and all scales will be oriented the same way. Care will be taken to insure that all scales are laid flat, not curled. Another glass slide will be placed on top and then both slides will be taped together. Each slide will be labeled with the sample identification number and date. Each scale will then be examined under a microscope at both 10x and 40x power so that annuli can be discerned.

Age of fish will be determined using scale analysis following the methods of DeVries and Frie (1996). Results will be recorded in a MS Excel spreadsheet. Scales will be available for independent analysis by USFWS, CDFG and/or NMFS staff. If there is a difference of opinion between analysts or other difficulty reading any scale, all examining staff will convene to review the scales and determine the age.

<u>Step 4 – Prepare Report</u>. The Districts will prepare a report that includes the following sections: (1) Study Goals and Objectives; (2) Methods and Analysis; (3) Results; (4) Discussion; and (5) Conclusions. The report for this study will include an *O. mykiss* length at age relationship and estimated growth rates.

6.0 Schedule

The Districts anticipate the schedule to complete the study proposal as follows:

- Study Design and Permitting (Step 1) ....February – May 2012
- Scale collection (Step 2)……………………………………………… ... March –July 2012
- Analysis and Synthesis (Step 3) ....August – September 2012
- Report Preparation (Step 4) ....September – December 2012
- Report Issuance ....January 2013

Initiation of scale collection is dependent on acquisition of the necessary permit modifications from CDFG and/or NMFS. Every effort will be made by the Districts to complete the permit process prior to data collection during the summer of 2012.

7.0 Consistency of Methodology with Generally Accepted Scientific Practices

The methods presented in this study plan are consistent with other generally accepted scientific study methods concerning the ageing and analysis of age-growth relationships for salmonids, including those conducted by the state and federal resource agencies.

8.0 Deliverables

The Districts will prepare a final study report, which will document the methodology and results of the study. The study products will include a description of *O. mykiss* length at age relationships in the lower Tuolumne River.

9.0 Level of Effort and Cost

The Districts estimates that the cost to complete this study is $89,000.

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From: Staples, Rose
Sent: Tuesday, January 24, 2012 12:03 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB
Subject: TID - MID Motion Filed Today with FERC

Please be aware that the Districts have filed the following motion with FERC:

On 1/24/2012, the following Filing was submitted to the Federal Energy Regulatory Commission (FERC), Washington D.C.:

Filer: Turlock Irrigation District and Modesto Irrigation District
Winston & Strawn LLP (as Agent)

Docket(s): P-2299-075
Filing Type: Procedural Motion
Description: Motion of the Modesto and Turlock Irrigation Districts to Disqualify Agency Dispute Panel Member under P-2299-075.

The filing can be viewed on FERC's E-Library website at www.ferc.gov.

ROSE STAPLES
CAP-OM

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Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Tuesday, January 24, 2012 12:27 PM
To: 'Alves, Jim - City of Modesto'; 'Anderson, Craig - USFWS'; 'Asay, Lynette - N-R'; 'Aud, John - SCERD'; 'Barnes, James - BLM'; 'Barnes, Peter - SWRCB'; 'Beuttler, John - CSPA'; 'Blake, Martin'; 'Bond, Jack - City of Modesto'; 'Boucher, Allison - TRC'; 'Boucher, Dave - Allison - TRC'; 'Bowes, Stephen - NPS'; 'Bowman, Art - CWRMP'; 'Brenneman, Beth - BLM'; 'Brewer, Doug - TetraTech'; 'Brochini, Anthony - SSMN'; 'Brochini, Tony - NPS'; 'Buckley, John - CSERC'; 'Buckley, Mark'; 'Burley, Silvia-CVMT'; 'Burt, Charles - CalPoly'; 'Cadagan, Jerry'; 'Carlin, Michael - SFPUC'; 'Catlett, Kelly - FOR'; 'Charles, Cindy - GWWF'; 'Cismowski, Gail - SWRCB'; 'Costa, Jan - Chicken Ranch'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob - TBMWI'; 'Cranston, Peggy - BLM'; 'Cremeen, Rebecca - CSERC'; 'Day, Kevin - TBMI'; 'Day, P - MF'; 'Denean - BVR'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne - OHP'; 'Dowd, Maggie-SNF'; 'Drekmeier, Peter - TRT'; 'Edmondson, Steve - NOAA'; 'Eicher, James - BLM'; 'Fety, Lauren - BLM'; 'Findley, Timothy - Hanson Bridgett'; 'Freeman, Beau - CalPoly'; 'Fuller, Reba - TMTC'; 'Furman, Donn W - SFPUC'; 'Ganteinbein, Julie - Water-Power Law Grp'; 'Giglio, Deborah - USFWS'; 'Gorman, Elaine - YSC'; 'Grader, Zeke'; 'Gutierrez, Monica - NOAA-NMFS'; 'Hackamack, Robert'; 'Hastreiter, James L - FERC'; 'Hatch, Jenny - CT'; 'Hayat, Zahra - MF'; 'Hayden, Ann'; 'Hellam, Anita - HH'; 'Heyne, Tim - CDFG'; 'Holden, James '; 'Holm, Lisa'; 'Horn, Jeff - BLM'; 'Horn, Tini'; 'Hudelson, Bill - StanislausFoodProducts'; 'Hughes, Noah'; 'Hughes, Robert - CDFG'; 'Hume, Noah - Stillwater'; 'Jackman, Jerry '; 'Jackson, Zac - USFWS'; 'Jennings, William - CSPA'; 'Jensen, Art - BAWSCA'; 'Jensen, Laura - TNC'; 'Johannis, Mary'; 'Johnson, Brian - CalTrout'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn - NOAA-MNFS'; 'Kinney, Teresa'; 'Koepele, Patrick - TRT'; 'Kordella, Lesley - FERC'; 'Lein, Joseph'; 'Levin, Ellen - SFPUC'; 'Lewis-Reggie-PRCI'; 'Linkard, David - TRT /RH'; 'Looker, Mark - LCC'; Loy, Carin; 'Lwenya, Roselynn, BVR'; 'Lyons, Bill - MR'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul '; 'Marshall, Mike - RHH'; 'Martin, Michael - MFFC'; 'Martin, Ramon - USFWS'; 'Mathiesen, Lloyd - CRRMW'; 'McDaniel, Dan -CDWA'; 'McDevitt, Ray - BAWSCA'; 'McDonnell, Marty - SMRT'; 'McLain, Jeffrey - NOAA-NMFS'; 'Means, Julie - CDFG'; 'Mills, John - TUD'; 'Morningstar Pope, Rhonda - BVR'; 'Motola, Mary - PRCI'; 'O'Brien, Jennifer - CDFG'; 'Orvis, Tom - SCFB'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane - Cardno'; 'Pavich, Steve-Cardno'; 'Pinhey, Nick - City of Modesto'; 'Pool, Richard'; 'Porter, Ruth - RHH'; 'Powell, Melissa - CRRMW'; 'Puccini, Stephen - CDFG'; 'Raeder, Jessie - TRT'; 'Ramirez, Tim - SFPUC'; 'Rea, Maria - NOAA-NMFS'; 'Reed, Rhonda - NOAA-NMFS'; 'Richardson, Kevin - USACE'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O - N-R'; 'Roos-Collins, Richard - Water-Power Law Grp for NHI'; 'Roseman, Jesse'; 'Rothert, Steve - AR'; 'Sander, Max - TNC'; 'Sandkulla, Nicole - BAWSCA'; 'Saunders, Jenan'; 'Schutte, Allison - HB'; 'Sears, William - SFPUC'; 'Shipley, Robert'; 'Shumway, Vern - SNF'; 'Shutes, Chris - CSPA'; 'Sill, Todd'; 'Slay, Ronn - CNRF/AIC'; 'Smith, Jim - MPM'; 'Steindorf, Dave - AW'; 'Steiner, Dan'; 'Stone, Vicki -TBMI'; 'Stork, Ron - FOR'; 'Stratton, Susan - CA SHPO'; 'Taylor, Mary Jane - CDFG'; 'Terpstra, Thomas'; 'TeVelde, George A '; 'Thompson, Larry - NOAA-MNFS'; 'Vasquez, Sandy '; 'Verkuil, Colette - TRT/MF'; 'Vierra, Chris'; 'Villalabos, Ruben'; 'Walters, Eric - MF'; 'Wantuck,

Rick - NOAA-NMFS'; 'Welch, Steve - ARTA'; 'Wesselman, Eric - TRT'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas - RHH'; 'Wilcox, Scott - Stillwater'; 'Williamson, Harry (NPS)'; 'Willy, Alison - FWS'; 'Wilson, Bryan - MF'; 'Winchell, Frank - FERC'; 'Wood, Dave - FR'; 'Wooster, John -NOAA'; 'Workman, Michelle - USFWS'; 'Yoshiyama, Ron'; 'Zipser, Wayne - SCFB'

Subject: RE: TID - MID Motion Filed Today with FERC

I understand that once you access FERC's E-Library website, searching on "P-2299-075" is NOT producing any results. Please try just entering the project number (P-2299), leaving off the sub-docket number 075. I was able to successfully locate the document a few minutes ago by going that route in their search function. Thank you.

ROSE STAPLES
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From: Staples, Rose
Sent: Tuesday, January 24, 2012 12:01 PM

Please be aware that the Districts have filed the following motion with FERC:

On 1/24/2012, the following Filing was submitted to the Federal Energy Regulatory Commission (FERC), Washington D.C.:

Filer:	Turlock Irrigation District and Modesto Irrigation District Winston & Strawn LLP (as Agent)
Docket(s):	P-2299-075
Filing Type:	Procedural Motion
Description:	Motion of the Modesto and Turlock Irrigation Districts to Disqualify Agency Dispute Panel Member under P-2299-075.

The filing can be viewed on FERC's E-Library website at www.ferc.gov.

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From: Staples, Rose
Sent: Tuesday, February 07, 2012 8:15 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shakal, Sarah - Humboldt State; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB
Subject: Don Pedro Project Relicensing Water & Aquatic Study Plans Workshop/Meeting Schedule for 2012

In accordance with FERC's Study Plan Determination and the Districts' Water & Aquatic (W&AR) study plans to be underway in 2012, we have developed schedule dates for the various workshops contained within the study plans. Please make note of these below:

April 2012
Apr 09 1:00 pm - 5:00 pm PT Don Pedro Project Relicensing - Hydrology Workshop (W&AR-2) (Modesto Irrigation District Offices, Modesto {MID})
Apr 10 8:00 am – 10:00 am PT Don Pedro Project Relicensing - Reservoir Temperature Modeling Data and Methods (MID)
Apr 10 10:15 am - 5:00 pm PT Don Pedro Project Relicensing - Salmonid Population Information Workshop (W&AR-5) (MID)

June 2012
Jun 26 9:00 am – 4:00 pm PT Don Pedro Project Relicensing - Salmonid Population Information Workshop (W&AR-5) (MID)

September 2012
Sep 18 9:00 am - 4:00 pm PT Don Pedro Project Relicensing - Temperature Model Verification/Calibration Meeting (MID)

November 2012
Nov 15 9:00 am - 4:00 pm PT Don Pedro Project Relicensing - Chinook Population (W&AR-6) and O.mykiss Population (W&AR-10) Modeling Workshop (MID)

In addition, in accordance with FERC's direction regarding the development and implementation of a more explicit consultation program for those studies with workshops, we are proposing to hold a meeting on March 20th at MID (from 1:30 to 4:30 p.m.) to discuss and finalize such a Workshop Consultation Program. An initial proposal will be forwarded by March 5 to all participants.

March 2012
Mar 20 1:30 pm – 4:30 pm PT Don Pedro Project Relicensing - Workshop on Consultation Process (as per Appendix B of FERC's Study Plan Determination) (MID)

We look forward to continuing to work with all relicensing participants in 2012.

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ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB
Subject:FW: FERC Acceptance for Filing in P-2299-075

Please be advised that the TID and MID Districts have filed a request with FERC to extend the deadline to February 28, 2012 to submit Water & Aquatic Study Plans 18, 19, and 20 (the drafts of which you are currently reviewing) for Commission approval.

As stated in the letter:

The Commission's Study Plan Determination for the Don Pedro Project, which was issued on December 21, 2011, directed Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts) to submit for Commission approval three study plans as follows:

W&AR-18	Sturgeon Study
W&AR-19	Lower Tuolumne Riparian Information and Synthesis Study
W&AR-20	O.mykiss Scale and Age Determination

The Commission directed the Districts to file these three study plans within 60 days after the issuance date of the Study Plan Determination, or February 19, 2012. Since February 19 falls on a Sunday and February 20 is a holiday (Presidents' Day), the study plans must be filed by Tuesday, February 21. The Districts issued the three study plans to Relicensing Participants for review and comment on January 20, 2012, and requested that all comments be provided no later than February 20, 2012.

As mentioned above, February 20 is a holiday, so comments would be due from the Relicensing Participants by February 21. To give the Districts adequate time to review and address all of the Relicensing Participants' comments, the Districts respectfully request an extension of time for filing the three study plans with the Commission until February 28, 2012.

A copy of the letter is available on FERC's E-Library at www.FERC.gov under docket P-2299-075 -- and it is also available on the www.donpedro-relicensing.com website under the Introduction/Announcement banner.

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From: Staples, Rose
Sent: Friday, February 17, 2012 5:04 PM
To: Staples, Rose; Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas -

	RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John - NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB
Subject:	RE: : Don Pedro Draft Study Plans – Sturgeon, Riparian, and O.myskiss Scale Studies

On January 20th I sent an email (copy below) advising that comments on the following three study plan were due to the DISTRICTS, via email to me (rose.staples@hdrinc.com) or via fax (207-775-1742), no later than February 20, 2012.

W&AR 18 – Sturgeon Study
W&AR 19 – Lower Tuolumne Riparian Information and Synthesis Study
W&AR 20 – Oncorhynchus mykiss Scale Collection and Age Determination Study

As Monday, February 20th is a holiday, the due date for comments to be received by me is now: No later than Tuesday, February 21st.

Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Friday, January 20, 2012 2:46 PM
To: 'Alves, Jim - City of Modesto'; 'Anderson, Craig - USFWS'; 'Asay, Lynette - N-R'; 'Aud, John - SCERD'; 'Barnes, James - BLM'; 'Barnes, Peter - SWRCB'; 'Beuttler, John - CSPA'; 'Blake, Martin'; 'Bond, Jack - City of Modesto'; 'Boucher, Allison - TRC'; 'Boucher, Dave - Allison - TRC'; 'Bowes, Stephen - NPS'; 'Bowman, Art - CWRMP'; 'Brenneman, Beth - BLM'; 'Brewer, Doug - TetraTech'; 'Brochini, Anthony - SSMN'; 'Brochini, Tony - NPS'; 'Buckley, John - CSERC'; 'Buckley, Mark'; 'Burley, Silvia-CVMT'; 'Burt, Charles - CalPoly'; 'Cadagan, Jerry'; 'Carlin, Michael - SFPUC'; 'Catlett, Kelly - FOR'; 'Charles, Cindy - GWWF'; 'Cismowski, Gail - SWRCB'; 'Costa, Jan - Chicken Ranch'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob - TBMWI'; 'Cranston, Peggy - BLM'; 'Cremeen, Rebecca - CSERC'; 'Day, Kevin - TBMI'; 'Day, P - MF'; 'Denean - BVR'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne - OHP'; 'Dowd, Maggie-SNF'; 'Drekmeier, Peter - TRT'; 'Edmondson, Steve - NOAA'; 'Eicher, James - BLM'; 'Fety, Lauren - BLM'; 'Findley, Timothy - Hanson Bridgett'; 'Freeman, Beau - CalPoly'; 'Fuller, Reba - TMTC'; 'Furman, Donn W - SFPUC'; 'Ganteinbein, Julie - Water-Power Law Grp'; 'Giglio, Deborah - USFWS'; 'Gorman, Elaine - YSC'; 'Grader, Zeke'; 'Gutierrez, Monica - NOAA-NMFS'; 'Hackamack, Robert'; 'Hastreiter, James L - FERC'; 'Hatch, Jenny - CT'; 'Hayat, Zahra - MF'; 'Hayden, Ann'; 'Hellam, Anita - HH'; 'Heyne, Tim - CDFG'; 'Holden, James '; 'Holm, Lisa'; 'Horn, Jeff - BLM'; 'Horn, Tini'; 'Hudelson, Bill - StanislausFoodProducts'; 'Hughes, Noah'; 'Hughes, Robert - CDFG'; 'Hume, Noah - Stillwater'; 'Jackman, Jerry '; 'Jackson, Zac - USFWS'; 'Jennings, William - CSPA'; 'Jensen, Art - BAWSCA'; 'Jensen, Laura - TNC'; 'Johannis, Mary'; 'Johnson, Brian - CalTrout'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn - NOAA-MNFS'; 'Kinney, Teresa'; 'Koepele, Patrick - TRT'; 'Kordella, Lesley - FERC'; 'Lein, Joseph'; 'Levin, Ellen - SFPUC'; 'Lewis-Reggie-PRCI'; 'Linkard, David - TRT /RH'; 'Looker, Mark - LCC'; Loy, Carin; 'Lwenya, Roselynn, BVR'; 'Lyons, Bill - MR'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul '; 'Marshall, Mike - RHH'; 'Martin, Michael - MFFC'; 'Martin, Ramon - USFWS'; 'Mathiesen, Lloyd - CRRMW'; 'McDaniel, Dan -CDWA'; 'McDevitt, Ray -

BAWSCA'; 'McDonnell, Marty - SMRT'; 'McLain, Jeffrey - NOAA-NMFS'; 'Means, Julie - CDFG'; 'Mills, John - TUD'; 'Morningstar Pope, Rhonda - BVR'; 'Motola, Mary - PRCI'; 'O'Brien, Jennifer - CDFG'; 'Orvis, Tom - SCFB'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane - Cardno'; 'Pavich, Steve-Cardno'; 'Pinhey, Nick - City of Modesto'; 'Pool, Richard'; 'Porter, Ruth - RHH'; 'Powell, Melissa - CRRMW'; 'Puccini, Stephen - CDFG'; 'Raeder, Jessie - TRT'; 'Ramirez, Tim - SFPUC'; 'Rea, Maria - NOAA-NMFS'; 'Reed, Rhonda - NOAA-NMFS'; 'Richardson, Kevin - USACE'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O - N-R'; 'Roos-Collins, Richard - Water-Power Law Grp for NHI'; 'Roseman, Jesse'; 'Rothert, Steve - AR'; 'Sander, Max - TNC'; 'Sandkulla, Nicole - BAWSCA'; 'Saunders, Jenan'; 'Schutte, Allison - HB'; 'Sears, William - SFPUC'; 'Shipley, Robert'; 'Shumway, Vern - SNF'; 'Shutes, Chris - CSPA'; 'Sill, Todd'; 'Slay, Ronn - CNRF/AIC'; 'Smith, Jim - MPM'; Staples, Rose; 'Steindorf, Dave - AW'; 'Steiner, Dan'; 'Stone, Vicki -TBMI'; 'Stork, Ron - FOR'; 'Stratton, Susan - CA SHPO'; 'Taylor, Mary Jane - CDFG'; 'Terpstra, Thomas'; 'TeVelde, George A '; 'Thompson, Larry - NOAA-MNFS'; 'Vasquez, Sandy '; 'Verkuil, Colette - TRT/MF'; 'Vierra, Chris'; 'Villalabos, Ruben'; 'Walters, Eric - MF'; 'Wantuck, Rick - NOAA-NMFS'; 'Welch, Steve - ARTA'; 'Wesselman, Eric - TRT'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas - RHH'; 'Wilcox, Scott - Stillwater'; 'Williamson, Harry (NPS)'; 'Willy, Alison - FWS'; 'Wilson, Bryan - MF'; 'Winchell, Frank - FERC'; 'Wood, Dave - FR'; 'Wooster, John -NOAA'; 'Workman, Michelle - USFWS'; 'Yoshiyama, Ron'; 'Zipser, Wayne - SCFB'
Subject: : Don Pedro Draft Study Plans – Sturgeon, Riparian, and O.myskiss Scale Studies

Don Pedro Relicensing Participants,

Following discussions of the Revised Study Plan (RSP) and in response to relicensing participant requests, the Districts agreed to develop three additional study plans:

W&AR 18 – Sturgeon Study
W&AR 19 – Lower Tuolumne Riparian Information and Synthesis Study
W&AR 20 – Oncorhynchus mykiss Scale Collection and Age Determination Study

Pursuant to the Study Plan Determination issued by FERC on December 22, 2011, the Districts are providing drafts of these three study plans for your review. These three studies can be downloaded from the Don Pedro Relicensing Website at donpedro-relicensing.com. In the row of banner headings across the top, please click on DOCUMENTS, then scroll down and select STUDIES under "Documents Now Available." Then you will need to scroll down again, under STUDIES, until you reach WATER-AQUATIC RWG (3). Click on that and you should see the three study plan drafts. Any problems accessing, please let me know.

Following the 30-day review period, the Districts will respond to comments received and file the study plans with FERC within 60 days of the Study Determination.

Please provide comments directly to the Districts via email to Rose.Staples@hdrinc.com (or Fax 207-775-1742) no later than February 20, 2012.

Thank you.

ROSE STAPLES
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From: Staples, Rose
Sent: Tuesday, February 21, 2012 8:11 PM
To: Alves, Jim - City of Modesto; Anderson, Craig - USFWS; Asay, Lynette - N-R; Aud, John - SCERD; Barnes, James - BLM; Barnes, Peter - SWRCB; Beuttler, John - CSPA; Blake, Martin; Bond, Jack - City of Modesto; Boucher, Allison - TRC; Boucher, Dave - Allison - TRC; Bowes, Stephen - NPS; Bowman, Art - CWRMP; Brenneman, Beth - BLM; Brewer, Doug - TetraTech; Brochini, Anthony - SSMN; Brochini, Tony - NPS; Buckley, John - CSERC; Buckley, Mark; Burley, Silvia-CVMT; Burt, Charles - CalPoly; Cadagan, Jerry; Carlin, Michael - SFPUC; Catlett, Kelly - FOR; Charles, Cindy - GWWF; Cismowski, Gail - SWRCB; Costa, Jan - Chicken Ranch; Cowan, Jeffrey; Cox, Stanley Rob - TBMWI; Cranston, Peggy - BLM; Cremeen, Rebecca - CSERC; Day, Kevin - TBMI; Day, P - MF; Denean - BVR; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne - OHP; Dowd, Maggie-SNF; Drekmeier, Peter - TRT; Edmondson, Steve - NOAA; Eicher, James - BLM; Fety, Lauren - BLM; Findley, Timothy - Hanson Bridgett; Freeman, Beau - CalPoly; Fuller, Reba - TMTC; Furman, Donn W - SFPUC; Ganteinbein, Julie - Water-Power Law Grp; Giglio, Deborah - USFWS; Gorman, Elaine - YSC; Grader, Zeke; Gutierrez, Monica - NOAA-NMFS; Hackamack, Robert; Hastreiter, James L - FERC; Hatch, Jenny - CT; Hayat, Zahra - MF; Hayden, Ann; Hellam, Anita - HH; Heyne, Tim - CDFG; Holden, James ; Holm, Lisa; Horn, Jeff - BLM; Horn, Tini; Hudelson, Bill - StanislausFoodProducts; Hughes, Noah; Hughes, Robert - CDFG; Hume, Noah - Stillwater; Jackman, Jerry ; Jackson, Zac - USFWS; Jennings, William - CSPA; Jensen, Art - BAWSCA; Jensen, Laura - TNC; Johannis, Mary; Johnson, Brian - CalTrout; Justin; Keating, Janice; Kempton, Kathryn - NOAA-MNFS; Kinney, Teresa; Koepele, Patrick - TRT; Kordella, Lesley - FERC; Lein, Joseph; Levin, Ellen - SFPUC; Lewis-Reggie-PRCI; Linkard, David - TRT /RH; Looker, Mark - LCC; Loy, Carin; Lwenya, Roselynn, BVR; Lyons, Bill - MR; Madden, Dan; Manji, Annie; Marko, Paul ; Marshall, Mike - RHH; Martin, Michael - MFFC; Martin, Ramon - USFWS; Mathiesen, Lloyd - CRRMW; McDaniel, Dan -CDWA; McDevitt, Ray - BAWSCA; McDonnell, Marty - SMRT; McLain, Jeffrey - NOAA-NMFS; Means, Julie - CDFG; Mills, John - TUD; Morningstar Pope, Rhonda - BVR; Motola, Mary - PRCI; O'Brien, Jennifer - CDFG; Orvis, Tom - SCFB; Ott, Bob; Ott, Chris; Paul, Duane - Cardno; Pavich, Steve-Cardno; Pinhey, Nick - City of Modesto; Pool, Richard; Porter, Ruth - RHH; Powell, Melissa - CRRMW; Puccini, Stephen - CDFG; Raeder, Jessie - TRT; Ramirez, Tim - SFPUC; Rea, Maria - NOAA-NMFS; Reed, Rhonda - NOAA-NMFS; Richardson, Kevin - USACE; Ridenour, Jim; Robbins, Royal; Romano, David O - N-R; Roos-Collins, Richard - Water-Power Law Grp for NHI; Roseman, Jesse; Rothert, Steve - AR; Sander, Max - TNC; Sandkulla, Nicole - BAWSCA; Saunders, Jenan; Schutte, Allison - HB; Sears, William - SFPUC; Shakal, Sarah - Humboldt State; Shipley, Robert; Shumway, Vern - SNF; Shutes, Chris - CSPA; Sill, Todd; Slay, Ronn - CNRF/AIC; Smith, Jim - MPM; Staples, Rose; Steindorf, Dave - AW; Steiner, Dan; Stone, Vicki -TBMI; Stork, Ron - FOR; Stratton, Susan - CA SHPO; Taylor, Mary Jane - CDFG; Terpstra, Thomas; TeVelde, George A ; Thompson, Larry - NOAA-MNFS; Vasquez, Sandy ; Verkuil, Colette - TRT/MF; Vierra, Chris; Villalabos, Ruben; Walters, Eric - MF; Wantuck, Rick - NOAA-NMFS; Welch, Steve - ARTA; Wesselman, Eric - TRT; Wheeler, Dan; Wheeler, Dave; Wheeler,

Douglas - RHH; Wilcox, Scott - Stillwater; Williamson, Harry (NPS); Willy, Alison - FWS; Wilson, Bryan - MF; Winchell, Frank - FERC; Wood, Dave - FR; Wooster, John -NOAA; Workman, Michelle - USFWS; Yoshiyama, Ron; Zipser, Wayne - SCFB

Subject: Don Pedro Study Plan W&AR-12 O mykiss Habitat Survey DRAFT for your review and comments

Attachments: Study W AR-12 O mykiss Habitat Survey-DRAFT_02-20-12.doc

Attached please find a modified study plan draft for **W&AR-12 - *Oncorhynchus mykiss* Habitat Survey Study Plan**. Changes were made to the study plan to incorporate NMFS and other agency comments, pursuant to FERC's Study Plan Determination issued December 22, 2011. In the Study Plan Determination, FERC requested that the Districts re-file the study plan, incorporating comments from the resource agencies, within 90-days of the Study Plan Determination. There have been a number of changes throughout the study plan in order to fully incorporate comments received, as discussed in the Study Plan Determination (pages 49-52).

Please provide comments to the Districts on the attached study plan draft no later than March 20, 2012, via email to rose.staples@hdrinc.com. Thank you.

ROSE STAPLES
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TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT
FERC NO. 2299
WATER & AQUATIC RESOURCE WORK GROUP

Study Plan W&AR-12
Oncorhynchus mykiss Habitat Survey Study Plan
February 2012

1.0 Project Nexus

The continued project operation and maintenance of the Don Pedro Project (Project) may contribute to cumulative effects on anadromous fish habitat in the lower Tuolumne River. These potential environmental effects include changes in the type of physical habitat available for juvenile *Oncorhynchus mykiss (O. mykiss*). Changes to habitat may include reduction in habitat complexity and structure due to reduced availability of large woody debris (LWD). Lack of habitat complexity may affect fish populations in the lower Tuolumne River.

2.0 Resource Agency Management Goals

The Districts believe that four agencies have resource management goals related to salmonid species and/or their habitat: (1) U.S. Department of Interior, Fish and Wildlife Service (USFWS); (2) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS); (3) California Department of Fish and Game (CDFG); and (4) State Water Resources Control Board, Division of Water Rights (SWRCB).

A goal of the USFWS (2001) Anadromous Fish Restoration Program, as stated in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to double the long-term production of anadromous fish in California's Central Valley rivers and streams. Objectives in meeting this long-term goal include: (1) improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat; (2) improve survival rates by reducing or eliminating entrainment of juveniles at diversions; (3) improve the opportunity for adult fish to reach spawning habitats in a timely manner; (4) collect fish population, health, and habitat data to facilitate evaluation of restoration actions; (5) integrate habitat restoration efforts with harvest and hatchery management; and (6) involve partners in the implementation and evaluation of restoration actions.

NMFS has developed Resource Management Goals and Objectives for species listed under the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 et seq.) and the Endangered Species Act (ESA) (16 U.S.C. §1531 et seq.), as well as anadromous species that are not currently listed but may require listing in the future. NMFS' (2009) Public *Draft* Recovery Plan for Sacramento River Winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and Central Valley steelhead outlines NMFS' framework for the recovery of ESA-listed species and populations in California's Central Valley. For Central Valley steelhead, the recovery actions identified for the Tuolumne River are to: (1) conduct habitat evaluations; and (2) manage cold water pools behind La Grange and Don Pedro dams to provide suitable water temperatures for all downstream life stages. For Central Valley fall/late fall-run Chinook, the relevant goals are to enhance the essential fish habitat downstream of the Project and achieve a viable population of Central Valley fall/late fall-run Chinook salmon in the Tuolumne River.

CDFG's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFG's resource management goals, as summarized in restoration planning documents such as "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993), are to restore and protect California's aquatic ecosystems that support fish and wildlife, and to protect threatened and endangered species under California Fish and Game Code (Sections 6920-6924).

SWRCB has responsibility under the federal Clean Water Act (33 U.S.C. §11251-1357) to preserve and maintain the chemical, physical and biological integrity of the State's waters and to protect water quality and the beneficial uses of stream reaches consistent with Section 401 of the federal Clean Water Act, the Regional Water Quality Control Board Basin Plans, State Water Board regulations, the California Environmental Quality Act, and any other applicable state law.

3.0 Study Goals

The primary goal of this study is to provide information on habitat distribution, abundance and quality in the lower Tuolumne River with a focus on *O. mykiss* habitat related to LWD. An inventory of LWD and associated habitat quality, availability and use by salmonids will inform the evaluation of in-river factors that may affect the juvenile *O. mykiss* life stage. As recommended by FERC staff in its Study Plan Determination of December 27, 2012, several modifications have been made to this study at the request of Relicensing Participants (Elements No. 5 and 6 in Study Request NMFS-5, dated June 10, 2011) in an effort to provide more detailed characterization of LWD distribution in the lower Tuolumne River. In addition, the study will provide a rough estimate of the quantities of LWD removed from Don Pedro on an annual basis.

4.0 Existing Information and Need for Additional Information

Juvenile habitat quality and use has been found to be directly related to habitat complexity (Bustard and Narver 1971; Bisson et al. 1987). Instream habitat complexity is typically associated with large woody debris, pools, and off channel habitat. Cederholm (1997) and others observed a direct relationship between increased steelhead smolt production and increased habitat complexity in the form of LWD. Increases in numbers of anadromous (Ward and Slaney 1981; House and Boehne 1995) and non-anadromous (Gowan and Fausch 1995) fishes after addition of LWD to a stream have been demonstrated.

Instream LWD recruitment is generally from the adjacent riparian forest or allochthonous, originating from the upstream watershed. Large dams, that rarely spill, like Don Pedro Dam, can reduce recruitment from upstream sources. Reduction or elimination of large riparian trees will also reduce LWD recruitment.

The quality and condition of habitat in the lower Tuolumne River has been investigated for Chinook salmon since the 1996 FERC Order (76 FERC 61, 117). The order required that the condition of spawning habitat be assessed along with other monitoring requirements, specific to Chinook salmon. As a result, information is available for other salmonids in the river. For example, McBain and Trush (2000) identified that the uppermost reach of the lower Tuolumne River (River Mile [RM] 52–46.6) was primarily used for spawning salmon where they found gravel bed and banks, along with little valley confinement within the bluffs. Surveys of the channel downstream of La Grange Dam showed the occurrence of channel downcutting and widening, armoring, and depletion of sediment storage features (e.g., lateral bars and riffles) due to sediment trapping in upstream reservoirs, gold and gravel mining, and other land use changes since the 1850s (DWR 1994; McBain & Trush 2004).

Previous riparian investigations found large scale removal of riparian vegetation that was a direct result of mining activities and urban/agricultural encroachment. Clearing of riparian forests decreased large woody debris recruitment, allowed exotic plants to invade the riparian corridor, reduced shading of the water's surface, and contributed to increased water and air temperatures in the Tuolumne River corridor (McBain & Trush 2000). Grazing and other land uses have also resulted in direct impacts on riparian vegetation.

LWD plays an important role in habitat forming events within low-order streams. Where LWD dimensions are large relative to the channel width, LWD readily collects within the channel forming areas of velocity gradation, encouraging localized sediment deposition and scour (McBroom 2010). In higher order streams, such as the lower Tuolumne River, the role of LWD in habitat formation decreases with the stream width. However, LWD becomes more ecologically significant in high order streams where it can provide the majority of stable, firm substrate that supports a substantial portion of invertebrate productivity (McBroom 2010).

Salmonid habitat quality and quantity, including characterization of habitat limitations and relative salmonid production potential is routinely assessed through surveys of instream habitat composition and structure, such as those surveys described by CDFG (2010). Results of such surveys can help identify land use and other related effects on habitat quality, thus the relative potential of the anadromous fish population. Such surveys also can identify opportunities to restore or enhance habitat conditions and salmonid and other aquatic production. In July 2008, Stillwater Sciences conducted a focused assessment of *O. mykiss* in the Tuolumne River that incorporated a habitat mapping component. The assessment identified general habitat units (e.g., pool, riffles) and then discussed the relationship between habitat type and observed *O. mykiss* use (Table 4.0-1). Habitat maps were also created displaying general habitat type from approximately RM 52 to RM 39.5. The results of recent *O. mykiss* monitoring surveys (e.g. Stillwater Sciences 2008) provide a foundation for the focused *O. mykiss* habitat evaluations in this proposed study.

While existing historical data provide a broader characterization of the existing habitat, a more detailed investigation into habitat conditions is proposed. A more detailed assessment of *O. mykiss* habitat availability would include the level and kind of complexity, factors associated with complexity (such as bars, backwater pools, scour pools, etc.), and the amount of habitat available as a function of complexity and use.

Table 4.0-1 Example habitat use by habitat type for two *O. mykiss* size classes during summer (adapted from Stillwater Sciences 2008**).**

Habitat	*O. mykiss* < 150 mm				*O. mykiss* ≥ 150 mm				Total			
	Seen [1]	Est.	Std dev	95% Interval [2]	Seen [1]	Est.	Std dev	95% Interval [2]	Seen	Est.	Std dev	95% Interval
Pool Head	12	20	10.1	12–40	17	45	13.2	19–71	29	65	16.7	33–98
Pool Body	0				3	24	18.0	3–59	3	24	18.0	3–59
Pool Tail	1	2	2.6	1–7	0				1	2	2.6	1–7
Run Head	46	166	179.0	46–517	1	6	8.8	1–23	47	172	179.2	47–523
Run Body	5	860	115.6	634–1,087	6	319	77.5	167–471	11	1,179	139.2	906–1,452
Run Tail	0				0				0			
Riffle	65	1,428	198.2	1,039–1,816	13	226	126.7	13–474	78	1,653	235.2	1,192–2,114
Total	**129**	**2,476**	**291.2**	**1,905–3,047**	**40**	**619**	**150.4**	**325–914**	**169**	**3,096**	**327.7**	**2,453–3,738**

[1] Largest numbers seen in any single dive pass for each unit, summed over units. Note that summation of the largest numbers seen within individual (50 millimeter [mm]) size bins yields higher estimates of total fish smaller and larger than 150 mm.
[2] Nominal confidence intervals calculated as +/- 1.96 standard deviations. When this yielded lower bounds less than the numbers seen, the lower bound was truncated accordingly and the interval shaded.

In addition to a focused survey and assessment of the associations of LWD and other contributors to habitat complexity, and the relationships among complexity and *O. mykiss* utilization, a general accounting of LWD within the study reach will be conducted to identify location, general condition, density and abundance of LWD.

5.0 Study Methods

The study methods described below will be implemented to meet the study objectives.

5.1 Study Area

A one-year habitat assessment will be conducted in the salmonid spawning and rearing reach of the lower Tuolumne River from La Grange to Roberts Ferry Bridge (approximately RM 52–39). The LWD survey area will also extend from approximately RM 52 downstream to RM 24. A separate investigation of LWD removed from Don Pedro reservoir will also be conducted.

5.2 General Concepts

The following general concepts apply to the study:

- Personal safety is an important consideration of each fieldwork team. The Districts and their consultants will perform the study in a safe manner.
- Field crews may make minor modifications in the field to adjust to and to accommodate actual field conditions and unforeseeable events. Any modifications made will be documented and reported in the draft study report.

5.3 Study Methods

The study will consist of two separate components: 1) a semi-quantitative inventory of instream habitat types and physical habitat characteristics, and 2) an appraisal of distribution, abundance, and function of LWD in the lower Tuolumne River. The first component will rely on available aerial photography and habitat mapping, and a reconnaissance-level survey of the lower

Tuolumne River, between approximately RM 52 and RM 39. This study component will rely upon existing broader habitat mapping conducted by Stillwater Sciences (2008) to identify focal research areas where *O. mykiss* occur and then utilize an adaptation of the high-resolution CDFG habitat typing methodology (CDFG 2010), to further characterize and evaluate these areas. CDFG identified four levels of typing, ranging from general broad habitat identification (Level I) to more detailed characterizations entailing 24 different potential habitat descriptors at Level IV. This study will utilize the highest level of detail that is appropriate for a river of this size and which will allow for a strongly supported assessment of habitat for *O. mykiss* and other fish species. In addition, a detailed description of LWD will be made at each focal study location using standard methods (e.g., Moore et al. 2006, Montgomery 2008), as described further below.

The second study component, an LWD inventory, will consist of a detailed survey of large wood and an assessment of its influence on *O. mykiss* habitat quality and quantity. The LWD inventory will be conducted between RM 52 and RM 24. In addition, as recommended by FERC Staff in the December 22, 2011 Study Determination, an evaluation of the frequency and volume of LWD trapped and removed from Don Pedro reservoir on an annual basis will be made (as described by NMFS in their June 10, 2011 study request Element No. 2).

<u>Step 1 – Site Selection, Field Reconnaissance, and Planning</u>. Habitat typing conducted for this study includes a 13 mile reach of the lower Tuolumne River (RM 52–39), with LWD surveys from RM 52–24. Field planning will begin by reviewing reports of existing habitat mapping conducted by Stillwater Sciences (2008), McBain & Trush (2004), and others. Field staff will coordinate with CDFG staff and others knowledgeable of access and navigability of the river to determine proper timing and related survey conditions that would optimize conducting the survey. As recommended by FERC Staff in the December 22, 2011 Study Determination, ortho-rectified digital aerial photographs of the study reach will be prepared for use with habitat typing and in developing a spatial inventory of mapped LWD. A subset of representative sampling units in the study reach will be selected for detailed habitat measurements using CDFG (2010). As recommended by CDFG (2010), sampling units selected for detailed habitat measurements will encompass 10–20 percent of the study reach and will be preferentially located where *O. mykiss* observations have been documented (e.g., Stillwater Sciences 2008).

As recommended by FERC Staff in the December 22, 2011 Study Determination, sampling units for inventorying LWD will be up to 20 channel widths long, consistent with guidelines used in California and the Pacific Northwest (e.g., Leopold 1994). The average bankfull width of the lower Tuolumne is 150 ft; therefore, the average length of a sample site will be around 3,000 ft long. Seven to ten sampling units that are 20 bankfull widths long will be selected for detailed characterization of LWD, encompassing approximately 4 to 6 miles (i.e., 10 to 20 percent) of the study reach by the estimates above.

<u>Step 2 – Field Data Collection</u>. Field surveys will be implemented using multiple teams of two field technicians. Each team will have a map and aerial photos delineating the portions of reach that will be surveyed. Upon accessing these survey areas, each team will collect the suite of measurements detailed in Table 5.3-1. These measurements are representative of the required data collection for Level III and IV CDFG habitat typing. Data will be documented on template datasheets to ensure that all data are collected and in a consistent manner between teams. Each habitat unit will have its upstream and downstream boundaries delineated on an aerial photograph and have an identification number that is the same as that on the datasheet. Field

measurements will be made with standard field equipment: a handheld thermometer will be used to collect water temperature data, a stadia rod will be used to measure water depth, a steel meter tape or optical range finder will be used to measure site dimensions, and a spherical densitometer will measure percent overhead canopy cover. Each team will also be equipped with a handheld GPS and camera with habitat unit dimensions estimated in the field as well as by GIS.

Table 5.3-1 A summary of data collected as part of the Level IV CDFG habitat mapping.

Gathered Data	Description
Form Number	Sequential numbering
Date	Date of survey
Stream Name	As identified on USGS quadrangle
Legal	Township, Range, and Section
Surveyors	Names of surveyors
Latitude/Longitude	Degrees, Minutes, Seconds from a handheld GPS
Quadrant	7.5 USGS quadrangle where survey occurred
Reach	Reach name or rivermile range
Habitat Unit #	The habitat unit ID # that the bankfull width was measured
Time	Recorded for each new data sheet start time
Water Temperature	Recorded to nearest degree Celsius
Air Temperature	Recorded to nearest degree Celsius
Flow Measurement	Can be obtained from USGS monitoring stations
Mean Length	Measurement in meters of habitat unit
Mean Width	Measurement in meters of habitat unit
Mean Depth	Measurement in meters of habitat unit
Maximum Depth	Measurement in meters of habitat unit
Depth Pool Tail Crest	Maximum thalweg depth at pool tail crest in meters
Pool Tail Embeddedness	Percentage in 25% bucket ranges
Pool Tail Substrate	Dominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Large Woody Debris Count	Detailed inventory criteria are listed below
Shelter Value	Assigned categorical value: no shelter, minimal shelter (small debris, bubble curtain etc.), significant shelter (large woody debris, root wads, vegetative cover, etc.)
Percent Unit Covered	Percent of the unit occupied
Substrate Composition	Composed of dominant and subdominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Percent Exposed Substrate	Percent of substrate above water
Percent Total Canopy	Percent of canopy covering the stream
Percent Hardwood Trees	Percent of canopy composed of hardwood trees
Percent Coniferous Trees	Percent of canopy composed of coniferous trees
Right and Left Bank Composition	Identify dominant substrate: sand/silt, cobble, boulder, bedrock
Right and Left Bank Dominant Vegetation	Identify dominant vegetation: grass, brush, hardwood trees, coniferous trees, no vegetation
Right and Left Bank Percent Vegetation	Percent of vegetation covering the bank
Comments	Additional notes as needed

USGS = U.S. Geological Survey

The LWD distribution survey will use the Montgomery (2008) wood size classes, adapted to the Tuolumne River as follows. Information to be collected will include location (e.g., GPS coordinates), LWD size category, type, orientation, associated CDFG (2010) habitat type, and likely source. As recommended by FERC Staff in the December 22, 2011 Study Determination, within each LWD sample site, GPS locations and characteristics of each piece of LWD greater than 3 ft (1 m) long within the active channel will be recorded and binned within six length classes [3–6.5 ft (1–2 m), 6.5–13 ft (2–4 m), 13–26 ft (4–8 m), 26–52 ft (8–16 m), 52–105 ft (16–32 m), and >105 ft (>32 m)] and four diameter classes [4-8 in (0.1–0.2 m), 8–16 in (0.2–0.4 m), 16–31 in (0.4–0.8 m), 31–63 in (0.8–1.6 m)]. More detailed measurements will be taken for key LWD, which are defined as pieces either longer than 1/2 times the bankfull width, or of sufficient size and/or are deposited in a manner that alters channel morphology and aquatic habitat (e.g., trapping sediment or altering flow patterns). In addition to recording the GPS locations for mapping on ortho-rectified aerial photographs, detailed information to be collected on key LWD pieces includes:

- Piece location, mapped on aerial photos/GPS documentation
- Piece length
- Piece diameter
- Piece orientation to bank
- Position relative to channel
- Rootwad present
- Tree type (hardwood or conifer)
- Associated with log jam
- Jam size (estimated dimensions/number of pieces)
- Source (imported/riparian/unknown)
- Channel dynamic function
- Habitat function (cover, sediment collection, hard substrate)

Lastly, although no detailed records of the quantities of LWD removed from Don Pedro Reservoir or other Project facilities exist, the Don Pedro Recreation Agency (DPRA) conducts an annual program to remove floating LWD at various locations in Don Pedro reservoir as it presents a boating hazard. This material is then placed in piles within suitable landing areas around the reservoir for burning, as conditions permit. To provide an order of magnitude estimate of LWD currently trapped in the reservoir, a team of two field technicians will travel by boat to each landing area and measure the quantity of LWD at each stockpile location in May 2012. Understanding that no meaningful relationship between this annual storage estimate and a LWD budget or loading rate to the lower Tuolumne River is possible, a discussion of the relative sizes and characteristics of LWD in Don Pedro reservoir and at locations in the lower Tuolumne River will be made.

Step 3 – Data Processing and Analyses. Collected data will be stored and managed using a digital spreadsheet database. All data sheets will be physically copied after each week of survey. All data will then be entered into a spreadsheet database. Entered data will be QA/QC'd by two independent technicians reading and confirming each line of data together. Data will be summarized in tables and figures depicting overall habitat characteristics and conditions by reach. The quality and suitability of the habitat will be assessed in light of existing resources that include *O. mykiss* life history needs. This assessment will also discuss patterns of habitat use as found in recent O. mykiss snorkel survey efforts (e.g., Stillwater Sciences 2008). Final data will be made available to Relicensing Participants in digital spreadsheet form (Step 4). Maps depicting the location of the surveys, habitat types and LWD locations with each survey reach, and images of the surveyed habitat will also be provided within the report.

Data collected during the LWD distribution survey will be summarized relative to size class, reach, habitat association, density, and complexity. LWD trapped and removed from Don Pedro Reservoir in 2012 by the Don Pedro Recreation Agency will be quantified and a comparison of size characteristics of trapped LWD with those observed in the lower Tuolumne River will be made. These data summaries will be analyzed to determine the functioning of LWD in the lower Tuolumne River in the context of its channel and habitat type, and ecological role.

The quantity, quality, and use of the lower Tuolumne River by *O. mykiss* will be discussed in the context of other anadromous salmonid streams. The comparison will identify the occurrence and role of LWD and other habitat attributes in the lower Tuolumne River, and provide a basis for assessing the potential implications on *O. mykiss* abundance. Comparisons with other Central Valley streams and similar stream systems outside the Central Valley will be made to place LWD function in the lower Tuolumne River in context with other streams of similar stream order, recruitment potential, and sources.

Step 4 – Prepare Report**.** The Districts will prepare a report that includes the following sections: (1) Study Goals, (2) Methods and Analysis, (3) Results, (4) Discussion, and (5) Conclusions. The quality and suitability of the habitat will be assessed and reported in light of existing resources that include steelhead life history needs. The report will discuss the findings from the Stillwater (2008) report and compare current conditions to population and habitat data collected in 2008.

The report will also contain GIS maps of sampled areas with delineated habitat and LWD features, organized and labeled photos of select habitat, and relevant summary tables and graphs. The reported data will be organized by reach site to allow for a spatial presentation of the findings. Final data will be made available to Relicensing Participants (Section 8.0).

6.0 Schedule

The Districts anticipate the schedule to complete the study as follows:

Project Preparation..April – May 2012
Field Mapping..June – August 2012
Data QA/QC..September 2012
Prepare Report..October – November 2012
Report Issuance..January 2013

7.0 Consistency of Methodology with Generally Accepted Scientific Practices

The habitat mapping methodology was developed by CDFG based upon notable prior researchers. The methods described are standards that have been reviewed and used by numerous researchers since 1991. The study will follow the latest survey approach that has been refined into the current 4th edition (CDFG 2010).

8.0 Deliverables

The Districts will prepare a report, which will document the methodology and results of the study. In addition, at the request of relicensing participants, the Districts will provide GIS-based maps of survey locations documented as part of this study, as well as all LWD survey data (both focused and distribution survey) and all other habitat unit data in tabular (spreadsheet) and geo-spatial (e.g., ArcGIS shapefiles) formats.

9.0 Level of Effort and Cost

The Districts estimate the cost to complete this study to be $110,000

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DRAFT
WORKSHOP CONSULTATION PROCESS
ON INTERIM STUDY PLAN DECISIONS

As part of certain studies to be undertaken in the Don Pedro Project relicensing, the Districts had proposed a series of workshops to share and discuss relevant data with Relicensing Participants (RPs). FERC has recommended that the Workshop Consultation process be formalized. In accordance with Appendix B of FERC's December 22, 2011 Study Plan Determination, the draft workshop consultation process outlined below has been developed to provide guidance for the decision-making process involved within the following study plans:

- W&AR-2 (Project Operations Model): Hydrology Workshop
- W&AR-5 (Salmonid Population Information Synthesis): Literature/Data Review Workshop and Conceptual Model Review Workshop
- W&AR-6 (Chinook Population Model): Conceptual Model Review Workshop and Modeling Approach Workshop
- W&AR-10 (*O.Mykiss* Population Model): Conceptual Model Review Workshop and Modeling Approach Workshop
- W&AR-14 (Temperature Criteria Assessment): Water Temperature Evaluation Criteria Workshop

The purpose of the eight workshops is to provide opportunity for RPs and the Districts to discuss relevant data sources, methods of data use and development, and modeling parameters at key points in the execution of these study plans. The goal of the workshops is for RPs and the Districts to reach agreement where possible after thorough discussion of data, methods and parameters. Consensus on decisions dealing with data acceptability, or study approaches or methods can only be achieved by the active and consistent in-person attendance and participation of interested Relicensing Participants. Additional workshops beyond those already specified above may be held as agreed to between the RPs and the Districts.

FERC has also directed the Districts to formalize the workshop process to define how interim decisions on model inputs and parameters will be made. To promote clear communication and informed participation, the Districts will make a good-faith effort to provide two (2) weeks before each workshop, in electronic format, information and presentation materials to be discussed at the workshops. For studies that involve resource modeling, presentation materials will be tailored to the audience at a level that assumes familiarity with the resource issues being addressed. To promote a common understanding of terms, a glossary of definitions will be prepared prior to each initial workshop, updated and expanded upon periodically, and included in the final study report. Prior to the initial workshops, the Districts will also prepare a logic diagram of the study steps from data selection through model development and numerical procedures to model scenario evaluation. This study "process diagram" will aid in promoting a common understanding of the step-wise approach being used in model development.

Following each workshop, draft meeting notes of the consultation workshop will be distributed to participants within approximately eight (8) working days. The notes will identify areas where participants reached agreement on data, methods and/or parameters, areas where there is disagreement among participants, and action items for any future meetings. Following a 30-day comment period, the Districts will file with FERC a revised version of the consultation workshop notes describing areas of agreement, areas where agreement was not reached, copies of comments received, a discussion of how the Relicensing Participant comments and recommendations have been considered by the Districts, as well as the rationale for the Districts not adopting any Relicensing Participants recommendations.

The proposed schedule for workshops is included below. All meetings will be held at MID offices in Modesto.

March 2012
Mar 20 - 1:30 pm – 4:30 pm
Don Pedro Project Relicensing - Workshop on Consultation Process (as per Appendix B of FERC's Study Plan Determination)

April 2012
Apr 09 - 1:00 pm - 5:00 pm
Don Pedro Project Relicensing - Hydrology Workshop (W&AR-2)

Apr 10* - 10:30 am - 5:00 pm Don Pedro Project Relicensing - Salmonid Population Information Workshop (W&AR-5)

Apr 11 - 9 am – 12:00 pm Don Pedro Project Relicensing – Temperature Criteria Workshop (W&AR-14)

June 2012
Jun 26 - 9:00 am - 4:00 pm Don Pedro Project Relicensing - Salmonid Population Information Workshop (W&AR-5)

November 2012
Nov 15 - 9:00 am - 4:00 pm Don Pedro Project Relicensing - Chinook Population (W&AR-6) and O.mykiss Population (W&AR-10) Modeling Workshop

2013 (Dates to be determined)

March 2013 (preliminary) - 9 am to 4 pm Don Pedro Project Relicensing - 2nd Workshop Chinook Population (W&AR-6) and O.mykiss Population (W&AR-10) Modeling

***NOTE:** From 8:30 am to 10:15 am, the Districts will conduct an introduction to the MIKE3 reservoir temperature model for use in W&AR-3. The goal is to introduce the model platform, computation methods, model development, and data sources. This is not considered a formal workshop. The Districts are also planning to conduct a discussion and presentation of the reservoir temperature model validation results at a Relicensing Participant Meeting on September 18, 2012 from 9 am to 4 pm at MID. Please add this meeting to your calendars.

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March 19, 2012

Carin Loy
Jenna Borovansky
HDR Engineering Inc.
2379 Gateway Oaks Drive, Suite 300
Sacramento, CA 95833

Re: *Don Pedro Relicensing Project*

Dear Carin and Jenna:

In connection with the TID/MID effort to relicense the Don Pedro Hydroelectric Project please consider the following:

We have property on Shawmut Road that leads to Lake Don Pedro. Periodically we report to TID/MID and to the Tuolumne County Public Works Department that garbage, refrigerators, car parts, tires and other trash has accumulated along Shawmut Road near the lake. We have several times suggested that additional barriers or fencing should be installed in a handful of locations to prevent people from pulling off of Shawmut Road in order to prevent illegal dumping.

On every occasion that we or our neighbors have reported this, both TID/MID and the County blame the other and tell us the clean up is not their responsibility. This is unacceptable. TID/MID need to protect the watershed and the lake.

Please confirm with me that this will be addressed in the relicensing process.

Very truly yours,

Alan J. Wilhelmy

A Professional Law Corporation

From: Staples, Rose
Sent: Thursday, March 29, 2012 11:02 AM
To: 'Alves, Jim'; 'Anderson, Craig'; 'Asay, Lynette'; 'Aud, John'; 'Barnes, James'; 'Barnes, Peter'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burley, Silvia'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Cismowski, Gail'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackman, Jerry'; 'Jackson, Zac'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; 'Looker, Mark'; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'McLain, Jeffrey'; 'Means, Julie'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pinhey, Nick'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Walters, Eric'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Relicensing Newsletter - New Issue Just Published on Website

The Districts have just published Volume 2 – Issue 1 of the ***Don Pedro Relicensing Newsletter*** and I have uploaded a copy for you onto the www.donpedro-relicensing.com website, in the Announcement section under the INTRODUCTION tab. If you cannot access and/or download the document, please advise me (rose.staples@hdrinc.com or 207-239-3857) and we can mail you a copy. Thank you.

ROSE STAPLES
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Volume 2 | Issue 1

Don Pedro

A newsletter about the relicensing of the Don Pedro Project

Year one of DP relicensing in the books

The year 2011 marked the Modesto and Turlock irrigation districts' first year of the Don Pedro relicensing process. The first year of the Integrated Licensing Process (ILP) was essentially devoted to working closely with Relicensing Participants (RPs) and the Federal Energy Regulatory Commission (FERC) to develop detailed studies to be conducted by the Districts to support the license application, which will be filed in April 2014. The year ended with FERC issuing its formal Study Plan Determination (SPD) on December 22.

The Districts will be conducting 35 different studies to investigate the project's potential to affect resources in the lower Tuolumne River and at and adjacent to the Don Pedro Reservoir. The Districts have retained the services of a number of experts in their respective fields to assist in the performance of these studies. By the end of 2012, the Districts will have completed most of these studies, but some will continue into 2013.

MORE INSIDE: FERC issues Study Plan Determination, including 35 studies in several resource fields.

Further details regarding the Revised Study Plan (RSP), the SPD, upcoming meetings and more are available inside this newsletter and on the DP relicensing website located at **www.donpedro-relicensing.com**.

FERC held two Scoping Meetings in 2011.

The Relicensing Process

The relicensing of the Don Pedro Project formally began in 2011. Below are some of the major stages of the process.

1. Districts filed PAD and Notice of Intent in 2/10/2011.
2. FERC conducts scoping in Spring '11.
3. Interested parties discuss issues and develop study requests.
4. Districts file Proposed Study Plan (PSP) on 7/25/11 and undertake a series of meetings with relicensing participants to review and discuss the PSP.
5. FERC issues Study Plan Determination on 12/22/11.
6. Studies are conducted and Study Report issued for review and comment.
7. Applicant files draft and final license applications.
8. FERC issues new license with new terms and conditions in 2016.

Important dates

April 9, 2012
Hydrology Workshop (W&AR-2)

April 10, 2012
Reservoir Temperature Modeling Data & Methods

April 10, 2012
Salmonid Population Information Workshop (W&AR-5)

April 11, 2012
Temperature Criteria Workshop (W&AR-14)

June 26, 2012
Salmonid Population Information Workshop (W&AR-5)

September 18, 2012
Temperature Model Validation/Calibration Meeting

What's inside

Revised Study Plan filed by Districts

On November 22, 2011, the Districts filed their 900-plus page Revised Study Plan (RSP) with FERC and RPs. The RSP contained the Districts detailed plans and schedules for conducting 35 studies. In all, the RPs had previously requested that the Districts perform more than 140 studies. The RSP also included the Districts' explanation of why they believed that many of the studies requested of the Districts were unnecessary, or were outside the proper scope of the Don Pedro relicensing.

Many RPs filed comments on the Districts RSP by the December 11 deadline. These filings contained comments on the RSP and any points of disagreement a relicensing participant might have with the Districts' reasoning for not undertaking studies that the RPs had requested.

Near the marina at Lake Don Pedro.

A screenshot of the Meetings page located at http://www.donpedro-relicensing.com.

Website offers information

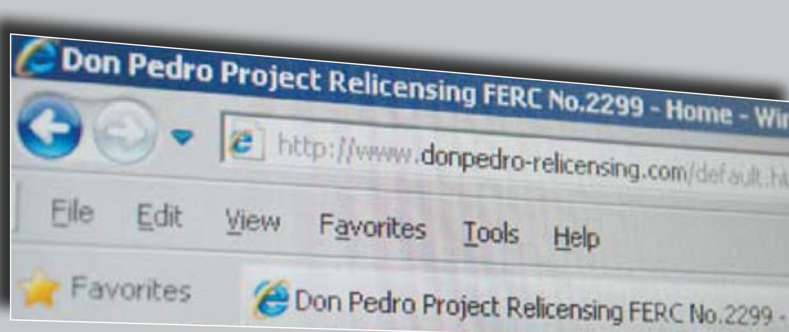
Interested parties can obtain meeting schedules and much more

The Districts have updated the Don Pedro Project Relicensing website with the 2012 schedule of meetings. People interesting in viewing a list of these meetings along with other meeting information can visit the **Meetings** tab located on the relicensing website's main page. The public is welcome to attend and participate in these meetings.

In addition to being regularly updated with the aforementioned meeting times, the site is also updated with agendas, documents, filings and other information. The website also provides a good overall primer and describes the relicensing process, provides useful links and offers contact information.

The website serves as one of the primary communication outlets informing stakeholders of events and meetings that are part of the relicensing process.

The most robust section of the website is the **Documents** page, which has nearly 150 downloadable documents ranging from more recent documents such as FERC's Study Plan Determination all the way back to the Districts' Pre-Application Document (PAD) filings.



FERC issues 140-page Study Plan Determination

On December 22, 2011, FERC issued its 140-page Study Plan Determination (SPD). FERC approved 17 of the Districts studies without modification and 16 with modifications, most of which were minor modifications. FERC also said that two of the studies were not required to be conducted. FERC added one additional study that had been requested by the United States Bureau of Land Management – a bald eagle survey along the reservoir area.

With FERC's SPD issued, the Districts immediately planned to undertake the approved studies in accordance with FERC's directive. Most of the studies involve extensive field work; considerable coordination and logistics need to be worked out to execute the studies efficiently and consistent with the study plans approved by FERC. Some field work began as early as January.

The Studies

The more than 30 studies being undertaken by the Districts can be subdivided into resource areas as follows:

- Two large studies are devoted to Cultural Resources;
- Four studies focus on recreational resources, including a significant study of reservoir recreation;
- Ten studies dealing with resources investigating botanical, wildlife and wetland species and habitats.
- Nineteen studies deal with water resources and aquatic/fish resources. Many of these studies deal with salmon and O. mykiss (rainbow trout/steelhead) in the lower river. One of the studies that FERC did not require the Districts to undertake (temperature preferences for life stages of anadromous fish) will still be completed by the Districts because, although FERC did not find it essential for its own purposes, the Districts continue to feel it is important to the relicensing process.

The studies themselves, as currently proposed, are expected to cost over $7 million by the time they are completed.

Notices of Dispute

Three of the resource agencies filed a formal Notice of Dispute on FERC's SPD as described by the regulations of the Integrated Licensing Process (ILP). The agencies – the National Marine Fisheries Service (NMFS), the United States Fish and Wildlife Service, and the State Water Resources Control Board – are disputing FERC's decisions about certain studies the Districts did not adopt and FERC did not require. The dispute process is detailed in the ILP regulations and involves the convening of a three-member advisory Technical Panel to consider the areas of dispute, and provide an opinion to FERC's Director of the Office of Energy Projects (OEP). The dispute, which is a normal aspect of the relicensing process, will likely be decided sometime this spring. The FERC Director makes the final decision giving due consideration to the opinion of the three-member Technical Panel.

Land Access

Some of the studies required by FERC will require the Districts' consultants to access private lands adjacent to or near the Don Pedro Reservoir, though no one will enter private land without the landowner's consent. The Districts have mailed requests to landowners to allow access. Consultants have been instructed in the need for the utmost care of and respect to private property near the Project. The Districts and consultants will make every effort to contact landowners about the approximate timing of the need for such access. The Districts understand and respect that the final decision to allow, or not allow, such access is to be decided to each landowner.

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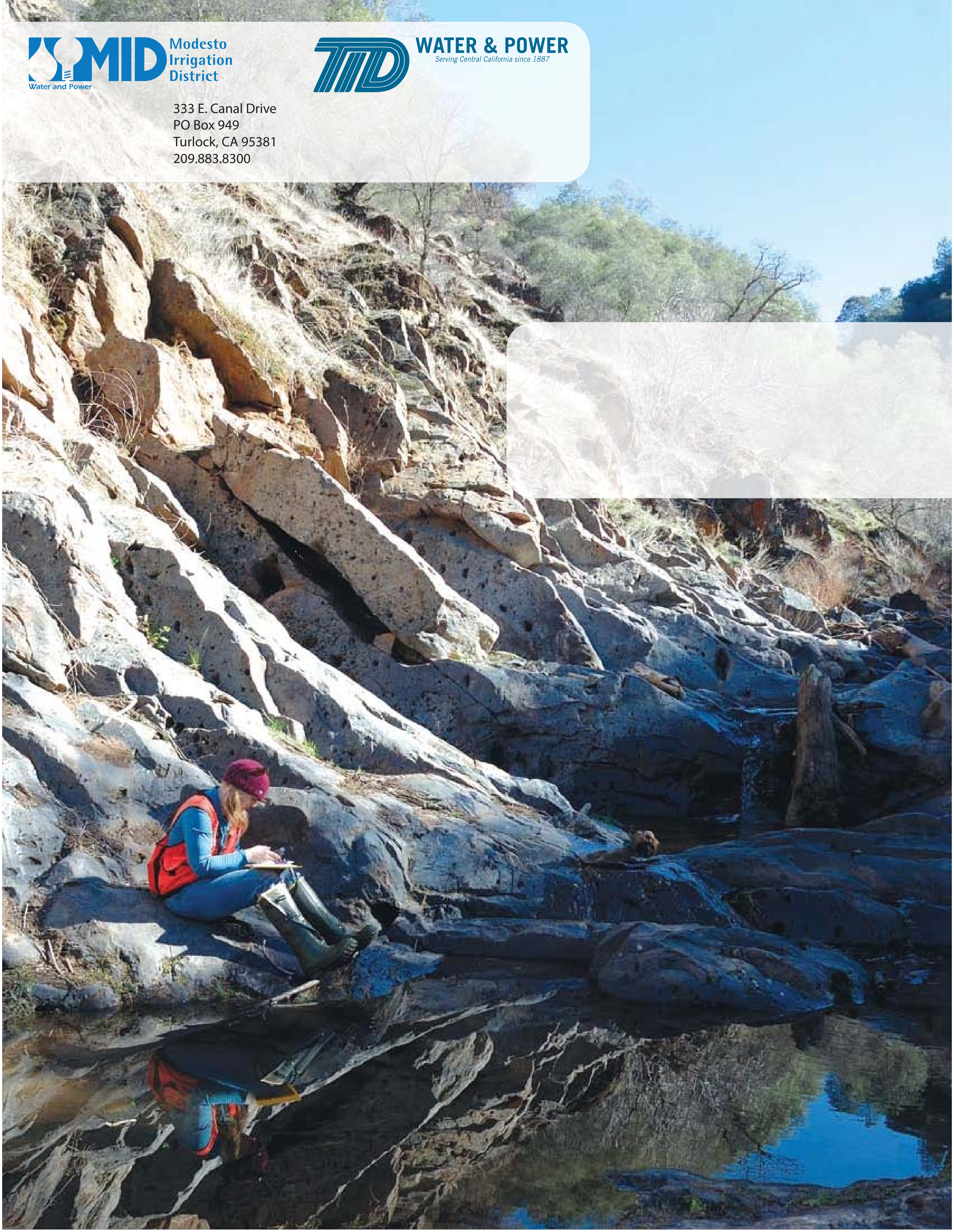

From: Staples, Rose
Sent: Monday, April 02, 2012 8:15 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Aud, John; Barnes, James; Barnes, Peter; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burley, Silvia; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cismowski, Gail; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Looker, Mark; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Means, Julie; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Walters, Eric; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: AGENDA and MATERIAL for Don Pedro W&AR-14 Temp Criteria Evaluation Meeting April 11 at 9:00 am
Attachments: WAR14 meeting materials list_04-11-12.docx; Temperature Criteria Mtg No 1 AGENDA_120402.pdf; W&AR14_Potential_Empirical_Studies.doc

Please find attached the AGENDA and MATERIAL for the Don Pedro W&AR-14 Temperature Criteria Evaluation Consultation Meeting on Wednesday, April 11th at 9:00 am:

1. AGENDA
2. Preliminary Reference List
3. Draft List of Potential Empirical Studies

These documents will also be uploaded to the www.donpedro-relicensing.com website later today.

If you have any problems accessing this information, please let me know. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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Modesto Irrigation District
The Power to Grow

Don Pedro Project - FERC Relicensing
Agenda for Temperature Criteria Assessment Study (W&AR 14)
Meeting with Relicensing Participants
April 11, 2012 – 9:00 a.m. to Noon – MID Offices
Conference Line Call-In Number 866-994-6437; Conference Code 5424697994

1. **Introductions**

    a. **Overview of Study Plan W&AR 14 Temperature Criteria Assessment**

    b. **FERC Determination (December 2011)**

        Reliance on EPA (2003)

        While the Districts' temperature criteria assessment may have the potential to inform W&AR-5 Salmonid Populations Information Integration and Synthesis Study, we will continue to rely upon the temperature criteria in EPA (2003) for our evaluation of project effects,

        Empirical evidence would be considered

        …unless empirical evidence from the lower Tuolumne River is provided that suggests different criteria are appropriate for salmonids in the lower Tuolumne.

2. **Purpose and Scope**

    Develop and implement an approach to identify appropriate temperature criteria for evaluating project effects on anadromous salmonids in the lower Tuolumne River

    Evaluate the appropriateness of site specific temperature evaluation criteria for Chinook salmon and *O. mykiss* relative to the proposed threshold temperatures described in EPA (2003) and identified by FERC and Participants as temperature criteria to be met in the lower Tuolumne River

    Two general questions are to be addressed:

    i. **Do the local populations of Chinook salmon and *O. mykiss* in the lower Tuolumne River have temperature tolerances that allow performance similar to that associated with the EPA (2003) threshold metrics at higher temperatures, and, if so, what are those temperatures; and**

ii. If the temperature regime that can be achieved in the Tuolumne River exceeds those threshold criteria, what is the associated effect on the Chinook salmon and *O. mykiss* population in reference to agency goals and objectives?

3. Study Approach

The Districts have identified several investigations that are intended to reduce uncertainties and potentially confirm or adjust temperature evaluation criteria to be based on empirical information that has been previously obtained from the lower Tuolumne River or is being contemplated for future acquisition. Consistent with the FERC determination (December 22, 2011), the Districts have determined that evaluation of empirical evidence describing the relationships among temperature conditions and the anadromous fish populations in the lower Tuolumne River should be considered when evaluating project-related, temperature effects on these populations. Such an approach would employ the best available science, which may not necessarily be the direct application of findings from other regions or populations. In developing the approach, the Districts will be guided by methods and procedures that have demonstrated utility in addressing development of temperature criteria for evaluation of anadromous salmonids, with a focus on such approaches conducted in other FERC processes involving Central Valley resources.

In general, each investigation will:

- **Identify issue being addressed (How does it relate to the question)**
- **Develop hypothesis/question**
- **Develop approach and methods to be based on best available science**
- **Consider refinement of evaluation based on input from interested parties, as appropriate**
- **Prepare detailed evaluation protocol and analytical procedures**
- **Apply, implement, analyze, report, integrate into overall assessment of temperature evaluation criteria (W&AR 14)**

Results of the evaluations should serve to identify appropriate modifications in temperature evaluation criteria by revising the temperature thresholds and/or by defining a level of effect associated with threshold exceedance.

Attached is a preliminary list of potential evaluations the Districts have identified as meeting the above guidance.

4. Next Meeting

Preliminary list of materials to support discussion with Relicensing Participants regarding Temperature Criteria Assessment Study

(Don Pedro Project, W&AR 14)

1. Teo, L.H., P.L. Sandstrom, E.D. Chapman, R.E.Null, K. Brown, P. Klimley, and B.A. Block. 2011. Archival and acoustic tags reveal the post-spawning migrations, diving behavior, and thermal habitat of hatchery-origin Sacramento River steelhead kelts (Oncorhynchus mykiss). Environ Biol Fish DOI 10.1007/s10641-011-9938-4 http://biotelemetry.ucdavis.edu/publications/EBF_Teo%20et%20al_%20Steelhead%20migration.pdf

2. Strange, Joshua S.(2010) 'Upper Thermal Limits to Migration in Adult Chinook Salmon: Evidence from the Klamath River Basin', Transactions of the American Fisheries Society, 139: 4, 1091 — 1108, First published on: 09 January 2011 http://dx.doi.org/10.1577/T09-171.1

3. Parsons, E.J.E. 2011. Carduirespitory physiology and temperature tolerance among populations of sockeye salmon (Onchorhynchus nerka) Ph D Thesis. University of British Columbia, Vancouver, August 2011.

4. Myrick, C.A. and J.J. Cech. 2001. Temperature Effects on Chinook Salmon and Steelhead: A Review Focusing on California's Central Valley Populations. Bay-Delta Modeling Forum Technical Publication 01-1. Available at http://www.sfei.org/modelingforum/.

5. Deas, M., J. Bartholow, C. Hanson, and C. Myrick. 2004. Peer Review of Water Temperature Objectives Used as Evaluation Criteria for the Stanislaus – Lower San Joaquin River Water Temperature Modeling and Analysis Task 9 - BDA Project No.: ERP-02-P28.

6. Essig, D.A. 1998. The Dilemma of Applying Uniform Temperature Criteria in a Diverse Environment: An Issue Analysis Idaho Division of Environmental Quality Water Quality Assessment and Standards Bureau Boise, Idaho

7. CDFG. 2010. Effects of Water Temperature on Anadromous Salmonids in the San Joaquin River Basin Prepared for the Informational Proceeding to Develop Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources Before the State Water Resources Control Board Beginning March 22, 2010. CDFG Central Region Fresno, CA. February 2010

8. EPA. 2003. EPA Region 10 Guidance For Pacific Northwest State and Tribal Temperature Water Quality Standards http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf

9. Lower Yuba River Accord River Management Team Planning Group. 2011. Lower Yuba River water temperature objectives Technical Memorandum.

10. Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute, Portland, Oregon, Draft report.

11. Pagliughi, S.W. 2008. Lower Mokelumne River reach specific thermal tolerance criteria by life stage for fall-run Chinook salmon and winter-run steelhead. East Bay Municipal Utility District, Lodi, CA 95240

12. Jaeger, H.K., H.E. Cardwell, M.J. Sale, M.S. Bevelhimer, C.C. Coutant, W. Van Winkle.1997. Modeling the linkages between flow management and salmon recruitment in rivers. Ecological Modeling 103(1977)171-191

13. Stillwater Sciences. 2002. Stream Temperature Indices, Thresholds, and Standards Used to Protect Coho Salmon Habitat: a Review. Prepared for Campbell Timberland Management, Fort Bragg, CA. March 2002.

List of Potential Empirical Evaluations Addressing Temperature Requirements for Tuolumne River Chinook salmon and *O mykiss*

1. Local adaptation of temperature tolerance of *O mykiss* juveniles

Question: Are *O mykiss* that occur in Tuolumne River locally adapted to higher temperature tolerances that may define site-specific temperature performance metrics.

General Approach – Evaluate capabilities of local *O mykiss* to accommodate warmer temperatures, both physiological and anatomical, following methods described by Parsons (2011) and others.

a. Potential local adaptation to higher range of temperature regimes experienced by O. mykiss may be expressed in physiological and related anatomical performance capabilities. A comprehensive discussion and related investigations conducted by Parsons (2011) strongly suggests that there is good reason to expect that temperature tolerance can vary among anadromous salmonid populations/stocks and provide a good, scientific approach to investigating that tolerance in the Tuolumne River O. mykiss population relative to the extant temperature conditions and criteria and thresholds currently used to assess temperature induced effects to condition, performance, and survival.
b. Identify performance at range of temperatures using methods similar to
c. Evaluate physiological performance vs. temperature per UBC study
d. Collect mortalities from RST or other sources to examine organs that can indicate performance adaptation

2. Spatial distribution response to temperature.

Question: Is *O mykiss* distribution influenced by changes in longitudinal temperature distribution between winter and late-summer/ early-fall.
General Approach: Evaluate distribution of O. mykiss during winter and following late summer/early fall to determine potential response related to temperature change

a. Temperature gradient along Tuolumne River changes from winter to summer as temperatures changes increase with distance downstream from La Grange Dam.
b. Spatial distribution, observed as presence/absence and potentially as density, along the Tuolumne River should change between winter and summer corresponding to change in temperature. Temperature tolerances and potentially evaluation criteria would be identified based on temperatures where O. mykiss continue to occur versus where they disappear between winter and late-summer, early-fall.

April 2, 2012

c. Data are available under various annual temperature regimes that range from substantial change in temperature from winter to fall, to temperature conditions meeting identified thresholds (EPA 2003) throughout a substantially great portion of the river.

3. Influence of temperature on growth of *O. mykiss* and *Chinook salmon*

Question: Is growth of *O mykiss* and Chinook salmon in Tuolumne River being adversely affected by temperature. (Direct observation of individual growth is not likely to be allowed due to permitting issues (ESA), but may not be necessary to address question.)

General Approach: Evaluate growth of *O mykiss* and Chinook salmon based on size distribution within and among years with varying temperature regimes and compare with a reference growth expectation based on literature and observations of other *O mykiss* populations.

a. Growth can be determined for Chinook salmon and *O mykiss* based on size at time. An age and growth evaluation of *O mykiss* to be performed per W&AR 20, will determine if size at time can be used to distinguish age composition of observed *O mykiss* and allow characterization of growth. Observed growth will be evaluated relative to expected results, based on growth rates reported in literature and observed in other waters where conditions are considered suitable for *O mykiss*(and *Chinook salmon*)
b. Growth rates determined to be comparable or expected would indicate that conditions for growth, including temperature, are sufficient so support *O mykiss* in good condition.

4. Effect of temperature observed as changes in condition/health of Chinook salmon

Question: Is the temperature regime of the Tuolumne River affecting Chinook salmon survival potential, measured as specific temperature-related affects to health and condition

General Approach: Evaluate quality of Chinook salmon smolt in reared in the Tuolumne River as temperatures change during the rearing/emigration phase.

Fish health/condition can be influenced by temperature conditions. Significant stages of concern include smolting of Chinook salmon. Methods used previously to evaluate smolt condition in the San Joaquin River and other locals will be used to assess juvenile Chinook salmon collected during emigration surveys. Fish will be collected during the period when larger fish begin to emigrate typically when temperatures and growth conditions increase, after mid-March, through the end of the emigration (June).

5. Influence of temperature on location, movement, survival potential of O. mykiss.

Question: How do *O mykiss* respond to (excessive) summer temperature conditions in Tuolumne River?
Do *O mykiss* relocate of remain in areas as temperature increase during summer and how does temperature exposure affect behavior and ultimately survival potential.

General Approach: Acoustic tagging *O mykiss* during early summer in various locals with various temperature expectations and monitor movement and survival to emigration.

6. Influence of excessive temperatures early in the Chinook salmon spawning period on egg survival as expressed in production v temperature conditions during spawning and incubation

Question: Does exposure to warmer (than EPA thresholds) temperature conditions during spawning significantly affect Chinook salmon survival (to emergence).

General Approach: Evaluate previous emergence trapping studies conducted by Stillwater Science on Tuolumne River.

7. Timing of spawning v temperature

Question: Does temperature during the early spawning period influence timing of spawning?
Do Chinook salmon avoid spawning when temperatures exceed "suitable"/ threshold temperatures?

General Approach: Evaluate spawning distribution versus temperature using CDFG redd surveys.

8. Chinook salmon production related to precedent temperature conditions

Question: Does early temperature regime influence Chinook salmon production
Emigration population v temperature (conditioned by escapement)
In combination with 7, above, can early spawning temperature evaluation criteria be defined based on when Chinook salmon spawn versus temperature, in combination with survival (based on the corresponding year's production estimates (per emigration monitoring)?

General Approach: Evaluate estimated Chinook salmon production relative to temperature conditions during spawning.

From: Staples, Rose
Sent: Friday, April 06, 2012 7:43 PM
To: 'Alves, Jim'; 'Anderson, Craig'; 'Asay, Lynette'; 'Aud, John'; 'Barnes, James'; 'Barnes, Peter'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Cismowski, Gail'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackman, Jerry'; 'Jackson, Zac'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; 'Looker, Mark'; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'McLain, Jeffrey'; 'Means, Julie'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pinhey, Nick'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Walters, Eric'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Revised Don Pedro W-AR-12 O.mykiss Habitat Survey Study Plan filed with FERC today
Attachments: Bose_P-2299-075_RevisedW-AR-12_120406 efiling.pdf

The revised Don Pedro W&AR-12 O.mykiss Habitat Survey Study Plan has been filed with FERC today—and a copy of the filing is attached. It will also be available shortly on FERC's E-Library and on the Don Pedro relicensing website at www.donpedro-relicensing.com--in the Announcement Section accessible via the INTRODUCTION tab.

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CAP-OM

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April 6, 2012
VIA Electronic Filing

The Honorable Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington DC 20426

Re: **Don Pedro Project Relicensing**
FERC Project No. 2299-075
Revised Study Plan for W&AR-12 *O. mykiss* Habitat Survey Study

Dear Secretary Bose,

This filing is being made on behalf of the Turlock Irrigation District and Modesto Irrigation District (collectively, the Districts).

On November 22, 2011, pursuant to Section 5.11 of 18 CFR, the Districts filed with the Federal Energy Regulatory Commission (FERC) their revised study plan (RSP) for the Don Pedro Project (P-2299). In FERC's study plan determination issued December 22, 2011, FERC recommended modifications to the Water and Aquatic Resources (W&AR) Study 12 - *Oncorhynchus mykiss* Habitat Survey Study Plan. FERC also recommended that after incorporating the recommended modifications, the Districts file a revised W&AR-12 study plan within 90-days of FERC's study plan determination. Subsequently, the Districts requested, and FERC granted an extension of the filing deadline to April 6, 2012.

The Districts revised W&AR-12 to address FERC's recommendations, and provided the revised study plan to relicensing participants on February 21, 2012. Comments were received from the United States Fish and Wildlife Service (USFWS) on March 21, 2012. The attached revised W&AR-12 study plan incorporates clarifications to the habitat typing methodology and large woody debris definitions to be used as requested by the UWFWS. Additional information on references to scientific literature that will be used to support habitat quality and suitability analysis and identification of comparison streams will be incorporated in the study reports after the data collection and analysis under this study plan is conducted.

Respectfully Submitted,

John Devine

John Devine P.E.
Project Manager

cc: Turlock Irrigation District, Modesto Irrigation District, Relicensing Participants

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TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT
FERC NO. 2299
WATER & AQUATIC RESOURCE WORK GROUP

Study Plan W&AR-12
Oncorhynchus mykiss Habitat Survey Study Plan
April 2012

1.0 Project Nexus

The continued project operation and maintenance of the Don Pedro Project (Project) may contribute to cumulative effects on anadromous fish habitat in the lower Tuolumne River. These potential environmental effects include changes in the type of physical habitat available for juvenile *Oncorhynchus mykiss (O. mykiss*). Changes to habitat may include reduction in habitat complexity and structure due to reduced availability of large woody debris (LWD). Lack of habitat complexity may affect fish populations in the lower Tuolumne River.

2.0 Resource Agency Management Goals

The Districts believe that four agencies have resource management goals related to salmonid species and/or their habitat: (1) U.S. Department of Interior, Fish and Wildlife Service (USFWS); (2) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS); (3) California Department of Fish and Game (CDFG); and (4) State Water Resources Control Board, Division of Water Rights (SWRCB).

A goal of the USFWS (2001) Anadromous Fish Restoration Program, as stated in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to double the long-term production of anadromous fish in California's Central Valley rivers and streams. Objectives in meeting this long-term goal include: (1) improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat; (2) improve survival rates by reducing or eliminating entrainment of juveniles at diversions; (3) improve the opportunity for adult fish to reach spawning habitats in a timely manner; (4) collect fish population, health, and habitat data to facilitate evaluation of restoration actions; (5) integrate habitat restoration efforts with harvest and hatchery management; and (6) involve partners in the implementation and evaluation of restoration actions.

NMFS has developed Resource Management Goals and Objectives for species listed under the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 et seq.) and the Endangered Species Act (ESA) (16 U.S.C. §1531 et seq.), as well as anadromous species that are not currently listed but may require listing in the future. NMFS' (2009) Public *Draft* Recovery Plan for Sacramento River Winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and Central Valley steelhead outlines NMFS' framework for the recovery of ESA-listed species and populations in California's Central Valley. For Central Valley steelhead, the recovery actions identified for the Tuolumne River are to: (1) conduct habitat evaluations; and

(2) manage cold water pools behind La Grange and Don Pedro dams to provide suitable water temperatures for all downstream life stages. For Central Valley fall/late fall-run Chinook, the relevant goals are to enhance the essential fish habitat downstream of the Project and achieve a viable population of Central Valley fall/late fall-run Chinook salmon in the Tuolumne River.

CDFG's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFG's resource management goals, as summarized in restoration planning documents such as "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993), are to restore and protect California's aquatic ecosystems that support fish and wildlife, and to protect threatened and endangered species under California Fish and Game Code (Sections 6920-6924).

SWRCB has responsibility under the federal Clean Water Act (33 U.S.C. §11251-1357) to preserve and maintain the chemical, physical and biological integrity of the State's waters and to protect water quality and the beneficial uses of stream reaches consistent with Section 401 of the federal Clean Water Act, the Regional Water Quality Control Board Basin Plans, State Water Board regulations, the California Environmental Quality Act, and any other applicable state law.

3.0 Study Goals

The primary goal of this study is to provide information on habitat distribution, abundance and quality in the lower Tuolumne River with a focus on *O. mykiss* habitat related to LWD. An inventory of LWD and associated habitat quality, availability and use by salmonids will inform the evaluation of in-river factors that may affect the juvenile *O. mykiss* life stage. As recommended by FERC staff in its Study Plan Determination of December 27, 2012, several modifications have been made to this study at the request of Relicensing Participants (Elements No. 5 and 6 in Study Request NMFS-5, dated June 10, 2011) in an effort to provide more detailed characterization of LWD distribution in the lower Tuolumne River. In addition, the study will provide a rough estimate of the quantities of LWD removed from Don Pedro on an annual basis.

4.0 Existing Information and Need for Additional Information

Juvenile habitat quality and use has been found to be directly related to habitat complexity (Bustard and Narver 1971; Bisson et al. 1987). Instream habitat complexity is typically associated with large woody debris, pools, and off channel habitat. Cederholm (1997) and others observed a direct relationship between increased steelhead smolt production and increased habitat complexity in the form of LWD. Increases in numbers of anadromous (Ward and Slaney 1981; House and Boehne 1995) and non-anadromous (Gowan and Fausch 1995) fishes after addition of LWD to a stream have been demonstrated.

Instream LWD recruitment is generally from the adjacent riparian forest or allochthonous, originating from the upstream watershed. Large dams, that rarely spill, like Don Pedro Dam, can reduce recruitment from upstream sources. Reduction or elimination of large riparian trees will also reduce LWD recruitment.

The quality and condition of habitat in the lower Tuolumne River has been investigated for Chinook salmon since the 1996 FERC Order (76 FERC 61, 117). The order required that the condition of spawning habitat be assessed along with other monitoring requirements, specific to Chinook salmon. As a result, information is available for other salmonids in the river. For example, McBain and Trush (2000) identified that the uppermost reach of the lower Tuolumne River (River Mile [RM] 52–46.6) was primarily used for spawning salmon where they found gravel bed and banks, along with little valley confinement within the bluffs. Surveys of the channel downstream of La Grange Dam showed the occurrence of channel downcutting and widening, armoring, and depletion of sediment storage features (e.g., lateral bars and riffles) due to sediment trapping in upstream reservoirs, gold and gravel mining, and other land use changes since the 1850s (DWR 1994; McBain & Trush 2004).

Previous riparian investigations found large scale removal of riparian vegetation that was a direct result of mining activities and urban/agricultural encroachment. Clearing of riparian forests decreased large woody debris recruitment, allowed exotic plants to invade the riparian corridor, reduced shading of the water's surface, and contributed to increased water and air temperatures in the Tuolumne River corridor (McBain & Trush 2000). Grazing and other land uses have also resulted in direct impacts on riparian vegetation.

LWD plays an important role in habitat forming events within low-order streams. Where LWD dimensions are large relative to the channel width, LWD readily collects within the channel forming areas of velocity gradation, encouraging localized sediment deposition and scour (McBroom 2010). In higher order streams, such as the lower Tuolumne River, the role of LWD in habitat formation decreases with the stream width. However, LWD becomes more ecologically significant in high order streams, where it can provide the majority of stable, firm substrate that supports a substantial portion of invertebrate productivity (McBroom 2010).

Salmonid habitat quality and quantity, including characterization of habitat limitations and relative salmonid production potential is routinely assessed through surveys of instream habitat composition and structure, such as those surveys described by CDFG (2010). Results of such surveys can help identify land use and other related effects on habitat quality, thus the relative potential of the anadromous fish population. Such surveys also can identify opportunities to restore or enhance habitat conditions and salmonid and other aquatic production. In July 2008, Stillwater Sciences conducted a focused assessment of *O. mykiss* in the Tuolumne River that incorporated a habitat mapping component. The assessment identified general habitat units (e.g., pool, riffles) and then discussed the relationship between habitat type and observed *O. mykiss* use (Table 4.0-1). Habitat maps were also created displaying general habitat type from RM 52 to RM 39.5. The results of recent *O. mykiss* monitoring surveys (e.g. Stillwater Sciences 2008) provide a foundation for the focused *O. mykiss* habitat evaluations in this proposed study.

While existing historical data provide a broader characterization of the existing habitat, a more detailed investigation into habitat conditions is proposed. A more detailed assessment of *O. mykiss* habitat availability would include the level and kind of complexity, factors associated with complexity (such as bars, backwater pools, scour pools, etc.), and the amount of habitat available as a function of complexity and use.

Table 4.0-1 Example habitat use by habitat type for two *O. mykiss* size classes during summer (adapted from Stillwater Sciences 2008**).**

Habitat	*O. mykiss* < 150 mm				*O. mykiss* ≥ 150 mm				Total			
	Seen [1]	Est.	Std dev	95% Interval [2]	Seen [1]	Est.	Std dev	95% Interval [2]	Seen	Est.	Std dev	95% Interval
Pool Head	12	20	10.1	12–40	17	45	13.2	19–71	29	65	16.7	33–98
Pool Body	0				3	24	18.0	3–59	3	24	18.0	3–59
Pool Tail	1	2	2.6	1–7	0				1	2	2.6	1–7
Run Head	46	166	179.0	46–517	1	6	8.8	1–23	47	172	179.2	47–523
Run Body	5	860	115.6	634–1,087	6	319	77.5	167–471	11	1,179	139.2	906–1,452
Run Tail	0				0				0			
Riffle	65	1,428	198.2	1,039–1,816	13	226	126.7	13–474	78	1,653	235.2	1,192–2,114
Total	**129**	**2,476**	**291.2**	**1,905–3,047**	**40**	**619**	**150.4**	**325–914**	**169**	**3,096**	**327.7**	**2,453–3,738**

1 Largest numbers seen in any single dive pass for each unit, summed over units. Note that summation of the largest numbers seen within individual (50 millimeter [mm]) size bins yields higher estimates of total fish smaller and larger than 150 mm.

2 Nominal confidence intervals calculated as +/- 1.96 standard deviations. When this yielded lower bounds less than the numbers seen, the lower bound was truncated accordingly and the interval shaded.

In addition to a focused survey and assessment of the associations of LWD and other contributors to habitat complexity, and the relationships among complexity and *O. mykiss* utilization, a general accounting of LWD within the study reach will be conducted to identify location, general condition, density and abundance of LWD.

5.0 Study Methods

The study methods described below will be implemented to meet the study objectives.

5.1 Study Area

A one-year habitat assessment will be conducted in the salmonid spawning and rearing reach of the lower Tuolumne River from La Grange to Roberts Ferry Bridge (approx. RM 52–39). The LWD survey area will extend from RM 52 downstream to RM 24. A separate investigation of LWD removed from Don Pedro reservoir will also be conducted.

5.2 General Concepts

The following general concepts apply to the study:

- Personal safety is an important consideration of each fieldwork team. The Districts and their consultants will perform the study in a safe manner.
- Field crews may make minor modifications in the field to adjust to and to accommodate actual field conditions and unforeseeable events. (e.g., In the field it may not be possible to use tape to measure the length or average width of a very long habitat type as some pools are over 1,500 ft long; therefore GIS would be used to measure the habitat length rather than using a tape.) Any modifications made will be documented and reported in the draft study report.

5.3 Study Methods

The study will consist of two separate components: 1) a semi-quantitative inventory of instream habitat types and physical habitat characteristics, and 2) an appraisal of distribution, abundance, and function of LWD in the lower Tuolumne River. The first component will rely on available aerial photography and habitat mapping, and a reconnaissance-level survey of the lower Tuolumne River, between RM 52–39.5. This study component will rely upon existing broader habitat mapping conducted by Stillwater Sciences (2008) to identify focal research areas where *O. mykiss* occur and then utilize an adaptation of the high-resolution CDFG habitat typing methodology (CDFG 2010), to further characterize and evaluate these areas. CDFG identified four levels of typing, ranging from general broad habitat identification (Level I) to more detailed characterizations entailing 24 different potential habitat descriptors at Level IV. This study will utilize the Level III protocol, which differentiates six habitat types (main channel pool, scour pool, backwater pool, riffle, cascade, and flatwater) that can be further compressed into pool, riffle, and flatwater. The Level III will facilitate comparison with the pool, riffle, and run habitat types that were delineated during the 2010 IFIM Mesohabitat typing survey and other earlier efforts. In addition, a detailed description of LWD will be made at each focal study location using standard methods (Moore et al. 2006, Montgomery 2008), as described further below.

The second study component, an LWD inventory, will consist of a detailed survey of large wood and an assessment of its influence on *O. mykiss* habitat quality and quantity. The LWD inventory will be conducted between RM 52 and RM 24. In addition, as recommended by FERC Staff in the December 22, 2011 Study Determination, an evaluation of the frequency and volume of LWD trapped and removed from Don Pedro reservoir on an annual basis will be made (as described by NMFS in their June 10, 2011 study request Element No. 2).

<u>Step 1 – Site Selection, Field Reconnaissance, and Planning</u>. Habitat typing conducted for this study includes a 12.5 mile reach of the lower Tuolumne River (RM 52–39.5), with LWD surveys from RM 52–24. Field planning will begin by reviewing reports of existing habitat mapping conducted by Stillwater Sciences (2008), McBain & Trush (2004), and others. Field staff will coordinate with CDFG staff and others knowledgeable of access and navigability of the river to determine proper timing and related survey conditions that would optimize conducting the survey. As recommended by FERC Staff in the December 22, 2011 Study Determination, ortho-rectified digital aerial photographs of the study reach will be prepared for use with habitat typing and in developing a spatial inventory of mapped LWD. A subset of representative sampling units in the study reach will be selected for detailed habitat measurements using CDFG (2010). As recommended by CDFG (2010), sampling units selected for detailed habitat measurements will encompass 10–20 percent of the study reach and will be preferentially located where *O. mykiss* observations have been documented (e.g., Stillwater Sciences 2008).

As recommended by FERC Staff in the December 22, 2011 Study Determination, sampling units for inventorying LWD will be up to 20 channel widths long, consistent with guidelines used in California and the Pacific Northwest (e.g., Leopold 1994). The average bankfull width of the lower Tuolumne is 150 ft; therefore, the average length of a sample site will be around 3,000 ft long. Seven to ten sampling units that are 20 bankfull widths long will be selected for detailed characterization of LWD, encompassing approximately 4 to 6 miles (i.e., 10 to 20 percent) of the study reach by the estimates above.

Step 2 – Field Data Collection. Field surveys will be implemented using multiple teams of two field technicians. Each team will have a map and aerial photos delineating the portions of reach that will be surveyed. Upon accessing these survey areas, each team will collect the suite of measurements detailed in Table 5.3-1. These measurements are representative of the required data collection for Level III and IV CDFG habitat typing. Data will be documented on template datasheets to ensure that all data are collected and in a consistent manner between teams. Each habitat unit will have its upstream and downstream boundaries delineated on an aerial photograph and have an identification number that is the same as that on the datasheet. Field measurements will be made with standard field equipment: a handheld thermometer will be used to collect water temperature data, a stadia rod will be used to measure water depth, a steel meter tape or optical range finder will be used to measure site dimensions, and a spherical densitometer will measure percent overhead canopy cover. Each team will also be equipped with a handheld GPS and camera with habitat unit dimensions estimated in the field as well as by GIS.

Table 5.3-1 A summary of data collected as part of the Level IV CDFG habitat mapping.

Gathered Data	Description
Form Number	Sequential numbering
Date	Date of survey
Stream Name	As identified on USGS quadrangle
Legal	Township, Range, and Section
Surveyors	Names of surveyors
Latitude/Longitude	Degrees, Minutes, Seconds from a handheld GPS
Quadrant	7.5 USGS quadrangle where survey occurred
Reach	Reach name or rivermile range
Habitat Unit #	The habitat unit ID # that the bankfull width was measured
Time	Recorded for each new data sheet start time
Water Temperature	Recorded to nearest degree Celsius
Air Temperature	Recorded to nearest degree Celsius
Flow Measurement	Can be obtained from USGS monitoring stations
Mean Length	Measurement in meters of habitat unit
Mean Width	Measurement in meters of habitat unit
Mean Depth	Measurement in meters of habitat unit
Maximum Depth	Measurement in meters of habitat unit
Depth Pool Tail Crest	Maximum thalweg depth at pool tail crest in meters
Pool Tail Embeddedness	Percentage in 25% bucket ranges
Pool Tail Substrate	Dominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Large Woody Debris Count	Detailed inventory criteria are listed below
Shelter Value	Assigned categorical value: no shelter, minimal shelter (small debris, bubble curtain etc.), significant shelter (large woody debris, root wads, vegetative cover, etc.)
Percent Unit Covered	Percent of the unit occupied
Substrate Composition	Composed of dominant and subdominant substrate: silt, sand, gravel, small cobble, large cobble, boulder, bedrock
Percent Exposed Substrate	Percent of substrate above water
Percent Total Canopy	Percent of canopy covering the stream
Percent Hardwood Trees	Percent of canopy composed of hardwood trees
Percent Coniferous Trees	Percent of canopy composed of coniferous trees
Right and Left Bank Composition	Identify dominant substrate: sand/silt, cobble, boulder, bedrock
Right and Left Bank Dominant Vegetation	Identify dominant vegetation: grass, brush, hardwood trees, coniferous trees, no vegetation
Right and Left Bank Percent Vegetation	Percent of vegetation covering the bank
Comments	Additional notes as needed

USGS = U.S. Geological Survey

The LWD distribution survey will use the Montgomery (2008) wood size classes, adapted to the Tuolumne River as follows. Information to be collected will include location (e.g., GPS coordinates), LWD size category, type, orientation, associated CDFG (2010) habitat type, and likely source. As recommended by FERC Staff in the December 22, 2011 Study Determination, within each LWD sample site, GPS locations and characteristics of each piece of LWD greater than 3 ft (1 m) long within the active channel will be recorded and binned within six length classes [3–6.5 ft (1–2 m), 6.5–13 ft (2–4 m), 13–26 ft (4–8 m), 26–52 ft (8–16 m), 52–105 ft (16–32 m), and >105 ft (>32 m)] and four diameter classes [4-8 in (0.1–0.2 m), 8–16 in (0.2–0.4 m), 16–31 in (0.4–0.8 m), 31–63 in (0.8–1.6 m)].

More detailed measurements will be taken for key pieces of LWD. Key LWD piece definitions are generally based upon channel widths that are found in lower order timberland channels. For example, Fox (1994) determined that the lengths of key pieces are between 1.4 and 1.5 times the active channel width. No key pieces of LWD would be present in the lower Tuolumne River given that the channel averages 150 ft in width and trees in the area are not 225 ft tall. The focus of this study component is to assess LWD availability as it relates to *O. mykiss* habitat in the Tuolumne River. Therefore, the Districts will use a definition related to the habitat value of the LWD that is appropriate for a river of this size. For this study, a key piece of LWD is defined as a piece that is either longer than 1/2 times the bankfull width, or of sufficient size and/or deposited in a manner that alters channel morphology and aquatic habitat (e.g., trapping sediment or altering flow patterns). The detailed information collected on each piece of LWD will be comparable with other definitions of LWD. In addition to recording the GPS locations for mapping on ortho-rectified aerial photographs, detailed information to be collected on key LWD pieces includes:

- Piece location, mapped on aerial photos/GPS documentation
- Piece length
- Piece diameter
- Piece orientation to bank
- Position relative to channel
- Rootwad present
- Tree type (hardwood or conifer)
- Associated with log jam
- Jam size (estimated dimensions/number of pieces)
- Source (imported/riparian/unknown)
- Channel dynamic function
- Habitat function (cover, sediment collection, hard substrate)

Lastly, although no detailed records of the quantities of LWD removed from Don Pedro Reservoir or other Project facilities exist, the Don Pedro Recreation Agency (DPRA) conducts an annual program to remove floating LWD at various locations in Don Pedro reservoir as it presents a boating hazard. This material is then placed in piles within suitable landing areas around the reservoir for burning, as conditions permit. To provide an order of magnitude estimate of LWD currently trapped in the reservoir, a team of two field technicians will travel by boat to each landing area and measure the quantity of LWD at each stockpile location in May 2012. Understanding that no meaningful relationship between this annual storage estimate and a LWD budget or loading rate to the lower Tuolumne River is possible, a discussion of the relative sizes and characteristics of LWD in Don Pedro reservoir and at locations in the lower Tuolumne River will be made.

<u>Step 3 – Data Processing and Analyses</u>. Collected data will be stored and managed using a digital spreadsheet database. All data sheets will be physically copied after each week of survey. All data will then be entered into a spreadsheet database. Entered data will be QA/QC'd by two independent technicians reading and confirming each line of data together. Data will be summarized in tables and figures depicting overall habitat characteristics and conditions by reach. The quality and suitability of the habitat will be assessed using existing literature resources that include documented *O. mykiss* life history needs. Literature resources used to define characteristics of habitat quality and suitability will be described in the study report. This assessment will also discuss patterns of habitat use as found in recent O. mykiss snorkel survey efforts (e.g., Stillwater Sciences 2008). Final data will be made available to Relicensing Participants in digital spreadsheet form (Step 4). Maps depicting the location of the surveys, habitat types and LWD locations with each survey reach, and images of the surveyed habitat will also be provided within the report.

Data collected during the LWD distribution survey will be summarized relative to size class, reach, habitat association, density, and complexity. LWD trapped and removed from Don Pedro Reservoir in 2012 by the Don Pedro Recreation Agency will be quantified and a comparison of size characteristics of trapped LWD with those observed in the lower Tuolumne River will be made. These data summaries will be analyzed to determine the functioning of LWD in the lower Tuolumne River in the context of its channel and habitat type, and ecological role.

The quantity, quality, and use of the lower Tuolumne River by *O. mykiss* will be discussed in the context of other anadromous salmonid streams. The comparison will identify the occurrence and role of LWD and other habitat attributes in the lower Tuolumne River, and provide a basis for assessing the potential implications on *O. mykiss* abundance. Comparisons with other Central Valley streams and similar stream systems outside the Central Valley will be made to place LWD function in the lower Tuolumne River in context with other streams of similar stream order, recruitment potential, and sources. The rationale for selection of and documentation of comparability of stream characteristics will be included in the study report.

<u>Step 4 – Prepare Report</u>**.** The Districts will prepare a report that includes the following sections: (1) Study Goals, (2) Methods and Analysis, (3) Results, (4) Discussion, and (5) Conclusions. The quality and suitability of the habitat will be assessed and reported in light of existing resources that include steelhead life history needs. The report will discuss the findings from the Stillwater (2008) report and compare current conditions to population and habitat data collected in 2008.

The report will also contain GIS maps of sampled areas with delineated habitat and LWD features, organized and labeled photos of select habitat, and relevant summary tables and graphs. The reported data will be organized by reach site to allow for a spatial presentation of the findings. Final data will be made available to Relicensing Participants (Section 8.0).

6.0 Schedule

The Districts anticipate the schedule to complete the study as follows:

Project Preparation..April – May 2012
Field Mapping..June – August 2012
Data QA/QC.. September 2012
Prepare Report ....October – November 2012
Report Issuance..January 2013

7.0 Consistency of Methodology with Generally Accepted Scientific Practices

The habitat mapping methodology was developed by CDFG based upon notable prior researchers. The methods described are standards that have been reviewed and used by numerous researchers since 1991. The study will follow the latest survey approach that has been refined into the current 4th edition (CDFG 2010).

8.0 Deliverables

The Districts will prepare a report, which will document the methodology and results of the study. In addition, at the request of relicensing participants, the Districts will provide GIS-based maps of survey locations documented as part of this study, as well as all LWD survey data (both focused and distribution survey) and all other habitat unit data in tabular (spreadsheet) and geo-spatial (e.g., ArcGIS shapefiles) formats.

9.0 Level of Effort and Cost

The Districts estimate the cost to complete this study to be $120,000.

10.0 References

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From: Staples, Rose
Sent: Monday, April 09, 2012 1:25 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Aud, John; Barnes, James; Barnes, Peter; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cismowski, Gail; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Looker, Mark; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Means, Julie; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Walters, Eric; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro-NEW LIVE MEETING LINK--BUT USE HDR CALL-IN NUMBER

Importance: High

It is now my understanding that the HDR Call-In Number previously announced will STILL be used for the audio portion of the meeting—but the "live meeting" link will be GOTOMEETING link shown below. Thank you.

1. Please join my meeting.
https://www3.gotomeeting.com/join/480822654
2. Use your microphone and speakers (VoIP) - a headset is recommended. Or, call in using your telephone.
~~Dial +1 (213) 493-0605~~
~~Access Code: 480-822-654~~
Audio PIN: Shown after joining the meeting
Meeting ID: 480-822-654
GoToMeeting®
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ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

From: Staples, Rose
Sent: Tuesday, April 10, 2012 10:51 AM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Aud, John; Barnes, James; Barnes, Peter; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cismowski, Gail; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Looker, Mark; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Means, Julie; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Walters, Eric; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Use Links Below for Don Pedro Apr 10 - Apr 11 Meetings-Workshop

Importance: High

For today's meeting / workshop and tomorrow's meeting, we will be using the "live meeting" links previously announced last week—and I have copied them below for your ease of use. If you are unable to connect, please send me an email or call me at 207-239-3857! Thank you.

AUDIO INFORMATION
Use call-in number: **866-994-6437**, Conference Code **5424697994**

ON-LINE MEETING INFORMATION
(On-Line Meetings will be open approximately half hour prior to the meeting start time to allow for any technical issues to be resolved. If you have not used On-Line Meeting in the past, please allow a few extra minutes for your first log-on.)

Tuesday, April 10 (8:30 – 10:15am): Reservoir Temperature Modeling Data and

Methods Consultation Meeting (W&AR-3)

Join online meeting
https://meet.hdrinc.com/jenna.borovansky/QC5C5HN1

First online meeting?

Tuesday, April 10 (10:30am – 5:00pm) Salmonid Information Synthesis Workshop (W&AR-5)

Join online meeting
https://meet.hdrinc.com/jenna.borovansky/37NNBCDP

First online meeting?

Wednesday, April 11 (9:00 am – Noon): Temperature Criteria Evaluation Consultation Meeting (W&AR-14)

Join online meeting
https://meet.hdrinc.com/jenna.borovansky/MHVKDJYZ

First online meeting?

ROSE STAPLES
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From: Staples, Rose
Sent: Friday, April 13, 2012 7:14 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Aud, John; Barnes, James; Barnes, Peter; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cismowski, Gail; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Looker, Mark; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Means, Julie; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Walters, Eric; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro April 9-11 Workshops-Meetings Presentations-Materials on Relicensing Website

In addition to materials distributed and posted prior to the workshops and meetings, the following meeting materials from the April 9-11 relicensing workshops and meetings have been posted to the Don Pedro Relicensing Website at www.donpedro-relicensing.com in the INTRODUCTION / Announcement section:

April 9 – Hydrology Workshop
Schematic of Tuolumne River Storage and Flow Locations

April 10 – Reservoir Temperature Model Overview Meeting
Presentation for Reservoir Temperature Modeling (W&AR-3)

April 10 – Salmonid Information Synthesis Study Workshop
Presentation for Salmonid Information Synthesis Study Workshop (W&AR-5)

April 11 Temperature Criteria Consultation Meeting
Presentation for Temperature Criteria Study (W&AR-14)

If you are unable to view and/or download any of this material, please let me know at rose.staples@hdrinc.com.

Temperature Criteria Assessment Study (W&AR 14)

April 11, 2012

Overview of Study Plan W&AR 14

The overall objective is to develop information on the influence of temperature on the in-river life-stages of Chinook salmon and *O. mykiss*.

Specific study objectives include the following:

- Identify life stage-specific fisheries population effects related to water temperature
- Identify life stage-specific water temperature parameters and compare to current temperature regimes.
- Assess and select an acceptable, informative approach to analyzing temperature regimes and their influences on Chinook salmon and *O. mykiss* in the lower Tuolumne River.

Study Methods

1. Review Relevant Literature

Focus: temperatures beyond optimum thresholds/ benchmarks (e.g., EPA 2003)

Emphasize San Joaquin River Watershed and Central Valley Specific

- Include Other Relevant FERC proceedings (YCWA, Merced River)
- Other Relevant Temperature Reviews (e.g., Upper San Joaquin River, Yuba River Management Team, Mokelumne River, Upper Yuba River Reintroduction)

The review and subsequent tasks to be conducted during this study will involve RP participation to be facilitated by convening bimonthly coordination meetings once the study begins.

Study Methods

2. Develop Water Temperature Evaluation Parameters

- What in-river temperatures would be protective of Chinook salmon and steelhead at each identified in-river life-stage?
- What indices, or metrics, should be used to assess individual and population-level effects of a specific water temperature regime on Chinook salmon and steelhead in the Tuolumne River?
- What are the appropriate water temperature evaluation criteria for the Tuolumne River

Study Methods

3. Relate Baseline Water Temperature Conditions to Population

Results will identify:

- In the lower Tuolumne River, how often was each of the life stage-specific water temperature evaluation parameters met under baseline conditions?
- Based on how often water temperature evaluation parameters were met, what were the likely sub-lethal and population-level effects on Tuolumne River salmonids?

FERC Determination (December 2011)

Reliance on EPA (2003)

While the Districts' temperature criteria assessment may have the potential to inform W&AR-5 Salmonid Populations Information Integration and Synthesis Study, we will continue to <u>rely upon the temperature criteria in EPA (2003) for our evaluation of project effects</u>,

Empirical evidence would be considered

…unless <u>empirical evidence from the lower Tuolumne River</u> is provided that suggests different criteria are appropriate for salmonids in the lower Tuolumne.

"What if the Temperature Criteria are Unattainable or Inappropriate?"

EPA recognizes that because of the inherent variability of Pacific Northwest rivers and streams there are likely to be situations where the recommended temperature criteria will be unattainable or inappropriate. The guidance offers several approaches a State or Tribe can take to address these situations. For example, where the natural background temperature (i.e., the temperature absent human impacts) is estimated to be higher than the recommended criteria, the natural background temperature can be adopted as criteria. Further, if human impacts cannot be remedied, alternative criteria can be established based on the water temperature that is attainable."

(EPA 2003 Temperature Fact Sheet)

Response to FERC Determination

Updated Study-

Purpose and Scope :

Develop and implement an approach to identify appropriate temperature criteria for evaluating project effects on anadromous salmonids in the lower Tuolumne River

Evaluate the appropriateness of site specific temperature criteria for Chinook salmon and *O. mykiss* relative to the proposed threshold temperatures described in EPA (2003) and identified by FERC and Participants as temperature criteria to be met in the lower Tuolumne River

Updated Study

Two general questions are to be addressed:

- Do the local populations of Chinook salmon and *O. mykiss* in the lower Tuolumne River have temperature tolerances that allow performance similar to that associated with the EPA 2003 metric at higher temperatures, and, if so, what are those temperatures; and

- If the temperature regime that can be achieved in the TR exceeds those criteria, what is the associated effect on the Chinook salmon and *O. mykiss* population in reference to agency goals and objectives

Updated Study

Study Approach :

- Conduct investigations that are intended to reduce uncertainties and potentially confirm or adjust temperature criteria to be based on empirical information

- Results of the evaluations should serve to identify appropriate modifications in temperature evaluation criteria by revising the temperature thresholds and/or by defining a level of effect associated with threshold exceedance.

Discussion of Potential Evaluations

- The following are potential evaluations the Districts have identified as meeting the above guidance.

1. Local adaptation of temperature tolerance of *O mykiss* juveniles

Question: Are *O mykiss* that occur in Tuolumne River locally adapted to higher temperature tolerances that may define site-specific temperature performance metrics.

General Approach – Evaluate capabilities of local *O mykiss* to accommodate warmer temperatures, both physiological and anatomical, following methods described by Parsons (2011) and others.

- Potential local adaptation to higher range of temperature regimes experienced by O. mykiss may be expressed in physiological and related anatomical performance capabilities. A comprehensive discussion and related investigations conducted by Parsons (2011) strongly suggests that there is good reason to expect that temperature tolerance can vary among anadromous salmonid populations/stocks and provide a good, scientific approach to investigating that tolerance in the Tuolumne River O. mykiss population relative to the extant temperature conditions and criteria and benchmarks currently used to assess temperature induced effects to condition, performance, and survival.

2. Spatial distribution response to temperature.

Question: Is *O. mykiss* distribution influenced by changes in longitudinal temperature distribution between winter and late-summer/ early-fall.

General Approach: Evaluate distribution of *O. mykiss* during winter and following late summer/earl y fall to determine potential response related to temperature change.

- Temperature gradient along Tuolumne River changes from winter to summer as temperatures changes increase with distance downstream from La Grange Dam.
- Spatial distribution, observed as presence/absence and potentially as density, along the Tuolumne River should change between winter and summer corresponding to change in temperature. *O. mykiss* should continue to occur in those areas where temperature meets criteria and should disappear where temperatures exceed criteria, between winter and late-summer, early-fall.
- Data are available under various annual temperature regimes that range from substantial change in temperature from winter to fall, to temperature conditions meeting identified thresholds (EPA 2003) throughout a substantially great portion of the river.

3. Influence of temperature on growth of *O. mykiss* and *Chinook salmon*

Question: Is growth of *O. mykiss* and Chinook salmon in Tuolumne River being adversely affected by temperature. (Direct observation of individual growth is not likely to be allowed due to permitting issues (ESA), but may not be necessary to address question.)

General Approach: Evaluate growth of *O. mykiss* and Chinook salmon based on size distribution within and among years with varying temperature regimes and compare with a reference growth expectation based on literature and observations of other *O. mykiss* populations.

- Growth can be determined for Chinook salmon and *O. mykiss* based on size at time. An age and growth evaluation of *O. mykiss* to be performed per W&AR 20, will determine if size at time can be used to distinguish age composition of observed *O. mykiss* and allow characterization of growth. Observed growth will be evaluated relative to expected results, based on growth rates reported in literature and observed in other waters where conditions are considered suitable for *O. mykiss* (and Chinook salmon)
- Growth rates determined to be comparable or expected would indicate that conditions for growth, including temperature, are sufficient so support *O. mykiss* in good condition.

4. Effect of temperature observed as changes in condition/health of Chinook salmon

Question: Is the temperature regime of the Tuolumne River affecting Chinook salmon survival potential, measured as specific temperature-related affects to health and condition.

General Approach: Evaluate quality of Chinook salmon smolt in reared in the Tuolumne River as temperatures change during the rearing/emigration phase.

- Fish health/condition can be influenced by temperature conditions. Significant stages of concern include smolting of Chinook salmon. Methods used previously to evaluate smolt condition in the San Joaquin River and other locals will be used to assess juvenile Chinook salmon collected during emigration surveys when temperatures and growth conditions increase, after mid-March, through the end of the emigration (June).

5. Influence of temperature on location, movement, survival potential of *O. mykiss*.

Question: How do *O. mykiss* respond to (excessive) summer temperature conditions in Tuolumne River?

- Do *O. mykiss* relocate or remain in areas as temperature increase during summer and how does temperature exposure affect behavior and ultimately survival potential.

General Approach: Acoustic tagging *O. mykiss* during early summer in various locals with various temperature expectations and monitor movement and survival to emigration.

6. Influence of excessive temperatures early in the Chinook salmon spawning period on egg survival as expressed in production v temperature conditions during spawning and incubation.

Question: Does exposure to warmer (than criteria) temperature conditions during spawning significantly affect Chinook salmon survival (to emergence).

General Approach: Evaluate previous emergence trapping studies conducted by Stillwater Science on Tuolumne River.

7. Timing of spawning v temperature

Question: Does temperature during the early spawning period influence timing of spawning? Do Chinook salmon avoid spawning when temperatures exceed “suitable”/ threshold temperatures?

General Approach: Evaluate spawning distribution versus temperature using CDFG redd surveys.

8. Chinook salmon production related to precedent temperature conditions

Question: Does early temperature regime influence Chinook salmon production

- Emigration population v temperature (conditioned by escapement)
- In combination with 7, above, can early spawning temperature criteria be defined based on when Chinook salmon spawn versus temperature, in combination with survival (based on the corresponding year's production estimates (per emigration monitoring)?

General Approach: Evaluate estimated Chinook salmon production relative to temperature conditions during spawning.

Additional Discussions?

- Wrap Up

THANK YOU FOR COMING TODAY

- Set date for next discussion in about 2 months

(Mid June)

From: Staples, Rose
Sent: Monday, April 23, 2012 7:33 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Aud, John; Barnes, James; Barnes, Peter; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cismowski, Gail; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lara, Marco; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Looker, Mark; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Means, Julie; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Walters, Eric; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: TID - MID Response to NMFS Additional Information Filing Regarding Don Pedro Project
Attachments: 2012-4-23 Response to NMFS.PDF

The Districts filed with FERC today their response (copy attached) to the National Marine Fisheries Service's Additional Information Filing of April 13th. It is also available for viewing/download from FERC's E-Library at www.FERC.gov or from the Don Pedro relicensing website at www.donpedro-relicensing.com (Introduction tab/Announcements).

Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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April 23, 2012

VIA ELECTRONIC FILING

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, N.E.
Washington, DC 20426

Re: Modesto and Turlock Irrigation Districts' Response to the National Marine Fisheries Service's Additional Information Filing; Docket No. P-2299-075

Dear Secretary Bose:

This letter is in response to the National Marine Fisheries Service's (NMFS) filing entitled "Additional Information for Consideration by the Study Dispute Resolution Panel, Don Pedro Hydroelectric Project (P-2299-075)," filed with the Secretary on April 13, 2012. The Modesto and Turlock Irrigation Districts (Districts) will be providing separate comments on the NMFS filing entitled "Additional Information for the Commission's Use in its Jurisdictional Review, La Grange Hydroelectric Project, UL11-1-000," that was dated April 12, 2012, and filed with the Secretary on April 13, 2012, in Docket No. UL11-1-000. This latter document, along with two other documents addressing the La Grange Project, were included with the first NMFS filing referenced above.

As a preliminary matter, the Districts object to NMFS' last-minute attempt to interject into the study dispute materials and information regarding the Commission's jurisdictional review of the La Grange Project. These materials and information have nothing to do with the Study Dispute Resolution Panel's (Panel) review of the pending study disputes. The jurisdictional review of the Districts' La Grange Project is a separate proceeding and is not connected with the relicensing proceeding for the Don Pedro Project. As the Panel is well aware, the Commission has already determined that the La Grange Project is not part of the Don Pedro Project.

The Districts concur with the Panel's initial conclusion during the April 17, 2012 technical conference that the jurisdictional issues regarding the La Grange Project are outside the scope of the Panel's review, which was to address the study disputes filed by NMFS and to make recommendations on those disputes.

Furthermore, the filing by NMFS at the last minute deprived the parties to the relicensing proceeding an opportunity to review the materials prior to the hearing by the Panel.

The Districts also object to NMFS' request to add to the record before the Panel the administrative record for the "Proceeding on Interim Conditions before an Administrative Law Judge" (Interim Proceeding). While it is true that the Interim Proceeding dealt with many of the same issues involved in the current relicensing proceeding, these materials have nothing to do with the Panel's review of the NMFS study disputes. NMFS purposefully confuses the issue of Ms. Strange's dismissal from the Study Dispute Panel because of her involvement as a material witness in the Interim Proceeding with information that is relative to this study dispute. Furthermore, there is simply not enough time during the study dispute process for the Panel to review the voluminous testimony submitted in the Interim Proceeding.

Finally, the recently released *A Guide to Understanding and Applying the Integrated Licensing Process Study Criteria* (March 2012) (Guide) that NMFS also included with its April 13, 2012 filing in P-2299-075 is certainly helpful to participants in the relicensing process. In fact, its purpose is "to help stakeholders craft study requests (18 CFR § 5.9(b)) that clearly identify and explain the basis of their information needs and recommended study methods." (Guide, p. 3.) However, NMFS' assertion that the "rationale [the Guide] contains is at issue in the Study Dispute" is erroneous The reference to the Guide in the April 11, 2012 response from the OEP Director is nothing more than a recitation of the current ability of staff to request additional information, if needed, to conduct its cumulative effects analysis. (See, Guide, p. 11, "Commission staff will consider cumulative effects in its environmental document, when appropriate, based on existing information. If the project contributes to cumulative effects, staff may require additional information from the applicant on the project to assess the issues appropriately.") (Footnote omitted.)

Respectfully submitted,

/s/ John A. Whittaker, IV

John A. Whittaker, IV
ATTORNEY FOR MODESTO AND TURLOCK
IRRIGATION DISTRICTS

DC:705454.2

From: Staples, Rose
Sent: Tuesday, July 31, 2012 5:58 PM
To: 'Alves, Jim'; 'Anderson, Craig'; 'Asay, Lynette'; 'Aud, John'; 'Barnes, James'; 'Barnes, Peter'; 'Beniamine Beronia'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackman, Jerry'; 'Jackson, Zac'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Lara, Marco'; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; 'Looker, Mark'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'McLain, Jeffrey'; 'Mein Janis'; 'Mills, John'; 'Minami Amber'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pinhey, Nick'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro FERC Filing - Request for Clarification of Director's Formal Study Dispute Resolution of May 24 2012

Today we have filed, on behalf of the Districts, a request for clarification of certain elements in the FERC Director's Formal Study Dispute Resolution of May 24, 2012. A copy of today's filing has been uploaded to the www.donpedro-relicensing.com website (Introduction/Announcement)—and it is also available on FERC's e-library www.ferc.gov (P-2299-075).

From: Staples, Rose
Sent: Monday, August 06, 2012 3:46 PM
To: 'Karl Morton'
Subject: RE: Don Pedro re-licensing

Thank you for your interest in the Don Pedro relicensing. Let me direct you to two websites for background information on the relicensing:

www.donpedro-relicensing.com (especially the INTRODUCTION/Announcements section for the most recent notifications and the DOCUMENTS section (for major documents as noted in the paragraph below)

www.ferc.gov (Documents and Filings/E-Library for docket P-2299).

The major documents that have been released so far in the relicensing process are the Districts' PAD (Pre-Application document-February 10, 2011), the RSP (Revised Study Plan-November 22, 2011), and FERC's Scoping Document (April 8, 2011) & Study Plan Determination (December 22, 2011). You can find copies of these documents on both the FERC E-Library site under the P-2299 and/or P-2299-075 docket number using the date range of February 10, 2011 to the present date) and on the relicensing website under DOCUMENTS (the PAD and Scoping Documents are under the PAD\NOI\SCOPING subheading and the Revised Study Plan and FERC Study Plan Determination is under the STUDIES sub-heading).

Currently the Districts are working on the first-year studies, and are in the midst of the Workshop Consultation Process (see FERC E-Library filing of May 18, 2012). Dates of the upcoming workshops are posted via announcements on the relicensing website (INTRODUCTION/Announcements Section).

If you would like your email address added to the general email distribution (for relicensing participants' meeting notices and other announcements), please advise.

P.S.: Also note the three relicensing newsletters that have been published by the Districts, copies of which are on the relicensing website/INTRODUCTION/Announcements (by date):

Volume 1 – Issue 1 – May 2, 2011
Volume 1 – Issue 2 – October 1, 2011
Volume 2 – Issue 1 – March 29, 2012

P.S.: If you have any difficulty locating and/or downloading any of these documents, please let me know. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com | hdrinc.com

From: Karl Morton [mailto:farmerkarl.karl@[redacted]
Sent: Monday, August 06, 2012 10:05 AM
To: Staples, Rose
Subject: Don Pedro re-licensing

Please provide all available information. Thank you.

Karl Morton

From: Staples, Rose
Sent: Wednesday, September 26, 2012 7:02 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Looker, Mark; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Districts File Request for Schedule Extension for Don Pedro Initial Study Reports and Initial Study Report Meeting Dates

The Districts have filed with FERC today a request for a minor extension to the schedule for the Initial Study Reports and the Initial Study Report Meetings to January 17, 2013 and January 30, 2013 respectively. A copy of this filing has been posted to the www.donpedro-relicensing.com website (INTRODUCTION Tab/Announcements) and will also be available, most probably by tomorrow, on FERC's E-Library (under docket P-2299-075). If you have any difficulty locating and/or downloading this document, please let me know.

From: Devine, John
Sent: Thursday, October 18, 2012 8:30 AM
To: Jim Alves
Subject: FW: Don Pedro Operations Modeling Training - Validation Meeting October 23 2012
Importance: High

Jim,

Thank you for your recent email to Rose Staples, and letting us know of your concerns . First, let me answer that HDR has, with Districts' approval, retained Cardno Entrix to perform the socioeconomic study for the Don Pedro FERC relicensing. HDR is overseeing the work. The meeting this Friday is just between Cardno and the City of Modesto, with MID attending too. The purpose is to gather relevant information specific to the City for inclusion into the Socioeconomic Study. My understanding is that this meeting date was scheduled a couple of weeks ago in consideration of Rich Ulm's calendar, and that the agenda was sent out yesterday. Meetings with other individual agencies and organizations have been scheduled in a similar manner.

We are also currently trying to schedule a broader Socioeconomic Study Meeting with all interested parties to provide an status report on the overall Socioeconomic study. I hope to have that announcement out today, in fact, and I know that you are included in that invite list. We do appreciate your involvement, and the City's, in the Don Pedro relicensing and I am sorry for any confusion the Friday meeting may have caused.

Please do not hesitate to contact me directly to share any further concerns or discuss the Don Pedro relicensing.

JOHN DEVINE
P.E.

HDR Engineering, Inc.
Senior Vice President, Hydropower Services

970 Baxter Boulevard Suite 301 | Portland, ME 04103
207.775.4495 | c: 207.776.2206 | f: 207.775.1742
john.devine@hdrinc.com | hdrinc.com

From: Staples, Rose
Sent: Wednesday, October 17, 2012 9:47 AM
To: Devine, John

Subject: FW: Don Pedro Operations Modeling Training - Validation Meeting October 23 2012
Importance: High

Please see Jim's comments below.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com | hdrinc.com

From: Jim Alves [mailto:jalves@modestogov.com]
Sent: Tuesday, October 16, 2012 9:08 PM
To: Staples, Rose
Subject: RE: Don Pedro Operations Modeling Training - Validation Meeting October 23 2012

Rose,

Is HDR overseeing the Socioeconomic Study Plan effort for the MID/TID relicensing? I know a firm was hired to conduct this effort, but I thought HDR was overseeing all the Study Plans efforts under the relicensing program for MID/TID. The reason I ask is that I was just informed of a meeting this Friday at MID offices on the Socio-economic Study, supposedly for a discussion on various documents, relevant information, etc. And that is all I know. I had to give a blank look in reply regarding any knowledge of it. This information came through our Department's Director, Rich Ulm, via another set of meetings outside of the FERC effort. I was wondering if other stakeholders are aware of this if I was not, since so far I have been notified of such FERC related meetings or if this particular meeting is somehow a separate item from the actual Socio-economic Study Plan being conducted as part of the FERC effort.

My boss, Jack Bond, will attend for Modesto but I am a bit concerned since a longer heads up would have been beneficial in preparation for this meeting. Jack Bond is on the same FERC notification list as I. I had not heard anything on this Study Plan since attending the Study Plan development meetings before it was finalized and was about to inquire of its status.

Regards,

Jim Alves
City of Modesto
Associate Civil Engineer
Utility Planning & Projects Dept.
Ph: 209-571-5557
Fx: 209-522-1780

From: Staples, Rose
Sent: Friday, October 19, 2012 6:15 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Steindorf, Dave; Steiner, Dan; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Relicensing Nov 9 2012 Socioeconomics Study Progress Update Meeting AGENDA
Attachments: SocioeconomicsStudyProgressUpdateMeeting_Nov 9 2012_Agenda.pdf

Please find attached the AGENDA for the Don Pedro Relicensing Socioeconomics Study Progress Update Meeting scheduled for November 9, 2012 from 9:00 a.m. to 11:30 a.m. at the MID Offices in Modesto. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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MID Modesto Irrigation District
The Power to Grow

Socioeconomics Study Progress Update Meeting
Don Pedro Project Relicensing Water &Aquatic Resources Study Plan #15
November 9, 2012 - 9:00 a.m. – 11:30 a.m. – MID Offices
Call-In #866-994-6437, Conference Code 5424697994

1. **Provide an Overview of Socioeconomics Study Plan**

   The primary goals of the study on socioeconomic resources are to quantify the baseline economic conditions and resources in the region affected by the Don Pedro Project's water supply, flood control, and power benefits. In addition, the study will quantify the socioeconomic effects of the current Project operations and develop methodologies and a framework that can be used to evaluate the potential socioeconomic effects of any proposed changes to Project operations that may be considered as part of the relicensing process, including scenarios affecting the availability of agricultural and urban water supplies. Generally, the objectives of the study plan are to:

   - qualitatively and quantitatively describe local economic conditions in the regions that are affected by the existing Project operations,
   - assess the key factors influenced by Project operations that generate economic activity in affected regions,
   - estimate the economic value generated by the Project's water storage in various uses, both consumptive (agriculture and urban) and non-consumptive (recreation),
   - measure the role and significance of the Project in the economies of the regions, and
   - use these findings to assess the socioeconomic impacts on affected groups and industries resulting from potential changes in Project operations.

2. **Provide a Status Report on Resource Areas**

   A summary of information sources identified and the approach for analysis in each of the resource areas below will be presented and discussed. The Districts are seeking further input from those potentially affected by changes in Project operations. The primary focus of first year activities has been to gather relevant information on the baseline economic values and socioeconomic effects of current Project operations in the following areas:

   - Agriculture
   - Municipal & Industrial
   - Recreation
   - Hydropower Generation
   - Land Values
   - Regional Economics

3. **Request Additional Information and Data**

   The Districts continue their search for additional information that may assist in the development of baseline economic values and socioeconomic effects, as well as sources of information that may be used in the development of future use alternatives.

4. **Review Study Schedule and Discuss Next Steps**

   Review upcoming schedule and opportunity for relicensing participants to provide any further information.

From: Staples, Rose
Sent: Tuesday, October 30, 2012 2:19 PM
To: Alves, Jim; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackman, Jerry; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Relicensing Dispersed Recreation Use Site Assessments November 8, 2012

Recreation Facility Condition, Public Accessibility, and Recreation Use Assessment Study (Study RR-1)
Dispersed Recreation Use Site Assessment Fieldwork
Thursday, November 8, 2012

As you know, HDR, on behalf of the Districts, is continuing fieldwork for the Recreation Facility Condition, Public Accessibility, and Recreation Use Assessment Study (Study RR-1), which includes dispersed recreation use site assessments.

The FERC-approved study plan states the Districts will schedule the field survey in advance so that Relicensing Participants may attend. Field work is scheduled to occur Thursday, November 8, 2012. On this date, we will be conducting assessments at dispersed recreation sites accessible by vehicle on public roads.

If you plan to attend November 8, 2012, please contact Nancy Craig by November 6th (at Nancy.Craig@hdrinc.com) for details and logistics—or email me at rose.staples@hdrinc.com.

Thank you.

ROSE STAPLES
CAP-OM

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Executive Assistant, Hydropower Services

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From:	Staples, Rose
Sent:	Thursday, November 01, 2012 8:23 PM
To:	Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject:	Don Pedro Relicensing Studies WAR14 Meeting and WAR06-10 Workshop - November 15-16 2012
Attachments:	DP_TempCriteriaAssessmtMtg_Nov16_AGENDA_121101.doc

W&AR-06 Tuolumne River Chinook Salmon and W&AR-10 O. mykiss Population Model Workshops

November 15 (9:00 am – 4:30 pm) and November 16 (9 am – Noon): The agenda for these workshops will be forthcoming soon; please continue to hold these dates.

W&AR-14 Temperature Criteria Study Meeting

November 16 (1:00 pm – 4:00 pm): AGENDA attached. This Temperature Criteria Study Meeting is to update relicensing participants on the status of empirical studies proposed at the April 2012 meeting. Written background materials on proposed studies will be provided next week.

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Temperature Criteria Assessment Meeting
Don Pedro Relicensing Study W&AR-14
November 16, 2012 - 1:00 p.m. to 4:00 p.m. – MID Offices

AGENDA

1. **Introductions**

2. **Purpose of Meeting: Report and Discuss Status of Study Plan Implementation**

    - Original study plan
    - FERC Study Determination
    - Additional empirical evaluations proposed during April 2012 meeting

3. **W&AR 14 Study Plan**

    -Review relevant literature
    -Develop water temperature evaluation parameters
    -Relate baseline water temperature conditions to population

4. **Additional Studies and Evaluations**

    -Empirical studies proposed by Districts for implementation

    Study 1: Local Adaptation of Temperature Tolerance of O. mykiss Juveniles in the Lower Tuolumne River
    Study 2: Spatial distribution juvenile O. mykiss in response to temperature
    Study 3(b): Influence of temperature on growth of Chinook salmon
    Study 7: Influence of temperature on pre-spawning of Chinook salmon

    -Empirical studies proposed by Districts at April meeting, but not proposed for implementation at this time

    Study 3(a): Influence of temperature on growth of O. mykiss
    Study 4: Effect of temperature on condition/health of Chinook salmon
    Study 5: Influence of temperature on location, movement, survival potential of O. mykiss.
    Study 6: Influence of temperatures during the early Chinook salmon spawning period on egg survival.
    Study 8: Chinook salmon production related to precedent temperature conditions

5. **Next Steps and Study Schedule**

From: Staples, Rose
Sent: Thursday, November 08, 2012 7:35 PM
To: Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

I have uploaded to the Don Pedro relicensing website (www.donpedro-relicensing.com) today, ***as attachments to the Meeting calendar for their respective meeting dates***, the following meeting materials:

Socioeconomics Study (W&AR-15) Progress Update Meeting, Friday, November 9
PowerPoint Presentation being used at the meeting

Temperature Criteria Assessment (W&AR-14) Meeting, Friday afternoon, November 16

Agenda updated with the LIVE MEETING link
Study Update

If you are not able to access or download these documents, please do contact me at rose.staples@hdrinc.com.

Thank you.

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Socioeconomics Study Progress Update Meeting
Don Pedro Project Relicensing Water &Aquatic Resources Study Plan #15
November 9, 2012 - 9:00 a.m. – 11:30 a.m. – MID Offices
Call-In #866-994-6437, Conference Code 5424697994

1. **Provide an Overview of Socioeconomics Study Plan**
   The primary goals of the study on socioeconomic resources are to quantify the baseline economic conditions and resources in the region affected by the Don Pedro Project's water supply, flood control, and power benefits. In addition, the study will quantify the socioeconomic effects of the current Project operations and develop methodologies and a framework that can be used to evaluate the potential socioeconomic effects of any proposed changes to Project operations that may be considered as part of the relicensing process, including scenarios affecting the availability of agricultural and urban water supplies. Generally, the objectives of the study plan are to:
   - qualitatively and quantitatively describe local economic conditions in the regions that are affected by the existing Project operations,
   - assess the key factors influenced by Project operations that generate economic activity in affected regions,
   - estimate the economic value generated by the Project's water storage in various uses, both consumptive (agriculture and urban) and non-consumptive (recreation),
   - measure the role and significance of the Project in the economies of the regions, and
   - use these findings to assess the socioeconomic impacts on affected groups and industries resulting from potential changes in Project operations.

2. **Provide a Status Report on Resource Areas**
   A summary of information sources identified and the approach for analysis in each of the resource areas below will be presented and discussed. The Districts are seeking further input from those potentially affected by changes in Project operations. The primary focus of first year activities has been to gather relevant information on the baseline economic values and socioeconomic effects of current Project operations in the following areas:
   - Agriculture
   - Municipal & Industrial
   - Recreation
   - Hydropower Generation
   - Land Values
   - Regional Economics

3. **Request Additional Information and Data**
   The Districts continue their search for additional information that may assist in the development of baseline economic values and socioeconomic effects, as well as sources of information that may be used in the development of future use alternatives.

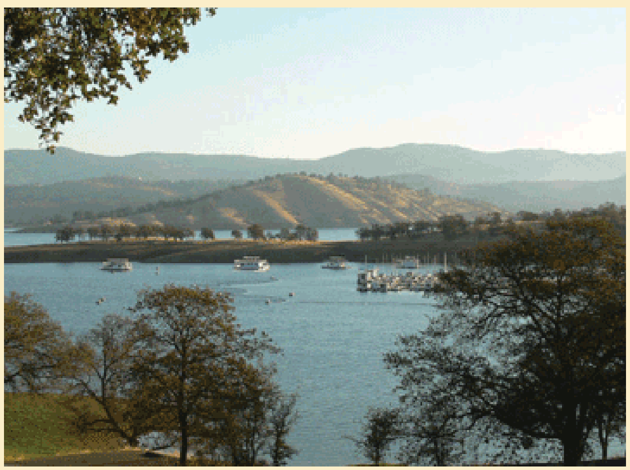
4. **Review Study Schedule and Discuss Next Steps**
   Review upcoming schedule and opportunity for relicensing participants to provide any further information.

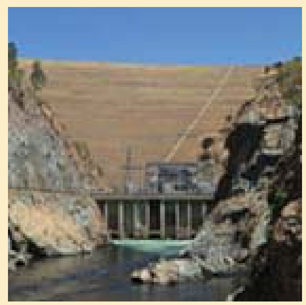
Don Pedro Project Relicensing

Socioeconomics Study Plan – Progress Meeting

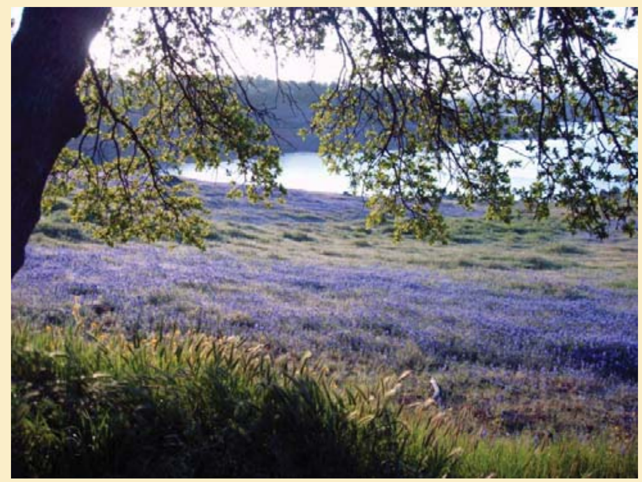
November 9, 2012

MODESTO IRRIGATION DISTRICT | TURLOCK IRRIGATION DISTRICT





FERC
PROJECT
NO. 2299



Agenda

- Overview of Socioeconomics Study Plan
- Status Report on Study Plan Analysis
- Request Additional Information and Data
- Review Study Schedule and Discuss Next Steps

Meeting Purposes

- Provide progress update on socioeconomic study plan
- Describe data sources and economic models
- Continue to seek relevant information from Relicensing Participants
- Describe next steps and schedule

Background & Process

- Pre-Application Document – Filed with FERC in Feb 2011
- FERC Scoping Documents – April 8 and July 25, 2011
- FERC Scoping Meeting – May 11, 2011
- Study Plan Development – July to Nov 2011
  - Meetings: August 23 and September 13, 2011
- FERC Study Plan Determination – Dec. 21, 2011
- First-year studies – 2012 (ongoing)

Research Team

- Cardno ENTRIX
  - Environmental & Natural Resource Management Consulting Firm
  - National Economics Practice
- Lead Researchers
  - Duane Paul, Ph.D., Senior Consultant
  - Steve Pavich, Senior Economist

Socioeconomics Study Plan - Overview

- Study Objectives
  - Characterize local economic conditions
  - Identify key drivers of economic activity related to the Project
  - Estimate economic values of Project water supplies
  - Measure the role of the Project on the local and statewide economies
  - Assess economic effects in context of affected groups and industries
- Study Process
  - Baseline study (2012/13)
  - Scenario analysis (2013) – evaluate future operating scenarios
  - Draft License Application (Nov 2013)
  - Final License Application (April 2014)

Scope of Economic Analysis

- Agriculture water supplies
- Municipal and industrial (M&I) water supplies
- Reservoir recreation
- Hydropower generation
- Land values
- Regional economics
- Environmental justice

Agricultural Water Supplies

- Purpose: Analyze value of irrigation water in agriculture use in MID and TID service areas
- Background
  - Irrigated agriculture about 200,000 acres between MID and TID
  - Broad mix of permanent and annual crops, skewed toward permanent crops
  - Major dairy industry
- Objective: Develop detailed quantitative baseline of agricultural value in the region

Agricultural Water Supplies (cont.)

- Based on Statewide Agricultural Production Model (SWAP)
  - Developed jointly by UC Davis and DWR
  - Based on Central Valley Production Model (CVPM), allows greater detail
  - Emulates farm-level decision making under various constraints, e.g. on water availability, costs
  - Provides estimate of marginal value of water in producing various crops
  - Model outputs will be used in regional economic model to assess role of agriculture to economy
- Data Collection and Sources
  - County, State, Federal government; University of California (crop budgets)
  - Crop prices and yields, costs of production, water requirements (ET), water application rates
  - Districts: crop acreages, water deliveries, irrigation techniques (AG Water Management Plans)
- Status
  - Calibration runs with SWAP model (match existing conditions as precursor for impact analysis)
  - Gross value of <u>crop</u> production in two districts: $413.6 million ($1,820/acre) - <u>preliminary</u>
  - Value of dairy and other agricultural products (under development)

M&I Water Supplies

- Value based on water as input to production/utility of domestic users
- Average and marginal value of water in M&I use
- Literature review
  - Multiple studies related to CA drought (1987-1992)
  - Jenkins, Lund, and Howitt (2003): urban water scarcity costs - $1,766/AF in 2020
  - PPIC (2007): urban scarcity costs, reduced Delta exports- $1,172/AF in 2050 in SJV
- Avoided costs – cost of replacement water for affected municipalities
  - Groundwater pumping costs (City of Modesto)
- Meetings and outreach
  - City of Modesto (October 19, 2012)
  - Other municipalities seeking surface water supplies

Reservoir Recreation

- Focus on value of flat-water recreation at reservoir
  - Value to recreation user (consumer surplus)
- Data sources
  - Interface with recreation surveys (Study RR-1) - identify recreation uses, quantify visitation levels, visitor characteristics (origin)
  - Don Pedro Recreation Agency (DPRA) - Davis-Grunsky reports
- Benefits-Transfer Methodology
  - Apply economic values from other/similar contexts to project
  - Representative values from Loomis (2005)
- Status
  - Awaiting final recreation estimates and RR-1 study report

Hydropower Generation

- Purpose: Quantify value of power produced by Project operations and related socioeconomic effects
- Background
  - Facility has authorized capacity of 168 Megawatts / average generation is 532,500 MWh
  - 2011 electric service revenues: TID revenues $267 million; MID $341 million
  - Customers: TID 100,000 accounts / MID 111,000 accounts
- Data
  - Quantity of hydropower generated
  - Unit values of power (ISO)
  - Replacement energy sources and costs
  - Facility operation costs, incl. O&M, payroll, other
- Coordination with hydrology model (power module)
  - Seasonal generation

Land Values

- Role of water availability on regional land values
- Land value data
  - Source: California Chapter, American Society of Farm Managers and Rural Appraisers (CASFMRA) - Trends in Agricultural Land & Lease Values (2012)
- Preliminary findings
  - MID/TID cropland ($18,500/acre) in 2011
  - Comparatively higher land values in MID/TID service areas relative to other regions in Merced and Stanislaus counties
  - Comparison to rangeland: land values 5x to 20x higher
  - Land values within MID/TID higher than other irrigation districts in region
- Coordination with local real estate appraisers / lenders
  - Identified appraisers/lenders from CASFMRA

Regional Economics

- Regional economic benefits associated with uses of Project water
  - Agriculture, M&I, recreation, and power generation
- IMPLAN economic model
  - Input-output framework
  - Direct, indirect, and induced effects (multiplier or "ripple" effects)
  - Metrics: output (production), labor income, and employment (jobs)
- Models have been constructed
  - Regional model (Merced, Stanislaus, and Tuolumne counties); Statewide model
  - 2010 dataset
- Documented existing demographic and economic conditions
  - Sources: U.S. Census, Bureau of Economic Analysis (BEA), CA EDD
- Awaiting on outputs from other resource analyses – model inputs

Environmental Justice

- Purpose: Provide demographic and social information of affected population in Districts' service areas
  - Used to assess whether minority or low-income populations are disproportionately represented in study area
  - Consistent with Federal guidelines (Executive Order 12898, CEQ guidance)
- Approach
  - Collect pertinent demographic, cultural, related data
  - Assess whether minority or low-income populations are disproportionately affected from changes Project operations
- Data
  - Race, income, housing, poverty measures
  - Sources: 2010 Census data (census tract level)
- Relicensing alternative-based analysis

Request for Additional Information

- Seeking input from relicensing participants
- Relevant data and/or studies
- Information contacts

Schedule & Next Steps

- Baseline conditions: research/analysis through Q1 2013
- Study report to be completed Q2 2013
  - Baseline economic values and benefits
- Analysis of potential future operating scenarios
  - Input for draft and final license application

Temperature Criteria Assessment Meeting
Don Pedro Relicensing Study W&AR-14
November 16, 2012 - 1:00 p.m. to 4:00 p.m. – MID Offices
Call-In Number 866-994-6437 – Conference Code 5424697994

Live Meeting Link:

Join online meeting
https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

First online meeting?

AGENDA

1. **Introductions**

2. **Purpose of Meeting: Report and Discuss Status of Study Plan Implementation**
   - **Original study plan**
   - **FERC Study Determination**
   - **Additional empirical evaluations proposed during April 2012 meeting**

3. **W&AR 14 Study Plan**
   - **Review relevant literature**
   - **Develop water temperature evaluation parameters**
   - **Relate baseline water temperature conditions to population**

4. **Additional Studies and Evaluations**
   - **Empirical studies proposed by Districts for implementation**
     - **Study 1: Local Adaptation of Temperature Tolerance of *O. mykiss* Juveniles in the Lower Tuolumne River**
     - **Study 2: Spatial distribution juvenile *O. mykiss* in response to temperature**
     - **Study 3(b): Influence of temperature on growth of Chinook salmon**
     - **Study 7: Influence of temperature on pre-spawning of Chinook salmon**
   - **Empirical studies proposed by Districts at April meeting, but not proposed for implementation at this time**
     - **Study 3(a): Influence of temperature on growth of O. mykiss**
     - **Study 4: Effect of temperature on condition/health of Chinook salmon**
     - **Study 5: Influence of temperature on location, movement, survival potential of *O. mykiss*.**
     - **Study 6: Influence of temperatures during the early Chinook salmon spawning period on egg survival.**
     - **Study 8: Chinook salmon production related to precedent temperature conditions**

5. **Next Steps and Study Schedule**

TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT FERC NO. 2299

Temperature Criteria Assessment
Water & Aquatic Resources Study #14 Update

November 2012

Eight studies identified by the Districts as potentially yielding empirical evidence on temperature effects in the Tuolumne River were discussed during the April 11, 2012 workshop on *W&AR 14 - Temperature Criteria Assessment Study*. During the workshop, questions were raised concerning data availability and utility to conduct the five studies considered "desktop" studies (Studies 2, 3, 6, 7 and 8) since they would involve evaluation of "existing" data. The studies and their status are briefly described in the following sections. Three additional studies also discussed during the workshop would require additional data collection and potentially Section 10 research permits from NMFS (Studies 1, 4 and 5). Subsequent to the workshop, the Districts have further evaluated the availability and utility of data to conduct the five "desktop" studies and have determined that data are sufficient to conduct all or part of three studies (2, 3 and 7), but are insufficient to conduct all or part of three studies (3, 6 and 8). Additionally, the Districts will proceed with proposed Study 1, but have determined that Studies 4 and 5 will not be pursued further. Further detail on each study is summarized below.

Study 1 - Local Adaptation of Temperature Tolerance of O. mykiss Juveniles in the Lower Tuolumne River

Objective
Determine the temperature tolerance of juvenile and subadult *O. mykiss* captured from the lower Tuolumne River (LTR) to assess any local adaptation to warmer temperatures occurring in the southern extent of *O. mykiss* range.

Status
The Districts have initiated discussions with the National Marine Fisheries Service ("NMFS") in order to obtain a Section 10 permit required to conduct this study. Supporting references for this study are available on the relicensing website with meeting materials.

Approach
Determine optimum and critical temperatures by challenging *O. mykiss* juveniles and subadults to increasing temperature conditions and observing oxygen consumption, following the methods of Parsons (2011)[1].

Speculation on the adaptability of anadromous salmonids to the various, potentially extreme temperature regimes encountered throughout their range suggests that *O. mykiss* in the southern

[1] Parsons, E.J.E. 2011. Cardiorespiratory physiology and temperature tolerance among populations of sockeye salmon (Oncorhynchus nerka). A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Faculty of graduate studies (Zoology) The University of British Columbia (Vancouver) August 2011.

extent of their range may be innately more tolerant of warmer temperature regimes than reported in the literature. The local adaptability of LTR *O. mykiss* would allow better performance at warmer temperatures than would be predicted based on studies of *O. mykiss* populations in the northern extent of the range. A determination that LTR *O. mykiss* are locally adapted to warmer temperatures would support discussions of reassessing optimum temperature thresholds (i.e., relative to EPA 2003)[2] that may be more appropriate for *O. mykiss* in the Central Valley stream system.

This study will evaluate if *O. mykiss* that occur in LTR are locally adapted to higher temperature tolerances that may better define site-specific temperature performance metrics. A case study of temperature tolerance among fishes is likely to prove extremely fruitful in addressing the more general and important question of animal resilience and adaptability to environmental change (Farrell 2009)[3]. Fishes generally have evolved around species-specific niches, living in almost every conceivable aquatic habitat and representing almost half of the earth's vertebrate species (Farrell 2009). Thus, it is expected that *O. mykiss* populations in different parts of the species range would show differences in physiological performance and in other biological traits that reflect adaptations to regional or more localized environmental conditions.

Methods

The Districts would follow methods described by Parsons (2011) and others to evaluate the capabilities of local *O. mykiss* to accommodate warmer temperatures. Specifically, Parsons (2011) studied the respiratory physiological basis for temperature tolerance in sockeye salmon and examined the overall hypothesis that each sockeye salmon population has adapted to meet their specific upriver migration conditions. Swimming respiratory performance was compared over a range of temperatures across wild, migrating adult sockeye salmon populations.

Fish evaluated per Parsons (2011) were tested in Brett-type swim tunnels. The first day (24-hour duration) of the Parsons (2011) study required placement of the fish into the swim tunnel to acclimate the fish to its new environment. The Districts have determined that swim tunnels can be used to measure the optimal temperature ("T_{opt}") and critical temperature ("T_{crit}") for fish 100 to 200 mm fork length ("FL"). The T_{opt} window, as defined by Parsons (2011) is *"the range in temperatures between the upper and lower T_p when maximum aerobic scope is maintained*". Aerobic scope--which is measured at a given temperature--is the observed difference or range between the maximum respiratory performance (i.e., maximum oxygen consumption) and resting respiratory performance (i.e., resting oxygen consumption) at that temperature. The T_p points are the pejus temperatures (pejus means getting worse); therefore, the T_p points are the temperatures where aerobic scope is getting worse (i.e., becomes smaller in width) (**Figure 1**). If a respiratory limitation exists for exercising salmonids during warming, increases in aerobic scope should cease once T_{opt} is reached (Farrell 2009). Ultimately, as warming approaches T_{opt}

[2] EPA. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. Available online at: http://www.epa.gov/region10/pdf/water/final_temperature_guidance_2003.pdf

[3] Farrell, A.P., Commentary – Environmental, antecedents and climate change: lessons from the study of temperature physiology and river migration of salmonids. The Journal of Experimental Biology 212, 3771-3780 Published by The Company of Biologists 2009 doi:10.1242/jeb.023671. Available online at: http://jeb.biologists.org/content/212/23/3771.full.pdf

the potential to increase maximum respiratory performance (oxygen consumption by exercising fish) fails to keep up with the required increase in respiratory rate in a resting fish (Farrell 2009). As a result, because aerobic scope does not increase above T_{opt} (Fig. 5), swimming effort either declines or stops (Farrell 2009).

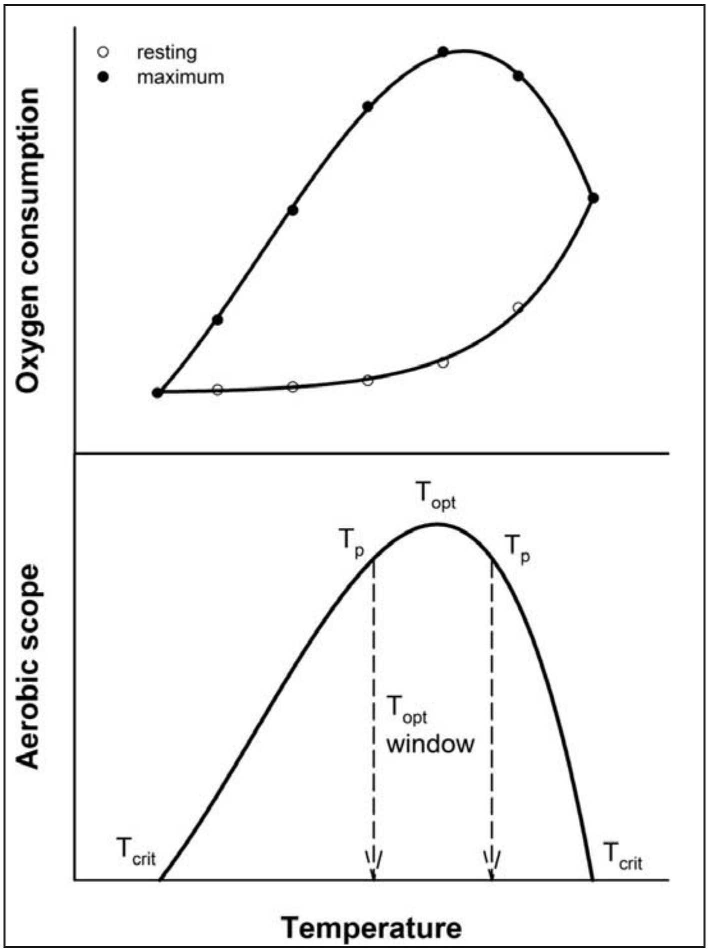


Figure 1. Schematic of resting and maximum oxygen consumption and aerobic scope. See text for details. T_{opt} = optimum temperature, T_p = pejus temperatures, T_{crit} = critical temperatures. The T_{opt} window corresponds to the range of temperatures between the upper and lower T_p (Source – Parsons 2011).

The primary goal of the swim tunnel experiment would be to determine the temperatures that bound the T_{opt} window for LTR *O. mykiss*, and how rapidly aerobic scope declines between the upper T_p and T_{crit}. These temperatures and the shape of the aerobic scope curve could then be compared with those of other *O. mykiss* populations to determine if there is evidence for local temperature adaption for LTR fish compared to more northern populations. These results could also be applied to assess relative responses to temperatures including potential variation in observed T_{opt} compared to EPA (2003) criteria, and relative performance between T_{opt} and Tcrit.

This assessment could help define more accurate criteria for evaluation of temperature tolerance for juvenile *O. mykiss* rearing.

Juvenile *O. mykiss* would be collected from the LTR during spring 2013, using seining or similar methods that would need to be approved by CDFG and NMFS in a 4d or Section 10 permit. Parsons (2011) indicates that between 25 and 30 individuals would be needed for the study. After collection in the field, individual fish would be placed into the Brett-type swim tube for a period of 24 hours to acclimate to the equipment. The experiment would be conducted during the second day once the fish have acclimated to the tube. Following completion of the experiment, fish would be held until they recover. Once recovered, fish would be released further downstream of the initial capture location. One fish per swim tube per use-day would be needed. Results of previous, similar tests conducted by the investigators indicate that the risk of mortality resulting from the test is extremely low.

The study will comprise of four tasks:

Task 1. - Planning and Logistics

- Apply for a 4d Permit or Section 10 Research Permit from NMFS to collect and evaluate up to 30 *O. mykiss* from the LTR
- Secure laboratory equipment and personnel to conduct field evaluations
- Identify source (method) and personnel to collect fish
- Finalize schedule based on permit process and personnel and equipment availability Set up stream-side facilities for tests

Various questions will need to be resolved per this task, including the method to be used to collect the test fish. Based on previous year's RST trapping results on the LTR, the likelihood is that sufficient numbers of *O. mykiss* will not be available from RST captures in a timely manner. Seining surveys of the lower Tuolumne River being conducted by FISHBIO for the Districts have shown seining can most likely be used to successfully capture juvenile *O. mykiss* during the spring to support this study. The abundance of seine-caught *O. mykiss* has been low, less than would be required for the study. However, the abundance of fish required, up to 30 over a 30 day period, would likely be accommodated with an increase in seining effort and an expansion in sampling locations. Other methods of acquiring test fish need to be considered, potentially in conjunction with RST trapped fish, to be used in an opportunistic manner. Ultimately, a Section 10 permit would dictate the allowable capture method. Additionally, the potential effect of the capture method on the ability to acclimate the fish and to conduct the study would need to be evaluated prior to requesting the NMFS permit.

The required test equipment would be available for lease from the University Of British Columbia ("UBC"). Alternative sources of equipment may be available locally and will be explored.

The permit application process has been started which will include informal discussions with NMFS staff to identify specific study details necessary to determine the potential utility of the study and associated take, as determined by NMFS. The application process includes confirmation of options for collecting fish, the details of holding, acclimating, testing, and post-testing and how the tests are to be conducted at "streamside". Logistical requirements would be identified and accommodated based on the permit.

Task 2. - Fish collection and testing
The conduct of the testing is proposed to occur during spring of 2013 . The targeted species will be *O. mykiss*, ranging in size from ~ 100 mm to 200 mm (FL). Based on current studies being conducted by the Districts to collect *O. mykiss* for an age structure evaluation, collection of *O. mykiss* via angling has successfully yielded fish in this range (primarily between 150 and 200 mm FL. The results of the age structure survey should be included in an assessment of the timing of the study (e.g., if the targeted size can be obtained by angling earlier or later), of if the targeted size should be increased.

Task 3. - Data analysis and QA/QC
Data analysis and QA/QC would be conducted by UBC with and UCD personnel

Task 4. - Report
A report will be prepared and submitted to agencies and FERC.

Schedule
The Districts anticipate the schedule to complete the study proposal as follows, assuming appropriate permits are obtained from NMFS and CDFG by spring 2013:

Prepare implementation plan and other information necessary to prepare and submit Section 10 Permit to NMFS (Task 1) …………………………….………October-November 2012

<u>Schedule</u>
Prepare for field survey…………………………………………..…..… February-March 2013
Collect test fish and conduct field evaluations (Task 2)……………………… March-April 2013
Conduct QA/QC and data analysis (Task 3)..May-June 2013
Prepare and deliver final report (Task 4)... July-September 2013

Study 2. Spatial distribution juvenile O. mykiss in response to temperature

Objective
Identify temperature thresholds that define rearing temperature tolerances for juvenile *O. mykiss* rearing.

Status
Data availability and utility have been determined to be sufficient to support conduct of this study.

Approach
Compare intra and inter annual distribution of juvenile *O. mykiss* rearing relative to precedent temperature conditions in the LTR.

This study is intended to provide empirical evidence of the influence of temperature on juvenile *O. mykiss* rearing. The expectation is that *O. mykiss* will occupy areas as long as temperatures are tolerable for their survival. This study will compare occupancy with precedent temperature conditions to potentially bracket a threshold for rearing temperature tolerance. Inter-annual variations in longitudinal distribution of *O. mykiss* would be related to differences among temperature gradations. For example, when O. *mykiss* are present within a particular reach of the river subjected to one temperature regime but not there during a different (assume warmer) temperature regime, occupancy versus precedent temperature conditions would be considered an indicator of temperature tolerances. As such, temperature tolerances would be reflected in the response (occupied or vacated) to temperature longitudinally within and among years using existing information on spatial distribution of juvenile rearing and concurrent temperatures.

Existing data have been identified that includes survey results showing longitudinal distributions of *O. mykiss* and data will be subject of a QA/QC assessment to determine if they meet the needs of this study. Some of the results include fish density and some of the surveys occurred seasonally (during both the cool and warm seasons). An example of the data that could support this study is summarized by Stillwater Sciences (2012)[4] and is provided below as Table 1.

Table 1. Example of distribution data available to conduct this study (Stillwater 2012).

Table 3. Tuolumne River reference count snorkel survey locations (2001-2011) with number of *O. mykiss* observed.

Location	River Mile	2001		2002		2003		2004			2005	2006	2007		2008	2009	2010		2011	
		June	September	June	September	June	September	June	August	September	September	September	June	September	June	June	August	November	September	November
Riffle A3/A4	51.6								5											
Riffle A7	50.7	7	3	5	1	66	16	12	6	11	10	115	106	75	76	80	35	33	249	6
Riffle 1A	50.4								4											
Riffle 2	49.9	3	3	1	4	8	2	23	2	7	7	15	34	16	9	12	58	67	203	27
Riffle 3B	49.1	8	1	11	1	5	21	22	5	7	6	66	45	12	78	27	73	67	261	8
Riffle 4B	48.4								8											
Riffle 5B	48.0	4	2	3	X	6	10	11	15	6	36	54	92	10	21	11	26	16	149	41
Riffle 7	46.9	4	X	5	2	14	9	13	5	2	2	106	22	7	13	6	25	6	88	9
Riffle 9	46.4								3											
Riffle 13A–B	45.6	3	X	2	4	1	6	5	13	X	46	103	15	57	24	4	33	14	129	8
Riffle 21	42.9	2	3	1	X	X	6	5	9	7	15	32	10	10	11	X	8	2	33	8
Riffle 23B–C	42.3	X	X	X	X	1	1	X	1	X	14	27	5	7	X	2	9	10	52	32
Riffle 30B	38.5			X	X															
Riffle 31	38.1	X	X			X	X	X	X	X	1	21	12	4	X	X	1	X	10	2
Riffle 35A	37.0			X	X	X	X	X	X	X	2		X	X	X	X	X	X	3	X
Riffle 36A	36.7											4								
Riffle 37	36.2	X	X																	
Riffle 41A	35.3	X	X	X	X	X	X	X	X	X	X	X	2	X	X	X	X	3	2	6
Riffle 57–58	31.5	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	1
Total *O. mykiss*		**31**	**12**	**28**	**12**	**101**	**71**	**91**	**76**	**40**	**139**	**543**	**343**	**198**	**232**	**142**	**268**	**218**	**1179**	**148**

X = Locations that were sampled with no *O. mykiss* observed.

We would evaluate the spatial distribution of rearing *O. mykiss* relative to temperature precedent conditions to identify temperatures where occupancy continued and occupancy ended. The temperature regime where occupancy continued would be considered tolerable and the regime where occupancy ended would be considered intolerable.

4 Stillwater Sciences (2012). Tuolumne River 2011 Oncorhynchus mykiss monitoring summary report. Final Report. Prepared for Turlock Irrigation District and Modesto Irrigation District.

Response to temperature in the form of occupancy will be identified within years as seasonal temperatures increase and occupancy either continues or ends, and inter annually where sites known to be occupied during the later, warmer period at least once during the 10 year period would be evaluated to determine if and under what precedent temperature conditions occupancy either continued or ended.

Where occupancy continued, the temperature regime would be considered tolerable, where occupancy was not observed, precedent temperature conditions would be considered intolerable. Temperature conditions would be characterized by several, acceptable metrics (used by other investigators to describe temperature conditions relative to fish tolerance), including 7DADM, daily max, mean daily, etc.

For example, if mean daily temperatures increased from May to September, from 15 to 20 ^{o}C and fish continue to occupy the site, the mean daily temperature of 20 ^{o}C would be considered tolerable (for the lifestage/age of fish size etc). If site A is occupied in year 1 when September temperatures are 19 ^{o}C but not in year 2 when September temperatures were 25 ^{o}C, 25 ^{o}C would be considered intolerable, 19 ^{o}C tolerable. The expectation is that the variation in temperature conditions within the 10 year period would be sufficient to broaden understanding of temperature tolerances within the LTR.

This study assumes that distribution is influenced by changes in longitudinal temperature distribution between winter and late-summer/ early-fall.

The following are hypotheses for this specific empirical study:

- Longitudinal temperature gradient along LTR changes from winter to summer as temperatures changes increase with distance downstream from La Grange Dam.
- Spatial distribution, observed as presence/absence and potentially as density, along the Tuolumne River should change between winter and summer corresponding to change in temperature. *O. mykiss* should occur in those areas where temperature meets criteria and should not where temperatures exceed criteria, between winter and late-summer, early-fall.
- Spatial distribution, observed as presence/absence and potentially as density, along the LTR should change between years corresponding to different temperature regimes. Observed relationships between temperature distribution and O mykiss distribution should allow identification of temperature tolerance or intolerance.
- Data are available under various annual temperature regimes that range from substantial change in temperature from winter to fall, to temperature conditions meeting identified thresholds (EPA 2003) throughout a substantially great portion of the Tuolumne River.

The data to be used in the evaluation has been identified and evaluated for applicability and quality and will be used to conduct an evaluation to determine the potential level of confidence that can be obtained from the evaluation.

Study 3. Influence of temperature on growth of O. mykiss and Chinook salmon

Objective

Evaluate influence of temperature on growth of O. mykiss and Chinook salmon juveniles in the LTR by comparing growth observed in the LTR with that reported in the literature and, in particular, observed in other Central Valley streams supporting *O. mykiss* and Chinook salmon populations.

Status

Evaluation of the availability and utility of data to support this study has shown that data are not available to conduct an evaluation of the observed influence of temperature on growth of *O. mykiss*. Data are available and suitable for conducting an evaluation of observed temperature influences on growth of fall-run Chinook salmon.

Approach

Compare observed size at time/age, interpreted as growth, of *O. mykiss* and Chinook salmon in the LTR with expected growth based on literature and growth rates observed/reported in other, similar waters. Relate temperature regime associated with observed growth in the LTR to identify those temperature conditions that either support or do not support expected growth.

This study would evaluate growth of *O. mykiss* and fall-run Chinook salmon in the LTR as a function of precedent temperature conditions. Growth would be evaluated by comparing observed growth in the LTR with expected growth to be defined based on the literature or observations from other similar watersheds, including the Merced, Stanislaus, Mokelumne, and American rivers. The size at time, to be estimated based on timing of spawning and emergence, (as data are available), would be contrasted with reported, acceptable or expected size at time.

Concern has been expressed that Chinook salmon growth in the LTR is too slow, potentially delaying Chinook salmon from reaching a larger, smolt-sized fish in time to successfully emigrate. For example, growth would be considered as expected if the majority of fall-run Chinook salmon achieve 70-90 mm FL by end of April and essentially all fall-run Chinook salmon have the opportunity to achieve smolt size by the end of May. By tracking RST size composition from the earliest migrating juvenile Chinook salmon, a trend in growth can be identified and the timing and cumulative composition of emigrating smolt-sized fish can be determined and contrasted with the precedent temperature regime to evaluate the effects on Chinook salmon growth.

Data on size of *O. mykiss* at time was to be derived from snorkel surveys conducted in the LTR during the previous 10 years or so, and was to be compared with an expected size at time (defined from literature or observations made in similar waters). However, the data that were to be used were not of sufficient detail to allow such an evaluation. Snorkel-derived data were recorded in size bins that did not adequately identify the size of *O. mykiss* to allow comparisons of growth among streams or even over time in the LTR. Size bins were at least 50 mm wide and routinely the data were reported as fish less than or greater than 150 mm in length. As such, the Districts determined that the data would not support the *O. mykiss* growth evaluation component of this study.

This study will evaluate growth of Chinook salmon as described above.

Study 4. Effect of temperature observed as changes in condition/health of Chinook salmon

Objective

This study would evaluate the influence of the temperature regime of the Tuolumne River on Chinook salmon survival potential, measured as specific temperature-related affects to health and condition of smolt or smolt-sized Chinook salmon. The study would evaluate quality of Chinook salmon smolt rearing in the Tuolumne River using methods previously applied by CDFG (Rich and Loudermilk 1991) and USFWS (Nichols and Foote 2002) to assess Chinook salmon condition in the San Joaquin River system

Status: The Districts do not plan to pursue this study. The Districts study lead discussed proposed study goals with Scott Foote, Director of the California-Nevada Fish Health Laboratory. Dr. Foote provided information regarding his experience with Chinook salmon smolt development in the Central Valley, including San Joaquin River tributaries relative to influences of temperature on smolt quality. Dr. Foote stated that although temperature can affect smoltification and in some instances reverse the smolting process, the ability to separate a variety of other factors that can influence smolt quality from those resulting from temperature would not be possible in the wild. Parameters of smolt quality, including hormone levels, lipid content, etc can vary within an individual within short periods, potentially varying simply due to ontogenetic factors as well as exogenous factors, and these variations are normal in smolting Chinook salmon, and as such are not necessarily indicative of stressors or adverse effects. Based on these discussions, the Districts are not planning on pursuing the study.

Study 5. Influence of temperature on location, movement, survival potential of O. mykiss.

Objective

Acoustic tagging *O. mykiss* during early summer in various locations within the LTR with various temperature expectations and monitor movement and survival to emigration.

Status

The Districts will not pursue implementation of this study. Although the Districts believe that the study would provide important information on LTR *O. mykiss* life history including potential responses of *O. mykiss* to various temperature conditions during rearing and migration within the LTR, the study would not be expected to provide empirical information informative to FERC for three years or more. Additionally, the scope of the study is well beyond temperature, and its greatest value would likely be informing the larger fish management community on a variety of currently unknown aspects of steelhead ecology in the San Joaquin River and Central Valley, which ultimately would require substantial logistic and technical support, and is beyond the scope of this relicensing.

Study 6. Influence of temperatures during the early Chinook salmon spawning period on egg survival.

Objective

Identify the relationship between temperature and egg-fry survival in the LTR. Study would evaluate the influence of observed temperature conditions during spawning on Chinook salmon spawning (egg to emergence survival).

Status

The Districts will not to pursue implementation of this study. The Districts determined that data required to conduct this study are not available. Data on emergence of Chinook salmon fry from redds within the LTR are available, but those data are not associated with temperature conditions, were not complete, or were too few to allow evaluation of influences of temperature on redd survival.

Study 7. Influence of temperature on pre-spawning mortality of Chinook salmon

Objective

Identify adult Chinook salmon response to typically warmer temperatures occurring in the LTR in the early portion of the spawning period. Evaluation of inner inter-annual timing of spawning will be compared with temperatures during early spawning period using redd surveys or carcass survey results to identify temporal distribution of early spawning, and pre-spawning mortality, potentially measured as egg retention during carcass surveys.

Status

The Districts have reviewed the data available for this study and have determined that there are data available of sufficient quality to conduct the study.

Study 8 - Chinook salmon production related to precedent temperature conditions

Objective

Identify influence of cumulative temperature regime, from spawning through emigration, on Chinook salmon emigrating population (e.g., abundance, composition, timing, survival-per-spawner). Evaluate estimated Chinook salmon production relative to temperature conditions during spawning.

Status

The Districts have decided not to pursue implementation of this study. The Districts gathered and reviewed data on estimated production of juvenile Chinook salmon obtained from RST monitoring during recent years. These data included estimates of production of emigrating juvenile Chinook salmon per female spawner. Additionally, precedent temperature conditions were characterized as accumulated temperature units (“ATU”) from spawning through emigration to determine if ATU was related to estimated production. The Districts determined that the estimated production, a key variable in the evaluation, did not have the level of confidence that would allow distinction among the years when emigration was estimated.

From: Borovansky, Jenna
Sent: Thursday, November 15, 2012 7:04 PM
To: Staples, Rose; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; McLain, Jeffrey; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne; ulibarri@standard.edu
Subject: MEETING TIME CHANGE: Don Pedro Relicensing WAR14 Meeting - Start at 9am
Attachments: DP_TempCriteriaAssessmtMtg_Nov16_AGENDA_Revised.doc

Importance: High

The WAR-14 Temperature Criteria Study Meeting scheduled for 1-4pm on Friday (11/15) will be moved to **begin at 9am on Friday (11/15).**

The same phone number and live meeting link will be used for the meeting.

Mape's Ranch
and
Lyons' Investments
10555 Maze Road Modesto, CA 95358
Office: (209) 522-1762 FAX: (209) 522-7871

November 16, 2012

John J. Devine, PE
HDR
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Portland, ME 04103-5346

Duane Paul
Cardno Entrix
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Sacramento, CA 95825

Steve Pavich
Cardno Entrix
701 University Ave., Suite 200
Sacramento, CA 95825

Re: Socioeconomics Study Meeting

Dear Steve, Duane, and John:

I wanted to personally thank you for the opportunity to discuss and provide input regarding the Socioeconomic Study at the FERC workshop held in Modesto at MID on 11-09-12.

I would again encourage you from an agricultural perspective to contact organizations such as; **A) Financial** – Yosemite Farm Credit, Joe Mauzy and Steve Mizuno, 1213 – 13th Street, Modesto, CA 95354, (209) 527-1900; American Ag Credit, Ted Reimers, 3201 W. Monte Vista Ave., Turlock, CA 95380, (209) 667-5101. **B) Farm Appraisal Values** – Way & Associates, Tina & Bruce Way, 4248 Tully Road, Hughson, CA 95326, (209) 883-2796; Edwards, Lein & Toso, Randy Edwards, 8408 N. Lander Ave., Hilmar, CA 95324, (209) 634-9484. **C) Sales** – Lane Menezes, PMZ Real Estate, 1200 E. Orangeburg Ave., Suite 201, Modesto, CA 95350, (209) 527-5640. **D) Farmers** – Farm Bureau, Wayne Zipser, (209) 522-7278; Western United Dairymen, Mike Marsh, (209) 527-6453 to line up some on the ground dairymen, farmers, and ranchers to expand your input and validate your information.

I was personally surprised and disappointed by the lack of attendance by organizations and groups such as the Chamber of Commerce (Modesto, Turlock, Ceres), Manufacturers Council, Stanislaus Economic Development & Workshop Alliance, Stanislaus County Taxpayers Association, Latino Community Roundtable, Senior and Low Income advocates, organized labor, BIA, Stanislaus County, cities of Ceres, Hughson, Turlock, Denair, Waterford, Hilmar, etc. The only elected leader in attendance was Tom Van Groningen from MID, along with Tom Orvis from Farm Bureau, several farmers, several ratepayers, and various staff from MID, TID, City of Modesto, and one representative from Tuolumne River Trust.

It is very apparent that the outreach to the community has seriously missed the mark as demonstrated by such low attendance at this workshop/meeting. Statements from MID and TID staff that they sent out emails, put a notice in the paper, etc. appears to have failed in conveying to the local organizations, the public, and ratepayers how important this workshop was.

Suggestions

1. Personal Contact - Staff needs to make personal contact with the groups that represent these large blocks of ratepayers and personally encourage their engagement and input. Also, staff should request and follow up with senior leadership and board members to personally reach out to the community and encourage engagement and input.

2. Workshop – Hold one evening meeting so that ratepayers and interested parties can attend.

3. Retention – Perhaps contract with a local professional outreach firm to inform, encourage and follow up with the community and its many organizations. Base a contract on performance.

I would hope that both MID and TID's staff were disappointed by the low turnout. As a former MID board member, I would certainly question the outreach plan/effort and the need to change the outreach effort/plan.

The FERC workshop process is very important and the Socioeconomic Study workshop is an area that would benefit greatly from input from many of these organizations.

Sincerely,

Bill Lyons

William (Bill) J. Lyons, Jr.

Cc:
MID Board
TID Board
MID Staff
TID Staff
Modesto Chamber of Commerce
Turlock Chamber of Commerce
Ceres Chamber of Commerce
Manufacturers Council
Latino Community Roundtable
Stanislaus Alliance, Bill Bassitt
Wayne Zipser, Farm Bureau
Ted Reimers, American Ag Credit
Tina Way, Way & Associates
Randy Edwards, Edwards, Lein & Tosso
Mike Marsh, Western United Dairymen
LTF Members
Chris Vierra, Ceres Mayor
Ramon Bawanan, Hughson Mayor
John Lazar, Turlock Mayor
Garrad Marsh, Modesto Mayor

WJL/crc

From: Staples, Rose
Sent: Friday, November 30, 2012 5:20 PM
To: 'Timothy D. Findley'
Subject: RE: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

A list of the Action Items from the meeting is being prepared—along with information on significant areas of discussion--and will eventually be forwarded by email and posted on the relicensing website; but I don't have a date yet when this will be available.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com | hdrinc.com

From: Timothy D. Findley [mailto:TFindley@hansonbridgett.com]
Sent: Thursday, November 29, 2012 4:49 PM
To: Staples, Rose
Subject: RE: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

Great. Thanks, Rose. I appreciate it.

From: Staples, Rose [mailto:Rose.Staples@hdrinc.com]
Sent: Thursday, November 29, 2012 1:48 PM
To: Timothy D. Findley
Subject: RE: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

Let me check further into this and get back to you hopefully tomorrow, if not sooner. Thank you.

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From: Timothy D. Findley [mailto:TFindley@hansonbridgett.com]
Sent: Thursday, November 29, 2012 1:32 PM
To: Staples, Rose
Subject: RE: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

Hi Rose.

I hadn't heard back from you, so I'm just following up again regarding whether there were any official meeting notes for the 11/9 socioeconomic meeting.

Thanks,

-Tim

From: Timothy D. Findley
Sent: Friday, November 09, 2012 11:55 AM
To: 'Staples, Rose'
Subject: RE: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

Hi Rose.

Unfortunately, I wasn't available to attend or call in to today's socioeconomic study update meeting. Will there be official meeting notes released for the meeting?

Best,

-Tim

Timothy D. Findley
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From: Staples, Rose [mailto:Rose.Staples@hdrinc.com]
Sent: Thursday, November 08, 2012 4:35 PM
To: Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug;

Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Timothy D. Findley; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; Ray E. McDevitt; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Allison C. Schutte; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Socioeconomics Study and Temp Criteria Assessment Meetings Materials Uploaded to Relicensing Website

I have uploaded to the Don Pedro relicensing website (www.donpedro-relicensing.com) today, ***as attachments to the Meeting calendar for their respective meeting dates***, the following meeting materials:

Socioeconomics Study (W&AR-15) Progress Update Meeting, Friday, November 9
PowerPoint Presentation being used at the meeting

Temperature Criteria Assessment (W&AR-14) Meeting, Friday afternoon, November 16
Agenda updated with the LIVE MEETING link
Study Update

If you are not able to access or download these documents, please do contact me at rose.staples@hdrinc.com.

Thank you.

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From: Staples, Rose
Sent: Thursday, December 06, 2012 5:26 PM
To: 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Beniamine Beronia'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Minami Amber'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pinhey, Nick'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Ulibarri, Nicola'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Initial Study Report 2-Day Meeting AGENDA January 30-31, 2013

We have filed with FERC today, on behalf of the Districts, the AGENDA for the upcoming January 30-31, 2013 Initial Study Report Meeting, to be held at the MID Offices in Modesto. A copy of this AGENDA will also be uploaded to the Don Pedro relicensing website www.donpedro-relicensing.com, both as an attachment to the MEETING DATE and as an Announcement under the INTRODUCTION tab.

DON PEDRO PROJECT RELICENSING
FERC PROJECT NO. 2299

DAY 1

Initial Study Report Meeting (Day 1)
Wednesday January 30, 2013 8:00 am – 5:15 pm
Meeting Location: MID Offices, Modesto

Time	Topic		Lead By
	Water & Aquatic Resources Study Plans		
8:00	**Opening** – Agenda Review, Purpose of Meeting		
8:15	W&AR-15	Socioeconomics Study	S. Pavich/D. Paul
8:40	W&AR-01	Water Quality Assessment	C.Loy
9:05	W&AR-02	Project Operations/Water Balance Model	D. Steiner
9:30	W&AR-03	Reservoir Temperature Model	S. Lowe
9:55	W&AR-04	Spawning Gravel Study	J. Stillman
Break – 10:20			
10:35	W&AR-05	Salmonid Populations Information Integration	N. Hume/S. Wilcox
11:00	W&AR-06	Tuolumne River Chinook Salmon Population	N. Hume
11:25	W&AR-10	*Onchorhynchus mykiss* Population Study	N. Hume
Lunch Break – 11:50			
12:50	W&AR-07	Predation Study	A. Fuller
1:15	W&AR-08	Salmonid Redd Mapping	J. Guigard
1:40	W&AR-11	Chinook Salmon Otolith Study	M. Singer
2:05	W&AR-12	*Onchorhynchus mykiss* Habitat Assessment	D. Halligan
2:30	W&AR-13	La Grange Reservoir Fish Assemblage and	B.Snider
Break – 2:55			
3:10	W&AR-14	Temperature Criteria Assessment	B. Snider
3:35	W&AR-17	Don Pedro Reservoir Fish Population Study	A. Fuller/B.Snider
4:00	W&AR-18	Sturgeon Study	D. Haligan
4:25	W&AR-19	Riparian Information Study	A. Merrill
4:50	W&AR-20	*O.mykiss* Scale & Age	D. Halligan

Time		Topic	Lead By
Water & Aquatic Resources Study Plans			
5:15		Adjournment	

DAY 2

Initial Study Report Meeting (Day 2)
Thursday January 31, 2013 8:00 am – 4:25 pm
Meeting Location: MID Offices, Modesto

Time		Topic	Lead By
Cultural Resources Studies			
8:00	**Opening** – Agenda Review, Purpose of Meeting		
8:15	CR-01	Historic Properties Study	D. Risse
8:40	CR-02	Native American Traditional Cultural Properties	D. Risse
Terrestrial Resources Studies			
9:05	TR-01	Special-Status Plants	R. Kent/D. Malkin
9:30	TR-02	ESA- and CESA-Listed Plants Study	R. Kent/D. Malkin
9:55	TR-03	Wetland Habitats Associated with Don Pedro	G. Bailey/D. Malkin
Break – 10:20			
10:35	TR-04	Noxious Weed Survey	R. Kent/D. Malkin
11:00	TR-05	ESA-Listed Wildlife - Valley Elderberry Longhorn	R. Kent/D. Malkin
11:25	TR-06	Special-Status Amphibians-Aquatic Reptiles	S. Imholt/D. Malkin
11:50	TR-07	ESA-Listed Amphibians - California Red-Legged	S. Imholt/D. Malkin
Lunch Break – 12:15			
1:15	TR-08	ESA-List Amphibians - California Tiger Salamander	S. Imholt/D. Malkin
1:40	TR-09	Special-Status Bats	J. Tortosa/D. Malkin
2:05	TR-10	Bald Eagle Study	J. Tortosa/D. Malkin
Recreation Resources Studies			
2:30	RR-01	Recreation Facility and Public Accessibility	N. Craig

Time		Topic	Lead By
		Cultural Resources Studies	
Break – 2:55			
3:10	RR-02	Whitewater Boating Take Out Improvement	N. Craig
3:35	RR-03	Lower Tuolumne River Boatable Flow Study	N. Craig
4:00	RR-04	Visual Quality Study	N. Craig
4:25		**Adjournment**	

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From: Staples, Rose
Sent: Wednesday, December 12, 2012 5:44 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Anderson, Craig'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Beniamine Beronia'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Minami Amber'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pinhey, Nick'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Ulibarri, Nicola'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro W-AR-14 Temp Criteria Assessment Draft Nov 16 Update Meeting Notes for Review
Attachments: P-2299_W-AR-14_Nov 16_UpdateMtgDrftNotes_121212.docx

Attached please find the DRAFT Meeting Notes from the Don Pedro Project Relicensing Water & Aquatic Resources (“W&AR”) Study No. 14: Temperature Criteria Assessment update meeting held on

November 16, 2012. The materials listed under ***Action*** Items for uploading to the relicensing website www.donpedro-relicensing.com are in the process of being uploaded this week.

While Study No. 14 and the notes resulting from its update meetings do not fall under the Workshop Consultation Protocol, we wanted to give relicensing participants the opportunity to review the notes before we file them with FERC. Could you please provide any comments on the draft notes to me at rose.staples@hdrinc.com by no later than Wednesday, December 19. Thank you.

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Don Pedro Project Relicensing
W&AR-14 Temperature Criteria Assessment
(Chinook salmon and *O.mykiss*)
DRAFT Summary Meeting Notes

Friday, November 16, 2012
MID Offices, Modesto CA

Attendees

Bill Sears (CCSF)	Bill Johnston (MID)
Noah Hume (Stillwater Sciences)	Greg Dias (MID)
Karl English (LGL)	Bob Nees (TID)
Ron Yoshiyama (Consultant)	Art Goodwin (TID)
John Devine (HDR)	Allyson Boucher (TRC)
Bao Le (HDR)	Ramon Martin (USFS)
Allison Willy (USFWS)	Mike Maher (SWRCB)
Peter Barnes (SWRCB)	

Attended via phone:	
Bill Snider (HDR)	
Jim Hastreiter (FERC)	
Patrick Koepele (TRT)	
Ellen Levin (CCSF)	
Tim Findley (HB)	
Donn Furman (CCSF)	

Meeting Summary

Following introductions, John Devine (HDR) reiterated that the purpose of this meeting was to provide relicensing participants with an update on the status and progress of W&AR-14, the study that is evaluating temperature criteria for Tuolumne River Chinook salmon and *O.mykiss*. Mr. Devine indicated that as this study was not included under the Workshop Consultation Protocols, only brief meeting notes would be provided.

Mr. Devine then provided background information on W&AR-14, referencing the Districts' Revised Study Plan filed in November 2011 and FERC's Study Plan Determination in December 2011. In the Study Plan Determination, FERC staff indicated they would use the temperature guidelines of EPA 2003 and therefore recommended that the study not be undertaken, unless the study developed empirical data that was site-specific to the Lower Tuolumne River salmonids. An initial study meeting was held on April 11, 2012 where the Districts indicated that they would continue to proceed, but would concentrate on studies that would develop site-specific empirical information, consistent with FERC staff's guidance/determination. Eight possible studies were then presented at the April 11, 2012 meeting.

Mr. Devine advised that the Districts, upon further evaluation, have now reduced this number to four proposed studies, one being a new investigation not previously discussed. Thus, the purpose of this meeting was to review with relicensing participants these four proposed studies.

A participant asked Jim Hastreiter (FERC) how FERC would deal with a study that FERC staff did not recommend be undertaken. Mr. Hastreiter indicated that FERC staff would consider studies that provided Tuolumne River empirical data. Mr. Devine indicated that it was the Districts' understanding that the purpose of the FERC Study Plan Determination was to identify the studies **required** to be undertaken by the Districts, but not to limit the studies. The Districts were free to undertake other studies, just as are the relicensing participants. Mr. Hastreiter agreed.

Mr. Devine also explained that with the re-scoping of these planned studies, they will now become 2013 studies and a detailed schedule will be included in the Initial Study Report ("ISR") document scheduled to be issued on January 17, 2013.

Patrick Koepele (TRT) asked if there were meeting notes for the April 11, 2012 meeting. Mr. Devine indicated that the pre-meeting package contained a large amount of information and a number of handouts, but noted that as this is not a study to which the Workshop Consultation protocols applied, there were no subsequent meeting notes.

Mr. Devine introduced Karl English of LGL Consultants who presented the proposed Swim Tunnel Study. Mr. English pointed out that this study is being pursued by the Districts to investigate effects on Tuolumne River salmonids of being exposed to temperatures different than EPA 2003 guidelines and to investigate the potential for site-specific adaptations to Tuolumne River temperatures. EPA 2003 identifies optimum temperatures, but this study will investigate effects at sub-optimal temperatures. Mr. English referenced findings from studies done on the Fraser River in British Columbia on sockeye that showed considerable local adaptation to temperatures even within the same river, which are indicative of localized life history strategies. Mr. English described the study methods, basically consisting of measurements of oxygen uptake.

Mr. Hastreiter asked if there would be actual measurements of blood gas levels. Mr. English indicated no, but that there are known relationships between blood gas levels and O2 concentrations. Mr. English indicated that oxygen consumption level in the swim tube is what will be measured. There would be no blood or bodily fluid samples. During exercise trials, the oxygen is fixed and will deplete over time so as to act as the control measurement.

Ramon Martin (USFWS) asked if the data presented to show local adaptations are statistically significant. Mr. English agreed to check this and see how the curves were compared in the Eliason et al. 2012 paper and provide feedback. It appeared that the Parsons paper dealt with this. The Districts will upload the Parsons paper to the website. The Districts also agreed to upload the Farrell paper discussed at the meeting, along with Mr. English's presentation.

Bill Snider (HDR) then provided an update on NMFS consultation related to the necessary Section 10 permitting for the Swim Tube Study. The Districts are currently working through the lengthy Section 10 permitting application online. There have been discussions with NMFS staff and the study appears to be doable in 2013. Once the application is completed, detailed consultations will ensue with NMFS, followed by a public notice in the Federal Register. The scope is currently being refined per NMFS comments and the Districts are hoping to file the application soon. It looks as though the earliest for permit issuance would be April of next year. NMFS' primary questions concerned fish acquisition and study area security.

Mr. Martin noted that in the Districts' permitting conversations with NMFS, they need to make sure to convey that this work is in consultation with agencies and to make sure that it is consistent with the number of research permits allowed in the basin. Mr. Martin indicated that USFWS has a Section 10 permit.

Mr. Martin asked if a detailed study plan will be prepared. Mr. Devine agreed to provide an updated W&AR-14 Study Plan for relicensing participants to review. He made it clear that the Districts were not going to be asking FERC to change its December 2011 Determination; therefore, it would be for information only. The ISR would seem to be a reasonable opportunity to provide the revised study plan.

Mr. Snider then briefly described the updates to the other three site-specific investigations to be undertaken as part of W&AR-14. These were largely reiterations of the April 11 discussions.

Mr. Hastreiter asked when the full description of the studies was sent out. Bill Snider said they were uploaded to the website on November 8, 2012 and participants notified. Mr. Hastreiter also asked if the other three studies could be characterized as desktop studies. Mr. Snider responded yes, but they are all based on Tuolumne River specific data.

Mr. Snider pointed out that CDFG redd surveys and adult weir data will be needed to look at timing of spawning vs. temperature.

Art Godwin noted that the study information write-up does not distinguish between Chinook and O.mykiss evaluations as different studies. This will be clarified as appropriate.

Mr. Martin asked if study W&AR-20 could be discussed briefly. He asked how many fish would be used. Noah Hume (Stillwater Sciences) said 70-75 fish, as limited by permits. Mr. Hume also noted that the Zimmerman report has data that can be used as well. This should result in a fairly robust data set. Mr. Martin wondered if the Districts could back calculate the Zimmerman work to temperature data for those years. This would require a number of additional assumptions. The Districts will look into this.

<u>Action Items:</u>

(1) Upload the Fry, Farrell, and Parsons papers to the website.
(2) Upload Karl English's presentation to the website.
(3) The Districts will develop study plans for the four temperature criteria studies to be provided in the Initial Study Report (ISR) to further facilitate discussions/review/comment.

The Journal of Experimental Biology 212, 3771-3780
Published by The Company of Biologists 2009
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Commentary

Environment, antecedents and climate change: lessons from the study of temperature physiology and river migration of salmonids

A. P. Farrell

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Accepted 19 August 2009

Summary

Animal distributions are shaped by the environment and antecedents. Here I show how the temperature dependence of aerobic scope (the difference between maximum and minimum rates of oxygen uptake) is a useful tool to examine the fundamental temperature niches of salmonids and perhaps other fishes. Although the concept of aerobic scope has been recognized for over half a century, only recently has sufficient evidence accumulated to provide a mechanistic explanation for the optimal temperature of salmonids. Evidence suggests that heart rate is the primary driver in supplying more oxygen to tissues as demand increases exponentially with temperature. By contrast, capacity functions (i.e. cardiac stroke volume, tissue oxygen extraction and haemoglobin concentration) are exploited only secondarily if at all, with increasing temperature, and then perhaps only at a temperature nearing that which is lethal to resting fish. Ultimately, however, heart rate apparently becomes a weak partner for the cardiorespiratory oxygen cascade when temperature increases above the optimum for aerobic scope. Thus, the upper limit for heart rate may emerge as a valuable, but simple predictor of optimal temperature in active animals, opening the possibility of using biotelemetry of heart rate in field situations to explore properly the full interplay of environmental factors on aerobic scope. An example of an ecological application of these physiological discoveries is provided using the upriver migration of adult sockeye salmon, which have a remarkable fidelity to their spawning areas and appear to have an optimum temperature for aerobic scope that corresponds to the river temperatures experienced by their antecedents. Unfortunately, there is evidence that this potential adaptation is incompatible with the rapid increase in river temperature presently experienced by salmon as a result of climate change. By limiting aerobic scope, river temperatures in excess of the optimum for aerobic scope directly impact upriver spawning migration and hence lifetime fecundity. Thus, use of aerobic scope holds promise for scientists who wish to make predictions on how climate change may influence animal distributions.

Key words: thermal niches, optimal temperature, aerobic scope, oxygen uptake, metabolic rate, cardiac output, heart rate, tissue oxygen extraction, oxygen partial pressure, biotelemetry, lifetime fecundity, climate change.

Introduction

The study of the physiological and biochemical mechanisms that set the limits for environmental tolerance, and which in many ways distinguish species, is an active area of investigation that has gained importance in the current era of climate change. This article is focused on the physiological mechanisms that become critical when fishes, particularly salmonids, approach their upper temperature limits. Furthermore, to address the need for examples of how large-scale environmental records of climate are translated at the scale of the organism (Helmuth, 2009), this mechanistic understanding is applied to the river migration of an adult Pacific salmon species.

My focus on predominantly one group of fishes (the salmonids) and on one environmental variable (temperature) is for two reasons. First, this is where data are most abundant. Second, a case study of temperature tolerance among fishes is likely to prove extremely fruitful in addressing the more general and important question of animal resilience and adaptability to environmental change. This is because fishes have evolved around species-specific niches, living in almost every conceivable aquatic habitat and representing almost half of the earth's vertebrate species. However, no single fish species tolerates the entire temperature range exploited by fishes (from –2°C in Antarctica to +42°C in Lake Magadi, Kenya). Similarly, ~43% of all fish species live in freshwater rather than the vastly more abundant saline habitats [>99% of the available aquatic habitat (Nelson, 2006)]. Although the foundation for the thermal distributions that we see today may seem to reflect an absence of the requisite genomic machinery, a more circumspect view may be need. For example, Antarctic fishes, which have lived in a thermally stable environment for many thousands of years, are now known to be able to thermally acclimate to temperatures previously thought to be lethal and well above those found in their present ecological niche (Franklin et al., 2007). Thus, observing a stenothermal existence does not necessarily mean insufficient phenotypic plasticity to tolerate a broader temperature range.

Temperature and aerobic scope

Temperature has a central role in shaping the distribution of animals. In explaining latitudinal and longitudinal limits of biomes, Shelford's law of tolerances envisaged a centre of animal abundance bounded by 'toleration' of environmental 'controlling factors' (Fig. 1A). Clearly, the poleward shift in fish distributions with the progressive warming of aquatic habitats (Brander et al., 2003; Brander, 2007; Pörtner and Knust, 2007; Dulvy et al., 2008)

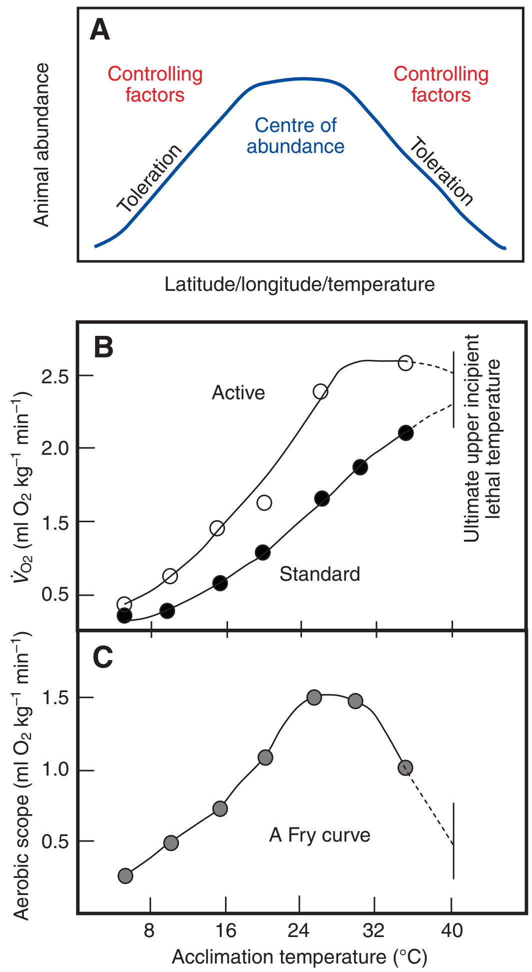

Fig. 1. The controlling and limiting effects of temperature on animal distributions, metabolic rate and scope for activity. (A) A schematic representation of Shelford's law of tolerances (Shelford, 1931). (B) Measurements of standard and active metabolic rates for goldfish as a function of temperature approaching their upper incipient lethal temperature. (C) Aerobic scope (or scope for activity) as a function of temperature, which is the difference between the measurements of standard and active metabolic rates shown in B (Fry, 1947).

represents a more insidious manifestation of the anthropogenic-driven change in animal distribution that Shelford characterised nearly 80 years ago (Shelford, 1931).

Temperature tolerance at the whole animal level was first given a mechanistic explanation for fishes by Fry (Fry, 1947), who showed that temperature both controlled *and* limited their metabolic rate. To illustrate his ideas, he used scope for activity, which is now termed aerobic or metabolic scope, i.e. the difference between standard and active metabolic rates (Fig. 1B,C). In doing so, Fry recognized that the predictive value of knowing the temperature dependence of aerobic scope was considerably greater than that of knowing a temperature tolerance range (e.g. critical maximum and minimum temperatures; CT_{max} and CT_{min}). Indeed, the aerobic scope concept is now being used broadly to examine the impacts of the aquatic warming trends and other environmental climate changes on marine ectotherms (Pörtner, 2001; Pörtner, 2002; Mark et al., 2002; Pörtner and Knust, 2007; Pörtner and Farrell, 2008), illustrating an importance well beyond fishes. Even so, and as shown in the following, our understanding of the proximate causes that limit a fish's aerobic scope beyond its optimal temperature range remains formative.

The Fry curve for aerobic scope

Aerobic scope is derived from measurements of a fish's minimum and maximum rates of oxygen uptake ($\dot{V}_{O2}$) as a function of temperature (Fig. 1B). The difference between these two rates is aerobic scope, which takes the form of a bell-shaped curve as a function of temperature – a 'Fry curve' for aerobic scope (Fig. 1C). Simplistically, a Fry curve represents an animal's capacity for activity as a function of temperature.

Minimum $\dot{V}_{O2}$ (standard or basal metabolic rate) represents the metabolic cost to support an animal's existence in a non-feeding, non-reproducing and non-motile state. Minimum $\dot{V}_{O2}$ is directly affected by body temperature [thermodynamics (Krogh, 1914)], typically doubling or tripling with a 10°C acute increase in temperature (termed a Q_{10} effect; Fig. 1B). Minimum $\dot{V}_{O2}$ also varies among species (a genetic basis) and with body size [scaling (Schmidt-Nielsen, 1984)].

Clearly, life beyond short-term existence requires a capacity to increase $\dot{V}_{O2}$ above this minimum level. Energy expenditure for feeding, growth, reproduction and locomotion (used for foraging as well as escape from predators and unfavourable environments) needs an active $\dot{V}_{O2}$. In terms of the temperature dependence of active $\dot{V}_{O2}$, Fry (Fry, 1947; Fry and Hart, 1948) made the crucial observation that maximum $\dot{V}_{O2}$ of exercising goldfish (*Carassius auratus*) failed to continue increasing with temperature beyond an optimal temperature (T_{opt}). By contrast, standard $\dot{V}_{O2}$ of resting fish continued its exponential increase until temperature approached a lethal level (Fig. 1B). Thus, the T_{opt} for aerobic scope is created by the failure of maximum $\dot{V}_{O2}$ to continue increasing with temperature. Consequently, because activities such as growth depend on aerobic scope, it is not surprisingly that growth rate as a function of temperature has a similar bell-shaped, species-specific curve for fishes (Fig. 2B) (Brett, 1971). In fact, fish must eat more just to deal with the exponential increase in standard $\dot{V}_{O2}$. Like minimum $\dot{V}_{O2}$, active $\dot{V}_{O2}$ is also species-specific and varies with body size.

At a critical temperature (T_{crit}), aerobic scope is zero and aerobic activity becomes impossible. Thus, a thermal niche for existence in a resting state is bounded by the upper and lower T_{crit} values (which correspond closely to the CT_{max} and CT_{min} values determined using other methods). However, existence without an aerobic scope is necessarily short-lived in nature because, besides being an easy target for predators, starvation is just a matter of time. Consequently, an animal's functional thermal niche is narrower than that bounded by T_{crit}.

Fry curves are species specific. Differences result from their position on the temperature scale (temperature niches), being centred near 27°C for goldfish and at cooler temperatures (<20°C) for most salmonids (Fig. 2A). There are also species differences in standard and active $\dot{V}_{O2}$. Athletic species such as salmonids have a high aerobic scope, but this does not necessarily translate into a larger thermal niche. For example, generalists such as goldfish (Fig. 2A) and *Fundulus heteroclitus* (Fangue et al., 2006) have a low aerobic scope and a broader thermal niche (eurythermal) compared with salmonids.

Scaling up of laboratory-derived aerobic scope data to ecology and biogeography will not necessarily be a simple task because other environmental factors reduce aerobic scope and narrow an

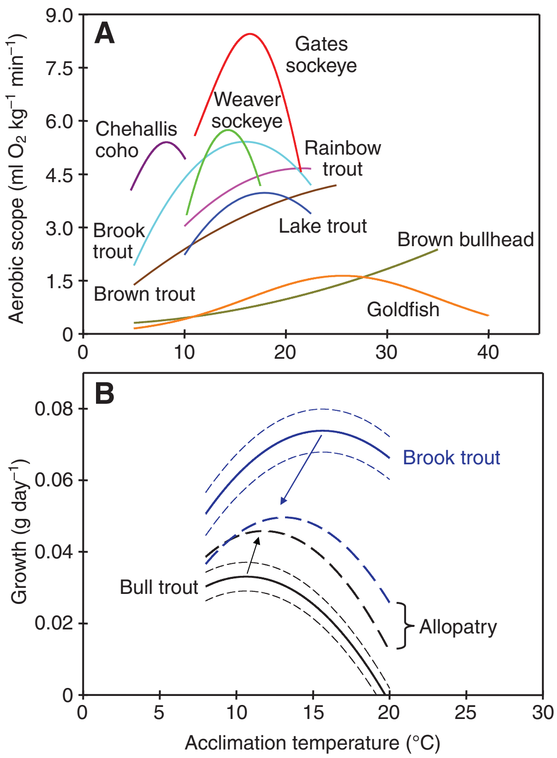

Fig. 2. The influence of temperature on aerobic scope and growth rate. (A) Fry curves for a range of salmonids and other species (Fry, 1947; Fry, 1948; Fry and Hart, 1948; Lee et al., 2003). (B) Growth rates of brook trout and bull trout grown either separately (solid lines with the accompanying dashed lines showing the 95% confidence limits) or together (long dashed lines grouped by allopatry) (McMahon et al., 2007).

animal's functional thermal niche (Fry, 1947; Fry, 1971; Brett, 1971; Pörtner and Farrell, 2008; Munday et al., 2009). For example, aquatic hypoxia, independent of temperature, can reduce aerobic scope (Graham, 1949; Gibson and Fry, 1954; Fry, 1971; Brett, 1971) to the extent that feeding and growth are halted, and development and reproduction are delayed (see Richards et al., 2009). Therefore, both hypoxia and hypercapnia are likely to constrain the breadth and height of a Fry curve (Pörtner and Farrell, 2008). Furthermore, the aerobic scope for a developing fish may not reach its full potential until the cardiorespiratory system is fully developed. Therefore, a family of Fry curves may exist for different life stages. Behaviour adds further complexity. For example, inter-specific competition can shift the T_{opt} for growth (Fig. 2B), as seen in brook trout (*Salvelinus fontinalis*) when growth was suppressed while competing with bull trout (*Salvelinus confluentus*), but not *vice versa* (McMahon et al., 2007).

An important index that can be derived from a Fry curve is the thermal window, the temperature difference between T_{opt} and T_{crit}. This thermal window is an index of a species' resilience to temperature change. In salmonids, the thermal window for the collapse of aerobic scope with warming is just 6–7°C (Fry, 1947; Farrell et al., 2008), which is a relatively small safety margin in the context of global warming scenarios. Tropical species apparently have narrow thermal windows too (Hoegh-Guldberg et al., 2007; Tewksbury et al., 2008) and live close to their T_{crit}. For example, cardinalfishes (*Ostorhinchus doederleini* and *O. cyanosoma*) were found to lose nearly 50% of their aerobic scope with only a 2°C increase above the average summer temperature (Nilsson et al., 2009), and an increase of 3°C compromised growth of spiny-damselfish (*Acanthochromis polyacanthus*) (Munday et al., 2008). However, the collapse of aerobic scope at warm temperatures was less evident (Fig. 2A) for the bullhead (*Ameiurus nebulasa*) and brown trout (*Salmo trutta*), suggesting that other factors may set thermal tolerance.

The rise and fall of aerobic scope in salmonids

As temperature increases, exponentially more oxygen must be delivered to tissues, which is the task of the cardiorespiratory system. Since maximum $\dot{V}_{O_2}$ fails to increase beyond T_{opt}, the decline in aerobic scope beyond T_{opt} (i.e. the downward trend of a Fry curve) therefore reflects the inability of the *maximum* cardiorespiratory capability to keep pace with these increasing tissue oxygen demands. By contrast, T_{crit} corresponds with a failure of the *resting* cardiorespiratory capability to keep pace with increasing tissue oxygen demands. The resultant mismatch between oxygen supply and oxygen demand forces animals to progressively switch to anaerobic metabolism to survive (Pörtner, 2001; Frederich and Pörtner, 2000), perhaps causing an acceleration of cardiorespiratory collapse (Farrell et al., 2008) and the rightward skew often seen in Fry curves.

At present, cardiorespiratory information pertaining to the collapse of aerobic scope during warming is most abundant for salmonids. The data are examined below within the context of the cardiorespiratory oxygen cascade in order to explore why active $\dot{V}_{O_2}$ does not increase beyond T_{opt} and why minimum $\dot{V}_{O_2}$ collapses at T_{crit}.

Active $\dot{V}_{O_2}$ and the cardiorespiratory oxygen cascade

The cardiorespiratory oxygen cascade conceptualizes the movement of oxygen down its partial pressure gradient from a respiratory medium to tissues. Hence, $\dot{V}_{O_2}$ corresponds to the oxygen flux per unit time through this cascade and oxygen diffusion rates are proportional to the relevant oxygen partial pressure (P_{O_2}) gradients. For fish, oxygen diffuses from water across gill secondary lamellae and binds to haemoglobin (Hb) in red blood cells, which are transported by the circulatory system to tissues where oxygen diffuses across the capillary wall and into the cell to be used in mitochondrial respiration (Fig. 3).

A countercurrent arrangement of blood and water flow at the secondary lamellae ensures that the arterial blood leaving the gills has a P_{O_2} (Pa_{O_2}) close to ambient water, and its Hb is almost fully saturated, i.e. the oxygen content of arterial blood (Ca_{O_2}) is near maximal. Convection of oxygen to tissues by the arterial system is quantified as the product of Ca_{O_2} and cardiac output. Thus, increasing cardiac output is the only means to internally transport more oxygen to the tissues, unless stored red blood cells are released from the spleen to increase Hb concentration [Hb] and hence Ca_{O_2} (see Gallaugher and Farrell, 1998). Once in tissue capillaries, factors such as the architecture of the capillaries, the presence of myoglobin and lipid droplets in the cytoplasm and the actual location of mitochondria within the cell significantly influence the rate of diffusion of oxygen from the red blood cell to the mitochondria.

In a resting fish, increasing tissue oxygen delivery with increasing temperature could simply recruit mechanisms that are normally used during exercise. When salmonids exercise at a constant temperature, there are increases in gill ventilation (to deliver more water), cardiac output (to transport more oxygen to

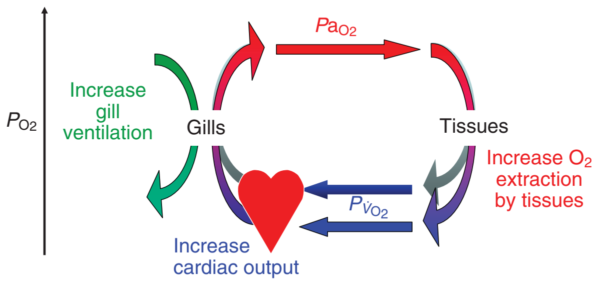

Fig. 3. A schematic diagram representing the oxygen cascade for a fish during rest (shaded lines and arrows) and swimming (dark lines and arrows). The oxygen partial pressure is an arbitrary scale (see text for details).

the tissues) and tissue oxygen extraction from blood (Stevens et al., 1967; Kiceniuk and Jones, 1977). Increased tissue oxygen extraction can contribute almost as much to the increased $\dot{V}_{O_2}$ as cardiac output because resting fish remove only about one third of the arterial oxygen and so venous oxygen content (Cv_{O_2}) and venous blood P_{O_2} (Pv_{O_2}) can decrease considerably during exercise (Fig. 3). While all of these exercise-induced cardiorespiratory changes are possible during warming, as shown below, not all of them occur when resting fish are warmed up to T_{crit}.

When an exercising fish is warmed, it is more a matter of how much the warming increases the rate and force of muscle contraction to enhance maximum cardiorespiratory capacity. In addition, oxygen diffuses at a faster rate, potentially allowing a lower Pv_{O_2}. Furthermore, the temperature sensitivity of the Hb–oxygen binding curve (e.g. Clark et al., 2008a) is such that a rightward shift with warming increases the Pa_{O_2} of fully saturated arterial blood. This also promotes a faster unloading of oxygen at the tissues. In fact, Cv_{O_2} could decrease during warming without a decrease in Pv_{O_2} (this direct temperature effect is in addition to a similar benefit from the Root- or Bohr-shifts as tissues release more carbon dioxide and H^+ during exercise).

Some fairly simple theoretical predictions can be made using this conceptual framework, against which existing cardiorespiratory data on warming in fishes can be compared. The analysis is further simplified by asking where the potential limitation might exist (gills, circulatory system or tissues), and by focusing on underlying mechanisms (at near T_{crit} for resting fish and at T_{opt} for exercising fish).

Changes in cardiorespiratory variables with acute warming in association with T_{opt} in exercising salmonids and T_{crit} in resting salmonids

A limitation at the gills?

Oxygen is poorly soluble in water. Compounding this, its solubility in water decreases ~2% per degree centigrade. Therefore, gill ventilation must compensate for the decreased oxygen availability and the lower Hb–oxygen affinity, as well as increased tissue oxygen demand as temperature increases. Therefore, a decrease in Pa_{O_2} during warming would indicate a clear problem associated with gill oxygen delivery and transfer. However, the data for salmonids are inconsistent on this matter.

When exercising adult sockeye salmon (*Oncorhynchus nerka*) were warmed to a temperature well above T_{opt}, Pa_{O_2} was maintained (Steinhausen et al., 2008). Similar results were found in resting Chinook salmon (*O. tshawytscha*) warmed up to T_{crit} (Clark et al., 2008a). In fact, Pa_{O_2} actually increased in resting sockeye salmon warm to T_{crit} (Steinhausen et al., 2008).

Interpreting Ca_{O_2} data during warming is more complex because of potential pH and temperature effects on the Hb–oxygen affinity curve, and because warming has variable effects on blood [Hb] (Taylor et al., 1997; Farrell, 1997; Sandblom and Axelsson, 2007). Even so, Ca_{O_2} was maintained in resting sockeye salmon warmed to T_{crit} as well as in exercising sockeye salmon warmed above T_{opt} (Steinhausen et al., 2008). By contrast, Ca_{O_2} decreased at T_{crit} in resting rainbow trout (*O. mykiss*) (Heath and Hughes, 1973) and in resting Chinook salmon (Clark et al., 2008a). The modest decrease in Ca_{O_2}, in the absence of an effect on Pa_{O_2}, in resting Chinook salmon probably reflects a decrease in Hb–oxygen affinity rather than a limitation on oxygen diffusion at the gills.

A limitation in the circulatory system?

If a circulatory limitation exists for exercising salmonids during warming, increases in cardiac output should cease once T_{opt} is reached. Indeed, maximum cardiac output in exercising sockeye salmon (Brett, 1971; Steinhausen et al., 2008) and rainbow trout (Taylor et al., 1996) reached a maximum value at a temperature well below T_{crit}, as did $\dot{V}_{O_2}$. Thus, ultimately as warming approaches T_{opt} the potential to increase maximum cardiac output (as revealed by exercising fish) fails to keep up with the required increase in cardiac output in a resting fish (Fig. 4). As a result, because scope for cardiac output does not increase above T_{opt} (Fig. 5), swimming effort either declines or stops.

For resting salmonids, the cardiac limitation at T_{crit} is even more obvious. Cardiac arrhythmias and bradycardia often develop at T_{crit} (Heath and Hughes, 1973; Clark et al., 2008a), although their physiological basis has not been studied. Thus, experimental evidence points unequivocally towards a cardiac limitation both at T_{opt} in exercising salmonids and at T_{crit} in resting salmonids. Further insight into the mechanistic basis of the cardiac response to warming and its limitations comes from an analysis of heart rate (the rate function) and cardiac stroke volume (the capacity function).

The importance of increased heart rate during acute warming is extremely clear. Warming increases cardiac output solely by increasing heart rate. This is true for both resting and exercising salmonids (Sandblom and Axelsson, 2007; Clark et al., 2008a; Steinhausen et al., 2008), presumably through a direct temperature effect on the cardiac pacemaker rate (Randall, 1970). However, because fish have a maximum heart rate (Farrell, 1991) and heart rate is already elevated by the exercise, the maximum heart rate must be reached at a temperature well below that for resting fish (Steinhausen et al., 2008). In fact, the scope for heart rate plummets from its maximum at T_{opt} to zero near T_{crit} (Fig. 5). Fred Fry made a similar observation for heart rate in *Salvelinus fontinalis* alevins (Fig. 6A) (Fry, 1947) and commented that this might reflect the T_{opt} for the activity of an organ (i.e. the heart)! We now know that Fry's assertion was correct because the T_{opt} for the maximum performance of isolated rainbow trout hearts is well below T_{crit} (Fig. 6B).

In contrast to heart rate, cardiac stroke volume appears to be thermally insensitive to warming. This is true for resting and exercising salmonids (Sandblom and Axelsson, 2007; Clark et al., 2008a; Steinhausen et al., 2008), but it is an especially surprising result for resting fish. In fact, it seems paradoxical, given that cardiac stroke volume can triple during swimming at constant temperature (Stevens et al., 1967; Brett, 1971; Kiceniuk and Jones, 1977; Farrell and Jones, 1992; Thorarensen et al., 1996; Gallaugher

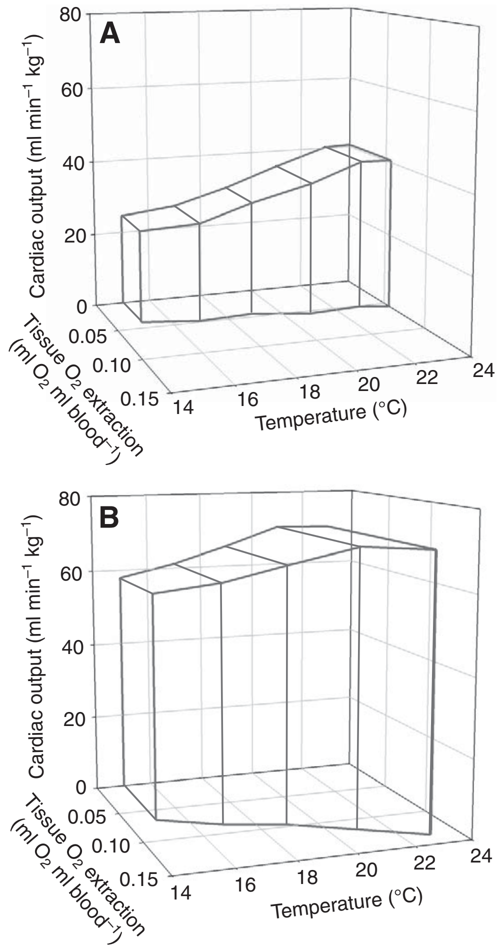

Fig. 4. Cardiac output and tissue oxygen extraction (Ca_{O_2}–Cv_{O_2}) for 12°C-acclimated sockeye salmon either (A) at rest, or (B) swimming continuously at about 70% of maximum swimming speed, while the temperature was acutely increased at 2°C h^{-1} and held at the temperature for 1 h while cardiorespiratory measurements were made. All resting fish completed the temperature challenge and recovered, but above 19°C swimming fish began to stop swimming and so progressively fewer are represented at higher temperatures. The *x*–*y* surface at each temperature represents oxygen uptake (i.e. the product of cardiac output and tissue oxygen extraction), which clearly increases with temperature in resting but not swimming fish above their optimum temperature of around 15°C. Changes in cardiac output with temperature are a result of increased heart rate (see text) (Steinhausen et al., 2008).

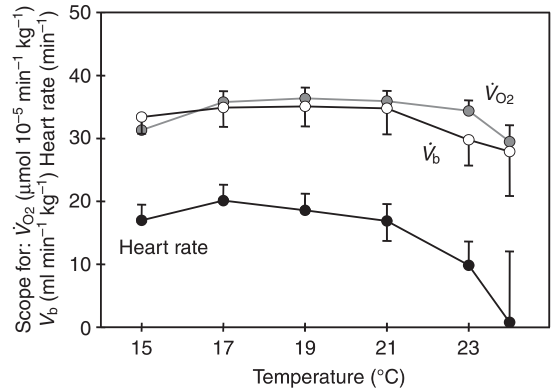

Fig. 5. Changes in scope for oxygen uptake ($\dot{V}_{O_2}$), cardiac output ($\dot{V}_b$) and heart rate (f_H) in swimming sockeye salmon during acute warming. Note that although all fish continued swimming in temperatures up to and including 19°C, some fish stopped swimming at higher temperatures and so the data are only for those that continued to swim (Steinhausen et al., 2008).

et al., 2001), that this additional capacity for increasing cardiac stroke volume is not exploited by resting fish when they are warmed to T_{crit} (Fig. 4). So why is this?

The difficulty may revolve around the fact that cardiac end-systolic volume is essentially zero in salmonids (Franklin and Davie, 1992). This means that, unless venous return and end-diastolic volume are increased first, an increase in cardiac contractility cannot increase cardiac stroke volume appreciably (Sandblom and Axelsson, 2007). Furthermore, there are indications that during warming inadequate venous return may limit cardiac stroke volume in the first instance. In resting rainbow trout warmed from 10 to 13°C, cardiac stroke volume was maintained when heart rate increased because venous blood pressure and mean circulatory filling pressure also increased (Sandblom and Axelsson, 2007). However, with further warming to 16°C, which is near T_{opt}, venous blood pressure was unchanged and cardiac stroke volume decreased when heart rate increased further. Although a complete systolic emptying of the ventricle may be a disadvantage with regard to the capacity to increase cardiac stroke volume during warming, it may be more important in ensuring a completely 'fresh' supply of oxygen enters the lumen of the heart with each heart beat given oxygen diffusion to the myocardium is driven by a low Pv_{O_2} (see Farrell, 2002).

The increase in cardiac stroke volume when salmonids swim at a constant temperature is supported by an increase in venous blood pressure (Kiceniuk and Jones, 1977) and by contraction of locomotory muscles aiding venous return (Farrell et al., 1988). There are several potential reasons why warming does not increase cardiac stroke volume any further. There could be physical upper limits to venous return and end-diastolic volume. Also, increasing heart rate during warming reduces cardiac filling time and creates a negative frequency effect on cardiac contraction, both of which could constrain cardiac stroke volume (Farrell, 2007). In addition, at a time when the heart is working maximally, its extracellular environment (the venous blood) becomes acidemic and hyperkalemic, and has a low Pv_{O_2} (Steinhausen et al., 2008). Although the negative inotropic effects of these extracellular changes were prevented by adrenergic stimulation of the heart (Driedzic and Gesser, 1994; Nielsen and Gesser, 2001; Hanson et al., 2006), this adrenergic protection was greatly reduced at 18°C compared with 10°C in rainbow trout (Hanson and Farrell, 2007).

A limitation at the tissues?

The rate and degree of oxygen diffusion from capillaries to tissues is influenced by several factors besides the P_{O_2} gradient. These include tissue capillary density, the intracellular mitochondrial location, regional blood flow and red blood cell capillary contact time. Taylor et al. (Taylor et al., 1997) suggested that regional oxygen delivery by convective transport in exercising rainbow trout is determined mainly by changes in cardiac output as temperature changes, i.e. active peripheral redistribution of blood flow is modest. Even so, red muscle blood flow during aerobic swimming

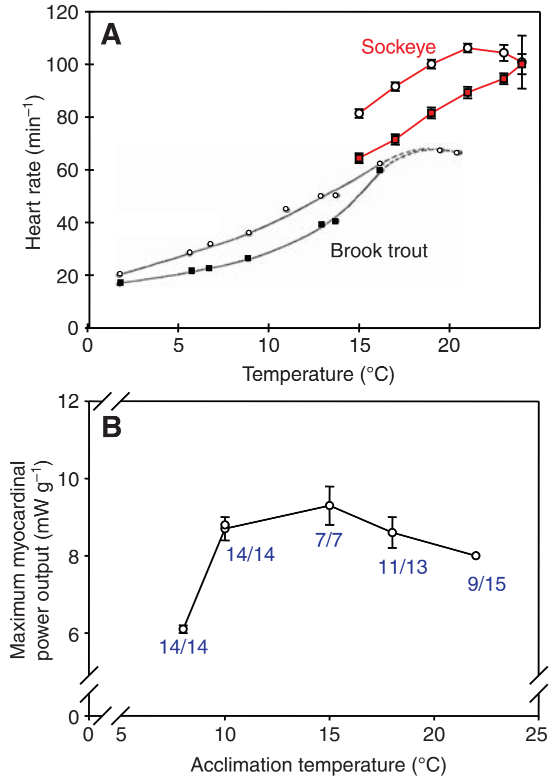

Fig. 6. (A) A comparison of heart rates measured in brook trout alevins (Fry, 1947) and adult sockeye salmon (Steinhausen et al., 2008) to illustrate the convergence of heart rate in resting (lower lines) and active (upper lines) fish such that there is no scope for heart rate at T_{crit}. (B) A composite of the maximum cardiac performance for isolated perfused rainbow trout hearts acclimated to different temperature to illustrate that there is a peak performance around 15°C for the heart. Beyond this temperature, an increasing number of preparations would fail as indicated by the ratio of successful/attempted preparations besides each data point (Farrell et al., 1988; Keen and Farrell, 1994; Farrell et al., 1996).

was lower at 18°C than at 11°C (Taylor et al., 1997). In addition, the basal oxygen requirement of white (fast glycolytic) muscle in fish increases during warming because it accounts for >50% of body mass and receives 28–50% of routine cardiac output in resting rainbow trout (Randall and Daxboeck, 1982; Bushnell et al., 1992). Indeed, the finding that blood flow to white muscle increased from 40% to 75% of cardiac output at 6°C *versus* 18°C in resting rainbow trout (Barron et al., 1987) clearly reflects a significant elevation of white muscle oxygen demand relative to whole animal $\dot{V}_{O_2}$. White muscle also has a low capillary density (Egginton, 2000), which increases the likelihood of a diffusion limitation developing for oxygen diffusion.

Further insight into potential limitations on tissue oxygen removal during warming is evident from measurements of $C\mathrm{v}_{O_2}$ and $P\mathrm{v}_{O_2}$. For example, $P\mathrm{v}_{O_2}$ and $C\mathrm{v}_{O_2}$ could not decrease if there was a diffusion limitation. In fact, a decrease in $C\mathrm{v}_{O_2}$ is a very important mechanism for increasing tissue oxygen extraction during swimming at constant temperature (Fig. 4). However, for resting sockeye salmon, warming actually increased $P\mathrm{v}_{O_2}$ and $C\mathrm{v}_{O_2}$, and tissue oxygen extraction (Fig. 4) remained unchanged (Steinhausen et al., 2008). Similarly, $P\mathrm{v}_{O_2}$ was temperature insensitive in resting Chinook salmon, except at 25°C when there was acidemia and $C\mathrm{v}_{O_2}$ decreased (Clark et al., 2008a). When exercising sockeye salmon were warmed, $P\mathrm{v}_{O_2}$ again remained temperature insensitive, albeit it at a lower level compared with resting fish (Steinhausen et al., 2008). This consistent temperature insensitivity of $P\mathrm{v}_{O_2}$ points to a diffusion limitation for oxygen unloading (see Farrell, 2002; Farrell and Clutterham, 2003). Why in resting fish warming does not decrease $P\mathrm{v}_{O_2}$ to the level seen with swimming at a constant temperature is unclear.

In resting salmonids, the decrease in $C\mathrm{v}_{O_2}$ just prior to T_{crit} may reflect a desperate situation created by inadequate tissue perfusion. The ability of fish to recover from warming may be informative in this regard. For example, when sockeye salmon and Chinook were incrementally warmed at 2–4°C h^{-1} and kept at a constant temperature for 1 h between temperature steps, the fish recovered well at the control temperature and within 1–2 h, especially if the heat stress was terminated before cardiac arrhythmias developed (Steinhausen et al., 2008; Clark et al., 2008a). In these experiments, sockeye salmon maintained $C\mathrm{v}_{O_2}$ and Chinook salmon decreased $C\mathrm{v}_{O_2}$ only in association with acidemia at 24°C. By contrast, when ‘opportunistic’ blood samples were taken from resting rainbow trout during continuous warming (1.5°C h^{-1}), all but one fish died and venous blood became depleted of oxygen (Heath and Hughes, 1973).

What emerges from the above is that the heart becomes a weak link for the cardiorespiratory oxygen cascade when exercising salmonids are warmed above T_{opt}. Although a direct temperature effect on the cardiac pacemaker rate appears to be the predominant mechanism for improving tissue oxygen transport, a crucial limitation is reached when this rate function reaches its maximum. This apparently occurs at T_{opt} for exercising fish and at T_{crit} for resting fish. What follows during warming is a sequela of events: a decrease in scope for heart rate preceding that for cardiac output, which precedes that for aerobic scope (Fig. 5). It is also evident that during warming the contributions of several capacity functions ([Hb], tissue oxygen extraction and cardiac stroke volume) are only small and variable. Why this excess capacity is not exploited when resting fish are warmed is particularly perplexing and warrants further study.

Beyond salmon

The details provided above for salmonids apparently apply more broadly to other fishes. For example, warming of three species showed that like rainbow trout: (1) cardiac output increases predominantly through increased heart rate, (2) routine heart rate shows a plateau or collapse before T_{crit} that is species specific, and (3) cardiac stroke volume is temperature insensitive (Fig. 7) (Sandblom and Axelsson, 2007 and references therein). In addition, the temperature dependence of Hb–oxygen affinity and the variable effects of warming on [Hb] are well known among fishes (Cech et al., 1976; Gallaugher and Farrell, 1998; Gollock et al., 2006), and a direct temperature effect on the spontaneous pacemaker rate is recognised for plaice (*Pleuronectes platessa*) (Harper et al., 1995). Furthermore, in resting Atlantic cod (*Gadus morhua*), although heart rate and cardiac output both collapsed before CT_{max}, heart rate reached a plateau before cardiac output and $\dot{V}_{O_2}$ (at 18°C *versus* at 20°C) (Gollock et al., 2006).

The effects of acute warming have been thoroughly studied in winter flounder (*Pseudopleuronectes americanus*) seasonally acclimated between 5°C and 18°C (Cech et al., 1975; Cech et al., 1976). After a 5°C warming at each acclimation temperature, an increase in $\dot{V}_{O_2}$ (67–83% per 5°C increment) was always accompanied by a nearly equivalent increase heart rate (54–77%

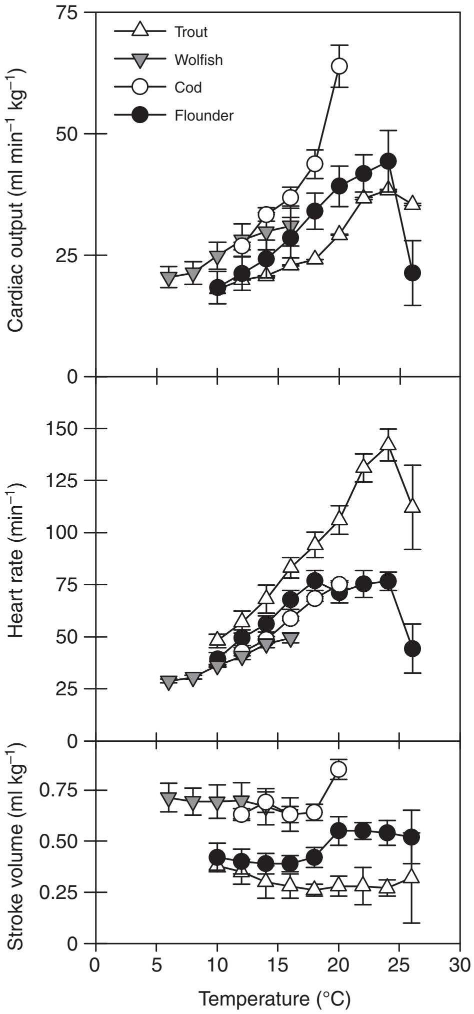

Fig. 7. Changes in cardiorespiratory variables in resting fishes during acute warming: a comparison of wolffish, winter flounder and Atlantic cod with rainbow trout. (Data kindly supplied by Dr Kurt Gamperl: wolffish – N. Joaquim and A. K. Gamperl, unpublished; trout – A. K. Gamperl, unpublished; Atlantic cod – L. H. Petersen and A. K. Gamperl, unpublished; flounder – P. C. Mendonca and A. K. Gamperl, unpublished.)

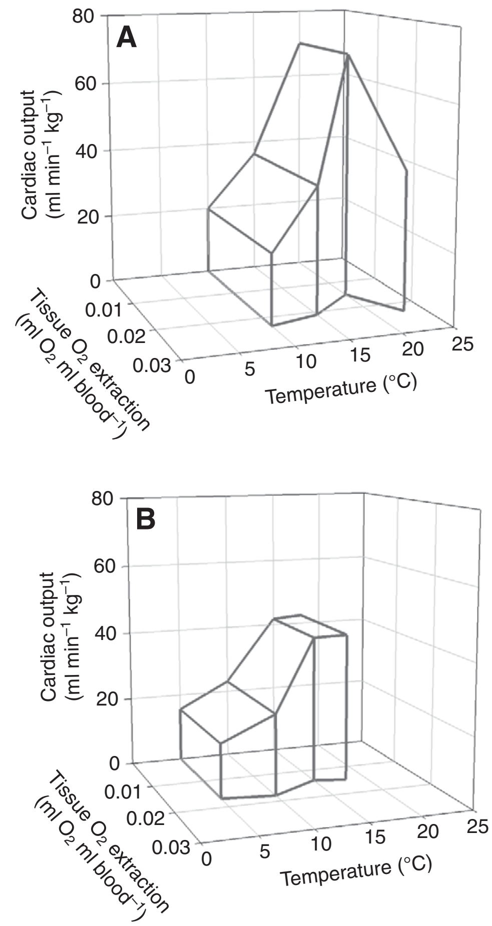

Fig. 8. Cardiac output (V_b) and tissue oxygen extraction (Ca_{O_2}–Cv_{O_2}) for winter flounder either (A) seasonally acclimated to a temperature, or (B) acutely warmed by 5°C increments from the acclimation temperature. The x-y surface at each temperature represents oxygen uptake (the product of V_b and Ca_{O_2}), which clearly increases with temperature and either reaches a plateau between acclimation temperatures of 15 and 18°C, or collapses with an acute increase to 23°C. The greatest contributor to increases in $\dot{V}_{O_2}$ is almost always V_b, which is a result of increased heart rate (see text) (Cech et al., 1975; Cech et al., 1976).

per 5°C increment). However, with warming from 18°C to a near-lethal temperature, cardiac output and cardiac stroke volume collapsed even though heart rate increased (Fig. 8). Ca_{O_2}, Pa_{O_2}, Cv_{O_2} and Pv_{O_2} were all maintained, except for 5°C- and 18°C-acclimated fish when tissue oxygen extraction increased (Fig. 8).

Heart rate may be a limiting factor during warming in decapod crustaceans as well. Heart rate is reported to reach a plateau near T_{crit} in various crab species: the spider crab [*Maja squinado* (Frederich and Pörtner, 2000)], the rock crab [*Cancer irroratus* (Frederich et al., 2009)] and the kelp crab [*Taliepus dentatus* (Storch et al., 2009)]. Cardiac stroke volume was also temperature insensitive in the kelp crab. Therefore, the upper limit for heart rate may emerge as a valuable, yet simple predictor of T_{opt} in active animals and T_{crit} in resting animals. If this is the case, biotelemetry of heart rate could easily extend this work to field situations (Clark et al., 2008b; Clark et al., 2009), allowing the full interplay of environmental factors on aerobic scope to be properly explored. Accompanying such fieldwork is the need to better understand the control of heart rate at high temperature and to determine if the heart is operating at its maximum pacemaker rate.

Temperature and the river migration of sockeye salmon

Beyond direct temperature reactions (i.e. acute effects occurring in minutes to hours considered above), two other time scales can be applied to temperature effects. Thermal adaptation spans generations and occurs at the population level through natural selection acting on individual variability. The study of heritable factors related to thermal tolerance is in its infancy. Thermal acclimation (or thermal compensation), however, occurs when an individual undertakes physiological and biochemical adjustments over days to weeks [or perhaps months for Antarctic fishes at near freezing temperatures (Franklin et al., 2007)]. Here, a new phenotype emerges from an existing genome as an animal acclimates to a new thermal environment. Given the potential for thermal acclimation and adaptation, the obvious question becomes: Do the acute responses to temperature in fishes have any ecological or evolutionary relevance? In the specific case of adult sockeye salmon that return to the Fraser River, BC, Canada to spawn, the answer is categorically yes. During this return migration, sockeye salmon can experience large and rapid temperature changes when they make daily vertical ocean movements prior to river entry and exploit deeper, cool water in lakes (Fig. 9).

Adult sockeye salmon return migrations also provide a fascinating insight into something that is normally difficult to witness, an ecological significance for T_{opt} and T_{crit}. The linkage between aerobic scope and lifetime fecundity is obvious for sockeye salmon because their entire lifetime fitness hinges on a single, precise spawning date that is preceded by an energetic upstream migration lasting up to several weeks. Therefore, to spawn, they are committed to an upriver migration that periodically may require their full aerobic scope, with only a sensory imprint for navigation, while developing gonads, without feeding and without prior experience of the temperature conditions en route (Hinch et al., 2006). Consequently, if a warm river temperature reduces aerobic scope, sockeye salmon do not have an option of postponing reproduction as other fishes might do. In fact, with just 4–6 weeks to live after entering the river, even a slower migration could reduce lifetime fecundity.

Using Weaver Creek sockeye salmon as an example and considering only aerobic swimming, upstream migration should be favoured at 14.3°C (their T_{opt} for aerobic scope) but impossible at 20.4°C (their T_{crit}) (Lee et al., 2003). As predicted, when adult Weaver Creek sockeye salmon were intercepted in 2004, implanted with biotelemetry devices and released back to the river to follow their subsequent progress, migration success was inversely related to river temperature above T_{opt}. In fact, migration success was only 0–11% when river temperature was near T_{crit} (at 18–21°C), but increased to 77% when the river seasonally cooled to 14°C and near their T_{opt} (Farrell et al., 2008). This result suggests that a warm river temperature limited aerobic scope, and impaired upriver migration and lifetime fecundity. These warm river temperatures experienced by Weaver Creek sockeye salmon in 2004, which turned out to be record highs, contributed to a catastrophic 70% loss of the migrating population!

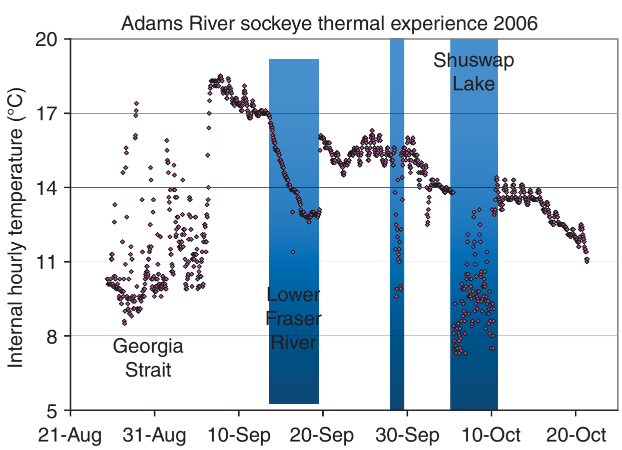

Fig. 9. Hourly temperature recordings from an I-button temperature logger that was recovered from an Adams River sockeye salmon after implantation in the peritoneal cavity in the Georgia Strait (ocean conditions) and a 40-day migration through the Fraser River watershed to its spawning area near the Shuswap Lake, BC, Canada. The highlighted areas represent periods where the fish behaviourally sought out water that was cooler than either the mainstem river or at the surface of lakes. The general downward trend over time represents seasonal cooling of the watershed, and daily oscillations in temperature can be resolved in the shallow spawning streams towards the end of the trace. (Data kindly supplied by David Patterson.)

Thermal acclimation

Warm acclimation alters thermal tolerance (Fry et al., 1942), increasing T_{opt}, T_{crit} and maximum aerobic scope (Fry and Hart, 1948). Warm acclimation, in addition to permitting a higher maximum heart rate, also decreases routine heart rate at the level of the pacemaker. This acclimatory change then provides compensation for the limitation that maximum heart rate imposes on aerobic scope by restoring the scope for heart rate either fully (Harper et al., 1995) or partially (Farrell, 1997). However, the benefits of temperature acclimation for specialists like salmon are small compared with temperature generalist. For example, CT_{max} for salmon increases by only 2°C over a 15°C acclimation temperature range *versus* an increase in CT_{max} of 10°C for goldfish over a 30°C acclimation range (Brett, 1956). In fact, routine and maximum heart rate in 22°C-acclimated sockeye salmon [86 beats min^{-1} and 106 beats min^{-1}, respectively (Brett, 1971)] are barely different for a 14°C-acclimated fish acutely warmed to 22°C [90 beats min^{-1} and 106 beats min^{-1} (Steinhausen et al., 2008)]. Other documented responses to warm acclimation, such as the decrease in cardiac mass (Gamperl and Farrell, 2004) and decrease in capillary density the red (slow aerobic) muscle of rainbow trout (Taylor et al., 1996; Egginton, 2000), even seem counterproductive. Conversely, compensatory decreases in gill epithelial thickness, as seen for other species (Taylor et al., 1997), would be beneficial.

Antecedents and concluding remarks

Like a salmon down on the Fraser, swimmin' with their battered fins,
Searchin' for their childhood home,
A patch of gravel they knew as their own.
Excerpt from 'The Ballad of Old Tom Jones' *by Barney Bentall*

The genomic information passed down by antecedents determines an individual's potential for survival, growth and reproduction. The antecedents of present day Fraser River salmon have passed on their environmental experiences through natural selection for over ~10,000 years since their post-glacial invasion. However, we have only ~60 years of reliable archival records of the river temperatures experienced during recent salmon migrations (Farrell et al., 2008). Nevertheless, remarkably the historic mean and median river migration temperature for Weaver Creek sockeye salmon is 14.5°C (their T_{opt} is 14.3°C). This observation, combined with the fact that the thermal window between T_{opt} and T_{crit} is only 7.3°C and that thermal acclimation provides little benefit to CT_{max}, suggests that their T_{opt} is potentially a product of natural selection. If this is the case, one has to question whether or not natural selection among sockeye salmon can accommodate the rapid warming trend already evident for the Fraser River (peak summer temperature has increased 1.8°C in the past 60 years).

If the salmonid genome is too inflexible to adapt to a new T_{opt}, perhaps the genetic determinants of the spawning date are more flexible. Dangerously high temperatures could then be avoided by migrating when the river is seasonally cooler (see Keefer et al., 2008), but this may result in a fish encountering other unfavourable conditions such as faster river flows earlier in the year and an inevitable run-on-effect on the timing of larval emergence. Alternatively, warm water could be avoided behaviourally if opportunities exist. Behavioural temperature preferences are certainly shown by adult salmon during migration, which include seeking water cooler than their T_{opt} (Fig. 9) to lower $\dot{V}_{O_2}$ and perhaps slow energy depletion, suggest they likely know which temperature conditions are best for them. However, opportunities to seek cool refuges are very limited in the Fraser River (Donaldson et al., 2009). Without such behavioural responses, the warmer than normal river temperatures may force Pacific salmon near the southern limit of their geographic distribution to follow the fate of other species, a heart-breaking (Wang and Overgaard, 2006) northward shift in their distribution. The response of tropical coral reef fish species to climate change could be equally dramatic.

In closing, the best, albeit limited data set for a single animal group appears to provide a mechanistic understanding for the Fry curve. Heart rate, which is the main driver for the increase in $\dot{V}_{O_2}$ during warming, reaches its maximum rate at T_{opt} and becomes a weak link for the cardiorespiratory oxygen cascade. Shelford (Shelford, 1931) recognized that 'Animals are better short-period indicators (of environmental change) than plants' because animals can potentially move away from unfavourable environments. However, this behavioural response requires an aerobic scope, which is both controlled and limited by temperature. Future study on aerobic scope will continue to inform us of an animal's fundamental thermal niche. By contrast, a continued focus on temperature tolerances for resting animals will only inform us of thermal niche for existence and perhaps create needless worry about the precise techniques for such measurements (Chown et al., 2009).

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Glossary

Aerobic scope	the difference between maximum and minimum (standard or basal) oxygen uptake under a given set of test conditions
Ca_{O_2}	concentration of oxygen in arterial blood
Cv_{O_2}	concentration of oxygen in venous blood
CT_{max}	the critical thermal maximum that a fish can tolerate
CT_{min}	the critical thermal minimum that a fish can tolerate
Fry curve	the relationship between aerobic scope and temperature
Hb	haemoglobin
Pa_{O_2}	partial pressure of oxygen in arterial blood
P_{O_2}	partial pressure of oxygen
Pv_{O_2}	partial pressure of oxygen in venous blood
T_{crit}	the temperature at which a fish has no aerobic scope
T_{opt}	the temperature at which a fish has maximum aerobic scope
$\dot{V}_{O_2}$	rate of oxygen uptake

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MAXIMUM CARDIAC PERFORMANCE OF RAINBOW TROUT (*ONCORHYNCHUS MYKISS*) AT TEMPERATURES APPROACHING THEIR UPPER LETHAL LIMIT

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Summary

Numerous studies have examined the effect of temperature on *in vivo* and *in situ* cardiovascular function in trout. However, little information exists on cardiac function at temperatures near the trout's upper lethal limit. This study measured routine and maximum *in situ* cardiac performance in rainbow trout (*Oncorhynchus mykiss*) following acclimation to 15, 18 and 22 °C, under conditions of tonic (30 nmol l^{-1}), intermediate (60 nmol l^{-1}) and maximal (200 nmol l^{-1}) adrenergic stimulation. Heart rate increased significantly with both temperature and adrenaline concentration. The Q_{10} values for heart rate ranged from 1.28 at 30 nmol l^{-1} adrenaline to 1.36 at 200 nmol l^{-1} adrenaline. In contrast to heart rate, maximum stroke volume declined by approximately 20 % (from 1.0 to 0.8 ml kg^{-1}) as temperature increased from 15 to 22 °C. This decrease was not alleviated by maximally stimulating the heart with 200 nmol l^{-1} adrenaline. Because of the equal and opposite effects of increasing temperature on heart rate and stroke volume, maximum cardiac output did not increase between 15 and 22 °C. Maximum power output decreased (by approximately 10–15 %) at all adrenaline concentrations as temperature increased. This reduction reflected a poorer pressure-generating ability at temperatures above 15 °C. These results, in combination with earlier work, suggest (1) that peak cardiac performance occurs around the trout's preferred temperature and well below its upper lethal limit; (2) that the diminished cardiac function concomitant with acclimation to high temperatures was associated with inotropic failure; (3) that Q_{10} values for cardiac rate functions, other than heart rate *per se*, have a limited predictive value at temperatures above the trout's preferred temperature; and (4) that heart rate is a poor indicator of cardiac function at temperatures above 15 °C.

Key words: heart, stroke volume, heart rate, cardiac output, temperature, adrenaline, rainbow trout, *Oncorhynchus mykiss*.

Introduction

Much of our knowledge on fish cardiovascular responses to temperature change is limited to information on heart rate. There are two reasons for this. First, heart rate is the easiest cardiac variable to measure. Second, in mammals at least, heart rate is a reliable predictor of cardiac performance. If heart rate were equally reliable as a predictor of integrated cardiac function in fish, this large data base would have a tremendous predictive potential for fish cardiac performance. Unfortunately, there are many indications that heart rate alone is a poor predictor of integrated cardiac function in fish. Among the concerns are the following: (1) stroke volume can change by as much as, and even more than, heart rate when cardiac output increases (Farrell, 1991; Farrell and Jones, 1992); (2) the relative contributions of stroke volume and heart rate to changes in cardiac output vary between species and as a function of temperature (see Kolok and Farrell, 1994); (3) maximum stroke volume can decrease at high heart rates (Farrell *et al.* 1989); and (4) maximum isometric tension developed by cardiac muscle decreases at high contraction frequencies (i.e. a negative staircase effect) (Ask *et al.* 1981; Ask, 1983; Driedzic and Gesser, 1985, 1988). In view of these observations, it would be unwise to predict changes in cardiac performance from temperature-induced changes in heart rate alone. Indeed, a temperature-induced increase in heart rate does not necessarily produce a proportional increase in cardiac output (Brett, 1971; Yamamitsu and Itazawa, 1990; Kolok and Farrell, 1994).

The present study, which reports the first measurements of maximum cardiac performance in rainbow trout at temperatures near their upper lethal limit (23–25 °C; Black, 1953), extends our knowledge of how numerous variables (heart rate, stroke volume, cardiac output, power output) affect cardiac function in fish. The results support our contention that heart rate is a poor indicator of integrated cardiac performance in fish. In addition, this novel information should prove valuable in predicting the effects of increased environmental temperature on fish performance. Our approach was to use an *in situ* perfused heart to measure routine and maximum cardiac performance at 15, 18 and 22 °C after the fish had acclimated to these temperatures. The *in situ* perfused rainbow trout heart is an appropriate model for investigating the relationship between high environmental temperature and cardiac performance since it is capable of performing at work levels equal to maximum *in vivo* levels (Farrell *et al.* 1989).

Materials and methods

Experimental animals

Rainbow trout [*Oncorhynchus mykiss* (Walbaum)] (weighing 403–727 g) were obtained from a local supplier (West Creek Trout Farms, Aldergrove, BC, Canada) and maintained in a 2000 l fibreglass tank receiving dechlorinated Vancouver tapwater. Throughout the experiment only one stock of fish was used. All fish were initially maintained at 15 °C, before subsequent exposure to 18 and then 22 °C. Fish were acclimated at each temperature for at least 2 weeks prior to use. Water temperature was regulated to within 1 °C of the desired test temperature by a Min-O-Cool cooling unit (Frigid Units, Blissfield, MI, USA) and two countercurrent heat exchangers of local construction. Photoperiod was 12 h:12 h L:D. Fish were fed commercially prepared trout pellets daily.

Perfused heart preparations

Fish were anaesthetized in a buffered solution of tricaine methane sulphonate ($0.1\,g\,l^{-1}$ MS 222, with $0.1\,g\,l^{-1}$ sodium bicarbonate) and transferred to an operating table where their gills were irrigated with aerated buffered anaesthetic at 4 °C ($0.05\,g\,l^{-1}$ MS 222 in $0.1\,g\,l^{-1}$ sodium bicarbonate). Fish were injected with 0.6 ml of heparinized ($100\,i.u.\,ml^{-1}$) saline *via* the caudal vessels, and an *in situ* heart preparation was obtained, as detailed in Farrell *et al.* (1986) and modified by Farrell *et al.* (1989). Briefly, an input cannula was secured into the sinus venosus through a hepatic vein and perfusion with saline containing $30\,nmol\,l^{-1}$ adrenaline was begun immediately. Silk thread was used to secure the input cannula and to occlude any remaining hepatic veins. The output cannula was inserted into the ventral aorta at a point confluent with the bulbus arteriosus and tied firmly in place. Finally, silk ligatures were tied around each ductus Cuvier to occlude these veins and to crush the cardiac branches of the vagus nerve. This procedure left the pericardium intact, while isolating the heart in terms of saline input and output.

Once the surgery had been completed (15–20 min), the fish was immersed in a temperature-controlled saline bath at 15, 18 or 22 °C. The input cannula was attached to a constant-pressure reservoir and the output cannula was connected to a constant pressure head. Output pressure was initially set at 5 kPa to simulate resting *in vivo* ventral aortic blood pressure (Stevens and Randall, 1967), and filling (input) pressure was adjusted to give a cardiac output of $20\,ml\,min^{-1}\,kg^{-1}$ body mass for the 15 and 18 °C groups. Cardiac output was set at $25\,ml\,min^{-1}\,kg^{-1}$ body mass for the 22 °C group to account for temperature effects on *in vivo* resting cardiac output (Farrell and Jones, 1992). At all temperatures, the heart maintained this initial control level of performance for a period of 20 min to allow for recovery from surgery and for equilibration to the organ bath.

The saline in the organ bath and the perfusion reservoirs was maintained at the desired acclimation temperature by a Lauda cooling unit (Brinkmann Instruments, Rexdale, Ontario, Canada). The saline (pH 7.8 at 15 °C) contained (in $mmol\,l^{-1}$): NaCl, 124; KCl, 3.1; $MgSO_4{\cdot}7H_2O$, 0.93; $CaCl_2{\cdot}2H_2O$, 2.52; glucose, 5.6; Tes salt, 6.4; and Tes acid, 3.6 (Keen *et al.* 1994). The Tes buffer system was selected to simulate the buffering capacity of trout plasma and the normal change in blood pH with temperature ($\Delta pKa/dT$=0.016 pH units $°C^{-1}$). The saline was equilibrated with 100 % O_2 for at least 30 min prior to experimentation. The coronary artery, which supplies the outer compact myocardium of the ventricle, was not perfused and so oxygenated saline was used to ensure that a sufficient amount of oxygen diffused from the ventricular lumen to the compact myocardium. The oxygen gradient from the lumen to the mycardium of our perfused heart was at least 20 times greater than that *in vivo*. The control saline contained $30\,nmol\,l^{-1}$ adrenaline bitartrate because Graham and Farrell (1989) have established that tonic adrenergic stimulation with $10\,nmol\,l^{-1}$ adrenaline is essential for long-term viability of perfused hearts at 5 °C. In addition, Keen *et al.* (1994) showed that trout acclimated to high temperatures (18 °C) have a decreased cardiac sensitivity to adrenaline.

Experimental protocols

The maximum pumping ability of the heart was assessed by measuring the following: (1) the ability of the heart to maintain stroke volume when exposed to increases in output pressure (i.e. homeometric regulation); (2) maximum cardiac output; (3) maximum power output; and (4) output pressure at maximum power output. Homeometric regulation was investigated by increasing diastolic output pressure from 4 to 8 kPa in increments of 1 kPa, or until cardiac output fell by 40 %. During homeometric regulation, the input pressure was maintained at control levels. Output pressure was not increased further to ensure that the heart was not damaged prior to the measurement of maximum cardiac output and maximum power output. In fish swimming maximally, or exposed to high adrenaline doses, diastolic ventral aortic pressure is unlikely to exceed 8 kPa (Kiceniuk and Jones, 1977; Gamperl *et al.* 1994*a*). Maximum cardiac output was determined under control conditions by increasing filling pressure in 8–12 steps (in increments of 0.005–0.01 kPa) until cardiac output reached a maximum value. Once maximum cardiac output had been attained, output diastolic pressure was raised in steps of 0.5–1 kPa until the maximum power output was reached. The output pressure at this point was noted. Each step in filling and output pressure was maintained for approximately 1–2 min. The heart was returned to the control work load for a recovery period of 15 min after the determination of homeometric regulation and following the determination of maximum power output. This allowed the heart to recover fully between tests and/or to equilibrate to new adrenaline concentrations. This series of experimental procedures required approximately 1 h to complete.

All cardiovascular measurements were repeated at two additional adrenaline concentrations (60 and $200\,nmol\,l^{-1}$) to cover the range for circulating catecholamine levels observed in stressed rainbow trout (Milligan *et al.* 1989; Gamperl *et al.* 1994*b*; Randall and Perry, 1992). In addition, preliminary experiments at 15 °C (Fig. 1) showed that 200 nmol l^{-1} adrenaline achieved maximum adrenergic stimulation of the *in situ* preparation and that 60 nmol l^{-1} adrenaline was near the EC$_{50}$ for maximum stimulation.

Instrumentation and analysis

An in-line electromagnetic flow probe (Zepeda instruments, Seattle, Washington, USA) was used to record mean cardiac output, and pressure transducers (Narco Life Sciences, Houston, TX, USA) were used to measure input and output pressures through saline-filled side-arms. Prior to experimentation, pressure changes due to cannula resistance were calculated at known flow rates. These values were then used to adjust input and output pressure to the levels experienced by the sinus venosus and bulbus arteriosus, respectively. Calibration of the pressure transducers was performed daily against a static water column. Pressure and flow signals were amplified and displayed on a four-channel chart recorder (Gould, Cleveland, OH, USA) in conjunction with a microcomputer running Labtech Notebook (Laboratory Technologies Corporation, Wilmington, MA). Data were collected at 5 Hz, and block averages were calculated every 15 s. Heart rate was measured by counting the number of systolic peaks recorded during a 10 s period.

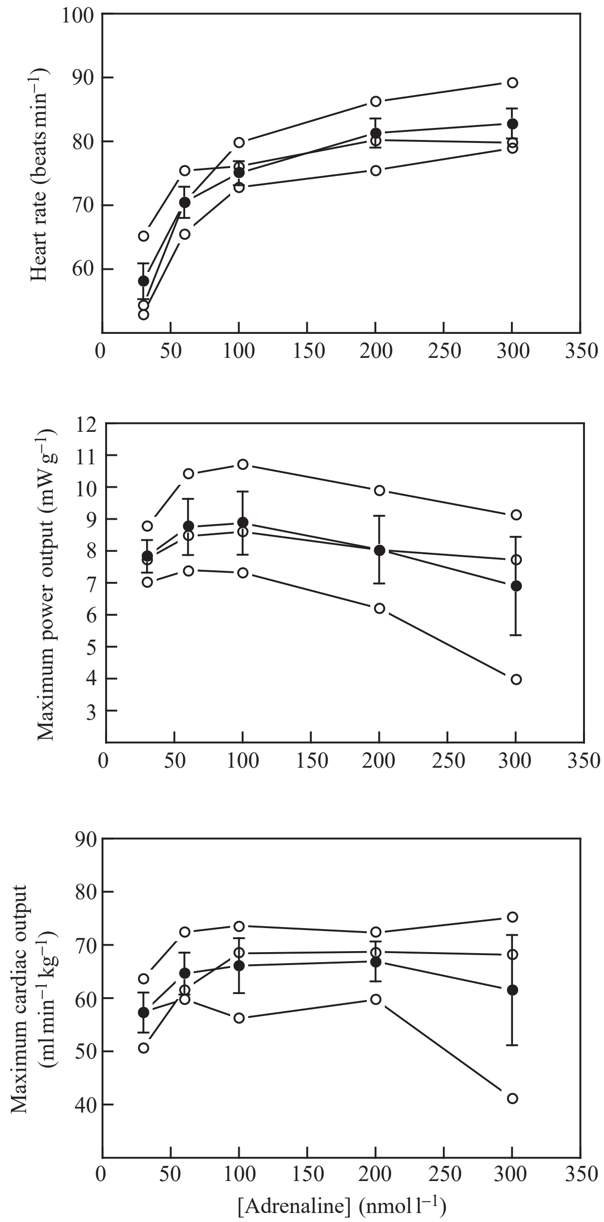

Fig. 1. Relationship between adrenaline concentration and cardiovascular variables for *in situ* perfused trout hearts at 15 °C. Open circles represent individual hearts and filled circles represent group means (*N*=3). Vertical bars represent ± 1 S.E.M.

Stroke volume and power output were calculated as follows:

$$V_S = (\dot{Q}/f_H)/M_b\,, \quad (1)$$

$$p = [\dot{Q} \times (P_o - P_i) \times \alpha]/M_v\,, \quad (2)$$

where $\dot{Q}$ (ml min^{-1}) is cardiac output, P_o is mean output pressure (kPa), P_i is mean filling pressure (kPa), V_S is stroke volume (ml kg^{-1} body mass), f_H is heart rate (beats min^{-1}), M_b is body mass (kg), p is power output (mW g^{-1} ventricle mass), M_v is ventricular mass (g) and α is 0.00162 mW min ml^{-1} kPa^{-1}.

Within each temperature group, paired *t*-tests were used to identify statistical differences between cardiovascular variables recorded at 30, 60 and 200 nmol l^{-1}. The effect of temperature within a particular adrenaline concentration was assessed using a one-way analysis of variance (ANOVA). A covariant analysis of variance (ANCOVA) was applied to the stroke volume–heart rate relationship to isolate the interactive effects of temperature and adrenaline. A general linear model (Zar, 1974) was used to examine whether temperature and adrenaline affected the relationship between filling pressure and stroke volume (i.e. the Starling curve) (Proc GLM, SAS Institute). For all statistical analyses, the fiducial limit of significance was chosen as 5 %. Values throughout the text are expressed as means ± S.E.M.

Results

Homeometric regulation

In our experience, cardiac failure is not normally a problem once the surgery has been completed. This fact is illustrated by the success of all seven of the preparations attempted at 15 °C. However, at temperatures above 15 °C, increases in output pressure either during the initial elevation to control conditions (5 kPa final pressure) or during the first homeometric regulation test caused cardiac failure (indicated by sustained cardiac arrhythmia) in some hearts. At 18 °C, two of the 13 attempts failed, and at 22 °C the failure rate reached 40 % (six out of 15 preparations). In these failing preparations, increasing the adrenaline concentration to 60 nmol l^{-1} occasionally restored the normal beat frequency, but only temporarily. These observations suggest that above 15 °C there was a particularly strong negative effect of temperature on the pressure-generating ability of certain hearts. As a result, it should be remembered that the mean values we report for cardiac variables do not take into account the fact that a proportion of heart preparations failed at 18 °C and 22 °C.

At all temperatures, an increase in diastolic output pressure significantly decreased resting stroke volume (Fig. 2). There was also a significant effect of temperature on the relationship between resting stroke volume and temperature. At 15 °C, stroke volume was maintained above 90 % of the resting value even at an output pressure of 8 kPa. In contrast, at 18 °C stroke volume was reduced to less than 80 % of the resting value at an output pressure of only 7 kPa (Fig. 2). There was no significant difference between the curves for 15 °C and 22 °C.

Adrenergic stimulation had no marked effect on the general shape of the homeometric relationships (Fig. 2). However, adrenaline consistently displaced the relationship downwards because adrenergically mediated increases in heart rate meant that the set point for resting stroke volume was lower (see below).

Heart rate

Heart rate increased significantly with both temperature and adrenaline concentration (Fig. 3A). Increasing the temperature from 15 to 22 °C increased heart rate by 13.9 beats min^{-1} (from 69.9 to 83.8 beats min^{-1}) with 30 $nmol\,l^{-1}$ adrenaline, and by 20.8 beats min^{-1} (from 81.5 to 102.3 beats min^{-1}) with 200 $nmol\,l^{-1}$ adrenaline. The Q_{10} values for 30 $nmol\,l^{-1}$ and 200 $nmol\,l^{-1}$ adrenaline were calculated as 1.28 and 1.36, respectively.

Increasing the adrenaline concentration from 30 to 200 $nmol\,l^{-1}$ significantly increased heart rate at all temperatures. This increase was 18.5 beats min^{-1} (22 %) at 22 °C and approximately 10 beats min^{-1} at 15 °C (17 %) and 18 °C (13 %).

Stroke volume

In almost all cases, the filling pressures at the routine work loads were subambient and there were no significant effects of temperature on the filling pressure required to generate routine cardiac output (Table 1). Increasing the filling pressure generated a typical Starling curve for stroke volume at all temperatures. However, acclimation temperature significantly altered the shape of the Starling curve (Fig. 4). Acclimation to higher temperatures (18 and 22 °C) caused a significant downward shift in the upper arm of the Starling curve (Fig. 4) and significantly decreased maximum stroke volume (Figs 3B, 4). Maximum stroke volumes were approximately 1 $ml\,kg^{-1}$ at 15 °C and 0.8 $ml\,kg^{-1}$ at 22 °C. Adrenaline had no significant effect on maximum stroke volume regardless of the acclimation temperature (Fig. 3B).

Maximum cardiac output

Although there was some variability in cardiac output

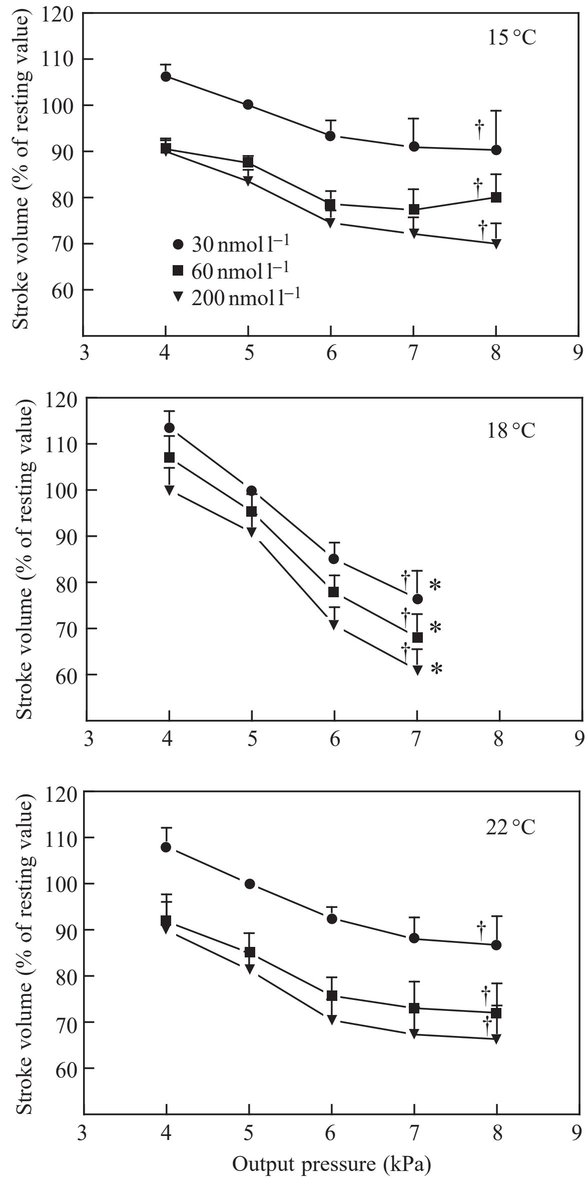

Fig. 2. Relationship between stroke volume and output pressure for *in situ* hearts exposed to various temperatures (15 °C, *N*=7; 18 °C, *N*=11; 18 °C, *N*=8) and adrenaline concentrations. Measurements for hearts at 18 °C and 8 kPa of output pressure are not shown because further increases in output pressure greatly reduced cardiac output (see Materials and methods). A dagger denotes a significant ($P<0.05$) decrease in the stroke volume at the highest output pressure tested when compared with the resting value. An asterisk indicates a significant difference from the value for stroke volume of the 15 °C fish tested at the highest output pressure. Vertical bars represent ± 1 S.E.M.

between temperature groups, there were no significant differences between values. Furthermore, it is clear that maximum cardiac output with 60 and 200 $nmol\,l^{-1}$ adrenaline was unchanged by acclimation temperature (Fig. 3C). This indicates that the temperature-induced increases in heart rate

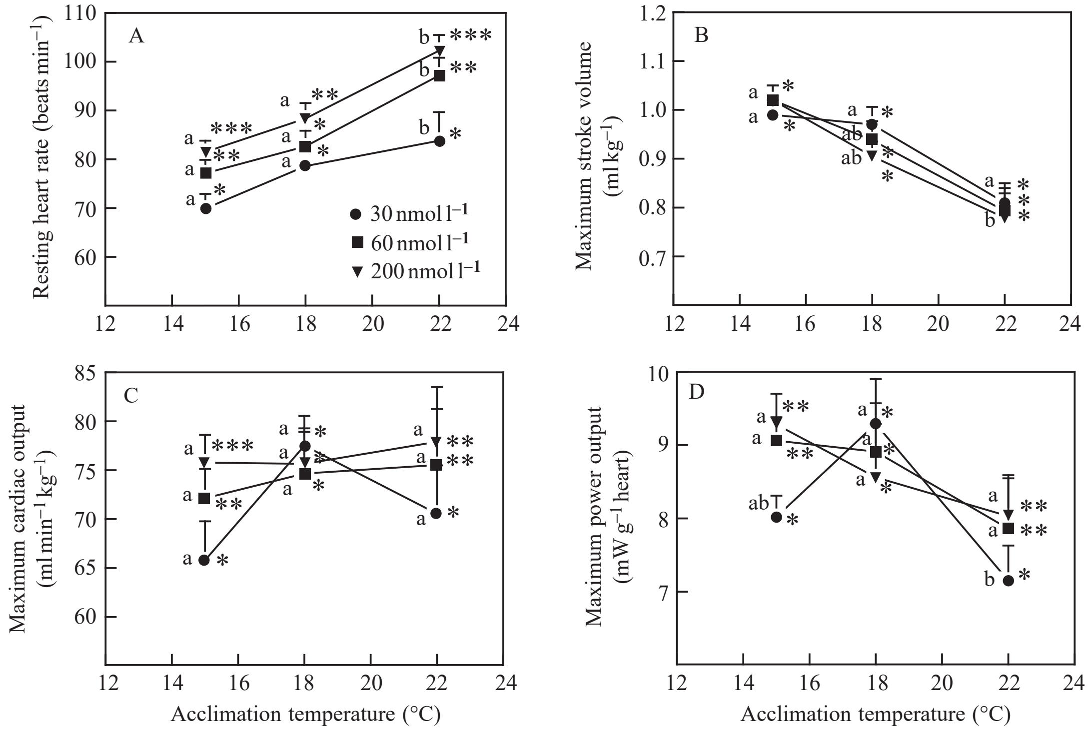

Fig. 3. Relationship between acclimation temperature and (A) resting heart rate, (B) maximum stroke volume, (C) maximum cardiac output and (D) maximum power output for *in situ* perfused trout hearts at 15 (N=7), 18 (N=11) and 22 °C (N=8). Vertical bars represent 1 S.E.M. Dissimilar letters indicate values that are significantly different (P<0.05) between acclimation temperatures within each adrenaline concentration. Within each temperature, means with an unequal number of asterisks indicate significant differences between adrenaline concentrations (P<0.05).

were offset by equal and opposite changes in maximum stroke volume. This point is illustrated in Fig. 5, where the 29 % increase in heart rate between 15 and 22 °C was associated with a 23 % reduction in stroke volume.

Within the 15 and 22 °C temperature groups, there were statistically significant effects of adrenaline (Fig. 3C). Increasing the adrenaline concentration from 30 to 200 nmol l^{-1} increased maximum cardiac output by 10 ml min^{-1} kg^{-1} (15 %) at 15 °C and by 7.5 ml min^{-1} kg^{-1} (10 %) at 22 °C. There was no significant effect of adrenaline on cardiac output at 18 °C.

Maximum power output

While the homeometric regulation test and the failure of a high proportion of hearts hinted at poorer inotropic performance under resting conditions at 22 °C, a reduced maximum power output was a clear indicator of inotropic failure at this acclimation temperature. Maximum power

Table 1. *Morphometric and cardiovascular variables for rainbow trout (*Oncorhynchus mykiss*) acclimated to 15, 18 and 22 °C*

Test temperature (°C)	Body mass (g)	Heart mass (g)	RVM (%)	Resting P_i (kPa) 30 nmol l^{-1}	Resting P_i (kPa) 60 nmol l^{-1}	Resting P_i (kPa) 200 nmol l^{-1}	P_o at maximum power (kPa) 30 nmol l^{-1}	P_o at maximum power (kPa) 60 nmol l^{-1}	P_o at maximum power (kPa) 200 nmol l^{-1}
15 (N=7)	493.1±29.7[a]	0.40±0.1[a]	0.081±0.01	–0.08±0.02	–0.08±0.02	–0.08±0.03	7.14±0.28[a]	7.38±0.23[a]	7.20±0.33[a]
18 (N=11)	515.1±28.9[a,b]	0.40±0.0[a]	0.078±0.00	–0.07±0.04	0.00±0.03	–0.01±0.04	6.84±0.15[a,b]	6.80±0.16[a,b]	6.14±0.19[b]
22 (N=9)	606.5±41.7[b]	0.53±0.0[b]	0.088±0.00	–0.07±0.03	–0.06±0.02	–0.07±0.03	6.26±0.21[b]	6.60±0.27[b]	6.13±0.24[b]

Resting input pressure, and output pressure at maximum power output, were recorded at three different adrenaline concentrations (30, 60 and 200 nmol l^{-1}) using an *in situ* heart preparation.

Values are expressed as means ± 1 S.E.M.

RVM, relative ventricular mass.

Dissimilar letters indicate significantly different values (P<0.05) within a column.

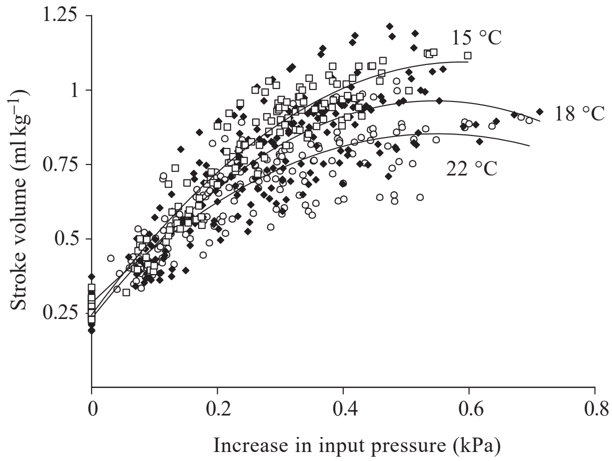

Fig. 4. Starling curves for *in situ* perfused trout hearts at acclimation temperatures of 15 (N=7, □), 18 (N=11, ◆) and 22 °C (N=9, ○). Within each temperature, each point represents data for an individual heart at adrenaline concentrations of 30, 60 and 200 nmol l^{-1}. Best-fitting equations for each acclimation temperature were: 15 °C, $y=-2.439x^2+2.878x+0.245$ (r^2=0.942); 18 °C, $y=-2.454x^2+2.678x+0.233$ (r^2=0.829); 22 °C, $y=-1.887x^2+2.072x+0.284$ (r^2=0.824). Analysis of covariance showed that the stroke volume–input pressure relationships at all temperatures were significantly different from each other (P<0.05).

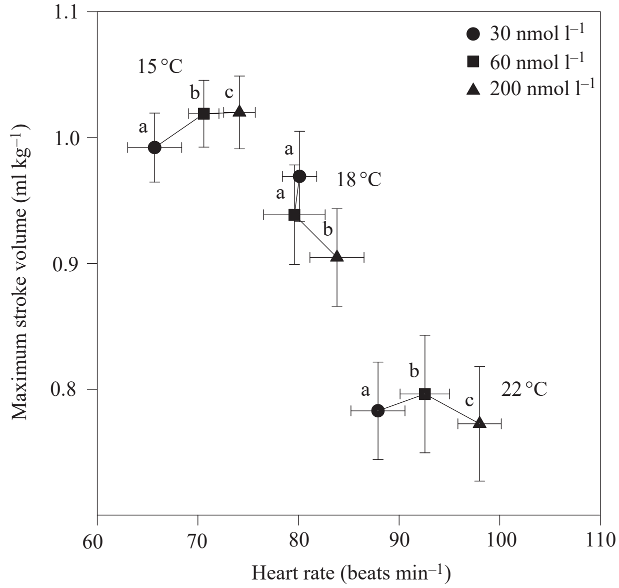

Fig. 5. The relationship between maximum stroke volume and heart rate for *in situ* perfused trout hearts at various temperatures and adrenaline concentrations. Values are expressed as means ± 1 S.E.M. Dissimilar letters within temperature groups indicate significant differences (P<0.05) between adrenaline concentrations. Means for each adrenaline concentration were significantly different between temperatures (P<0.05).

output was significantly lower at 22 °C that at 15 °C, irrespective of the adrenaline concentration (Fig. 3D). This reduction in maximum power output occurred primarily because the maximum pressure-generating ability of the heart was significantly lower (Table 1), since maximum cardiac output was unaffected (Fig. 3C).

Discussion

The present study, which is the first to measure the maximum performance of a perfused salmonid heart at temperatures near the upper lethal temperature, clearly shows that maximum cardiac output reaches a plateau at approximately 15 °C and that temperatures above 18 °C are associated with a reduced pressure-generating ability. This conclusion is consistent with *in vivo* measurements made on another salmonid, the sockeye salmon (*Oncorhynchus nerka*). Davis (1968) and Brett (1971) found that cardiac output in swimming sockeye salmon was essentially unchanged between 15 and 22 °C. In addition, they estimated that cardiac work during activity had a peak at 15 °C because ventral aortic blood pressure was lower at 22 °C than at 15 °C. If it is assumed that maximal prolonged swimming activity elicits a maximal

Table 2. *A comparison of maximum cardiac performance variables at various temperatures using* in situ *heart preparations with intact pericardia and tonic (5–30 nmol l^{-1} adrenaline) or maximal levels of adrenergic stimulation (values in parentheses)*

Temperature (°C)	Heart rate (beats min^{-1})	Stroke volume (ml kg^{-1})	Cardiac output (ml min^{-1} kg^{-1})	Power output (mW g^{-1})	Reference
8	52	0.96	50	6.1	Keen and Farrell (1994)
10	50	0.97	53	5.9	Farrell *et al.* (1988)
10	66	0.69	46	6.5	Milligan and Farrell (1991)
10	62 (73)	0.89 (0.86)	56 (63)	5.2 (6.9)	Farrell *et al.* (1991)
10 (TR)	66 (75)	1.05 (1.05)	67 (75)	6.7 (8.7)	Farrell *et al.* (1991)
15	70 (82)	0.99 (1.02)	66 (76)	8.00 (9.3)	Present study
18	78	0.79	62	8.81	Keen and Farrell (1994)
18	79 (88)	0.97 (0.91)	78 (76)	9.3 (8.6)	Present study
22	84 (102)	0.81 (0.77)	71 (78)	7.2 (8.0)	Present study

TR indicates that this group of fish was exercise-trained for 1 month.

cardiac response in sockeye salmon, then the sockeye salmon's maximal *in vivo* cardiac performance peaks at its preferred temperature (12–14 °C; Brett, 1971) and well below its upper lethal limit (24 °C). We believe that a similar conclusion can be drawn for the rainbow trout, whose preferred temperature and upper lethal temperature are almost identical to those of the sockeye salmon (Black, 1953; Garside and Tait, 1958).

When using a perfused trout heart preparation without a coronary circulation, the exchange of gases and solutes between the myocardium and the perfusate will be affected. This is of particular concern in the present study for two reasons. First, the experimental conditions promoted cardiac failure and, second, any problems with diffusion may have been exacerbated in the hearts of the 22 °C fish because their ventricles were 30 % larger than those of the 15 °C fish. Nonetheless, there are several important reasons why the absence of a coronary circulation was unlikely to bias the experiments towards the poorer cardiac performance observed at 22 °C. Foremost, there is good agreement between the cardiac performance measures for our perfused *in situ* hearts and reported *in vivo* values for swimming sockeye salmon (Davis, 1968; Brett, 1971). In both studies, heart rate increased at 22 °C while stroke volume, cardiac output, pressure generation and cardiac power output decreased. Second, by limiting fish size to less than 750 g and oxygenating the perfusate, we believe that any problem with oxygen diffusion into the myocardium was largely eliminated. The oxygen partial pressure gradient was at least 20 times that normally found in venous blood, and the thickness of the compact myocardium in our fish (<1 mm) was no more than that used in examining cardiac performance with electrically paced, isolated strips. Third, Davie and Farrell (1991) were unable to improve the performance of normoxic dogfish hearts by perfusing the coronary circulation with air-saturated saline. Although we may have eliminated the possibility of an oxygen limitation, there is an additional concern regarding solute transfer, particularly the removal of H^+ and K^+, which in themselves could reduce heart contractility. We know from previous studies that lactate and H^+ are released into the lumen and can be measured in the perfusate leaving the trout heart (Farrell and Milligan, 1986). Therefore, transfers of solute from the trout myocardium are far from completely inhibited. If the larger hearts of the 22 °C group did lead to a poorer cardiac performance, we would predict a negative correlation between heart size and cardiac power output. However, no significant relationship exists between these two variables (r^2=0.30). In view of the above discussion, we feel confident in extrapolating our observations to the *in vivo* situation and in providing mechanistic explanations.

To illustrate the point that peak cardiac performance occurs at approximately 15 °C in rainbow trout, Table 2 summarizes the available data on maximum cardiac performance of perfused rainbow trout hearts at various temperatures. The data in Table 2 are comparable because they were collected in the same laboratory using the same type of heart preparation (i.e. an *in situ* heart with an intact pericardium) and an initial tonic adrenergic stimulation (5–30 nmol l^{-1} adrenaline). Table 2 clearly shows that the maximum stroke volume under conditions of tonic adrenergic stimulation occurs between 10 and 15 °C, whereas maximum cardiac output and maximum power output occur at 18 °C. Although these data suggest that maximum cardiac performance in rainbow trout occurs at 18 °C, it is unlikely that *in vivo* maximal cardiac performance is achieved without significant adrenergic stimulation (humoral and/or sympathetic). Under conditions of 'maximal' adrenergic stimulation, cardiac output remains constant between 10 and 22 °C, an effect which shifts the optimum temperature for maximum power output to 15 °C (Table 2; Fig. 3D). Because power output is the most appropriate index of integrated cardiac performance, it appears that maximum performance of rainbow trout hearts is achieved at 15 °C.

Temperature is generally regarded as having positive chronotropic and negative inotropic effects on the teleost myocardium (Lennard and Huddart, 1992; Matikainen and Vornanen, 1992). The present study supports this generalization with regard to both the chronotropic and inotropic effects of temperature. Matikainen and Vornanen (1992) nicely illustrated the simultaneous and opposing effects of temperature-related negative inotropy and positive chronotropy using isolated carp cardiac muscle. By deriving a maximum tissue pumping capacity term (the product of the spontaneous heart rate and the maximum isometric force; g mg^{-1} tissue min^{-1}), they demonstrated a peak tissue pumping capacity at approximately 20 °C, a temperature well below the upper lethal temperature of carp (approximately 35 °C). The performance curve for isolated carp cardiac muscle strips had an inverted U shape as a function of temperature. Consequently, the decline in tissue pumping capacity of the carp heart at warm temperatures bears a striking resemblance to the decline in maximum power output in *in situ* rainbow trout hearts (see Table 2; see Fig. 6) and *in vivo* in sockeye salmon (Brett, 1971). In all three instances, there was a decrease in inotropic performance and/or decreased maximum stroke volume at higher temperatures.

Inotropic failure in our rainbow trout hearts at temperatures greater than 15 °C was demonstrated by lower values for maximum power output and maximum output pressure at 18 and 22 °C. In addition, the significance of this result is magnified when one considers that the failure of a number of preparations at these temperatures resulted in only the stronger hearts being tested (this bias may in fact explain why the homeometric regulation curves were similar for 15 and 22 °C hearts). The finding that rainbow trout hearts had a poorer pressure-generating ability at temperatures above 15 °C has indirect support from *in vivo* studies. For example, Davis (1968) reported reduced ventral and dorsal aortic blood pressures in swimming sockeye salmon at 22 °C compared with values at 15 °C, even though cardiac output was the same. Also, Wood *et al.* (1979) found a significant attenuation of the increase in dorsal aortic blood pressure in rainbow trout in response to adrenaline injections at 22 °C compared with 12 °C. Thus, in both of these studies, the heart performed less pressure work at 22 °C. These *in vivo* observations could be related to increased temperature directly affecting the normal neural, hormonal and local control of vasomotor status in the systemic circulation (i.e. either a greater vasodilatory capacity or a weaker vasoconstrictory capacity). However, on the basis of the present observations, we can include another possibility. In response to a poorer cardiac pressure-generating ability at 22 °C, the vasomotor system may produce a vasodilatation to allow for the maintenance of cardiac output. Interestingly, Gamperl *et al.* (1994*a*) reported that adrenaline injection into rainbow trout resulted in significantly lower *in vivo* dorsal aortic pressures if the pericardium was opened. Opening the pericardium is known to cause poorer pressure generation in both the rainbow trout (Farrell *et al.* 1988) and the eel (*Anguilla dieffenbacchi*) (Franklin and Davie, 1991), and reduces maximum power output in the rainbow trout heart by approximately 45 %.

Work on isolated cardiac muscle strips from teleost fish clearly shows that maximum tension decreases with increasing pacing frequencies, a negative staircase effect (Driedzic and Gesser, 1985; Vornanen, 1989; Bailey and Driedzic, 1990). It seems likely that this negative staircase effect would explain the negative inotropic effect of warm temperature in our hearts. Indeed, there is a decrease in force when the spontaneous beat frequency increases with temperature (Ask, 1983; Matikainen and Vornanen, 1992), and indications are that factors associated with either a shortening of the duration of the active state or a reduction in the intensity of the active state may become limiting at high beat frequencies (Vornanen, 1989; Driedzic and Gesser, 1994). The factors could include the inability of the contractile proteins to generate maximal force at shortened active states or impaired calcium delivery to and removal from the contractile proteins (Vornanen, 1989; Matikainen and Vornanen, 1992).

Nevertheless, alternative explanations for the reduction in maximum power output and maximum pressure-generating ability with increasing temperature should not be excluded at this time. For example, decreases in β-receptor number and/or affinity could have diminished the positive inotropic influence of adrenaline. In ventricular strips, Keen *et al.* (1993) showed that it takes approximately 10 times the adrenaline concentration at 18 °C to achieve the same level of tension generation measured at 8 °C, and that this effect was associated with fewer sarcolemmal β-adrenoreceptors. In addition, Ask *et al.* (1981), using atrial tissue, showed that the contractile force elicited by a maximally effective dose of adrenaline ($1.4\,\mu$mol l^{-1}) at 14 °C was only 30 % of that produced at 2 °C. Although the observation that heart rate increased with increasing adrenaline concentration at all temperatures (Fig. 3A) is apparently inconsistent with diminished adrenergic influence at high temperatures, it must be remembered that positive chronotropy is mediated primarily through effects on the heart's pacemaker cells (Huang, 1973), whereas inotropic effects occur primarily because of adrenergic stimulation of the ventricle. Thus, there could be differential temperature effects on adrenergic sensitivity for these two regions of the heart.

It is clear from the present study that the application of Q_{10} values to maximum cardiac output has a limited value. At temperatures above the preferred temperature, Q_{10} values could be misleading because of the plateau in maximum cardiac output. Furthermore, because temperatures above 15 °C are associated with increased heart rates but constant cardiac output and falling power outputs, heart rate must be considered to be a very poor predictor of cardiac performance at these temperatures.

Maximum stroke volume decreased with increasing temperature (Fig. 3B). Previous studies with *in situ* trout hearts have also reported that maximum stroke volume decreased with increasing temperature (Graham and Farrell, 1990; Keen and Farrell, 1994). Likewise, Yamamitsu and Itazawa (1990) showed that stroke volume decreased with increasing temperature in the isolated carp heart, although it is unlikely that they measured maximum performance. The data presented in Table 2 suggest that maximum stroke volume of the *in situ* rainbow trout heart (approximately 1 ml kg^{-1}) occurs at temperatures of 15 °C and below. In a heart preparation with a punctured pericardium, Graham and Farrell (1990) showed that stroke volume decreased from 1 ml kg^{-1} at 5 °C to 0.7 ml kg^{-1} at 15 °C. Because stroke volume in our *in situ* heart with an intact pericardium was still 1 ml kg^{-1} at 15 °C, it is possible that the pericardium plays an important role in maintaining maximum stroke volume at warm temperatures.

Heart rate clearly had an important influence on maximum stroke volume (Fig. 5). This agrees with numerous previous studies where temperature-induced decreases in stroke volume were associated with concomitant increases in heart rate (Graham and Farrell, 1989; Lennard and Huddart, 1992; Keen and Farrell, 1994). There are two possible explanations for this inverse relationship between heart rate and maximum stroke volume: either a limitation on cardiac filling or the negative staircase effect on cardiac contractility referred to above. To what degree these two factors influence stroke volume at higher heart rates can be resolved only by direct measurements of heart chamber volumes during the cardiac cycle. Using echocardiography, Franklin and Davie (1992) showed that ventricular end-systolic volume in rainbow trout is normally near zero. Therefore, if a negative staircase effect is involved in the reduced stroke volume at high heart rates, end-systolic volume would be found to increase. In contrast, a lower end-diastolic volume would account for the decrease in stroke volume if filling time was a problem, as suggested by Farrell *et al.* (1989) to explain a decrease in maximum stroke volume of 0.2 ml kg^{-1} when isolated trout hearts were paced at 60 beats min^{-1}. One piece of evidence which suggests that limitations on cardiac filling may contribute to the decrease in stroke volume at high heart rates comes from studies on *in situ* hearts with intact (present study) *versus* punctured pericardia (Graham and Farrell, 1990). Stroke volume decreased by 0.3 ml kg^{-1} (from 1 ml kg^{-1}) when intrinsic heart rate reached 60 beats min^{-1} in hearts with a punctured pericardium. In contrast, hearts with an intact pericardium were able to maintain maximum stroke volume until heart rate exceeded

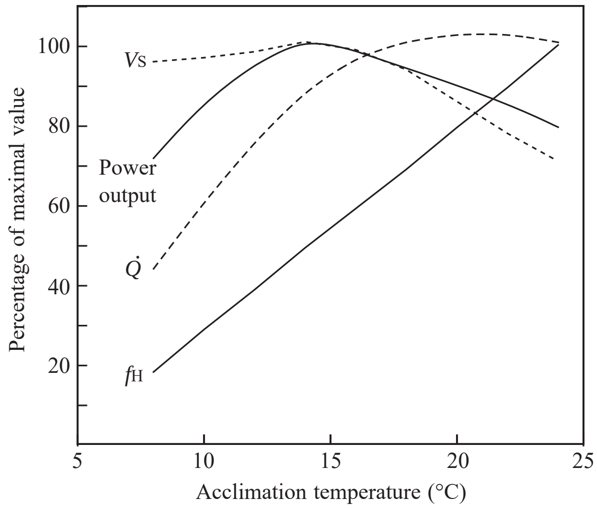

Fig. 6. Proposed relationship between acclimation temperature and the maximal level of cardiovascular variables for the rainbow trout. The 100 % values for stroke volume (*V*s), heart rate (*f*H), power output and cardiac output ($\dot{Q}$) are $1\,ml\,kg^{-1}$, $120\,beats\,min^{-1}$, $9.5\,mW\,g^{-1}$ and $80\,ml\,min^{-1}\,kg^{-1}$, respectively.

$80\,beats\,min^{-1}$. A mechanistic explanation for the enhanced maintenance of maximum stroke volume in hearts with an intact pericardium is that the pericardium in rainbow trout permits *vis-a-fronte* filling of the heart (Farrell *et al.* 1988) and this type of cardiac filling is likely to be faster than *vis-a-tergo* filling (Farrell and Jones, 1992).

Fig. 6, while somewhat speculative at this time, summarizes our ideas on cardiac performance in rainbow trout as a function of acclimation temperature. We hope that it will provide a useful framework for further research in this area. Heart rate follows a Q_{10} relationship up to the upper lethal temperature, where it reaches its maximum level of approximately $120\,beats\,min^{-1}$. Maximum stroke volume (approximately $1\,ml\,kg^{-1}$) is maintained up to the preferred temperature, above which it decreases. For several degrees above the preferred temperature, the decrease in stroke volume is matched by the increase in heart rate. Consequently, maximum cardiac output (approximately $80\,ml\,min^{-1}\,kg^{-1}$) has a broad plateau extending for several degrees higher than the preferred temperature. In contrast, the pressure-generating ability of the heart decreases at temperatures higher than the preferred temperature such that peak maximum power output (around $9.5\,mW\,g^{-1}$) occurs around the preferred temperature.

Mechanistic explanations for the decline in maximum performance above the preferred temperature require further work at both the organ and tissue level. However, the observation that maximum stroke volume was not maintained at high temperatures suggests that myocardial adaptations are quite limited above the preferred temperature. This is not the case at colder temperatures. For example, cold acclimation results in a larger cardiac mass (Graham and Farrell, 1989) and a greater number of sarcolemmal adrenoceptors that increase the sensitivity of the trout heart to adrenaline (Keen *et al.* 1993). As a result of cold-acclimation, maximum stroke volume and power output tend to be higher than otherwise possible with the accompanying temperature-dependent decrease in heart rate.

Whether any of the above generalizations apply to other teleost species, such as sockeye salmon and carp, remains to be determined. However, it is clear for the rainbow trout (1) that maximum cardiac performance declines at temperatures above the preferred temperature; (2) that the usefulness of Q_{10} relationships for cardiac functions other than heart rate is highly dependent upon the section of the thermal regime of the fish under consideration; and (3) that heart rate is a poor indicator of integrated cardiac function at temperatures above the preferred temperature.

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Influence of seasonal temperature on the repeat swimming performance of rainbow trout *Oncorhynchus mykiss*

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Summary

While the temperature dependence of exercise performance in fishes is reasonably well documented, information on the temperature dependence of metabolic recovery and reperformance is scant. This study examined the recovery of swimming performance after exhaustive exercise in rainbow trout *Oncorhynchus mykiss* at seasonal temperatures ranging from 5 to 17°C and explored the relationship between performance and preceding metabolic state. The primary objective of the study was to test the hypothesis that increased temperature increases the capability of rainbow trout to repeat a critical swimming speed (U_{crit}), as assessed by two consecutive critical swimming speed tests separated by a 40 min rest interval. An additional expectation was that certain plasma ionic, metabolic and humoral parameters would be correlated with how well fish reperformed and so plasma levels of lactate, potassium, ammonia, osmolality, sodium and cortisol, as well as hematocrit, were monitored before, during and after the swim challenges *via* an indwelling cannula in the dorsal aorta. As expected, performance in the first U_{crit} test (U_{crit1}) was positively related to temperature. However, the relationship between U_{crit1} and reperformance (U_{crit2}) was not dependent on acclimation temperature in a simple manner. Contrary to our expectations, U_{crit2} was less than U_{crit1} for warm-acclimated fish (14.9±1.0°C), whereas U_{crit2} equaled U_{crit1} for cold-acclimated fish (8.4±0.9°C). Cold-acclimated fish also exhibited a lower U_{crit1} and less metabolic disruption compared with warm-acclimated fish. Thus, while warm acclimation conferred a faster U_{crit1}, a similar swimming speed could not be attained on subsequent swim after a 40 min recovery period. This finding does not support the hypothesis that the ability of rainbow trout to reperform on U_{crit} test is improved with temperature. Both plasma lactate and plasma potassium levels were strongly correlated with U_{crit1} performance. Therefore, the higher U_{crit1} of warm-acclimated fish may have been due in part to a greater anaerobic swimming effort compared with cold-acclimated fish. In fact, a significant correlation existed between the plasma lactate concentration prior to the start of the second test and the subsequent U_{crit2} performance, such that U_{crit2} decreased when a threshold plasma lactate level of around 12.2 mmol l^{-1} was surpassed for the initial swim. No other measured plasma variable showed a significant relationship with the U_{crit2} performance. We conclude that warm-acclimated fish, by apparently swimming harder and possibly more anaerobically compared with cold-acclimated fish, were unable to recovery sufficiently well during the fixed recovery period to repeat this initial level of performance, and this poorer repeat performance was correlated with elevations in plasma lactate levels.

Key words: fish, rainbow trout, *Oncorhynchus mykiss*, critical swimming speed, temperature acclimation, repeat swimming, plasma, lactate threshold, ammonium.

Introduction

An extensive literature exists on the recovery of metabolites and ions following exhaustive exercise in fish (see reviews by Driedzic and Hochachka, 1978; Milligan, 1996; Kieffer, 2000). Considerably fewer studies have measured how quickly or how well swimming performance recovers following exhaustive exercise (e.g. Stevens and Black, 1966; Randall et al., 1987; Brauner et al., 1994; Jain et al., 1998; Farrell et al., 1998, 2001, 2003). Given that metabolic recovery in skeletal muscle (muscle lactate, ATP and glycogen, but not PCr) occurs more rapidly at warm than cold temperatures in exhausted rainbow trout *Oncorhynchus mykiss* and Atlantic salmon *Salmo salar* (Kieffer et al., 1994; Wilkie et al., 1997; Kieffer, 2000), the expectation is that swimming performance is restored faster at a higher temperature. This expectation would be consistent with the known increase in both maximum oxygen uptake and maximum cardiac output with temperature (e.g. Butler et al., 1992; Farrell, 1997; Taylor et al., 1997) because an improved oxygen delivery system could support a more rapid recovery of the metabolic debt incurred with exhaustive exercise. However, when Atlantic salmon were angled rather than chased to exhaustion, muscle glycogen, intracellular pH and lactate were restored more rapidly under cold conditions than warm conditions (Wilkie et al., 1996). Therefore, given this uncertainty and the absence of any study that has directly measured how acclimation temperature affects the recovery of swimming performance, the primary objective of the present study was to test the hypothesis that the ability of rainbow trout to repeat a critical swimming speed (U_{crit}) test is improved with temperature.

A second objective of the present study was to search for correlations between the ability to reperform after an exhaustive U_{crit} swim and the alteration in plasma levels of ions, metabolites and hormones during exercise. In particular, possible linkages were sought between the recovery of swimming performance and the post-exhaustion levels of plasma potassium, lactate and total ammonia concentrations (T_{amm}), all of which have been linked with muscular exhaustion in both mammals and fish. For example, high intensity exercise in mammals produces a potassium loss from the muscle (Sjøgaard et al., 1985; Vøllestad et al., 1994; Hallén, 1996), which could decrease the muscle membrane excitability and compromise tension development (reviewed by Sjøgaard, 1991). Plasma potassium levels increase in rainbow trout just prior to U_{crit} and, moreover, exercise training increased U_{crit} while blunting and delaying the increases in plasma potassium and lactate just prior to exhaustion (Holk and Lykkeboe, 1998). Plasma lactate concentration has long been considered a useful indicator of aerobic limitations and anaerobic capabilities in exercise studies. Indeed, rainbow trout refused to perform repetitive bouts of burst exercise when plasma lactate concentration exceeded 13 mmol l^{-1} (Stevens and Black, 1966) and a poorer repeat U_{crit} was found for sockeye salmon *Oncorhynchus nerka* when plasma lactate concentration was >10 mmol l^{-1} (Farrell et al., 1998). In mammals, elevated plasma T_{amm} has been implicated in exercise fatigue (reviewed by Mutch and Banister, 1983) due to inhibitory influences on anaerobic metabolism (Zaleski and Bryla, 1977; Su and Storey, 1994), aerobic metabolism (McKhann and Tower, 1961; Avillo et al., 1981) and neuromuscular coordination (Binstock and Lecar, 1969; O'Neill and O'Donovan, 1979). Plasma T_{amm} also increases in rainbow trout during exercise (Turner et al., 1983; Wang et al., 1994; but see Beaumont et al., 1995a,b). Furthermore, when routine T_{amm} was elevated in brown trout *Salmo trutta*, as a result of exposure to acidic, copper-containing water, the subsequent U_{crit} performance was inversely related to pre-exercise plasma T_{amm} concentration (Beaumont et al., 1995a). Thus, because plasma levels of potassium, lactate and T_{amm} are good indicators of exhaustion in fish, we anticipated that they are potentially strong indicators of repeat swimming capability in rainbow trout. If this is the case, the expectation is that individual variation in these plasma variables prior to a second swim would be correlated with individual variation in the performance of a second U_{crit} test compared to the initial performance.

Materials and methods

Fish

Rainbow trout *Oncorhynchus mykiss* Walbaum [mass=871.49±43.34 g (mean ± standard error of the mean, S.E.M.); fork length (*FL*)=40.95±0.77 cm, *N*=15] were obtained from a local hatchery (Sun Valley Trout Farm, Mission, British Columbia, Canada). They were held outdoors in a 2000 liter round fiberglass aquarium provided with aerated and dechlorinated Vancouver municipal water, pH 6.7, hardness 5.2–6.0 mg l^{-1} $CaCO_3$, and ambient temperature 5–17°C. Experiments were performed between November 1997 and April 1998, and September–October 1998. All experimental work conformed to the guidelines set out by the Canadian Council on Animal Care, as approved by the Simon Fraser University Animal Care Committee.

Swim tunnel

Fish were swum in a modified Brett-type swim tunnel, similar to that described by Gehrke et al. (1990). The swim chamber was 21 cm diameter and 97 cm length, with a metal grid at each end. The rear grid was equipped with an electrical pulse generator (4 V) that, when contacted by the fish, provided a mild stimulation to encourage the fish to swim forward. Water speed was uniform across the swim tunnel throughout the speed range used in these experiments. The water current in the tunnel was produced by a 3-phase induction motor and a centrifugal pump attached to a tachometer whose readings (Hz) were calibrated with known water velocities, as measured with a Valeport current meter (Valeport Marine Scientific Ltd., Dartmouth, UK).

Protocol for arterial cannulation

The dorsal aorta was cannulated to permit sampling of blood prior to and during the swimming tests, and during the recovery periods. Arterial cannulation was performed under anesthesia (0.1 g l^{-1} buffered MS-222; Syndel Laboratories, Vancouver, BC, Canada), using the method of Smith and Bell (1964). Fish mass, fork length, maximum width and maximum depth were also measured at this time. Cannulated fish were either placed in the swim tunnel to recover or returned to the outdoor tank, where they recovered for up to 3 days before being placed in the swim tunnel. During subsequent transfer from the outdoor tank to the tunnel, fish were lightly and briefly anaesthetized (0.05 g l^{-1} buffered MS-222). There was no significant relationship between post-cannulation recovery time and measured swimming performance (data not presented).

Habituation to the swim tunnel and high water velocities

Fish recovered from anesthesia in the tunnel at a water speed of 10 cm s^{-1} for at least 45 min. After this time, fish performed a 20 min practice swim, as suggested in Jain et al. (1997), during which water speed was increased in 9–10 cm s^{-1} increments every 2 min to a speed of ~41 cm s^{-1}. Water speed was then returned to 10 cm s^{-1} for 2 min and again increased in the same fashion to a speed of either 55 or 59 cm s^{-1}, depending on the fish's swimming capability. The practice swim, which did not exhaust the fish, prevented the training effect often observed with naive fish on a second U_{crit} (Farlinger and Beamish, 1977; Jain et al., 1997). Fish then recovered overnight (14–16 h) at a water speed of 10 cm s^{-1}.

Swimming protocol

All experiments were started between 08:00 h and 10:00 h. Fish performed a ramp-U_{crit} test (Jain et al., 1997). The first U_{crit} test was followed by a 40 min recovery period at a water speed of 10 cm s^{-1} and then a second ramp-U_{crit} test followed by another recovery period. Each ramp-U_{crit} test involved increasing water speed to ~50% of U_{crit} over a 5 min period, after which water speed was increased in 10 cm s^{-1} increments (~15% of U_{crit}) every 20 min until exhaustion. Exhaustion was taken as the point at which the fish failed to swim away from the electrified rear grid after 20 s of contact. The ramp-U_{crit} protocol produces similar values for U_{crit} to the more standard U_{crit} testing protocol in which the longer time intervals are used from the onset of the test (Jain et al., 1997).

U_{crit} values were calculated for the first (U_{crit1}) and second (U_{crit2}) swims, as described by Brett (1964):

$$U_{crit} = u_i + (t_i/t_{ii} \times u_{ii}) , \quad (1)$$

where u_i is the highest speed at which the fish swam for the full time period (cm s^{-1}); u_{ii} is the incremental speed increase (cm s^{-1}); t_i is the time the fish swam at the final speed (min), and t_{ii} is the prescribed period of swimming per speed (20 min). As the cross-sectional area of each fish was <20% but sometimes >10% of that of the swimming chamber, the calibrated water speed was corrected for the solid blocking effect according to the calculations described by Bell and Terhune (1970):

$$\text{corrected } U_{crit} = U_{crit} \times \{1 + [0.4FL / 0.5(w+d)] \times (0.25\pi dw/A_t)^{1.5}\} , \quad (2)$$

where FL is fork length (cm), w is maximum fish width (cm), d is maximum fish depth (cm) and A_t is tunnel cross-sectional area. Water temperature did not fluctuate by more than 0.5°C from ambient temperature during the period that the fish spent in the tunnel.

Blood sampling

Blood samples (0.9 ml) were taken through the dorsal aorta cannula to measure plasma ion and metabolite levels. Normally, samples were taken immediately prior to the swimming protocol (routine samples), at exhaustion for both swim tests (U_{crit} exhaustion samples), and after a 40 min recovery for both tests (recovery samples; the recovery sample for the first U_{crit} swim also served as the sample taken immediately before the second U_{crit} swim). In 14 of the 16 fish, a blood sample was taken during aerobic swimming, i.e. after 15 min at 45 cm s^{-1} (approx. 69% U_{crit}). (These data are not reported as they simply provided intermediate values between the routine and U_{crit} values.) An equal volume of physiological saline solution was used to replace all blood samples (Gallaugher et al., 1992). Routine hematocrit was never less than 23% and remained elevated throughout the swim tests (see Fig. 2D).

Analytical techniques

Hematocrit was measured in microcapillary tubes after centrifugation at 2000 ***g*** for 3 min. The remainder of the blood was centrifuged at 10 000 ***g*** for 5 min to obtain plasma, which was stored at –80°C. Within 1 week of testing, plasma lactate and glucose concentrations were measured on 25 µl samples using a YSI 2300 lactate/glucose analyzer (Yellow Springs, OH, USA) that calibrated automatically every five samples. Plasma potassium and sodium concentrations were measured using a model 510 Turner flame photometer (Palo Alto, CA, USA). Plasma (5 µl) was diluted 1:200 with a prepared 15 mEq l^{-1} lithium diluent for analysis. The machine was calibrated prior to use and checked against a standard approximately every six samples. The measurement was repeated if there was disagreement between duplicates beyond 2% of absolute value. Osmolality was measured on duplicate 10 µl samples using a calibrated Wescor Vapour Pressure Osmometer, Model 5500 (Wescor, Logan, UT, USA). The measurement was repeated if there was disagreement between duplicates beyond 3% of absolute value. The thermocouple heads were cleaned periodically in order to maintain consistency. Plasma cortisol concentration was measured using a commercial radioammunoassay kit (ICN Biomedicals, Inc., Costa Mesa, CA, USA), with a detection limit of 1.5 ng ml^{-1}. Plasma ammonia concentration (T_{amm}) was measured spectrophotometrically on 0.1 ml plasma samples (Sigma Diagnostics kit no. 171, St Louis, MI, USA) with a calibration every seven samples.

Data analysis

All plasma metabolites and ions were measured in duplicate and averaged for individual data. Fish were subdivided into two temperature acclimation groups based on their swimming performance (see Results) and values (mean ± S.E.M.) are presented for cold- and warm-acclimated fish. One warm-acclimated female fish that was overtly gravid was not included in the statistical analysis to eliminate any confounding effect, because reproductive maturity is known to negatively affect U_{crit} performance in salmon (Williams et al., 1986). Statistical comparisons within temperature groups were made with a one-way repeated measures analysis of variance (ANOVA) followed by a *post hoc* Tukey test. With this test, the values associated with each fish were compared to other levels at other sampling times for the same fish to determine whether either swimming speed or metabolite levels changed throughout testing. Comparisons of swimming performance and metabolite levels between temperature groups were made using *t*-tests. U_{crit1} was compared to U_{crit2} using a Bland–Altman plot. Bland and Altman (1986, 1995) introduced this method of graphical analysis to assess the equivalency of two testing approaches (here U_{crit1} and U_{crit2}), while removing the bias that comes from assuming that one method represents the true value (independent variable). The Bland–Altman plot uses the mean of both methods as the independent variable and the difference between the two testing methods as the dependent variable. If the linear regression of the points is non-significant, then the two testing procedures (i.e. U_{crit1} and U_{crit2} here) can be considered to be equivalent testing procedures. Sub-groups can be identified within a data set in a Bland–Altman plot by demonstrating different significant linear regressions from each other. In the present study, different regressions would identify sub-groups with different relationships between U_{crit1} and U_{crit2}. Relationships between U_{crit} values and plasma variables were fitted with the best-fitting regressions using the options provided in Sigma-Plot (SPSS Inc.; Chicago, IL, USA). $P<0.05$ was used to establish statistical significance.

Results

Swimming performance

As water speed increased, fish progressed from a steady swimming mode to one that included periods of burst-and-glide swimming. In conjunction with higher speeds, fish ram-ventilated their gills, except during burst-and-glide swimming when active ventilation was observed. Visually, swimming behavior did not appear to be different for the first and second U_{crit} tests.

A Bland–Altman plot revealed that U_{crit1} and U_{crit2} were equivalent testing procedures (P=0.98), but visual inspection of the plot revealed that overall the fish could be divided into two sub-groups each with a different and significant linear relationship (Fig. 1A). Each of the two sub-groups corresponded to different acclimation temperatures and hereafter are termed warm- and cold-acclimated fish (14.9±1.0°C and 8.4±0.9°C, respectively; see Table 1).

U_{crit1} performance was temperature dependent (Fig. 1B; r^2=0.74, $P<0.05$). U_{crit1} (78.9±1.0 cm s^{-1}) for warm-acclimated fish was significantly greater ($P<0.05$) than that for cold-acclimated fish (59.1±2.5 cm s^{-1}; Table 1). However, U_{crit2} did not show any temperature dependency. Unexpectedly, U_{crit2} performance (65.8±2.70 cm s^{-1}) for warm-acclimated fish was significantly lower than U_{crit1}, whereas U_{crit2} for cold-acclimated fish (58.0±4.2 cm s^{-1}) was

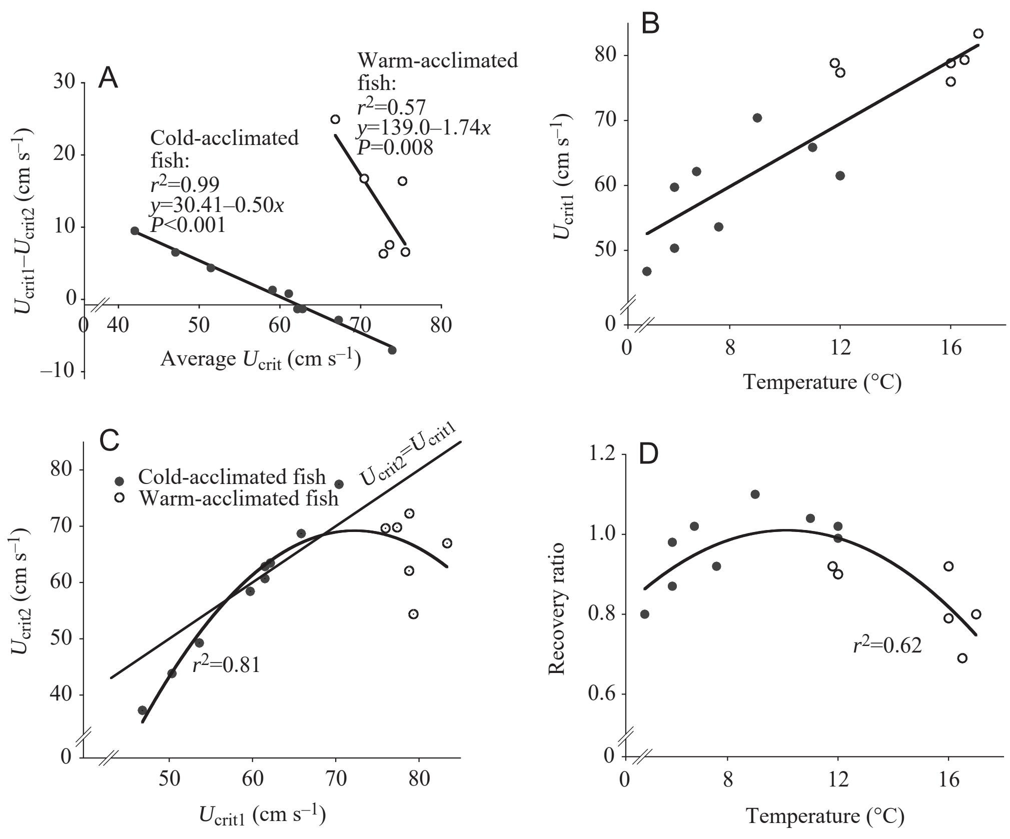

Fig. 1. (A) Bland–Altman plot comparing consecutive U_{crit} tests (U_{crit1} and U_{crit2}) performed by rainbow trout, separated by a 40 min recovery period. Regression lines indicate the existence of two sub-groups, cold-acclimated (filled symbols) and warm-acclimated (open symbols) fish, based on the visible groupings in this graph. (B) U_{crit1} *versus* ambient water temperature for rainbow trout. Fish are divided into two sub-groups, cold-acclimated (filled symbols) and warm-acclimated (open symbols) fish. Regression: y=40.44+2.42x, r^2=0.74; $P<0.001$. (C) U_{crit2} *versus* U_{crit1} for individual rainbow trout performing two U_{crit} tests separated by a 40 min recovery period. Fish are divided into cold-acclimated and warm-acclimated groups. The thin line is the line of identity where x=y, i.e. the predicted line if U_{crit1}=U_{crit2} independent of temperature, and this was not the case. Regression (thick line): y=–204.3+7.57x–0.05x^2, r^2=0.81, $P<0.001$. (D) Recovery ratios for individual rainbow trout as a function of acclimation temperature (filled symbols, cold-acclimated group; open symbols, warm-acclimated group). The regression line for these data illustrates that warm-acclimated fish could not attain the same U_{crit} after a 40 min recovery.

Table 1. *Critical swimming speed of the cold- and warm-acclimated groups of rainbow trout for the first and second swim tests*

	Cold-acclimated fish (N=9)	Warm-acclimated fish (N=6)
U_{crit1} (cm s^{-1})	59.1±2.5	78.9±1.0^{a}
U_{crit2} (cm s^{-1})	58.9±4.2	65.9±2.7^{b}
U_{crit1} (FL s^{-1})	1.51±0.10	1.84±0.04^{a}
U_{crit1} (FL s^{-1})	1.48±0.14	1.54±0.08^{b}

Cold-acclimation temperature = 8.4±0.9°C; warm-acclimation temperature = 14.9±1.0°C.

U_{crit1}, first swim test; U_{crit2}, second swim test; FL, fork length.

Values are means ± S.E.M.

[a]Statistically significant difference (P<0.05) compared with cold sub-group; [b]statistically significant difference (P<0.05) between comparable U_{crit1} and U_{crit2} values.

the same as their U_{crit1} values (Table 1). As a result, the overall relationship between U_{crit1} and U_{crit2} was best described by a polynomial equation (y=–204.3+7.57x–0.05x^2; P<0.001; Fig. 1C), with cold-acclimated fish lying close to the line of identity and warm-acclimated fish lying below the line of identity. Thus, while warm acclimation conferred a faster U_{crit1}, a similar swimming speed could not be attained after a 40 min recovery period, as shown by recovery ratios that are less than unity for warm-acclimated fish (Fig. 1D).

Plasma status before, during and after U$_{crit}$ *tests*

There were no significant differences between the cold- and warm-acclimated groups of fish in terms of routine values for plasma levels of lactate, potassium, T_{amm}, sodium, glucose, cortisol and osmolality and hematocrit. When cold-acclimated fish were exhausted at U_{crit1}, plasma levels of lactate, potassium and T_{amm}, as well as hematocrit, all increased significantly (Fig. 2A–D). Plasma cortisol (Fig. 2E) and sodium (Fig. 2F) levels were unchanged at exhaustion for U_{crit1}. After a 40 min recovery from U_{crit1}, plasma lactate increased significantly beyond the level observed at exhaustion, plasma T_{amm} decreased to the routine level, and plasma potassium and hematocrit remained elevated at the same level. As a result, plasma lactate and potassium levels, and hematocrit were all significantly elevated at the outset of the U_{crit2} test.

For cold-acclimated fish exhausted at U_{crit2}, plasma levels of lactate, potassium, sodium and T_{amm}, and hematocrit, were again significantly elevated compared with the routine values, but no more so than for U_{crit1}. In fact, compared with the recovery values for U_{crit1}, plasma lactate levels had decreased significantly (Fig. 2A) at exhaustion for U_{crit2}, while T_{amm} had increased significantly (Fig. 2C). Similar to U_{crit1}, plasma lactate increased during the 40 min recovery from U_{crit2} to a level significantly higher than that observed at exhaustion, plasma T_{amm} decreased to the routine level, and plasma potassium and hematocrit remained elevated at the same level. As a result, none of the recovery values for U_{crit2} in cold-acclimated fish were significantly different to those for U_{crit1}. Plasma levels of cortisol, glucose and osmolality remained unchanged throughout both swimming protocols (data not shown). Therefore, the second swim for cold-acclimated fish had no additive effects on any of the measured plasma variables.

When warm-acclimated fish were exhausted at U_{crit1}, plasma T_{amm} and hematocrit increased by the same amount as for cold-acclimated fish (Fig. 2C,D). In contrast, the faster U_{crit1} of the warm-acclimated fish was associated with significantly larger increases in plasma levels of lactate and potassium (Fig. 2A,B) compared with cold-acclimated fish. Furthermore, warm-acclimated fish significantly increased plasma sodium and cortisol levels at exhaustion for U_{crit1} (Fig. 2E,F), unlike cold-acclimated fish. After a 40 min recovery from U_{crit1}, the levels of plasma lactate, potassium, T_{amm}, sodium and cortisol, as well as hematocrit all remained significantly elevated in warm-acclimated fish, whereas only plasma levels of lactate, potassium and hematocrit remained elevated in cold-acclimated fish (Fig. 2). In addition, plasma lactate, potassium, sodium and cortisol remained elevated in warm-acclimated fish at levels that were significantly greater than those observed in cold-acclimated fish during recovery. In fact, the plasma lactate level was about threefold higher and plasma potassium almost twofold higher. These results suggest that the higher U_{crit1} of warm-acclimated fish may have been partly due to a greater anaerobic swimming effort compared with cold-acclimated fish, and (or) lactate and potassium were released from muscle to plasma to a greater extent.

Compared with cold-acclimated fish, warm-acclimated fish clearly began the second U_{crit} test with a greater plasma ionic and metabolic disruption and, as a result in these fish, U_{crit2} was significantly lower than U_{crit1}. In addition, while U_{crit2} for warm-acclimated and cold-acclimated fish was the same, warm-acclimated fish displayed a significant, further increase in plasma potassium levels (Fig. 2B) at exhaustion and a significant, further increase in plasma lactate levels (Fig. 2A) during the recovery from U_{crit2}. However, plasma T_{amm} did not recover to a routine level, as it did in the cold-acclimated fish (Fig. 2C). Therefore, the second U_{crit} swim of warm-acclimated fish produced significant additive effects on some of the plasma variables, unlike in cold-acclimated fish where there were none.

Correlational analysis

The initial swimming performance of individual fish was related to the appearance of lactate in the plasma. Plasma lactate concentrations measured at U_{crit1} and after a 40 min recovery were both linearly related to U_{crit1} (Fig. 3; r^2=0.73, P<0.05 and r^2=0.79, P<0.05, respectively). As might be expected from Fig. 3, plasma lactate concentrations were highly correlated with each other (2nd exhaustion with 1st exhaustion: r^2=0.95, P<0.05; 1st exhaustion with 1st recovery: r^2=0.92, P<0.05; 2nd exhaustion with 1st recovery: r^2=0.94, P<0.05; 2nd recovery with 2nd exhaustion: r^2=0.94, P<0.05).

The difference in swimming performance between U_{crit1} and U_{crit2} was significantly related to the plasma lactate concentration prior to the second U_{crit} test (Fig. 4). This relationship was described by either a polynomial (r^2=0.74), or a 2-parameter power (r^2=0.65) regression. Both types of analysis suggest that the reduction in U_{crit2} relative to U_{crit1} occurred when fish reached a plasma lactate of 12.2 mmol l^{-1} (95% confidence intervals of 7.9 and 16.5 mmol l^{-1}) 40 min after being exhausted by an initial U_{crit} swim test. Only warm-acclimated fish reached this threshold plasma lactate level.

Swimming effort in the initial swim was also related to the appearance of potassium in the blood. Plasma potassium concentration measured at U_{crit1} was linearly related to U_{crit1} (r^2=0.60, P<0.05). However, there was no significant correlation between plasma potassium levels and performance on the second swim. Plasma T_{amm} at exhaustion was not significantly related to U_{crit1}, but T_{amm} values for the 1st

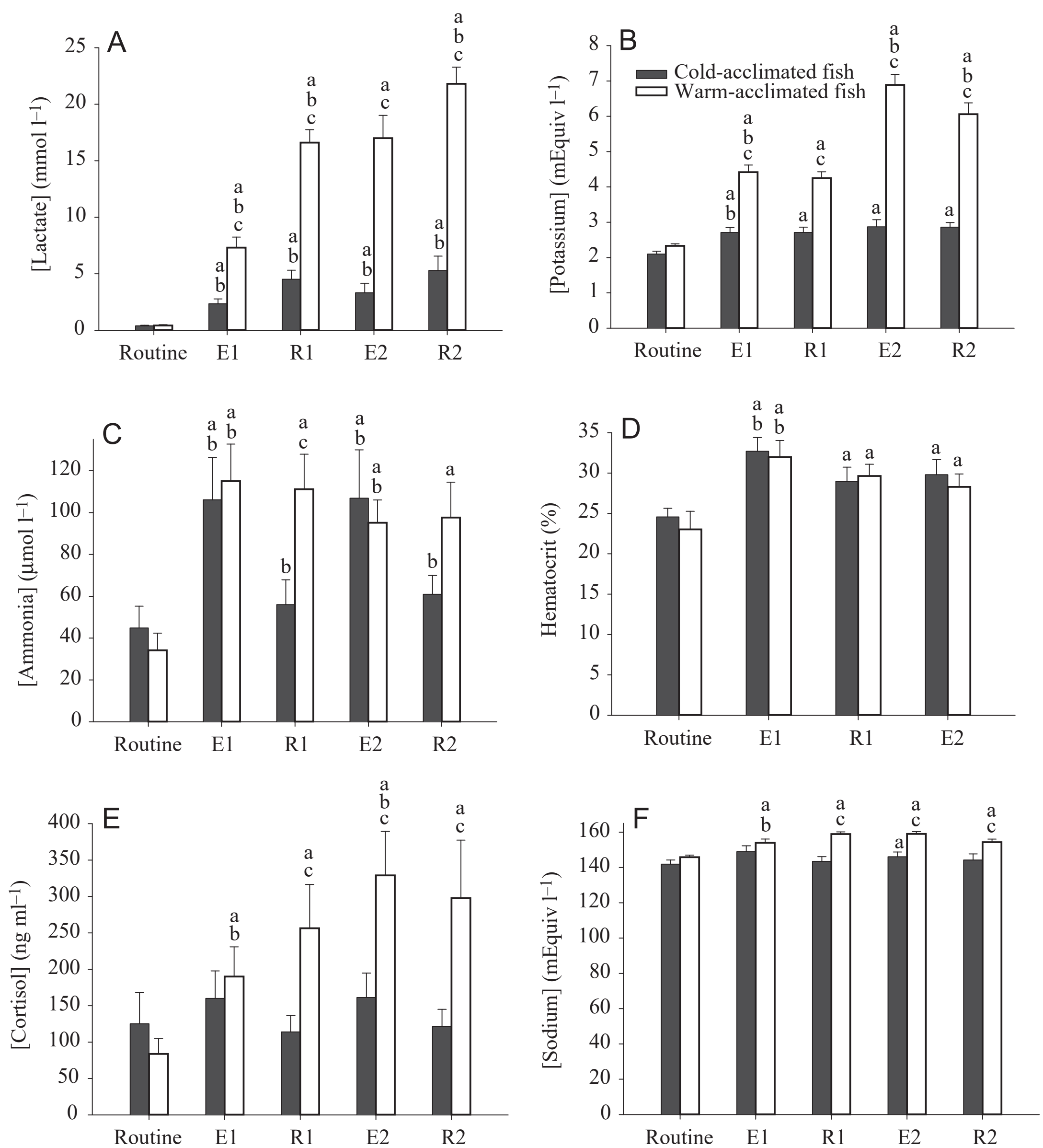

Fig. 2. Blood parameters in cold-acclimated (N=8–9) and warm-acclimated (N=5–6) fish before testing (Routine), at failure in the first U_{crit} test (E1), after a 40 min recovery (R1; this was also immediately before the start of the second U_{crit} test), at failure in a second U_{crit} test (E2), and after another 40 min recovery period (R2). [a]Level different from the routine value; [b]level different from the previous sampling time; [c]value for warm-acclimated fish different from the corresponding value for cold-acclimated fish. (A) Plasma lactate concentration. (B) Plasma potassium concentration. (C) Plasma ammonia concentration. (D) Hematocrit. (E) Plasma cortisol concentration. (F) Plasma sodium concentration.

recovery were related to U_{crit1} (Fig. 5; r^2=0.34, P<0.05). There were no other significant correlations for plasma T_{amm}.

The influence of acclimation temperature on the plasma ionic and metabolic responses to exercise is illustrated by the significant linear correlations that existed between plasma lactate, cortisol and potassium levels and temperature (Table 2). There were no significant correlations with temperature and the other parameters measured (T_{amm}, [sodium] and hematocrit).

One overtly gravid, warm-acclimated female fish was treated as an outlier, based on its slow swimming performance, and was not used for any correlation analysis. However, it is important to note that all the plasma changes observed in this fish were consistent with the slower swimming performance of the cold-acclimated fish.

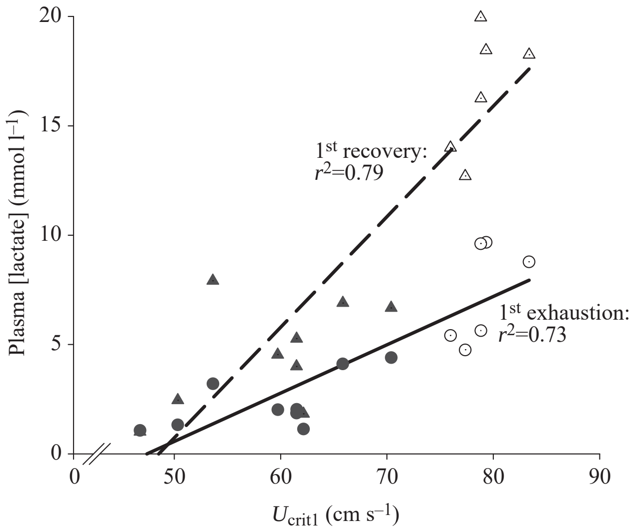

Fig. 3. Plasma lactate concentration at 1st exhaustion (circles) and 1st recovery (triangles) sampling times *versus* U_{crit1} for rainbow trout. Fish are divided into two sub-groups, cold-acclimated (filled symbols) and warm-acclimated (open symbols) fish. Regression for 1st exhaustion plasma [lactate] (solid line): y=–10.48+0.22x, r^2=0.73; P<0.001; for 1st recovery plasma [lactate] (broken line): y=–24.52+0.51x, r^2=0.79; P<0.001.

Discussion

This study tested the hypothesis that warm-acclimated rainbow trout would perform better in repeated U_{crit} swimming tests than cold-acclimated fish. The present findings, however, do not support this hypothesis because U_{crit2} was significantly lower than U_{crit1} in warm-acclimated fish than in cold-acclimated fish. At U_{crit1}, the warm-acclimated fish showed a greater metabolic disturbance in the plasma compared with cold-acclimated fish and also showed additive effects for the second U_{crit}, unlike the cold-acclimated fish. Therefore, although warm-acclimated fish swam better than cold-acclimated fish for U_{crit1}, as expected, the consequence of this faster U_{crit1} was a reduced performance on the second U_{crit} test. If anything, it appeared that warm-acclimated fish, by apparently swimming harder and possibly more anaerobically, were unable to recover sufficiently well during the fixed recovery period to repeat this initial level of performance. For cold-acclimated fish, however, the 40 min recovery period was sufficient for adequate recovery and allowed swimming performance to be repeated. Therefore, we are left with the

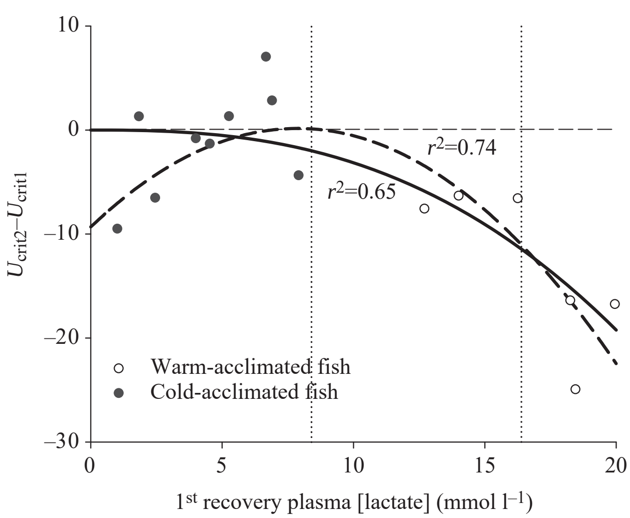

Fig. 4. U_{crit2}–U_{crit1} *versus* the plasma lactate concentration prior to the second U_{crit} test (recovery 1) for individual rainbow trout. Fish were divided into two sub-groups: cold-acclimated (filled symbols) fish and warm-acclimated (open symbols) fish. The data could be described by either a polynomial (broken line; r^2=0.74) or a 2-parameter power (solid line; r^2=0.65) relationship.

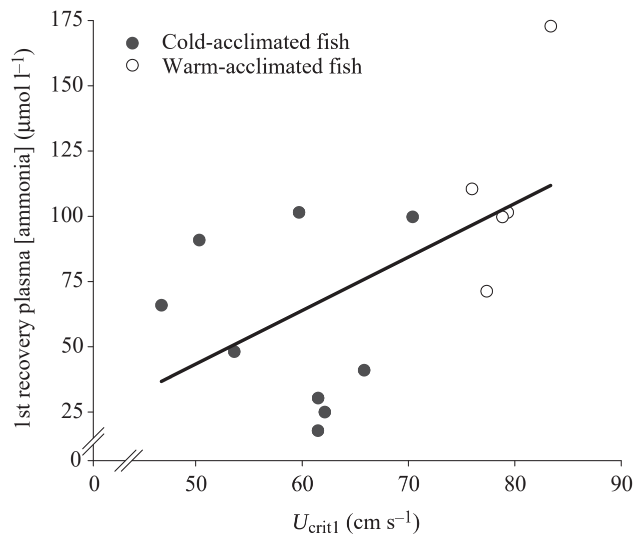

Fig. 5. Plasma ammonia concentration at first recovery *versus* U_{crit1} for rainbow trout. Fish are divided into two sub-groups, cold-acclimated (filled symbols) and warm-acclimated (open symbols) fish. Regression: y=–56.51+2.02x, r^2=0.30, P<0.05.

Table 2. *Significant linear regressions between ambient water temperature and individual plasma variables during repetitive swim tests in rainbow trout*

Plasma variable	*P*-value	r^2
[Lactate]		
1st exhaustion	<0.001	0.72
1st recovery	<0.001	0.74
2nd exhaustion	<0.001	0.68
2nd recovery	<0.001	0.69
[Potassium]		
1st exhaustion	<0.001	0.65
1st recovery	<0.001	0.69
2nd exhaustion	<0.001	0.74
2nd recovery	<0.001	0.78
[Cortisol]		
1st exhaustion	<0.01	0.41
1st recovery	<0.05	0.27
2nd exhaustion	<0.05	0.33

conclusion that overall recovery, as it pertains to repeat swimming capabilities and time allowed for recovery, was superior for the cold-acclimated compared with the warm-acclimated group of rainbow trout.

Our original hypothesis, which we now reject, was based on the established temperature dependence of post-exercise metabolic and ionic recovery when salmonids are chased to exhaustion to produce similar levels of intracellular acidosis, lactate accumulation and glycogen depletion in white muscle regardless of temperature (Kieffer et al., 1994; Wilkie et al., 1997). However, when Atlantic salmon were angled to exhaustion at a warmer temperature, essentially the opposite effect of temperature on post-exercise muscle recovery was obtained; they displayed a greater depletion of muscle glycogen, a greater intracellular acidosis and a slower recovery of muscle metabolites at the warmer temperature compared with colder temperatures (Booth et al., 1995; Wilkie et al., 1996). The present findings for U_{crit} swim tests are more in line with data obtained when fish are angled rather than chased to exhaustion because the metabolic disturbances were higher and performance recovery slower at warmer temperatures. We suggest that the disparity among studies could simply reflect differences in the degree of exhaustion and the methods used to exhaust the fish, with fish becoming more exhausted because they perceive the chasing protocol as more of a threat or provocation than either angling or U_{crit} testing. Given this possibility, cold-acclimated fish could opt to stop swimming sooner than warm-acclimated fish to preserve glycogen reserves.

A U_{crit} value, like time-to-exhaustion at a prescribed water speed (e.g. Facey and Grossman, 1990; Mitton and McDonald, 1993), allows quantification of the swimming effort, something that is not easily done when fish are chased or angled to exhaustion. U_{crit} tests also encompass a spectrum of swimming speeds, with the aerobic demands of swimming up to maximum oxygen uptake being met by cardiorespiratory adjustments, while white muscle recruitment and anaerobic metabolism increasingly supports the higher muscular power output near U_{crit} (Burgetz et al., 1998), culminating in exhaustion (Brett, 1964; Beamish, 1978). The simplest explanation for the higher U_{crit1} values obtained for warm-acclimated compared with cold-acclimated fish is a greater involvement of anaerobic swimming, given the significantly larger alterations in plasma metabolites observed for warm-acclimated rainbow trout. Certainly, the warm-acclimated fish were more stressed than the cold-acclimated fish, as judged by the greater elevation in plasma cortisol levels. However, since muscle metabolites were not measured here, we cannot exclude other possibilities. The higher levels of plasma potassium, lactate and T_{amm}, as well as the additive effects of the second swim, could simply reflect a greater release of lactate and potassium into the plasma because the release of lactate and hydrogen ions from white muscle to the blood is known to be temperature dependent (see Kieffer, 2000). Nevertheless, it is unlikely that different muscle glycogen levels were a factor since these are unaffected by acclimation temperature (Kieffer, 2000).

Rome et al. (1985) showed that acutely exposing warm-acclimated carp *Cyprinus carpio* to cold water resulted in white muscle fibres being recruited at a lower swimming speed, and this ‘compression of recruitment order’ led to earlier fatigue and a reduced sustained swimming speed. However, when the carp were cold-acclimated, they recruited white muscle at a higher swimming speed than warm-acclimated fish, presumably because cold temperature acclimation had improved the mechanical performance of the red muscle. The present findings are consistent with this earlier work with carp in that the cold-acclimated rainbow trout appeared to rely less on anaerobic white muscle than warm-acclimated fish, but the two studies differ in that cold-acclimated rainbow trout had a lower U_{crit} than warm-acclimated rainbow trout whereas cold-acclimated carp swam to the same maximum speed as warm-acclimated fish (Rome et al., 1985). Rome et al. (1985) suggested three possible physiological differences in cold-acclimated fish compared with warm-acclimated fish: (1) a higher mechanical power output from aerobic muscle, (2) limitations on the neural control of locomotory muscle and (3) limitations of the respiratory and circulatory systems in supplying oxygen. The present findings suggest a fourth possibility: fish may opt to swim to different states of exhaustion depending on either the temperature or a resulting physiological condition. One benefit of limiting the level of exhaustion under cold conditions appears to be a more reasonable recovery rate, which allows for repeated performance. At warm temperatures, fish benefit from a higher initial level of performance but, by exhausting themselves to a relatively greater degree, have the disadvantage of a more prolonged recovery period. An additional disadvantage, but for unknown reasons, is that exhaustive exercise at warm, but not at cold temperatures, can result in appreciable levels of post-exercise mortality (see Kieffer, 2000).

The present conclusions are also in line with the results of McKenzie et al. (1996) working with Nile tilapia *Oreochromis* *nilotica*. They found that warm-acclimated fish had a greater cost of recovery (a higher and more prolonged post-exercise oxygen consumption) after being chased to exhaustion than cold-acclimated fish. Interestingly, white muscle lactate accumulation was similar for 16°C-acclimated and 23°C-acclimated tilapia, suggesting that muscle lactate may not always be a reliable measure of post-exercise recovery. However, 23°C-acclimated tilapia excreted over twice the amount of ammonia post-exercise than 16°C-acclimated fish. Kieffer et al. (1998) similarly found that ammonia excretion at 75% U_{crit} was almost threefold higher for 15°C-acclimated than 5°C-acclimated rainbow trout, while protein utilization at 75% U_{crit} was 30% at 15°C *versus* 15% at 5°C. Likewise, in the present study, we observed a significantly higher plasma T_{amm} in warm-acclimated rainbow trout. As discussed by McKenzie et al. (1996), the elevated ammonia production could be a result of either increased protein metabolism to fuel locomotion or increased protein degradation from tissue damage. Since elevated T_{amm} is thought to have inhibitory actions on neural and muscle activity in fish (Beamount et al., 1995a), the larger elevation in plasma T_{amm} in warm-acclimated fish is perhaps critical to survival post-exhaustion. On the other hand, tissue damage might negatively affect U_{crit2}.

U_{crit} values were comparable to those reported earlier by Jain et al. (1997) for rainbow trout of the same size in the same swim tunnel [1.64–1.66 body lengths (*BL*) s^{-1}] and higher than those reported for 822–1118 g rainbow trout (0.94 *BL* s^{-1} and 0.53 *BL* s^{-1} at 11°C and 18°C, respectively; Taylor et al., 1996). Comparisons also can be made with studies on smaller rainbow trout, which are expected to attain slightly higher U_{crit} values (Brett, 1964) than the 879 g fish used here. U_{crit} values of 1.8 to 2.0 *BL* s^{-1} are reported for 530–730 g rainbow trout at 18–19°C (Gallaugher et al., 1992) and 2.13 *BL* s^{-1} for 431–483 g rainbow trout at 7–11°C (Burgetz et al., 1998). For 320–520 g brown trout, U_{crit} values were 2.2 *BL* s^{-1} at 15°C and 1.85 *BL* s^{-1} at 5°C (Butler and Day, 1993; Butler et al., 1992).

As anticipated, a 40 min recovery period allowed full recovery of swimming performance for cold-acclimated fish. Originally it was suggested that salmonids be given 4 h between U_{crit} tests (Brett, 1964) to ensure a return to routine O_2 consumption but not necessarily to routine glycogen levels. Subsequently, recovery times of 2 h (Brauner et al., 1994), 1 h (Randall et al., 1987), 45 min (Farrell et al., 1998, 2003) and 40 min (Jain et al., 1998) have all been shown to be sufficient for salmonids to repeat U_{crit} tests without any significant decline in performance. Here fish were provided with a low speed water current during recovery and this may have aided their recovery, since recent studies with rainbow trout (Milligan et al., 2000) and coho salmon *Oncorhynchus kisutch* (Farrell et al., 2001) have shown that low to moderate swimming post-exhaustion greatly aids metabolic recovery through a warm-down effect. In contrast, recovery time without a warm-down is >2 h for optimal performance on a time-to-exhaustion test (Mitton and McDonald, 1994). Wang et al. (1994) reported that muscle phosphocreatine and ATP levels were restored within 30 min of rainbow trout being chased to exhaustion, while the post-exercise decline of oxygen consumption lasted 3–3.5 h (Scarabello et al., 1991). However, routine oxygen consumption does not have to be restored before adult sockeye salmon can repeat a second U_{crit} test (Farrell et al., 1998, 2003).

There was generally good agreement between the routine plasma variables reported here and those reported in previous studies (Butler and Day, 1993; Eros and Milligan, 1996; Pagnotta et al., 1994; Thorarensen et al., 1994; Wang et al., 1994). However, the plasma lactate concentrations at U_{crit} in this study, especially those for the warm-acclimated fish (7.3 mmol l^{-1}), were at the high end of literature values for U_{crit} swimming (1.5–5.5 mmol l^{-1}) (Butler and Day, 1993; Gallaugher et al., 1992; Thorarensen et al., 1993; Holk and Lykkeboe, 1998; Farrell et al., 1998). Milligan (1996) cites a range for plasma lactate levels of 2–13 mmol l^{-1} immediately after chasing, increasing to peak values of 12–20 mmol l^{-1} at 2 h post-exercise. The values reported here for cold-acclimated fish of 4.3 mmol l^{-1} at U_{crit} and 8.9 mmol l^{-1} 40 min later are at the low end of this range, whereas those for the warm-acclimated fish (7.3 mmol l^{-1} at U_{crit} and 16.6 mmol l^{-1} 40 min later) are at the upper end of the range and approached the level reached (17.8 mmol l^{-1}) approximately 90 min after a hypoxic U_{crit} test (Farrell et al., 1998).

The second objective of the present study was to determine whether any of the measured metabolites displayed threshold levels that, if surpassed in the first swim challenge, were indicative of a metabolic condition that negatively affected subsequent swimming performance. Plasma lactate level was the only candidate: the plasma lactate level before U_{crit2} was significantly correlated to the subsequent swimming performance (U_{crit2}). The threshold plasma lactate level of approximately 12.2 mmol l^{-1} (95% CI 7.9–16.4) agrees with that of 13 mmol l^{-1} reported by Stevens and Black (1966) for burst exercise with rainbow trout and 10 mmol l^{-1} for sockeye salmon (Farrell et al., 1998). In the earlier studies, fish refused to swim if the lactate threshold was surpassed. However, no fish refused to swim outright in the present study and instead U_{crit} performance was reduced by 8–31%. Thus, because anaerobic metabolism is increasingly required to support swimming speeds greater than 70% U_{crit} (Burgetz et al., 1998), elevated levels of lactate above the lactate threshold is probably indicative of a failure to fully recruit anaerobic metabolism in white muscle (e.g. through decreased muscle pH and glycogen stores). This idea needs further study, however, because plasma lactate dynamics are complex, reflecting rates of production in the muscle, rates of release from the muscle and rates of clearance from the blood. While the present study suggests that production may be greater at warmer temperatures, release rate is dependent on temperature (Keiffer et al., 1994) and clearance rate is inversely related to temperature (Kieffer and Tufts, 1996).

Beaumont et al. (1995a,b) reported that copper-exposed brown trout in water of low pH had poor U_{crit} values and suggested that the elevated plasma T_{amm} inhibited white muscle activity either directly or through CNS inhibitory mechanisms, because elevated plasma T_{amm} levels were correlated with the reduced U_{crit} values. In the present study, we found no significant correlations between swimming performance and plasma T_{amm}. However, our data are not necessarily at odds with the suggestion of Beaumont et al., (1995a,b) because the plasma T_{amm} levels reported in the present work were half those measured in copper-exposed brown trout and, in the earlier studies, U_{crit} was not reduced appreciably until plasma T_{amm} reached levels >200 μmol l^{-1}. A plasma T_{amm} level >600 μmol l^{-1} resulted in fish refusing to swim. In the present study, T_{amm} reached only 100 μmol l^{-1} and was restored between U_{crit} tests for cold-acclimated fish, although not for warm-acclimated fish (Fig. 2).

Several studies report a temperature optimum for U_{crit}. For sockeye salmon, 15°C was the optimum temperature for U_{crit}, metabolic scope (Brett, 1964) and cardiac performance (Brett, 1971; Davis, 1968). The preferred temperature for sockeye salmon, however, appears to be slightly cooler (10–12°C; Birtwell et al., 1994; Spohn et al., 1996). Garside and Tait (1958) suggested a preferred temperature range for rainbow trout of 11–16°C, which coincides with the optimum temperature range suggested for cardiac performance (Farrell et al., 1996; Taylor et al., 1997; Farrell, 2002). The present experiments show that the shift in responses to repeated swimming for cold- and warm-acclimated fish occurred at around 12°C. Therefore, the fish's preferred temperature may reflect sub-maximal rates for certain activities because of negative consequences in terms of rates of recovery.

In summary, we provide evidence that warm-acclimated rainbow trout have a higher U_{crit} than cold-acclimated fish, but associated with this higher U_{crit} is a greater metabolic and ionic disturbance. A consequence of this elevated disturbance is that warm-acclimated fish do not recover well enough after a 40 min rest to perform a second test at the same level as the first one, whereas cold-acclimated fish do. Elevations in plasma lactate (but not plasma potassium, T_{amm} and cortisol) were significantly correlated with the poorer repeat swimming performance.

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CARDIORESPIRATORY PHYSIOLOGY AND TEMPERATURE TOLERANCE AMONG POPULATIONS OF SOCKEYE SALMON (*ONCORHYNCHUS NERKA*)

by

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ABSTRACT

Elevated summer water temperature has been associated with high mortality in adult sockeye salmon (*Oncorhynchus nerka*) during their once-in-a-lifetime migration up the Fraser River (British Columbia, Canada) to their spawning grounds. There are over 100 genetically distinct populations of sockeye salmon in the Fraser River watershed, varying in migration distance, elevation gain, river temperature and river flow. This thesis studied the physiological basis for temperature tolerance in sockeye salmon and examined the overall hypothesis that each sockeye salmon population has physiologically adapted to meet their specific upriver migration conditions.

Swimming and cardiorespiratory performance were compared over a range of temperatures across six wild, migrating adult sockeye salmon populations. All populations maintained maximum performance across the entire range of temperatures typically encountered during their upriver migration, with Chilko sockeye salmon emerging as the most high temperature-tolerant. In addition, populations with more challenging migrations had greater aerobic scope, larger hearts and improved coronary supply. These results suggest that sockeye salmon populations have physiologically adapted to cope with their local upriver migration conditions, despite never before having performed the upriver migration.

Temperatures exceeding the population-specific thermal optimum resulted in severely impaired aerobic scope and swimming performance. This study suggests that population-specific thermal limits are set by physiological limitations in aerobic performance. Specifically, fish may be unable to swim at warm temperature due to insufficient oxygen supply to meet demand, triggered via a cardiac limitation due to reduced scope for heart rate.

Given the key role of the heart in limiting thermal tolerance, the role of cardiac adrenergic stimulation was examined as a potential mechanism underlying the observed

differences in thermal tolerance across sockeye salmon populations. Chilko sockeye salmon had a greater density of ventricular β-adrenoceptors, which may provide greater cardiac capacity and protection at temperature extremes, thereby expanding their breadth of thermal tolerance compared to other populations.

This thesis suggests that sockeye salmon populations will be differentially affected by warming river temperatures, raising conservation concerns for biodiversity. This work provides important insight into local adaptation in sockeye salmon and identifies a possible cause for in-river mortality associated with warm temperatures in sockeye salmon.

PREFACE

Some of the data presented in Chapters 3, 6 and 7 were previously published in E. J. Eliason, T. D. Clark, M. J. Hague, L. M. Hanson, Z. S. Gallagher, K. M. Jeffries, M. K. Gale, D. A. Patterson, S. G. Hinch, A. P. Farrell. 2011. Differences in thermal tolerance among sockeye salmon populations. *Science* 332: 109-112.

E. J. Eliason was the primary contributor to the experimental design, data collection, data analysis and manuscript preparation. A. P. Farrell and S. G. Hinch provided supervision, assistance with experimental design and helped with manuscript preparation. T. D. Clark, L. M. Hanson, Z. S. Gallagher, K. M. Jeffries and M. K. Gale provided valuable secondary assistance in the field and during data collection. M. J. Hague and D. A. Patterson provided Fraser River temperature information and modeling expertise.

All procedures were approved by the University of British Columbia's Animal Care Committee in accordance with the Canadian Council on Animal Care (A06-0328 and A08-0388).

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LIST OF ABBREVIATIONS

% compact	percentage compact myocardium
AIC	Akaike's Information Criterion
ATP	adenosine triphosphate
ATU	accumulated thermal units
$A\text{-}V_{O2}$	tissue oxygen extraction
bl s^{-1}	body lengths per second
B_{max}	β_2-adrenoceptor density
CAER	Centre for Aquaculture and Environmental Research
C_{aO2}	arterial oxygen content
Cl^-	chloride
CLL	Cultus Lake Laboratory
C_{O2}	oxygen content
COT	cost of transport
COT_{net}	net cost of transport
$COT\text{-}\dot{Q}$	cardiovascular cost of transport
$COT\text{-}\dot{Q}_{net}$	net cardiovascular cost of transport
C_{vO2}	venous oxygen content
DFO	Department of Fisheries and Oceans Canada
D_M	migration distance
E_M	migration elevation
EPOC	excess post oxygen consumption
f_H	heart rate
f_{Hmax}	maximum heart rate

f_{Hrest}	resting heart rate
F_M	migration Fraser River flow
GSI	gonadalsomatic index
Hb	haemaglobin
Hct	hematocrit
HSI	hepatosomatic index
K^+	potassium
K_d	β_2-adrenoceptor binding affinity
M	body mass
MCHC	mean corpuscular haemaglobin concentration
$\dot{M}O_2$	rate of oxygen consumption (measured in mg)
$\dot{M}O_{2max}$	maximum oxygen consumption
$\dot{M}O_{2rest}$	resting oxygen consumption
MS-222	tricaine methanesulfonate
Na^+	sodium
$NaHCO_3$	sodium biocarbonate
OCLTT	oxygen- and capacity-limited thermal tolerance
P_{aO2}	arterial partial pressure of oxygen
P_{O2}	partial pressure of oxygen
POF	post-orbital-fork length
POH	post-orbital-hypural length
P_{vO2}	venous partial pressure of oxygen
$\dot{Q}$	cardiac output
$\dot{Q}_{max}$	maximum cardiac output

$\dot{Q}_{rest}$	resting cardiac output
RDCM	relative dry compact mass
RDVM	relative dry ventricular mass
RR	recovery ratio
RVM	relative wet ventricular mass
SEM	standard error of the mean
SSI	splenosomatic index
T90%	upper temperature experienced by the 90th percentile of fish
T_{aO2}	arterial oxygen transport
T_{crit}	critical temperature
T_M	migration Fraser River temperature
$T_{max0-50}$	group of fish swum at temperatures higher than T_{opt} at which 0-50% of maximum aerobic scope was attained
$T_{max50-90}$	group of fish swum at temperatures higher than T_{opt} at which 50-90% of maximum aerobic scope was attained
$T_{min50-90}$	group of fish swum at temperatures lower than T_{opt} at which 50-90% of maximum aerobic scope was attained
T_{opt}	optimal temperature
T_p	pejus temperature
T_{vO2}	venous oxygen transport
U_{crit}	critical swimming velocity
$\dot{V}_{O2}$	rate of oxygen consumption (measured in ml)
V_s	stroke volume
V_{smax}	maximum stroke volume

V_{srest}	resting stroke volume
w	AIC weight
β-AR	β-adrenoceptor

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DEDICATION

In loving memory to Grandpa Eliason, who taught me the value of gratitude, the power of a smile, to embrace life and most of all, sparked my love and wonder of fish.

CHAPTER 1: INTRODUCTION

Temperature has profound effects on the distribution and physiology of animals. Temperature effects occur over three distinct time scales: acute (direct effects occurring in minutes to hours), acclimation (physiological, morphological and biochemical adjustments occurring over days to weeks) and adaptation (spans generations, due to natural selection acting on individuals). Given that most fish are ectotherms, they are highly susceptible to perturbations in temperature that occur in their aquatic environment. The study of the physiological mechanisms that limit temperature tolerance is a biological problem of fundamental importance.

A central tenet in evolutionary biology is that geographically and reproductively isolated populations are locally adapted to cope with their specific environment (see Schluter, 2000; Taylor, 1991). Heritable traits that enhance survival and reproductive success in a given environment will likely be under strong selection pressure. This thesis examines temperature tolerance and local adaptation using genetically and geographically distinct populations of Fraser River sockeye salmon (*Oncorhynchus nerka*) as a model.

1.1 The Fry Curve for Aerobic Scope

Fry (1947) established that temperature both controlled and limited metabolic rate in fish, making a direct link between thermal tolerance and oxygen consumption. Fry recognized that temperature tolerance tests (e.g. CT_{min} and CT_{max}) were restrictive, only differentiating the temperature limits for short-term survival. Instead, Fry realized that it was essential to characterize and understand the temperature limits for a fish to thrive and interact within its environment – e.g. to escape predators, to interact with other animals, to migrate upstream, to find, digest and assimilate food. As such, Fry examined the effects of temperature on aerobic scope, or the difference between minimum and maximum oxygen consumption. The 'Fry curve' for aerobic scope is typically bell-shaped as a function of temperature and represents the maximum oxygen available for activities beyond those considered maintenance, such as swimming, reproduction, feeding and growth. Thus, Fry curves can be used to examine the functional temperature limits for performance.

Oxygen consumption ($\dot{M}O_2$) varies as a function of temperature. Minimum or resting $\dot{M}O_2$ ($\dot{M}O_{2rest}$) represents the metabolic cost to simply exist in a resting, thermally acclimated, non-digesting, non-reproducing fish. $\dot{M}O_{2rest}$ typically increases exponentially with increasing temperature until it approaches lethal temperatures, as expected for temperature effects on rate functions (Fig 1.1). Obviously, in order to feed, reproduce, grow and move, fish must be able to increase $\dot{M}O_2$ above minimum levels. As temperatures increases, active or maximum $\dot{M}O_2$ ($\dot{M}O_{2max}$) increases faster than $\dot{M}O_{2rest}$, thus increasing aerobic scope (Fig 1.1). The optimal temperature (T_{opt}) coincides with maximal aerobic scope, as do maximal cardiac and swimming performance (Brett, 1971). Beyond T_{opt}, $\dot{M}O_{2max}$ fails to further increase and rapidly declines, causing a reduction in aerobic scope. The temperatures at which aerobic scope starts to decline are termed the pejus temperatures [T_p, pejus means getting worse (Pörtner, 2001)]. The range of temperatures between the upper and lower T_p when maximum aerobic scope is maintained is termed the T_{opt} window (Fig 1.1). At critical temperatures (T_{crit}), aerobic scope approaches zero (Fig 1.1), resulting in a transition to anaerobic metabolism and only passive, short-term survival (Pörtner, 2002; Pörtner, 2001; Pörtner and Farrell, 2008).

$\dot{M}O_2$ and aerobic scope varies considerably among species. Likewise, Fry curves take on different shapes. For example, eurythermal species such as goldfish (*Carassius auratus*) and

Fundulus heteroclitus have a broader T_{opt} window compared to more stenothermal fish like sockeye salmon (Fangue et al., 2006; Fry, 1947; Fry, 1957; Lee et al., 2003c). In addition, more athletic fish like wild sockeye salmon have a higher maximum aerobic scope compared to goldfish or hatchery-reared rainbow trout (*Oncorhynchus mykiss*) (Farrell, 2009). Moreover, aerobic scope will vary throughout the life cycle of an individual fish, shifting both the T_{opt} window and height of aerobic scope (Brett, 1965; Farrell, 2009). Aerobic scope also varies with environmental conditions (Farrell, 2009). For example, hypoxia (low environmental O_2) and hypercapnia (high environmental CO_2) reduce maximum aerobic scope and constrain the T_{opt} window (Pörtner and Farrell, 2008). Behaviour has also been demonstrated to alter T_{opt}. For example, competition shifted T_{opt} and supressed growth in brook trout (*Salvelinus fontinalis*) (McMahon et al., 2007). Thus, aerobic scope is highly pliable, varying across species, life stages, environmental conditions and with behaviour.

To understand the mechanistic basis of aerobic scope and its dependent relationship with temperature, details of how oxygen is delivered from the water to the mitochondria via the cardiorespiratory system are required. For fish such as salmonids, maximum $\dot{M}O_2$ occurs during maximum aerobic swimming. Therefore, information on cardiorespiratory physiology during swimming is necessary.

1.2 Cardiorespiratory Physiology with Swimming

According to the Fick equation for vascular perfusion, whole-animal $\dot{M}O_2$ is determined by the product of cardiac output ($\dot{Q}$) and the difference between arterial and venous oxygen content (C_{aO2} and C_{vO2}, respectively), which is termed the tissue oxygen extraction ($A\text{-}V_{O2}$ =

$C_{aO2} – C_{vO2}$): $\dot{M}O_2 = \dot{Q} \times A\text{-}V_{O2}$. $\dot{Q}$ is the product of heart rate (f_H) and stroke volume (V_s): $\dot{Q} = f_H \times V_s$. $A\text{-}V_{O2}$ is determined by the partial pressure of oxygen and the capacitance for oxygen in the blood. Accordingly, any change in $\dot{M}O_2$ must be due to alterations in some combination of these factors (i.e. f_H, V_s, C_{aO2} and C_{vO2}).

In order to support aerobic swimming, oxygen must be transported from the gills to the swimming muscles, which is one of the roles of the cardiovascular system. During maximal aerobic swimming, $\dot{Q}$ increases 2-3 fold in salmonids (Kiceniuk and Jones, 1977; Stevens and Randall, 1967; Thorarensen et al., 1996). While increases in both f_H and V_s contribute to the increase in $\dot{Q}$ during swimming, V_s typically increases to a greater extent in salmonids (Kiceniuk and Jones, 1977).

Another factor that can potentially be altered to increase $\dot{M}O_2$ is C_{aO2}. Oxygen transport to the tissues (T_{aO2}) by the circulatory system can be expressed as the product of $\dot{Q}$ and C_{aO2}. Arterial blood leaves the gills close to fully saturated as a consequence of the counter-current arrangement of blood and water flow at the gills. As a result, C_{aO2} is near maximal at rest and during swimming (Gallaugher et al., 2001; Kiceniuk and Jones, 1977; Randall and Daxboeck, 1982; Thorarensen et al., 1996). C_{aO2} could further increase by raising the blood haemoglobin (Hb) concentration either acutely via splenic contraction or chronically via erythropoiesis. However, blood [Hb] appears to be optimized in swimming rainbow trout (Gallaugher et al., 1995; Gallaugher et al., 1998), thus alterations to blood [Hb] may not play a major role during swimming. Therefore, the primary means of increasing T_{aO2} during swimming is via an increase in $\dot{Q}$.

The last means of increasing $\dot{M}O_2$ during swimming is through increased oxygen extraction from the blood by the tissues, which results in decreased C_{vO2} and P_{vO2} and typically a

2-3 fold increase in A-V_{O2} (Farrell and Clutterham, 2003; Kiceniuk and Jones, 1977; Stevens and Randall, 1967). However, evidence has been presented for a minimum P_{vO2} threshold of around 15 torr in cold and 29 torr in warm, normoxic salmonids (Farrell and Clutterham, 2003, Farrell, 2007), which may serve as a mechanism to ensure sufficient oxygen is supplied to the heart (see section 1.3.2 below). Notably, during maximal swimming, tissue oxygen extraction may continue to increase despite a constant P_{vO2} since a decrease in blood pH (due to anaerobic metabolism) may elicit Root and Bohr effects on haemoglobin (a right and downward shift in the oxyhaemoglobin dissociation curve) thus facilitating oxygen unloading (Rummer, 2010).

As fish approach maximal swimming velocity during critical swimming tests, they switch to anaerobic metabolism (Burgetz et al., 1998). As a result, blood becomes acidic (low pH), hypoxemic (low P_{vO2}) and hyperkalemic (high $[K^+]$) (Holk and Lykkeboe, 1998; Kiceniuk and Jones, 1977), inhibiting cardiac contractility (Driedzic and Gesser, 1994). Adrenergic stimulation acts to maintain $\dot{Q}_{max}$ and protect against these noxious venous blood conditions during swimming (Hanson et al., 2006).

During recovery from anaerobic exercise, $\dot{M}O_2$ remains elevated (termed the excess post-exercise oxygen consumption; EPOC) in order to restore oxygen stores and support the metabolic costs associated with restoring high-energy phosphates, biochemical imbalance (e.g. glucose and lactate), ionic and osmotic imbalance and glycogen levels (Scarabello et al., 1992). EPOC represents a cost to the fish and could limit the ability for fish to resume normal activity in a timely manner. Even so, salmonids have been shown to have a remarkable ability to recover rapidly and repeat maximum swim performance after only a brief 30-45 min recovery period (Farrell et al., 1998; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003b; MacNutt et al., 2006; MacNutt et al., 2004; Wagner et al., 2006).

Two important concepts emerge from this brief overview of cardiorespiratory physiology during swimming in fish. First, temperature could be acting on any or all of the components linking the transport of oxygen from the environment to the mitochondria. Second, in order to understand the effect of temperature on aerobic scope, I need to measure temperature effects on $\dot{M}O_2$, $\dot{Q}$, f_H, V_s, P_{aO2}, C_{aO2}, P_{vO2} and C_{vO2}, which are considered in section 1.3 below.

1.3 Oxygen and Capacity Limited Thermal Tolerance

Oxygen is the final electron acceptor in the suite of mitochondrial reactions that ultimately create ATP, the energy currency of the cell. The oxygen cascade is composed of several convection and diffusion steps during which oxygen travels down a partial pressure gradient from the environment to the mitochondria (Fig 1.2). First, oxygen-rich water is brought into contact with the respiratory surface. Gill ventilation rate and volume determine this step. Next, oxygen diffuses from the water environment, across the secondary lamellae of the gills, and into the blood where it binds to Hb in red blood cells. The partial pressure gradient between the water and the blood as well as gill anatomy set this step. The circulatory system transports the oxygen-bound Hb by convection to the tissues. Cardiac output and [Hb] govern this step. Finally, oxygen diffuses across the capillary wall and into the cell where it is ultimately used during mitochondrial respiration. This final step is controlled by tissue anatomy and the partial pressure gradient between the blood and mitochondria.

The mechanism of the decline in aerobic scope at temperatures above T_{opt} is poorly understood. Oxygen- and capacity-limited thermal tolerance (OCLTT) suggests that thermal tolerance is set by oxygen limitations due to a mismatch between cellular oxygen supply and demand (Pörtner, 2001). This oxygen limitation is proposed to occur at the whole organism level, due to capacity limitations in ventilation and circulation (Pörtner, 2002; Pörtner, 2001; Pörtner and Knust, 2007). What is unclear is exactly which step(s) in the oxygen cascade limits oxygen flux, thus setting thermal limits. Specifically, is the mismatch in oxygen supply and demand due to a limitation at the gills, at the heart or at the tissues? Evidence for each of these possibilities has been detailed in Farrell (2009), and is outlined below.

The primary reason for the uncertainty is that few studies have studied the effect of temperature on performance limitations while simultaneously and directly measuring sufficient cardiorespiratory and oxygen status variables in order to identify the limiting factor(s) (Wang and Overgaard, 2007). While a small collection of studies have examined acute temperature effects on some of these variables in resting fish (e.g. Clark et al., 2008b; Gollock et al., 2006; Heath and Hughes, 1973; Sartoris et al., 2003), only Steinhausen et al. (2008) has measured all the necessary variables in fish swimming at close to maximum speed. Therefore, comprehensive cardiorespiratory studies in maximally swimming fish are needed.

1.3.1 Is There a Limitation in Oxygen Uptake at the Gill?

There are two primary reasons why an oxygen limitation at the gill has been proposed. First, it is well known that environmental oxygen availability decreases at high temperatures because water oxygen content decreases by around 2% per °C with increasing temperature (Dejours, 1975). Fish must therefore increase gill ventilation or increase oxygen extraction from the water to compensate. Second, there is decrease in blood oxygen affinity (a right-shift in the oxyhaemoglobin dissociation curve) as temperature increases (Jensen et al., 1998; Perry and

Reid, 1994), which hampers oxygen uptake at the gill, though it facilitates tissue oxygen extraction.

The key piece of evidence required to support the hypothesis that there is an oxygen limitation at the gill (via either insufficient oxygen delivery to the gills or an oxygen diffusion limitation across the gills) is a decrease in P_{aO2} and C_{aO2} at temperatures above T_{opt}.

Evidence supporting this hypothesis has been provided by Heath and Hughes (1973) who showed a decrease in C_{aO2} in resting rainbow trout exposed to an acute temperature increase. Notably, hematocrit was not measured to verify whether haemodilution occurred during repeated blood sampling. Similarly, Taylor et al. (1993) found a decrease in C_{aO2} at 18°C in resting and swimming rainbow trout acclimated to seasonal temperatures (4, 11 and 18°C), but hematocrit also decreased by half. A study by Clark et al. (2008b) produced conflicting results. Large resting adult chinook salmon (*Oncorhynchus tshawytscha*) displayed a decrease in C_{aO2} and P_{aO2} during an acute temperature increase while smaller adults did not. However, the holding tubes could have constrained gill movements in the larger chinook salmon, preventing adequate gill ventilation.

In contrast, two studies have found evidence against a limitation in oxygen uptake at the gill. Steinhausen et al. (2008) found that C_{aO2} and hematocrit remained constant in both resting and swimming sockeye salmon exposed to acute warming. Moreover, P_{aO2} actually increased in resting and remained constant in swimming sockeye salmon. Similarly, Sartoris et al. (2003) found that P_{aO2} remained constant during acute temperature increases in resting Atlantic cod (*Gadus morhua*). Therefore, current data are equivocal and further investigation is required.

1.3.2 Is There a Limitation in Oxygen Convection by the Heart?

An oxygen limitation at the level of the heart would be evident by the inability for $\dot{Q}_{max}$ to increase at temperatures above T_{opt}. Since oxygen demand increases with increasing temperature, $\dot{Q}_{max}$ must also increase in order to supply sufficient oxygen to keep pace with the tissue oxygen demand. If $\dot{Q}_{max}$ fails to keep up, insufficient oxygen will reach the muscles and the fish will cease or slow swimming. Indeed, several studies in swimming sockeye salmon and rainbow trout found that both $\dot{M}O_{2max}$ and $\dot{Q}_{max}$ ceased to increase above T_{opt} (Brett, 1971; Steinhausen et al., 2008; Taylor et al., 1996), providing evidence of a cardiac limitation.

The mechanistic basis of cardiac collapse at high temperature has been considered in detail (Farrell, 1997; Farrell, 2002; Farrell, 2007; Farrell, 2009; Farrell et al., 2009; Pörtner, 2002; Taylor et al., 1997). During warming, the increase in $\dot{Q}$ is almost entirely due to an increase in f_H (Clark et al., 2008b; Sandblom and Axelsson, 2007; Steinhausen et al., 2008). This is true in both resting and swimming fish (Farrell, 2009). Conversely, V_s has been demonstrated to be either insensitive to temperature (Cech Jr. et al., 1976; Clark et al., 2008b; Clark and Seymour, 2006; Gollock et al., 2006; Steinhausen et al., 2008) or to decrease at warm temperatures (Axelsson et al., 1992; Brodeur et al., 2001; Sandblom and Axelsson, 2007). The increase in f_H is likely mediated through a direct temperature effect on the pacemaker rate (Randall, 1970), which reaches a maximum of ~120 beats min^{-1} in many active fish (Davie and Farrell, 1991; Farrell, 1991). The prevailing idea is that maximum f_H is reached at T_{opt} (Farrell, 2009). Beyond T_{opt}, maximum f_H can no longer increase while resting f_H continues to increase, resulting in a decreased scope for f_H. Given that scope for f_H approached zero at high temperature for swimming sockeye salmon (Steinhausen et al., 2008), the inability for f_H to further increase

$\dot{Q}_{max}$ has been identified as a possible initiating factor limiting aerobic performance at high temperature (Farrell et al., 2009).

Another potential factor that could limit aerobic performance at high temperature is oxygen delivery to the heart itself. During exercise, oxygen requirements of the heart increase 3-5 fold, which makes up ~1% of total $\dot{M}O_2$ (Farrell and Steffensen, 1987). Salmonid hearts are composed of two types of myocardium; the compact myocardium and spongy myocardium. The outer, compact myocardium receives well-oxygenated arterial blood directly from the gills via the coronary system. As a result, the compact myocardium has a reliable source of oxygen during exercise, just like the skeletal muscles. Certainly, if P_{aO2} declines at warm temperatures (see section 1.3.1 above), then oxygen delivery to the compact myocardium could be impaired. In contrast, the inner spongy myocardium of salmonids lacks capillaries and receives oxygen from whatever is leftover in the venous blood by the other tissues. As such, the spongy myocardium has a much less reliable oxygen supply, especially since P_{vO2} decreases during swimming.

Though the *total* amount of oxygen in the blood (C_{vO2}) is likely sufficient to meet oxygen demand, a limitation may occur in the *rate* in which oxygen can be delivered, which depends on the oxygen tension (P_{vO2}), contact time of the blood (heart rate) and the arrangement of the spongy myocardium. The spongy myocardium is composed of trabeculae which are arranged in meshwork-like sheets that presumably increase the surface area for oxygen exchange (Pieperhoff et al., 2009). Regardless, if P_{vO2} decreases below a threshold level for an adequate rate of oxygen diffusion at high temperature, an oxygen diffusion limitation to the spongy myocardium may occur, resulting in cardiac failure and triggering a limitation in blood oxygen convection to the swimming muscles. In light of this, individuals possessing a greater percentage of compact myocardium may be able to maintain cardiac performance at higher temperatures.

Cardiac collapse at temperatures above T_{opt} may also relate to the noxious venous blood environment created when exercising at high temperature. Salmonids increase their reliance on anaerobic metabolism when swimming at high temperature (Brett, 1964; Jain and Farrell, 2003; Steinhausen et al., 2008). Anaerobic metabolism leads to the triple threat of acidotic, hypoxemic and hyperkalemic venous blood, which inhibits cardiac contractility (Dridezic and Gesser 1994). Though adrenergic stimulation protected cardiac function and maintained $\dot{Q}_{max}$ in *in situ* perfused rainbow trout hearts exposed to the triple threat at optimal temperatures (Hanson et al., 2006), adrenergic protection was diminished at temperatures above T_{opt} (Hanson and Farrell, 2007). The attenuation of the protective and stimulatory effects of adrenaline at high temperature has been attributed to a decline in adrenaline-binding ventricular cell-surface β-adrenoceptor density (B_{max}) (Keen et al., 1993). As a corollary, individuals possessing an elevated B_{max} may be able to maintain $\dot{Q}_{max}$ at higher temperatures.

In summary, a limitation in oxygen convection by the heart could manifest in a number of ways. $\dot{Q}_{max}$ could fail to increase above T_{opt} due to reduced scope for f_H, due to insufficient oxygen delivery to the cardiac myocardium or due to the negative ionotropic and chronotropic effects of acidotic, hypoxic and hyperkalemic venous blood.

1.3.3 Is There a Limitation in Oxygen Delivery to the Tissue Mitochondria?

Muscle oxygen demand increases at high temperature due to temperature effects on rate functions as well as an increase in mitochondria proton leakage which leads to inefficient ATP production in skeletal muscle (Barron et al., 1987; Pörtner, 2001). Therefore, the muscle must extract more oxygen from the blood in order to meet the increased demand at high temperature. Either a diffusion limitation or a perfusion limitation could lead to insufficient oxygen reaching the mitochondria to meet demand.

A diffusion limitation could develop due to inadequate driving force (low P_{aO2}), insufficient capillary density [white muscle has particularly low capillary density (Egginton et al., 2000)], or ineffective muscle cell morphology (poor mitochondria density or location). A perfusion limitation could result from inadequate $\dot{Q}$ leading to insufficient muscle capillary perfusion or an issue in blood flow distribution.

Several adjustments can help compensate for the increased oxygen demand at warm temperatures. The right-shift in the oxyhaemoglobin dissociation curve facilitates oxygen extraction (Jensen et al., 1998; Perry and Reid, 1994) as does the similar decrease in oxygen-affinity for myoglobin (Stevens and Carey, 1981). In addition, Krogh's diffusion coefficient for oxygen increases as biological fluid viscosity decreases with warming temperatures (Taylor et al., 1997).

An oxygen diffusion limitation at the tissues would become apparent if P_{vO2} was maintained at temperatures above T_{opt}, as has been reported in several studies. For example, Steinhausen et al. (2008) found no change in P_{vO2} with acute temperature increases in swimming sockeye salmon and P_{vO2} actually increased with temperature in resting fish. Further evidence comes from the observation that when fish quit swimming, venous blood was still partially saturated (Kiceniuk and Jones, 1977), and a venous threshold of ~20 torr (range = 15 to 29 torr in normoxia) has been proposed (Farrell and Clutterham, 2003; Farrell, 2007).

In contrast, other studies provide evidence against a tissue diffusion limitation. Heath and Hughes (1973) observed a decrease in C_{vO2} at high temperatures in resting rainbow trout, but as pointed out earlier, hematocrit was not measured. Likewise, Sartoris et al. (2003) reported a decrease in P_{vO2} in Atlantic cod exposed to an acute temperature increase. Clark et al. (2008b) found a significant decrease in P_{vO2} and C_{vO2} at the highest test temperatures in resting adult chinook salmon. Moreover, McKenzie et al. (2004) used optical fibre sensors in red muscle of rainbow trout at 13-15°C to determine that intramuscular P_{O2} never decreased below 45 torr, suggesting that oxygen supply to red muscle was not a limiting factor in exhaustion from swimming. Altogether, evidence is conflicting and further study is required.

1.4 Can Species Comparisons and Acclimation Studies Help Identify Limitations?

An indirect method of assessing potential limitations for exercise performance or thermal tolerance is to compare cardiorespiratory and morphological variables across a) species and b) with acclimation. Identified variables could represent potential locations where evolutionary adaptation has resulted in improved exercise performance or thermal tolerance.

For example, highly athletic fish such as tuna possess a greater $\dot{M}O_{2max}$, $\dot{Q}_{max}$, and C_{aO2}, enhanced gill surface area, large, pyramidal-shaped hearts with a higher percent compact myocardium, smaller red muscle fibres with greater capillary and mitochondrial density and a higher β-adrenoceptor density compared to less athletic species (Brill and Bushnell, 1991a; Brill and Bushnell, 1991b; Farrell, 1996; Mathieu-Costello et al., 1992; Mathieu-Costello et al., 1996; Olsson et al., 2000). In addition, aerobic exercise training in salmonids has resulted in higher $\dot{M}O_{2max}$, $\dot{Q}_{max}$, Hct, [Hb], C_{aO2}, and $A\text{-}V_{O2}$, increased cross-sectional area of red muscle, increased red muscle capillarity, and cardiac hypertrophy (Davie et al., 1986; Farrell, 1991; Farrell et al., 1990; Farrell et al., 1991; Gallaugher et al., 2001; Kiessling et al., 1994; Thorarensen et al., 1993).

The same principle can be applied for thermal tolerance. For example, acclimation to warm temperature in teleosts resulted in smaller relative ventricular mass with a higher percent compact myocardium, decreased gill epithelial thickness, decreased red muscle capillarization and decreased β-adrenoceptor density (Egginton et al., 2000; Farrell et al., 1988a; Gamperl and Farrell, 2004; Gamperl et al., 1998; Goolish, 1987; Keen et al., 1993; Pelouch and Vornanen, 1996; Taylor et al., 1997) though many of these findings seem counterintuitive. Notably, stenothermic salmonids appear to have a limited capacity to acclimate in comparison with more eurythermal species such as goldfish. For example, a 10°C difference in acclimation temperature changed the upper incipient lethal temperature by only 0-2°C in juvenile chinook salmon (Brett, 1952) compared to ~5°C in goldfish (Fry, 1947).

Rather than applying this principle by comparing across species, I took advantage of the enormous variety in upriver migration environment among genetically isolated populations of sockeye salmon in the Fraser River watershed in order to make intraspecific comparisons in aerobic performance and temperature tolerance.

1.5 Fraser River Sockeye Salmon

Every year, millions of sockeye salmon return to the Fraser River (BC, Canada) to perform the physically demanding upriver migration. During this highly aerobic feat, sockeye salmon must swim continuously against a fast-flowing river for several weeks, swimming 2 to 4 km h^{-1}, which equates to ground speeds of 20 to 40 km day^{-1} (English et al., 2005; Hinch and Rand, 1998). Sockeye salmon cease feeding in the ocean, prior to entering the river. Therefore, upriver swimming and reproductive maturation (secondary sexual characteristics, gonad growth) are fuelled entirely by endogenous energy stores. Moreover, sockeye salmon are semelparous, meaning that they only spawn once. As a result, individual fish have a single opportunity to complete the journey to their spawning grounds in order to reproduce. Those that don't make it have zero reproductive success and no lifetime fitness. As a corollary, there is likely strong selection pressure for successful upstream migration.

Fraser River sockeye salmon display a remarkable fidelity to return to their natal stream to spawn (Burgner, 1991). This has resulted in over 100 genetically and geographically distinct populations of sockeye salmon within the Fraser River watershed (Beacham et al., 2005). Populations vary in migration distance (100 to 1100 km), elevation gain (10 to 1200 m), river temperature (9° to 22°C), and river flow (2000 to 10,000 m^3 s^{-1}). Moreover, some populations must traverse major hydrological barriers, such as world-famous Hells Gate, located in the Fraser Canyon ~200 km upstream from the mouth of the Fraser River. Swimming through these difficult stretches requires maximum aerobic scope and anaerobic swimming (Hinch and Bratty, 2000; Rand and Hinch, 1998). As such, some populations have a more difficult upstream migration compared to others.

1.5.1 Environmental Adaptation

Local adaptation has been defined as the process that increases the frequency of traits within a population that augments the reproductive success or survival of individuals posessing such traits (Taylor 1991). For local adaptation to occur, a given trait must be 1) heritable, 2) differentially expressed across individuals, and 3) be associated with differential survival or fitness. Several correlational studies have provided circumstantial evidence of local adaption in salmonids (for a review, see Taylor, 1991). For example, juvenile Atlantic salmon (*Salmo salar*) and coho salmon (*Oncorhynchus kisutch*) from fast-flowing streams were more stream-lined and possessed longer paired-fins compared to fish residing in lower velocity streams (Riddell and Leggett, 1981; Taylor and McPhail, 1985a). Similarly, adult chum salmon (*Oncorhynchus keta*) and adult pink salmon (*Oncorhynchus gorbuscha*) from larger streams (and were thus exposed to faster flows) possessed larger fins relative to salmon in smaller streams (Beacham, 1984; Beacham, 1985; Beacham and Murray, 1987; Beacham et al., 1988a; Beacham et al., 1988b). Steelhead (*Oncorhynchus mykiss*) and coho populations with longer, more difficult upstream migrations had enhanced prolonged swimming performance compared to more coastal populations (Taylor and McPhail, 1985b; Tsuyuki and Williscroft, 1977). In addition, comparisons among 15 anadromous fish populations across 9 species found that populations with more difficult migrations were more energy efficient compared to those with easier migrations (Bernatchez and Dodson, 1985). Furthermore, a trade-off between egg number and migration distance was reported in chinook salmon (Kinnison et al., 2001).

Intraspecific variability in morphological, physiological and behavioural attributes in Fraser River sockeye salmon may be attributed to population-specific local adaptation which facilitates the adult migration and spawning. Indeed, Fraser River sockeye salmon populations with more difficult journeys started their migration with more somatic energy compared to those with shorter, easier migrations (Crossin et al., 2004; Gilhousen, 1980). Moreover, Crossin et al. (2004) demonstrated that Fraser River sockeye salmon populations with more challenging migrations had fewer eggs and a smaller, more stream-lined body shape. In addition, two Fraser River sockeye salmon populations have been shown to vary in aerobic scope and both possessed a T_{opt} matching their historical river migration temperature (Farrell et al., 2008; Lee et al., 2003c). Finally, one sockeye salmon population (Chilko, which has a particularly arduous migration to spawn at a high elevation in or adjacent to a glacial lake) had more energetically efficient swimming relative to two other populations (Hinch and Rand, 2000). Collectively, these findings suggest that sockeye salmon arrive at the Fraser River prepared for their specific journey ahead, despite never before having performed the upriver challenge. My thesis builds on this theoretical and empirical support for local adaptation of Fraser River sockeye salmon.

1.5.2 Behavioural and Physiological Responses of Salmon to Temperature

The effect of water temperature on Pacific salmon migration has received substantial attention. Water temperature is known to impact a variety of traits: survival (Crossin et al., 2008; Farrell et al., 2008; Gilhousen, 1990; Macdonald, 2000), behaviour (Berman and Quinn, 1991; Cooke et al., 2004; Crossin et al., 2008; Farrell et al., 2008; Goniea et al., 2006; Hodgson and Quinn, 2002; Keefer et al., 2008a; Newell and Quinn, 2005; Patterson et al., 2007), migration speed (Hanson et al., 2008; Keefer et al., 2008a), swimming performance (Lee et al., 2003c; Farrell et al., 2008; Steinhausen et al., 2008), energetics (Crossin et al., 2004; Hinch and Rand, 1998; Rand et al., 2006), physiology (Crossin et al., 2008; Steinhausen et al., 2008; Young et al., 2006) and disease development (Wagner et al., 2005).

Sockeye salmon are exposed to a wide variety of temperatures during their migration period (Hinch et al., 2006), and Fraser River temperatures have been increasing over the last 60 years (Patterson et al., 2007). An individual fish can encounter temperatures ranging from 11-22°C during the short 3-4 week upriver migration. For example, individual fish routinely experience temperature swings of 3-4°C over 8 days while migrating up the mainstem Fraser (Donaldson et al., 2009). Average peak summer water temperature has increased by ~2°C since the 1950s and 8 of the past 10 summers have been the warmest on record (see Patterson et al., 2007). When faced with unfavourably high temperatures, individual sockeye salmon could make some combination of behavioural and physiological modifications.

Behaviourally, Pacific salmon can slow or cease swimming when exposed to temperatures outside their thermal optimum (Goniea et al., 2006; Keefer et al., 2008b; Salinger and Anderson, 2006). Pacific salmon may also alter the timing of their migration in order to avoid peak temperatures (Hodgson and Quinn, 2002; Quinn and Adams, 1996; Quinn et al., 1997; Robards and Quinn, 2002). Finally, Pacific salmon seeking cold-water refuge have been demonstrated to have improved survival and spawning success (Farrell et al., 2008; Mathes et al., 2010; Roscoe et al., 2010). However, given that sockeye salmon have finite energy reserves, it is not a viable long-term option to excessively slow or cease swimming. Spawning date is highly conserved to ensure egg and juvenile survival (Burgner, 1991), so major alterations in entry timing into the Fraser River are not possible. Upriver migration is energetically expensive, typically depleting more than 50% of stored reserves (Brett, 1995; Crossin et al., 2004) and excessive energy use during migration has been demonstrated to cause premature mortality (Rand and Hinch, 1998). Finally, not all populations have cold refugia available to them. For example, Nechako and Early Stuart sockeye salmon spend weeks migrating up the mainstem Fraser River, which has little-to-no cool water relief (Donaldson et al., 2009).

Phenotypic plasticity can play an important role in temperature tolerance in ectothermic vertebrates. However, the role of physiological plasticity in temperature tolerance is poorly understood in adult salmonids. On one hand, beneficial physiological modifications could enable salmon to cope with warm temperatures. For example, modifications could be made in mitochondrial density, membrane composition and the type and kinetic properties of metabolic enzymes (Guderley and St-Pierre, 2002; Pörtner, 2002). In addition, beneficial changes in muscle capillarization, contractility or muscle fibre type could occur (Egginton and Cordiner, 1997; Egginton and Sidell, 1989; Sidell and Moerland, 1989). Cardiac remodelling to alter the size or composition of the ventricle (Farrell et al., 1988a; Graham and Farrell, 1989), adjustments to the number or binding affinity of adrenaline-binding ventricular β-adrenoceptors (Keen et al., 1993) or alteration in respiratory epithelium thickness (Leino and McCormick, 1993) could enhance oxygen delivery. Therefore, phenotypic plasticity may play an important role in allowing sockeye salmon to adjust to the ever-changing environment during their upstream journey.

On the other hand, acclimatory responses to temperature may play a minor role for salmonids. For example, increasing the acclimation temperature of juvenile sockeye salmon from 10 to 23°C only increased the upper lethal temperature by 0.9°C (Brett, 1952). Moreover, f_{Hrest} and f_{Hmax} were similar in sockeye salmon acclimated to 22°C [86 and 106 beats min^{-1}, respectively, (Brett, 1971)] compared to sockeye salmon acutely warmed to 22°C [90 and 106 beats min^{-1}, respectively (Steinhausen et al., 2008)]. In addition, swim performance did not vary between cutthroat trout (*Oncorhynchus clarki*) given 48 h or 3 weeks to acclimate to 7, 14, or 18°C (MacNutt et al., 2004). Given that migrating sockeye salmon are simultaneously senescing, not feeding, undergoing massive morphological modifications as they sexually mature and performing an incredible athletic feat as they swim upstream, normal acclimation mechanisms may be incomplete in adult sockeye salmon. In addition, temperature swings may be too swift during the short 3-4 week migration to allow a full physiological acclimatory response. As a consequence, swimming performance and cardiorespiratory capacity may be set at a level that is sufficient to meet the demand experienced at the highest and lowest temperatures typically encountered by a given population (Pörtner, 2002) and phenotypic plasticity may play a minor role in responding to temperature in migrating salmon. All told, the role of physiological acclimation in migrating sockeye salmon is poorly understood and warrants further investigation.

1.5.3 Conservation Implications

Peak summer river temperature in the Fraser River has warmed by ~2°C over the last 60 years (Fig 1.3). Elevated river temperatures have been repeatedly associated with adult mortality during the upriver migration, raising conservation concerns for this ecologically, economically and culturally important fish species (Hinch et al., 2006; Hinch and Martins, 2011). Current maximum river temperatures exceed T_{opt} for the two sockeye salmon populations (Gates and Weaver) that have been examined thus far (Farrell et al., 2008; Lee et al., 2003c). En-route mortality for returning adults clearly differs across populations and among years (Hinch and Martins, 2011). For example, in 2004, the Fraser River and its tributaries reached an exceptionally high temperature (>21°C) and an estimated 70-80% of Weaver sockeye salmon died during migration (Farrell et al., 2008). However, the proximate causes of in-river mortality are unknown. Physiological processes are critical in defining temperature-induced mortality (Wang and Overgaard, 2007; Wikelski and Cooke, 2006). Given that the current warming trends are expected to continue (Ferrari et al., 2007; Morrison et al., 2002), it is critical that population-specific temperature tolerance is defined in order to identify populations most vulnerable to climate change. These discoveries will have important implications for biodiversity and management decisions.

1.6 Thesis Objectives and Hypotheses

The general objective of my thesis was to examine the physiological basis for thermal tolerance in sockeye salmon populations. Specifically, I sought to characterize how cardiorespiratory physiology varies among sockeye salmon populations and determine the mechanism of cardiorespiratory collapse at high temperature. I used an integrative approach, examining several levels of biological organisation, in order to test the overall hypothesis that Fraser River sockeye salmon populations have physiologically adapted to meet their specific upriver migration challenges. I predicted that thermal limits are set at a local level by physiological limitations in aerobic performance due to cardiac collapse. At each level of biological organisation (whole animal, organ and cellular), I made comparisons across populations and temperatures in order to examine this hypothesis.

The form of the thesis is as follows. Chapter 2 provides a detailed description of the Fraser River system, the populations of sockeye salmon I examined and the materials and methods used throughout this thesis. For each experiment, wild, migrating sockeye salmon were collected from the lower Fraser River, very early in the river migration (at the time of capture, the salmon had been in the Fraser River approximately 1-3 days). Therefore, the fish were collected before they encountered the majority of the upriver migration conditions and after they had spent >2 years in a common, cool ocean environment.

The specific research questions are presented in Chapters 3-7. In Chapter 3, I compared cardiorespiratory performance as a function of temperature across four new populations and incorporated data from two previously assessed populations (Lee et al., 2003c). I predicted that populations with more challenging migrations would have greater aerobic, cardiac and heart rate scopes. In addition, I predicted that each population can maintain maximum scope across the entire range of temperatures the adult salmon most frequently encountered during the upriver migration, as has been previously established for two populations (Farrell et al., 2008; Lee et al., 2003c).

Chapter 4 details the swimming physiology for the four upriver populations swum at T_{opt}. Specifically, I compared cardiorespiratory performance as well as arterial and venous blood variables among populations during two consecutive swim challenges. I predicted that each population would demonstrate excellent repeat swim performance, as has been demonstrated in the literature (Farrell et al., 1998; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003b; MacNutt et al., 2004; MacNutt et al., 2006; Wagner et al., 2006). Moreover, I predicted that these four upriver populations would display similar cardiorespiratory performance since they all encounter similar challenging upriver conditions and demonstrated similar maximum aerobic and cardiac scopes in Chapter 3.

The detailed physiological studies in Chapters 3 and 4 allowed me to examine the mechanism of cardiorespiratory collapse at high temperature in Chapter 5.

In Chapter 5, I pooled the three upriver populations that did not differ in cardiorespiratory performance. I hypothesized that a limitation at the level of the heart, gills or tissue would lead to a mismatch between oxygen supply and demand, and result in impaired aerobic scope and swim performance. I predicted that aerobic scope is limited at high temperatures due to cardiac collapse.

Since the heart emerged as a key player in temperature tolerance and supporting aerobic swimming in Chapters 3, 4 and 5, I examined cardiac morphology in Chapter 6. I predicted that populations with more challenging migrations would have larger ventricles and a greater proportion of compact myocardium compared to those populations with easier migrations. I also examined how cardiac morphology is affected by temperature exposure.

In Chapter 7, I examined a potential mechanism at the cellular level of the heart for the higher and broader thermal tolerance of one population (Chilko) compared to another co-migrating population (Nechako). I hypothesized that Chilko sockeye salmon would possess an enhanced ability to use adrenaline which would provide greater cardiac capacity and protection at high temperatures, thereby expanding their thermal tolerance.

Chapter 8 concludes my thesis and provides a final synthetic discussion as well as future directions for research.

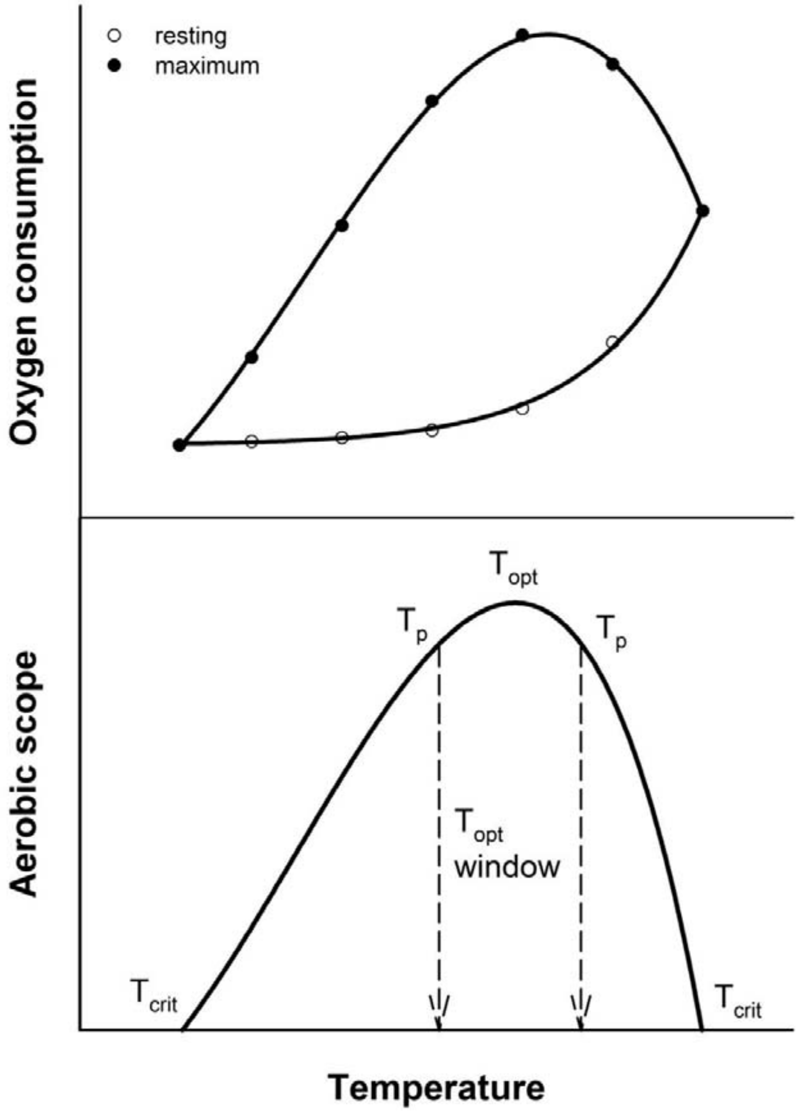

Figure 1.1. Schematic of resting and maximum oxygen consumption and aerobic scope. See text for details. T_{opt} = optimum temperature, T_p = pejus temperatures, T_{crit} = critical temperatures. The T_{opt} window corresponds to the range of temperatures between the upper and lower T_p.

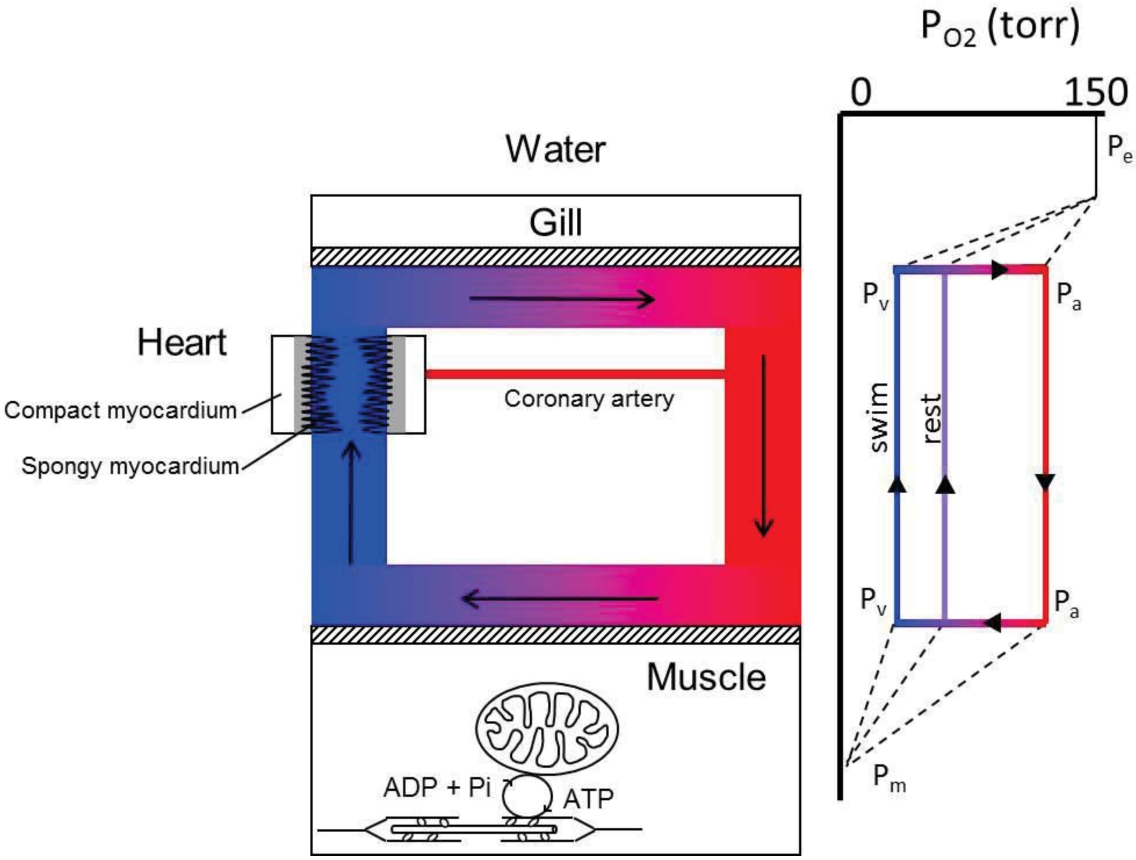

Figure 1.2. Schematic of the oxygen cascade. Step 1: Oxygen-rich water is brought into contact with the gill. This step is determined by gill ventilation and volume. Step 2: Oxygen diffuses from the environment, across the gills and into the blood where it binds to haemoglobin. This step is determined by the partial pressure gradient of oxygen (P_{O2}) between the water (P_e) and the blood (P_v to P_a) as well as gill anatomy (surface area, diffusion distance and the permeability coefficient of oxygen). Step 3: The circulatory system transports the oxygen-bound haemoglobin by convection to the tissues. This step is governed by cardiac output and the quantity of oxygen per unit arterial blood (which in turn is primarily determined by the haemoglobin concentration). Step 4: Oxygen diffuses across the capillary wall and into the cell, where it is ultimately used during mitochondrial respiration. This final step is determined by the partial pressure gradient between the blood (P_a to P_v) and the mitochondria (P_m) as well as tissue anatomy (surface area, diffusion distance, the permeability coefficient of oxygen and the quantity of mitochondria). During swimming, more oxygen is extracted by the swimming muscles, resulting in a lower P_{O2} in the venous blood. See Weibel (1984). Note that the heart is composed of two types of myocardium. The outer compact myocardium has a coronary circulation, so it is perfused with oxygen from the arterial system. The inner spongy myocardium is avascular, so it receives oxygen from the venous system.

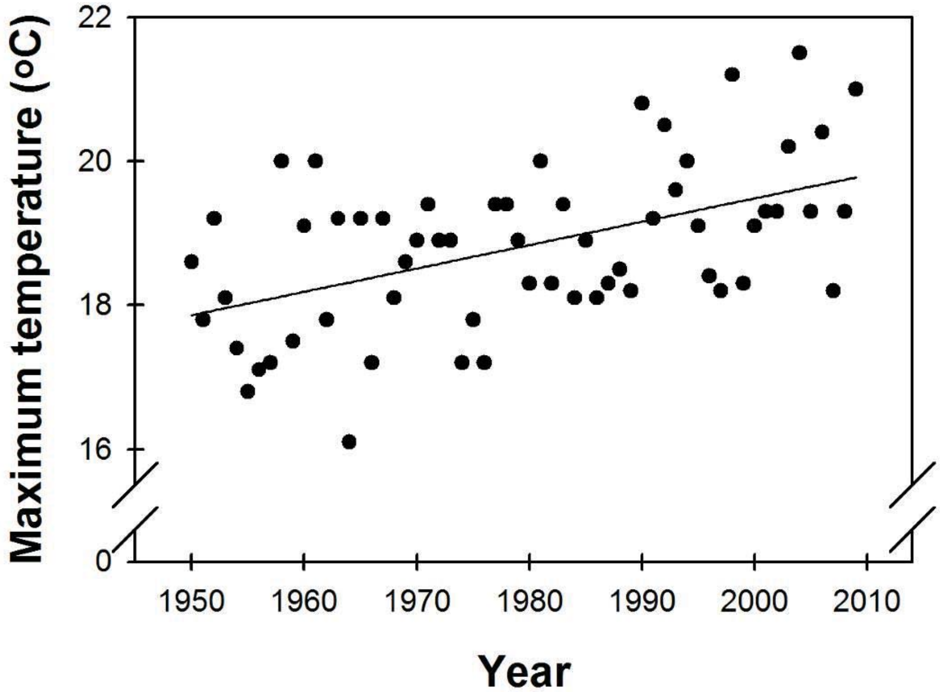

Figure 1.3. Maximum yearly Fraser River water temperature at Hells Gate from 1950-2009 ($y = 0.0324x - 45.3776$, $p < 0.0001$, $R2 = 0.25$) (see Patterson et al., 2007).

CHAPTER 2: MATERIALS AND METHODS

2.1 Migration Conditions and Migration Difficulty Indices

Spawning grounds differ in their distance and elevation from the mouth of the Fraser River (Table 2.1; Fig 2.1) and populations initiate up-river migrations at different times of the year. Fisheries managers categorize populations into four major run-timing groups (Early Stuart, Early Summer, Summer and Late) based on the historic timing of Fraser River entry. Mainstem Fraser River discharge decreases from June to November, but temperature typically increases until August and declines thereafter. The Early Stuart run populations enter the Fraser River in early July and experience the highest river flows and moderate temperatures early in their migration and increasing temperatures towards the end of their migration. Early Summer and Summer run populations enter in late July and August and experience the warmest temperatures in the mainstem Fraser River early in their migration and moderate flows. Late run populations enter in the fall and experience the lowest flows and coolest average temperatures compared to the other entry runs (Table 2.1). Therefore, the temperature and water velocity experienced also varies among populations.

Clearly, the relative difficulty of the migration varies considerably and complexly among populations. As a result, the difficulty of population-specific migrations was characterized using several indices. The first was based on whether or not populations pass through Hells Gate, a major hydraulic barrier (Hinch and Bratty, 2000) about 200 km upriver from the mouth of the Fraser River (Fig 2.1) and upstream of the location where fish were sampled for all the experiments in this thesis. Populations were categorized as “coastal” if they did not pass through Hells Gate and “upriver” if they did (Table 2.1).

Migration difficulty was also characterized for each population based on the river migration distance from the Fraser Delta (Steveston, BC) to the spawning grounds (D_M) and the elevation of the main spawning grounds (E_M) (Table 2.1). Three additional indices were calculated according to the concepts of physical work and river slope (Crossin et al., 2004; Gilhausen, 1980). In physics, “work” is defined as the product of force over a given distance. The amount of work a salmon must do to reach the spawning ground can be estimated using E_M or F_M (elevation or river discharge, as a surrogate for force) and D_M (distance). Migratory work was determined as $k_1 \bullet E_M \bullet D_M$ and migratory effort was determined as $k_2 \bullet D_M \bullet F_M$. In addition, while river distance and elevation do co-vary somewhat, a short migration can be steeper than a long migration. Therefore, river slope ($k_3(E_M\, D_M^{-1})$) was included as an additional index. The correction factors k_1, k_2 and k_3 (0.001, 0.0001 and 500, respectively) simplify presentation.

Historic environmental and migratory data were collected for eight sockeye salmon populations. Lower Fraser River discharge (F_M) data were obtained from the Water Survey of Canada. Lower Fraser River temperature (T_M) data were provided by Fisheries and Oceans Canada (DFO) Environmental Watch Program (see Patterson et al., 2007). For upstream populations, F_M and T_M were measured near Hope (Fig 2.1), centered on the historic date of peak salmon passage through Hells Gate. For coastal populations, F_M and T_M were measured at Mission (Fig 2.1), centered on peak Mission salmon passage. Lower river conditions have been previously used as indices of the total freshwater migratory experience given the generally strong correlation between lower and upper river environmental conditions (Hague et al., 2008). Furthermore, lower river temperature and flow have been correlated to both indirect and direct estimates of spawning migration mortality (Macdonald et al., 2010; Martins et al., 2011). Median and modal migration temperatures were calculated from the population-level temperature histograms used in the present study (see below, Table 2.1). While river migration speeds vary considerably among individuals and populations, biotelemetry experiments have repeatedly shown that sockeye salmon tend to migrate continuously in freshwater until they reach their natal systems, achieving ground speeds of 15-40 km d^{-1} depending on river section (English et al., 2005; Hanson et al., 2008). Average ground speeds for each population across the total freshwater migration route were determined using data obtained from radio-biotelemetry studies performed by LGL Environment Ltd from 2002-2007 (Hague et al., 2008; Martins et al., 2011). Migration duration was determined by dividing the migration distance by migration rate (Table 2.1).

The average thermal units accumulated during freshwater migration [i.e. Accumulated Thermal Units (ATU)] were calculated for the "active" part of the migration (i.e. the time when fish were actively migrating upstream, which did not include river or lake holding near the spawning ground). Peak Fraser River entry (average date between 1977-2008 at which 50% of the run-timing group passed Mission minus two days for travel time from Fraser Delta to Mission) and peak Hells Gate passage times (average date between 1977-2008 at which 50% of the run-timing group passed Mission plus 4-5 days travel time, depending on average migration rate for each population) were provided by the Pacific Salmon Commission. Peak spawning date was provided by Fisheries and Oceans Canada Stock Assessment Division (Table 2.1).

Population-level temperature distributions (see Chapter 3) were simulated using an individual-level freshwater migration model which integrated across daily average river and lake temperatures experienced over the "active" period of the spawning migration (i.e. did not include lake or river holding temperatures prior to spawning) from 1995 to 2008 (modified from Farrell et al., 2008).

Since 1995, several populations of late-run sockeye salmon (e.g. Weaver, Harrison, Lower Adams) have entered the Fraser River up to six weeks earlier than previously observed, a phenomenon that is poorly understood (Cooke et al., 2004; Hinch, 2009). As a result of the early river entry, these salmon encounter considerably warmer temperatures and in-river mortality has exceeded 90% in some years (Cooke et al., 2004; Hinch, 2009). Therefore, the environmental data (Table 2.1) and temperature frequency histograms (Chapter 3) are presented for both historical run timing (before 1995) and the current early entry phenomenon (1995-2008) for comparison.

Each population experiences a broad range of temperatures throughout their brief 1-4 week migration, which varies depending on river entry timing, spawning ground location and year-to-year variation. Some Summer run populations routinely experience temperatures as low as 11°C (e.g. Chilko during the final third of their migration when they enter the Chilcotin River and ascend to their spawning location in or downstream of a glacial lake) and as high as 22°C (e.g. near the mouth of the Fraser River during August when river temperatures tend to peak). Studies using radio tags and thermal loggers have shown that individual fish routinely experience temperature swings of 3-4°C over 8 days during their migration up the mainstem Fraser River (Donaldson et al., 2009). Experimental temperatures were selected to span the entire range of temperatures encountered during migration. In addition, brief exposures to temperatures exceeding those typically encountered in the wild were also used to assess high and low temperature tolerance.

For most populations, the highest temperature experienced during river migration occurs in the lower Fraser River. Since the 1940s, the maximum daily water temperature at Qualark (near Hells Gate in the lower Fraser River) has been 21.5°C, which occurred in 2004. The Early Summer and Summer run groups would experience such peak temperatures, as would any Late run population that entered the river early, as they have been doing since the mid-1990s. In fact, Weaver sockeye (which belong to the Late run group) entered the Fraser River early in 2004, experienced temperatures reaching 21.5°C and over 50% of the population died en route to the spawning area (Mathes et al., 2010). The main exception to this generalization is Early Stuart sockeye salmon, which typically experience cool water in the lower Fraser River but warmer temperatures later in their migration when they are closer to their spawning grounds ~1,000 km upstream (Macdonald et al., 2007). A temperature of 21.5°C is a reasonable maximum temperature experienced by Early Stuart sockeye salmon during the final stage of their river migration. Therefore, 21.5°C is indicated in Chapter 3 as the current temperature maxima experienced by Fraser River sockeye salmon.

2.2 Fish Collection

Wild adult sockeye salmon were collected in the lower Fraser River or Harrison River (a lower Fraser tributary) using a beach seine or gill net while fish were en-route to their spawning grounds and shortly after entry into freshwater (Fig 2.1). Notably, the fish were collected very early in their river migration and before they had experienced most of the upriver migration conditions. The sockeye salmon were transported 25-75 km by land to the DFO Cultus Lake Salmon Research Laboratory (CLL, Cultus Lake, BC, Canada). Following capture, all sockeye salmon were given a unique cinch tag or PIT tag (Passive Integrated Transponder tag, approximately 8.5 mm x 2 mm size, Biomark Inc., Boise, Idaho) for individual identification, a scale was removed and <0.1 g of the adipose fin was clipped for population identification via DNA analysis (Beacham et al., 2005). The DNA analysis compares one major histocompatibility complex (MHC) loci or five single nucleotide polymorphisms (SNPs) in addition to 14 microsatellite loci and assigns a probability of population identification (Beacham et al., 2005). This method has been demonstrated to correctly assign 94% of individuals to the correct population aggregate (as defined below) using simulations run with the program cBAYES (Beacham et al., 2005; Beacham et al., 2004; Beacham et al., 2010). Due to low sample sizes or an inability to definitively assign population identification between co-migrating, adjacent populations, some populations spawning in adjacent rivers or lakes were grouped as a single population. Chilko is composed of two spawning populations, one that spawns in the lake and one that spawns in the lake outlet (Chilko River). Quesnel comprises two main populations which spawn 47 km apart (Mitchell and Horsefly Rivers; inlet tributaries to Quesnel Lake). Nechako is composed of four populations that spawn within 100 km of each other (Stellako, Nadina, Tachie and Middle River). Early Stuart is made up of 40 small populations that spawn within 100 km of each other (Beacham et al., 2005). Lower Adams, Weaver, Harrison and Gates are all genetically distinct, single populations. All procedures were approved by the University of British Columbia's Animal Care Committee in accordance with the Canadian Council on Animal Care (A06-0328 and A08-0388).

2.3 Surgical Procedures

In order to measure cardiorespiratory variables, the fish underwent surgery before the swim tests. Individual fish were anaesthetized with buffered tricaine methanesulfonate in freshwater (0.2 g l^{-1} $NaHCO_3$ and 0.1 g l^{-1} MS-222, Sigma, St. Louis, MO), weighed and transferred onto wet foam on a surgical table where their gills were continually irrigated with aerated, chilled freshwater with a lower dose of anaesthetic (0.15 g l^{-1} $NaHCO_3$ and 0.075 g l^{-1} MS-222). Surgical procedures have been detailed elsewhere (Steinhausen et al., 2008). To sample arterial blood, a PE-50 cannula was inserted into the dorsal aorta (Soivio et al., 1973). To measure cardiac output, a 3 mm SB flowprobe (lateral cable exit, Transonic systems, Ithaca, NY, USA) was positioned around the ventral aorta without opening the pericardium (Steffensen and Farrell, 1998). To sample venous blood, a PE-50 cannula was inserted into the ductus of Cuvier and advanced towards the heart into the sinus venosus (Farrell and Clutterham, 2003). Both cannulae were filled and regularly flushed with heparinized saline solution (150 IU ml^{-1}). The flowprobe lead and cannulae were secured together and sutured to the fish's body using 2-0 silk. The fish were placed in a Brett-type swim tunnel and allowed to recover overnight at low water velocity of ~0.39 bl s^{-1} before starting the swim tests.

2.4 Swimming Experiments

The swimming tests were conducted in 2007, 2008 and 2009 at CLL (N = 97). Fish were held at 11-12°C for 1-4 weeks in outdoor 8,000–12,000 l circular aquaria supplied with filtered and UV sterilized freshwater (~40 l min^{-1}; LS-Permabead Filtration System, Integrated Aqua

Systems Inc., Escondido, California) under seasonal photoperiod. The fish were not fed because they had ceased feeding naturally before entering the Fraser River. Three days before the swimming test, fish were placed in 1,400 l circular aquaria and the temperature was progressively increased to the test temperature (13-22°C) by no more than 5°C day^{-1}. The fish were maintained at this temperature for at least one day before the swim tests were conducted.

Following overnight recovery from surgery at their test temperature, resting oxygen consumption ($\dot{M}O_2$), cardiac output ($\dot{Q}$), arterial and venous blood were measured at a water velocity of ~0.39 bl s^{-1}. Then the fish underwent a ramp-U_{crit} swim protocol (Jain et al., 1997; Lee et al., 2003c). The velocity of the water was increased every 5 min until approximately 50% of U_{crit} was reached (~1.0 bl s^{-1}). Thereafter, the speed was increased by approximately 0.25 bl s^{-1} every 20 min until the fish no longer swam continuously and rested on the back grid for >30 s. The water speed was reduced to the resting velocity and the fish were allowed a 45-min recovery before repeating the same ramp-U_{crit} swim protocol. The fish were allowed to recover for 2 h after the second swim test.

$\dot{Q}$ was measured continuously throughout the swim trial. $\dot{M}O_2$ was measured during the second half of every 20-min speed interval. If the dissolved oxygen levels approached 7.0 mg O_2 l^{-1}, $\dot{M}O_2$ was deliberately not measured to maintain a normoxic environment in the swim tunnel. Blood samples (~0.7 ml per sample) were collected during the second half of the first 20-min swim interval (mean speed = 1.18 bl s^{-1}, or 56% of maximum swim speed) during steady swimming. Blood was sampled again when the fish exhibited burst-and-coast swimming near exhaustion (mean speed = 2.1 bl s^{-1}, or 93% of maximum swim speed). Additional blood samples were occasionally taken at intermediate speeds for some fish. $\dot{M}O_2$ and blood were sampled immediately after the fish quit swimming (fatigue), and again after 45 min of recovery. Final samples were collected after a 2-h recovery period following the second swim.

A subset of fish did not undergo surgery, but were otherwise treated the same as the fish that were instrumented.

I was unable to hold fish at extremely high or low temperatures; therefore, some fish did not undergo the same three-day temperature exposure prior to surgery. Instead, they were allowed to recover overnight from surgery in the swim tunnel at 12°C and in the morning the water temperature was acutely increased or decreased by 4°C h^{-1} to the test temperature (8-10°C or 22-26°C). After one hour at the test temperature, resting values were recorded as above and then the fish underwent a single ramp-U_{crit} swim protocol, after which the temperature was returned to 12°C over 2 h. Occasionally, some fish at the highest test temperatures displayed cardiac disrhythmias while resting and before the swim test. In the few cases when this occurred, the temperature was immediately decreased and the fish were not used. As such, all fish began their swim test with a regular, rhythmic heart rate.

Upon conclusion of the swim test, the fish was removed from the swim tunnel and sacrificed by a cranial blow. A post-mortem caudal blood sample was collected using a Vacutainer (2-3 ml) and mass (whole body, liver, gonad, spleen, heart), length [standard length, fork length, post-orbital-hypural (POH) length, post-orbital-fork (POF) length], girth and depth were measured for each fish. Gonadosomatic index (GSI), hepatosomatic index (HSI) and splenosomatic index (SSI) were calculated as the mass of the gonad, liver and spleen divided by body mass, respectively (see below for details of heart calculations). In order to estimate the energy status of each fish, proximate constituent analysis was conducted on a ~200 g piece of dorsal muscle, removed from the left side of the fish between the operculum and the dorsal fin.

The concentrations of protein, lipid, moisture and ash were assessed so that gross energy could be estimated (Crossin et al., 2004; Higgs et al., 1979).

2.5 Swim Tunnels

Two Brett-type swim tunnels were used to swim individual fish, which have been fully described elsewhere (Lee et al., 2003c; Steinhausen et al., 2008). Both swim tunnels were equipped with a custom-designed heating system which could maintain the set water temperature ± 0.5°C. The velocity of the water was calibrated (± 1 cm s^{-1}) using an anemometer (Valeport Marine Scientific, Dartmouth, UK).

2.6 Whole Blood and Plasma Analysis

Whole blood samples were used to measure partial pressure of oxygen (P_{O2}), oxygen content (C_{O2}), haemoglobin concentration (Hb) and hematocrit (Hct). The samples were held at 4°C and analyzed shortly after collection. Blood P_{O2} was measured using a blood gas monitor (PHM 73, Radiometer, Copenhagen, Denmark) which was calibrated and maintained at each temperature using a water jacket. Blood C_{O2} was measured according to the method of Tucker (1967). Hb was measured using either a handheld haemoglobin analyzer (Hemacue 201^+, Ängelholm, Sweden) calibrated for fish blood (Clark et al., 2008a) or the spectrophotometer method with Drabkin's solution (Clark et al., 2008a; Drabkin and Austin, 1935). Hct was measured in duplicate using microhematocrit capillary tubes spun at 10,000 g. The remaining blood was centrifuged at 7,000 g and the plasma was flash frozen in liquid nitrogen and stored at -80°C for subsequent analyses.

Plasma cortisol (ELISA kit, Neogen , Lexington, KY, USA), glucose and lactate (YSI 2300 Stat Plus analyzer), sodium and potassium (Cole-Parmer, model 41- single channel flame photometer) and chloride (Haake Buchler digital chloridometer) were measured on all blood samples (see Farrell et al., 2001a). Plasma testosterone and 17β-estradiol (ELISA kit, Neogen , Lexington, KY, USA) were only determined for the final caudal blood sample from Early Stuart and Chilko sockeye salmon in 2008 and 2009.

2.7 Data Analysis and Calculations for Cardiorespiratory Variables

During an $\dot{M}O_2$ measurement, the inflow and outflow water to the tunnel were turned off and the decrease in oxygen content over time was measured. Oxygen content of the water in the swim tunnel (mg O_2 l^{-1}) was measured using an Oxyguard probe (Point Four Systems, Richmond, Canada) attached to a Windaq box (Dataq instruments, Akron, ON, USA) interfaced with Labview software (6.0, National Instruments, Austin, TX, USA). The duration of the measurement was sufficient so that the dissolved oxygen decreased by at least 0.3 mg O_2 l^{-1}, which resulted in a linear regression with r^2 values typically >0.95. $\dot{M}O_2$ (mg O_2 kg^{-1} min^{-1}) was calculated as: $\dot{M}O_2 = \triangle[O_2] \bullet v \bullet M^{-1} \bullet t^{-1}$ where $\triangle[O_2]$ is the change in water content (mg O_2 l^{-1}), v is the volume of the water minus the volume of the fish (l), M is the mass of the fish (kg) and t is the time (min). Background $\dot{M}O_2$ was measured after each swim trial and determined to be negligible.

U_{crit} was calculated as in Brett (1965): $U_{crit} = U_f + (t_f/ti \bullet Ui)$ where U_f is the water velocity of the last fully completed increment, t_f is the time spent in the final water velocity increment, t_i is the time period for each completed increment, and U_i is the water velocity increment. U_{crit} was calculated in both body lengths per second (bl s^{-1}) and cm per second (cm s^{-1}). U_{crit} was corrected for the solid blocking effect according to Bell and Terhune (1970) using the following equation: $U_F = U_T \bullet (1 + \varepsilon_s)$ where U_F is the corrected flow speed, U_T is the speed in the tunnel without the fish, and ε_s is the error due to solid blocking. ε_s is calculated as: $\varepsilon_s = \tau \bullet \lambda \bullet (A_o/A_T)^{1.5}$ where τ is a dimensionless factor depending on the swim chamber cross section (0.8 in this study), λ is the shape factor for the fish (0.5 body length/body thickness), A_o is the cross sectional area of the fish and A_T is the cross sectional area of the swimming chamber. The recovery ratio (RR) was calculated as RR = U_{crit} 2/ U_{crit} 1 to determine how the first U_{crit} compared to the second U_{crit}.

To measure $\dot{Q}$, the flowprobe was connected to a flowmeter (Transonic systems, Ithaca, New York, USA) and blood flow was measured at 200 hz using Biopac hardware and Acknowledge software (Biopac systems, Santa Barbara, CA, USA). $\dot{Q}$ was calculated as the mean of at least three 30 s segments. Heart rate (f_H) was measured from the flow trace during the 30 s segments using the automated software which was confirmed with manual counting. Stroke volume (V_s) was calculated as $\dot{Q} = f_H \bullet V_s$.

Cost of transport (COT) was calculated as: COT = $\dot{M}O_2$/U where $\dot{M}O_2$ was measured in mg O_2 kg^{-1} min^{-1} and U was the swimming speed in m s^{-1}, corrected for the solid blocking effect. Net cost of transport (COT_{net}) was calculated as: $COT_{net} = (\dot{M}O_2 - \dot{M}O_{2rest})/U$. Similarly, cost of transport for cardiac output (COT-$\dot{Q}$) and net cost of transport for cardiac output (COT-$\dot{Q}_{net}$) were calculated.

Oxygen extraction ($A\text{-}V_{O2}$) was calculated as arterial oxygen content (C_{aO2}) - venous oxygen content (C_{vO2}) and was only assessed in fish that had both cannulae working simultaneously. Arterial oxygen transport (T_{aO2}) to the tissues was calculated as the product of $\dot{Q}$ and C_{aO2}. Venous oxygen transport (T_{vO2}) to the spongy myocardium and gills was calculated as the product of $\dot{Q}$ and C_{vO2}. Mean corpuscular haemoglobin concentration (MCHC) was calculated as [Hb]/(Hct/100).

Aerobic scope and cardiac scope were determined as the difference between the resting and maximum values. Scope for heart rate and scope for stroke volume were determined as the difference between the resting values and those measured at maximum cardiac output.

To determine the Fry curves for aerobic scope, a second order polynominal regression was fitted to the aerobic scope data from individual fish of each population swum across a range of temperatures. The same method was used to develop the curves for cardiac scope, scope for heart rate and scope for stroke volume. Optimal temperature (T_{opt}) for each population was determined as the temperature corresponding to the peak of the polynomial regression for aerobic scope. The upper and lower pejus temperatures (T_p) were assigned to 90% of the maximum aerobic scope, with the T_{opt} window being defined as the range of temperatures between the upper and lower T_p. The upper critical temperature (T_{crit}) was defined by extrapolating the polynominal regression for aerobic scope to the upper temperature when aerobic scope reached zero. The value of aerobic scope at T_{opt} was determined as the average of the individual data points within the T_{opt} window for each population. The upper temperature experienced by the 90th percentile of each population (T90%) was determined from the historic temperature distributions and the percentage of maximum aerobic scope available at T90% was determined for each population.

There were insufficient data points across a range of temperatures to plot an aerobic scope curve or determine T_{opt} for Lower Adams sockeye salmon. Similarly, there were insufficient data points at cooler temperatures to define the lower T_p or determine T_{opt} for Quesnel sockeye salmon. Therefore, aerobic scope at T_{opt} was based on the plateau of individual data points from fish swum at temperatures corresponding to those typically encountered during upriver migration. For Lower Adams, this temperature range also corresponds with optimal temperatures previously estimated for this population (Steinhausen et al., 2008)

Data from the swim tests conducted in 2007, 2008 and 2009 are presented over three chapters (Chapters 3-5). Chapter 3 presents the overall highest maximum and scope values obtained over the two swims. All fish were included in this chapter. Chapter 4 compares swim 1 and swim 2 in fish that had undergone surgery from four upriver populations (Early Stuart, Nechako, Chilko and Quesnel). Chapter 5 compares cardiorespiratory performance of swim 1 across four different temperature categories (details of the temperature categories are provided in Chapter 5).

2.8 Gross Heart Morphology

2.8.1 Animal Acquisition

Sockeye salmon heart samples were collected from a variety of experiments. In all cases, the fish were collected early in their migration, prior to encountering any of the major upriver migration challenges (as outlined in section 2.2). The three sections below detail the different experimental conditions.

Population Comparisons

Male and female sockeye salmon hearts from seven populations (N = 194, Early Stuart, Chilko, Quensel, Nechako, Lower Adams, Weaver, Harrison) were collected opportunistically from various experiments conducted at CLL in 2007 and 2008 (e.g. the swimming experiment outlined above). However, I restricted population comparisons of cardiac morphology to female sockeye salmon. It is well known that salmonids can rapidly remodel their hearts in response to biological and environmental cues (Gamperl and Farrell, 2004). For example, male salmonids increase RVM up to 2-fold with sexual maturation. In contrast, female salmonid ventricles do not change size with sexual maturation (Bailey et al., 1997; Clark and Rodnick, 1998; Franklin and Davie, 1992). Consistent with this knowledge, cardiac morphology significantly varied with temperature treatment among male but not female sockeye salmon (see Chapter 6). There were insufficient numbers of male fish from a particular temperature treatment and sexual maturation level for all populations in order to make comparisons, so males were excluded from the population analysis.

Temperature Exposure

In 2007, Chilko sockeye salmon (N = 34) were collected from the lower Fraser River and held at CLL in 8,000 – 12,000 l tanks for 4-6 days at 12°C. The fish were then exposed to 14, 16.5 or 19°C (± 0.5°C) for up to 14 days, or until they died. Only fish that were held at their temperature treatment for at least 5 days before dying were included in the analysis.

Swimming Experiment

In 2006, Lower Adams sockeye salmon (N = 16) were collected by purse seine in the Strait of Georgia, held at the DFO & UBC Centre for Aquaculture and Environmental Research (CAER, West Vancouver, BC, Canada) and used in a swimming experiment detailed in Steinhausen et al. (2008). Briefly, the fish were swum at a fixed speed of ~1.35 bl s^{-1}, which is approximately 75% of U_{crit}, in the Brett-type swim tunnels outlined above. The water temperature was incrementally increased at a rate of 2°C h^{-1} from 15°C to 17, 19, 21, 23 and 24°C, or until the fish quit swimming.

2.8.2 Heart Sampling and Analysis

Regardless of the experiment, the heart tissue was processed by the same method. Following death, fish were weighed (M) and the heart was removed and placed in a vial containing 70% ethanol. The compact and spongy myocardial layers of the preserved ventricles were separated according to established methods (Farrell et al., 2007; Poupa and Carlsten, 1973) to provide an index of the proportion of the ventricle composed of compact relative to spongy myocardium. The two layers were dried to a constant mass (at least 3 days at 60°C) and weighed to the nearest 0.1 mg. Percent ventricular compact mass (% compact) was determined using dry compact (M_{CD}) and dry spongy masses (M_{SD}): % compact = $100M_{CD} (M_{CD} + M_{SD})^{-1}$. Total dry ventricular mass ($M_{VD} = M_{CD} + M_{SD}$) was used to determine relative dry ventricular mass (RDVM): RDVM = $100M_{VD} M^{-1}$. Since compact myocardium can vary independent of ventricular mass (i.e. a large ventricle with lower % compact could have the same total compact myocardium as a smaller ventricle with higher % compact), the total compact myocardium was expressed as the relative dry compact mass (RDCM): RDCM = $100M_{CD} M^{-1}$.

To simplify comparisons of our data with the more commonly presented wet ventricular mass (M_{VW}), M_{VW} was measured in a subset of fish (n = 35 from 2 populations, Chilko and Weaver). Immediately after death, the ventricle was blotted dry and weighed to 0.1 g prior to storage in 70% ethanol. Relative wet ventricular mass (RVM) was determined: RVM = $100M_{VW} M^{-1}$. Dry ventricular mass (M_{VD}) was determined to be 14.7 ± 0.3% of M_{VW} (no significant differences existed between Weaver and Chilko fish, data not shown), which corresponds to previous studies on salmonids (12-14%, Simonot and Farrell, 2007). Therefore, we extrapolated from M_{VD} to M_{VW} (using a correction factor of 14.7%) for all populations.

2.9 β-Adrenoceptor Experiment

Chilko and Nechako sockeye salmon were collected from the lower Fraser River on August 11 and 12, 2009 and brought to CLL. The fish were placed in 1,400 l circular aquaria at 13°C and the temperature was either maintained at 13°C or increased to 19 or 21°C over 24 h. After four days at the test temperature, the fish were euthanized by a cranial blow and the ventricle was quickly removed, weighed and freeze-clamped in liquid nitrogen. The hearts were stored at -80°C until analysis. Gross body morphology was measured in each fish (body mass, fork length, gonad mass, condition factor). Condition factor = (body mass/length^3) × 100.

Male rainbow trout acclimated to 6°C freshwater at CAER were included as a reference group to validate the assay technique.

Ventricular cell-surface β_2-adrenoceptor density (B_{max}) and binding affinity (K_d) were determined using the tritiated ligand technique [Watson-Wright et al. (1989) as modified for fish hearts (Gamperl et al., 1994; Hanson et al., 2005)]. The frozen ventricles were rinsed in saline to remove any remaining blood and sliced (350 um thickness) using a McIlwain tissue chopper (Brinkman, Rexdale, ON, Canada). Ventricular tissue punches (2 mm diameter) were taken from both the spongy and compact myocardium. Single punches were incubated with various concentrations (0.05 – 3.5 nM) of the hydrophilic β_2-adrenoceptor ligand [^{3}H] CGP-12177 (Amersham Life Science). Separate punches were incubated at each concentration with the competitive β_2-adrenoceptor antagonist timolol (10 μM) to determine non-specific binding.

2.10 Statistics

All data are presented as mean ± SEM, unless otherwise indicated. P-values less than 0.05 were considered statistically significant.

2.10.1 Swimming Experiments in Chapters 3, 4 & 5

All data in Chapters 3 and 4 were compared between sexes and among populations. If there were no statistically significant relationships with sex or population, the data were often pooled for subsequent analysis. All data in Chapter 5 were compared among temperature groups (populations were pooled and sex was not considered).

Independent data were compared using a t-test, one-way ANOVA or two-way ANOVA, as appropriate. Dependent data were compared using a paired t-test, one-way repeated measures ANOVA or a two-way repeated measures ANOVA, as appropriate. When the requirement for normal distribution and equal variance could not be met after transformation, the data were compared using the appropriate nonparametric test (e.g. Mann-Whitney U test, Kolmogorov-Smirnov test, Kruskal-Wallis test). A post-hoc Holm-Sidak or Dunn's test was used to test for differences among groups.

A Pearson correlation was used to compare aerobic scope with the migration difficulty indices. Three different critical p-values are reported. First, $p < 0.05$ is indicated, with no correction for multiple comparisons. Second, $p < 0.018$ is indicated, which is the critical level using the Benjamini and Yekutieli False Discover Rate correction for multiple comparisons (Benjamini and Yekutieli, 2001; Narum, 2006). Finally, $p < 0.006$ is indicated, which is the critical level using Bonferroni correction for multiple comparisons (Holm, 1979; Rice, 1989).

Linear regression was used to relate maximum aerobic scope with distance to the spawning ground. Linear regression was also used to relate aerobic scope, cardiac scope and scope for heart rate from individual fish.

The goodness of fit of the population-specific aerobic scope curves to the full suite of historic temperature frequency distributions were assessed using AIC (Akaike's Information Criterion, Burnham and Anderson, 2002). In addition, rigorous sensitivity analyses was conducted to test the robustness of the results from the initial AIC analysis (data not shown). For example, the response and predictor variables were reversed in the regression and fit aerobic scope curves to population-specific temperature distributions. Second, the temperatures used to generate the scope data for the linear regression were restricted to match the minimum and maximum temperatures used to fit the population-specific aerobic scope curves. This reduced the uncertainty introduced from extrapolating scope values beyond the ranges of the observed data. Next, the uncertainty in scope was further reduced by re-fitting the linear regressions using observed values for each population, removing any assumptions about the true shape of the aerobic scope curve. The regression was also fit using raw temperature frequencies, as opposed to logged values. Finally, alternate modelling approaches were attempted, including a comparison of the scope and temperature distributions using single critical values (e.g. regression between T_{opt} and the median of the temperature distribution across all stocks; regression between upper T_p and the 90th percentile of the temperature distribution). While each approach yielded subtly different results, they all demonstrated that aerobic scope is significantly related to the average thermal migratory experience encountered by each population. Notably, the upriver populations encounter very similar average temperatures, which increases the likelihood that the temperature distribution for a given population matches the aerobic scope curve for another co-migrating population. Indeed, all the upriver populations had a similar temperature median (range 16.4-17.6°C) and mode (range 16.8-17.3°C).

2.10.2 Ventricular Morphology in Chapter 6

To examine whether traveling through hydraulically challenging sections of the river (e.g. Hells Gate) imposes strong selection pressure, the cardiac morphology variables were first compared between upriver and coastal populations using a t-test. Comparisons of cardiac variables in female sockeye salmon among seven populations were analyzed using one-way ANOVA. A Pearson correlation matrix was used to relate the various migration difficulty indices to the three cardiac variables in female sockeye from the seven populations, and three critical p-values are reported, as outline above. Linear regression was used to test for relationships between the cardiac variables and the various measures of migration difficulty and with fail temperature during the swimming experiment performed by Steinhausen et al. (2008). The effect of temperature on the cardiac variables in Chilko sockeye salmon was assessed using a two-way ANOVA (sex × temperature). When appropriate, a Holm-Sidak post-hoc test was used to distinguish between groups.

2.10.3 β-Adrenoceptor Experiment in Chapter 7

Two-way ANOVA was used to test for differences in gross morphology, B_{max} and K_d between populations and temperature treatments.

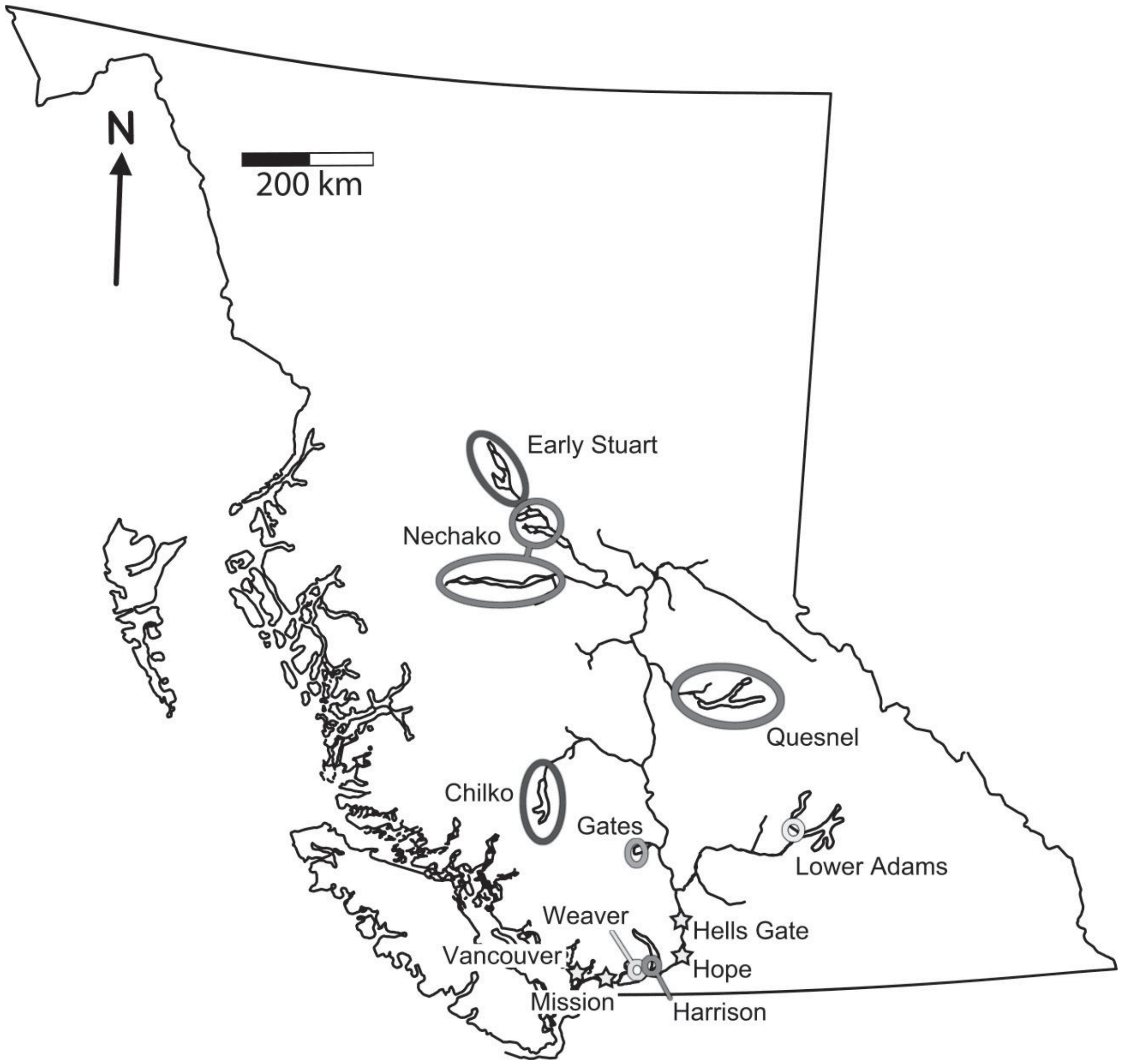

Figure 2.1. Map of the Fraser River, British Columbia, Canada indicating the spawning locations for the eight sockeye salmon populations included in this study.

Table 2.1. Environmental characteristics and migration difficulty indices for eight populations of Fraser River sockeye salmon. Mean ± SEM are presented for T_M, F_M and ATU. Minimum and maximum values for migration rate and migration duration are in parentheses. For late run sockeye salmon populations (Lower Adams, Weaver and Harrison), environmental data corresponding to the current early entry phenomenon are shown in parentheses underneath the historical river entry timing information.

	Early Stuart	**Gates**	**Nechako**	**Quesnel**	**Chilko**	**Lower Adams**	**Weaver**	**Harrison**
Spawning region	upriver	upriver	upriver	upriver	upriver	upriver	coastal	coastal
Run timing group	Early Stuart	Early Summer	Summer	Summer	Summer	Late	Late	Late
Peak Fraser River entry	Jul-07	Jul-31	Aug-11	Aug-11	Aug-11	Sep-27 (Aug-27)	Sep-27 (Aug-27)	Sep-27 (Aug-27)
Peak Hells Gate passage	Jul-14	Aug-07	Aug-17	Aug-17	Aug-17	Oct-04 (Sep-3)	n/a	n/a
Peak spawning ground arrival	Aug-06	Sep-02	Sep-30	Sep-15	Sep-25	Oct-16	Oct-21	Nov-14
Lower Fraser temperature (T_M) (°C)	15.8 ± 1.3	17.7 ± 1.1	17.3 ± 1.0	17.3 ± 1.0	17.3 ± 1.0	11.4 ± 1.4 (16.5 ± 0.8)	12.3 ± 1.2 (17.0 ± 0.8)	12.3 ± 1.2 (17.0 ± 0.8)
Lower Fraser discharge (F_M) (m^3 s^{-1})	5686 ± 1331	3860 ± 893	3419 ± 780	3419 ± 780	3419 ± 780	2040 ± 580 (2582 ± 537)	2093 ± 577 (2754 ± 578)	2093 ± 577 (2754 ± 578)
Migration temperature median (°C)	16.4	17.6	16.2	16.6	16.6	14.2 (16.9)	14.9 (17.4)	14.8 (17.4)
Migration temperature mode (°C)	17.3	17.3	16.8	16.8	17.3	15.3 (17.8)	15.3 (17.3)	15.3 (17.3)
Accumulated thermal units (ATU) (°C)	502 ± 36	177 ± 11	492 ± 27	341 ± 15	325 ± 16	281 ± 27 (326 ± 29)	87 ± 11 (104 ± 7)	103 ± 11 (121 ± 9)
Migration distance (D_M) (km)	1071	364	958	796	642	480	117	121
Migration elevation (E_M) (m)	690	280	716	728	1174	346	32	10
Migration duration (d)	30 (23-42)	11 (8-17)	28 (17-43)	21 (15-31)	19 (14-28)	20 (13-47)	5 (3-10)	7 (4-14)
Migration rate (km d^{-1})	36 (26-46)	35 (21-48)	34 (22-57)	39 (26-51)	34 (23-45)	24 (10-37)	22 (11-44)	18 (9-27)
Work ($0.001 \cdot E_M \cdot D_M$)	739	102	686	579	754	166	4	1
River slope ($500(E_M D_M^{-1})$)	322	385	374	457	914	360	137	41
Migratory effort ($0.0001 \cdot F_M \cdot D_M$)	609	141	328	272	219	98	24	25

CHAPTER 3: DIFFERENCES IN THERMAL TOLERANCE AND MAXIMUM CARDIORESPIRATORY PERFORMANCE AMONG SOCKEYE SALMON POPULATIONS

3.1 Introduction

The Fraser River is home to over 100 genetically and geographically distinct populations of sockeye salmon (Beacham et al., 2005), each of which encounters different upriver migration conditions. For example, populations vary in migration distance (100 to 1100 km), elevation gain (10 to 1200 m), river temperature (9° to 22°C), and river flow (2000 to 10,000 m^3 s^{-1}) (see Chapter 2, Fig 2.1, Table 2.1). The upriver spawning migration is critical for reproductive success since sockeye salmon are semelparous (only spawn once). Consequently, local migratory conditions are expected to exert strong selection pressure. Indeed, morphological and behavioural characteristics (gross somatic energy, body morphology, egg number and swimming behaviour) have been correlated with river migration distance, elevation and/or work (distance × elevation) in Fraser River sockeye salmon populations (Crossin et al., 2004; Gilhousen, 1980; Hinch and Rand, 2000).

The energetic upriver migration is sustained by the cardiorespiratory system, which provides oxygen to the swimming muscles among other valuable functions. Cardiorespiratory performance can be quantified by measuring aerobic scope, which is defined as the difference between maximum oxygen consumption ($\dot{M}O_{2max}$) and resting oxygen consumption ($\dot{M}O_{2rest}$) (Fry, 1947). Aerobic scope represents the maximum amount of oxygen available for any activity beyond routine maintenance, activities such as swimming, reproduction and growth.

Aerobic scope has a strong temperature dependence (Fry, 1947). $\dot{M}O_{2rest}$ typically increases exponentially with temperature until lethal levels are approached, as expected for a temperature effect on a rate function. $\dot{M}O_{2max}$ similarly increases with increasing temperature but reaches a maximum, which may be a plateau. Then $\dot{M}O_{2max}$ sharply declines as temperature increases toward lethal levels. The temperature at which aerobic scope is maximal is termed the optimal temperature (T_{opt}), which in salmonids corresponds to maximal swimming and cardiac performance (Brett, 1971; Lee et al., 2003c; Taylor et al., 1997). The temperatures at which aerobic scope starts to decline from the maximum are termed the pejus temperatures (T_p), which has a lower and upper value. At critical temperatures (T_{crit}), $\dot{M}O_{2rest}$ and $\dot{M}O_{2max}$ intersect and aerobic scope becomes zero. Beyond T_{crit}, there is insufficient oxygen to support the routine needs of the fish and survival becomes passive, time-limited and supported by anaerobic metabolism (Pörtner, 2001; Pörtner and Farrell, 2008).

The central hypothesis of my thesis is that each population has physiologically adapted through natural selection to meet their specific migration challenges. Specifically, I hypothesized that populations with more challenging migrations have greater aerobic, cardiac and heart rate scopes. I predicted that migration distance, elevation gain and work would exert the strongest selection pressure on aerobic scope, given their importance in selecting for morphological traits (Crossin et al., 2004), which has never been tested before. In addition, I hypothesized that each population can maintain maximum scope across the entire range of temperatures most frequently encountered during upriver migration, as has been previously demonstrated for two populations of sockeye salmon (Farrell et al., 2008; Lee et al., 2003c).

Wild, migrating adult sockeye salmon were intercepted in the lower Fraser River, when the fish had only been migrating upstream for 1-3 days and prior to encountering any of the major selective elements. Individual sockeye salmon were then instrumented to measure cardiovascular variables [cardiac output ($\dot{Q}$), heart rate (f_H), stroke volume (V_s)] and swum at a single temperature (ranging from 8-26°C) in a Brett-type swim tunnel. Detailed materials and methods are found in Chapter 2 (sections 2.2-2.7 & 2.10).

3.2 Results

3.2.1 Gross Morphology and Reproductive Status

Gross body morphology (body mass, fork, standard, POH, and POF lengths, GSI, HSI, SSI) did not differ significantly among the five populations (Table 3.1), although significant differences did exist between sexes. When all populations were pooled, male fish had a significantly greater body mass, fork length, standard length and SSI. Female fish had significantly higher GSI and HSI. None of the swum fish were fully sexually mature (no loose eggs or milt production) but they had begun their sexual maturation process (body colour was starting to turn red, gonads were developing). In addition, plasma cortisol, 17β-estradiol and testosterone did not significantly differ between the two populations tested (Chilko and Early Stuart). Plasma cortisol and 17β-estradiol were significantly higher in females compared to males (cortisol: 619 ± 87 and 380 ± 34 ng ml^{-1}; 17β-estradiol: 0.88 ± 0.18 and 0.07 ± 0.01 ng ml^{-1}, respectively). Plasma testosterone did not significantly differ between sexes (overall mean ± SEM: 2.84 ± 0.52 ng ml^{-1}).

Gross energy density did not significantly differ among populations or between sexes (mean ± SEM: 8.0 ± 0.2 MJ kg^{-1}, range: 5.6-11.3 MJ kg^{-1}).

3.2.2 *Cardiorespiratory Performance at T_{opt}*

For measurements made at T_{opt}, there were no significant differences in $\dot{M}O_{2rest}$, $\dot{M}O_{2max}$ or aerobic scope between Early Stuart sockeye salmon that had undergone surgery and swam with the added drag of leads and those that had no surgery and had no additional drag during swimming (Table 3.2). Sockeye salmon with leads had a significantly higher $\dot{M}O_2$ after the 45-min recovery period between the first and second swim, but not after the 45-min or 2-h recovery periods following the second swim. Sockeye salmon swum without leads had an 18-23% significantly higher U_{crit} compared to those with leads. Notably, both instrumented and un-instrumented fish repeated their swim performance (no significant differences existed between U_{crit} 1 and U_{crit} 2 within a group). Given these comparable results, fish swum without leads were included in the estimates of $\dot{M}O_{2rest}$, $\dot{M}O_{2max}$ and aerobic scope presented below. Also, this lack of effect of leads meant that my population-specific $\dot{M}O_2$ data could reliably be compared with previous literature on fish swum without instrumentation (e.g. Lee et al., 2003c).

No significant differences existed between male and female sockeye salmon for any of the cardiorespiratory variables measured at T_{opt} (resting, maximum or scope for $\dot{M}O_2$, $\dot{Q}$, f_H and V_s, p>0.05); therefore, data for males and females were pooled within a population to increase statistical power (Table 3.3).

Gates sockeye salmon had a significantly higher $\dot{M}O_{2rest}$ compared to Early Stuart, Nechako, Quesnel, Chilko and Weaver sockeye salmon at their respective T_{opt}. Weaver sockeye salmon had a significantly lower $\dot{M}O_{2max}$ compared to Early Stuart, Nechako, Chilko and Gates sockeye salmon (Table 3.3).

Aerobic scope varied by 69% across populations. Aerobic scope was significantly highest in Early Stuart and Nechako, intermediate in Lower Adams and lowest in Weaver fish. A Pearson correlation matrix revealed that several of the migration difficulty indices correlated significantly with aerobic scope (migration distance, work, duration, rate, ATU; Table 3.4). Among these, aerobic scope had the strongest relationship with migration distance to the spawning ground (Fig 3.1, Table 3.4).

$\dot{Q}$ and f_H did not differ significantly among populations (Table 3.3). Nechako had a significantly higher scope for V_s compared to Early Stuart, Chilko and Lower Adams fish, though V_{srest} and V_{smax} did not significantly differ.

3.2.3 Influence of Temperature on Cardiorespiratory Performance

Resting, Maximum and Scope

$\dot{M}O_{2rest}$ increased exponentially with increasing temperature in each population (Q_{10} ranged from 2.2 to 2.9 across populations, Fig 3.2A). $\dot{M}O_{2max}$ also increased with increasing temperature up to its maximum at T_{opt}, and then declined thereafter. As a result, aerobic scope displayed a clear peak for each population (Fig 3.2B).

$\dot{Q}$ measured in resting and exercising fish showed similar patterns to $\dot{M}O_{2rest}$ and $\dot{M}O_{2max}$ with the result that cardiac scope showed a discernible peak (only Chilko data shown, Fig 3.3A, D).

As expected, f_{Hrest} also increased exponentially with rising temperatures ($Q_{10} = 2.0$) while f_{Hmax} reached a plateau well below T_{crit} (Fig 3.3B). f_{Hrest} and f_{Hmax} intersected at high temperatures above T_{opt}. Remarkably, f_{Hmax} decreased below the resting value at the highest temperatures, with the result that scope for f_H became negative at the highest test temperatures (Fig 3.3E). Aerobic scope, cardiac scope and scope for f_H were all positively correlated (Fig 3.4).

In contrast, temperature had no effect on V_{srest} (Fig 3.3C). Furthermore, V_{smax} declined with increasing temperature leading to a decrease in scope for V_s at the highest temperatures (Fig 3.3C, F).

Associations between Aerobic Scope and Historic River Temperatures

The coastal Weaver population experiences the coldest temperatures during upriver migration and had the lowest T_{opt} (14.5°C). Upriver populations experience similar river temperatures during migration and accordingly had a similar T_{opt} (range 16.4-17.2°C, Fig 3.5 and Table 3.5). Notably, Weaver sockeye salmon are currently entering the Fraser River much earlier than normal, which exposes them to considerably warmer temperatures compared with their T_{opt} (see the right-shift for the current Weaver temperature histogram, Fig 3.5).

The width of the T_{opt} window (difference between the upper and lower T_p values) ranged from 4-8°C among populations (Table 3.5). Among the upriver populations (Early Stuart, Nechako, Quesnel, Chilko, Gates), the Chilko population displayed the broadest optimal thermal range (Fig 3.5, Table 3.5). For all upriver populations, between 89-98% of maximum aerobic scope consistently fell within the 90th percentile of historic river temperatures encountered by each population (T90%). In contrast, the Weaver population retained only 81% of maximum aerobic scope for their historical T90% and an alarmingly low 45% for the current T90% (Fig 3.5, Table 3.5).

The maximum river temperature (21.5°C) exceeded the upper T_p of every population examined (Fig 3.6). Extrapolation of the aerobic scope curves to T_{crit} resulted in T_{crit} values that varied between 21 and 29°C among populations (Fig 3.6, Table 3.5).

Aerobic scope curves for each population were significantly related to the historic temperature frequencies they typically experience (Fig 3.5, Table 3.6). While all regressions were significant, the AIC weights indicate that there was typically strong support for a single aerobic scope-temperature frequency relationship. In general, the Early Stuart temperature distribution was the best fit for the aerobic scope data for upriver populations; the Gates and current Weaver temperature distributions provided the poorest fit to upriver populations. The historic Weaver temperature distribution was the best fit for aerobic scope of Weaver sockeye salmon.

3.3 Discussion

This study demonstrates that Fraser River sockeye salmon populations differ in their cardiorespiratory performance and suggests that sockeye salmon populations have physiologically adapted to meet the specific challenges of their local upriver migration conditions. This study greatly extends a previous study which suggested that T_{opt} for aerobic scope varied between two sockeye salmon populations (Lee et al., 2003c) by considering aerobic scope of five additional populations. A novel and strong relationship was found between maximum aerobic scope and the river migration distance to the spawning ground. Populations that travel the furthest had the highest aerobic scope, while those traveling short distances had the lowest aerobic scope. In addition, every population examined could maintain maximum aerobic, cardiac and heart rate scopes across the entire range of temperatures typically encountered during their migration, although it was clear that the current unusual migratory behaviour of Weaver sockeye salmon exposes them to temperatures well beyond optimal.

3.3.1 Comparing Instrumented and Un-Instrumented Fish

In order to measure cardiorespiratory performance, fish underwent surgery and dragged leads while swimming. Nevertheless, $\dot{M}O_{2rest}$, $\dot{M}O_{2max}$ and aerobic scope were the same for instrumented and uninstrumented Early Stuart sockeye salmon, despite the observation that fish swum without leads achieved higher swim speeds compared to those swum with leads. Indeed, values for $\dot{M}O_{2rest}$, $\dot{M}O_{2max}$ and aerobic scope (means: 3.0, 14.6 and 11.8 mg O_2 min^{-1} kg^{-1}, respectively) are within the previously observed ranges for Early Stuart sockeye salmon (ranges: 2-6, 11-19 and 9-14 mg O_2 min^{-1} kg^{-1}, respectively, (Lee et al., 2003c; MacNutt et al., 2006). Also, U_{crit} values for uninstrumented Early Stuart sockeye salmon in the current study (mean maximum $U_{crit} = 2.44 \pm 0.13$ bl s^{-1}) compare favourably with two previous studies examining this same population (2.26 – 2.36 bl s^{-1}, Lee et al., 2003c; MacNutt et al., 2006). Both instrumented and un-instrumented groups had excellent repeat swim performance (U_{crit} 1 $\cong$ U_{crit} 2).

These findings suggest that while the leads did have a substantial drag effect, limiting U_{crit} by ~20%, oxygen delivery was not significantly effected (i.e. the increased drag resulted in the same swimming effort for a lower U_{crit}). Collectively, these results suggest that the data in the current study are consistent with previously published data. Furthermore, I could pool instrumented and uninstrumented fish for the analysis of aerobic scope and I was confident in using published aerobic scope data for sockeye salmon swum without instrumentation (e.g. Weaver and Gates populations from Lee et al., 2003c) in my population comparisons.

3.3.2 Baseline Morphology and Reproductive Status

The minimum somatic energy density threshold to sustain life for sockeye salmon has been estimated to be 3.5-4.0 MJ kg^{-1}, and the energy required to reach the spawning grounds is estimated to be between 1.5-2.4 MJ kg^{-1}, depending on the migration distance (Clark et al., 2009; Gilhousen, 1980; Hendry and Berg, 1999; Williams et al., 1986). Given that somatic energy ranged from 6-11 MJ kg^{-1}, every fish in the present study likely had sufficient energy to complete its migration and the energetic challenge of the swim test was small by comparison.

Sex-specific differences in mass, length, GSI, and SSI are all consistent with previously published reports (Clark et al., 2010; Gilhousen, 1980; Idler and Clemens, 1959; Patterson et al., 2004; Sandblom et al., 2009). In contrast to previous findings, body size and morphology did not differ among populations (Crossin et al., 2004). However, morphology was only compared across upriver populations and some populations had low sample sizes within a sex (e.g. Lower Adams) which may have limited statistical power. I would expect to find significant differences in body morphology if coastal Weaver sockeye salmon were included in the analysis (e.g. see Crossin et al., 2004, Lee et al., 2003c).

As expected for fish that were collected early in their river migration and several weeks before spawning, sexual maturation was in progress and incomplete. GSI ranged from 0.7-3.1% in males and 4.0-13.4% in females. Given that GSI reaches ~4 and 17% in fully mature males and females, respectively, (Gilhousen, 1980), the fish in the present study were still maturing. In fact, both 17β-estradiol and testosterone levels were very low relative to values reported in the literature on migrating adult sockeye salmon (Cooperman et al., 2010; Crossin et al., 2008; Hruska et al., 2007; Sandblom et al., 2009; Young et al., 2006). Sex hormones were significantly depressed in association with increased cortisol levels in Early Stuart sockeye salmon navigating through Hells Gate (Hinch et al., 2006). The stress of sequential swim tests performed here may have had the same effect.

Plasma cortisol levels (range: 79-837 ng ml^{-1}) were within the range of published values for adult sockeye salmon (e.g. ~50-800 ng ml^{-1}; Cooke et al., 2006; Cooperman et al., 2010; Sandblom et al., 2009; Young et al., 2006). The present values were likely elevated in part because the final blood sample was taken after the swimming experiment and after extensive handling to remove the fish from the swim tunnel. Even so, it has long been established that salmon normally have very high plasma cortisol levels during this final phase of life (e.g. Hane and Robertson, 1959). Chronically high cortisol levels in migrating salmonids have been hypothesized to be either a consequence of stress during the migration, or due to endogenous mechanisms associated with reproductive maturation, or possibly due to enhance home-stream olfactory memory (Carruth et al., 2002; Kubokawa et al., 1999; Sandblom et al., 2009). Consistent with the literature, females had significantly higher cortisol levels compared to males, which is a phenomenon reported for the entire upriver migration (Carruth et al., 2002; Crossin et al., 2008; Kubokawa et al., 1999; Sandblom et al., 2009; Schmidt and Idler, 1962).

3.3.3 Maximum Cardiorespiratory Performance Among Populations

Aerobic scope at T_{opt} varied considerably (by 69%) across sockeye salmon populations (range: 7.7-13.0 mg O_2 kg^{-1} min^{-1}) and by 3.6 fold among individuals (range: 4.3-15.4 mg O_2 kg^{-1} min^{-1}). Given that the cardiorespiratory system sustains swimming during the upriver migration, I hypothesised that aerobic scope would relate to the migratory environment. The substantial intraspecific variability in aerobic scope and 10-fold variation in migration difficulty across the seven populations examined allowed me to test this hypothesis. Coastal populations only travel ~100 km in cooling fall river temperatures, with little change in river elevation to reach their spawning grounds. In contrast, upriver populations must navigate the difficult passages through the Fraser Canyon, including the notorious Hells Gate, often in mid-summer when river temperatures peak. Some upriver populations must travel over 1000 km to reach their spawning grounds while Chilko sockeye salmon ascend ~1200 m in elevation. Because of this high degree of variability, migration difficulty was quantified using various environmental indicies (see Chapter 2): distance, elevation gain, temperature, migration rate, migration duration, work, river slope and migration effort. Elevation does not appear to have exerted a strong selective pressure since neither elevation gain nor river slope had a significant relationship with aerobic scope. However, aerobic scope was significantly related to numerous indices, including work, migration duration, migration rate and accumulated thermal units, with migration distance emerging as the best predictor. These results suggest population level adaptation of maximum aerobic scope to the selection imposed by certain river conditions encountered during migration (see discussion below, Endler, 1986; Schluter, 2000; Taylor, 1991).

This was the first study to compare cardiovascular variables across populations of sockeye salmon. In contrast to the findings for aerobic scope, neither maximum cardiac scope nor maximum scope for f_H varied among the five populations examined. However, I only examined cardiorespiratory performance in upriver populations that travel through Hells Gate. Due to logistical constraints, cardiorespiratory performance was not measured in the population with the lowest aerobic scope (Weaver). Given the findings for aerobic scope and the good correlation between aerobic and cardiac scope, I would expect coastal populations to exhibit lower cardiac performance compared to upriver populations, a subject that should be considered for future studies. Scope for V_s was significantly higher in Nechako sockeye salmon compared to the Early Stuart, Chilko and Lower Adams populations. This demonstrates that the mechanism of achieving the same $\dot{Q}$ differs among populations, a finding that is explored further in Chapter 4.

3.3.4 Cardiorespiratory Performance with Temperature

Aerobic scope, cardiac scope and scope for heart rate were all postively correlated and varied in parallel with temperature, suggesting that the temperature dependence of cardiac performance is linked to that of aerobic capacity at the population level. The optimal water temperature for cardiorespiratory performance matched the typical water temperatures historically encountered by each population. The upriver populations all experience a similar range, mean and mode for river temperature, and accordingly demonstrated a similar T_{opt}. In contrast, the coastal Weaver population historically experience colder temperatures and had a corresponding colder T_{opt}. All six populations had 81-98% of maximum aerobic scope at the upper 90th percentile of encountered temperatures, clearly demonstrating that each population could theoretically maintain swimming performance across the majority of river temperatures that they currently encounter. These findings support earlier work demonstrating that aerobic scope matched historic temperatures for two sockeye salmon populations (Gates and Weaver, Farrell et al., 2008; Lee et al., 2003b). Therefore, the present study adds considerably more weight to the idea of intraspecific variability for aerobic scope among Fraser River sockeye populations. This then opens up the possibility that other salmon populations with similar reproductive isolation may also demonstrate local adaptations.

While the overall temperature range may be similar among upriver populations, the timing of river entry and spawning location can create more subtle differences. For example, Early Stuart sockeye salmon, which have a very long river migration, encounter moderate temperatures and the fastest river flow early in their migration, but temperatures escalate (up to ~21.5°C) during the final stages of their migration when they are close to their spawning grounds (Macdonald et al., 2007). Chilko sockeye salmon experience the opposite temperature pattern. They encounter peak summer temperatures (again up to ~21.5°C) early in their migration while traveling through Hells Gate, but the final third of their migration is spent ascending the hydraulically challenging, but up to 10°C cooler, Chilcotin river to reach spawning grounds in or adjacent to a glacier lake. The effect of temporal differences in temperature exposure on salmon physiology and selection pressure is poorly understood. Regardless, the present data suggests that Chilko sockeye salmon possess the broadest and highest thermal tolerance for aerobic scope of all the populations examined due to adaptations to the difficult migration conditions at both warm (Hells Gate) and cold (Chilcotin river) temperatures.

The mechanism of the decline in aerobic scope above T_{opt} will be examined in detail in Chapter 5. Suffice it to say here that scope for f_H collapsed at a lower temperature than aerobic scope in two populations, suggesting that the reduced scope for f_H above T_{opt} may limit $\dot{Q}_{max}$ and the capacity of the cardiorespiratory system to transport oxygen. This result corroborates earlier work (Steinhausen et al., 2008).

3.3.5 Perspectives and Significance

Collectively, these results suggest that populations have locally adapted to their specific upriver migration environment. Considering that the upriver migration only lasts a few weeks, representing a mere ~2% of a sockeye salmon's lifespan, this finding is remarkable. However, given the semelparous life history of sockeye salmon, successful upriver migration is essential in order to achieve reproductive success and thus is likely under strong selection pressure. In order for local adaptation to occur, three conditions must be met: 1) the trait must have a genetic basis, 2) variability in trait expression must result in differential survival or reproductive capability, and 3) a functional link between variability in the trait and variability in survival or reproductive success. The correlations presented here provide circumstantial, but promising, evidence for local adaption (Endler, 1986; Schluter, 2000; Taylor, 1991). Conclusive evidence for local adaptation would require breeding studies to generate an F1 and F2 generation, which would demand 4 and 8 years, respectively, a timeframe well beyond the scope of my thesis. Given the present results, such experiments would be worthwhile.

It is highly unlikely that the intraspecific differences observed in the present study were due to a plastic response to encountered river conditions prior to capture and experimentation. The fish were collected only 1-3 days into their upriver migration, after spending more than two years in the much cooler Pacific Ocean and prior to encountering any of the upriver migratory challenges. In addition, it is highly unlikely that conditions prior to ocean entry (during rearing and downstream smolt migration) caused differential expression of the physiological characteristics that distinguished the adult populations. Foremost, downstream migration occurs at a cooler spring temperature (<12°C), goes with rather than against the current, and reduces in vertical elevation. Therefore, adults have never before experienced nor will they ever experience again the warm river migration conditions that they must overcome to successfully reproduce. As a result, the physiological traits that enabled a successful upriver migration are passed on to the offspring and their genetic basis is conserved by the strong reproductive fidelity of sockeye salmon to their natal spawning area (Burgner, 1991), which are geographically isolated. Thus, I conclude that the population-specific differences observed in the present study were most likely due to genetic adaptation, rather than phenotypic plasticity.

Peak summer temperature in the Fraser River has warmed by ~2°C since the 1950s and is expected to continue along the same trajectory (Ferrari et al., 2007; Morrison et al., 2002). The present study supports the hypothesis that further increases in summer river temperatures will result in population-specific responses in sockeye salmon (Farrell et al., 2008). Populations markedly differ in T_{crit} (when aerobic scope is zero), however, the highly aerobic, long upriver migration is clearly impossible at T_{crit}. Thus, T_{crit} is an unreliable management tool, particularly since it also suffers from the inaccuracy of extrapolating from a polynomial curve. It is unknown exactly how much of aerobic scope is required for successful upriver migration. A biotelelmetry study with Weaver sockeye salmon suggests that at least 50% of maximum aerobic scope was needed for their short, low elevation upriver migration [<10% of fish reached their spawning area at 18 to 21°C when aerobic scope is 0 to 68% of maximal (Farrell et al., 2008; Mathes et al., 2010)]. However, for upriver populations experiencing greater migration difficulty, perhaps up to

90% of maximum aerobic scope is needed. This suggestion is based on the observation that all the upriver populations retained 89-97% of maximum aerobic scope at T90%. Future research should incorporate biotelemetry and biologging techniques in the field with lab-derived cardiorespiratory data to determine the population-specific functional aerobic scope requirements.

Temperatures exceeding the population-specific upper T_p must at some point limit upriver swimming due to a functional collapse in aerobic scope. The T_{opt} window is rather narrow across populations (4-8°C). Thus, only 2-4°C separates T_{opt} from the upper T_p, leaving sockeye salmon with a narrow safety margin for temperature change. In fact, the current temperature maximum (21.5°C) already exceeds the upper T_p (set at 90% of aerobic scope) for every population in the current study. As a result, populations are already experiencing temperatures at their upper limit, and given the individual variability in aerobic scope, some individuals may be dying en route because they cannot reach the spawning ground due to insufficient aerobic scope. Given the present data, it is not surprising that no sockeye salmon population has initiated river migration at temperatures exceeding 21°C (Hyatt et al., 2003), nor has a historic mean migration temperature been above 19°C (Hodgson and Quinn, 2002). Nechako and Weaver populations appear especially susceptible to high temperature, which could prove catastrophic under the continued warming scenario. In particular, Weaver sockeye salmon could be considered "dead fish swimming" if they continue to enter the Fraser River up to six weeks earlier than normal, exposing themselves to temperatures higher than their historic norm and suffering high mortality (Cooke et al., 2004; Farrell et al., 2008; Mathes et al., 2010). In contrast, Chilko sockeye salmon appear to be "superfish", and may have greater resilience to climate change by being able to maintain cardiorespiratory performance at a higher temperature compared with the other populations studied so far. A potential mechanism for Chilko sockeye salmon's exceptionally high and broad thermal tolerance relative to the co-migrating Nechako population is explored in Chapter 6.

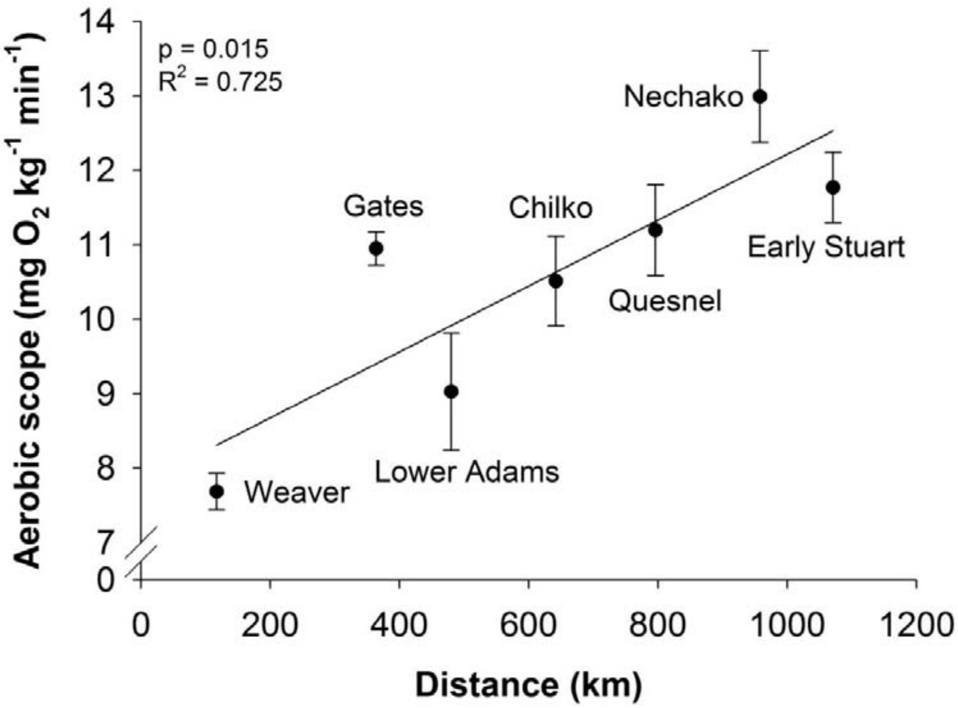

Figure 3.1. Linear regression between migration distance to the spawning ground and population-specific maximum aerobic scope measured at T_{opt}. Means ± SEM are presented.

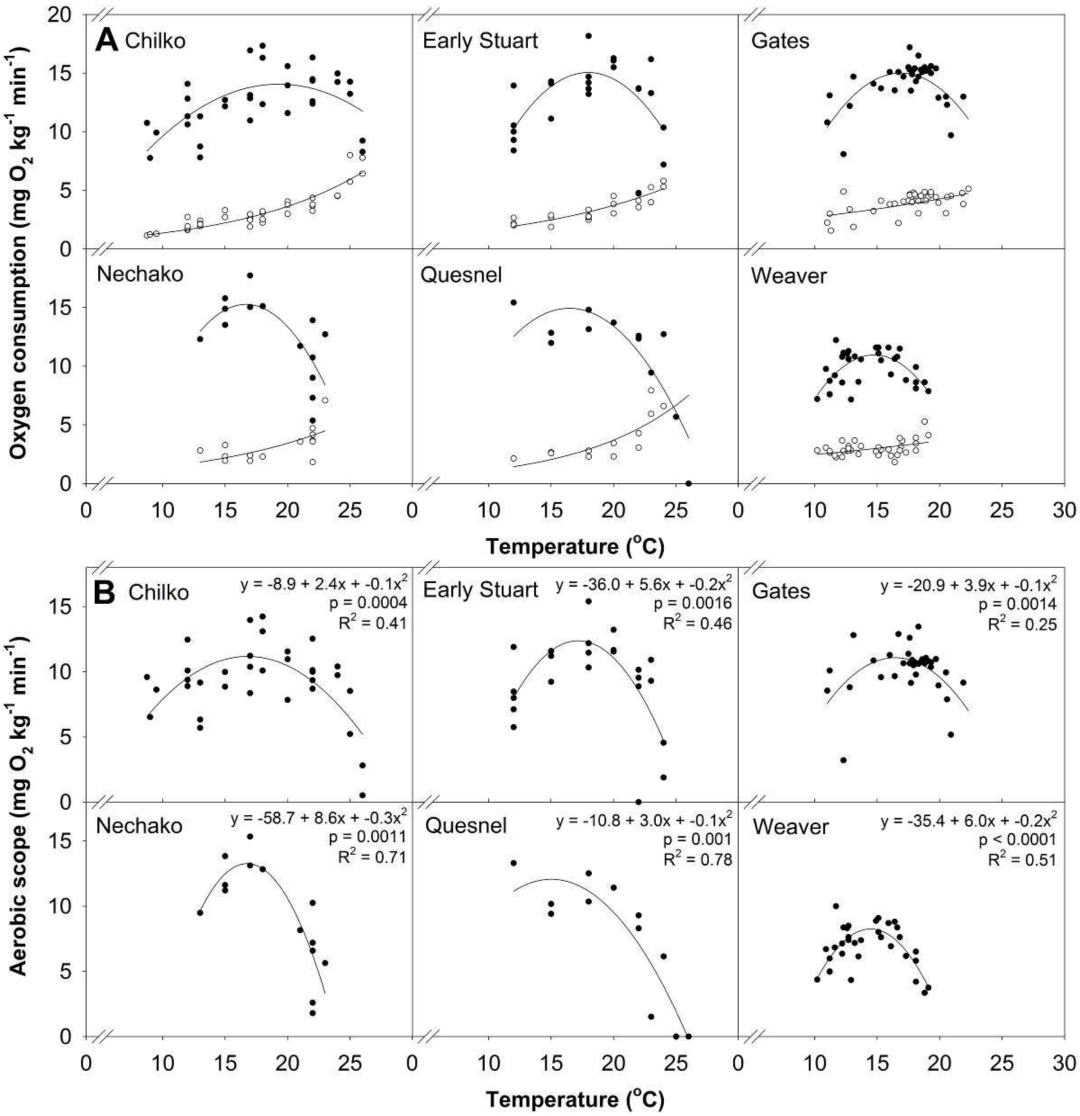

Figure 3.2. (A) Population-specific estimates of resting (open circles) and maximum (closed circles) oxygen consumption rates in relation to water temperature for sockeye salmon. Each point corresponds to a single fish. (B) Population-specific estimates of aerobic scope, the difference between the maximum and resting oxygen consumption data presented in panel A. An exponential equation was fit to the minimum oxygen consumption rate and a polynomial quadratic equation was fit to the maximum oxygen consumption rate and aerobic scope data sets for each population. Data for Gates and Weaver provided by Lee et al. (2003c).

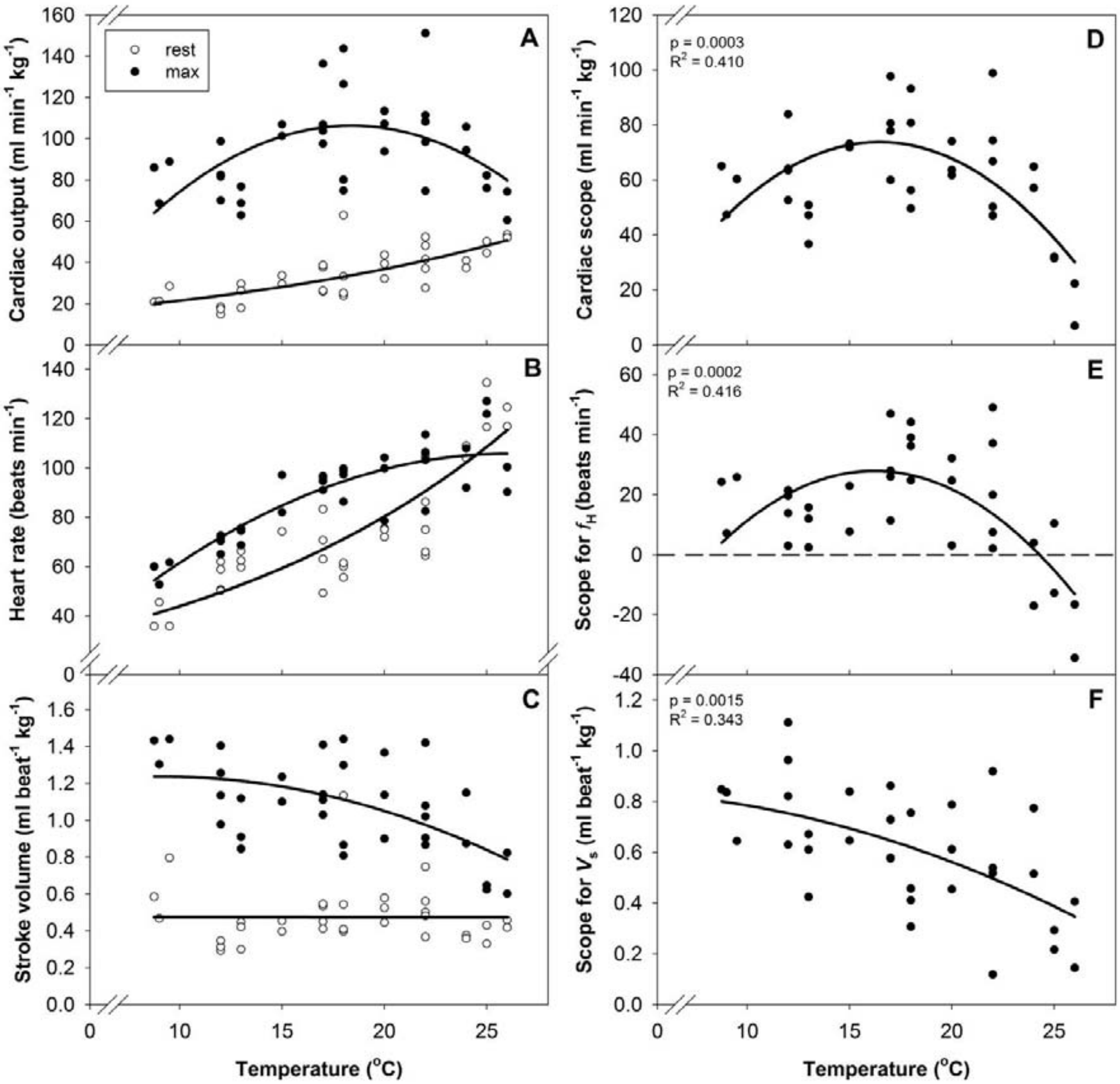

Figure 3.3. Resting (open circles) and maximum (closed circles) values for (A) cardiac output, (B) heart rate and (C) stroke volume in Chilko sockeye salmon. Each point corresponds to a single fish. Scope, the difference between maximum and resting data presented in A, B and C are shown in (D) cardiac scope, (E) scope for heart rate (f_H) and (F) scope for stroke volume (V_s). A polynomial quadratic equation was fit to the maximum and scope data, an exponential equation was fit to the resting data for cardiac output and heart rate and no relationship was found with temperature for resting stroke volume.

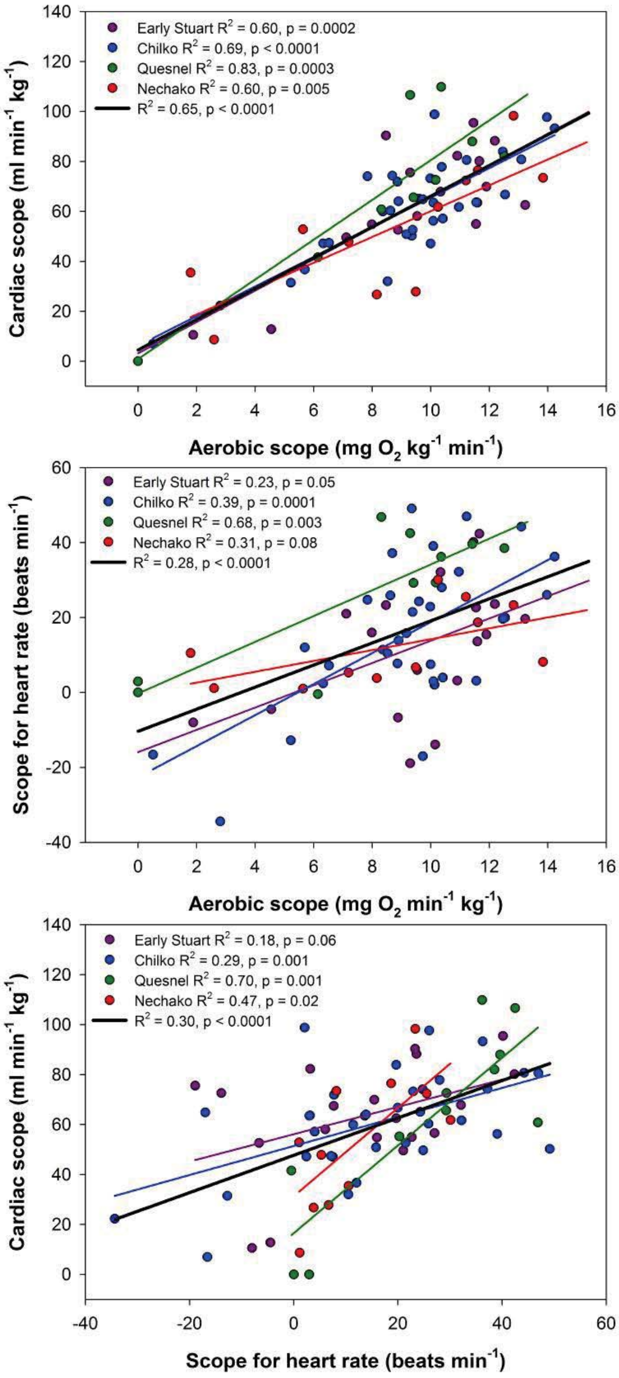

Figure 3.4. Linear regressions between aerobic scope, cardiac scope and scope for heart rate. Each data point corresponds to an individual fish, the overall R^2 and p-value with all populations and temperatures combined is indicated in black.

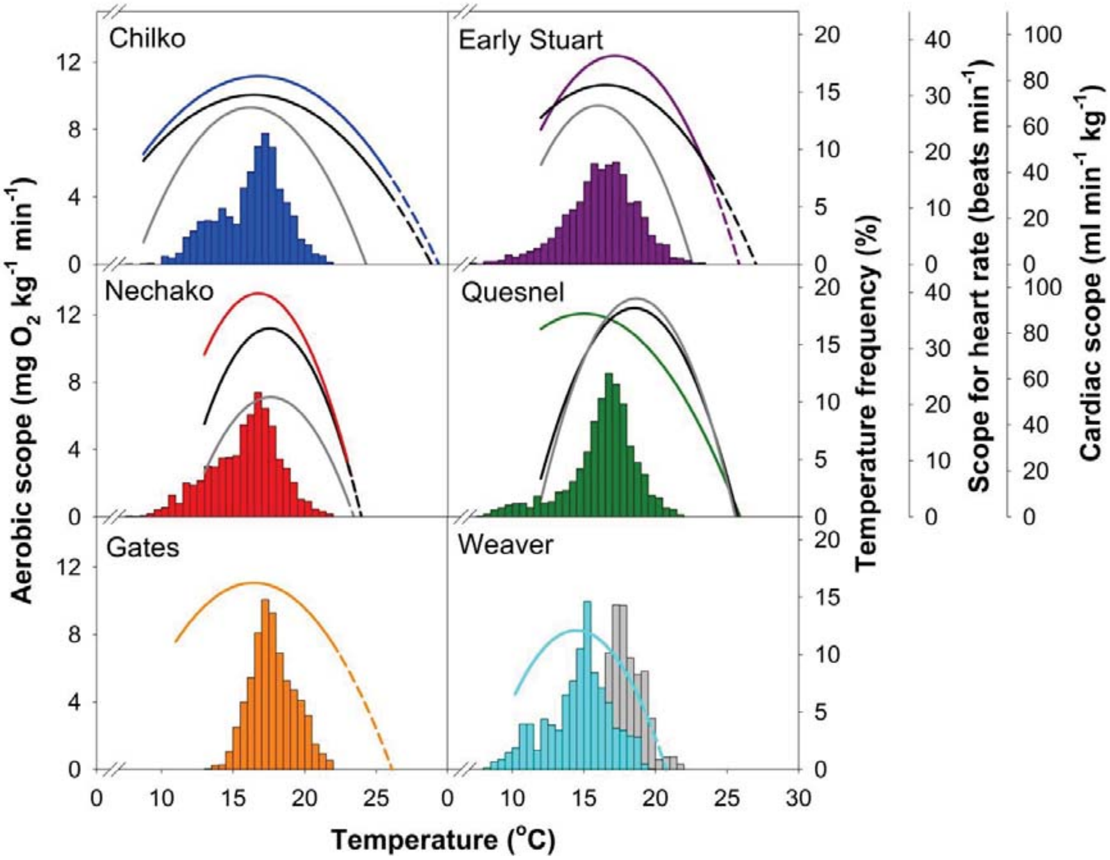

Figure 3.5. Population-specific estimates of aerobic scope (coloured lines) cardiac scope (black lines) and scope for heart rate (grey lines) in relation to water temperature. The frequency histogram shows simulated distributions of average river temperatures encountered by individual modeled fish from each population during their upriver migration from 1995 to 2008. For Weaver fish, two temperature histograms are presented, one for historical river entry (blue), the other for the current early entry phenomenon (grey). Aerobic scope data for Gates and Weaver were provided by Lee et al. (2003c).

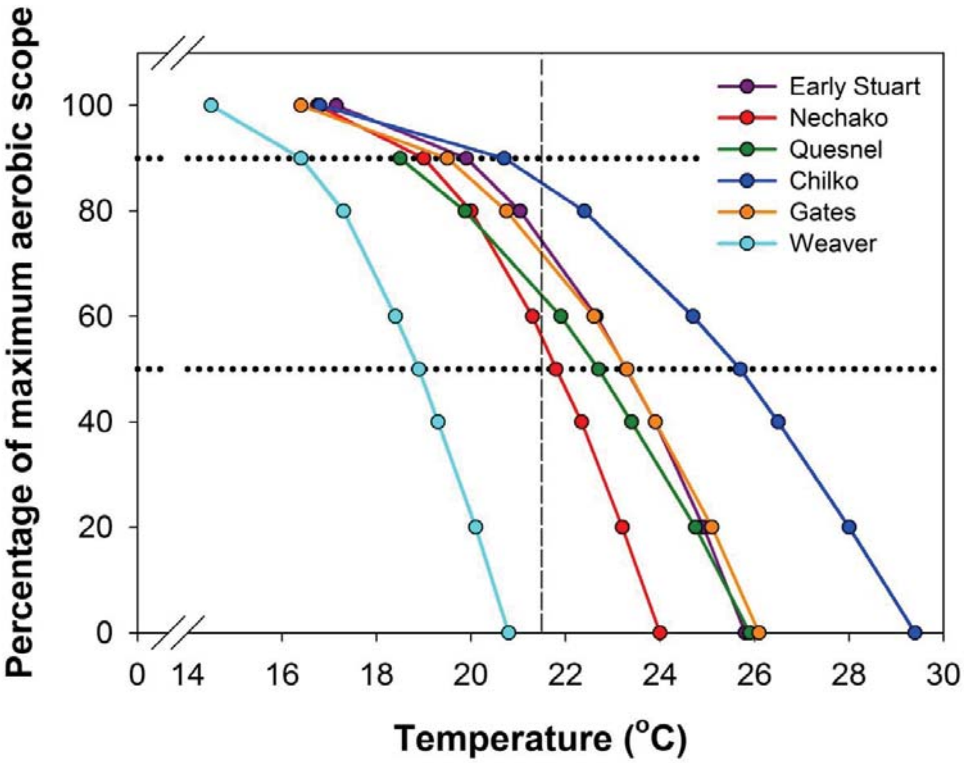

Figure 3.6. Percentage of maximum aerobic scope available for each population in relation to temperature. Dashed line at 21.5°C indicates the maximum Fraser River temperature measured near Hells Gate since the 1940s. Although it is unknown what proportion of aerobic scope is needed to successfully ascend the river, 90% and 50% are indicated as guidelines (dotted lines).

Table 3.1. Gross morphology among populations and between sexes. Post-orbital-hypural (POH) length, post-orbital-fork (POF) length, gonadosomatic index (GSI), hepatosomatic index (HSI), and splenosomatic index (SSI) are indicated.

	Early Stuart		**Nechako**		**Quesnel**		**Chilko**		**Lower Adams**	
	male	*female*	*male*	*female*	*male*	*female*	*male*	*female*	*male*	*female*
N	17	9	6	8	4	9	24	11	4	3
mass (kg)	2.41 ± 0.04	2.39 ± 0.08	2.46 ± 0.20	2.11 ± 0.13	2.86 ± 0.20	2.24 ± 0.07	2.52 ± 0.09	2.12 ± 0.12	2.85 ± 0.17	2.41 ± 0.18
fork length (cm)	59.6 ± 0.4	59.9 ± 0.9	60.6 ± 1.2	57.5 ± 1.0	63.5 ± 2.4	58.4 ± 0.6	60.6 ± 0.6	57.6 ± 0.7	61.8 ± 0.7	59.3 ± 1.2
standard length (cm)	54.4 ± 0.4	53.6 ± 1.0	55.1 ± 2.8	51.6 ± 1.2	57.2 ± 2.2	53.0 ± 0.5	54.8 ± 0.7	52.3 ± 0.7	56.0 ± 0.7	53.7 ± 1.6
POH (cm)	49.5 ± 0.5	50.2 ± 0.6	50.5 ± 1.1	48.4 ± 1.0	51.5 ± 2.3	50.3 ± 0.8	50.3 ± 0.6	48.5 ± 0.6	51.5 ± 0.7	49.0 ± 1.2
POF (cm)	54.6 ± 0.4	55.6 ± 0.7	55.8 ± 1.1	54.2 ± 0.8	57.7 ± 2.4	54.2 ± 0.8	55.8 ± 0.6	53.5 ± 0.6	57.3 ± 0.7	54.8 ± 1.1
GSI (%)	2.01 ± 0.09	5.75 ± 0.49	1.49 ± 0.26	5.49 ± 0.31	1.71 ± 0.22	8.31 ± 0.88	1.88 ± 0.10	6.24 ± 0.80	1.54 ± 0.24	6.95 ± 0.77
HSI (%)	1.42 ± 0.05	1.66 ± 0.06	1.32 ± 0.08	1.53 ± 0.14	1.47 ± 0.19	1.58 ± 0.06	1.46 ± 0.06	1.53 ± 0.10	1.51 ± 0.08	1.44 ± 0.13
SSI (%)	0.14 ± 0.01	0.11 ± 0.01	0.14 ± 0.03	0.11 ± 0.02	0.13 ± 0.02	0.10 ± 0.01	0.16 ± 0.01	0.13 ± 0.02	0.20 ± 0.02	0.15 ± 0.01
energy (MJ kg^{-1})	7.77 ± 0.23	8.08 ± 0.46	8.90 ± 0.25	7.69 ± 0.47	7.02 ± 1.08	7.95 ± 0.39	8.55 ± 0.33	8.45 ± 0.58	6.80 ± 0.71	7.04 ± 0.79

Table 3.2. Measurements of oxygen consumption ($\dot{M}O_2$), critical swimming velocity (U_{crit}) and recovery ratio (RR) in Early Stuart sockeye salmon swum at T_{opt} that had (with leads) and had not (no leads) been instrumented with a flowprobe and catheters to measure cardiovascular variables. Mean ± SEM are presented, an asterisk indicates a statistically significant difference between fish with leads and those without ($p<0.05$).

$\dot{M}O_2$ (mg O_2 kg^{-1} min^{-1})	**n**	**No leads**	**n**	**With leads**
rest	4	2.6 ± 0.2	8	3.2 ± 0.2
maximum	4	14.4 ± 1.4	8	14.7 ± 0.4
scope	4	11.9 ± 1.3	7	11.7 ± 0.3
fatigue 1	3	8.6 ± 0.2	7	10.0 ± 0.8
fatigue 2	4	9.0 ± 2.3	7	8.9 ± 0.8
45-min recovery 1	4	4.2 ± 0.9	7	6.6 ± 0.3*
45-min recovery 2	4	6.3 ± 1.4	7	5.4 ± 0.8
2-h recovery 2	4	4.0 ± 0.7	7	3.9 ± 0.4
U_{crit} 1 (bl s^{-1})	4	2.41 ± 0.13	9	2.02 ± 0.06*
U_{crit} 2 (bl s^{-1})	4	2.35 ± 0.19	8	1.91 ± 0.06*
U_{crit} 1 (cm s^{-1})	4	144.1 ± 7.6	9	122.1 ± 4.1*
U_{crit} 2 (cm s^{-1})	4	140.6 ± 12.1	8	114.4 ± 3.5*
RR	4	0.97 ± 0.05	8	0.95 ± 0.02

Table 3.3. Oxygen consumption ($\dot{M}O_2$), cardiac output ($\dot{Q}$), heart rate (f_H) and stroke volume (V_s) at the optimal temperature (T_{opt}) (mean ± SEM). $\dot{M}O_2$ data for Gates and Weaver are taken from Lee et al. (2003c). No cardiac variables were measured in Lee et al. (2003c). Populations with differing letters are significantly different within each variable ($p<0.05$).

	Early Stuart	Nechako	Quesnel	Chilko	Lower Adams	Gates	Weaver
n	9-12	4-6	6-7	12-13	4-5	27	24-26
$\dot{M}O_{2rest}$ (mg O_2 kg^{-1} min^{-1})	3.0 ± 0.2^a	2.4 ± 0.2^a	2.6 ± 0.2^a	2.9 ± 0.2^a	3.4 ± 0.5^{ab}	4.0 ± 0.1^b	2.8 ± 0.1^a
$\dot{M}O_{2max}$ (mg O_2 kg^{-1} min^{-1})	14.6 ± 0.5^a	15.3 ± 0.6^a	13.7 ± 0.5^{ab}	13.8 ± 0.6^a	12.6 ± 1.4^{ab}	15.0 ± 0.2^a	10.5 ± 0.3^b
$\dot{M}O_2$ scope (mg O_2 kg^{-1} min^{-1})	11.8 ± 0.5^a	13.0 ± 0.6^a	11.2 ± 0.6^{ab}	10.9 ± 0.6^{ab}	9.0 ± 0.8^b	10.9 ± 0.2^{ab}	7.7 ± 0.2^c
$\dot{Q}_{rest}$ (ml min^{-1} kg^{-1})	34.8 ± 2.7	29.9 ± 1.7	34.7 ± 3.9	34.8 ± 2.9	27.8 ± 3.1	-	-
$\dot{Q}_{max}$ (ml min^{-1} kg^{-1})	105.5 ± 5.5	110.0 ± 5.6	113.6 ± 10.7	107.1 ± 5.5	85.4 ± 10.4	-	-
$\dot{Q}$ scope (ml min^{-1} kg^{-1})	70.7 ± 4.7	80.2 ± 6.1	78.9 ± 7.8	72.4 ± 3.9	57.6 ± 7.4	-	-
f_{Hrest} (beats min^{-1})	70.1 ± 2.3	65.8 ± 2.6	60.9 ± 4.7	67.3 ± 2.7	67.7 ± 6.7	-	-
f_{Hmax} (beats min^{-1})	95.5 ± 2.8	84.7 ± 4.0	93.1 ± 3.5	94.1 ± 2.1	91.2 ± 7.4	-	-
f_H scope (beats min^{-1})	25.4 ± 3.8	18.9 ± 3.9	32.2 ± 3.0	26.7 ± 3.7	23.5 ± 9.7	-	-
V_{srest} (ml $beat^{-1}$ kg^{-1})	0.49 ± 0.03	0.46 ± 0.02	0.57 ± 0.06	0.53 ± 0.05	0.43 ± 0.06	-	-
V_{smax} (ml $beat^{-1}$ kg^{-1})	1.10 ± 0.05	1.30 ± 0.05	1.22 ± 0.11	1.14 ± 0.06	0.93 ± 0.06	-	-
V_s scope (ml $beat^{-1}$ kg^{-1})	0.60 ± 0.04^a	0.85 ± 0.05^b	0.65 ± 0.05^{ab}	0.62 ± 0.05^a	0.50 ± 0.02^a	-	-

Table 3.4. Pearson correlation matrix relating aerobic scope of fish from seven populations and eight migration difficulty variables (see Table 2.1). ATU = accumulated thermal units, F_M = Fraser River discharge. Three critical values are indicated: $p < 0.05$ (no correction for multiple comparisons), $p < 0.018$ (Benjamini and Yekutieli False Discovery Rate) and $p < 0.006$ (Bonferroni). Bold font indicates the migration difficulty variable with the highest correlation coefficient.

	Aerobic scope
migration distance (D_M)	**0.856**†
migration elevation (E_M)	0.653
work ($0.0001 \cdot E_M \cdot D_M$)	0.785*
river slope ($500(E_M\, D_M^{-1})$)	0.335
migration effort ($0.0001 \cdot D_M \cdot F_M$)	0.732
migration duration	0.777*
migration rate	0.842†
ATU	0.832*

* p < 0.05; † p < 0.018 , ‡ p < 0.006

Table 3.5. Population-specific optimal temperature (T_{opt}), upper and lower pejus temperatures (T_p) and predicted critical temperatures (T_{crit}). T_p range refers to the width of the T_{opt} window (i.e. upper T_p – lower T_p). T90% indicates the upper 90th percentile of historic temperatures encountered by each population (1995-2008). % Scope at T90% indicates the percent of maximum aerobic scope available at T90%. Values for current river entry timing for Weaver are shown in parentheses under the historical timing.

Population	T_{opt} (°C)	Lower T_p (°C)	Upper T_p (°C)	T_p range (°C)	T90% (°C)	% Scope at T90%	Predicted T_{crit} (°C)
Early Stuart	17.2	14.4	19.9	5.5	19.0	96	25.8
Nechako	16.8	14.5	19.0	4.5	18.4	95	24.0
Quesnel	-	-	18.5	-	18.6	89	25.9
Chilko	16.8	12.9	20.7	7.8	18.8	98	29.4
Gates	16.4	13.4	19.5	6.1	19.7	89	26.1
Weaver	14.5	12.5	16.4	3.9	17.2	81	20.8
					(19.1)	(45)	

Table 3.6. Summary of model selection statistics for regressions between population-specific aerobic scope predictions and population-specific temperature frequency distributions. Best-fit relationships correspond to ΔAIC ≤ 2 (bold font). Both current (WeaverCurrent) and historical (WeaverHistoric) temperature frequency histograms for Weaver are included.

Population scopes	Temperature frequencies	AIC	ΔAIC	*w*	R^2	p-value	Bonferroni corrected
Early Stuart							
	Early Stuart	182.53	0.00	0.94	0.72	8.35E-12	3.51E-10
	Nechako	200.18	17.65	0.00	0.62	1.08E-09	4.54E-08
	Quesnel	206.71	24.18	0.00	0.55	2.53E-08	1.06E-06
	Chilko	187.98	5.45	0.06	0.72	3.08E-12	1.29E-10
	Gates	194.68	12.15	0.00	0.67	7.68E-11	3.23E-09
	WeaverCurrent	231.99	49.47	0.00	0.16	6.89E-03	2.89E-01
	WeaverHistoric	226.41	43.88	0.00	0.27	3.98E-04	1.67E-02
Nechako							
	Early Stuart	179.13	1.99	0.27	0.81	4.54E-15	1.91E-13
	Nechako	197.43	20.29	0.00	0.73	1.12E-12	4.70E-11
	Quesnel	205.95	28.82	0.00	0.67	6.69E-11	2.81E-09
	Chilko	177.14	0.00	0.73	0.84	2.00E-16	8.40E-15
	Gates	195.18	18.05	0.00	0.75	3.82E-13	1.60E-11
	WeaverCurrent	239.72	62.58	0.00	0.23	9.63E-04	4.04E-02
	WeaverHistoric	232.31	55.17	0.00	0.36	2.39E-05	1.00E-03
Chilko							
	Early Stuart	123.41	0.00	1.00	0.78	5.43E-14	2.28E-12
	Nechako	151.63	28.22	0.00	0.66	1.49E-10	6.26E-09
	Quesnel	155.80	32.38	0.00	0.62	1.11E-09	4.66E-08
	Chilko	148.83	25.41	0.00	0.68	3.87E-11	1.63E-09
	Gates	166.99	43.58	0.00	0.49	2.49E-07	1.05E-05
	WeaverCurrent	183.82	60.40	0.00	0.23	1.00E-03	4.20E-02
	WeaverHistoric	176.99	53.58	0.00	0.35	3.32E-05	1.39E-03
Gates							
	Early Stuart	135.53	0.00	1.00	0.86	2.00E-16	8.40E-15
	Nechako	160.52	24.99	0.00	0.78	2.26E-14	9.49E-13
	Quesnel	169.16	33.63	0.00	0.73	1.41E-12	5.92E-11
	Chilko	157.08	21.55	0.00	0.80	4.35E-15	1.83E-13
	Gates	190.17	54.64	0.00	0.54	3.46E-08	1.45E-06
	WeaverCurrent	206.21	70.68	0.00	0.32	8.87E-05	3.73E-03
	WeaverHistoric	196.87	61.34	0.00	0.46	8.97E-07	3.77E-05
Weaver							
	Early Stuart	169.31	46.00	0.00	0.64	7.58E-10	3.18E-08
	Nechako	158.12	34.81	0.00	0.75	2.61E-13	1.10E-11
	Quesnel	171.22	47.91	0.00	0.66	1.40E-10	5.88E-09
	Chilko	168.74	45.44	0.00	0.68	4.25E-11	1.79E-09
	Gates	207.36	84.05	0.00	0.15	7.16E-03	3.01E-01
	WeaverCurrent	140.68	17.37	0.00	0.84	2.00E-16	8.40E-15
	WeaverHistoric	123.30	0.00	1.00	0.90	2.00E-16	8.40E-15

CHAPTER 4: A COMPARISON OF CARDIORESPIRATORY AND SWIMMING PERFORMANCE AMONG UPRIVER SOCKEYE SALMON POPULATIONS AT T_{opt}

4.1 Introduction

The previous chapter compared resting, maximum and scope for $\dot{M}O_2$, $\dot{Q}$, f_H and V_s among sockeye salmon populations and demonstrated that aerobic scope varies according to the difficulty of the upriver spawning migration. However, detailed analyses of how the various components of the cardiorespiratory oxygen convection system change with swimming were not considered. Therefore, this chapter greatly expands on Chapter 3 through a comprehensive assessment of swimming physiology at T_{opt}.

The upriver spawning migration is physically demanding for sockeye salmon. During this once-in-a-lifetime migration, Fraser River sockeye salmon swim continuously against a fast flowing river for several weeks at swimming speeds of 2 to 4 km h^{-1} and ground speeds of 20 to 40 km day^{-1} (English et al., 2005, Hinch and Rand, 1998). Moreover, because the fish cease feeding in the ocean, upriver swimming is fuelled entirely by endogenous energy stores. Also, sockeye salmon have a finite amount of time to complete their migration in order to successfully spawn. Upriver populations must negotiate hydraulically challenging river sections through the Fraser Canyon, such as Hells Gate, which requires anaerobic swimming (Hinch and Bratty, 2000; Rand and Hinch, 1998). Consequently, it is critical that sockeye salmon are able to recover rapidly from exhaustive exercise in order to continue their upriver migration. Indeed, previous studies on sockeye salmon, pink salmon, coho salmon, cutthroat trout and rainbow trout showed that salmonids have an excellent ability to repeat their swim performance after a short recovery period of 30-60 min (Farrell et al., 1998; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003b; MacNutt et al., 2004; MacNutt et al., 2006; Wagner et al., 2006).

This is the first study to compare cardiovascular performance and blood variables across wild sockeye salmon populations. The objective of this study was to examine how the cardiovascular system supports aerobic scope and swim performance and whether the mechanism changes over sequential swim tests or across populations. I compared swimming and cardiorespiratory performance among upriver Fraser River sockeye salmon populations (N = 32, Early Stuart, Chilko, Quesnel and Nechako) performing two sequential U_{crit} swim challenges at their T_{opt}. By performing these comparisons at T_{opt}, I removed temperature as a confounding factor in the population comparison. Only fish that had been instrumented were included in the analysis. Detailed materials and methods are found in Chapter 2 (sections 2.2-2.7 and 2.10).

All four populations must navigate through Hells Gate and travel 650 to 1100 km upstream, reaching an elevation of 700 to 1200 m on their spawning grounds. Furthermore, all four populations encounter a similar migration temperature median and mode (Table 2.1, 16-17°C) and have a similar T_{opt} (Table 3.6, ~17°C). I hypothesized that all four populations would be able to repeat their swim performance following a brief 45-min recovery, since there is likely strong selection pressure on the ability to rapidly recover from exhaustive exercise in adult sockeye salmon. Furthermore, since all four populations experience challenging migrations and did not differ in aerobic scope (Chapter 3), I hypothesized that they would have similar cardiorespiratory and swimming performance.

4.2 Results

4.2.1 Swimming Behaviour and Performance

Most of the sockeye salmon ventilated regularly and remained steady and calm during the rest period, with occasional exploratory movements. Many sockeye salmon exhibited unsteady, erratic swimming behaviour or they tended to rest on the bottom during the initial ramping phase of the U_{crit} swim challenge until they reached swim speeds of ~1 bl s^{-1}. Thereafter, there were typically three clear swimming phases. During the first phase, fish regularly ventilated their gills via opercular pumping while swimming steadily. Throughout phase two, fish continued to swim in a steady manner, but switched to ram ventilation. In the third swim phase, the fish transitioned to burst-and-coast swimming and continued to ram ventilate. Phase three typically started during the penultimate or final swim speed, which corresponded to speeds ~80-90% of maximum or ~2.0 bl s^{-1}. Interestingly, during the first two swim phases, fish occasionally exhibited “side burst” behaviour, where they would slowly fall back in the swim tunnel and then flip onto their sides and burst forward with a few quick tail flicks to regain their position at the front of the swim tunnel. This behaviour differed from the vertical burst-and-coast behaviours exhibited at the fastest swim speeds. Most sockeye salmon spent the duration of the recovery periods ventilating via opercular pumping with occasional light swimming, near the front of the swim tunnel.

U_{crit} 1, U_{crit} 2 and RR did not significantly differ among populations or between sexes (Table 4.1). In addition, all populations were able to repeat their swim performance because U_{crit} 1 did not significantly differ from U_{crit} 2 (overall mean maximum $U_{crit} = 2.04 \pm 0.04$).

4.2.2 Cardiorespiratory Performance

There were no significant differences in any of the cardiorespiratory variables between sexes, therefore, the data were pooled.

$\dot{M}O_{2max}$ and aerobic scope were not compared between swim 1 and swim 2 due to missing paired measurements. Likewise, Nechako sockeye salmon were excluded from the $\dot{M}O_2$ analysis because there were insufficient measurements at each swimming speed.

During swimming, $\dot{M}O_2$ significantly increased ~5-fold from resting values (Fig 4.1). $\dot{M}O_2$ did not significantly differ among the three populations at any swimming speed (Fig 4.1, Table 4.2). $\dot{M}O_2$ remained significantly elevated above resting levels at both 45-min recovery periods; however, it had recovered by the 2-h recovery period (Table 4.2). $\dot{M}O_2$ did not significantly differ between swim 1 and 2 at any swimming speed. Accordingly, COT and COT_{net} did not significantly differ between swims (Fig 4.2). Notably, COT did not display the characteristic U-shape, instead, it plateaued between 1.12 and 2.37 bl s^{-1}.

As expected, $\dot{Q}$ significantly increased ~3-fold above resting levels during swimming (Fig 4.3A). $\dot{Q}$ did not significantly differ among the four populations at any swimming speed (Fig 4.3A, Table 4.2, 4.3). $\dot{Q}$ did not recover back to resting levels during any of the recovery periods, except in Nechako sockeye salmon at 2 h (Table 4.2). In addition, $\dot{Q}$ did not significantly differ between swim 1 and swim 2, except at the very first swim speed (0.62 bl s^{-1}). Consequently, COT-$\dot{Q}$ and COT-$\dot{Q}_{net}$ only significantly differed between swims at 0.62 bl s^{-1}, although there was a general, non-significant trend for COT-$\dot{Q}$ and COT-$\dot{Q}_{net}$ to be higher during swim 2 compared to swim 1 (Fig 4.2).

V_s increased ~2-fold above resting levels during swimming. V_s did not significantly differ among populations at rest, during either swim or during recovery (Fig 4.3B, Table 4.2, 4.3). Even so, scope for V_s during swim 1 was significantly higher in Nechako compared to Quesnel sockeye salmon (Table 4.3). V_s returned back to resting levels by the 45-min recovery time point following both swims (Table 4.2). V_s did not significantly differ between swim 1 and swim 2 at any of the swimming speeds or recovery times, although scope for V_s was significantly higher in swim 2 compared to swim 1 for Quesnel sockeye salmon (Table 4.3).

During the first swim, f_H increased by ~1.5 fold from resting levels. f_H did not significantly differ among populations at any swim speed during swim 1 (Fig 4.3C). Notably, f_H did not recover back to resting levels after swim 1 for Early Stuart, Chilko and Quesnel populations (Table 4.2). Instead, following a brief decrease at fatigue, f_{Hmax} was maintained throughout the recovery period and the entire second swim for these three populations (Fig 4.3). In contrast, f_H recovered back to resting levels after swim 1 in Nechako sockeye salmon (Fig 4.3C, Table 4.2). During swim 2, f_H was significantly lower in Nechako compared to the Early Stuart and Quesnel populations until they reached a velocity of 1.37 bl s^{-1} (Fig 4.3C). Moreover, Nechako had a significantly lower f_H relative to Quesnel sockeye salmon during fatigue following the second swim (Table 4.2). f_H remained elevated above resting levels at the 2-h recovery period for Early Stuart, Chilko and Quesnel sockeye salmon (Table 4.2). Despite differences in the f_H response to swimming and recovery, f_{Hmax} and scope for f_H did not significantly vary among populations or between swims (Table 4.3).

4.2.3 Oxygen Transport and Removal by Tissues

Since $\dot{M}O_2$, $\dot{Q}$, V_s and f_H did not significantly differ at rest or during swimming in Early Stuart, Chilko and Quesnel sockeye salmon, I pooled the results for the blood analyses from these three populations. Nechako sockeye salmon were not included in the analysis because V_s and f_H differed from the other populations at various time points. Again, there were no significant differences in any of the blood variables between male and female sockeye so the data were pooled.

Blood samples were collected at rest, during steady state swimming when most of the fish were still ventilating by opercular pumping ("steady", mean speed = 1.18 ± 0.02 bl s^{-1}, or 55.8 ± 0.9% of maximum swim speed), during burst-and-coast swimming with ram ventilation ("burst", mean speed = 2.05 ± 0.06 bl s^{-1} or 92.6 ± 1.7% of maximum swim speed), immediately following fatigue, following 45 min of recovery and 2 h after the second swim was terminated.

P_{aO2}, P_{vO2}, C_{aO2} and C_{vO2} all significantly decreased from rest during swimming (Fig 4.4). P_{vO2} and C_{vO2} reached a plateau of 17.6-24.0 torr and 2.5-3.3 ml dl^{-1}, respectively, during burst swimming and fatigue. P_{aO2}, P_{vO2}, C_{aO2} and C_{vO2} did not differ between swim 1 and swim 2, despite significant decreases in [Hb] and Hct during swim 2. Both P_{aO2} and P_{vO2} returned to resting levels by the 45-min recovery periods. However, C_{aO2} and C_{vO2} remained depressed below resting levels during the second 45-min and the 2-h recovery period (Fig 4.4).

Hct only significantly varied between arterial and venous blood samples during fatigue 1; however, both [Hb] and Hct were consistently higher in venous compared to arterial blood throughout both swim tests. Moreover, MCHC was consistently lower in venous compared to arterial blood and significantly differed during several time points (Table 4.4). To verify whether this was an artefact, I compared paired arterial and venous blood samples from fish that had both cannulae working simultaneously (paired samples, Table 4.5). Paired samples revealed that [Hb] was equivalent between arterial and venous blood samples, except at steady 1 (Table 4.5). However, Hct was significantly higher and MCHC was significantly lower in venous compared to arterial blood, but only during burst swimming and at fatigue (Table 4.5).

Hct and [Hb] were significantly lower during swim 2 compared to swim 1, suggesting that hemodilution may have occurred (Table 4.4). To check for this possibility, comparisons were made between fish that had both cannulae working (~20 blood samples collected total, ≅14 ml of blood) and those with only the venous cannula working (~10 blood samples, ≅ 7 ml of blood). Both [Hb] and Hct were significantly lower during swim 2 in fish that had two cannulae compared to those that only had one functioning cannula, confirming that [Hb] and Hct were significantly lower during swim 2 due to hemodilution (Fig 4.6). This hemodilution had no effect on P_{vO2}; however, C_{vO2} was significantly lower during the recovery periods in fish with two cannulae relative to those with one cannula (Fig 4.6). There were insufficient fish with only the arterial cannula functioning to perform a similar analysis for arterial blood.

There was a general trend for A-V_{O2} to increase during swimming. However, A-V_{O2} did not significantly differ from rest or between swims (Fig 4.6); probably because comparisons were limited to fish with both cannulae working (N = 9). Notably, A-V_{O2} decreased by ~50% from resting values during the 2-h recovery period, since both C_{aO2} and C_{vO2} remained depressed below resting levels.

Arterial transfer of oxygen to the tissues (T_{aO2}) integrates changes in $\dot{Q}$ and C_{aO2} ($T_{aO2} = \dot{Q} \times C_{aO2}$). T_{aO2} significantly increased from rest by 2.5-fold during burst swimming and returned back to resting levels by the 45-min recovery period (Fig 4.6). No significant differences were detected between swim 1 and 2. In contrast, venous transfer of oxygen to the heart and gills ($T_{vO2} = \dot{Q} \times C_{vO2}$) remained constant throughout the entire swimming protocol and did not significantly vary from rest or between swim 1 and 2 (Fig 4.6).

4.2.4 Other Blood Variables

Plasma lactate did not significantly differ between arterial and venous blood samples. Plasma lactate was significantly elevated above resting levels during fatigue and 45 min after swim 1, verifying that the salmon did transition to anaerobic swimming during the swim challenge (Fig 4.4). Plasma lactate levels also remained significantly elevated during swim 2, resulting in a significant difference between swim 1 and swim 2 during steady swimming. Although plasma lactate did tend to recover somewhat by burst 2, it was again significantly elevated above resting levels during fatigue 2 and the second 45 -min recovery. However, plasma lactate did not significantly differ from resting levels at the 2-h recovery period (Fig 4.4).

Plasma glucose, chloride and sodium varied minimally from resting levels and no significant differences were detected between arterial and venous blood samples (Table 4.4). In contrast, plasma potassium was highly variable between swim 1 and 2 and between arterial and venous blood samples. In general, plasma potassium was higher in arterial relative to venous blood (Tables 4.4 and 4.5). In addition, plasma potassium tended to be higher during swim 2 compared to swim 1. Remarkably, plasma potassium actually decreased from rest during burst swimming and at fatigue with swim 1 (Table 4.4).

4.2.5 General Trends with Swimming

To summarize the general trends in cardiovascular physiology and oxygen status associate with swimming, fold changes from the initial resting value were examined for $\dot{V}O_2$, $\dot{Q}$, A-V_{O2}, T_{aO2} and T_{vO2} exclusively from fish with both cannulae working from pooled data from the Early Stuart, Chilko and Quesnel populations (Fig 4.7). $\dot{V}O_2$ increased 5-fold during both swims, primarily due to a 3-fold increase in $\dot{Q}$ (Fig 4.7A). $\dot{V}O_2$ returned to resting levels by the 2-h recovery after swim 2, even though $\dot{Q}$ remained elevated, because A-V_{O2} decreased by ~50% from resting levels (Fig 4.7A, B & C). The 3-fold increase in $\dot{Q}$ during both swims was primarily due to a >2-fold increase in V_s (Fig 4.7B). f_H increased ~1.5 fold above resting levels during the first swim and never decreased below maximum levels throughout the entire second swim and both recovery periods. As such, $\dot{Q}$ remained elevated above rest at both 45-min and the 2-h recovery periods, even though V_s had returned to resting levels. The ~1.5-fold increase in A-V_{O2} was driven by a large decrease in C_{vO2}, though the A-V_{O2} response was attenuated since C_{aO2} also decreased (Fig 4.7C). T_{aO2} increased by 2.5-fold during both swims, which was entirely due to the aforementioned increase in $\dot{Q}$ (Fig 4.7D). T_{vO2} changed very little from rest throughout both swims and the recovery periods because the decrease in C_{vO2} was offset by the increase in $\dot{Q}$ (Fig 4.7E).

4.3 Discussion

The goal of the present study was to compare cardiorespiratory performance and blood variables across upriver Fraser River sockeye salmon populations swimming two sequential swim tests. As anticipated, all four populations demonstrated similar increases in $\dot{M}O_2$ and $\dot{Q}$ with swimming. However, in comparison to the other three populations, Nechako sockeye salmon relied more on V_s than f_H to increase $\dot{Q}$. This finding suggests that the mechanism of achieving the same $\dot{M}O_2$ and $\dot{Q}$ can vary across populations. In addition, despite incomplete metabolic recovery, all populations showed an exceptional ability to repeat their swim performance following a brief 45-min recovery, supporting previous studies on salmonids (Farrell et al., 1998; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003b; MacNutt et al., 2004; MacNutt et al., 2006; Wagner et al., 2006). A rapid rate of recovery is clearly beneficial for salmon to ensure a timely migration to reach the spawning grounds.

4.3.1 Swimming Behaviour and Performance

Preliminary, practise swim tests have been demonstrated to improve ramp-U_{crit} swim performance in rainbow trout (Jain et al., 1997), presumably because the fish become habituated to the tunnel and learn how to swim effectively. I was unable to give the sockeye salmon a practise swim due to time and logistical constraints. Although the fish often swam erratically during the initial ramping phase of the U_{crit} swim test, they quickly grew accustomed to the tunnel at faster speeds. Despite swimming with leads, the sockeye salmon demonstrated classic swim behaviours and clearly transitioned to burst-and-coast anaerobic swimming at the highest swim speeds, as confirmed by the appearance of lactate in the plasma at fatigue and during recovery. Advanced sexual maturation has been reported to decrease swim performance in pink salmon (Williams et al., 1986), sockeye salmon (M. Steinhausen, pers. communication) and chinook salmon (E. Eliason, pers. observation). This was not a major concern in the present study since the sockeye salmon were collected early in their migration, several weeks before their spawning date and none of the fish were fully sexually mature (no loose eggs or milt production).

The U_{crit} values obtained in the present study for adult sockeye salmon swum with leads (mean overall maximum U_{crit} = 2.0 bl s^{-1}) were within the reported range for un-instrumented adult salmonids: sockeye salmon (1.4-2.4 bl s^{-1}, Brett and Glass, 1973; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003c; MacNutt et al., 2006), chinook salmon (2.1 bl s^{-1}, Geist et al., 2003), pink salmon (1.6-3.2 bl s^{-1}, Farrell et al., 2003; MacNutt et al., 2006; Williams et al., 1986), coho salmon (1.4-1.9 bl s^{-1}, Farrell et al., 2003; Lee et al., 2003a; Lee et al., 2003c), Arctic charr *Salvelinus alpinus* (L.) (2.8 bl s^{-1}, Jones et al., 1974), mountain whitefish *Prosopium williamsoni* (1.4 bl s^{-1}, Jones et al., 1974), Arctic cisco *Coregonus autumnalis* (1.9 bl s^{-1}, Jones et al., 1974), least cisco *Coregonus sardinella* Valenciennes (2.0 bl s^{-1}, Jones et al., 1974), wild-caught rainbow trout (2.2 bl s^{-1}, Jones et al., 1974), and hatchery-reared rainbow trout (2.1-2.8 bl s^{-1}, Jain et al., 1997; Jones et al., 1974).

U_{crit} did not differ between swim 1 and 2 or among populations, supporting the observation that migrating, adult Pacific salmon have excellent repeat swim performance (Farrell et al., 1998; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003b; MacNutt et al., 2004; MacNutt et al., 2006; Wagner et al., 2006). Collectively, these comparisons suggest that the fish in the present study had recovered well from surgery since the repeatability of swim test decreases when sockeye salmon or rainbow trout are diseased or exposed to toxicants (Jain et al., 1998; Tierney and Farrell, 2004; Wagner et al., 2005).

4.3.2 Cardiorespiratory Performance with Comparisons across Populations

$\dot{M}O_{2rest}$ measured at T_{opt} (15-20°C) did not differ among the four upriver sockeye salmon populations and ranged between 2.4 and 3.2 mg O_2 kg^{-1} min^{-1} (also see Chapter 3). This range is comparable to resting values in other adult salmonids: sockeye salmon at 11-21°C (1.6-4.4 mg O_2 kg^{-1} min^{-1}, Farrell et al., 1998; Farrell et al., 2003; Jain et al., 1998; Lee et al., 2003c; Steinhausen et al., 2008; Wagner et al., 2005; Wagner et al., 2006), chinook salmon at 8-17°C (2.0-3.4 mg O_2 kg^{-1} min^{-1}, Clark et al., 2008b; Geist et al., 2003), pink salmon at 9-22°C (1.1-4.3 mg O_2 kg^{-1} min^{-1}, Farrell et al., 2003; MacNutt et al., 2006; Williams et al., 1986), coho salmon at 8-10°C (2.2-2.9 mg O_2 kg^{-1} min^{-1}, Farrell et al., 2003; Lee et al., 2003a; Lee et al., 2003c).

Studies on sexually immature rainbow trout report considerably lower $\dot{M}O_{2rest}$ values ranging from 0.8-1.3 mg O_2 kg min^{-1} (Claireaux et al., 2005; Eliason et al., 2008; Kiceniuk and Jones, 1977; Taylor et al., 1996; Thorarensen et al., 1996). The finding that adult Pacific salmon have a comparatively higher $\dot{M}O_{2rest}$ relative to immature rainbow trout is not surprising since adult salmon undergo considerable morphological changes (developing gonads and secondary sexual characteristics) which undoubtedly has an oxygen cost. They may have also been more restless in the swim tunnel due to the migratory life stage (Lee et al., 2003c; Wagner et al., 2006). In addition, the fish in the present study were only allowed an overnight recovery due to logistical issues and to time constraints. Farrell et al. (2003) demonstrated that $\dot{M}O_{2rest}$ significantly declined for fish given a 48-h habituation period to the swim tunnel compared to those only given an overnight recovery. Moreover, some of the studies with rainbow trout attempted to measure standard metabolic rate and thus measurements were made over several days under dark conditions (e.g. Eliason et al., 2008). These comparisons emphasize the importance of considering experimental apparatus and design when comparing across studies, particularly with $\dot{M}O_2$. To what degree aerobic scope was underestimated in these population comparisons will require further study, though the oxygen cost of sexual development and restlessness are likely unavoidable when measuring $\dot{M}O_{2rest}$ in adult salmonids.

All the populations increased $\dot{M}O_2$ by ~5-fold during swimming, attaining $\dot{M}O_{2max}$ values ranging between 13.7-15.3 mg O_2 kg^{-1} min^{-1} and aerobic scope values of 10.9-13.0 mg O_2 kg^{-1} min^{-1} (see Chapter 3). This increase is at the high end of the 3- to 5-fold increase reported for other adult salmonids (Farrell et al., 2003; Geist et al., 2003; Lee et al., 2003c; MacNutt et al., 2006; Williams et al., 1986). Similarly, the present study's $\dot{M}O_{2max}$ values are at the high end relative to previous studies on adult salmonids: sockeye salmon (5.8-15.1 mg O_2 kg^{-1} min^{-1}, Brett and Glass, 1973; Farrell et al., 2003; Hinch et al., 1996; Jain et al., 1998; Lee et al., 2003, MacNutt et al., 2006, Wagner et al., 2005, Wagner et al., 2006), chinook salmon (11.2 mg O_2 kg^{-1} min^{-1}, Geist et al., 2003), pink salmon (12.6-16 mg O_2 kg^{-1} min^{-1}, Farrell et al., 2003; MacNutt et al., 2006; Williams et al., 1986) and coho salmon (8.7-9.8 mg O_2 kg^{-1} min^{-1}, Farrell et al., 2003; Lee et al., 2003a; Lee et al 2003c).

$\dot{Q}$ at rest and during swimming were indistinguishable across populations. Only two previous studies have examined $\dot{Q}$ in sockeye salmon [Davis, 1968 (as reported in Brett, 1971); Steinhausen et al., 2008]. $\dot{Q}_{rest}$ reported here (30-35 ml min^{-1} kg^{-1}) is slightly higher than $\dot{Q}_{rest}$ at 15°C for Lower Adams sockeye salmon (25 ml min^{-1} kg^{-1}, Steinhausen et al., 2008) but comparable with $\dot{Q}_{rest}$ in adult chinook salmon at 13°C (29 ml min^{-1} kg^{-1}, Clark et al., 2008b). $\dot{Q}$ steadily increased with increasing swimming velocity until the fish fatigued. Both $\dot{Q}_{max}$ (100-118 ml min^{-1} kg^{-1}) and $\dot{Q}$ measured at ~75% of U_{crit} (80 ml min^{-1} kg^{-1}) in the present study exceeded $\dot{Q}$ for Lower Adams sockeye salmon swimming at ~75% of U_{crit} (~68 ml min^{-1} kg^{-1}; Steinhausen et al., 2008). Davis (1968) only reported $\dot{Q}$ in ml min^{-1}($\dot{Q}_{max}$ at 20°C = ~165 ml min^{-1}) and did not report body mass for the adult sockeye salmon of unknown origin. However, if we assume the sockeye salmon were ~2.3 kg, $\dot{Q}_{max}$ is estimated to be ~72 ml min^{-1} kg^{-1}, which is substantially lower than the present study. Moreover, $\dot{Q}_{max}$ greatly exceeded $\dot{Q}_{max}$ values reported for other salmonids from hatchery sources: rainbow trout at 10-18°C (42-69 ml min^{-1} kg^{-1}, Brodeur et al., 2001; Claireaux et al., 2005; Kiceniuk and Jones, 1977; Taylor et al., 1996; Thoraresnsen et al., 1996) and immature chinook salmon at 8-10°C (66 ml min^{-1} kg^{-1}, Gallaugher et al., 2001). Therefore, the wild, upriver sockeye salmon used here have a greater cardiac capacity compared with the limited dataset available for other salmonid species.

V_{srest} was similar across populations (0.46-0.57 ml beat^{-1} kg^{-1}) and within the range reported for other salmonids (e.g. 0.38-0.63 ml beat^{-1} kg^{-1}, in sockeye salmon, chinook salmon and rainbow trout, Claireaux et al., 2006; Clark et al., 2008b; Gallaugher et al., 2001; Kiceniuk and Jones, 1977; Steinhausen et al., 2008). Similar to $\dot{Q}$, V_s steadily increased with increasing swim speed until the fish fatigued. V_{smax} (1.08-1.29 ml beat^{-1} kg^{-1}) also exceeded the range reported for hatchery-reared salmonids (0.66-1.04 ml beat^{-1} kg^{-1} in rainbow trout and immature chinook salmon, Claireaux et al., 2006; Gallaugher et al., 2001; Kiceniuk and Jones, 1977).

f_{Hrest} ranged between 61-70 beats min^{-1} across populations, which is similar to f_{Hrest} reported for Lower Adams adult sockeye salmon at 15°C (65 beats min^{-1}, Steinhausen et al., 2008) but slightly higher than f_{Hrest} reported in adult chinook salmon at a slightly cooler temperature of 13°C (58 beats min^{-1}, Clark et al., 2008b), Stamp River adult sockeye salmon at 13-16°C (49 beats min^{-1}, Smith et al., 1967) and Weaver and Harrison sockeye salmon at 11-13°C (43-52 beats min^{-1}, Sandblom et al., 2009). Free-swimming adult sockeye salmon equipped with biologgers exhibited a lower $f_{Hroutine}$ (35-44 beats min^{-1} at 13°C, Clark et al., 2010) and (50-

59 beats min^{-1} at 10°C, Clark et al., 2009). Differences in f_H among studies may partially be attributed to the $\dot{Q}_{10}$ effect. Also, free-swimming fish were able to swim throughout their environment and measurements were made over several days which would likely result in lower values since f_H appears to lag behind other cardiorespiratory variables during recovery (see Fig 4.3 and 4.7).

f_{Hmax} ranged between 81-95 beats min^{-1} across populations, which is similar to f_{Hmax} in tethered Lower Adams sockeye salmon swimming at ~75% of U_{crit} at 15°C (81 beats min^{-1}, Steinhausen et al., 2008) and tethered Stamp River sockeye salmon at 13-16°C (83 beats min^{-1}, Smith et al., 1967). In free-swimming sockeye salmon on the spawning ground or in a raceway at 10-13°C, f_{Hmax} reached ~75-79 beats min^{-1} (Clark et al., 2009, Clark et al., 2010).

Although $\dot{Q}$ did not differ among populations, f_H was lower and V_s was higher at some of the time points in Nechako sockeye salmon relative to the other populations. During the first swim, f_H steadily increased with swimming speed in all populations. However, f_H remained elevated at maximal levels throughout the first 45-min recovery, the entire second swim and the duration of second recovery period in Early Stuart, Chilko and Quesnel sockeye salmon. In contrast, f_H recovered back to resting levels in Nechako sockeye salmon. Notably, this recovery may be partially attributed to the low scope for f_H in Nechako sockeye salmon since f_H at the first 45-min recovery period did not differ from f_{Hmax} or f_{Hrest}. As such, Nechako sockeye salmon rely more on V_s and less on f_H in order to achieve the same $\dot{Q}$ as the other three populations. A similar phenomenon was reported by Nelson et al. (1994), who found that despite differences in exercise physiology between two populations of Atlantic cod, swimming performance and aerobic scope were identical.

No significant differences were detected in U_{crit}, $\dot{M}O_2$, $\dot{Q}$, V_s or f_H between male and female sockeye salmon. Despite significant differences in relative ventricular mass (RVM) between males and females (male RVM was 2-25% higher than female RVM depending on the temperature, see Chapter 6), this did not translate to significant differences in $\dot{Q}_{max}$ or V_{smax}. Similarly, Gallaugher et al. (2001) found that a 13% increase in RVM in exercise-trained immature chinook salmon did not result in differences in $\dot{Q}$. In contrast, sexually mature male rainbow trout with larger ventricles were demonstrated to have higher $\dot{Q}_{max}$ and V_{smax} compared to sexually mature females in an *in situ* perfused heart preparation (Franklin and Davie, 1992). However, the male trout had ~2-fold larger RVM compared to females, which is a much more dramatic difference then the present study. In addition, Sandblom et al. (2009) reported significantly higher f_{Hrest} in female compared to male sockeye salmon confined in holding tubes, while biologging and telemetry studies on free-swimming fish report that male salmonids spent a greater proportion of time with a high f_H (Altimiras et al., 1996; Clark et al., 2009; Lucas et al., 1993), likely due to increased activity and aggressive behaviour on the spawning grounds. Regardless, no significant differences in f_H were detected between sexes in the present study.

4.3.3 Oxygen Transport and Removal by Tissues

Resting Hct, [Hb] and MCHC were within expected levels (Clark et al., 2009; Sandblom et al., 2009). However, Hct and [Hb] decreased throughout the experiment until Hct reached ~22-24% during the final sample at the 2-h recovery. This was clearly due to haemodilution since fish with both cannulae operational (and thus had twice the amount of blood samples removed) had a significantly lower Hct and [Hb] during the second swim relative to fish with only one cannula operational. Approximately 20 blood samples or ~14 ml of blood was collected from fish with paired cannulae. Overall mean body mass was 2.3 kg, so assuming a blood volume of 3.5 ml 100 g^{-1} body mass (Olson, 1992), each sockeye salmon had on average ~80.5 ml of blood. Thus, around 17% of the blood volume was removed and replaced with saline throughout the experiment. Notably, reduced [Hb] due to hemodilution during the second swim also decreased C_{vO2}, without affecting P_{vO2}. I could not confirm that that C_{aO2} was also reduced due to insufficient numbers of fish with only the arterial cannula functioning. However, since T_{aO2} was identical between swim1 and swim 2, the decreased Hct and [Hb] did not result in a differential perfusion limitation to the tissues between swims and accordingly, U_{crit} did not differ between swims. Similarly, Gallaugher et al. (1995) previously found that U_{crit} was not impaired in rainbow trout until Hct declined below 22%.

No significant differences in Hct, [Hb] or MCHC were detected between males and females, which is consistent with a previous study on sockeye salmon (Sandblom et al., 2009). In contrast, Clark et al. (2009) reported significantly higher [Hb] in female compared to male sockeye salmon on the spawning ground.

Resting P_{aO2} and C_{aO2} were within the expected range for salmonids (Clark et al., 2008b; Gallaugher et al., 1992; Gallaugher et al., 2001; Farrell et al., 1998; McKenzie et al., 2004; Steinhausen et al., 2008; Thorarensen et al., 1993). Both P_{aO2} and C_{aO2} declined during swimming by 34 and 23%, respectively. Several studies on salmonids report a similar decrease in P_{aO2} with swimming (Farrell et al., 1998; Gallaugher et al., 1992; Gallaugher et al., 2001; McKenzie et al., 2004; Steinhausen et al., 2008; Thorarensen et al., 1993) but C_{aO2} remained constant during swimming in several studies (Kiceniuk and Jones, 1977; Gallaugher et al., 2001; McKenzie et al., 2004; Thorarensen et al., 1993). Conversely, another report found a 21%

decrease in C_{aO2} when sockeye salmon swam ~75% of U_{crit} (Steinhausen et al., 2008). Two possibilities may account for the decrease in C_{aO2} during swimming. A normal problem encountered by salmon migrating upriver is the accumulation of fungus on the gills and body. In addition, the surgery to implant the flowprobe and sinus venosus cannula may have caused some gill damage. As such, the gill surface area for diffusion may have been limited and/or the diffusion distance may have increased, resulting in impaired C_{aO2}. Regardless, T_{aO2} was exceptionally high in the present study, primarily due to the extremely high $\dot{Q}$.

As expected, P_{vO2} and C_{vO2} also significantly declined during swimming by 57 and 70%, respectively, due to increased oxygen uptake to support the increased oxygen demand at the tissues. A threshold value for P_{vO2} during swimming has been proposed, which would ensure adequate oxygen supply to the spongy myocardium (Davie and Farrell, 1991; Farrell, 2002; Farrell, 2007; Farrell and Clutterham, 2003). Notably, the minimum P_{vO2} values measured here were 18-24 torr, which compare well with previous studies which suggest a P_{vO2} threshold of 15-16 and 29 torr in normoxic rainbow trout at 6-10°C and 13-15°C, respectively (Farrell and Clutterham, 2003).

4.3.4 Repeat Swim Performance

U_{crit} swim tests involve aerobic swimming at the lower swim speeds, followed by a transition to anaerobic metabolism as the fish near U_{crit} (Jones, 1982), as is evident by the accumulation of lactate in the blood (Black, 1955). Furthermore, during exhaustive exercise, the blood becomes acidic (low pH due to CO_2 and lactate accumulation), hypoxemic (low P_{vO2} and C_{vO2} due to oxygen extraction by the tissues) and hyperkalemic (high $[K^+]$ due to K^+ loss from working muscles) (Holk and Lykkeboe, 1998; Kiceniuk and Jones, 1977). As expected, plasma lactate levels increased and P_{vO2} and C_{vO2} decreased during swimming. However, plasma K^+ was highly variable, decreasing during swim 1, and increasing during swim 2. Moreover, plasma K^+ was significantly higher in the arterial relative to the venous blood. The difference in [K+] between the arterial and venous blood may be attributed to the effect of pH and haemoglobin-oxygen saturation on K^+ movement across red blood cells. Specifically, red blood cells take up K^+ when blood pH and haemoglobin-oxygen saturation is low and lose K^+ when pH and haemoglobin-oxygen saturation is high (Nielsen and Lykkeboe, 1992b).

The elevated $\dot{M}O_2$ following an anaerobic swim challenge is termed the excess post oxygen consumption (EPOC). EPOC represents the $\dot{M}O_2$ cost to restore oxygen stores, high energy phosphates and glycogen and reverse biochemical, ionic and osmotic imbalances (Gaesser and Brooks, 1984; Scarabello et al., 1992). An extended EPOC and prolonged rate of recovery could be detrimental to migrating sockeye salmon since they must migrate upstream in a timely manner. However, as described above, sockeye salmon from all four upriver populations were able to repeat their swim performance after a 45-min recovery and $\dot{M}O_2$ had returned to resting revels by 2 h after the second swim challenge, which is a comparable timeframe to an earlier study for sockeye salmon (Lee et al., 2003b).

Complete recovery of cardiovascular and metabolic indicators was not required in order for the fish to repeat their U_{crit} swim performance. The same $\dot{Q}_{max}$, V_{smax}, f_{Hmax}, and T_{aO2} were obtained during swim 2 as compared with swim 1, even though $\dot{M}O_2$, $\dot{Q}$, f_H, and plasma lactate remained significantly elevated and C_{vO2} remained significant depressed at the outset of swim 2.

There are several potential explanations for this. Naïve fish may swim inefficiently or prematurely quit swimming during the first swim, but improve during the second attempt. The increased scope for $\dot{Q}$ and V_s during the second swim in Quesnel sockeye salmon may be attributed to these types of behavioural differences between swims.

The consistent repeat swim performance was not due to a larger anaerobic contribution during swim 2 relative to swim 1 since lactate did not accumulate in the plasma. In fact, plasma lactate was highest during the 45-min recovery period following swim 1. A similar finding was reported for sockeye salmon swum twice and even three times (Farrell et al., 1998, Jain et al., 1998). In the present study, plasma lactate levels were always less than 10-13 mmol l^{-1}, which is the proposed threshold above which sockeye salmon and rainbow trout cannot repeat their swim performance (Farrell et al., 1998; Jain and Farrell, 2003; Stevens and Black, 1966).

Training effects may physiologically allow fish to improve or maintain swim performance during the second swim, despite incomplete metabolic recovery. For example, faster recovery rates for lactate, creatine phosphate and respiratory gases during a second exhaustive burst swim test were suggested to be training effects (Scarabello et al., 1992). Notably, plasma lactate decreased between steady and burst swimming during swim 2, which suggests that lactate may have been used as a fuel or metabolically cleared during the lower speeds of the second swim. Indeed, light swimming has been demonstrated to accelerate recovery ability in rainbow trout (Milligan et al., 2000).

More efficient swimming during the second swim (lower COT) could allow for repeat swim performance (Farrell et al., 1998). However, this was not the case in the current study since COT did not differ between swims. In fact, COT-$\dot{Q}$ was consistently, though not significantly, higher during the second swim, which may have assisted metabolic recovery. Notably, neither COT nor COT-$\dot{Q}$ displayed the classic U-shaped curve with speed (e.g. Hoyt and Taylor, 1981; Lee et al., 2003c; Prange, 1976; Prange and Schmidt-Nielsen, 1970; Wakeman and Wohlschlag, 1982). Instead, both plateaued at speeds higher than ~1 bl s^{-1}. Thus, upriver sockeye salmon maintained their swimming efficiency across the entire range of swim speeds. While COT_{net} and COT-$\dot{Q}_{net}$ steadily increased with higher swim speeds, both plateaued once the fish transitioned to burst swimming, providing further evidence that high velocity swimming was fuelled by anaerobic metabolism.

An important consideration in this study system is that adult sockeye salmon must 'multi-task' during their upriver migration. Namely, while swimming almost continually upstream to their spawning grounds, sockeye salmon must also undergo sexual maturation (grow their gonads and develop secondary sexual characteristics). Thus, sockeye salmon may divert blood away from the gonads and to the muscle when swimming at high speeds, and blood flow distribution may vary across sequential swims. This idea is supported by the observation that gut blood flow in digesting salmon decreases with increased swimming speeds (Thorarensen et al., 1993). These ideas should be tested experimentally.

4.3.5 Summary and General Trends in Oxygen Convection with Swimming

In summary, comprehensive studies that have directly measured all the cardiovascular and oxygen transport variables in the Fick equation for vascular perfusion ($\dot{V}O_2 = \dot{Q} \times A\text{-}V_{O2}$) are rare in swimming fish (e.g. Steinhausen et al., 2008). Most studies have estimated $\dot{Q}$ from the Fick equation (e.g. Kiceniuk and Jones, 1977). All the variables were measured here for four populations of sockeye salmon swimming at T_{opt} to test two hypotheses. As hypothesized, all four populations had similar cardiorespiratory and swimming performance, though Nechako sockeye salmon relied more on V_s than f_H to achieve the same $\dot{Q}$. I similarly found support for the hypothesis that all four populations can repeat their swim performance following a brief 45-min recovery and it appears that sockeye salmon are able to recover while swimming aerobically at intermediate speeds.

In addition, a clear picture emerged for the quantitative changes in the various cardiorespiratory components during swimming. The 5-fold increase in $\dot{V}O_2$ came about primarily though a 3-fold increase in $\dot{Q}$, which was driven by a 2-fold increase in V_s. f_H and A-V_{O2} both increased ~1.5-fold. Though V_s returned to rest by the final 2-h recovery, f_H remained elevated at maximal levels and as a result, $\dot{Q}$ remained elevated by ~1.5-fold. However, $\dot{V}O_2$ did return back to resting levels since A-V_{O2} actually decreased by ~50% at the 2-h recovery. During swimming, T_{aO2} met the tissue oxygen demand entirely through an increase in $\dot{Q}$. T_{vO2} maintained a constant oxygen delivery to the spongy myocardium and gills throughout the swim tests and recovery since increases in $\dot{Q}$ offset decreases in C_{vO2}.

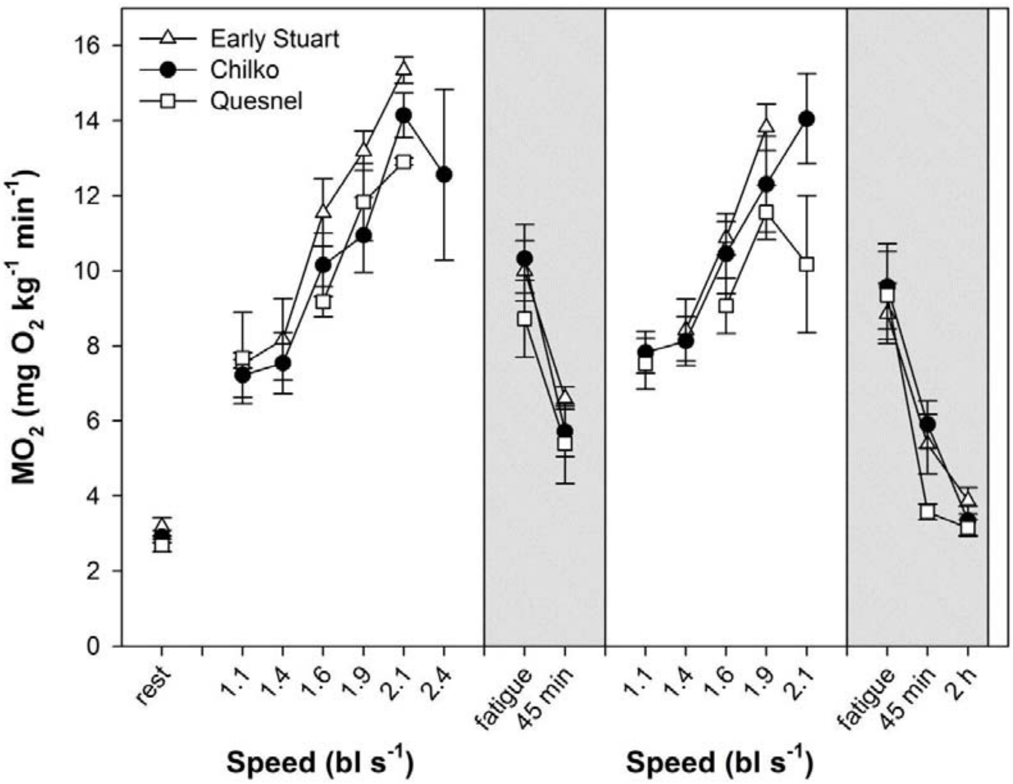

Figure 4.1. Oxygen consumption ($\dot{M}O_2$) with swimming speed over two consecutive swim challenges in three populations of sockeye salmon. There were no significant differences among populations or between sexes. Shaded areas indicate the recovery periods, starting with the fatigue value collected immediately following the U_{crit} test.

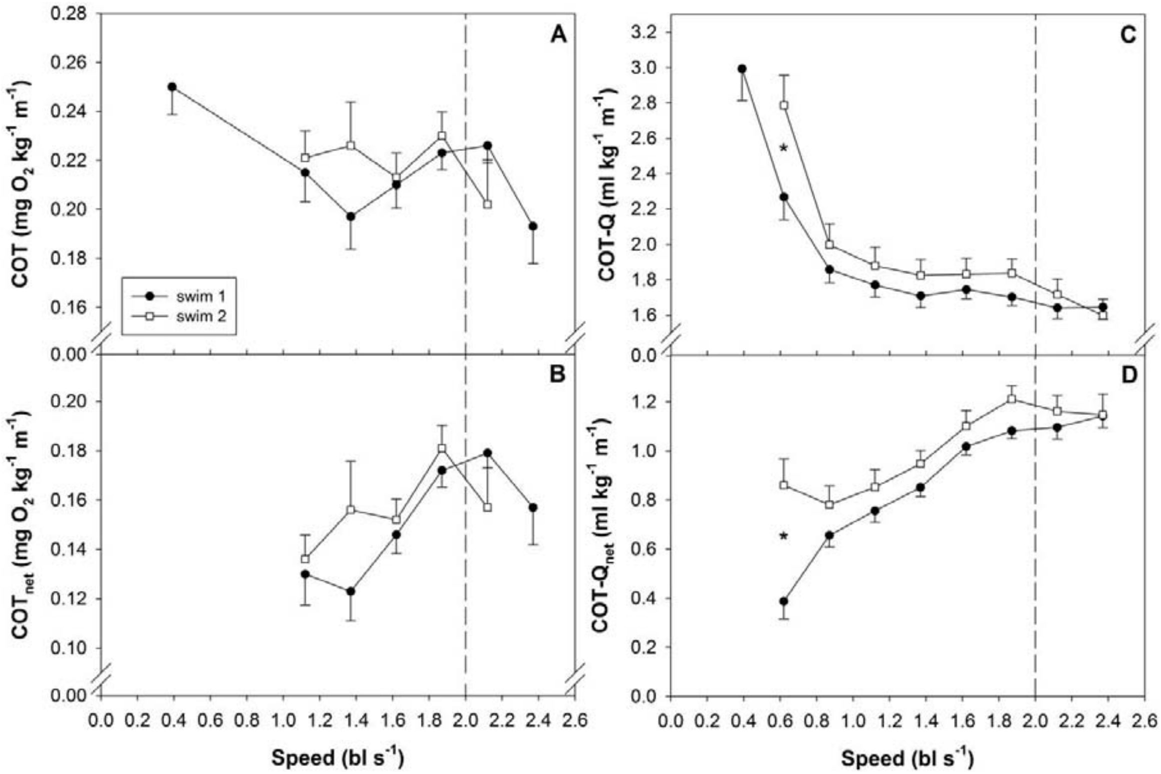

Figure 4.2. (A) Cost of transport (COT), (B) net cost of transport (COT_{net}), (C) cardiovascular cost of transport (COT-$\dot{Q}$) and (D) net cardiovascular cost of transport (COT-$\dot{Q}_{net}$) over two consecutive swim challenges. Since there were no significant differences in $\dot{M}O_2$ or $\dot{Q}$ among populations, all populations were combined. Dashed line indicates typical swim speed at which the fish transitioned from steady swimming to burst swimming. Mean ± SEM are presented. There were no significant differences between swim 1 and swim 2 in COT or COT_{net}. Significant differences between swims in COT-$\dot{Q}$ and COT-$\dot{Q}_{net}$ are indicated by an asterisk.

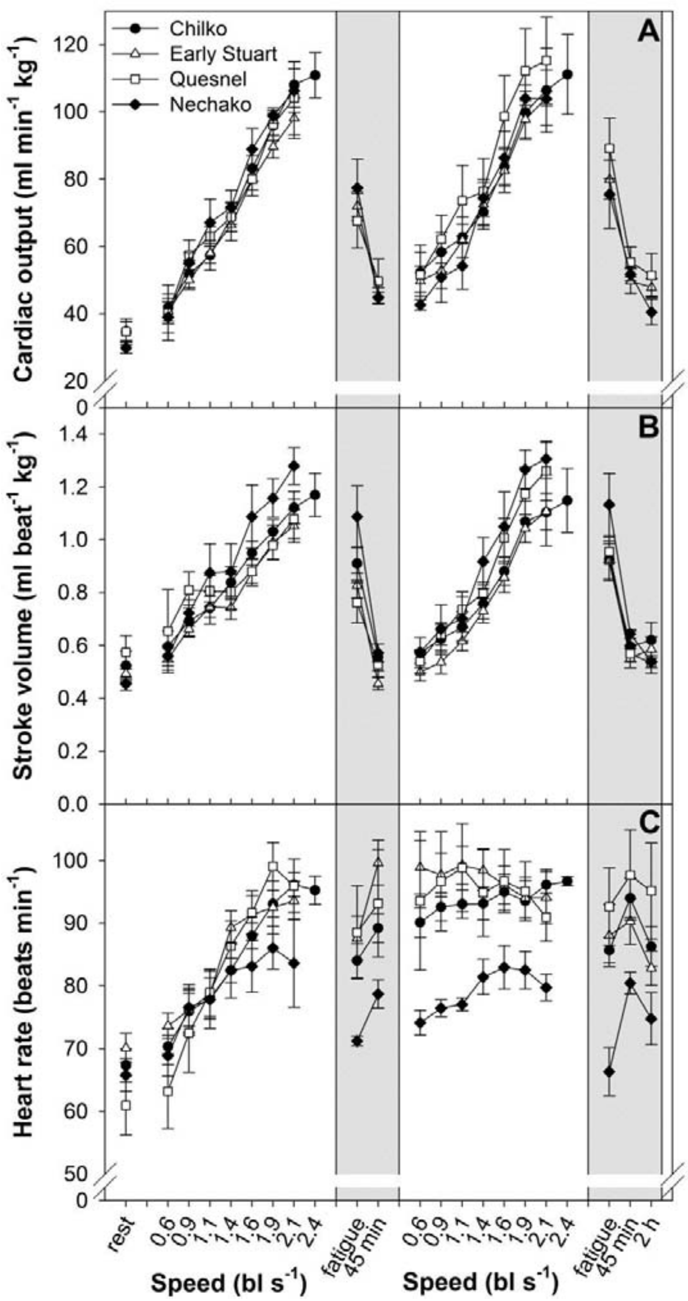

Figure 4.3. (A) Cardiac output, (B) stroke volume and (C) heart rate with swimming speed over two consecutive swim challenges in four populations of sockeye salmon. There were no significant differences in cardiac output or stroke volume among populations or between sexes. Heart rate was significantly lower in Nechako sockeye salmon compared to some of the other populations during the first three speeds of the second swim, see text for details.

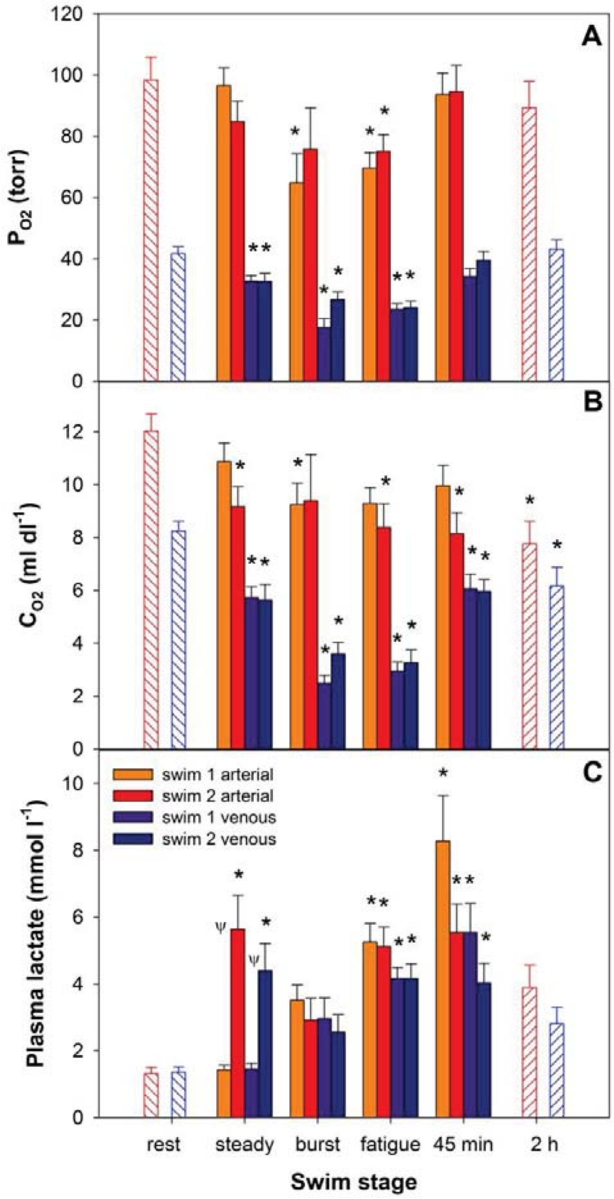

Figure 4.4. Arterial and venous (A) partial pressure of oxygen (P_{O2}), (B) oxygen content (C_{O2}) and (C) plasma lactate levels in Early Stuart, Chilko and Quesnel populations combined, over two consecutive swim challenges. Mean ± SEM are presented, there were no significant differences between sexes. Significant differences from rest are indicated by an asterisk (*), significant differences between swims are indicated by the symbol (ψ). Lactate did not significantly differ between arterial and venous blood samples. P_{O2} and C_{O2} significantly differed between arterial and venous blood samples at every time point, except C_{O2} did not differ at 2 h recovery.

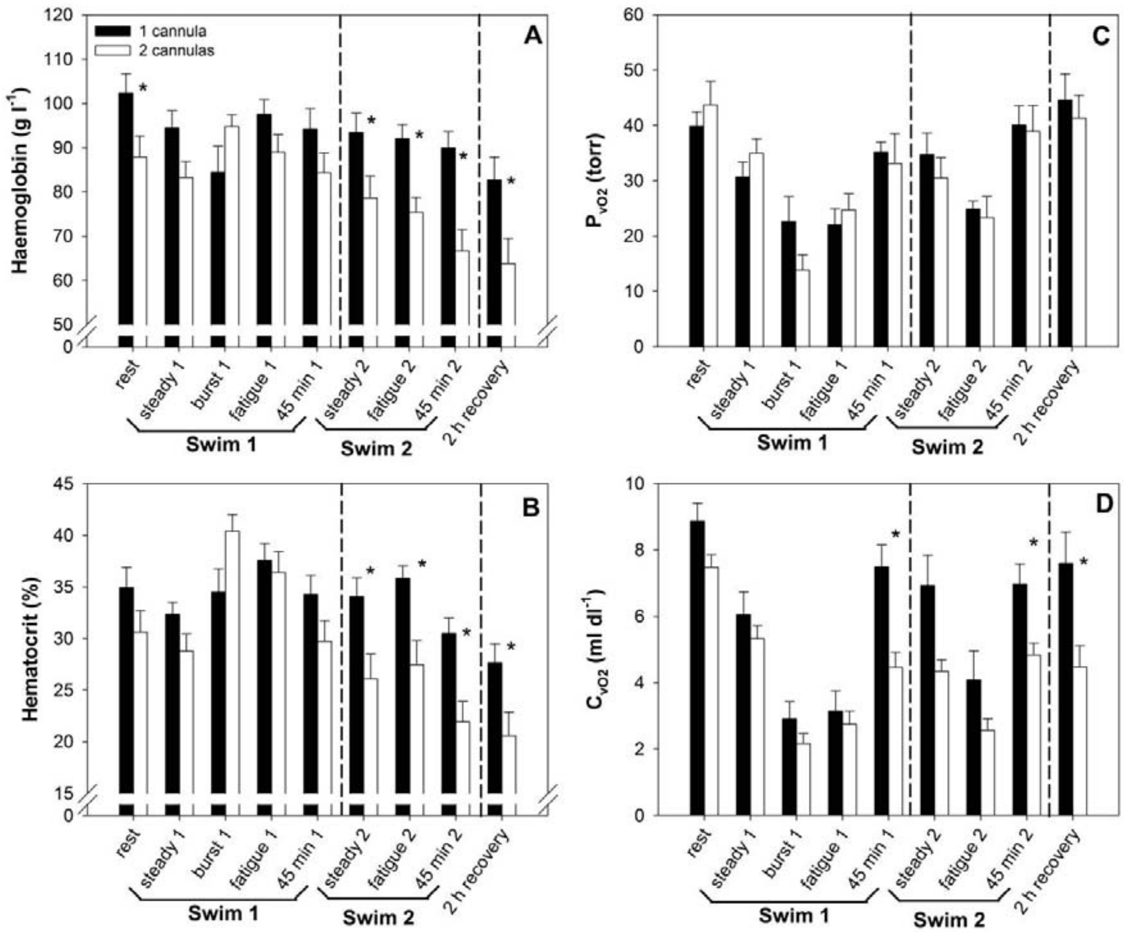

Figure 4.5. Venous (A) haemoglobin, (B) hematocrit, (C) partial pressure of oxygen and (D) oxygen content in fish with both the arterial and venous cannulae operational (2 cannulae, n = 9) and fish with only the venous cannula functioning (1 cannula, n = 11), over two consecutive swim challenges. Mean ± SEM are presented, significant differences between fish with 2 cannulae and those with 1 cannula working are indicated by an asterisk (*). Note that there were insufficient blood samples during burst swimming in the second swim to compare between groups.

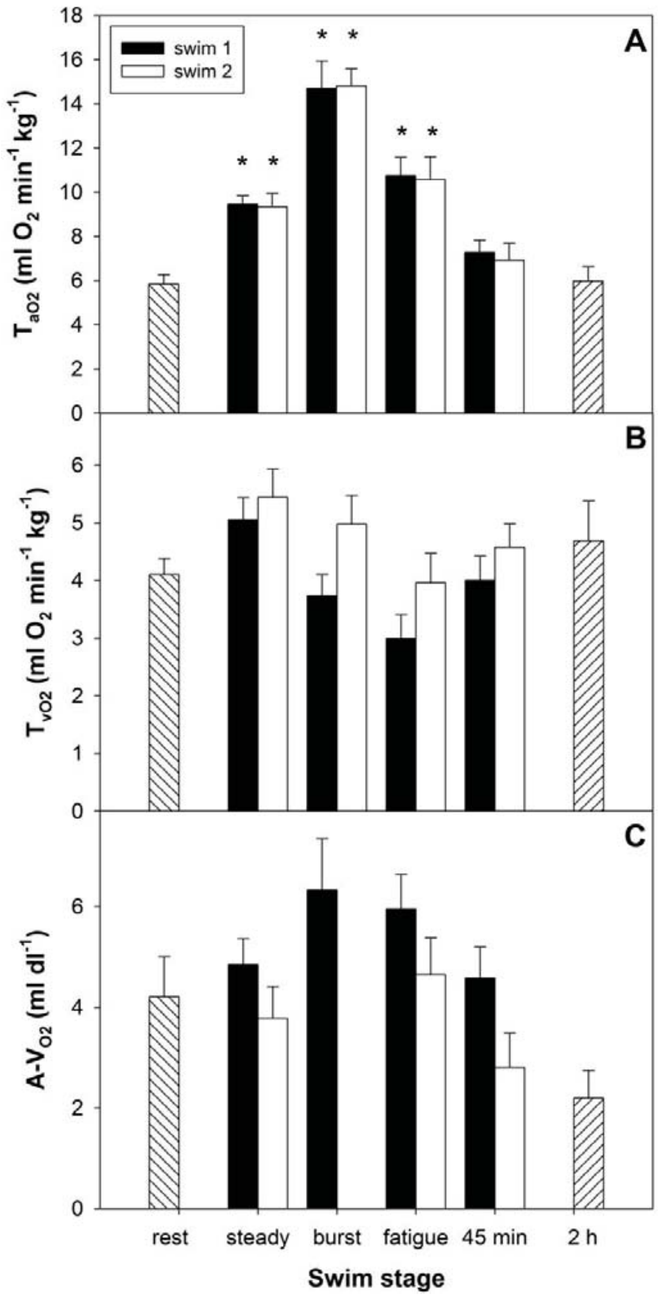

Figure 4.6. (A) Arterial oxygen transport (T_{aO2}), (B) venous oxygen transport (T_{vO2}) and (C) tissue oxygen extraction (A-V_{O2}) in Early Stuart, Chilko and Quesnel populations combined, over two consecutive swim challenges. Measurements were made at rest, during steady swimming (steady), during burst swimming (burst) immediately after the fish quit swimming (fatigue), 45 min after the fatigue (45 min) and 2 h after the conclusion of the second swim test (2 h). Mean ± SEM are presented, significant differences from rest are indicated by an asterisk (*), there were no significant differences between swim 1 and swim 2 or between sexes.

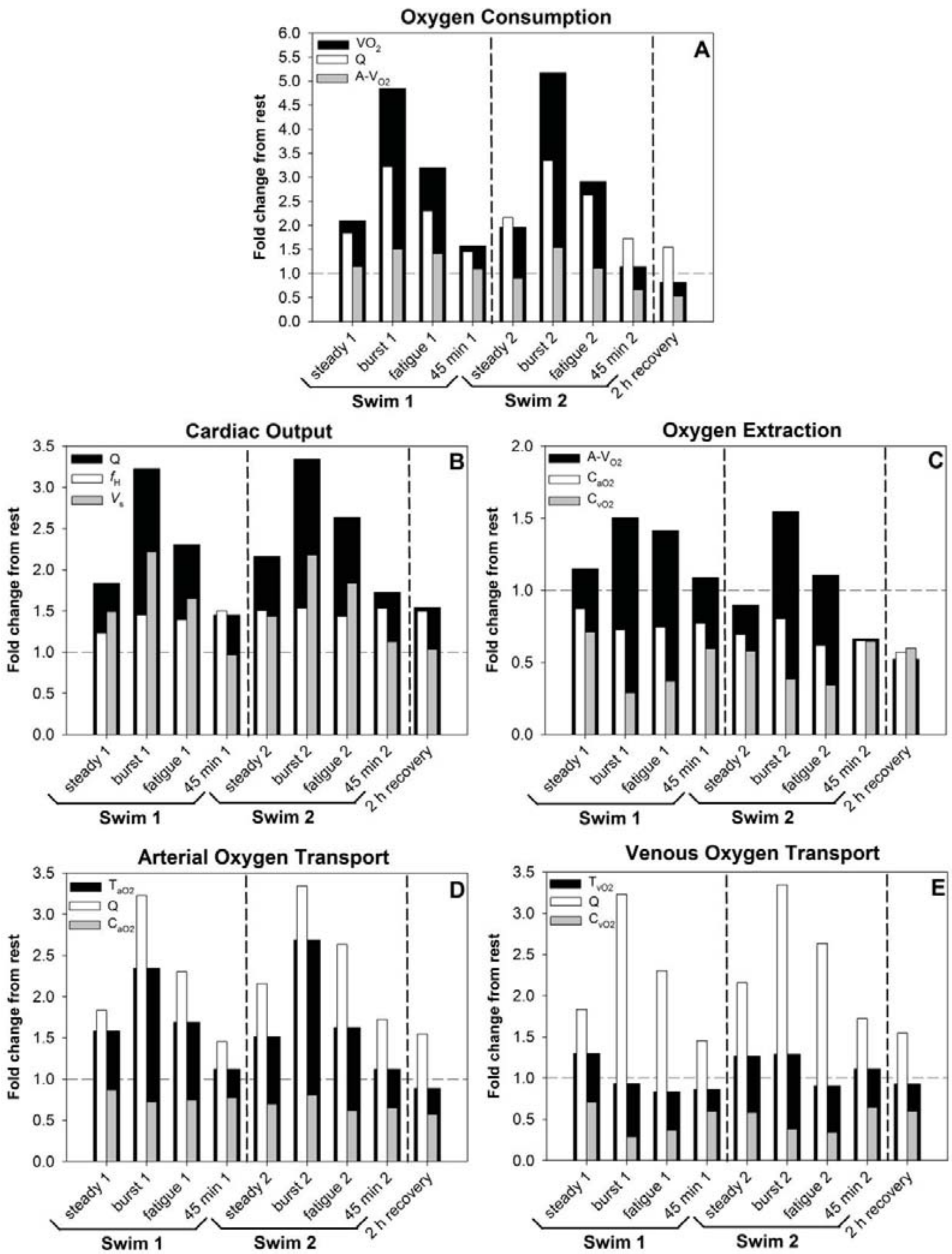

Figure 4.7. Fold changes from rest for (A) oxygen consumption ($VO_2 = \dot{Q} \times A\text{-}V_{O2}$), (B) cardiac output ($\dot{Q} = f_H \times V_s$), (C) tissue oxygen extraction ($A\text{-}V_{O2} = C_{aO2} - C_{vO2}$), (D) arterial oxygen delivery ($T_{aO2} = \dot{Q} \times C_{aO2}$) and (E) venous oxygen transport ($T_{vO2} = \dot{Q} \times C_{vO2}$). f_H = heart rate, V_s = stroke volume, C_{aO2} = arterial oxygen content, C_{vO2} = venous oxygen content. Only fish from Early Stuart, Chilko and Quesnel with both cannulae working were included in this analysis.

Table 4.1. Measurements of critical swimming speed (U_{crit}) and the recovery ratio (RR) in four populations of sockeye salmon at their T_{opt}. Mean ± SEM are presented, there were no significant differences in U_{crit} between sexes, among populations or between swim 1 and swim 2 ($p > 0.05$).

		U_{crit} (bl s^{-1})		**U_{crit} (cm s^{-1})**		
Population	n	U_{crit} 1	U_{crit} 2	U_{crit} 1	U_{crit} 2	RR
Early Stuart	8-9	2.02 ± 0.06	1.91 ± 0.06	122.1 ± 4.1	114.4 ± 3.5	0.95 ± 0.02
Chilko	9-13	1.99 ± 0.08	1.95 ± 0.09	117.8 ± 3.8	114.2 ± 4.9	0.97 ± 0.03
Quesnel	6	2.02 ± 0.11	1.98 ± 0.04	121.1 ± 6.3	118.7 ± 3.2	0.99 ± 0.05
Nechako	3-4	1.94 ± 0.11	1.96 ± 0.06	111.0 ± 5.6	114.4 ± 2.5	1.07 ± 0.06

Table 4.2. Recovery measurements for oxygen consumption ($\dot{M}O_2$), cardiac output ($\dot{Q}$), heart rate (f_H) and stroke volume (V_s) in four sockeye salmon populations after two consecutive U_{crit} swim challenges. Measurements were made at rest, immediately after the fish quit swimming (fatigue), 45 min after fatigue (45-min recovery) and 2 h after the conclusion of the second swim test (2-h recovery). Mean ± SEM are presented. There were no significant differences between sexes. Significant differences from rest are indicated by an asterisk (*), significant differences between swim 1 and swim 2 are indicated by a dagger (‡) and significant differences among populations are indicated by differing letters.

	n	Rest	Fatigue 1	Fatigue 2	45-min recovery 1	45-min recovery 2	2-h recovery 2
$\dot{M}O_2$ (mg O_2 kg^{-1} min^{-1})							
Early Stuart	5-8	3.2 ± 0.2	10.0 ± 0.8*	8.9 ± 0.8*	6.6 ± 0.3*	5.4 ± 0.8*	3.9 ± 0.4
Chilko	8-13	2.9 ± 0.2	10.3 ± 0.9*	9.6 ± 1.1*	5.7 ± 0.7*	5.9 ± 0.6*	3.3 ± 0.4
Quesnel	5-6	2.7 ± 0.2	8.7 ± 1.0*	9.3 ± 1.2*	5.4 ± 1.1*	3.6 ± 0.2*	3.1 ± 0.2
$\dot{Q}$ (ml min^{-1} kg^{-1})							
Early Stuart	7-9	34.8 ± 2.7	72.0 ± 4.3*	79.9 ± 5.8*	45.3 ± 2.5*	49.7 ± 3.7*	47.9 ± 2.7*
Chilko	9-13	34.8 ± 2.9	77.0 ± 6.4*	80.0 ± 8.2*	49.8 ± 4.9*	56.2 ± 5.9*	53.6 ± 6.2*
Quesnel	5-6	34.7 ± 3.9	67.6 ± 8.1*	89.2 ± 9.0*‡	49.6 ± 6.6*	55.4 ± 4.4*	51.4 ± 6.5*
Nechako	3-4	29.9 ± 1.7	77.4 ± 8.5*	75.5 ± 10.2*	44.9 ± 1.6*	51.8 ± 1.9*	40.5 ± 3.8
V_s (ml $beat^{-1}$ kg^{-1})							
Early Stuart	7-9	0.49 ± 0.03	0.83 ± 0.05*	0.92 ± 0.07*	0.46 ± 0.02	0.55 ± 0.04	0.59 ± 0.05
Chilko	9-13	0.53 ± 0.05	0.91 ± 0.06*	0.93 ± 0.08*	0.56 ± 0.05	0.60 ± 0.06	0.62 ± 0.07
Quesnel	5-6	0.57 ± 0.06	0.76 ± 0.08	0.96 ± 0.04*	0.53 ± 0.05	0.57 ± 0.03	0.54 ± 0.04
Nechako	3-4	0.46 ± 0.02	1.09 ± 0.12*	1.13 ± 0.12*	0.57 ± 0.03	0.64 ± 0.02	0.54 ± 0.02
f_H (beats min^{-1})							
Early Stuart	7-9	70.1 ± 2.3	87.6 ± 3.5*	88.0 ± 5.0[ab]*	99.6 ± 3.6*	90.3 ± 3.7*	82.8 ± 2.8*
Chilko	9-13	67.3 ± 2.7	84.0 ± 2.7*	85.7 ± 2.0[ab]*	89.2 ± 2.3*	94.0 ± 3.2*	86.3 ± 3.1*
Quesnel	5-6	60.9 ± 4.7	88.5 ± 7.4*	92.6 ± 6.2[a]*	93.1 ± 8.5*	97.7 ± 7.2*	95.1 ± 7.7*
Nechako	3-4	65.8 ± 2.6	71.2 ± 0.7	66.3 ± 3.8[b]	78.7 ± 2.3	80.4 ± 1.7	74.8 ± 4.2

Table 4.3. Maximum measurements for cardiac output ($\dot{Q}$), heart rate (f_H) and stroke volume (V_s) in four sockeye salmon populations taken over two U_{crit} swim challenges. Scope is the difference between maximum and resting values for each individual fish. Mean ± SEM are presented. There were no significant differences between sexes. Significant differences between swim 1 and swim 2 are indicated by a dagger (‡) and significant differences among populations are indicated by differing letters.

	n	Max 1	Max 2	Scope 1	Scope 2
$\dot{Q}$ *(ml min^{-1} kg^{-1})*					
Early Stuart	8-9	100.3 ± 5.2	104.1 ± 6.4	65.5 ± 4.7	68.2 ± 5.3
Chilko	9-13	105.0 ± 4.9	103.2 ± 9.3	70.2 ± 3.2	68.0 ± 6.5
Quesnel	5-6	101.9 ± 9.2	117.7 ± 12.1‡	67.2 ± 6.6	83.6 ± 7.6‡
Nechako	3-4	107.3 ± 6.7	104.5 ± 1.9	77.4 ± 7.0	74.1 ± 1.2
V_s *(ml beat^{-1} kg^{-1})*					
Early Stuart	8-9	1.08 ± 0.05	1.10 ± 0.06	0.58 ± 0.04^{ab}	0.60 ± 0.04
Chilko	9-13	1.11 ± 0.05	1.12 ± 0.09	0.59 ± 0.04^{ab}	0.57 ± 0.07
Quesnel	5-6	1.09 ± 0.10	1.28 ± 0.11	0.52 ± 0.07^{a}	0.69 ± 0.04‡
Nechako	3-4	1.25 ± 0.07	1.29 ± 0.07	0.80 ± 0.07^{b}	0.82 ± 0.06
f_H *(beats min^{-1})*					
Early Stuart	8-9	93.1 ± 2.2	94.6 ± 2.8	23.0 ± 3.7	23.5 ± 3.3
Chilko	9-13	94.4 ± 1.9	92.0 ± 3.2	27.1 ± 3.5	27.4 ± 5.4
Quesnel	5-6	94.0 ± 3.6	91.3 ± 3.6	33.1 ± 3.6	34.6 ± 2.2
Nechako	3-4	85.9 ± 3.9	81.3 ± 3.0	20.1 ± 4.3	17.5 ± 5.0

Table 4.4. Haematological variables from Early Stuart, Chilko and Quesnel populations combined over two consecutive swim challenges. Arterial and venous blood samples were taken at rest, during steady state swimming (steady) and burst-and-coast swimming (burst), immediately after the fish quit swimming (fatigue), 45 min after the fatigue (45 min) and 2 h after the conclusion of the second swim test (2 h rec). Haemoglobin concentration (Hb), hematocrit (Hct) and mean cell haemoglobin concentration (MCHC) are indicated. Mean ± SEM are presented. There were no significant differences between sexes. Significant differences from rest are indicated by an asterisk (*), significant differences between swim 1 and swim 2 are indicated by a dagger (‡) and significant differences between arterial and venous blood are indicated by differing letters.

		n	Hb ($g\ l^{-1}$)	Hct (%)	MCHC ($g\ l^{-1}$)	Glucose ($mmol\ l^{-1}$)	Chloride ($mmol\ l^{-1}$)	Sodium ($mmol\ l^{-1}$)	Potassium ($mmol\ l^{-1}$)
rest	*arterial*	12	92.4 ± 4.6	31.0 ± 1.7	300.5 ± 6.6	5.6 ± 0.5	127.5 ± 0.9	140.1 ± 1.7	4.9 ± 0.4[a]
	venous	19-20	95.9 ± 3.5	33.0 ± 1.5	293.7 ± 6.0	5.3 ± 0.4	128.2 ± 1.5	142.4 ± 1.7	3.4 ± 0.2[b]
steady 1	*arterial*	13-14	90.3 ± 4.2	30.4 ± 1.6	299.4 ± 6.8	5.1 ± 0.5	129.9 ± 1.4	143.8 ± 1.6	4.6 ± 0.4‡[a]
	venous	18-20	89.4 ± 2.9	30.7 ± 1.0	292.2 ± 5.9	5.1 ± 0.4	130.3 ± 1.3	146.7 ± 1.7	3.2 ± 0.3‡[b]
steady 2	*arterial*	12	81.3 ± 4.7	26.1 ± 1.9	315.7 ± 9.4[a]	5.5 ± 0.5	127.3 ± 1.8	140.5 ± 2.1	8.1 ± 0.6*‡[a]
	venous	15-16	86.0 ± 3.7*	30.1 ± 1.8	291.8 ± 7.7[b]	5.6 ± 0.4	127.4 ± 1.5	144.9 ± 1.9	4.3 ± 0.4‡[b]
burst 1	*arterial*	6	91.8 ± 5.4	33.9 ± 2.5‡	273.1 ± 8.1‡[a]	6.6 ± 0.5	130.2 ± 1.3	145.9 ± 2.1	2.7 ± 0.7*‡
	venous	7	90.4 ± 3.3	37.9 ± 1.7‡	239.4 ± 3.2*‡[b]	6.0 ± 0.7	126.8 ± 1.8	142.1 ± 2.4	2.8 ± 0.9
burst 2	*arterial*	3	86.5 ± 12.9	26.5 ± 4.7‡	329.1 ± 9.7‡[a]	6.5 ± 0.9	129.9 ± 4.9	139.8 ± 4.2	6.1 ± 1.5‡
	venous	8	84.8 ± 4.4*	29.4 ± 1.8‡	290.7 ± 6.0‡[b]	5.1 ± 0.4	126.1 ± 2.4	141.3 ± 2.5	3.5 ± 0.5
fatigue 1	*arterial*	11	87.3 ± 3.0‡	31.1 ± 1.4‡[a]	282.3 ± 4.9[a]	6.2 ± 0.6	133.3 ± 1.2*	152.9 ± 2.0*	2.6 ± 0.3*‡[a]
	venous	15-16	93.3 ± 2.7	37.0 ± 1.3‡[b]	253.8 ± 5.5*[b]	6.3 ± 0.4*	131.7 ± 1.3	152.1 ± 2.1*	1.8 ± 0.3*[b]
fatigue 2	*arterial*	11	79.3 ± 5.0*‡	26.8 ± 2.1‡	301.0 ± 7.7[a]	6.4 ± 0.7	130.0 ± 2.0	146.1 ± 2.2	4.4 ± 0.4‡[a]
	venous	14-15	82.5 ± 3.2*	31.4 ± 1.7‡	272.1 ± 8.8[b]	6.1 ± 0.5	127.9 ± 1.8	147.5 ± 2.4	2.6 ± 0.4[b]
45-min 1	*arterial*	11	89.7 ± 5.5‡	30.4 ± 2.2*‡	297.7 ± 7.0	5.7 ± 0.5	131.0 ± 1.6	148.6 ± 2.2	6.2 ± 0.6[a]
	venous	15-17	89.6 ± 3.3‡	32.1 ± 1.4‡	281.4 ± 6.2	5.4 ± 0.4	130.0 ± 1.3	147.0 ± 2.0	3.5 ± 0.3[b]
45-min 2	*arterial*	10	72.4 ± 5.7*‡	23.7 ± 2.0‡	307.2 ± 4.0	6.3 ± 0.9	129.3 ± 1.9	144.8 ± 1.7	6.4 ± 0.5[a]
	venous	14-17	79.0 ± 4.1*‡	26.5 ± 1.6*‡	302.3 ± 7.2	6.0 ± 0.6	127.6 ± 1.5	144.2 ± 2.3	4.1 ± 0.3[b]
2-h rec	*arterial*	8-9	72.2 ± 6.2*	22.0 ± 2.2*	334.7 ± 12.4*[a]	6.7 ± 0.9	127.3 ± 2.4	144.2 ± 2.2	5.9 ± 1.0[a]
	venous	11-13	74.0 ± 4.6*	24.4 ± 1.7*	306.9 ± 5.4[b]	6.1 ± 0.7	126.5 ± 1.2	143.8 ± 1.9	3.5 ± 0.3[b]

Table 4.5. Haematological variables from Early Stuart, Chilko and Quesnel populations combined over two consecutive swim challenges. Only fish with paired arterial and venous cannulae were included. Haemoglobin concentration (Hb), hematocrit (Hct) and mean cell haemoglobin concentration (MCHC) are indicated. Mean ± SEM are presented. Significant differences between arterial and venous blood are indicated by differing letters.

		n	Hb (g l^{-1})	Hct (%)	MCHC (g l^{-1})	Potassium (mmol l^{-1})
rest	*arterial*	9	89.5 ± 5.1	30.3 ± 2.1	298.0 ± 8.1	4.4 ± 0.4[a]
	venous	9	87.9 ± 4.7	30.6 ± 2.1	290.6 ± 9.6	3.3 ± 0.4[b]
steady 1	*arterial*	9	88.5 ± 4.1[a]	29.9 ± 1.6	297.7 ± 8.1	4.0 ± 0.3[a]
	venous	9	83.3 ± 3.6[b]	28.8 ± 1.7	292.2 ± 8.7	2.7 ± 0.4[b]
steady 2	*arterial*	8	79.0 ± 5.2	25.4 ± 2.3	316.9 ± 13.8	7.6 ± 0.7[a]
	venous	8	78.7 ± 4.9	26.1 ± 2.4	308.3 ± 11.8	4.1 ± 0.2[b]
burst 1	*arterial*	4	95.2 ± 2.2	36.6 ± 1.0[a]	260.4 ± 1.4[a]	1.6 ± 0.2
	venous	4	94.8 ± 2.6	40.4 ± 1.6[b]	235.2 ± 4.8[b]	1.0 ± 0.2
fatigue 1	*arterial*	8	88.9 ± 3.5	32.0 ± 1.6[a]	278.5 ± 4.8[a]	2.4 ± 0.3
	venous	8	89.0 ± 3.9	36.4 ± 2.0[b]	246.3 ± 6.0[b]	1.8 ± 0.5
fatigue 2	*arterial*	8	75.2 ± 5.0	25.1 ± 2.3[a]	304.9 ± 9.7[a]	3.9 ± 0.4[a]
	venous	8	75.4 ± 3.4	27.5 ± 2.3[b]	281.3 ± 12.7[b]	2.0 ± 0.3[b]
45-min 1	*arterial*	8	86.2 ± 5.5	28.9 ± 2.2	300.8 ± 9.3[a]	6.5 ± 0.7[a]
	venous	8	84.4 ± 4.4	29.7 ± 2.0	286.3 ± 7.6[b]	3.2 ± 0.4[b]
45-min 2	*arterial*	8	66.3 ± 4.4	21.6 ± 1.6	308.5 ± 4.9	5.7 ± 0.4[a]
	venous	8	66.7 ± 4.8	21.9 ± 2.0	308.4 ± 11.0	3.9 ± 0.4[b]
2-h rec	*arterial*	6	65.2 ± 7.2	20.1 ± 2.8	333.8 ± 19.0	4.1 ± 0.3[a]
	venous	6	63.8 ± 5.7	20.6 ± 2.3	315.1 ± 9.5	2.9 ± 0.3[b]

CHAPTER 5: CARDIORESPIRATORY COLLAPSE AT HIGH TEMPERATURE IN SOCKEYE SALMON

5.1 Introduction

Chapter 3 provided convincing evidence for a decline in aerobic scope and swim performance outside T_{opt} in every sockeye salmon population examined and confirmed the previously held notion that aerobic and cardiac scopes are closely linked (e.g. Brett, 1971; Farrell et al., 2009). The purpose of this chapter is to examine the mechanism of the decline in aerobic scope above T_{opt} in sockeye salmon.

Temperature has been coined the "ecological master factor" because of its role in biochemistry, physiology, behaviour and ecology (Fry, 1971). As previously discussed, all fish have an optimum temperature (T_{opt}) for performance, outside of which whole animal performance declines until eventually death occurs. The oxygen- and capacity-limited thermal tolerance (OCLTT) hypothesis attributes the decline in aerobic scope above an animal's optimum temperature to capacity limitations of the organ systems that deliver oxygen to the tissues (Pörtner, 2001; Pörtner and Knust, 2007). Any one of the steps in the oxygen cascade (from the environment to the mitochondria) could become problematic outside the T_{opt} window. Among these steps include the capacity for oxygen delivery to the gills, oxygen diffusion across the gills, oxygen transport via the blood, oxygen extraction by the tissues, and oxygen use by the mitochondria (Weibel, 1984). Thus, a limitation could occur at the organ level of the heart, the gills, or the muscle (Brett, 1971; Farrell, 1997; Farrell, 2002; Farrell, 2007; Farrell, 2009; Farrell et al., 2009; Heath and Hughes, 1973; Pörtner, 2002; Steinhausen et al., 2008; Taylor et al., 1997), though evidence supporting a limitation at any single site is incomplete.

I used the OCLTT hypothesis as a framework to examine cardiorespiratory collapse at high temperature in sockeye salmon. I hypothesized that the limitation on aerobic performance above T_{opt} is initiated by an oxygen limitation at the level of the heart.

It is possible to examine most of the critical steps in the oxygen cascade by simultaneously measuring $\dot{M}O_2$, $\dot{Q}$, and oxygen status [partial pressure (P_{O2}) and content (C_{O2})] in arterial and venous blood as a function of increasing temperature. For example, if there was a limitation in delivering oxygen to the gill or oxygen diffusion at the gill, I would expect P_{aO2} and C_{aO2} to decrease above T_{opt}. Alternatively, a limitation at the level of the heart would be apparent by a plateau or decrease in $\dot{Q}_{max}$ at temperatures above T_{opt}, Finally, if sufficient blood was delivered to the working muscles, but a limitation in oxygen diffusion to mitochondria was present, P_{vO2} would remain constant above T_{opt}.

Most of the studies to date examining temperature effects on aerobic scope in fish have not directly measured all the required variables outlined above (e.g. Brett, 1971; Fry, 1947; Taylor et al., 1993). Some variables have been measured in resting fish acutely exposed to increasing temperatures (e.g. Clark et al., 2008b; Gollock et al., 2006; Heath and Hughes, 1973; Sartoris et al., 2003), however, only Steinhausen et al. (2008) has directly measured all these variables in fish swimming near $\dot{M}O_{2max}$. Therefore, this is the first comprehensive study to simultaneously and directly measure all the necessary variables in fish swimming at U_{crit} in order to address these mechanistic questions.

To maximize statistical power, my approach was to pool data for Early Stuart, Chilko and Quesnel sockeye salmon since they did not differ in maximum cardiorespiratory performance

(Chapter 4) and had a similar T_{opt} (~17°C, Chapter 3). I pooled the data into four temperature groups based on aerobic scope (Fig 5.1). The T_{opt} grouping (n = 33) combined data for sockeye salmon that attained 90-100% of population-specific maximum aerobic scope. The temperature range for the T_{opt} grouping was 15-20°C for all three populations. The $T_{min50\text{-}90}$ grouping (n = 8) included sockeye salmon at temperatures below T_{opt} attaining only 50-90% of maximum aerobic scope. The $T_{min50\text{-}90}$ grouping corresponded to 12°C and 9-10°C, respectively, for Early Stuart and Chilko populations and no Quesnel sockeye salmon were included. The $T_{max50\text{-}90}$ grouping (n = 11), included fish swum at temperatures above T_{opt}, and attaining 50-90% of maximum aerobic scope. This grouping typically corresponded to 22-23°C for Early Stuart and Quesnel sockeye salmon and 24-25°C for Chilko sockeye salmon. The final $T_{max0\text{-}50}$ grouping (n = 8) included fish above T_{opt} whose aerobic scope was only 0-50% of maximum. This corresponded to 23-26°C for Early Stuart and Quesnel sockeye salmon and 25-26°C for Chilko sockeye salmon. While many fish were swum twice (e.g. all fish in the T_{opt} grouping and several fish in the $T_{min50\text{-}90}$ and $T_{max50\text{-}90}$ groupings), only the first swim was compared across the four groupings. This approach avoided the potentially confounding effect of incomplete recovery from the first swim. Detailed materials and methods are found in Chapter 2 (sections 2.2-2.7 and 2.10).

5.2 Results

5.2.1 Cardiorespiratory and Swimming Performance

Resting, Swimming, Maximum & Scope

The cardiorespiratory response of the four temperature groupings with swimming are shown in Fig 5.2. The corresponding rest, maximum and scope values for each temperature grouping are shown in Fig 5.3.

As defined, aerobic scope was highest at T_{opt}. Also, aerobic scope did not significantly differ between $T_{min50\text{-}90}$ and $T_{max50\text{-}90}$, and was lowest at $T_{max0\text{-}50}$ (Fig 5.3). Therefore, the four temperature groupings created the equivalent of a Fry aerobic scope curve.

The response for aerobic scope reflected the different responses of $\dot{M}O_{2rest}$ and $\dot{M}O_{2max}$ to temperature. As expected, $\dot{M}O_{2rest}$ increased significantly from the lowest to the highest temperature grouping (Fig 5.3). While swimming significantly increased $\dot{M}O_2$ for the $T_{min50\text{-}90}$, T_{opt} and $T_{max50\text{-}90}$ groupings, it did not for the $T_{max0\text{-}50}$ grouping (Fig 5.2). Furthermore, $\dot{M}O_{2max}$ increased significantly between $T_{min50\text{-}90}$ and T_{opt}, did not differ between T_{opt} and $T_{max50\text{-}90}$, and decreased significantly at $T_{max0\text{-}50}$ (Fig 5.3).

$\dot{Q}_{rest}$ and $\dot{Q}_{max}$ varied with temperature with similar patterns as $\dot{M}O_{2rest}$ and $\dot{M}O_{2max}$, respectively (Fig 5.3). $\dot{Q}$ significantly increased with swimming for the $T_{min50\text{-}90}$, T_{opt} and $T_{max50\text{-}90}$ groupings, but not the $T_{max0\text{-}50}$ group (Fig 5.2). Cardiac scope at $T_{max0\text{-}50}$ was significantly lower compared to the other three temperature groupings (Fig 5.3).

The relative contribution of f_H and V_s to $\dot{Q}$ varied with temperature and with swimming. f_{Hrest} significantly increased with each temperature grouping (Fig 5.3). In contrast, V_{srest} did not change substantially among temperature groups, but was significantly lower at $T_{max0\text{-}50}$ compared with T_{opt} (Fig 5.3).

At T_{opt}, swimming increased both V_s and f_H (Fig 5.2). Both $T_{min50\text{-}90}$ and $T_{max50\text{-}90}$ groupings only increased V_s with swimming, f_H did not change significantly from rest at any swimming speed (Fig 5.2). At $T_{max0\text{-}50}$, f_H actually decreased during swimming and V_s did not change from rest (Fig 5.2). Notably, at the lowest swim speeds, V_s was similar across temperature groupings. However, differences became apparent at higher swim velocities: V_s was highest in the $T_{min50\text{-}90}$ grouping and decreased with increasing temperature groups (Fig 5.2).

f_{Hmax} significantly increased with temperature until $T_{max50\text{-}90}$ and plateaued between the two warmest groups (Fig 5.3). Scope for f_H was highest at T_{opt}, approached zero for $T_{max50\text{-}90}$ and was actually negative for $T_{max0\text{-}50}$. V_{smax} significantly decreased above $T_{min50\text{-}90}$. As a result, scope for V_s was maintained between $T_{min50\text{-}90}$ and $T_{max50\text{-}90}$ but decreased significantly at $T_{max0\text{-}50}$.

For comparison among these cardiorespiratory variables with temperature, scope is presented as a percentage of its highest value (Fig 5.4). Scope was highest at T_{opt} for $\dot{M}O_2$, $\dot{Q}$ and f_H and highest at $T_{min50\text{-}90}$ for V_s (Fig 5.4). While scope for $\dot{M}O_2$, $\dot{Q}$ and V_s decreased by 13- 25% of maximum at $T_{max50\text{-}90}$, scope for f_H plummeted by 80% of maximum at $T_{max50\text{-}90}$ and became almost -40% of maximum for f_H at $T_{max0\text{-}50}$. At $T_{max0\text{-}50}$, scope for $\dot{M}O_2$, $\dot{Q}$ and V_s declined to 16-20% of maximum.

No cardiac disrhythmias or deaths accompanied swimming at either $T_{min50\text{-}90}$ or T_{opt}. In contrast, every fish swum at $T_{max0\text{-}50}$ exhibited an irregular heart rate immediately after failing the swim test. In addition, 57% of these fish exhibited cardiac disrhythmias during swimming, shortly before fatigue (Fig 5.5). Despite decreasing the temperature immediately following fatigue, 29% of the $T_{max0\text{-}50}$ fish died, even though they had swum at 1.1-1.5 bl s^{-1} before reaching fatigue. While 27% of $T_{max50\text{-}90}$ fish exhibited cardiac disrhythmias during swimming or fatigue, none died.

Swimming Performance

$T_{max0\text{-}50}$ fish attained a lower maximum swim speed compared to the other three groupings (Fig 5.2, 5.6), which is consistent with $\dot{M}O_2$ and $\dot{Q}$ not changing significantly during the swim test of this group.

Cost of transport (COT) at the slowest swim speed (0.4 bl s^{-1} = "rest") was ~ 2-fold higher in the $T_{max50\text{-}90}$ and $T_{max0\text{-}50}$ groups relative to the T_{opt} and $T_{min50\text{-}90}$ groups (Fig 5.6). COT decreased with increasing swimming speed and was maintained ~0.12-0.26 mg O_2 kg^{-1} m^{-1} across all groups. The $T_{max50\text{-}90}$ and $T_{max0\text{-}50}$ groups tended to have a higher COT compared to the T_{opt} and $T_{min50\text{-}90}$ groups across all speeds.

Similarly, COT-$\dot{Q}$ was significantly lower at $T_{min50\text{-}90}$ compared to the $T_{max50\text{-}90}$ and $T_{max0\text{-}50}$ groups at the slowest speed (Fig 5.6). COT-$\dot{Q}$ decreased with increasing swimming speeds until ~0.87 bl s^{-1}, after which it was maintained at around 0.7-1.9 ml kg^{-1} m^{-1} in $T_{min50\text{-}90}$, T_{opt} and $T_{max50\text{-}90}$. In contrast, COT-$\dot{Q}$ declined steadily in $T_{max0\text{-}50}$ until the fish quit swimming. Again, warmer temperature groups tended to have a higher COT-$\dot{Q}$ relative to the cooler groups across all speeds. The opposite temperature pattern was observed in COT_{net} and COT-$\dot{Q}_{net}$, both of which tended to be higher in colder groups.

5.2.2 Oxygen Transport and Removal by Tissues

Resting P_{aO2} and C_{aO2} were not significantly affected by an acute increase in temperature from 12°C (the starting temperature) to the test temperature (22-26°C) in either the $T_{max50-90}$ or $T_{max0-50}$ groupings (Table 5.1). The tendency for P_{aO2} to increase with temperature can likely be attributed to a decreased affinity for haemoglobin (right-shift in the oxyhaemoglobin dissociation curve).

P_{aO2} and C_{aO2} did not significantly differ across temperature groups at any of the swimming speeds (Table 5.2). There was an overall trend for P_{aO2} and C_{aO2} to decrease with swimming relative to rest (Table 5.2, Fig 5.7).

There were no significant differences in [Hb], Hct, or MCHC across temperature groups or with swimming, except that MCHC was significantly lower at fatigue relative to rest in the $T_{max50-90}$ grouping (Table 5.3). As a result, any changes in C_{aO2} or C_{vO2} reflected changes in Hb saturation. In fact, when C_{aO2} was divided by [Hb], there were no significant differences across temperatures or with swim speed (data not shown).

T_{aO2} was significantly lower during burst swimming and fatigue for the $T_{max0-50}$ grouping when compared with T_{opt} (Fig 5.8, Table 5.2). While the $T_{min50-90}$, T_{opt} and $T_{max50-90}$ groupings increased T_{aO2} by 294%, 153% and 80%, respectively, during burst swimming compared with rest, at $T_{max0-50}$ fish were unable to significantly increase T_{aO2} from resting values.

Unlike arterial blood, both P_{vO2} and C_{vO2} varied significantly among temperature groups (Table 5.2). Resting P_{vO2} declined above T_{opt}. Resting P_{vO2} was only 10 torr at $T_{max0-50}$, or 25% of the T_{opt} value. As a result, resting C_{vO2} at $T_{max0-50}$ was only 16-20% of the C_{vO2} for the other three temperature groupings.

At fatigue, C_{vO2} and P_{vO2} were 114% and 77%, respectively, lower in the $T_{max50\text{-}90}$ group compared to T_{opt}. Limited blood samples at $T_{max0\text{-}50}$ prevented analysis for swimming and fatigue (Table 5.2), but these limited numbers showed a decreasing trend for both resting and fatigue P_{vO2} and C_{vO2} at temperatures above T_{opt} (Fig 5.7).

The increase in oxygen uptake by swimming muscles was reflected in the significant decline of both P_{vO2} and C_{vO2} with swimming (Table 5.2). Analysis of $A\text{-}V_{O2}$ was restricted to paired arterial and venous samples (Table 5.2). With this caveat, the trend of increasing $A\text{-}V_{O2}$ with swimming and at warmer temperatures did not reach statistical significance, likely due to low statistical power (Table 5.2).

At rest, T_{vO2} was over 4-fold lower at $T_{max0\text{-}50}$ compared to T_{opt} (Table 5.2). In addition, T_{vO2} was maintained at resting levels throughout the swim test at T_{opt}, while it significantly declined at burst and fatigue in $T_{max50\text{-}90}$ fish (Fig 5.8).

5.2.3 Other Blood Variables

Plasma glucose did not vary significantly with temperature or swimming except for the $T_{max0\text{-}50}$ grouping where plasma glucose significantly declined with swimming (Table 5.3). In contrast, plasma lactate varied significantly with both temperature and swimming. Resting plasma lactate was more than 3-fold significantly higher in $T_{max0\text{-}50}$ compared to T_{opt} fish. At fatigue, the T_{opt}, $T_{max50\text{-}90}$ and $T_{max0\text{-}50}$ groupings all displayed significant elevations in plasma lactate, increasing by 2 to 4-fold relative to resting levels. Moreover, plasma lactate was significantly higher in $T_{max50\text{-}90}$ fish at fatigue compared to the other groups (Table 5.3).

Plasma sodium varied significantly with both temperature and swim speed (Table 5.3). It tended to be highest at T_{opt} and increased with swimming speed for T_{opt} and $T_{max50\text{-}90}$ fish. Plasma potassium did not vary significantly with temperature (Table 5.3). Plasma potassium tended to decrease with swimming speed and was lowest at fatigue. Plasma chloride varied significantly with temperature, but not with swimming (Table 5.3). In general, plasma chloride was significantly higher at T_{opt} relative to $T_{max0\text{-}50}$.

5.3 Discussion

This study is the most comprehensive assessment of the oxygen cascade in fish swimming at temperatures bracketing their T_{opt}. It greatly extends upon the study by Steinhausen et al. (2008), which swam fish at a constant speed (~1.35 bl s^{-1} or ~70% of maximum) while acutely increasing the water temperature, by swimming individual fish to U_{crit} and at discrete temperatures.

Aerobic scope and swim performance collapsed at temperatures above T_{opt}, which is consistent with previous assertions that a limitation in maximum cardiorespiratory performance inhibits exercise at high temperatures in salmonids (Brett, 1971; Farrell, 1997; Farrell, 2002; Farrell, 2009; Farrell et al., 2009; Lannig et al., 2004; Mark et al., 2002; Pörtner et al., 2004; Pörtner and Knust, 2007; Sartoris et al., 2003; Steinhausen et al., 2008; Taylor et al., 1996). In addition, novel findings with respect to venous oxygen status, heart rate and stroke volume were revealed.

The present study provides clear evidence for a cardiac limitation in fish swimming at warm temperatures. At temperatures above T_{opt}, $\dot{Q}_{max}$ failed to increase because f_{Hrest} reached its maximum and could not further increase during swimming. Moreover, cardiac disrhythmias developed at the highest temperatures grouping. As discussed further below, changes in both P_{aO2} and C_{aO2} were minor at warm temperature, so neither oxygen delivery to or across the gills presented themselves as a major problem in terms of the oxygen cascade, despite a decrease in oxygen content in the water. Instead, a perfusion limitation developed because T_{aO2} failed to increase above T_{opt} given that $\dot{Q}$ did not increase and C_{aO2} was unchanged. A diffusion limitation at the swimming muscles likely followed the cardiac limitation since P_{vO2} and C_{vO2} did decrease significantly at warm temperatures.

5.3.1 Fish Performance during Swim Challenge

Swimming a sufficient number of fish to resolve any subtle changes that occur in the oxygen cascade as a function of warming had many inherent challenges. Arterial and venous cannulae had to remain functional for multiple samples, yet blood sampling was selective to minimize hemodilution. In addition, adult Pacific salmon often acquire a fungal infection on the gills during migration. My fish were no exception, which may have contributed to the individual variability for P_{aO2} (see below). To compensate and increase statistical power, I pooled three populations and created four temperature groupings relative to T_{opt}. Notably, a similar analysis of the temperature responses in Chilko sockeye salmon for $\dot{M}O_2$, $\dot{Q}$, f_H and V_s (see Chapter 3) mimicked the responses observed here for the pooled populations. In addition, the variance was small for $\dot{M}O_{2rest}$, $\dot{M}O_{2max}$ and aerobic scope in each of the pooled temperature categories (see Fig 5.3). Furthermore, aerobic, cardiac and heart rate scopes measured over the full range of temperatures and populations were all positively correlated (see Chapter 3). Therefore, I have confidence that pooling was valid.

Sex-specific differences in cardiorespiratory physiology and blood oxygen status were not apparent at T_{opt} (see Chapters 3 and 4). Sex-specific differences were not considered in the analysis presented here due to low n-values. However, each temperature grouping contained approximately equal numbers of males and females, which offsets concerns regarding sex-differences. Nevertheless, the possibility that temperature tolerance as well as the physiological response to temperature varies between males and females has not been excluded and therefore should be considered in future studies.

As expected, fish swum above T_{opt} and attaining less than 50% of maximum aerobic scope had a much lower maximum swim velocity compared to the other groups. This result provides evidence of the link between aerobic scope and swim performance.

Also, lactate was elevated at temperatures above T_{opt} and at fatigue. It is well known that as fish approach U_{crit}, swimming gait transitions to burst-and-coast behaviours, which activates the white glycolytic muscles relying on anaerobic metabolism, producing lactate and lowering blood pH (Brauner et al., 2000). Moreover, fish are known to increase their reliance on anaerobic swimming at high temperatures (Brett, 1964; Jain and Farrell, 2003; Steinhausen et al., 2008), which was clearly evident here.

There was a clear trend for increasing COT and COT-$\dot{Q}$ with increasing temperature, though the characteristic “U-shaped” pattern of COT with speed (e.g. Hoyt and Taylor, 1981; Lee et al., 2003c; Prange, 1976; Prange and Schmidt-Nielsen, 1970; Wakeman and Wohlschlag, 1982) was not observed in any of the temperature groups. The remaining cardiovascular and oxygen status results are discussed in the sections below.

Arterial [Hb] and Hct did not significantly vary with temperature or swimming, supporting previous findings (Clark et al., 2008b; Steinhausen et al., 2008). A minor decrease in MCHC was observed at warm temperatures during swimming, which was primarily due to a general non-significant trend for increased Hct. Similar observations have previously been made in resting chinook (Clark et al., 2008b). Previous studies have shown a variable response of Hct with temperature. Hct has been shown to increase by up to 27% due to splenic contraction in acutely warmed resting rainbow trout (Sandblom and Axelsson, 2007), to decrease by 50% in warm-acclimated rainbow trout (Taylor et al., 1993) and to have minimal effects with temperature (see Farrell, 1997). Thus, though splenic contraction can be a short-term solution to increase [Hb] during swimming or acute temperature changes, this was not observed in the present study.

Plasma ions were differentially affected by temperature and swimming. Both plasma chloride and sodium were reduced above T_{opt}, in contrast to resting chinook salmon (Clark et al., 2008b). Plasma potassium was insensitive to temperature. The decrease in plasma potassium with swimming sharply contrasts previous results (Holk and Lykkeboe, 1998; Nielsen et al., 1994; Nielsen and Lykkeboe, 1992a; Steinhausen et al., 2008). As discussed in Chapter 4, increased plasma potassium during swimming has been attributed to potassium loss from working muscles and associated with reduced excitability of muscle cells, which is suggested to contribute to muscle fatigue (both cardiac and skeletal) (Bangsbo et al., 1996; Sjøgaard, 1996; Holk and Lykkeboe, 1998; Nielsen and Lykkeboe, 1992a). The decreased potassium levels observed here are interesting and warrant further study.

5.3.2 The Possibility of a Limitation in Gill Oxygen Uptake

Water oxygen content decreases by around 2% $°C^{-1}$ with increasing water temperature (Dejours, 1975), limiting environmental oxygen availability at high temperatures. In addition, haemoglobin oxygen affinity decreases (the oxyhaemoglobin dissociation curve shifts to the right) with high temperature exposure (Jensen et al., 1998; Perry and Reid, 1994), which hampers oxygen uptake at the gill although it facilitates tissue oxygen extraction. Accordingly, a limitation in oxygen uptake at the gills (either water delivery to the gills or diffusion of oxygen across the gills) has been proposed as a mechanism causing decreased cardiorespiratory and swimming performance at elevated temperatures in fish (Brett, 1971; Heath and Hughes, 1973; Taylor et al., 1997). In support of this hypothesis, Heath and Hughes (1973) showed that C_{aO2} decreased with acute increases in water temperature in resting rainbow trout though hematocrit was not measured concurrently to check for haemodilution. Similarly, Taylor et al. (1993) found a decrease in C_{aO2} at 18°C in resting and swimming rainbow trout seasonally acclimated to 4, 11 and 18°C, but hematocrit was halved. Clark et al. (2008b) found that large, but not smaller, resting adult chinook salmon decreased C_{aO2} and P_{aO2} during acute warming, but narrow holding tubes may have constrained gill movements in the larger fish.

In contrast, the present study found that C_{aO2} and P_{aO2} did not significantly differ across the four temperature categories. Similarly, Steinhausen et al. (2008) found that C_{aO2} and hematocrit remained constant in both resting and swimming sockeye salmon exposed to acute increases in temperature. Moreover, P_{aO2} increased in resting and remained constant in swimming sockeye salmon exposed to increasing temperatures. Likewise, Sartoris et al. (2003) found that P_{aO2} remained constant during acute warming in Atlantic cod. Thus, there is accumulating evidence that neither water delivery to the gills nor oxygen diffusion across the gills become limited at temperatures warmer than T_{opt}.

P_{aO2} and C_{aO2} did tend to decrease with swimming. A similar phenomenon was observed in swimming sockeye salmon exposed to acute temperature increases (Steinhausen et al., 2008). If instead fish had maintained or increased C_{aO2} during swimming, T_{aO2} would have been higher, which would have been particularly beneficial for warm fish.

Notably, there were a couple experimental concerns, which relate to the variation in P_{aO2} among individual fish. P_{aO2} and C_{aO2} varied considerably, ranging from 49-128 torr and 6.7-14.8 ml dl^{-1}, respectively, at rest, and from 42-104 torr and 6.1-16.1 ml dl^{-1}, respectively, at fatigue. As described in Chapter 4, this may be attributed to the progressive accumulation of fungus on the body and gills. Gill fungal infection could increase the diffusion distance and decrease the maximum surface area for oxygen, creating variable P_{aO2}. In addition, gill damage during surgery (implantation of the flowprobe and venous catheter occurs in the opercular cavity adjacent to the gills) may have created similar gill diffusion problems that might account for the tendency for C_{aO2} to decrease with swimming. Even so, arterial oxygen saturation was not substantially hampered during swimming.

5.3.3 The Possibility of a Limitation in Cardiac Performance

The idea that the temperature dependence of aerobic scope is closely linked with that of cardiac scope is clearly supported by the similarity of the temperature-induced changes for $\dot{Q}$ and $\dot{M}O_2$ in resting and swimming fish (also see Chapter 3). A striking observation was that maximum $\dot{M}O_2$, $\dot{Q}$ and T_{aO2} all failed to increase above T_{opt}, and all three decreased at $T_{max0\text{-}50}$.

This finding provides evidence of a cardiac limitation at high temperatures, supporting earlier studies (Brett, 1971; Steinhausen et al., 2008; Taylor et al., 1996).

Warming increased $\dot{Q}$ in resting and swimming fish entirely via an increase in f_H, corroborating previous work (Clark et al., 2008b; Sandblom and Axelsson, 2007; Steinhausen et al., 2008). Such increases in f_H are probably mediated through a direct temperature effect on the pacemaker rate (Randall, 1970). The highest f_H was achieved in resting fish in the highest temperature group (mean: 123.9 beats min^{-1}; range: 117-135 beats min^{-1}), and thus sometimes exceeded the proposed maximum of 120 beat min^{-1} in active fish (Davie and Farrell, 1991; Farrell, 1991). However, at temperatures above T_{opt}, f_H was unable to increase above resting levels during swimming and even decreased below resting levels for the $T_{max0\text{-}50}$ grouping. The negative scope for f_H is a novel finding for fish. Because scope for f_H became limiting at a lower temperature compared to scope for V_s or $\dot{Q}$, the present study provides support for the previous proposal (Farrell, 2009; Steinhausen et al., 2008) that reduced scope for f_H may be the mechanism that limits $\dot{Q}_{max}$ above T_{opt}.

Cardiac disrhythmias at the highest test temperatures provide further evidence of a cardiac limitation. Disrhythmias were never present in resting fish at any temperature, nor in swimming or fatigued fish at T_{opt} or $T_{min50\text{-}90}$. Yet, every fish in the $T_{max0\text{-}50}$ group exhibited cardiac disrhythmias during fatigue and 50% displayed disrhythmias during swimming. What is truly remarkable is that the fish at the highest test temperatures continued to swim, albeit to a lower swim speed, despite severe disrhythmias and dramatic declines in P_{vO2}, C_{vO2}, T_{aO2} and T_{vO2}, demonstrating an impressive tenacity that is obviously fuelled by anaerobic swimming given the high plasma lactate levels. This tenacity, however, could result in delayed mortality. Fish that displayed the most severe disrhythmias (29% of the $T_{max0\text{-}50}$ fish) died, despite quickly decreasing the water temperature following fatigue. In every case, the cardiac disrhythmia was preceded by bradycardia. While irregular heart rates have been reported in resting rainbow trout, Atlantic cod and chinook salmon acutely exposed to high temperatures (Clark et al., 2008b; Gollock et al., 2006; Heath and Hughes, 1973), this is the first known study to report bradycardia followed by disrhythmia in a swimming fish at high temperature.

The mechanism of the bradycardia and subsequent cardiac disrhythmia is unclear. During anaerobic swimming, venous blood becomes acidotic (low pH), hypoxemic (low P_{vO2}) and hyperkalemic (high K^+) (Holk and Lykkeboe, 1998; Kiceniuk and Jones, 1977), all of which can inhibit cardiac contractility (Dridezic and Gesser, 1994). High temperatures can exacerbate these conditions as salmonids rely more on anaerobic metabolism (Brett, 1964; Jain and Farrell, 2003; Steinhausen et al., 2008), though hyperkalemia was absent here. Simulated exercise conditions at high temperature with *in situ* rainbow trout hearts severely impaired maximum cardiac performance (Hanson and Farrell, 2007), thus it is possible that the deleterious venous blood environment caused the bradycardia and disrhythmias. However, bradycardia could also be under central nervous system control via the vagus nerve. A reduction in f_H would increase the residence time of blood in the lumen of the heart which may enhance oxygen delivery to the spongy myocardium (see below). The critical experiments to examine these questions require the use of atropine or vagotomy to determine if heart rate increases when the vagal tone is blocked.

Since scope for f_H declined above T_{opt}, $\dot{Q}$ could only increase by an increase in V_s. This was not evident. Resting V_s failed to increase with increasing temperatures, corroborating previous studies (Brodeur et al., 2001; Clark et al., 2008b; Gamperl et al., 2011; Gollock et al., 2006; Mendonça and Gamperl, 2010; Sandblom and Axelsson, 2007; Steinhausen et al., 2008). In addition, a novel negative relationship between temperature and V_s was observed here in swimming fish. V_{smax} decreased at the highest temperatures, resulting in a decreased scope for V_s. This result contrasts a previous report, which suggested that V_s was insensitive to temperature in salmonids exercising at ~75% of U_{crit} (Steinhausen et al., 2008). However, the present study pushed fish to swim at higher temperatures and higher speeds, resulting in substantially reduced scope relative to previous studies, which may have resulted in the observed decrease in V_{smax}.

Several potential reasons have been suggested for why V_s does not increase in conjunction with f_H at high temperature, especially since it can triple with swimming (Brett, 1971; Kiceniuk and Jones, 1977; Stevens et al., 1967). First, venous return and end-diastolic volume must first increase in order for cardiac contractility to increase V_s (Sandblom and Axelsson, 2007) because cardiac end-systolic volume is essentially zero in salmonids (Franklin and Davie, 1992). In addition, cardiac contractility could be inhibited by the deleterious blood environment at high temperatures (e.g. low pH, high K^+, low P_{vO2},) (Hanson et al., 2006). Finally, the negative force-frequency relationship for fish cardiac muscle dictates that cardiac contractility decreases with increasing contraction frequency (Hove-Madsen, 1992; Shiels et al., 2002). Accordingly, the high f_H at high temperatures decreases both filling time and ventricular contractions which may increase end-systolic volume and reduce V_s. In support of this concept, a recent study by Gamperl et al. (2011) demonstrated that elevated temperature, per se, does not limit the ability of rainbow trout to increase V_s since zatebradine treatment halved f_H at the highest test temperature but V_s doubled to maintain $\dot{Q}$. This result suggests that perhaps the increase in f_H associated with high temperature is an inescapable direct effect of temperature on the pacemaker, which prevents any beneficial changes in V_s.

It is important to note that the heart is a muscle requiring oxygen, and its requirements increase 3 to 5-fold during exercise, equating approximately to 1% of total $\dot{M}O_2$ (Farrell and

Steffensen, 1987). Salmonid hearts have two oxygen supply routes to their two distinct types of myocardium (see Chapter 6). The outer, compact myocardium is perfused with oxygenated blood from the arterial coronary circulation. Given that P_{aO2} and C_{aO2} were maintained with increasing temperature, and that coronary blood flow increases concomitantly with cardiac output during swimming (Axelsson and Farrell, 1993; Gamperl et al., 1995), T_{aO2} to the compact myocardium likely wasn't limited, except perhaps at the highest temperatures when T_{aO2} declined. The inner, spongy myocardium is avascular and relies on the leftover oxygen in venous blood returning to the heart. Since both P_{vO2} and C_{vO2} decrease during exercise due to increased oxygen extraction by the muscles, a diffusion limitation could develop. The temperature-induced increase in f_H could then exacerbate the situation by decreasing the residence time of the blood in the lumen and thereby decreasing diffusion time between heart beats. The bradycardia observed here during swimming at high temperatures could serve to alleviate a diffusion limitation.

Some have suggested that a threshold value for P_{vO2} exists in order to guarantee sufficient oxygen supply to the spongy myocardium (Davie and Farrell, 1991; Farrell, 2002; Farrell, 2007; Farrell and Clutterham, 2003). However, in the present study, P_{vO2}, C_{vO2}, and T_{vO2} declined in salmon swimming above T_{opt}. Thus, a state of cardiac hypoxia could have developed, possibly contributing to the disrhythmias discussed above, cardiac collapse and a concomitant decrease in oxygen delivery to the tissues, ultimately leading to decreased swimming performance.

5.3.4 The Possibility of a Limitation in Tissue Oxygen Extraction

As oxygen demand increases with warming, several situations could limit oxygen delivery to the mitochondria of the locomotory muscles. A diffusion limitation could occur due to inadequate capillary density, ineffective muscle morphology (e.g. poor mitochondria density or location) or insufficient driving force (low P_{aO2}). A perfusion limitation could result from inadequate $\dot{Q}$ or insufficient capillary perfusion at the muscle. Evidence exists for both possibilities in fish swimming at high temperatures.

Steinhausen et al. (2008) found evidence of a diffusion limitation since P_{vO2} was maintained during acute temperature increases in swimming sockeye salmon. In addition, when fish quit swimming, venous blood is still partially saturated (Farrell and Clutterham, 2003; Farrell, 2007; Kiceniuk and Jones, 1977).

In contrast, P_{vO2} and C_{vO2} decreased above T_{opt} in resting sockeye salmon in the present study. In fact, resting P_{vO2} decreased to 10 torr and resting plasma lactate became elevated in the highest temperature group, signifying insufficient oxygen delivery to tissue mitochondria. Similarly, warming decreased C_{vO2}, P_{vO2} or both in resting rainbow trout, Atlantic cod and adult chinook salmon (Clark et al., 2008b; Heath and Hughes 1973; Sartoris et al., 2003). Thus, a tissue diffusion limitation was likely not manifest at T_{opt}.

Given the dramatic decline in T_{aO2} and the obvious increase in plasma lactate during swimming and at fatigue in the highest temperature group relative to T_{opt}, there was clearly a mismatch between oxygen supply and demand at the tissues, suggesting a perfusion limitation. There were insufficient venous blood samples in $T_{max0\text{-}50}$ during swimming and at fatigue to include in the analysis across groups; however, the scatterplot in Fig 5.7 shows a steady decline in C_{vO2} and P_{vO2} at fatigue above T_{opt}. Therefore, I suggest that there may not have been an immediate diffusion limitation at the muscle in swimming fish at high temperature. However, a decrease in C_{vO2} and P_{vO2} does not definitively preclude a diffusion limitation since the decrease may not have been proportional to the oxygen demand (Wagner, 1996). Therefore, these data do not definitely exclude the possibility that both a diffusion and perfusion limitation may have been occurring.

The role of muscle morphology in limiting oxygen diffusion at high temperature and with exercise is ripe for future research. A diffusion limitation for oxygen uptake due to low capillarity in white muscle (Egginton and Sidell, 1989; Mosse, 1978) has been suggested to be an important mechanism "governing" systemic tissue utilization and thus ensuring an adequate P_{vO2} threshold to supply the spongy myocardium with oxygen (Farrell et al., 2009). It would be particularly interesting to compare cardiac and skeletal muscle morphology (e.g. capillary, mitochondria and lipid density and location) in sockeye salmon populations differing in cardiorespiratory capacity and temperature tolerance.

5.3.5 A Possible Death Spiral for Salmon Swimming above T_{opt}

A "death spiral" for salmon swimming at temperatures above T_{opt} was proposed by Farrell et al. (2009). Here, I provide further evidence for and expand upon the death spiral progression. My results are entirely consistent with the death spiral starting with a plateau in maximum heart rate above T_{opt}, which prevents $\dot{Q}_{max}$ from further increasing to satisfy the increased tissue oxygen demand. With no compensatory increase in C_{aO2}, a perfusion limitation to swimming muscles creates a mismatch between oxygen supply and demand, as evidenced by elevated lactate levels. Low P_{vO2} levels coupled with low pH due to anaerobic swimming likely impair cardiac contraction, further exacerbating the perfusion limitation and causing a positive feedback loop. At sufficiently low P_{vO2} levels, a diffusion limitation to the swimming muscles likely develops as well and eventually swimming ceases. At temperatures well above T_{opt}, corresponding to precipitous declines in aerobic scope that would certainly prevent successful upstream migration, the situation is dire. Even in resting fish, T_{aO2} levels are insufficient to meet the increased oxygen demand, as shown by high resting lactate levels. Swimming actually decreases f_H below resting levels and maximum V_s plummets, leading to a massive collapse of $\dot{Q}$. A perfusion limitation, which is likely followed by a diffusion limitation, develops at the swimming muscles. Dramatic declines in P_{vO2}, C_{vO2} and T_{vO2}, coupled with low pH, create a deleterious venous environment for the spongy myocardium, which weakens cardiac contraction and may be the cause of the bradycardia and cardiac disrhythmias. Eventually, fish quit swimming and at excessively warm temperatures, cardiac function cannot recover and the fish perish.

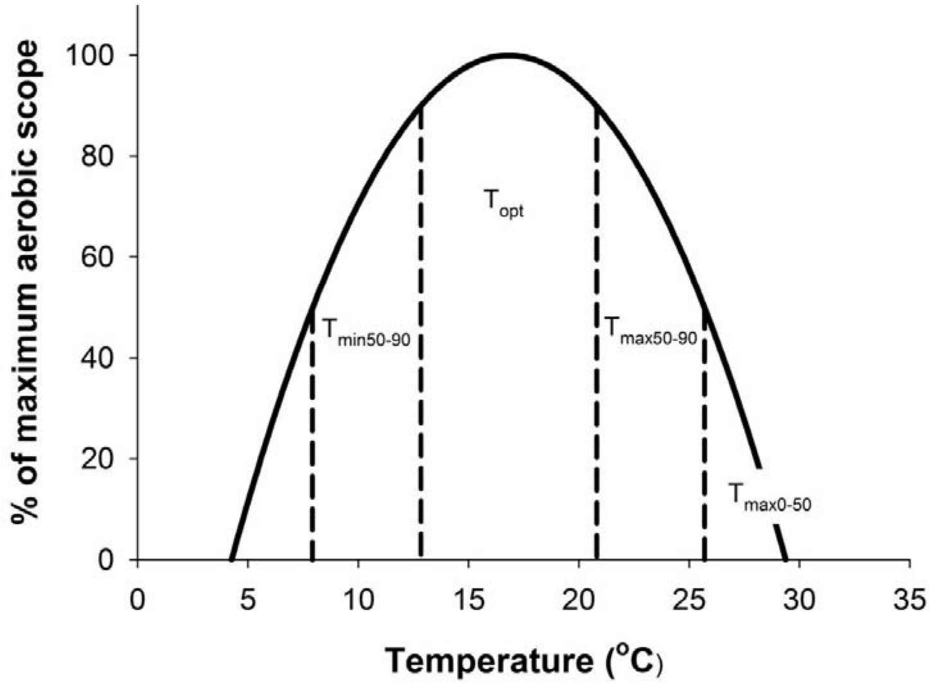

Figure 5.1. Schematic of the four categories of cardiorespiratory performance with temperature. T_{opt} included fish swum at the optimal temperature range, at which 90-100% of maximum aerobic scope was attained. $T_{min50\text{-}90}$ included fish that were swum at temperatures lower than T_{opt} at which only 50-90% of maximum aerobic scope was measured. $T_{max50\text{-}90}$ included fish swum at temperatures above T_{opt}, when 50-90% of maximum aerobic scope was measured. $T_{max0\text{-}50}$ included fish whose aerobic scope was only 0-50% of maximum.

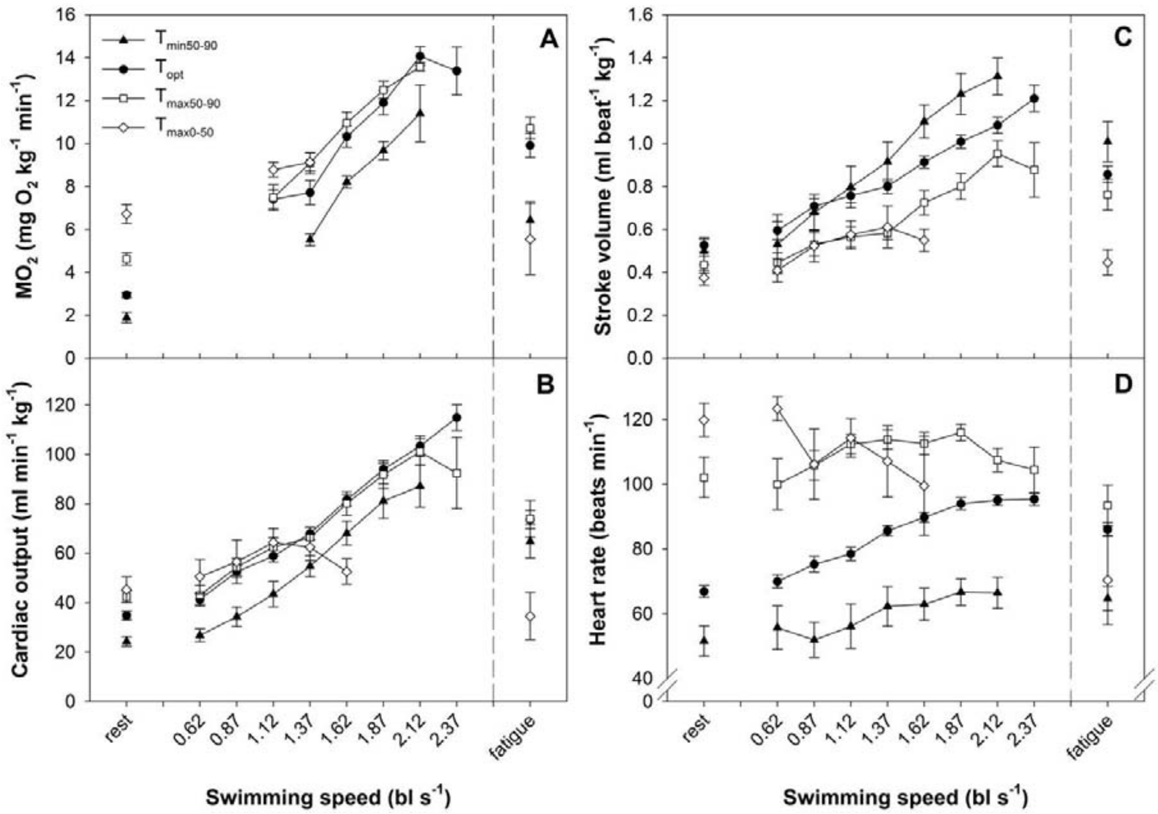

Figure 5.2. (A) Oxygen consumption ($\dot{M}O_2$), (B) cardiac output, (C) stroke volume and (D) heart rate with swimming speed across the four temperature groups. Mean ± SEM are shown.

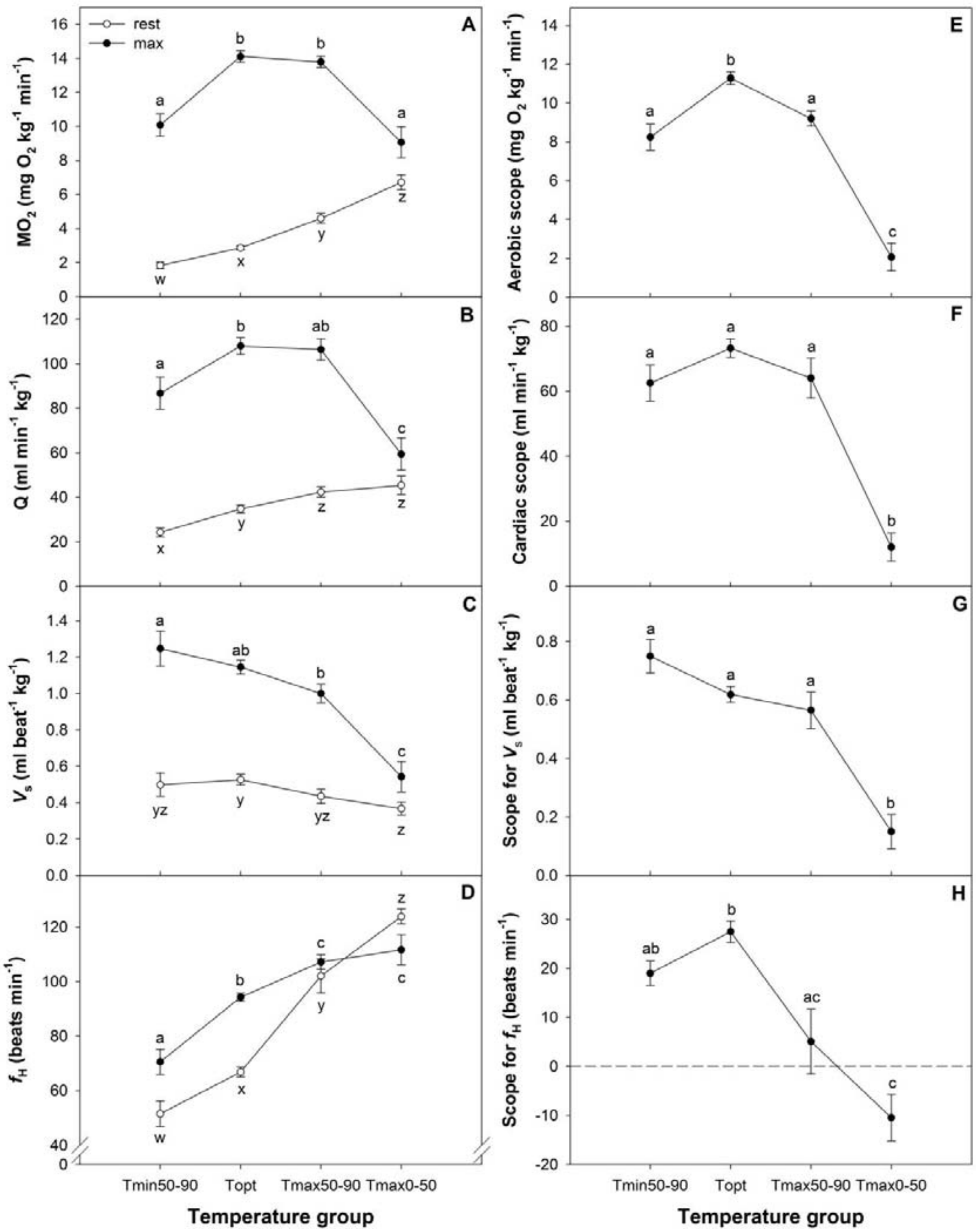

Figure 5.3. Resting and maximum (A) oxygen consumption ($\dot{M}O_2$), (B) cardiac output ($\dot{Q}$), (C) stroke volume (V_s), (D) heart rate (f_H) at the four temperature categories. Scope for $\dot{M}O_2$ (E), $\dot{Q}$ (F), V_s (G) and f_H (H) are shown. All values are presented as mean ± SEM. Significant differences among temperature categories are indicated by differing letters (p<0.05).

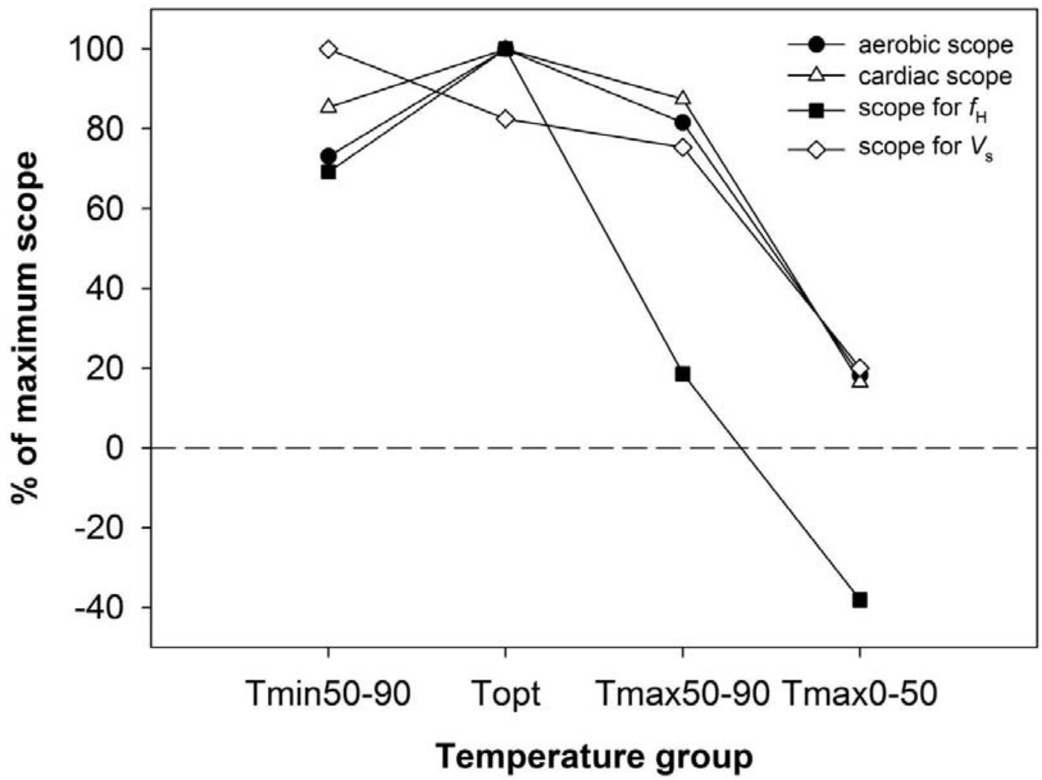

Figure 5.4. Percent of maximum aerobic scope, cardiac scope, scope for heart rate (f_H) and scope for stroke volume (V_s) for each temperature category.

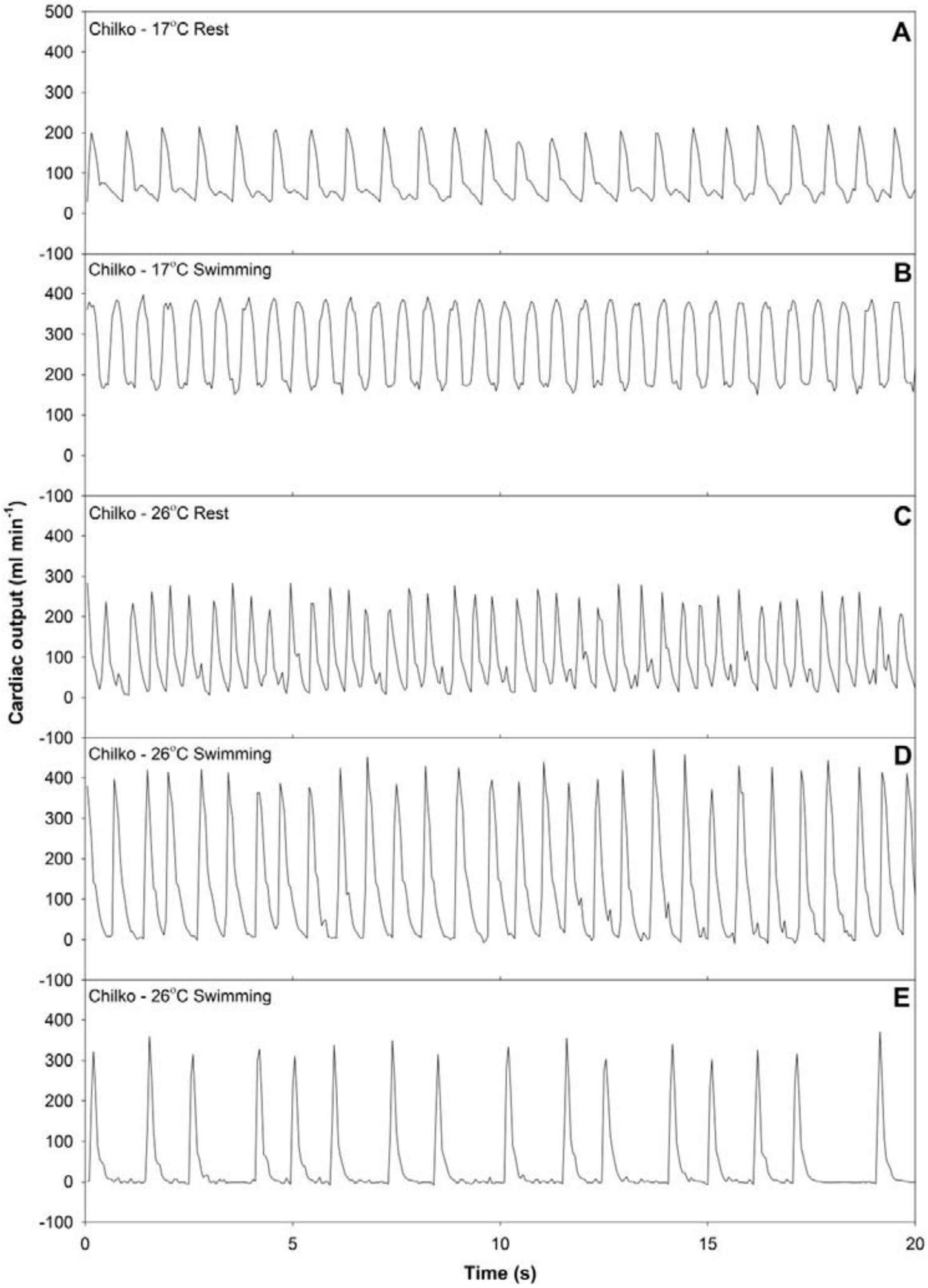

Figure 5.5. Individual blood flow traces for two Chilko sockeye salmon at 17°C (T_{opt}) and 26°C ($T_{max0\text{-}50}$) at rest (A, C) and during swimming (B, D, E). Swimming traces were recorded during the final swim speed before each fish fatigued (measured at 2.3 bl s^{-1} and 1.5 bl s^{-1} for the 17 and 26°C fish, respectively). Trace D was recorded 5 min before trace E, at the same swimming speed.

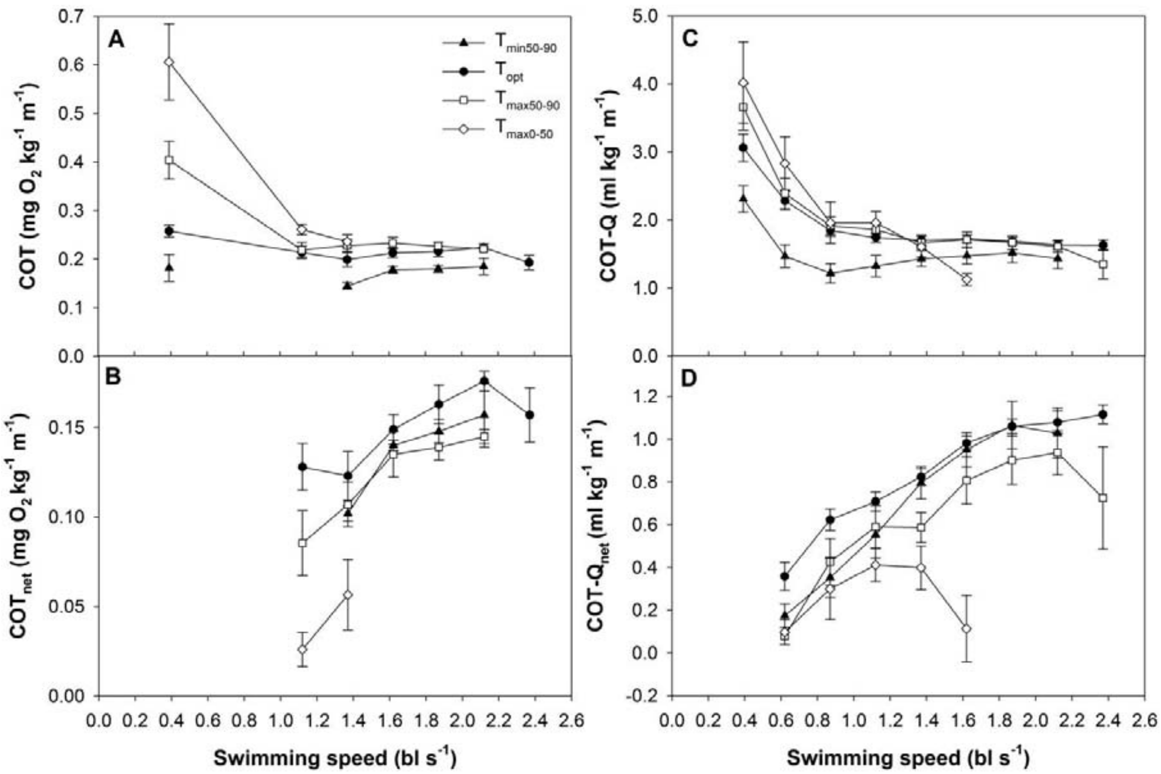

Figure 5.6. (A) Cost of transport (COT), (B) net cost of transport (COT_{net}), (C) cardiovascular cost of transport (COT-$\dot{Q}$) and (D) net cardiovascular cost of transport (COT-$\dot{Q}_{net}$) with swimming speed across the four temperature groups. Mean ± SEM are shown.

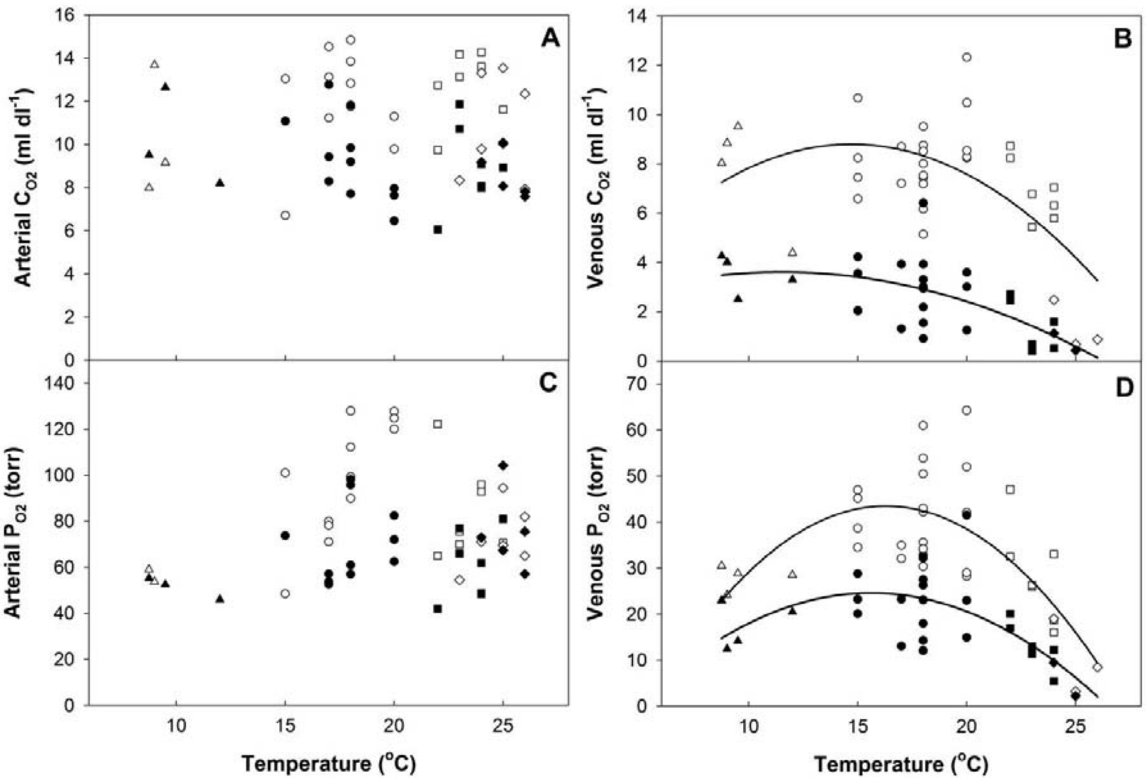

Figure 5.7. Arterial and venous (A, B) oxygen content (C_{O2}) and (C, D) partial pressure of oxygen (P_{O2}) at rest (open symbols) and fatigue (filled symbols) in four temperature groups (△= $T_{min50-90}$; ○ = T_{opt}; □ = $T_{max50-90}$; ◇ = $T_{max0-50}$). Each data point corresponds to an individual fish. A quadratic equation was fit through the venous data. Resting C_{vO2}: $R^2 = 0.37$, $p = 0.0007$; Fatigue C_{vO2}: $R^2 = 0.39$, $p = 0.002$; Resting P_{vO2}: $R^2 = 0.51$, $p < 0.0001$; Fatigue P_{vO2}: $R^2 = 0.41$ $p = 0.001$.

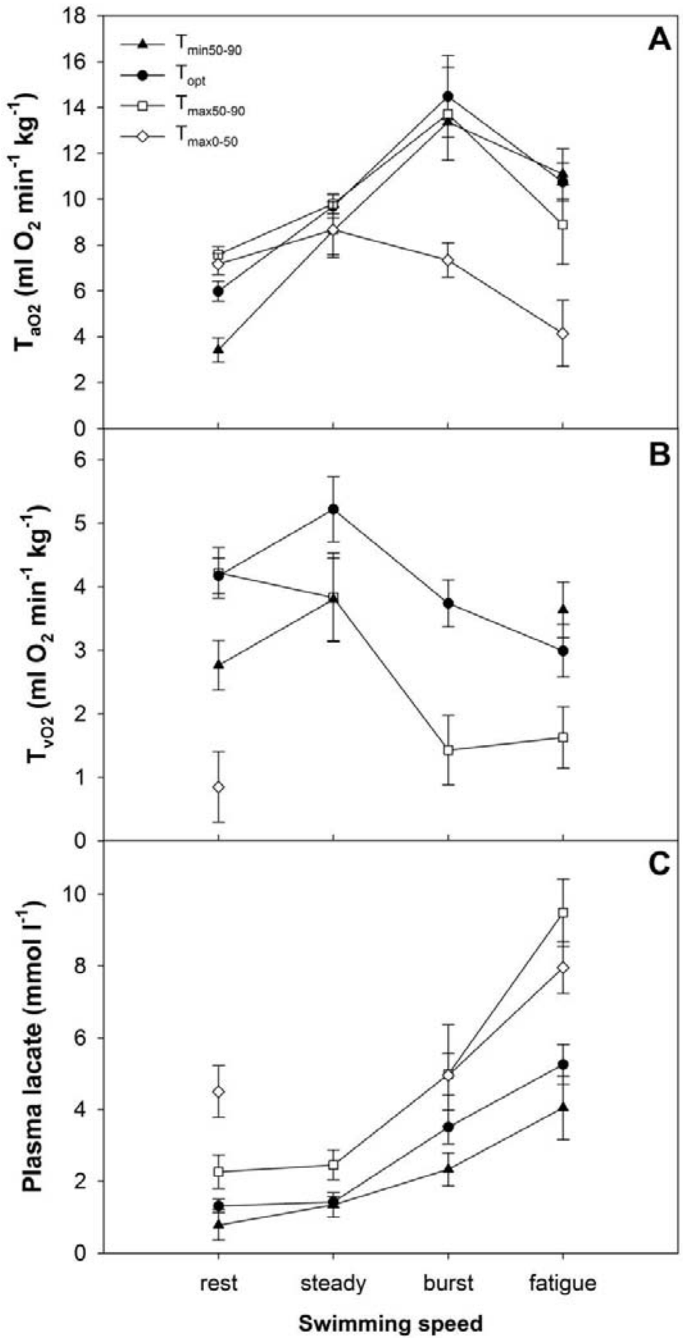

Figure 5.8. (A) Arterial oxygen transport (T_{aO2}), (B) venous oxygen transport (T_{vO2}) and (C) arterial plasma lactate across the four temperature groups and with swimming. Refer to Tables 5.2 and 5.3 for statistical information.

Table 5.1. Arterial partial pressure of oxygen (P_{aO2}) and oxygen content (C_{aO2}) in resting fish, measured at 12°C and at the test temperature. Mean ± SEM are presented, there were no significant differences within a temperature group ($p>0.05$).

		P_{aO2}		C_{aO2}	
	n	12°C	test temp	12°C	test temp
$T_{max50-90}$	5	67.5 ± 3.3	81.0 ± 5.6	14.2 ± 0.6	13.4 ± 0.5
$T_{max\ 0-50}$	7	63.5 ± 6.4	72.8 ± 4.8	12.0 ± 0.4	10.8 ± 0.9

Table 5.2. Oxygen status variables across the four temperature categories and with swimming. Arterial and venous partial pressure of oxygen (P_{aO2} and P_{vO2}), oxygen content (C_{aO2} and C_{vO2}), oxygen extraction ($A\text{-}V_{O2}$), arterial oxygen transport (T_{aO2}) and venous oxygen transport (T_{vO2}) are indicated. Mean ± SEM, temperatures groups with differing letters within a swim speed are statistically different, an asterisk indicates a statistically significant difference from rest within a temperature group ($p<0.05$).

		rest	steady	burst	fatigue
P_{aO2} (torr)	$T_{min50\text{-}90}$	-	60.7 ± 9.3	62.9 ± 3.5	49.8 ± 2.4
	T_{opt}	98.4 ± 7.4	96.5 ± 5.8	64.7 ± 9.6*	69.7 ± 4.9*
	$T_{max50\text{-}90}$	84.6 ± 7.7	71.9 ± 3.8	58.1 ± 4.3	60.7 ± 5.7
	$T_{max0\text{-}50}$	72.8 ± 4.8	70.8 ± 3.7	71.7 ± 7.4	75.4 ± 7.9
P_{vO2} (torr)	$T_{min50\text{-}90}$	28.0 ± 1.3^{ab}	24.0 ± 1.1	-	17.5 ± 2.5
	T_{opt}	41.6 ± 2.4^{a}	32.6 ± 1.9*	17.6 ± 2.8*	23.4 ± 2.0*
	$T_{max50\text{-}90}$	28.5 ± 3.9^{b}	21.1 ± 3.3	11.6 ± 3.7*	13.2 ± 2.18*
	$T_{max0\text{-}50}$	10.3 ± 4.6^{c}	-	-	-
C_{aO2} (ml dl^{-1})	$T_{min50\text{-}90}$	10.3 ± 1.7	11.6 ± 1.1	11.9 ± 1.2	11.6 ± 1.8
	T_{opt}	12.0 ± 0.6	10.9 ± 0.7	9.2 ± 0.8	9.3 ± 0.6
	$T_{max50\text{-}90}$	12.8 ± 0.6	11.2 ± 0.6	10.2 ± 0.5	9.0 ± 0.7*
	$T_{max0\text{-}50}$	10.8 ± 0.9	9.9 ± 1.6	9.2 ± 1.5	8.5 ± 0.5
C_{vO2} (ml dl^{-1})	$T_{min50\text{-}90}$	7.7 ± 1.1^{a}	4.9 ± 1.2	-	3.5 ± 0.4^{a}*
	T_{opt}	8.2 ± 0.4^{a}	5.7 ± 0.4*	2.5 ± 0.3 *	3.0 ± 0.4^{a}*
	$T_{max50\text{-}90}$	6.9 ± 0.5^{a}	4.3 ± 0.8	1.0 ± 0.4*	1.4 ± 0.4^{b}*
	$T_{max0\text{-}50}$	1.4 ± 0.6^{b}	-	-	-
$A\text{-}V_{O2}$ (ml dl^{-1})	$T_{min50\text{-}90}$	1.6 ± 1.6	-	-	6.8 ± 1.7*
	T_{opt}	4.2 ± 0.8	4.8 ± 0.5	6.3 ± 1.0	6.0 ± 0.7
	$T_{max50\text{-}90}$	6.1 ± 1.2	7.0 ± 0.9	9.2 ± 0.7	8.0 ± 1.4
	$T_{max0\text{-}50}$	-	-	-	-
T_{aO2} (ml O_2 min^{-1} kg^{-1})	$T_{min50\text{-}90}$	3.4 ± 0.5	8.6 ± 1.0	13.4 ± 0.1^{ab}*	11.1 ± 1.1^{a}*
	T_{opt}	5.8 ± 0.4	9.4 ± 0.4*	14.7 ± 1.2^{a}*	10.7 ± 0.8^{a}*
	$T_{max50\text{-}90}$	7.6 ± 0.3	9.8 ± 0.4	13.7 ± 2.0^{a}*	8.9 ± 1.7^{ab}
	$T_{max0\text{-}50}$	7.2 ± 0.5	8.7 ± 1.2	7.4 ± 0.7^{b}	4.1 ± 1.4^{b}
T_{vO2} (ml O_2 min^{-1} kg^{-1})	$T_{min50\text{-}90}$	2.8 ± 0.4^{b}	3.8 ± 0.7		3.6 ± 0.4
	T_{opt}	4.1 ± 0.3^{a}	5.1 ± 0.4	3.7 ± 0.4	3.0 ± 0.4
	$T_{max50\text{-}90}$	4.2 ± 0.4^{ab}	3.8 ± 0.7	1.4 ± 0.5*	1.6 ± 0.5*
	$T_{max0\text{-}50}$	0.8 ± 0.6^{b}	-	-	-

Table 5.3. Arterial haematological variables across the four temperature categories and with swimming. Haemoglobin concentration (Hb), hematocrit (Hct), mean cell haemoglobin concentration (MCHC), plama sodium (Na^+), plasma potassium (K^+) and plasma chloride (Cl^-) are indicated. Mean ± SEM, temperatures groups with differing letters within a swim speed are statistically different, an asterisk indicates a statically significant difference from rest within a temperature group ($p<0.05$).

		rest	steady	burst	fatigue
Hb (g l^{-1})	$T_{min50-90}$	92.3 ± 9.0	89.9 ± 10.6	93.5 ± 11.8	81.5 ± 12.6
	T_{opt}	92.4 ± 4.6	90.3 ± 4.2	91.8 ± 5.4	87.3 ± 3.0
	$T_{max50-90}$	100.3 ± 10.9	95.8 ± 2.7	89.3 ± 6.3	89.1 ± 6.3
	$T_{max0-50}$	89.0 ± 5.0	98.3 ± 6.0	91.6 ± 7.5	91.8 ± 2.3
Hct (%)	$T_{min50-90}$	30.7 ± 3.4	29.2 ± 1.6	30.6 ± 3.5	29.6 ± 5.2
	T_{opt}	31.0 ± 1.7	30.4 ± 1.6	33.9 ± 2.5	31.1 ± 1.4
	$T_{max50-90}$	32.9 ± 1.8	31.4 ± 0.8	34.2 ± 2.2	36.1 ± 1.4
	$T_{max0-50}$	32.6 ± 1.5	32.1 ± 0.9	35.8 ± 3.4	37.5 ± 3.3
MCHC (g l^{-1})	$T_{min50-90}$	302.2 ± 9.1	306.4 ± 19.7	305.1 ± 6.3	278.3 ± 10.9
	T_{opt}	300.5 ± 6.6	299.4 ± 6.8	273.1 ± 8.1	282.3 ± 4.9
	$T_{max50-90}$	308.4 ± 32.7	306.7 ± 13.5	267.7 ± 25.1	249.0 ± 22.0*
	$T_{max0-50}$	274.5 ± 15.8	305.7 ± 11.7	259.1 ± 19.4	250.4 ± 16.4
Glucose (mmol l^{-1})	$T_{min50-90}$	-	9.6 ± 0.7	9.0 ± 0.3	9.8 ± 0.7
	T_{opt}	5.6 ± 0.5	5.1 ± 0.5	6.6 ± 0.5	6.2 ± 0.6
	$T_{max50-90}$	7.6 ± 1.9	8.3 ± 1.2	6.9 ± 1.0	7.8 ± 1.1
	$T_{max0-50}$	10.2 ± 2.0	-	5.4 ± 1.9*	7.3 ± 1.6*
Lactate (mmol l^{-1})	$T_{min50-90}$	0.8 ± 0.4^{a}	1.3 ± 0.3	2.3 ± 0.5	4.0 ± 0.9^{a}
	T_{opt}	1.3 ± 0.2^{a}	1.4 ± 0.2	3.5 ± 0.5	5.3 ± 0.6^{ab}*
	$T_{max50-90}$	2.3 ± 0.5^{ab}	2.5 ± 0.4	5.0 ± 0.6	9.5 ± 0.9^{c}*
	$T_{max0-50}$	4.5 ± 0.7^{b}	-	5.0 ± 1.4	8.0 ± 0.7^{b}*
Na^+ (mmol l^{-1})	$T_{min50-90}$	142.3 ± 2.9^{a}	138.1 ± 1.1	133.1 ± 6.0	-
	T_{opt}	140.1 ± 1.7^{a}	143.8 ± 1.6	145.9 ± 2.1	152.9 ± 2.0^{a}*
	$T_{max50-90}$	120.7 ± 6.8^{b}	140.4 ± 5.2*	138.9 ± 3.2*	139.6 ± 4.7^{ab}*
	$T_{max0-50}$	137.7 ± 4.1^{ab}	-	135.9 ± 2.6	137.6 ± 2.6^{b}
K^+ (mmol l^{-1})	$T_{min50-90}$	3.3 ± 0.1	3.9 ± 0.5	4.3 ± 0.8	4.0 ± 1.8
	T_{opt}	4.9 ± 0.4	4.6 ± 0.4	2.7 ± 0.7	2.6 ± 0.3*
	$T_{max50-90}$	6.2 ± 1.0	4.5 ± 0.7	2.8 ± 0.6*	1.7 ± 0.3*
	$T_{max0-50}$	3.8 ± 0.3	-	3.9 ± 0.9	1.7 ± 0.6
Cl^- (mmol l^{-1})	$T_{min50-90}$	121.0 ± 2.0^{ab}	122.0 ± 5.2	117.4 ± 2.3^{ab}	123.6 ± 3.8^{ab}
	T_{opt}	127.5 ± 0.9^{a}	129.9 ± 1.4	130.2 ± 1.3^{a}	133.3 ± 1.2^{a}
	$T_{max50-90}$	119.3 ± 6.0^{ab}	119.8 ± 2.1	118.3 ± 4.5^{ab}	119.9 ± 5.2^{b}
	$T_{max0-50}$	112.0 ± 3.1^{b}	-	113.4 ± 3.9^{b}	111.9 ± 2.7^{b}

CHAPTER 6: DIFFERENCES IN GROSS CARDIAC MORPHOLOGY AMONG SOCKEYE SALMON POPULATIONS AND IN RELATION TO TEMPERATURE TREATMENT

6.1 Introduction

The preceding chapters demonstrated that aerobic scope is correlated with migration difficulty among Fraser River sockeye salmon populations (Chapter 3) and that cardiac and aerobic scope are tightly related (Chapters 3, 4 and 5). Furthermore, I proposed that cardiac collapse precipitates a decrease in aerobic swimming performance at temperatures above T_{opt} (Chapter 5). Given the key role of the heart in temperature tolerance and supporting aerobic swimming, I sought to determine whether there were differences in cardiac morphology across sockeye salmon populations related to migration difficulty and whether cardiac morphology was affected by temperature exposure.

Relative ventricular mass (RVM) varies considerably across fish species [ranging over 10-fold from 0.03 to 0.4% of body mass; (Santer, 1985)]. Some of these interspecific differences can be attributed to diversity of habitat, life history and activity levels. Like all other muscles, cardiac mass is a primary determinant of force development and a larger heart can presumably generate higher cardiac outputs ($\dot{Q}$) and greater arterial blood pressures. Correspondingly, athletic fish tend to have larger, more powerful hearts that generate higher $\dot{Q}$ and arterial blood pressure compared with sedentary species, though Antarctic icefishes are an important exception (Gamperl and Farrell, 2004). Such species distinctions also extend to ventricular composition. Salmonid ventricles are composed of two distinct layers of myocardium. The outer compact myocardium is perfused with well-oxygenated arterial blood via a coronary circulation. The inner spongy myocardium is avascular, so it relies on a more variable and lower oxygen tension from the venous blood returning to the heart. Some athletic species (e.g. salmonids and tunas) have 30-50% compact myocardium (Farrell et al., 1988a; Poupa and Lindström, 1983), while most sluggish fish (e.g. hagfishes, Atlantic cod) only have spongy myocardium. While the influence of athleticism on interspecific ventricular design is clear across fish species, its influence among populations within a fish species is unknown.

I predicted that cardiac morphology would vary among sockeye salmon populations according to migration difficulty, mimicking the patterns observed in aerobic scope (Chapter 3). Specifically, I hypothesized that sockeye salmon populations with more challenging migrations would have a larger relative ventricular mass (to allow the heart to generate more power output) and a greater percent compact myocardium (to have a more secure supply of oxygen while swimming). Furthermore, since the total amount of compact myocardium depends on both the size of the ventricle (RVM) and proportion of compact myocardium (% compact) (e.g. a large ventricle with a low proportion of compact myocardium can have the same total amount of compact myocardium as a smaller ventricle with a higher percent compact), I also assessed relative dry compact mass (RDCM). Again, I predicted that populations facing more difficult migrations would display a higher RDCM.

In making comparisons among sockeye salmon populations, I first broadly categorized migration difficulty by dividing the populations into those that pass through Hells Gate, a hydraulically challenging river segment (upriver populations) and those that do not [coastal populations (Table 2.1)]. I predicted that Hells Gate may impose a major selection pressure on the cardiovascular system, especially since Chapter 3 revealed that the coastal Weaver population possessed the lowest $\dot{M}O_{2max}$ and aerobic scope. I also considered that the river environment may impose selection at a finer scale since Chapter 3 showed that migration distance correlated significantly with aerobic scope across sockeye salmon populations. In addition, migration distance, elevation gain and work (distance × elevation) were the best predictors for various energetic, morphological and reproductive attributes among Fraser River sockeye salmon populations (Crossin et al., 2004). Therefore, my primary hypothesis was that migration distance, elevation gain and work correlate with the heart morphology indices. However, I also took into account the possibility that heart morphology may interact with the environment in a more complex manner. For example, warm temperatures may necessitate a greater percent compact myocardium because of the requirement for a more reliable, stable oxygen supply when P_{vO2} is reduced (see Chapter 5). In addition, swimming at a greater rate or against a stronger river current may require a larger heart to supply a greater $\dot{Q}$. Therefore, I included ATU and various new indices that had not been previously considered (e.g. migration rate, migration duration, migration effort) in the analysis.

It is well known that individual fish show remarkable cardiac plasticity and variability. Indeed, salmonids in particular can rapidly remodel their ventricle in response to various environmental and biological cues (Gamperl and Farrell, 2004). For example, ventricle mass and composition are known to change with temperature acclimation, exercise-training, anemia and sexual maturation in fishes (Bailey et al., 1997; Clark and Rodnick, 1998; Franklin and Davie, 1992; Gamperl and Farrell, 2004; Goolish, 1987; Graham and Farrell, 1989; Pelouch and Vornanen, 1996; Simonot and Farrell, 2007; West and Driedzic, 1999). Specifically, RVM increased during sexual maturation in male, but not female salmonids (Clark and Rodnick, 1998; Franklin and Davie, 1992; Graham and Farrell, 1992; West and Driedzic, 1999). In addition, cold acclimation significantly increased RVM, but decreased % compact in rainbow trout (Farrell et al., 1988a, Gamperl and Farrell, 2004; Graham and Farrell, 1989). Therefore, I also examined cardiac morphology in male and female sockeye exposed to different holding temperatures. I hypothesized that male sockeye salmon would have a greater RVM relative to females and that only males would demonstrate cardiac remodelling. I additionally predicted that RVM would decrease and % compact would increase at warmer temperatures in males, supporting previous observations in rainbow trout (Farrell et al., 1988a, Graham and Farrell, 1989). Finally, to further examine the effect of temperature, I compared cardiac morphology in sockeye salmon exposed to an acute temperature increase while swimming at a constant velocity (Steinhausen et al., 2008). I hypothesized that a greater % compact would translate to a higher temperature tolerance.

Detailed materials and methods are provided in Chapter 2 (sections 2.1, 2.2, 2.8 and 2.10.2).

6.2 Results

6.2.1 Population Comparisons with Migration Difficulty

Population comparisons were restricted to females because male cardiac morphology was shown to significantly differ with temperature treatment (see below). Notably, there were no significant relationships between GSI and any of the cardiac variables within a population (data not shown).

Upriver sockeye salmon had significantly higher RVM, % compact and RDCM compared to coastal sockeye salmon ($p<0.01$). In addition, RVM, % compact and RDCM varied across populations by 40, 27 and 60%, respectively (Table 6.1). Chilko and Quesnel fish had significantly higher RVM than Weaver fish and all populations had significantly higher RVM compared to Harrison fish. Early Stuart and Nechako had significantly higher % compact (~44%) compared to Quesnel, Lower Adams, Weaver and Harrison (~36%). RDCM exhibited more of a gradient across populations. Early Stuart, Nechako, Chilko and Quesnel had the highest RDCM (~0.0090%), Lower Adams and Weaver displayed an intermediate RDCM (~0.0075%) and Harrison exhibited the lowest RDCM of all (0.0060%).

Each cardiac morphology variable was significantly correlated with migration difficulty (Table 6.2). Linear regressions between the migration difficulty indices with the strongest Pearson correlation coefficient and each cardiac variable are shown in Figure 6.1. RVM, % compact and RDCM had the strongest correlation coefficients with migration rate, migration effort (distance × Fraser River discharge) and migration distance, respectively. In addition, RDCM significantly correlated with aerobic scope.

6.2.2 Temperature Effects and Sex Differences

Cardiac morphology varied significantly with holding temperature (>5 days of thermal acclimation to 14, 16.5 and 19°C) for males, but not for females (Figure 6.2). Males had a 17% higher RVM at 19^{o}C compared with 14^{o}C. Males also had a significantly higher RVM compared with females at 16.5^{o}C and 19^{o}C. Male fish held at 16.5^{o}C and 19^{o}C had a RDCM that was 19-21% significantly higher compared with male fish held at 14^{o}C. Again, males had a significantly higher RDCM compared to females at 16.5^{o}C and 19^{o}C. Percent compact myocardium did not vary significantly between sexes, or within males as a function of holding temperature. Notably, GSI did not significantly differ among temperature treatments within sex ($p>0.05$), thereby reducing the possibility that the temperature effects on ventricular composition were related to differences in the state of maturity.

6.2.3 High Temperature Swimming Experiment

There were no statistically significant differences in any of the cardiac variables between male and female Lower Adams sockeye salmon used in the high temperature swimming experiment performed by Steinhausen et al. (2008). Therefore, male and female fish were pooled in order to assess the relationship between the temperature at which the fish failed to continue swimming at approximately 75% of U_{crit} (fail temperature) and the various cardiac variables (Figure 6.3). No relationship was found between any of the cardiac variables and fail temperature ($p>0.05$).

6.3 Discussion

The present study clearly demonstrates for the first time that cardiac morphology can vary among wild populations of the same fish species. As predicted, the differences in ventricular morphology among Fraser River sockeye salmon populations were related to the difficulty of the upriver migration. These findings add to similar discoveries for population-specific variation in aerobic scope (Chapter 3) and gross morphology [e.g. body mass, egg number and energy content (Crossin et al., 2004; Gilhousen, 1980)] according to migration difficulty. The population differences in ventricular morphology likely represent adaptations to the upriver environment since all fish were sampled early in the migration, prior to encountering the major selective elements. Individuals from a given sockeye salmon population are therefore prepared for the athletic task that lies ahead during the upriver migration, even though they themselves have never experienced the upstream migration conditions. Consistent with previous studies, ventricular morphology was shown to be sexually dimorphic in sockeye salmon in some respects and plastic with response to environmental temperature in male fish.

6.3.1 Population Differences in Ventricular Morphology

The range for RVM (0.09-0.19%) among individual female sockeye salmon corresponds well with values reported for other sexually mature salmonids: sockeye salmon (0.11-0.13%, Clark et al., 2009; Sandblom et al., 2009), rainbow trout (0.07-0.24%, Bailey et al., 1997; Clark and Rodnick, 1998; Franklin and Davie, 1992; Graham and Farrell, 1992) but was lower than in sexually mature male chinook salmon near the spawning ground (0.24%, Clark et al., 2008b).

Substantial individual variation was also observed for % compact, ranging between 25 and 50%. This range corresponds with previously reported values for mature sockeye salmon (43%, Sandblom et al., 2009) and chinook salmon (53%, Clark et al., 2008b).

RDCM is a new metric that integrates the two cardiac measures, RVM and % compact, to illustrate how much total myocardium relative to body mass is independent of the venous circulation and instead has a secure oxygen supply via the coronary circulation. RDCM can increase either by maintaining RVM while increasing % compact, or by maintaining % compact while increasing RVM or by increasing both % compact and RVM. As such, a large ventricle with a smaller percentage compact myocardium could have the same total amount of compact myocardium as a small ventricle with a large percentage myocardium. In both cases, the same total amount of heart is perfused with stable, oxygenated blood via the coronary circulation. RDCM was observed to vary substantially across individual sockeye, between 0.005% and 0.011%.

Beyond individual variation, cardiac morphology also varied considerably across populations. Indeed, RVM, % compact and RDCM varied by 40, 27 and 60% across the seven Fraser River sockeye salmon populations investigated here. Clear differences in cardiac morphology existed between coastal and upriver populations, suggesting that the difficult journey through the Fraser Canyon and Hells Gate likely imposes strong selection pressure for a greater RVM, % compact and RDCM. In addition to this broad classification, other aspects of the upriver migration also appear to influence cardiac morphology. RVM only correlated with migration rate ($p < 0.05$, no correction for multiple comparisons), suggesting that fast swimming requires large ventricles. Alternatively, the primary selection force for RVM may simply have been Hells Gate. Percent compact myocardium correlated with several of the indices (i.e. migration distance, migration duration and ATU) but migration effort had the strongest correlation ($p < 0.006$, Bonferroni level). As such, long river distances with a strong current may necessitate a higher percentage compact myocardium. Finally, RDCM correlated with every difficulty index examined except river slope, and migration distance had the strongest relationship ($p < 0.006$, Bonferroni level). Additionally, RDCM correlated with aerobic scope. Therefore, RDCM appears to be under strong selection pressure across many levels of migration difficulty. None of the ventricular morphology variables significantly correlated with river slope, supporting an earlier finding by Crossin et al. (2004) which suggested that river slope was not a major selective element for gross morphology among Fraser River sockeye salmon populations.

Collectively, these correlational analyses suggest that migratory difficulty is likely a strong selective force responsible for the population-specific differences in cardiac morphology. As discussed in Chapter 3, correlations only provide circumstantial, though promising, evidence of local adaptation (Endler, 1986; Schluter, 2000; Taylor, 1991) and conclusive evidence would require breeding studies. I cannot reject the possibility that differences may be due to developmental plasticity. However, given that the fish were collected early in their migration, had never before encountered the upstream migration conditions and spent the last >2 years in a common ocean environment, I conclude that the observed differences among populations were most likely due to genetic adaptation rather than environmental acclimation (refer to Chapter 3 for further discussion).

6.3.2 Temperature and Sex Differences

Male sockeye salmon had up to 25% more RVM compared to females, depending on the temperature. These results correspond well to previously reported values for sexually maturing sockeye salmon (males had 11-13% greater RVM compared to females, Clark et al., 2009; Sandblom et al., 2009). In contrast, studies performed on sexually mature rainbow trout found a more dramatic, up to 2-fold difference between male and female fish (Bailey et al., 1997; Clark and Rodnick, 1998; Franklin and Davie, 1992).

The much larger RVM in mature male rainbow trout has been demonstrated to increase V_s and cardiac power output, which has been hypothesized to support increased functional demands placed on the hearts of spawning male salmon (Franklin and Davie, 1992, Gamperl and Farrell 2004). However, clear evidence supporting this hypothesis from wild migrating fish is lacking. In the present study, the smaller difference in RVM resulted in no differences in $\dot{Q}$ or V_s between male and female sockeye salmon (Chapter 4). Recent studies suggest that f_H was similar between sexes in sockeye salmon on the spawning ground, though males spent more time with elevated heart rates and had a higher routine $\dot{M}O_2$, both of which can be attributed to increased activity (Clark et al., 2009). In addition, no differences in arterial blood pressure were observed between mature male and female sockeye salmon (Sandblom et al., 2009). Perhaps, compared to wild conditions, the hatchery environment exacerbates the sexual diochotomy because hatchery-reared rainbow trout had significantly smaller RVM compared to wild, migrating trout (Graham and Farrell, 1989), which could potentially allow for a greater scope for cardiac growth with sex development. Collectively, these observations suggest that the remarkable ventricular growth observed in mature male rainbow trout may not be a general characteristic shared with all salmonids. Clearly, more research is needed to address these ideas.

Temperature clearly remodelled the heart in male, but not female, sockeye salmon. RVM and RDCM were 17-21% significantly higher in warm compared to cool temperature-treated male sockeye salmon, which was not due to differences in sexual maturation since GSI did not differ. Percent compact did not significantly differ with temperature treatment. These findings sharply contrast with my hypotheses and previous reports in the literature for rainbow trout. Rainbow trout acclimated to 5°C had a 20-40% higher RVM but a 15-30% decrease in % compact compared to fish held at 15°C (Farrell et al., 1988a, Graham and Farrell, 1989). A larger RVM at cold temperatures has been postulated to compensate for the decrease in contractility associated with cold, helping to maintain stroke volume, cardiac output and power output (Gamperl and Farrell, 2004). Why such a difference in the cardiac remodelling response to temperature exists within the genus *Oncorhynchus* is unclear. It could possibly be attributed to the different temperatures chosen for the studies, although this remains to be tested. Regardless, the higher RVM with no change in % compact in warm-temperature treated sockeye resulted in a concomitant higher RDCM, meaning that a larger total amount of myocardium was perfused with blood from the coronary rather than the venous circulation. This could enhance oxygen delivery to the ventricle at warm temperature, matching the increased oxygen demand.

The individual cardiac plasticity in male migrating, adult sockeye salmon is quite remarkable given that when the fish enter the river, they are 4-6 weeks from death, have ceased feeding, are in the midst of tremendous physiological flux as secondary sexual characteristics develop and the gonads grow all while performing the enormous athletic task of returning upstream to their spawning ground. This finding demonstrates that male sockeye salmon retain the ability to adjust morphological features when faced with changing environmental variables, even once they have commenced their upstream migration.

Individual variability in cardiac anatomy has been linked to differences in $\dot{Q}_{max}$, $\dot{M}O_{2max}$ and swim performance in rainbow trout (Claireaux et al., 2005). Specifically, poor swimmers had more rounded hearts compared to good swimmers. I similarly sought to examine the possible role of individual variation in cardiac composition on high temperature tolerance. However, no relationship was found between ventricular morphology and high temperature swim performance in fish subjected to a high temperature challenge while swimming near maximally (Steinhausen et al., 2008). Unfortunately, only three fish were truly classified as “poor” swimmers, resulting in very low statistical power. Therefore, these results do not preclude the possibility that population differences in cardiac composition are related to temperature tolerance, or that the cardiac responses to holding temperature could improve temperature tolerance. Rather, more experimental work is needed to test these ideas.

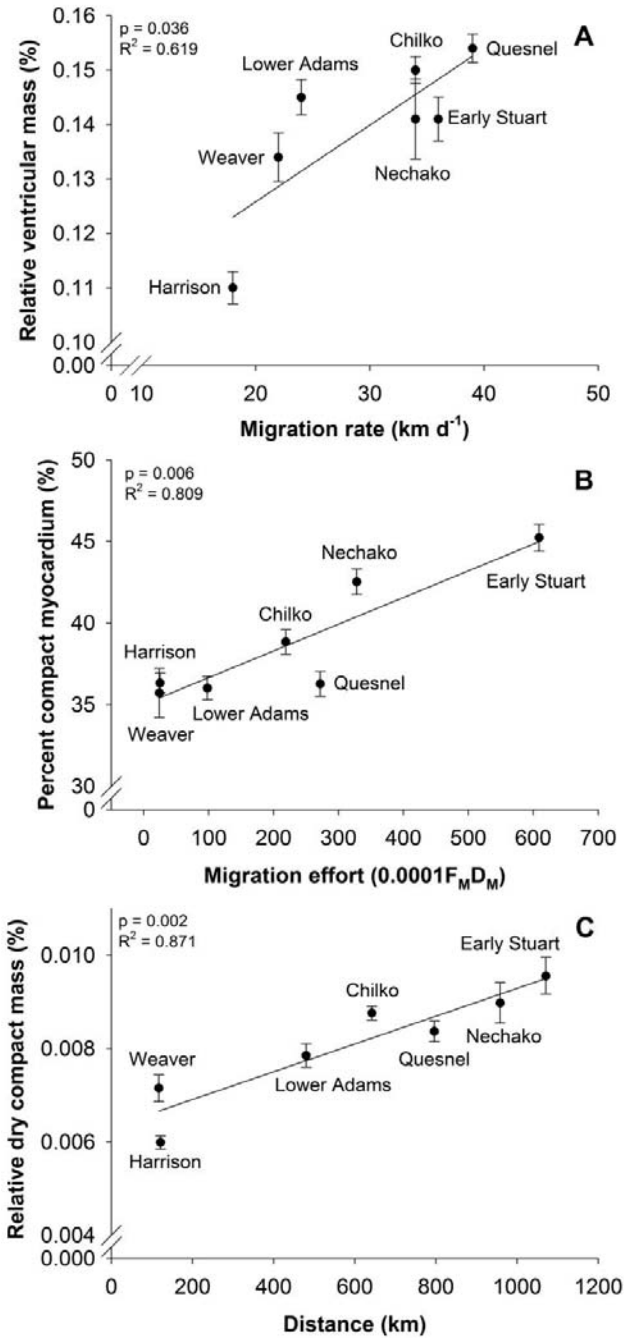

Figure 6.1. Linear regressions between migration difficulty indices and (A) relative ventricular mass (B) percent compact myocardium and (C) relative dry compact mass. Population means ± SEM are presented. The migration difficulty indices with the strongest Pearson correlation coefficient are presented (Table 6.2). F_M, Fraser River Discharge, D_M, distance to spawning grounds. Only female sockeye salmon were compared.

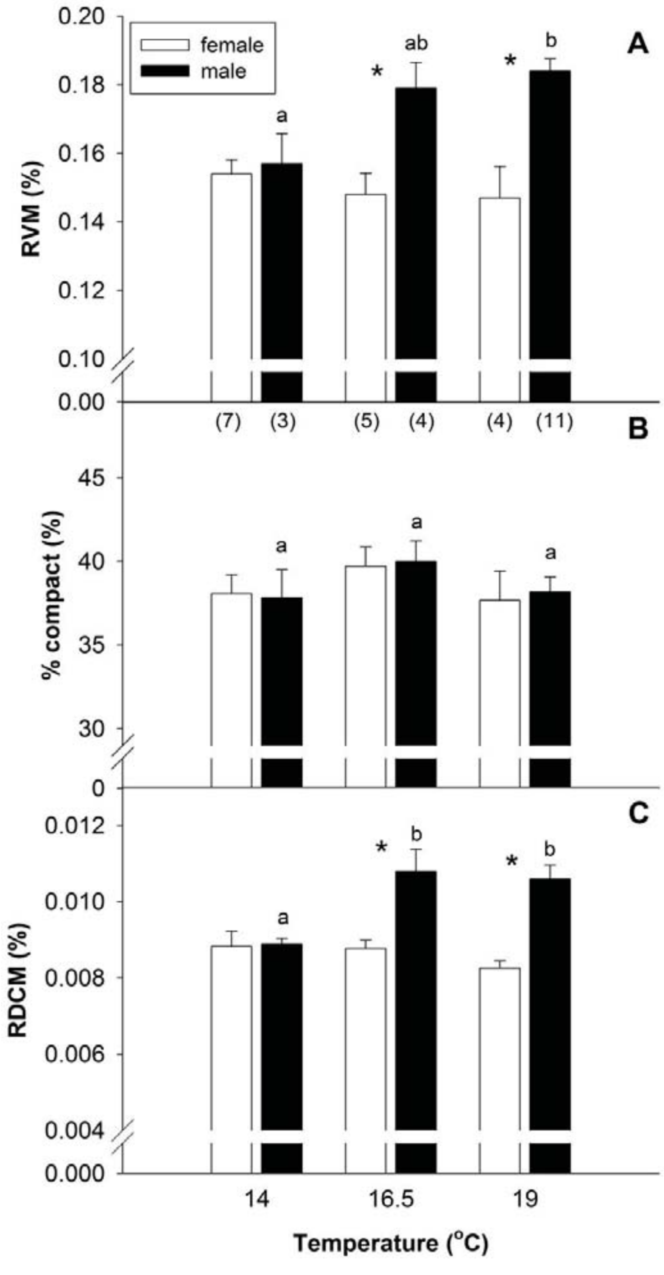

Figure 6.2. (A) Relative ventricular mass (RVM), (B) percentage compact myocardium (% compact), and (C) relative dry compact mass (RDCM) are shown for male and female Chilko sockeye salmon acclimated to 14, 16.5 and 19°C for at least 5 days before death. N values are indicated in parentheses. An asterisk indicates a statistically significant difference between male and female fish. Significant differences with temperature treatment among male sockeye are indicated by differing letters. There were no significant differences with temperature treatment among female sockeye (p>0.05).

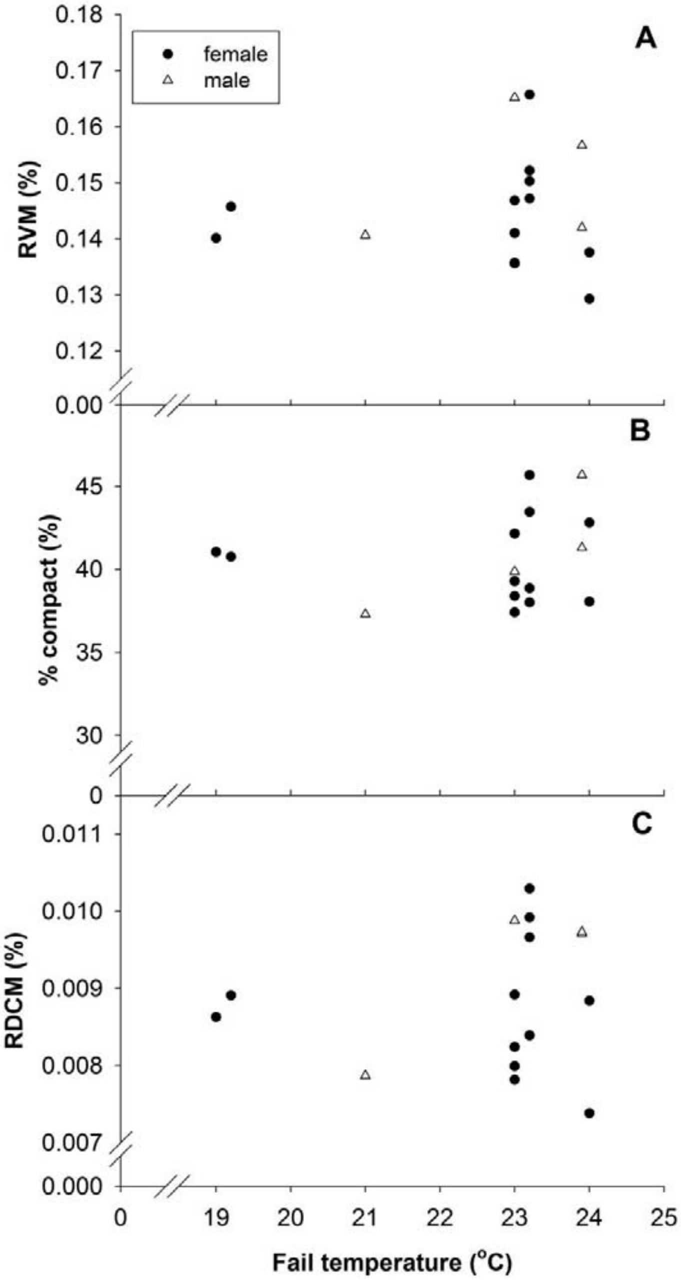

Figure 6.3. (A) Relative ventricular mass (RVM), (B) percentage compact myocardium (% compact), and (C) relative dry compact mass (RDCM) as a function of the temperature at which Lower Adams sockeye salmon failed to continue swimming at approximately 75% of U_{crit} (fail temperature). Each point corresponds to an individual fish. Males and females are indicated (open triangles and closed circles, respectively); however, none of the cardiac variables differed significantly with sex. Therefore, statistical analysis was performed on the entire group. No relationship was found between any of the cardiac variables and fail temperature ($p>0.05$).

Table 6.1. Relative ventricular mass (RVM), percentage compact myocardium (% compact) and relative dry compact mass (RDCM) for each sockeye salmon population (mean ± SEM). Only female sockeye salmon from each population were compared. Populations with differing letters are significantly different within each variable.

Population	Spawning location	n	RVM (%)	% compact	RDCM (%)
Early Stuart	upriver	7	0.141 ± 0.004^{ab}	45.2 ± 0.8^{a}	0.0096 ± 0.0004^{a}
Nechako	upriver	9	0.141 ± 0.007^{ab}	42.5 ± 0.8^{ab}	0.0090 ± 0.0004^{a}
Quesnel	upriver	11	0.154 ± 0.003^{a}	36.3 ± 0.8^{c}	0.0084 ± 0.0002^{ab}
Chilko	upriver	35	0.150 ± 0.002^{a}	38.9 ± 0.7^{bc}	0.0088 ± 0.0001^{a}
Lower Adams	upriver	21	0.145 ± 0.003^{ab}	36.0 ± 0.7^{c}	0.0079 ± 0.0003^{bc}
Weaver	coastal	11	0.134 ± 0.004^{b}	35.7 ± 1.5^{c}	0.0072 ± 0.0003^{c}
Harrison	coastal	13	0.110 ± 0.003^{c}	36.3 ± 0.6^{c}	0.0060 ± 0.0001^{d}

Table 6.2. Pearson correlation matrix relating relative ventricular mass (RVM), percentage compact myocardium (% compact), relative dry compact mass (RDCM) of female fish from seven sockeye salmon populations and eight migration difficulty variables (see Table 2.1). ATU = accumulated thermal units, F_M = Fraser River discharge. Bold font indicates the migration difficulty variable with the highest correlation coefficient for a given physiological variable. Three critical values are indicated: $p < 0.05$ (no correction for multiple comparisons), $p < 0.018$ (Benjamini and Yekutieli False Discovery Rate) and $p < 0.006$ (Bonferroni).

	RVM	**% compact**	**RDCM**
Migration distance (D_M)	0.626	0.801*	**0.933**‡
Migration elevation (E_M)	0.744	0.482	0.812*
Work ($0.0001 \bullet E_M \bullet D_M$)	0.662	0.725	0.913‡
River slope ($500(E_M D_M^{-1})$)	0.736	0.170	0.607
Migration effort ($0.0001 \bullet D_M \bullet F_M$)	0.426	**0.899**‡	0.866†
Migration duration	0.598	0.785*	0.906‡
Migration rate	**0.787***	0.558	0.880†
ATU	0.580	0.833*	0.925‡
Aerobic scope	0.354	0.748	0.893†
RVM	-	0.164	0.764*
% compact	-	-	0.761*
RDCM	-	-	-

* $p < 0.05$; † $p < 0.018$, ‡ $p < 0.006$

CHAPTER 7: THE EFFECT OF TEMPERATURE ACCLIMATION ON MYOCARDIAL β-ADRENOCEPTOR DENSITY AND LIGAND BINDING AFFINITY IN TWO POPULATIONS OF SOCKEYE SALMON

7.1 Introduction

The preceding chapters clearly demonstrated a link between maximum aerobic scope and maximum cardiac performance (Chapters 3, 4 and 5) and provided evidence that the decline in aerobic scope above T_{opt} is driven by cardiac collapse (Chapter 5). Similar to aerobic scope, ventricular composition also differed among populations and is likely under strong selection pressure by the upriver migration conditions (Chapters 3 and 6). Therefore, I again turned to the heart in order to examine whether adrenergic cellular stimulation was an important mechanism for high thermal tolerance in sockeye salmon.

Adrenergic stimulation is critical for increasing cardiac performance during exercise and maintaining cardiac performance at temperature extremes in salmonids (Hanson et al., 2006; Hanson and Farrell, 2007; Keen et al., 1993; Shiels et al., 2002). Adrenergic stimulation has both chronotropic (rate) and ionotropic (force) effects on the teleost heart (Ask, 1983; Axelsson et al., 1987; Cobb and Santer, 1973; Farrell et al., 1986; Farrell et al., 1982; Laurent et al., 1983; Temma et al., 1986; Vornanen, 1989). These effects are mediated through the β-adrenoceptor (β-AR) signalling pathway, which primarily involves a β_2 subtype in salmonids (Ask et al., 1980; Ask et al., 1981; Gamperl et al., 1994; Keen et al., 1993). Cardiac adrenergic stimulation is possible through both sympathetic and humoral (catecholamines are released from chromaffin tissue within the head kidney) routes in salmonids, though many other fish lack sympathetic cardiac innervation (Donald and Campbell, 1982; Farrell and Jones, 1992; Laurent et al., 1983). Indeed, circulating catecholamines increased 10-fold above resting levels in rainbow trout swum to 2 bl s^{-1} and as much as 92-fold in rainbow trout chased to exhaustion (Butler et al., 1986; Perry et al., 1996).

Cardiac sensitivity to adrenaline changes with temperature acclimation in rainbow trout (Ask et al., 1981; Farrell et al., 1996), which has partly been attributed to changes in cell surface β-AR density (Gamperl et al., 1998; Keen et al., 1993). Specifically, cardiac adrenergic stimulation protects rainbow trout cardiac function at low temperatures (Hanson and Farrell, 2007; Graham and Farrell, 1989; Keen et al., 1993), and β_2-AR density (B_{max}) increased almost 3-fold in cold-acclimated rainbow trout (Keen et al., 1993). However, adrenergic stimulation and protection diminishes at high temperatures in rainbow trout (Farrell et al., 1997; Hanson and Farrell, 2007). In light of these findings, an elevated B_{max} at warm temperatures could improve cardiac performance and protection, leading to enhanced thermal tolerance.

I sought a mechanistic explanation for the observed differences in thermal tolerance among populations of Fraser River sockeye salmon. Chilko and Nechako sockeye salmon are co-migrating populations that enter the river at the same time and encounter similar warm water temperatures and velocity conditions in the lower Fraser River and Hells Gate (Table 2.1, 3.5). Both the Chilko and Nechako populations have difficult migrations, traveling 642 and 958 km upstream and reaching 1174 and 716 m in elevation, respectively. However, Chilko sockeye salmon spend the final third of their migration ascending the steep, cool Chilcotin River and spawn in or near a glacial lake. Chilko sockeye salmon correspondingly displayed an exceptionally high and broad thermal tolerance compared with Nechako sockeye salmon (Chapter 3). I hypothesized that Chilko sockeye salmon would have a greater β_2-AR density in ventricular tissues compared to Nechako sockeye salmon. To test this hypothesis, I compared cell surface B_{max} and β_2-AR binding affinity (K_d) from Chilko and Nechako sockeye salmon exposed to 13, 19 and 21°C for 4 days. Detailed materials and methods are provided in Chapter 2 (sections 2.2, 2.9 and 2.10.3).

7.2 Results

All Chilko sockeye salmon survived the 4-day treatments at 13, 19 and 21°C, as did all the Nechako sockeye salmon at 13 and 19°C. In contrast, only 4 out of 21 Nechako sockeye salmon (19%) survived the 4-day treatment at 21°C.

There were no significant differences in gross body morphology among temperature treatments or between sexes within a population, except for the significantly higher gonadosomatic index (GSI) of females compared to males in both populations (Table 7.1). Body mass, fork length and condition factor did not significantly differ between the two populations. However, Chilko sockeye salmon had a significantly higher relative ventricular mass (RVM) and a higher GSI compared to Nechako sockeye salmon (Table 7.1).

Independent of the temperature treatment, Chilko sockeye salmon had a 2-fold higher B_{max} compared to Nechako sockeye salmon (Fig 7.1). Furthermore, B_{max} significantly increased when Chilko sockeye salmon were warmed to 19° and 21°C from 13°C (Fig 7.1). In contrast, temperature exposure had no effect on B_{max} in Nechako sockeye salmon. Thus, not only did Chilko sockeye salmon have a greater B_{max} compared to Nechako, they actually increased B_{max} in response to warming.

In contrast, K_d did not significantly differ between populations or with temperature treatment (Fig 7.2).

7.3 Discussion

Nechako and Chilko sockeye salmon populations clearly differ in both ventricular B_{max} and the ability to alter cell surface B_{max} within a short (4-day) thermal acclimation period. The response to warming in Chilko sockeye salmon sharply contrasts with previous studies that showed a decreased in B_{max} with warm acclimation in rainbow trout (Gamperl et al., 1998; Keen et al., 1993). Chilko sockeye salmon clearly have a higher thermal tolerance compared to Nechako sockeye salmon, as is evident from the respective aerobic scope Fry curves (Chapter 3), and the observation that only 19% of Nechako sockeye salmon survived the 4-day temperature treatment at 21°C, while all the Chilko sockeye salmon survived. I propose that the elevated B_{max} for Chilko sockeye salmon may provide greater cardiac performance and protection at temperature extremes and thus may be one of the mechanisms leading to their broader and higher thermal tolerance relative to the Nechako population.

7.3.1 Differences in B_{max} between Populations

Rainbow trout acclimated to 6°C were included as a reference group to confirm the quality of the assay. The present study's results (B_{max} = 36.3 fmol mg protein^{-1} and K_d = 0.23 nM) fall within expected values. Previous studies reported a B_{max} of 23-26 fmol mg protein^{-1} and K_d of 0.13-0.19 nM for rainbow trout acclimated to 12-14°C (Gamperl et al., 1998; Hanson et al., 2005; Olsson et al., 2000). Gamperl et al. (1994) reported a higher B_{max} and comparable K_d (40 fmol mg protein^{-1} and 0.25 nM) for rainbow trout acclimated to a colder temperature (8°C) in seawater. These results for rainbow trout provide confidence in the assay technique.

B_{max} for Chilko sockeye salmon was at least twice as high as any other salmonid (Gamperl et al., 1994; Gamperl et al., 1998; Hanson et al., 2005; Olsson et al., 2000). Similary, their B_{max} was also more than twice that of non-salmonid athletic fish species: mahimahi (*Coryphaena hippurus*) (46.9 fmol mg^{-1} protein^{-1}), skipjack tuna (*Katsowonus pelamis*) (41.3 fmol mg^{-1} protein^{-1}), yellowfin tuna (*Thunnus albacares*) (25.7 fmol mg^{-1} protein^{-1}), and Pacific mackerel (*Scomber japonicus*) (27.2 fmol mg^{-1} protein^{-1}) (Olsson et al., 2000). Only the winter flounder (*Pleuronectes americanus*) (B_{max} = 252 fmol mg^{-1} protein^{-1}) has a higher B_{max}, however, the binding affinity was extremely low, leading the investigators to propose that flounder hearts may also be populated by β_3-adrenoreceptors (Mendonca and Gamperl, 2009). In contrast, Nechako sockeye salmon displayed B_{max} values that were similar to mahi-mahi, skipjack tuna and previous estimates of sockeye and chinook salmon (Gamperl et al., 1998; Olsson et al., 2000). Both sockeye salmon populations displayed B_{max} values well above those determined for African catfish (*Claris gariepinus*) (14.3-17.8 fmol mg^{-1} protein^{-1}), warm acclimated-rainbow trout (12-14°C, 23-26 fmol mg^{-1} protein^{-1}) and an Antarctic nototheniid (*Trematomus bernacchii*) (10.5 fmol mg^{-1} protein^{-1}) (Hanson et al., 2005; Olsson et al., 2000).

This experiment on wild fish was conducted under a very controlled setting and many of the potential confounding factors for this population comparison were removed or minimized. For example, all the salmon were collected at the same time and over a period of two days. The fish were collected very early, ~1-3 days into the upriver migration; therefore, they had yet to experience the majority of the upriver conditions and had experienced a common ocean and river migration environment prior to capture. As a result, population differences were unlikely due to a plastic response to differential environmental conditions encountered prior to capture. Furthermore, all fish were held for the same amount of time and in the same tanks according to temperature treatment, thus eliminating the possibility for differential plastic responses after capture. Also, the differences in B_{max} were unlikely due to variation in the level of sexual maturation since previous studies suggest that gonadal steroid hormones do not modulate B_{max} in mature rainbow trout or chinook salmon (Gamperl et al., 1994; Gamperl et al., 1998). Finally, B_{max} was expressed per mg protein; therefore, the significant difference in RVM was not a factor. However, it is interesting to note that the larger RVM in Chilko sockeye salmon amplifies the difference in the total number of receptors on the ventricle.

7.3.2 Temperature Effects on B_{max}

The increase in B_{max} with warming in Chilko sockeye salmon was a novel response for fish and was not seen in Nechako sockeye salmon. Two previous studies with rainbow trout showed the opposite pattern, namely, an 11% decrease in B_{max} per °C increase in temperature (Gamperl et al., 1998; Keen et al., 1993).

Notably, the acclimation duration in the present study (4 days) was much shorter than previous studies (typically >3 weeks, Gamperl et al., 1998; Hanson et al., 2005; Keen et al., 1993). The assay used in the present study cannot determine whether the additional β-adrenoceptors were synthesized *de novo* or whether they were simply released from vesicles contained within the cell. Moreover, the time interval required to alter β_2-AR expression is unknown for fish and is an area of research should be pursued in future studies.

A case has been made for the importance of β_2-AR to *stimulate* maximum cardiac performance during exercise and at high temperature in salmon (Butler et al., 1986; Hanson et al., 2006; Hanson and Farrell, 2007; Randall and Perry, 1992) and to *protect* maximum cardiac function against a harmful acidotic and hypoxic venous environment, especially at high temperatures (Hanson and Farrell, 2007; Holk and Lykkeboe, 1998; Kiceniuk and Jones, 1977). *In vitro* and *in situ* perfused heart studies have consistently shown that acidic and hypoxic conditions lead to impaired cardiac contraction (Dridezic and Gesser 1994; Farrell et al., 1986; (Farrell et al., 1988b; Farrell and Milligan, 1986; Gesser et al., 1982; Gesser and Jorgensen, 1982; Kalinin and Gesser, 2002) and adrenergic stimulation plays a key role in maintaining or enhancing cardiac function under these conditions (Driedzic and Gesser, 1994; Hanson et al., 2006; Hanson and Farrell, 2007; Nielsen and Gesser, 2001).

When the ventricular cell-surface β_2-AR is activated, the signalling pathway ultimately increases intracellular calcium delivery to the cardiomyocytes, which enhances both the force and rate of cardiac contraction. Thus, calcium handling in the cardiomyocytes may play a critical role in temperature tolerance in sockeye salmon. Calcium cycling and sarcoplasmic reticulum function has been demonstrated to be critical for the broad temperature tolerance in bluefin tuna (Castilho et al., 2007; Landeira-Fernandez et al., 2004; Shiels et al., 2011). Specifically, bluefin tuna have more sarcoplasmic reticulum Ca^{2+} ATPase (SERCA2) in their cardiomyocytes, which regulates Ca^{2+} uptake into the sarcoplasmic reticulum, compared to warmer species that do not have to cope with a wide range of temperatures (Castilho et al., 2007; Landeira-Fernandez et al., 2004). Future studies should examine whether Chilko sockeye salmon similarly have more SERCA2 compared to populations with a more narrow optimal thermal range.

Given that the reduction in aerobic scope at high temperatures can likely be attributed to a limitation in maximum cardiovascular performance (Chapter 5), increased B_{max} could lead to superior thermal tolerance. Consequently, the exceptionally high and broad thermal tolerance of Chilko sockeye salmon may be due, at least in part, to elevated B_{max}. This hypothesis should be further investigated using perfused heart studies with Chilko and Nechako sockeye salmon.

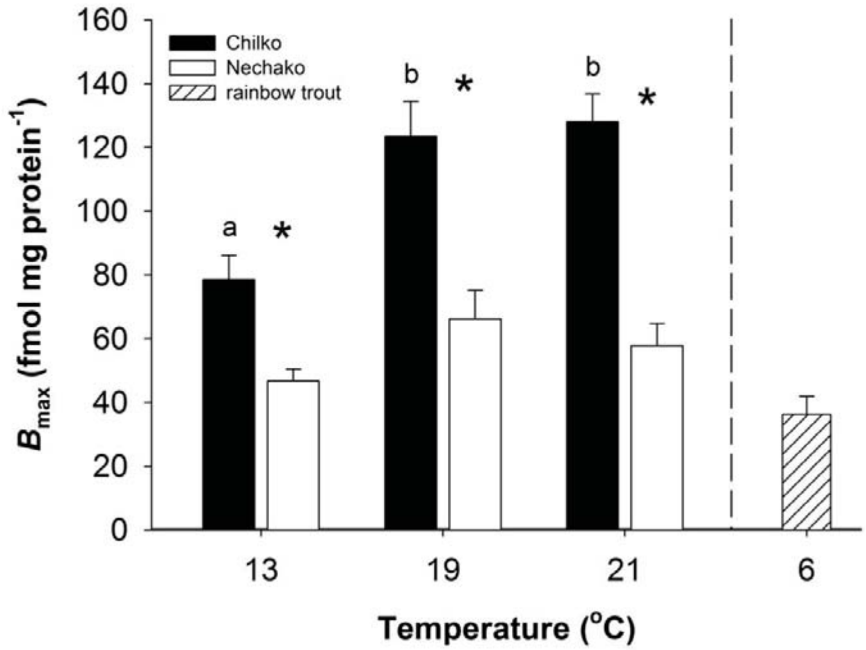

Figure 7.1. Ventricular β-adrenoceptor density (B_{max}). Significant differences between populations are indicated by * ($p < 0.001$). Significant differences between temperature treatments existed only for Chilko sockeye salmon and are indicated by differing letters. Rainbow trout were included as a reference group to confirm the assay technique.

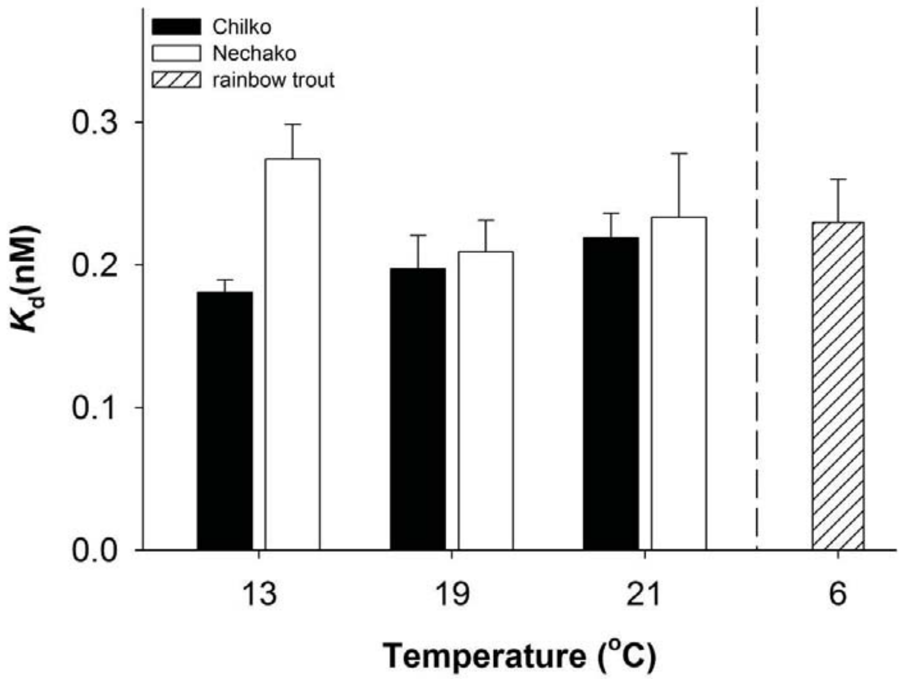

Figure 7.2. Ventricular β-adrenoceptor [3H]CGP-12177 dissociation constant (K_d). No significant differences were detected among sockeye salmon groups. Rainbow trout acclimated to 6°C in freshwater were included as a reference group to confirm the assay technique.

Table 7.1. Gross morphology for fish used in β-AR experiment. Relative ventricular mass (RVM) and gonadosomatic index (GSI) are indicated. Mean ± SEM are presented. Significant differences within and between populations are indicated by differing letters and an asterisk, respectively. N-values for GSI are indicated in parentheses.

	Chilko	Nechako	Rainbow trout
n	16	18	7
body mass (kg)	2.14 ± 0.10	2.31 ± 0.10	1.88 ± 0.08
fork length (cm)	58.0 ± 0.7	58.5 ± 0.6	47.1 ± 1.2
condition factor	1.09 ± 0.02	1.14 ± 0.03	1.81 ± 0.08
RVM %	0.156 ± 0.003	0.145 ± 0.004*	0.118 ± 0.009
GSI (males) %	2.3 ± 0.2 (9)[a]	1.4 ± 0.1 (10)[y]*	1.8 ± 0.5
GSI (females) %	5.1 ± 0.3 (7)[b]	3.8 ± 0.2 (8)[z]*	

CHAPTER 8: CONCLUSIONS

The general objective of this thesis was to examine the physiological basis for thermal tolerance among sockeye salmon populations. I hypothesized that thermal limits are set at a local level by physiological limitations in aerobic performance due to cardiac collapse.

In support of this hypothesis, my research suggests that sockeye salmon populations in the Fraser River watershed have physiologically adapted to meet the specific challenges of their local upriver migration conditions. Thermal optima for each population coincided with the river temperatures typically encountered during upstream migration. Temperatures exceeding the population-specific thermal optimum resulted in severely impaired aerobic scope and swimming performance. My research further suggests that fish are unable to swim at warm temperatures due to insufficient oxygen supply to meet the swimming muscles' demand, triggered via a cardiac limitation. Finally, I identified that thermal tolerance differs across sockeye salmon populations and suggest a potential mechanism for enhanced thermal tolerance in Chilko sockeye salmon. All told, important management and conservation implications may emerge from my research. I identified a possible cause for in-river mortality associated with warm temperatures in sockeye salmon and I identified certain populations most vulnerable to climate change.

8.1 Local Adaptation in Fraser River Sockeye Salmon Populations

The lifetime fitness of millions of sockeye salmon that annually return to the Fraser River depends on a physically demanding upriver migration. During this once-in-a-lifetime event, fish swim continuously against a fast flowing river for several weeks at ground speeds of 20 to 40 km day^{-1} (English et al., 2005). Feeding ceases in the ocean and upriver swimming is fuelled entirely by endogenous energy stores. Because sockeye salmon return to natal spawning grounds with remarkable fidelity, the Fraser River is home to more than 100 genetically and geographically distinct populations (Beacham et al., 2005), each of which experiences variable upriver migration conditions, depending on when they enter the river and where they spawn. Thus, populations vary in migration distance (100 to 1100 km), elevation gain (10 to 1200 m), river temperature (9° to 22°C), and river flow (2000 to 10,000 $m^3 s^{-1}$). Reproductively isolated populations can potentially adapt to the environmental conditions that induce maximal aerobic challenges, which for sockeye salmon likely occur during the upriver spawning migration. Indeed, local migratory conditions apparently exert strong selection pressure for adaptation because morphological and behavioural characteristics (gross somatic energy, body morphology, egg number and swimming behaviour) correlate with river migration distance, elevation gain and/or work (distance x elevation gain) in sockeye salmon (Crossin et al., 2004; Hinch and Rand, 2000). Therefore, I hypothesized that physiological adaptation in sockeye salmon occurs locally at the population level, reflecting the specific river migration conditions.

I applied an established conceptual and mechanistic framework for understanding temperature effects on aquatic ectotherms, the oxygen- and capacity-limited thermal tolerance (OCLTT) hypothesis (Pörtner 2002, Pörtner and Knust, 2007, Pörtner and Farrell, 2008). OCLTT attributes the decline in aerobic scope (the difference between resting and maximal oxygen consumption rates) above an animal's optimal temperature (T_{opt}) to capacity limitations of the organs systems that deliver oxygen to the tissues. The expectation is that local adaptations should extend to multiple levels of the cardiorespiratory system, explaining intraspecific variation in thermal tolerance and aerobic scope.

Eight sockeye salmon populations spanning a range of river migration difficulties were used to varying degrees in my study. Migration difficulty was quantified using various environmental river characteristics: distance, elevation gain, temperature, migration rate, duration, work, river slope and migration effort. I predicted that migration distance, elevation gain and work would exert the strongest selection pressure on aerobic scope given their importance in selecting for morphological traits (Crossin et al., 2004). I measured individual cardiorespiratory performance (N = 97) as a function of temperature in four populations. Aerobic scope curves for each population were significantly related to the historic range in river temperature they experienced, a finding consistent with two additional Fraser River sockeye salmon populations (Farrell et al., 2008; Lee et al., 2003c). The coastal Weaver sockeye salmon experience the coldest temperatures and had the lowest T_{opt} (14.5°C) whereas the upriver populations experience similar river temperatures and accordingly had a similar T_{opt} (range 16.4-17.2°C). The upriver Chilko population displayed an unusually broad optimal thermal range that corresponded with the lower temperatures encountered during their difficult migration in the Chilcotin watershed and the high temperatures encountered while migrating through Hells Gate. In addition, significant differences in maximum aerobic scope among the populations were positively correlated with the distance to the spawning ground. These results suggest population level adaptation of maximum aerobic scope to selection imposed by river conditions encountered during migration.

Given that cardiac capacity and aerobic scope are tightly related (Farrell, 2009), I expected populations with the greatest migratory demands to display similar adaptations in cardiac morphology and performance. Relative ventricular mass (RVM), percentage compact myocardium (% compact; the proportion of the ventricle supplied with coronary blood flow) and relative dry compact mass (RDCM) significantly differed among populations. All three morphological variables were significantly greater for upriver compared with coastal populations, suggesting that the hydraulically challenging sections of the river may impose selection on heart morphology. In addition, correlations between cardiac morphology and migration difficulty, and maximum aerobic scope with RDCM, provide promising evidence for local adaptation to river conditions on an even finer scale (Endler, 1986; Schluter, 2000; Taylor, 1991). Furthermore, aerobic scope, cardiac scope and scope for heart rate were all positively correlated, and varied in parallel with river temperature, suggesting that the temperature dependence of cardiac performance is linked to that of aerobic capacity at the population level. In contrast, maximum cardiovascular performance did not significantly differ among upriver populations, though notably, coastal populations were not included in the analysis. I predict that cardiovascular performance in coastal populations would be reduced compared to upriver populations, mimicking the trend observed with aerobic scope.

Altogether, this is the first ever large-scale study to demonstrate how wild fish within a single watershed are physiologically fine-tuned to their migration environment. I found a strong relationship between the difficulty of river migration and the cardiorespiratory physiology and cardiac morphology of the populations examined. Furthermore, optimal water temperature for aerobic swimming matched the typical water temperatures historically encountered by each population.

The failed attempt to transplant coastal sockeye salmon to upriver spawning grounds in order to help re-establish populations decimated by the 1913 Hells Gate rockslide (Ricker, 1972) provides a cautionary tale to managers. It is becoming clear that coastal populations are not adapted for the more arduous upriver migration and are ill-equipped to complete the more difficult migration (Taylor, 1991). Combining my results with those found in the literature (Crossin et al., 2004; Gilhousen, 1980; Lee et al., 2003c), the upriver, more athletic populations (Early Stuart, Nechako, Chilko and Quesnel) can be characterized as having more somatic energy at the start of their migration, fewer eggs, a smaller, more fusiform body shape, higher aerobic scope, more energetically efficient swimming behaviour and larger hearts with more compact myocardium compared to coastal populations (Weaver and Harrison). Lower Adams sockeye salmon fall somewhere in-between these extremes.

8.2 Mechanism of Cardiorespiratory Collapse at High Temperature

Sockeye salmon exposed to temperatures above their population-specific T_{opt} had severely impaired aerobic swimming performance. However, the mechanism of this decline in aerobic scope is poorly understood. Using the OCLTT hypothesis as a framework, I predicted that an oxygen limitation could occur at the level of the gills, the heart or the muscle. By simultaneously measuring oxygen consumption, cardiac output and arterial and venous oxygen status in fish swimming to U_{crit}, I comprehensively examined these possibilities for the first time.

Corroborating earlier work for sockeye salmon swimming at ~75% of U_{crit} (Steinhausen et al., 2008), my data showed that scope for f_H collapsed at a lower temperature than either aerobic scope, cardiac scope or scope for V_s. Thus, my data give weight to the idea that reduced scope for f_H above T_{opt} is the triggering factor that limits maximum $\dot{Q}$ and the capacity of the cardiorespiratory system to transport oxygen. There was no evidence of a gill limitation since P_{aO2} and C_{aO2} remained constant at temperatures above T_{opt}. Furthermore, there did not appear to be an immediate diffusion limitation at the muscle since P_{vO2} and C_{vO2} did decline with further warming above T_{opt}, though a diffusion limitation may have developed at the tissues at the warmer temperatures (Wagner, 1996). All told, the initiating step leading to a mismatch between oxygen supply and demand at the swimming muscle appears to be a cardiac limitation due to reduced scope for heart rate.

8.3 Potential Mechanism for Enhanced Thermal Tolerance

I sought a mechanistic explanation for the observed intraspecific variation in thermal tolerance. Cardiac adrenergic stimulation protects salmonid cardiac function at low temperatures (Keen et al., 1993; Shiels et al., 2002) and against the negative effects of acidosis and hypoxia during exercise (Hanson and Farrell, 2007), but protection diminishes at high temperatures associated with declining aerobic scope (Hanson and Farrell, 2007; Keen et al., 1993). Therefore, I hypothesized that the unusually broad and high thermal tolerance of the Chilko population would reflect a greater density of adrenaline-binding ventricular β-adrenoceptors compared with the co-migrating Nechako population that has a narrower and lower thermal tolerance. I determined ventricular β-adrenoceptor density (B_{max}) and binding affinity (K_d) in fish that had been held for 4 d at 13, 19 or 21°C. At all three temperatures, Chilko had a significantly higher B_{max} compared with Nechako sockeye salmon (K_d did not differ) and over twice that previously measured for salmonids. In contrast to rainbow trout (Gamperl et al., 1998; Keen et al., 1993), B_{max} increased significantly when Chilko sockeye salmon were warmed to 19 and 21°C from 13°C. Thus, not only did Chilko sockeye salmon have a greater B_{max} compared to Nechako, they actually increased B_{max} in response to warming. Consequently, elevated ventricular β-adrenoceptor expression for Chilko sockeye salmon may provide greater cardiac capacity and protection at temperature extremes, expanding their thermal tolerance compared with the Nechako population.

8.4 Conservation and Management Implications

Warm river temperatures have been repeatedly associated with high in-river mortality in ecologically, economically and culturally important Fraser River sockeye salmon. Mortality clearly differs across populations and among years in sockeye salmon (Hinch and Martins, 2011). My results support the hypothesis that continued increases in summer river temperatures will result in population-specific responses of sockeye salmon (Farrell et al., 2008).

The sockeye salmon populations included in my study clearly differ in T_{crit} (when aerobic scope is zero and fish survival is passive, time-limited and supported by anaerobic metabolism). While upstream migration is obviously impossible at T_{crit}, exactly how much aerobic scope is required for successful river migration is unknown. A biotelemetry study with Weaver sockeye salmon suggests that at least 50% of aerobic scope is needed [<10% of fish reached their spawning area at 18-21°C when aerobic scope is 0-68% of maximal (Farrell et al., 2008; Mathes et al., 2010)]. However, given that all the upriver populations studied here have 89-97% of maximum aerobic scope at the upper 90th percentile of historic temperatures encountered, perhaps ~90% of aerobic scope is necessary over a broader time scale for upriver populations experiencing greater migration difficulty. Accordingly, temperatures exceeding the population-specific upper T_p (temperature corresponding to 90% of maximum aerobic scope, which includes current temperature maxima of 21.5°C) could limit successful migrations due to a functional collapse in aerobic scope. Empirically, no sockeye salmon population has initiated river migration at a temperature exceeding 21°C (Hyatt et al., 2003), nor has a historic mean migration temperature been above 19°C (Hodgson and Quinn., 2002). However, Chilko sockeye salmon may emerge as "superfish" with greater resilience to climate change by being able to maintain cardiorespiratory performance at higher temperatures. Conversely, Weaver and Nechako populations appear especially susceptible to high temperature. If Weaver sockeye salmon continue to enter the Fraser River up to six weeks earlier than normal (Cooke et al., 2004), exposing themselves to such high temperatures, high en-route mortality will continue (Cooke et al., 2004; Farrell et al., 2008; Mathes et al., 2010,).

In summary, while warming water temperatures are undoubtedly a global issue for fishes at the species level, I propose a concern at the population level for Fraser River sockeye salmon. Since current warming trends in the Fraser River (1.9°C during the last 60 years) are expected to continue (Ferrari et al., 2007; Morrison et al., 2002), survival of sockeye salmon populations will require some combination of behavioural adaptations (to avoid high temperatures by entering the river when it is cooler) and physiological adaptations (a higher T_p to increase high temperature tolerance). Substantial shifts in entry timing are unlikely due to energy and time constraints to achieve highly conserved spawning dates. On the other hand, warming river temperatures could exert strong selective pressure for physiological adaptation. Physiological adaptation requires trait heritability, trait variability and differential fitness. Evidence of all three have been presented here: local adaptation of cardiorespiratory traits, individual variability in these traits and zero lifetime fitness for fish failing to complete their upriver migration. The salmonid genome clearly has the capacity for higher thermal tolerance [current thermal extremes are documented for redband trout (*Oncorhynchus mykiss*) which experienced 15-27°C diurnally, acutely tolerated 29°C and demonstrated a plateau in aerobic scope at 26°C (Rodnick et al., 2004)], suggesting that there is potential for future physiological adaptation in Fraser River sockeye salmon. I suggest that adaptations at the level of the heart that sustain cardiac performance at high temperatures, such as the increased ventricular β-adrenoceptor density displayed in Chilko sockeye salmon, could be beneficial in this regard. The current challenge is determining whether the rates and extents of physiological adaptation for Fraser River sockeye salmon will allow them to adapt quickly enough to cope with the current warming trend.

8.5 Future Directions

This thesis has identified numerous future directions for further research into questions surrounding the physiological basis of thermal tolerance and local adaptation in fishes.

First, the correlational evidence relating physiological variability to migration difficulty presented here only provides promising, but not definitive, evidence of local adaptation. Therefore, breeding studies should be conducted to look for more conclusive evidence of adaptation. In addition, this thesis only examined a single, brief stage of the life cycle of a sockeye salmon. Indeed, the upriver migration represents only ~2% of a sockeye salmon's entire life. It would be interesting to examine thermal tolerance and physiological variability across populations in other life stages. In addition, cardiovascular physiology should be examined in adult sockeye salmon from coastal populations to determine if the trends for aerobic scope and cardiac morphology extend to cardiac performance.

This thesis also opens up a myriad of questions regarding cardiorespiratory collapse at high temperature. Comparisons of ultrastructure in heart and skeletal muscle (e.g. capillary and mitochondria density) across populations varying in thermal tolerance and athletic ability would provide insight into the role of muscle morphology in limiting oxygen diffusion at high temperature and with exercise. Furthermore, the cause of the bradycardia and cardiac disrhythmia during high temperature swimming is unknown. Studies using atropine to block vagal tone should be conducted to determine if the bradycardia and disrhythmia are under cholinergic control. Notably, I was unable to investigate the possibility that thermal tolerance differs between male and female sockeye salmon, which is an area of research that should be pursued. Studies measuring blood flow distribution would also be beneficial, though there are problems with microsphere technique in fish (Farrell et al., 2001b). Direct measurement of gonadal blood flow during swimming and high temperature exposure would provide insight into important trade-offs between swimming and gonad development since all tissues cannot be simultaneously perfused. Finally, the capacity for migrating adult sockeye salmon to acclimate and the role of phenotypic plasticity in temperature tolerance is still poorly understood. Temperature studies should be used to examine the possibility and timecourse for acclimation from the gene to whole animal level.

A major concern emerging from my thesis is that populations are already experiencing temperatures at their upper thermal limit. Since Fraser River temperatures are expected to continue to warm along the same trajectory (~2°C over 60 years, Ferrari et al., 2007; Morrison et al., 2002), populations will have to adapt in order to cope. However, we don't know which or if any populations will be able to adapt quickly enough to keep pace with the warming temperatures. Therefore, studies examining the rate and extent of physiological adaptation are necessary.

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To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pinhey, Nick; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Ulibarri, Nicola; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Relicensing Newsletter-Vol 2 Issue 2 - Released
Attachments: Don Pedro Newsletter Vol 2 Issue 2 Dec 2012.pdf

Attached is a copy of the latest issue of the Don Pedro Project Relicensing Newsletter. A copy has also been posted on the relicensing website at www.donpedro-relicensing.com (Introduction Tab/Announcements).

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

Volume 2 | Issue 2

Don Pedro

A newsletter about the relicensing of the Don Pedro Project

Relicensing studies set to be reviewed

A major milestone of the Don Pedro Project relicensing process will occur January 17, 2013, when the Initial Study Report (ISR) is issued by the Districts and filed with the Federal Energy Regulatory Commission (FERC).

The ISR is a requirement of the Integrated Licensing Process as overseen by FERC. The ISR will contain progress reports on the more than 30 studies being implemented by the Districts as required by FERC's December 2011 Study Plan Determination.

> **MORE INSIDE:** Take a look inside for more detailed information about 2012 relicensing studies.

This large document will serve as part of the record of official information that FERC must consider as it deliberates over issuance of a new license, and what new conditions might be appropriate to accompany a new license.

This issuance of the ISR will then be followed up by an Initial Study Report Meeting on January 30-31, 2013 to be held in Modesto. Representatives from FERC will attend this public meeting along with other interested parties. The studies completed will be reviewed, the study results will be summarized and there will be a question and answer session.

Another important date comes 45 days later when relicensing participants can file comments on all the studies and request additional studies.

These dates are in accordance with an Oct. 12, 2012 letter issued to the Districts from FERC detailing target dates associated with the ISR. FERC issued its 140-page Study Plan Determination (SPD) in late 2011. In it, FERC approved a total of 34 studies to be conducted by the Districts as part of the relicensing process.

Most of the studies involve extensive field work and considerable coordination of logistics to execute the studies efficiently and consistent with the study plans approved by FERC. Some field work began as early as January 2012.

Initial Study Plan Meeting

When: *January 30-31, 2013 | 8 a.m.*

Where: *MID Multipurpose Room, 1231 11th St., Modesto, CA*

What: *Studies will be reviewed, results will be summarized and Q&A will be held.*

Studies like the one pictured here will be summarized at a Jan. 30-31 meeting.

Important dates

January 17, 2013
Initial Study Report filed with FERC

January 24, 2013
Training for Relicensing Participants interested in using the temperature models

January 30-31, 2013
Initial Study Report Meeting

February 8, 2013
Districts issue Initial Study Report Meeting Summary

March 10, 2013
Relicensing Participants file with FERC any requests for new studies or modifications to studies

What's inside

- More than 20 different relicensing studies took place in 2012
- Workshops the cornerstone of public input process

Dispute resolution process decision

On January 11, 2012, The National Marine Fisheries Service (NMFS) filed a Notice of Study Dispute contesting several aspects of the Federal Energy Regulatory Commission's (FERC) Study Plan Determination issued Dec. 21, 2011 regarding the Don Pedro Project.

As part FERC's Integrated Licensing Process (ILP), a hearing was held on the matter in front of a three-member advisory Technical Panel.

FERC issued its final decision on May 24, 2012, largely agreeing with the Districts' study plans and FERC's Determination, resulting in minor modifications to the Districts' studies. NMFS was disputing FERC's decisions about studies the Districts did not adopt in their plans.

The dispute process is detailed in the ILP regulations and involves the convening of a Technical Panel to consider the areas of dispute, and provide an opinion to FERC's Director of the Office of Energy Projects. The FERC Director makes the final decision giving due consideration to the opinion of the three-member Technical Panel.

Numerous workshops, meetings highlight importance of public input

Public input is a critical component in the relicensing of the Don Pedro Project. This component is well illustrated in the fact that the Districts have held eight workshops with relicensing participants (RPs) since March 2012.

Three workshops regarding salmon and *O.mykiss* were held. There were three workshops on hydrology and operations modeling and one workshop each held discussing reservoir and river temperature modeling. Here's a rundown of the eight workshops.

Eight public workshops regarding Don Pedro relicensing have been held since March 2012.

Water & Aquatics Resources Study 5 (W&AR-5) Workshop No.1 was held in April 2012 and featured discussions about issues affecting Tuolumne River salmonids. W&AR-5 Workshop No.2 was held in June and covered similar issues in additional detail.

Water & Aquatics Resources Study 2 (W&AR-2) Workshops Nos. 1, 2 and 3 were held in April, September and October, respectively, and focused in areas surrounding Project Operations Model Development and hydrology.

A pair of workshops on Water & Aquatics Resources Study 3 (W&AR-3) discussed a Don Pedro Reservoir Temperature Model in April and October. Additionally, one workshop on the lower Tuolumne River Temperature Model was held in October.

Socioeconomic Study Plan

In addition to the workshops, a public meeting discussing the Socioeconomic Study Plan was held in November 2012. The purpose of this meeting was to give an update on the progress of the Socioeconomic Study Plan, share information, seek relevant socioeconomic information from the public, and hear comments with respect to the plan.

The primary goals of the study on socioeconomic resources are to quantify the baseline economic conditions and resources in the region affected by the Don Pedro Project's water supply, flood control, and power benefits. In addition, the study will quantify the socioeconomic effects of the current project operations and develop methodologies and a framework that can be used to evaluate the potential socioeconomic effects of any proposed changes to project operations that may be considered as part of the relicensing process, including scenarios affecting the availability of agricultural and urban water supplies.

As usual, information about upcoming meetings and workshops is available on the relicensing website at donpedro-relicensing.com. Additionally, documents and filings are available.

Sampling of 2012 studies

As part of the relicensing process, the Districts are wrapping up the numerous studies that took place in 2012.

These include wide-ranging studies of recreation resources, cultural resources, botanical, wildlife and wetlands, and fish and river riparian resources.

What follows is a brief sampling of a few details from selected studies as part of the relicensing process. Reports from these studies and many others will be included in the Initial Study Report (ISR) to be filed Jan. 17, 2013.

Spawning Gravel Study (Water & Aquatics Resources Study 4)

The purpose of the spawning gravel study is to examine gravel availability and spawning utilization as a means of determining the current spawning capacity and spawner/recruit relationships for Chinook salmon and *O. mykiss* in the lower Tuolumne River. Specific information obtained by this study will update information from prior studies in order to:

- characterize the current area, distribution, and use of spawning riffles in the lower Tuolumne River,
- develop average annual gravel transport rates from channel geometry and mapped changes in riffle areas since 1988, and 1999–2000, and
- provide estimates of maximum spawning run sizes supported by the spawning riffles under current conditions.

Bathymetric surveys and fine sediment and gravel mapping were completed in summer 2012. Depth and velocity measurements to include in the assessment of habitat criteria were collected in the field in October 2012 when flows were within suitable salmonid spawning ranges.

Amphibians listed under the Endangered Species Act (Terrestrial Resources Studies 7 and 8)

The specific objectives of these studies are to:

- Identify and map known occurrences of the California Red-Legged Frog and California Tiger Salamander and determine, if appropriate, the closest known breeding locality;
- Evaluate the likelihood that either of these species currently exist in the study area using habitat assessments and historical records;
- Compile incidental observations of these species from other relicensing studies; and
- Provide information that can be used to develop a Biological Assessment and support a Biological Opinion.

GIS-based habitat assessments were completed for the study area. Surveys and field verification of potential habitat were completed between April and June 2012, including site visits during optimum temperatures for observations of the target species. No California Red-Legged Frog or Tiger Salamanders were observed.

Don Pedro Recreation Use Assessment (Recreation Resources Study 1)

The goal of the recreation facility condition, public accessibility, and recreation use assessment is to provide information about the need for maintenance or enhancement of existing recreation facilities to support current and future demand for public recreation at the Don Pedro Reservoir. The objectives of the study are to:

- assess the condition of existing developed recreation facilities at the Don Pedro Project, including dispersed use areas
- estimate present capacity of recreation facilities at the Project to support present and future demand for public recreation (i.e., facility carrying capacity),
- describe the preferences, attitudes, and characteristics of the Project's recreation users
- collect information about current Project recreation activities and future demand for activities, and
- undertake a creel survey in coordination with Study Plan W&AR-17, Reservoir Fish Population.

In accordance with the study plan, visitor surveys have been conducted on a monthly basis since January 2012 at Blue Oaks, Fleming Meadows and Moccasin Point recreation areas. Visitor surveys will continue through December 2012. The facilities inventory and dispersed recreation impact evaluations were conducted in October 2012.

www.donpedro-relicensing.com

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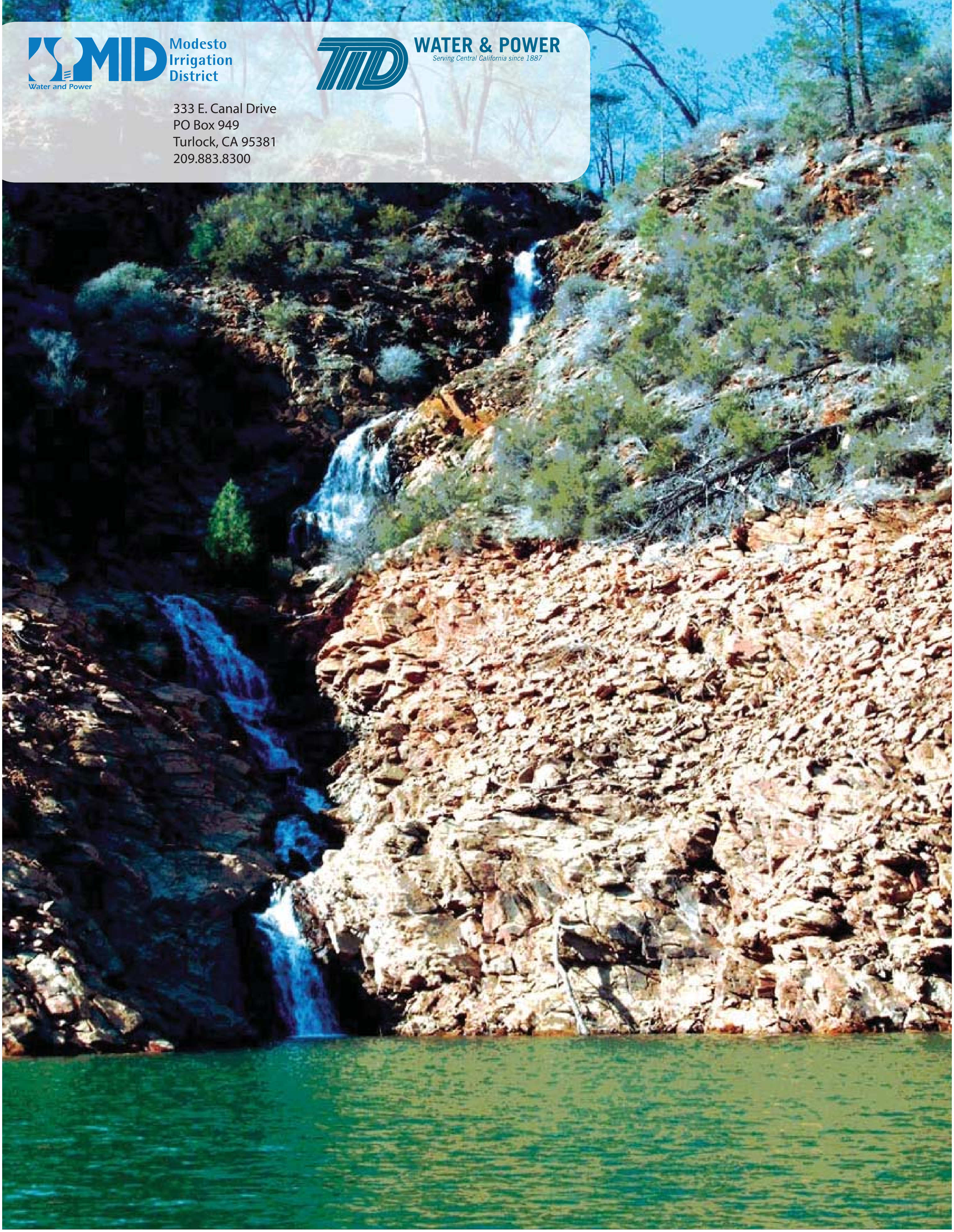

From: Annie Manji [Annie.Manji@wildlife.ca.gov]
Sent: Tuesday, January 08, 2013 6:48 PM
To: Steve Rothert; Dave Steindorf; William Jennings; Paul Marko; Bill Lyons; Bob Ott; Jerry Cadagan; Robert Shipley; Steve Welch; Martin Blake; Art Jensen; Nicole Sandkulla; Allison Boucher; Beth Brenneman; James Barnes; James Eicher; Jeff Horn; Lauren Fety; Peggy Cranston; Denean; Rhonda Morningstar Pope; Roselynn Lwenya; Charles Burt; Jenny Hatch; Duane Paul; Steve Pavich; Cindy Charles; Mary Motola; Chris Vierra; Riggs T; Dan Wheeler; Dave Wheeler; John Buckley; Rebecca Cremeen; Royal Robbins; Ann Hayden; Tim Byrd; Ron Slay; Minami Amber; Beniamine Beronia; Mein Janis; Damin Nicole; Frank Winchell; James Fargo; James Hastreiter; Lesley Kordella; Shana Murray; Ron Stork; Robert Hackamack; Maggie Dowd; Vern Shumway; Allison Willy; Deborah Giglio; Michelle Workman; Ramon Martin; Zac Jackson; Julia Jauregui; Harry Williamson; Janice Keating; Jesse Roseman; Chris Ott; Allison Schutte; Ray McDevitt; Timothy Findley; Le, Bao; Loy, Carin; Borovansky, Jenna; Devine, John; Staples, Rose; Mike Marshall; Douglas Wheeler; Ruth Porter; Joseph Lein; Noah Hughes; Todd Sill; Teresa Kinney; Sarah Shakal; Zeke Grader; Justin; Dan Steiner; Art Bowman; Jim Smith; David Linkard; Melissa Powell; George TeVelde; Vicki Stone; Jan Costa; Lloyd Mathiesen; Stanley Rob Cox; Reba Fuller; Kevin Day; Garth Stapley; Jack Bond; Jim Ridenour; Nick Pinhey; Bryan Wilson; Colette Verkuil; P Day; Zahra Hayat; Bill Amerine; Chris Shutes; John Stender; David O Romano; Lynette Asay; David K White; John Wooster; Kathryn Kempton; Larry Thompson; Maria Rea; Monica Gutierrez; Rhonda Reed; Richard Wantuck; Steve Edmondson; Thomas Holley; Stephen Bowes; Dan McDaniel; Jenan Saunders; Milford Wayne Donaldson; Susan Stratton; Mark Buckley; Maryann Moise Derwin; Richard Pool; Jeffrey Cowan; Mike Fleming; Donn W Furman; Ellen Levin; Michael Carlin; Tim Ramirez; William Sears; Marty McDonnell; John Mills; Nicola Ulibarri; Tom Orvis; Wayne Zipser; Michael Martin; Sandy Vasquez; Noah Hume; Scott Wilcox; Reggie Lewis; Tim Colvin; Doug Brewer; Thomas Terpstra; Laura Jensen; Brian Johnson; Chandra Ferrari; Eric Wesselman; Jessie Raeder; Patrick Koepele; Peter Drekmeier; Dan Madden; Ron Yoshiyama; Kevin Richardson; Lisa Holm; Mary Johannis; Peter Barnes; Susan Monheit; Julie Ganteinbein; Richard Roos-Collins; Annee Ferranti; Bob Hughes; Gretchen Murphey; Jennifer O'Brien; Mary Jane Taylor; Stephen Puccini; Tim Heyne; Anita Hellam; Bill Hudelson; Timi Horn; Elaine Gorman
Subject:Re: Don Pedro Initial Study Report 2-Day Meeting AGENDA January 30-31,2013
Attachments: CDFG_initial_study.pdf

FYI

The California Department of Fish and Wildlife (CDFW) filed a letter outlining CDFW objectives for the upcoming ISR and the meeting. It was posted on the FERC website on Dec 21st, right before Christmas (and before we changed our name). As it took me till today to catch up on all the email correspondence I received from FERC around the end of the year, I thought I would highlight that document for anyone who might be interested but missed seeing it in their mailboxes.

Thank you,
Annie

(Please note that as of Jan 1, 2013 our new name is the California Department of Fish and Wildlife (CDFW) and new department web and email addresses took effect).

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EDMUND G. BROWN, JR., Governor
CHARLTON H. BONHAM, Director

December 14, 2012

Via Electronic Submission

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Robert Nees
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Subject: California Department of Fish and Game Objectives for Initial Study Report and Meeting, Don Pedro Hydroelectric Project No. 2299, Tuolumne River

Dear Secretary Bose and Messrs. Nees and Dias:

On December 7, 2012, the California Department of Fish and Game (Department or CDFG) received a final meeting agenda submitted on behalf of the Turlock Irrigation District and Modesto Irrigation District (Districts) for the Don Pedro Project (Project) Initial Study Report (ISR) meeting scheduled to be held on January 30-31, 2013. By this letter, the Department respectfully highlights a few of its objectives for the upcoming ISR scheduled to be filed on January 17, 2013, and the subsequent two-day ISR meeting.

The upcoming ISR and meeting are important pre-filing milestones in the Federal Energy Regulatory Commission (Commission or FERC) Integrated Licensing Process (ILP). The Department provides these objectives prior to the ISR and meeting dates in the interest of facilitating a productive and efficient exchange of information. Ideally, the ISR and meeting will serve to update all interested participants on the status of multiple ongoing studies seeking to identify and evaluate Project impacts. In reviewing the meeting agenda, we note that two key water and aquatic resource studies required by the Commission are not explicitly identified as topics of interest by the Districts. The Department is amenable to suggestions from the Districts regarding how to incorporate

Conserving California's Wildlife Since 1870 our objectives into the ISR and meeting agenda, as long as the topics are fully addressed.

As background, in addition to the ILP relicensing studies, there are parallel study efforts underway pursuant to compliance with the current Project license. The Department is particularly interested in two studies the Commission is requiring pursuant to the July 16, 2009 Order on Rehearing, Amending License, Denying Late Intervention, Denying Petition, and Directing Appointment of Presiding Judge for a Proceeding on Interim Conditions, 128 FERC ¶ 61,035 (Paragraph (F) pages 44-45). Specifically, the Commission ordered as follows:

> "The Turlock and Modesto Irrigation Districts (Districts) shall develop and implement an IFIM/PHABSIM study plan to determine instream flows necessary to maximize fall-run Chinook salmon and *O. mykiss* production and survival throughout their various life stages... In connection with the IFIM study, the Districts shall also develop a water temperature model to determine the downstream extent of thermally suitable habitat to protect summer juvenile *O. mykiss* rearing under various flow conditions and to determine flows necessary to maintain water temperatures at or below 68 degrees Fahrenheit from La Grange Dam to Roberts Ferry Bridge." (July 16, 2009 Order, 128 FERC ¶ 61,035, page 44.)

The Commission ordered the instream flow and water temperature modeling studies noted above prior to the start of the relicensing. As a result, those studies pre-date the Commission's December 22, 2011 determination of study plans necessary to inform a new license. Filings responsive to the Commission's July 16, 2009 Order are cataloged in the Commission's administrative record under P-2299 Sub Docket 072, while documents relevant to the ILP relicensing effort are generally found under P-2299 Sub Docket 075. These two processes also have distinct Commission lead staff, with the first overseen by the Division of Hydropower Administration and Compliance and the second by the Division of Hydropower Licensing. However, the two processes are inextricably linked even though they have different start times, sub-docket numbers and Commission staff. Both processes ultimately share the objective of developing information on Project impacts and potential mitigation measures utilizing instream flow and water temperature modeling tools.

As noted previously, the upcoming ISR and meeting is a significant milestone, providing the basis for participants to request modification of studies or new studies. This window of opportunity for modifying ongoing studies within the ILP is fairly narrow. Specifically, within 15 days following the ISR meeting, the applicant must file a meeting summary including any proposed modifications to ongoing studies or new studies. Within 30 days of that meeting summary, any participant may file a disagreement or request for study modification or new studies pursuant to Title 18, Code of Federal Regulations, §5.15(c)(4). Based on the Commission's October 12, 2012 Extensions of Time for Filing the Initial Study Report and for the Initial Study Report Meeting, such requests for modifications and/or new studies from participants will be due on March 10, 2013.

Given the added complexity of not only ILP relicensing studies, but also the instream flow and water temperature modeling efforts ordered by the Commission in 2009, the Department anticipates the ISR will need to contain a substantial amount of information and cross-referencing. The intent of providing Department objectives prior to reviewing the report is to clarify our expectations and facilitate subsequent discussion of study modification or new study development. The Department's objectives are also intended to be consistent with the Commission's overall relicensing objectives of providing: 1) adequate consultation and comment by relicensing participants; and 2) oversight by Commission staff.

The following table provides a summary of key steps related to Commission-ordered studies with flow and water temperature modeling elements. While the studies required under the current license were initiated in 2009, approximately two years prior to the relicensing studies, for over a year and a half now there have been overlapping deadlines and products.

Table 1 Summary of Milestones for Current License Flow and Temperature Modeling Studies and Relicensing Studies of Don Pedro Project

Date	**Studies Developed Under Current License (2009 Commission Order)**	**Study Development Under New License (ILP)**
Jul 16, 2009	Commission Order, 128 FERC ¶ 61,035, requires development and implementation of IFIM and water temperature modeling studies	
Oct 14, 2009	Districts submit Final Study Plans with: 1-D PHABSIM, RIVER 2D Pulse Flow and HEC-5Q methodologies	
May 12, 2010	Commission Order, 131 FERC ¶ 62,110, modifies and approves Study Plans	

Date	Studies Developed Under Current License (2009 Commission Order)	Study Development Under New License (ILP)
Feb 10, 2011		Districts submit NOI and PAD and Study Plans
Mar 10, 2011	Districts submit FINAL HEC-5Q Water Temperature Report prepared by Stillwater Sciences	
Jun 10, 2011		CDFG, SWRCB, NMFS, FWS, BLM and multiple other participants submit Study Requests
Jul 25, 2011		Districts submit Proposed Study Plan for ILP
Aug 15, 2011	Districts request 1 year extension for 1D PHABSIM study	
Oct 24, 2011		CDFG and multiple other parties submit comments on District's Proposed Study Plan
Oct 31, 2011	Districts submit revised schedule for River 2D Pulse Flow Study Report	
Dec 22, 2011		Commission's Office of Energy Projects issues Study Plan Determination
Jun 18, 2012	Districts submit River 2D Pulse Flow Study Report	

Originally, the Commission-ordered studies initiated in 2009 were scheduled to be completed prior to the commencement of the ILP. However, due to delays in study implementation, the two parallel processes are now developing and reporting information concurrently. Linkages between studies begun under the current license and relicensing studies are cited throughout the administrative record. The following excerpts from the December 22, 2011 Study Plan Determination filed by the Commission's Office of Energy Projects highlight some of these relationships. The excerpts are organized by a relevant study plan requested by a relicensing party or proposed by the Districts.

Department Study Request - Instream Flow Study:

> "After review of CDFG's October 24, 2011 comments, it appears as though no disputes regarding the ongoing IFIM study remain at this time. We note that, pursuant to Commission regulations, *the Districts will be required to present results of the ongoing IFIM study in its Initial Study Report. If CDFG believes additional information is needed at that time, a study modification can be requested within the ILP criteria."*[1] [emphasis added].

US Fish and Wildlife Service (FWS) Study Request – Instream Flow and Juvenile Chinook Salmon Floodplain Rearing Study:

> "We agree, however, with FWS that under the existing study, an analysis of floodplain inundation and frequency would be beneficial in identifying potential project effects upon potentially important salmonid rearing habitat (study criterion 5). *We note that the Districts state that this information can be attained by utilizing the results of the ongoing flow study in conjunction with available hydrologic data.* We note that ILP procedures allow for an evaluation of study results upon filing of the initial study report, and participants may request to amend an approved study or request a new study at that time. *Therefore, should the FWS feel that the information produced in the results of the ongoing flow study are still not sufficient to meet its informational needs, it may request to amend the approved flow study at that time*."[2] [emphasis added].

Conservation Groups Study Request – Project Effects on Riparian Vegetation:

> "We do not recommend that the Districts conduct the Conservation Groups-9 *Effects of the Project and Related Activities on Recruitment of Cottonwoods and Other Native Riparian Vegetation*. We do, however, recommend the Districts consult with the relicensing participants and review the results of the [FWS] GIS study and the *results of the IFIM study for the Don Pedro Project to determine the need for a second-year study*

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[1] Federal Energy Regulatory Commission's Office of Energy Projects December 22, 2011 Study Plan Determination, Appendix B, page 104.

[2] *Id.*, page 90.

> *concerning the physical habitat relationship between flow and floodplain inundation in the lower Tuolumne River.*"[3] [emphasis added].

<u>Districts' Proposed W&AR-4 Spawning Gravel Study</u>:

> "As amended in the revised study plan, the Districts' proposed W&AR-4 study would provide for an evaluation of spawning habitat at a range of observed and modeled flows. However, an empirical evaluation of flows in excess of 4,000 cfs, as requested by the Conservation Groups, could result in potential flooding in downstream areas, and is therefore unadvisable. *We note that the ongoing IFIM study should be able to model spawning habitat at such high flows (study criterion 6*).
>
> Finally, we agree with [National Marine Fisheries Service] NMFS that providing relicensing participants with data would allow relicensing participants to perform individual analyses in order to critically evaluate the reported results from any study (study criterion 6)."[4] [emphasis added]
>
> "We note that as amended in the Revised Study Plan, the Districts proposed W&AR-4 study will provide for an evaluation of spawning habitat at a range of observed and modeled flows, as requested by the Water Board. *Should the results of the ongoing IFIM study indicate spawning flows that are significantly different that* [sic] *those mapped flows, the ILP process will allow for stakeholders to request a modification or request a new study upon filing of the Districts' Initial Study Plan.*"[5] [emphasis added].

<u>Districts' Proposed W&AR-7 Predation Study</u>:

> "As agreed to by the Districts and relicensing participants, additional analysis may be needed to quantify the relationship of flow to floodplain inundation in the lower Tuolumne River, to better understand how floodplain inundation influences predation of juvenile salmonids... If the results of the predation study... suggest that *a second year of study may*

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[3] *Id.*, page 129.

[4] *Id.*, page 31.

[5] *Id.*, page 114.

> *be needed, the Districts should propose such a study in its initial study report or explain why such a study is not needed.*"[6] [emphasis added].
>
> "As a part of the W&AR-7 *Predation Study*, we recommend that the Districts consult with the relicensing participants and review... the results of the IFIM study for the Don Pedro Project to determine the need for a second-year study concerning the physical habitat relationship between flow and floodplain inundation in the lower Tuolumne River. *We also note that under the existing license, the Districts are conducting an instream flow study on the lower Tuolumne River that includes an assessment of floodplain habitat, which will be completed in early 2012.*"[7] [emphasis added].

As demonstrated in the foregoing excerpts, the ISR should provide results of the incremental methodology (IFIM) studies which were initiated in response to the Commission's 2009 Order and articulate the linkages to several ongoing ILP studies. At a minimum, the ISR should describe:

- Relationship of instream flow to habitat for all life stages of fall-run Chinook salmon and *O. mykiss*.
- Relationship of floodplain inundation and frequency to juvenile salmon rearing habitat.
- Physical habitat relationship between flow and floodplain inundation.
- Relationship of flow to spawning habitat, including:
    - model results of flows sufficient to inundate floodplain, and
    - data sufficient for relicensing parties to conduct independent analyses.
- Relationship of flow to predation, including;
    - model results of flows sufficient to inundate floodplain.

There is a smaller subset of requested and proposed study plans focusing on water temperature impacts. Similar to the linkages between instream flow studies begun under the current license and relicensing studies, there is a link between relicensing

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[6] *Id.*, page 43.

[7] *Id.*, page 129.

studies and the water temperature studies required by the Commission in 2009. The following excerpts pertain to a study request made by the Department and the temperature model proposed by the Districts.

Department Study Request - Reservoir Water Temperature Management Feasibility Study:

> "Information gathered in the proposed Water Temperature Modeling studies, both of the thermal dynamic structure of the reservoir and of the lower Tuolumne River, will provide information concerning the project effects on water temperature. However, we do agree with CDFG that the results of the proposed water temperature modeling may indicate a need for a reservoir water temperature management plan, including analysis of a temperature control device. *If the results of the Water Temperature Modeling studies indicate such a need, relicensing participants, including Commission staff, may request the study under sections 5.15(d) and 5.15(e) of the regulations, in the second year of study.*"[8] [emphasis added].

Districts' W&AR–16 Lower Tuolumne River Temperature Model:

> "We recommend study W&AR-16 be modified to include provisions to: (1) produce output from the water temperature model in a format appropriate for use as input into the existing CalFed San Joaquin River Basin water temperature model; (2) model the flows necessary to meet the 7-day average of the daily maximum temperature as recommended by EPA (2003), and compare the results to the maximum weekly average temperature standard developed in Stillwater Sciences (2011); and (3) provide all data used in calibration or validation of the model in W&AR-16, as well as input files, to the relicensing participants."[9]

As indicated in the foregoing excerpts, the ISR should provide a recalibration of the HEC-5Q Water Temperature Model developed by Stillwater Sciences (2011) in response to the Commission's 2009 Order. At a minimum, these results should include:

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[8] *Id.*, page 103.

[9] *Id.*, page 62.

- Output from the water temperature model in a format appropriate for use as input into the existing CalFed San Joaquin River Basin water temperature model.

- Identification of flows necessary to meet the 7-day average of the daily maximum temperature as recommended by EPA (2003).

The Department hopes the preceding compilation of key linkages between the ILP studies and study efforts previously ordered by the Commission clarifies some of the Department's objectives for the upcoming ISR and meeting. If you have any questions regarding the Department objectives described in this letter, please contact Annie Manji, Staff Environmental Scientist, at (530) 225-2315 or amanji@dfg.ca.gov.

Sincerely,

Andrew G. Gordus, Ph.D.

for Jeffrey R. Single, Ph.D.
Regional Manager, Central Region

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References

Environmental Protection Agency. 2003. Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA. 57 pp.

Federal Energy Regulatory Commission. 2009. 128 FERC ¶ 61,035. Turlock Irrigation District and Modesto Irrigation District Project Nos. 2299-065 and 2299-053. Order on Rehearing, Amending License, Denying Late Intervention, Denying Petition, and Directing Appointment of a Presiding Judge for a Proceeding on Interim Conditions. Issued July 16, 2009. 46 pp.

Federal Energy Regulatory Commission. 2011. Turlock Irrigation District and Modesto Irrigation District Project No. 2299-075. Study Plan Determination for the Don Pedro Hydroelectric Project. Filed December 22, 2011 by Office of Energy Projects. 146 pp. (with appendices).

Stillwater Sciences. 2011. Tuolumne River water temperature modeling study. Final Report. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District, California. March 10, 2011. 13 pp.

From: Staples, Rose
Sent: Thursday, January 17, 2013 6:30 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Project Relicensing ISR and Accompanying Study Reports E-Filed Today

The ISR and accompanying 23 study/progress reports have been e-filed with FERC today, and all should be available on FERC's E-Library at www.FERC.gov. I am also in the process of uploading the documents to the Don Pedro Relicensing website at www.donpedro-relicensing.com. (Documents / Initial Study Reports). Currently on the site are the ISR and the Recreation Resources study reports. I plan to upload Cultural Resources and at least part of the Terrestrial Resources study reports today, with the rest going up tomorrow.

Please also note that we are in the process of updating the website text, tab names, and other features to make it easier for you to find the information you need. For instance, the INTRODUCTION TAB is now ANNOUNCEMENTS! And on the documents page, note the column heading called RELEVANT. By clicking on this heading, you activate a selection window with the Don Pedro Study Plans listed, from which you can then select the Study for which you would like a listing of the documents on the site "relevant" to that Study.

If you have any difficulties accessing and/or downloading any of the reports (we filed / and uploaded the attachments as separate files to make the file sizes smaller and more easily accessible), please do let me know. Thank you.

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From: Staples, Rose
Sent: Thursday, January 17, 2013 6:41 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Anderson, Craig'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Beniamine Beronia'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Minami Amber'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Availability of Don Pedro Relicensing ISR / Study-Progress Reports on CD

Besides being available for viewing/downloading from FERC's E-Library and the Don Pedro Project Relicensing website, there will also be a quantity of CDs with the ISR and accompany study/progress reports available at the ISR Meeting on January 30-31, 2013 at the MID Offices in Modesto.

In addition, if you would like a CD shipped to you, please let me at rose.staples@hdrinc.com and provide your address and any special shipping instructions. Thank you.

ROSE STAPLES
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Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Wednesday, January 23, 2013 5:33 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: AGENDA RESEND-CALL-IN NUMBER-LIVE MEETING LINK to Don Pedro Relicensing ISR Meeting Jan 30-31

For those who are unable to participant in person at the upcoming Don Pedro Relicensing Initial Study Report Meetings (January 30 and January 31, MID OFFICES in Modesto), please find below the call-in information, LIVE MEETING link, and meeting AGENDA.

- **Call-in Phone Number 866-994-6437, Conference Code 5424697994**
- Online meeting information (below – same for both days)

- AGENDA (below)

Join online meeting

https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

First online meeting?

Initial Study Report Meeting (Day 1)

Wednesday January 30, 2013 8:00 am – 5:30 pm
Meeting Location: MID Offices, Modesto

Time	Topic	
8:00	**Opening** – Agenda Review, Purpose of Meeting	
8:20	W&AR-15	Socioeconomics Study
8:40	W&AR-01	Water Quality Assessment
9:00	W&AR-02	Project Operations/Water Balance Model
9:25	W&AR-03	Reservoir Temperature Model
9:55	W&AR-04	Spawning Gravel Study
Break – 10:20		
10:35		IFIM Schedule and Update
10:45	W&AR-05	Salmonid Populations Information Integration
11:05	W&AR-06	Tuolumne River Chinook Salmon Population Model
11:30	W&AR-10	*Onchorhynchus mykiss* Population Study
Lunch Break – 11:50		
12:50	W&AR-07	Predation Study
1:15	W&AR-08	Salmonid Redd Mapping
1:40	W&AR-11	Chinook Salmon Otolith Study
2:05	W&AR-12	*Onchorhynchus mykiss* Habitat Assessment
2:30	W&AR-13	La Grange Reservoir Fish Assemblage and Population Study
Break – 2:55		
3:10	W&AR-14	Temperature Criteria Assessment
3:35	W&AR-17	Don Pedro Reservoir Fish Population Study
4:00	W&AR-18	Sturgeon Study
4:25	W&AR-19	Riparian Information Study
4:50	W&AR-20	*O.mykiss* Scale & Age Study
5:15		**Wrap-Up & Review 1/31 Schedule**

Initial Study Report Meeting (Day 2)

Thursday January 31, 2013 8:00 am – 5:00 pm

Meeting Location: MID Offices, Modesto

Time	Topic	
8:00	**Opening** – Agenda Review, Purpose of Meeting	
8:15	CR-01	Historic Properties Study
8:40	CR-02	Native American Traditional Cultural Properties Study
9:05	TR-01	Special-Status Plants Study
9:30	TR-02	ESA- and CESA-Listed Plants Study
9:55	TR-03	Wetland Habitats Associated with Don Pedro Reservoir Study
Break – 10:20		
10:35	TR-04	Noxious Weed Survey
11:00	TR-05	ESA-Listed Wildlife - Valley Elderberry Longhorn Beetle Study
11:25	TR-06	Special-Status Amphibians-Aquatic Reptiles Study
11:50	TR-07	ESA-Listed Amphibians - California Red-Legged Frog Study
Lunch Break – 12:15		
1:15	TR-08	ESA-List Amphibians - California Tiger Salamander Study
1:40	TR-09	Special-Status Bats Study
2:05	TR-10	Bald Eagle Study
2:30	RR-01	Recreation Facility and Public Accessibility Assessment
Break – 2:55		
3:10	RR-02	Whitewater Boating Take Out Improvement Feasibility
3:35	RR-03	Lower Tuolumne River Boatable Flow Study
4:00	RR-04	Visual Quality Study
4:25		**Wrap-Up and Next Steps**

Thank you

ROSE STAPLES
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From: Devine, John
Sent: Wednesday, January 23, 2013 8:10 PM
To: 'Peter Drekmeier'
Subject: RE: Socioeconomics Study

Peter,

The Socioeconomics Study is still in progress, so just a progress report is provided. That can be found in the ISR document itself. There is also a schedule included in the Progress Report. Without looking, so I may be wrong, I think the draft report is scheduled to be issued by the end of June 2013.

JOHN DEVINE
P.E.

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Senior Vice President, Hydropower Services

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john.devine@hdrinc.com | hdrinc.com

From: Peter Drekmeier [mailto:Peter@Tuolumne.org]
Sent: Wednesday, January 23, 2013 7:38 PM
To: Devine, John
Subject: Socioeconomics Study

Hi John,

Will there be a draft of the Socioeconomics Study prior to next week's meeting? I couldn't find anything on the website.

Thanks.

-Peter

Peter Drekmeier
Bay Area Program Director
Tuolumne River Trust
111 New Montgomery, #205
San Francisco, CA 94105
(415) 882-7252 x 302
peter@tuolumne.org
http://www.tuolumne.org/bayarea

From: Staples, Rose
Sent: Friday, January 25, 2013 10:33 AM
To: 'steveburke49@gmail.com'
Subject: Don Pedro Relicensing Email Group

Melissa Williams with Modesto Irrigation District has asked that I add you to the Don Pedro Relicensing Participants Email Group, which I have done so today. Besides confirming that this has been done, I wanted to share with you the following information, which was emailed to the group earlier this week, regarding the Initial Study Report Meeting scheduled for next Wednesday and Thursday at the MID Offices in Modesto. Copies of the Initial Study Report and the individual progress or study reports referenced in the Report can be viewed (and downloaded) from the Don Pedro Relicensing website at www.donpedro-relicensing.com: Documents Tab, Initial Study Report folder. Within the Initial Study Report folder you will then find sub-folders by Resources Group; i.e. Cultural Resources, Recreation Resources, Terrestrial Resources, and Water & Aquatic Resources. A CD of the documents will also be available at the ISR meeting—and you can also get one by sending me an emailed request, along with your shipping address.

For those who are unable to participant in person at the upcoming Don Pedro Relicensing Initial Study Report Meetings (January 30 and January 31, MID OFFICES in Modesto), please find below the call-in information, LIVE MEETING link, and meeting AGENDA.

- **Call-in Phone Number 866-994-6437, Conference Code 5424697994**
- Online meeting information (below – same for both days)
- AGENDA (below)

Join online meeting

https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

First online meeting?

Initial Study Report Meeting (Day 1)

Wednesday January 30, 2013 8:00 am – 5:30 pm
Meeting Location: MID Offices, Modesto

Time	Topic	
8:00	**Opening** – Agenda Review, Purpose of Meeting	
8:20	W&AR-15	Socioeconomics Study
8:40	W&AR-01	Water Quality Assessment
9:00	W&AR-02	Project Operations/Water Balance Model
9:25	W&AR-03	Reservoir Temperature Model
9:55	W&AR-04	Spawning Gravel Study
Break – 10:20		
10:35		IFIM Schedule and Update

Time	Topic	
10:45	W&AR-05	Salmonid Populations Information Integration
11:05	W&AR-06	Tuolumne River Chinook Salmon Population Model
11:30	W&AR-10	*Onchorhynchus mykiss* Population Study
Lunch Break – 11:50		
12:50	W&AR-07	Predation Study
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Break – 2:55		
3:10	W&AR-14	Temperature Criteria Assessment
3:35	W&AR-17	Don Pedro Reservoir Fish Population Study
4:00	W&AR-18	Sturgeon Study
4:25	W&AR-19	Riparian Information Study
4:50	W&AR-20	*O.mykiss* Scale & Age Study
5:15		**Wrap-Up & Review 1/31 Schedule**

Initial Study Report Meeting (Day 2)

Thursday January 31, 2013 8:00 am – 5:00 pm

Meeting Location: MID Offices, Modesto

Time	Topic	
8:00	**Opening** – Agenda Review, Purpose of Meeting	
8:15	CR-01	Historic Properties Study
8:40	CR-02	Native American Traditional Cultural Properties Study
9:05	TR-01	Special-Status Plants Study
9:30	TR-02	ESA- and CESA-Listed Plants Study
9:55	TR-03	Wetland Habitats Associated with Don Pedro Reservoir Study
Break – 10:20		
10:35	TR-04	Noxious Weed Survey
11:00	TR-05	ESA-Listed Wildlife - Valley Elderberry Longhorn Beetle Study
11:25	TR-06	Special-Status Amphibians-Aquatic Reptiles Study
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1:15	TR-08	ESA-List Amphibians - California Tiger Salamander Study
1:40	TR-09	Special-Status Bats Study
2:05	TR-10	Bald Eagle Study
2:30	RR-01	Recreation Facility and Public Accessibility Assessment
Break – 2:55		
3:10	RR-02	Whitewater Boating Take Out Improvement Feasibility
3:35	RR-03	Lower Tuolumne River Boatable Flow Study
4:00	RR-04	Visual Quality Study
4:25		**Wrap-Up and Next Steps**

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From: Staples, Rose
Sent: Tuesday, January 29, 2013 4:24 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro ISR Meeting Reminder - AGENDA-CALL-IN Number-LIVE MEETING Link
Attachments: Day 1 Agenda.pdf; Day 2 Agenda.pdf

For your reference, I am resending the location, meeting times, agendas, and audio / Live Meeting links for the Don Pedro Project Relicensing INITIAL STUDY REPORT MEETING being held over a two-day period, beginning tomorrow, January 30, at the Modesto Irrigation District Offices in Modesto. The same call-in number and live meeting link will be used for both days, for those who are not able to participate in person.

Don Pedro Project Relicensing
Initial Study Report Meeting

Day 1

Wednesday January 30, 2013 8:00 a.m. – 5:30 p.m.
Meeting Location: MID Offices, Modesto (1231 11th Street)
Call-In Number 866-994-6437 – Conference Code 5424697994

....

Join online meeting

https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

First online meeting?

....

Time	Topic	
8:00 a.m.	**Opening – Agenda Review, Purpose of Meeting**	
8:20 a.m.	W&AR-15	Socioeconomics Study
8:40 a.m.	W&AR-01	Water Quality Assessment
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9:25 a.m.	W&AR-03	Reservoir Temperature Model
9:55 a.m.	W&AR-04	Spawning Gravel Study
10:20 a.m.	**Break**	
10:35 a.m.	**IFIM Schedule and Update**	
10:45 a.m.	W&AR-05	Salmonid Populations Information Integration
11:05 a.m.	W&AR-06	Tuolumne River Chinook Salmon Population Model
11:30 a.m.	W&AR-10	*Oncorhynchus mykiss* Population Study
11:50 a.m.	**Lunch Break (on your own)**	
12:50 p.m.	W&AR-07	Predation Study
1:15 p.m.	W&AR-08	Salmonid Redd Mapping
1:40 p.m.	W&AR-11	Chinook Salmon Otolith Study
2:05 p.m.	W&AR-12	*Oncorhynchus mykiss* Habitat Assessment
2:30 p.m.	W&AR-13	La Grange Reservoir Fish Assemblage and Population Study
2:55 p.m.	**Break**	
3:10 p.m.	W&AR-14	Temperature Criteria Assessment
3:35 p.m.	W&AR-17	Don Pedro Reservoir Fish Population Study

Time	Topic	
4:00 p.m.	W&AR-18	Sturgeon Study
4:25 p.m.	W&AR-19	Riparian Information Study
4:50 p.m.	W&AR-20	*Oncorhynchus mykiss* Scale & Age
5:15 p.m.	**Wrap-Up & Review 1/31 Schedule**	

Day 2

Thursday January 31, 2013 8:00 a.m. – 5:00 p.m.
Meeting Location: MID Offices, Modesto (1231 11th Street)

Call-In Number 866-994-6437 – Conference Code 5424697994

Join online meeting

https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

First online meeting?

Time	Topic	
8:00 a.m.	**Opening – Agenda Review, Purpose of Meeting**	
8:15 a.m.	CR-01	Historic Properties Study
8:40 a.m.	CR-02	Native American Traditional Cultural Properties Study
9:05 a.m.	TR-01	Special-Status Plants
9:30 a.m.	TR-02	ESA- and CESA-Listed Plants Study
9:55 a.m.	TR-03	Wetland Habitats Associated with Don Pedro Reservoir
10:20 a.m.	**Break**	
10:35 a.m.	TR-04	Noxious Weed Survey
11:00 a.m.	TR-05	ESA-Listed Wildlife - Valley Elderberry Longhorn Beetle
11:25 a.m.	TR-06	Special-Status Amphibians - Aquatic Reptiles
11:50 a.m.	TR-07	ESA-Listed Amphibians - California Red-Legged Frog
12:15 p.m.	**Lunch Break (on your own)**	
1:15 p.m.	TR-08	ESA-List Amphibians - California Tiger Salamander
1:40 p.m.	TR-09	Special-Status Bats
2:05 p.m.	TR-10	Bald Eagle Study
2:30 p.m.	RR-01	Recreation Facility and Public Accessibility Assessment
2:55 p.m.	**Break**	
3:10 p.m.	RR-02	Whitewater Boating Take Out Improvement Feasibility

Time	Topic	
3:35 p.m.	RR-03	Lower Tuolumne River Boatable Flow Study
4:00 p.m.	RR-04	Visual Quality Study
4:25 p.m.	**Wrap-Up and Next Steps**	

Thank you!

ROSE STAPLES
CAP-OM

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Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

From: Staples, Rose
Sent: Wednesday, January 30, 2013 9:23 AM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Anderson, Craig'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Beniamine Beronia'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Minami Amber'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Initial Study Report Meeting Slide Presentations

Especially for those who will be connecting to the Don Pedro Project Relicensing INITIAL STUDY REPORT MEETING today via LiveMeeting—as a backup if you experience connection difficulties—or if you are joining by audio only (866-994-6437 / Conference Code 5424697994), we have uploaded to the Don Pedro Relicensing website (www.donpedro-relicensing.com) this morning a copy of each of the slide presentations being used in today's ISR Meeting.   Click on the ANNOUNCEMENT tab on the Home Page of the website—the presentations will be attached to the announcement posted earlier today. If you have any problems locating and/or accessing the documents, please let me know. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

From: Staples, Rose
Sent: Thursday, January 31, 2013 10:35 AM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Anderson, Craig'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Beniamine Beronia'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Brewer, Doug'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Fety, Lauren'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Lein, Joseph'; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Minami Amber'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Jan 31 Don Pedro ISR Meeting Slide Presentations

Similar to what we did yesterday, the slide presentations for today's ***Initial Study Report Meeting*** have been uploaded to the Don Pedro Project Relicensing website (www.donpedro-relicensing.com) under the ANNOUNCEMENT tab (on the Home Page), as backup if you are connecting in to the meeting via

LiveMeeting or audio only. If you have any difficulties locating or accessing the presentations, please let me know. Thank you.

ROSE STAPLES
CAP-OM

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Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
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rose.staples@hdrinc.com| hdrinc.com

From: Staples, Rose
Sent: Thursday, January 31, 2013 6:43 PM
To: 'Barnes, James'
Subject: RE: Request for ISR historic properties study and TCP study

Thank you; I will also forward on the request for an estimated delivery date.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
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rose.staples@hdrinc.com | hdrinc.com

From: Barnes, James [mailto:jjbarnes@blm.gov]
Sent: Thursday, January 31, 2013 6:19 PM
To: Staples, Rose
Subject: Re: Request for ISR historic properties study and TCP study

Thanks Rose. All I need is just the two cultural resources study progress reports CR-01 and CR-02 with ALL of the attachments. I do not need the other parts of the ISR. If my request is accepted by the Districts, what is the estimated delivery date? James
On Thu, Jan 31, 2013 at 3:10 PM, Staples, Rose <Rose.Staples@hdrinc.com> wrote:
Please be advised that I have received your information request below, and will be forwarding a copy of this message to the Districts for consideration of your request for Cultural Resources Study CR-02 Native American Traditional Cultural Properties-Attachment B, containing privileged information filed with FERC on January 17, 2013.

Could you please clarify that you would like a CD with the other parts of the INITIAL STUDY REPORT besides the Cultural Resources CR-01 Historic Properties Progress Report with Attachments A and B and CR-02 National American Traditional Cultural Properties Progress Report with Attachment A—or just the two Cultural Resources Study Progress Reports?

Thank you.

ROSE STAPLES
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Executive Assistant, Hydropower Services

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rose.staples@hdrinc.com | hdrinc.com

From: Barnes, James [mailto:jjbarnes@blm.gov]
Sent: Thursday, January 31, 2013 5:53 PM
To: Staples, Rose
Subject: Request for ISR historic properties study and TCP study

Hi Rose:

I'm an archaeologist with the Bureau of Land Management Mother Lode Field Office. I would like to get a copy of the ISR especially the portion of the ISR covering the Historic Properties Study and the Traditional Cultural Properties Study **with any confidential information included**. Thanks. PS: please let me know you got this email by responding.

My mailing address is

James Barnes, Archaeologist
Bureau of Land Management
Mother Lode Field Office
5152 Hillsdale Circle
El Dorado Hills, CA 95762
916-941-3140

From: Staples, Rose
Sent: Friday, February 08, 2013 4:25 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Minami Amber; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Initial Study Report Meeting Summary Filed Today with FERC

The Initial Study Report Meeting Summary for the Don Pedro ISR Meeting held on January 30-31, 2013, has been filed with FERC. A copy of the Summary has been uploaded to the Don Pedro relicensing website, under ANNOUNCEMENTS (www.donpedro-relicensing.com). A copy will also be available on FERC's E-Library, most probably on Monday. If you have any difficulties accessing or downloading the document, please let me know. Thank you.

From: Allison Boucher [aboucher@bendbroadband.com]
Sent: Monday, February 25, 2013 12:08 PM
To: Staples, Rose
Subject: RE: Lists Needed

Thanks.
Allison

From: Staples, Rose [mailto:Rose.Staples@hdrinc.com]
Sent: Monday, February 25, 2013 8:14 AM
To: Allison Boucher
Subject: RE: Lists Needed

In regards to the email group list of Don Pedro Project Relicensing Participants, you can CUT AND PASTE the group list into your own email the next time I send out an announcement (which will be later today)—or you should be able to REPLY ALL and send out a message to them all on top of my message.

Following is a list of the Don Pedro Project Relicensing Studies and their reference codes:

Cultural Resources
CR-01 Historic Properties Progress Report
CR-02 Native American Traditional Cultural Properties Progress Report

Recreation Resources
RR-01 Recreation Facility Conditions and Public Accessibility Assessment
RR-02 Whitewater Boating Take-Out Improvement Feasibility Study Report
RR-03 Lower Tuolumne River Lowest Boatable Flow Study Report
RR-04 Visual Quality Study Report

Terrestrial Resources
TR-01 Special-Status Plants Study Report
TR-02 ESA- and CESA-Listed Plants Study Report
TR-03 Wetland Habitats Associated with Don Pedro Reservoir Study Report
TR-04 Noxious Weeds Study Report
TR-05 ESA-Listed Wildlife - Valley Elderberry Longhorn Beetle Study Report
TR-06 Special-Status Amphibians and Reptiles Study Report
TR-07 ESA-Listed Amphibians - California Red-Legged Frog Study Report
TR-08 ESA-Listed Amphibians - California Tiger Salamander Study Report
TR-09 Special-Status Wildlife - Bats Study Report
TR-10 Bald Eagle Study Report

Water & Aquatic Resources
W&AR-01 Water Quality Assessment Study Report
W&AR-02 Project Operations Water Balance Model Study Report
W&AR-03 Reservoir Temperature Model Progress Report
W&AR-04 Spawning Gravel in the Lower Tuolumne River Progress Report
W&AR-05 Salmonid Population Information Integration and Synthesis Study Report
W&AR-06 Tuloumne River Chinook Salmon Population Model

W&AR-07 Predation Study Report
W&AR-08 Salmonid Redd Mapping Progress Report
W&AR-10 *Oncorhynchus mykiss* Population Study
W&AR-11 Chinook Salmon Otolith Study
W&AR-12 *Oncorhynchus mykiss* Habitat Survey Study Report
W&AR-13 Fish Assemblage and Population between Don Pedro Dam and La Grange Dam Study Report
W&AR-14 Temperature Criteria Assessment (Chinook Salmon and *Oncorhynchus mykiss)* Progress Report
W&AR-15 Socioeconomics Study
W&AR-16 Lower Tuolumne River Temperature Model Progress Report
W&AR-17 Don Pedro Reservoir Fish Population Survey Study Report
W&AR-18 Sturgeon Study Report
W&AR-19 Lower Tuolumne River Riparian Information and Synthesis Study Report
W&AR-20 *Oncorhynchus mykiss* Scale Collection and Age Determination Study Report

ROSE STAPLES
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rose.staples@hdrinc.com | hdrinc.com

From: Allison Boucher [mailto:aboucher[redacted]
Sent: Monday, February 25, 2013 1:10 AM
To: Staples, Rose
Subject: Lists Needed

Rose,
Do you have a list of participants with their email addresses?

Do you have a list of all the studies with their code names and descriptions?

Allison Boucher
Tuolumne River Conservancy, Inc.
[redacted]

HOME EMAIL ADDRESS REMOVED PER SECTION 2.4.3 DON PEDRO PAD

From: Staples, Rose
Sent: Tuesday, February 26, 2013 11:05 AM
To: 'Allison Boucher'
Subject: RE: Participants

That would be James Eicher; his email address is james_eicher@BLM.gov

Rose staples
cAP-OMHDR Engineering, Inc.
Executive Assistant, Hydropower Services
970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

From: Allison Boucher [mailto:abouche [redacted]]
Sent: Tuesday, February 26, 2013 12:20 AM
To: Staples, Rose
Subject: Participants

Rose,
Who is the BLM representative? I need to contact him/her.

Allison Boucher
Tuolumne River Conservancy, Inc.

HOME PHONE NUMBER REMOVED PER SECTION 2.4.3 DON PEDRO PAD

From: Staples, Rose
Sent: Monday, March 04, 2013 10:54 AM
To: 'Brian Welde'
Subject: RE: Don Pedro GIS Bathymetry Data

Thank you for your query; I will forward it to the Districts for consideration.

ROSE STAPLES, CAP-OM
HDR Engineering, Inc.
Executive Assistant,
Hydropower Services
970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

-----Original Message-----
From: Brian Welde [mailto:bwelde@angling-technologies.com]
Sent: Saturday, March 02, 2013 12:19 PM
To: Staples, Rose
Subject: Don Pedro GIS Bathymetry Data

Mrs. Staples,

I I own Angling Technologies, http://mapper.angling-technologies.com, an online interactive fishing map service for anglers. We have had a lot of requests to supply depth data for Don Pedro Reservoir and our research led us to the following publication - http://www.donpedro-relicensing.com/Lists/Announcements/Attachments/84/DonPedroReservoirBathymetricStudyRept_20121018.pdf.
I found you listed as a possible contact about this project on the Turlock Irrigation District home page.

I'm writing to see if I might be able to acquire and use the bathymetry data referenced. We can work with any type of spatial data format, cite all sources, and offer disclaimers that data is not for navigation.

Sincerely,

Brian Welde
[redacted]

From: Staples, Rose
Sent: Friday, March 08, 2013 5:43 PM
To: 'Allison Boucher'
Subject: RE: email address

I do not have the name of the new biologist at TID, so let me contact them regarding that—or I may check in with John Devine when he returns to the office on Monday. As to our main contact at TID since Bob Nees' retirement, it is Steve Boyd (seboyd@tid.org). Thank you.

From: Allison Boucher [mailto:abouche [redacted]]
Sent: Friday, March 08, 2013 12:14 PM
To: Staples, Rose
Subject: email address

Rose,
I don't see the new TID biologist's email address on the emails. I also don't see Bob Nees' email. Who at TID is getting our emails? I would like to contact someone about the scheduling conflict with the TRTAC.
Allison Boucher
Tuolumne River Conservancy

From: Staples, Rose
Sent: Saturday, March 09, 2013 3:05 PM
To: Allison Boucher (aboucher[redacted]
Subject: TID Biologist Contact Information

Allison, the TID biologist is Patrick Maloney; his email address is pemaloney@TID.org. Thank you.

ROSE STAPLES
CAP-OM
HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

From: Larry Thompson - NOAA Federal <larry.thompson@noaa.gov>
Sent: Monday, March 11, 2013 12:31 PM
To: Devine, John
Cc: James Hastreiter; John Wooster - NOAA Federal; Thomas Holley - NOAA Federal; Richard Wantuck - NOAA Federal; David White - NOAA Federal; Kathryn Kempton - NOAA Federal; Greg Dias (Gregd@mid.org); Joy Warren; Godwin, Arthur F; agengr6@aol.com; Steve Boyd; Bill Paris; Tim O'Laughlin; Borovansky, Jenna; Staples, Rose
Subject:Re: Information to fulfill Director's Determination Requirement

Thanks John.

I found those sectionsin the ISR, and refer to them in the comments NMFS intends to file today.

Larry
On Mon, Mar 11, 2013 at 9:22 AM, Devine, John <John.Devine@hdrinc.com> wrote:
Larry,

Thanks for the inquiry. I am just back from vacation. The Districts provided a specific section in the Initial Study Report responding to the FERC direction provided by the Study Dispute. The information you are seeking is contained in Section 1.4.2 of the Initial Study Report entitled Requirements of FERC's Study Dispute Determination. Please see pages 1-8 through 1-11; Figures 1.4-1, 1.4-2, and 1.4-3; and Table 1.4-2. The figures show the effects of the diversions at La Grange Dam on flows to the lower Tuolumne River. The table lists all of the existing information the Districts have for the area between the diversion dam and the tailrace. Please let me know if I can provide anything further.

JOHN DEVINE
P.E.
HDR Engineering, Inc.
Senior Vice President, Hydropower Services

970 Baxter Boulevard Suite 301 | Portland, ME 04103
207.775.4495 | c: 207.776.2206 | f: 207.775.1742
john.devine@hdrinc.com | hdrinc.com

From: Larry Thompson - NOAA Federal [mailto:larry.thompson@noaa.gov]
Sent: Tuesday, March 05, 2013 2:42 PM
To: Devine, John; James Hastreiter
Cc: John Wooster - NOAA Federal; Thomas Holley - NOAA Federal; Richard Wantuck - NOAA Federal; David White - NOAA Federal; Kathryn Kempton - NOAA Federal
Subject: Information to fulfill Director's Determination Requirement

Hello John and Jim,

I am seeking the location, in the Initial Study Report, of information to fulfill the requirements for NMFS' Request #1 "Effects of the Project and Related La Grange Complex Facilities on Anadromous Fish. "

As a result of the Study Dispute process, elements of this study were ordered (but modified by FERC).

The Director's Formal Study Dispute Determination (May 24, 2012) requires (p. 10):

"We recommend that the Districts identify and provide existing information, as part of the Initial Study Report, (related to Study NMFS-1, Element 3 and 6) on the Tuolumne River between La Grange dam and the La Grange gage. This additional information will provide a more comprehensive understanding of the potential effects of the Don Pedro Project on the hydrology of the Tuolumne River."

Jim, the language quoted above appears to lack detail as to what was ordered. Could you please clarify what is required?

John, I have searched for quite some time, and cannot find this La Grange reach information or discussion of it reported anywhere.

Could you please point me to the location(s) where this information is contained in the ISR report, or supporting documents?

Thanks in advance,

Larry

--
Larry Thompson
NOAA Fisheries
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814
(916) 930-3613
larry.thompson@noaa.gov

From: Devine, John
To: Martin, Ramon
Cc: gregd@mid.org; Joy Warren (Joy.Warren@mid.org); agodwin@mrgb.org; "William Johnston" ([redacted]m); Steve E. Boyd (seboyd@tid.org); bparis@olaughlinparis.com; Borovansky, Jenna
Subject: RE: ISR Meeting; Predation Study
Date: Saturday, March 16, 2013 6:51:36 AM

Thanks Ramon. We probably will have a couple of questions for you.

JOHN DEVINE
P.E.

HDR Engineering, Inc.
Senior Vice President, Hydropower Services

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john.devine@hdrinc.com | hdrinc.com

From: Martin, Ramon [mailto:ramon_martin@fws.gov]
Sent: Friday, March 15, 2013 6:21 PM
To: Devine, John
Cc: gregd@mid.org; Joy Warren (Joy.Warren@mid.org); agodwin@mrgb.org; 'William Johnston' (agengr6[redacted]); Steve E. Boyd (seboyd@tid.org); bparis@olaughlinparis.com; Borovansky, Jenna
Subject: Re: ISR Meeting; Predation Study

John,

Thanks for the update and we look forward to working with you and the Districts on any second year studies or reviewing any additional second year study proposals. Let me know if you have any questions regarding any of our comments to the ISR.

Thanks,
Ramon Martin
Assistant Program Manager
Anadromous Fish Restoration Program
US Fish and Wildlife Service
850 S. Guild Ave., Suite 105
Lodi, CA 95240
(209) 334-2968 ext. 401
(209) 334-2171 Fax

Our mission is, working with others, to conserve,
protect and enhance fish, wildlife, and plants
and their habitats for the continuing benefit
of the American people.

On Fri, Mar 15, 2013 at 1:23 PM, Devine, John <John.Devine@hdrinc.com> wrote:

Ramon,

I wanted to respond to your February 27 email to me on the subject of potentially expanding the Districts 2013 Predation Study to include a juvenile Chinook survival study. On March 6, Andrea Fuller and you were able to further discuss the specifics of what USFWS has in mind which resulted in our understanding that:

- USFWS is requesting a juvenile Chinook survival study in the SJR from the mouth of the Tuolumne to Mossdale because of the limited data available in this reach, and

- USFWS is requesting that the Districts in their 2013 Tuolumne River Predation study include age and growth analysis for black bass species using scales or otoliths

As you know, at the ISR meeting, the Districts indicated they were considering repeating the 2012 Predation Study in 2013. The Districts have since decided to proceed with undertaking certain components of the Predation Study; namely, a second year of the predator abundance and predation rate sampling following the same methods as work completed in 2012. Study plans will be provided for review in the coming weeks. As part of the 2012 study, the Districts performed acoustic tracking of salmon smolts and predators to evaluate habitat use under three flow conditions during 2012. Due to timing and costs the Districts are not planning to undertake acoustic tracking in 2013. Based on your call with Andrea, we understand the USFWS was going to be requesting both of the studies referenced in the bullets above in your ISR comments. At the present time, we are amenable to expanding the 2013 Predation Study to include age and growth analysis of black bass species using scale samples. With regard to additional 2013 studies, the Districts will review and respond to all study requests contained in the recently filed ISR comments by April 9.

We have appreciated the active and constructive participation of the USFWS in the Don Pedro project relicensing, and look forward to continuing to work with you, Zac, and USFWS staff as we move forward.

JOHN DEVINE
P.E.

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Senior Vice President, Hydropower Services

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john.devine@hdrinc.com | hdrinc.com

From: Ramon Martin [mailto:ramon_martin@fws.gov]
Sent: Wednesday, February 27, 2013 4:21 PM
To: Staples, Rose
Subject: Fw: Don Pedro Initial Study Report W&AR - 7 Predation Study

Rose,

Here is the email I sent to John earlier today that you can relay to the Districts.

Thanks,
Ramon Martin

From: Martin, Ramon [mailto:ramon_martin@fws.gov]
Sent: Wednesday, February 27, 2013 10:39 AM
To: john.devine@hdrinc.com <john.devine@hdrinc.com>
Subject: Don Pedro Initial Study Report W&AR - 7 Predation Study

John,

I just wanted to follow up with our request at the ISR Meeting on January 30th for the Districts to include juvenile Chinook salmon tagging with their predation study. We requested for the Districts to consider tagging juvenile Chinook salmon and collect habitat use, movement, and survival in conjunction with the predator tagging to assess how predators and Chinook salmon interact in the study reach during the Don Pedro Article 37 spring pulse flows. We would like to cooperate and provide input into your study design before you move forward with implementation this year. Let me know the status of the study and if you all have considered our request.

Thanks,
Ramon Martin
Assistant Program Manager
Anadromous Fish Restoration Program
US Fish and Wildlife Service
850 S. Guild Ave., Suite 105
Lodi, CA 95240
(209) 334-2968 ext. 401
(209) 334-2171 Fax

Our mission is, working with others, to conserve,
protect and enhance fish, wildlife, and plants
and their habitats for the continuing benefit
of the American people.

Staples, Rose

From: Staples, Rose
Sent: Tuesday, April 09, 2013 5:46 PM
To: Alves, Jim; Amerine, Bill; Anderson, Craig; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beniamine Beronia; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Brewer, Doug; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Colvin, Tim; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Ferranti, Annee; Ferrari, Chandra; Fety, Lauren; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayat, Zahra; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Lein, Joseph; Levin, Ellen; Lewis, Reggie; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Monheit, Susan; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Districts Response to Don Pedro ISR Comment Letters E-Filed Today with FERC

The Districts e-filed with FERC today their response to the Initial Study Report (ISR) comment letters filed. A copy of the response, along with the comment letters, have been uploaded to the www.donpedro-relicensing website (DOCUMENTS tab, Initial Study Reports Section, Study Comments folder). Their response should also be available on FERC's E-Library (www.ferc.gov) soon, most probably tomorrow. Also included in this filing are the draft meeting notes from the March 27, 2013 Hydrology Workshop No. 4 and the final meeting notes from the October 26, 2012 W&AR-03 and W&AR-16 River and Reservoir Temperature Models Consultation Workshop No. 2.

ROSE STAPLES
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From: Rose.Staples@hdrinc.com
To: jalves@modestogov.com; william[redacted]; craig.anderson@fws.gov; lynette@newman-romano.com; james_barnes@blm.gov; pbarnes@waterboards.ca.gov; Linda.Barrera@wildlife.ca.gov; benamine@envres.org; martinblake[redacted]; jbond@modestogov.com; Jenna.Borovansky@hdrinc.com; aboucher[redacted]; Stephen_Bowes@nps.gov; artbow[redacted] beth_brenneman@blm.gov; douglas.brewer@tetratech.com; johnb@cserc.org; buckley@Portland.econw.com; steveburke49[redacted] cburt@calpoly.edu; tim.byrd@ejgallo.com; socialchr[redacted]; mcarlin@sfwater.org; cindy[redacted] timcolvin@tds.net; chixrnch@mlode.com; J.cowan[redacted] receptionist@mlode.com; pcransto@blm.gov; rebeccac@cserc.org; ndamin@envres.org; tmtc@mlode.com; Pday@mofo.com; denean@buenavistatribe.com; mderwin@portolavalley.net; John.Devine@hdrinc.com; mwdonaldson@parks.ca.gov; mdowd@fs.fed.us; WesternPalms[redacted] Peter@tuolumne.org; steve.edmondson@noaa.gov; james_eicher@BLM.gov; James.Fargo@ferc.gov; AFerranti@dfg.ca.gov; cferrari@tu.org; lfety@blm.gov; TFindley@hansonbridgett.com; mcf7491[redacted]; rfuller@mlode.com; donn.w.furman@sfgov.org; jgantenbein@waterpowerlaw.com; Deborah_Giglio@fws.gov; vevado[redacted]; zgrader[redacted] monica.gutierrez@noaa.gov; bhackamack[redacted]; James.Hastreiter@FERC.gov; jhatch@caltrout.org; Zhayat@mofo.com; ahayden@edf.org; anitajhellam[redacted] theyne@dfg.ca.gov; thomas.holley@noaa.gov; lholm@usbr.gov; jhorn@blm.gov; timihorn[redacted] b.hudelson[redacted]; noahnsa[redacted] rwhughes@dfg.ca.gov; noah@stillwatersci.com; zachary_jackson@FWS.gov; Julia.jauregu[redacted]; deltakeep[redacted]; ajensen@bawsca.org; Laura_Jensen@TNC.org; mjohannis@usbr.gov; bjohnson@tu.org; Christy.A.Jones@usace.army.mil; Jsansley@duanemorris.com; justin[redacted]; jekeating66[redacted]; kathryn.kempton@noaa.gov; tkinney86[redacted]; patrick@tuolumne.org; lesley.kordella@ferc.gov; Bao.Le@hdrinc.com; Mortalis46[redacted]; elevin@sfwater.org; rlewis@tcouncil.com; dslinkard[redacted] Carin.Loy@hdrinc.com; roselynn@buenavistatribe.com; maperanch[redacted] dmadden@turlock.ca.us; annie.manji@wildlife.ca.gov; Dmarko[redacted] mike@hetchhetchy.org; mmartin[redacted]; ramon_martin@fws.gov; chixrnch2@mlode.com; dampl[redacted] rmcdevitt@hansonbridgett.com; marty[redacted]; Jmein@envres.org; sixbit[redacted]; SMonheit@waterboards.ca.gov; rhonda@buenavistatribe.com; mary.motola@chukchansi.net; gmurphey@dfg.ca.gov; shana.murray@ferc.gov; JKObrien@dfg.ca.gov; TomO@stanfarmbureau.org; rsce[redacted]; ottfarms.chris[redacted] duane.paul@cardno.com; steve.pavich@cardno.com; rbpoo[redacted] ruth.porter@hoganlovells.com; chixrnch@lodelink.com; spuccini@dfg.ca.gov; jessie@tuolumne.org; tramirez@sfwater.org; maria.rea@noaa.gov; rhonda.reed@noaa.gov; drichardson@co.tuolumne.ca.us; Kevin.A.Richardson@usace.army.mil; jridenour@modestogov.com; TRiggs@co.tuolumne.ca.us; royalrobbins[redacted]; dave@newman-romano.com; rrcollins@waterpowerlaw.com; spreck@hetchhetchy.org; jessetroseman[redacted] srothert@americanrivers.org; nsandkulla@bawsca.org; jsaunders@parks.ca.gov; aschutte@hansonbridgett.com; wsears@sfwater.org; sarah.shakal@humboldt.edu; squabbob[redacted]; vshumway@fs.fed.us;

blancapaloma[redacted]; plranches[redacted]; CNRF@elite.net; jpsmith@ldpmarina.com; Rose.Staples@hdrinc.com; gstapley@modbee.com; dave@americanwhitewater.org; steinero[redacted]; john.stender[redacted]; vstone@mewuk.com; rstork@friendsoftheriver.org; sstratton@parks.ca.gov; mtaylor@dfg.ca.gov; tterpstra@thtlaw.com; [redacted]; larry.thompson@noaa.gov; Tmberliner@duanemorris.com; [redacted] rulm@modestogov.com; sandyvasquez[redacted]; cverkuil@mofo.com; chris.vierra@ci.ceres.ca.us; richard.wantuck@noaa.gov; arta[redacted] wengnut001[redacted] eric@tuolumne.org; dan.wheelerhay[redacted]; dave.wheelerhay[redacted]; douglas.wheeler@hoganlovells.com; David.K.White@noaa.gov; scott@stillwatersci.com; hbwillia44[redacted] alison_willy@fws.gov; bwilson@mofo.com; frank.winchell@ferc.gov; john.wooster@noaa.gov; michelle_workman@fws.gov; rmyoshiyama@ucdavis.edu; waynez@stanfarmbureau.org
Subject: No Don Pedro Workshop Meetings Next Week--New Schedule Coming Soon
Date: Thu, 11 Apr 2013 22:23:13 +0000

We are currently developing a revised schedule for the Project Operations Model Base Case rollout, the Integrated Model Training, and the W&AR-6 Salmon Population Model Workshop (previously scheduled for April 18th). The new schedule will be issued next week—and I will advise you at that time as well as update the relicensing website calendar. So, therefore, there will be NO meetings/workshops next week. Thank you.

ROSE STAPLES
CAP-OM

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Executive Assistant, Hydropower Services

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Staples, Rose

From: Staples, Rose
Sent: Tuesday, April 30, 2013 5:11 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Lewis, Reggie'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Monheit, Susan'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; Rosekrans, Spreck; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Relicensing 2013 Predation Study Plan Filed with FERC Today

The Districts have filed with FERC today the 2013 Predation Study Plan for the Don Pedro Project. The filing is on FERC's E-Library (www.ferc.gov) and will be on the Don Pedro Project relicensing website shortly (www.donpedro-relicensing.com). If you have any difficulties accessing and/or downloading the document, please let me know. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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rose.staples@hdrinc.com | hdrinc.com

Staples, Rose

From: Staples, Rose
Sent: Tuesday, June 11, 2013 6:28 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; Rosekrans, Spreck; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; Wetzel, Jeff; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: AGENDA for Don Pedro W-AR-7 2014 Draft Predation Study Meeting June 19 2013
Attachments: DonPedroW-AR-7_2014draftPredationStudyMtg_130619.doc

In its May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project, FERC recommended that the Districts consult with FWS, NMFS, CDFW, and Conservation Groups in developing a draft 2014 Predation Study Plan to be submitted for Commission approval by August 1, 2013. The Districts invite you to participate in a meeting from 1:30 to 4:30 pm on June 19 at HDR's Sacramento office. The purpose of this meeting is to discuss and clarify recommendations provided in FERC's Determination. The draft 2014 Predation Study Plan will reflect this discussion and will be submitted to Relicensing Participants by July 8, 2013 for a 30-day review. The Districts are planning to file the study plan with FERC for approval by September 15, 2013.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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Don Pedro Relicensing

W&AR-07 – Draft 2014 Predation Study Meeting

Wednesday, June 19, 2013
1:30 pm to 4:30 pm

HDR Offices
2379 Gateway Oaks Drive, Suite 200, Sacramento, CA

MEETING PURPOSE / AGENDA

PURPOSE: The purpose of this meeting is to discuss and clarify recommendations made by FERC in its Determination, and the discussion will include:

- Review of study objectives
  - Predator abundance
  - Predation rates
  - Relative habitat use

- Predation rate sampling design
  - Summary and clarification of comments
  - Definition of study reach
  - Timing
  - Potential capture methods
  - Effort and certainty

- Predator abundance sampling design
  - Summary and clarification of comments
  - Definition of study reach
  - Timing
  - Potential capture methods
  - Effort and certainty

- Relative habitat use sampling design
  - Summary and clarification of comments
  - Scale

Staples, Rose

From: Staples, Rose
Sent: Thursday, June 13, 2013 8:24 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; Rosekrans, Spreck; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; Wetzel, Jeff; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro - Districts file Request for Time Extension on Filing Two New Study Plans
Attachments: P-2299_DP_ReqExtnTimeFileStudyPlans_130613.pdf

The Districts have filed with FERC today a *Request for Extension of Time to File* (see attached) the following two new study plans: 2014 Predation Study and the Juvenile Chinook Salmon Floodplain Rearing Hydraulic Analysis.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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rose.staples@hdrinc.com | hdrinc.com

June 13, 2013

FERC Project No. 2299-075 California
Don Pedro Hydroelectric Project

Secretary Kimberly D Bose
Federal Energy Regulatory Commission
888 First Street NE
Washington DC 20426

Subject: Request for Extension of Time to File Study Plans
Don Pedro Hydroelectric Project No. 2299-075

Dear Ms. Bose:

Turlock Irrigation District and Modesto Irrigation District (collectively the "Districts") are in receipt of the Commission's May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Project. In the Determination, the Commission directs the Districts to file two new study plans as follows:

- Predation Study
- Juvenile Chinook Salmon Floodplain Rearing Hydraulic Analysis

The May 21, 2013 letter indicates that these two study plans are to be filed with the Commission by August 1, 2013. Both study plans are to be developed through consultation with relicensing participants and provide 30 days for the consulted parties to provide written comments and recommendations. These two studies are important undertakings and the study plan details, especially those related to the Predation Study to be conducted in 2014, are likely to take significant time to work through with relicensing participants. Therefore, the Districts are requesting an extension of time to September 15, 2013 for filing the final study plans with the Commission for approval. The Districts have held initial conversations with several of the resource agencies. These resource agencies concur with the need for additional time to collaborate in the development of these study plans.

Sincerely,

Steven Boyd
Turlock Irrigation District
P O Box 95381
Turlock CA 95381
(209) 883-8364
seboyd@tid.org

Greg Dias
Modesto Irrigation District
P O Box 4060
Modesto CA 95352
(209) 526-7566
gregd@mid.org

cc: Peter Barnes, SWRCB
Annie Manji, CDFW
Robert Hughes, CDFW
Ramon Martin, USFWS
Zac Jackson, USFWS

Staples, Rose

From: Staples, Rose
Sent: Tuesday, June 18, 2013 4:06 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Colvin, Tim'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayat, Zahra'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; Rosekrans, Spreck; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; Wetzel, Jeff; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro June 19 2013 W-AR-07 Draft 2014 Predation Study Plan Meeting in Sacramento

Please find below the ***Call-In Number***, ***On-Line Meeting*** link, and a repeat of the previously-issued ***AGENDA*** for the ***June 19 W&AR-07 Draft 2014 Predation Study Plan Meeting*** to be held at the HDR Offices in Sacramento (2379 Gateway Oaks Drive, Suite 200) beginning at 1:30 p.m.

1-866-994-6437 Call-in
2300743 password

Join online meeting
https://meet.hdrinc.com/jenna.borovansky/3D64F0F5

First online meeting?

Wednesday, June 19, 2013
1:30 pm to 4:30 pm

MEETING PURPOSE / AGENDA

PURPOSE: The purpose of this meeting is to discuss and clarify recommendations made by FERC in its Determination, and the discussion will include:

- Review of study objectives
  - Predator abundance
  - Predation rates
  - Relative habitat use

- Predation rate sampling design
  - Summary and clarification of comments
  - Definition of study reach
  - Timing
  - Potential capture methods
  - Effort and certainty

- Predator abundance sampling design
  - Summary and clarification of comments
  - Definition of study reach
  - Timing
  - Potential capture methods
  - Effort and certainty

- Relative habitat use sampling design
  - Summary and clarification of comments
  - Scale

Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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rose.staples@hdrinc.com| hdrinc.com

From: Staples, Rose
Sent: Wednesday, July 10, 2013 10:10 AM
To: 'Mike Marshall'
Subject:RE: cost of re-licensing process?

Received your query, thank you. The Districts are the best source for this information, so I will be forwarding your request on to them today.

ROSE STAPLES
CAP-OM
HDR Engineering, Inc.
Executive Assistant, Hydropower Services

970 Baxter Boulevard, Suite 301 | Portland, ME 04103
207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com| hdrinc.com

From: Mike Marshall [mailto:mike@hetchhetchy.org]
Sent: Monday, July 08, 2013 5:58 PM
To: Staples, Rose
Subject: cost of re-licensing process?

Rose:
Is there a document or individual that can tell me how much TID/MID will spend on the participating in the re-licensing process? I don't need anything elaborate....just a ballpark number.

Thanks!
Mike

Mike Marshall, Executive Director
Restore Hetch Hetchy
Join me in Yosemite on Muir's March July 28 - August 3, 2013 or Muir's Ride July 31 - August 3, 2013
415.956.0401 office
415.745.0626 cell
101 Montgomery Street, Suite 2600
San Francisco, California 94103
www.hetchhetchy.org

Volume 3 | Issue 1

Don Pedro

A newsletter about the relicensing of the Don Pedro Project

FERC weighs in on Initial Study Report

As part of the joint Modesto Irrigation District-Turlock Irrigation District process to relicense the Don Pedro Project, the Federal Energy Regulatory Commission (FERC) issued its 45-page Determination on Requests for Study Modifications and New Studies on May 21, 2013.

FERC's determination follows the Districts' April 9, 2013 submittal to FERC of their Response to Relicensing Participants Comments regarding the Districts' Initial Study Report (ISR). As part of the Integrated Licensing Process (ILP), the Districts completed a number of environmental studies in 2012 and prepared reports which were provided to FERC and relicensing participants with the Jan. 17, 2013 submittal of the ISR. The studies are required in accordance with FERC's Study Plan Determination issued in 2011.

The reports included in the ISR were summarized by the Districts and their consultants at meetings with the public held Jan. 30-31. These open meetings served to summarize each study and address questions or initial comments on the studies. Attendance was excellent and many questions were addressed. Of key interest were the results of the lower Tuolumne River Predation Study, the Lower Tuolumne River Operations Model, and the Spawning Gravel Study.

Relicensing participants then had until March 9 to file comments on the reports, and the Districts had until April 9 to file their responses to those comments. Comments were received from the National Marine Fisheries Service, the Unites States Fish and Wildlife Service, National Park Service, California Department of Fish and Wildlife, the State Water Resources Control Board, various conservation groups, and the Bureau of Land Management As part of the ILP, FERC then resolves any remaining disagreements about the need for new studies or modifications to the studies already completed by issuing its formal determination.

Interested in Studies?
Glance inside for more details about relicensing studies, including a planned 2014 study focusing on predation of young salmon by bass and pikeminnow.

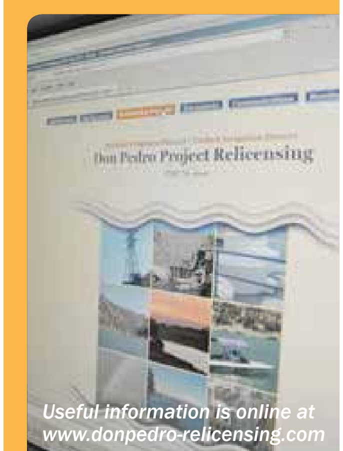
On April 9, the Districts responded to all the comments received, amounting to more than 100 separate responses. This response document was filed with FERC and is available online at www.don-pedro-relicensing.com/documents.

The ISR contains status reports or results of field work completed for over 30 cultural, terrestrial, recreation, and resource studies. Work continues into 2013 analyzing results of these field studies, incorporating information into models, and responding to FERC's May 21, 2013 study plan determination.

Important dates

by Nov. 30, 2013
DRAFT License Application filed with FERC

by April. 30, 2014
Final License Application filed with FERC



Useful information is online at www.donpedro-relicensing.com

What's inside

- Public workshops
- Studies
- Dry water year
- State flow proposal

www.donpedro-relicensing.com

Hands-on analysis part of model workshops

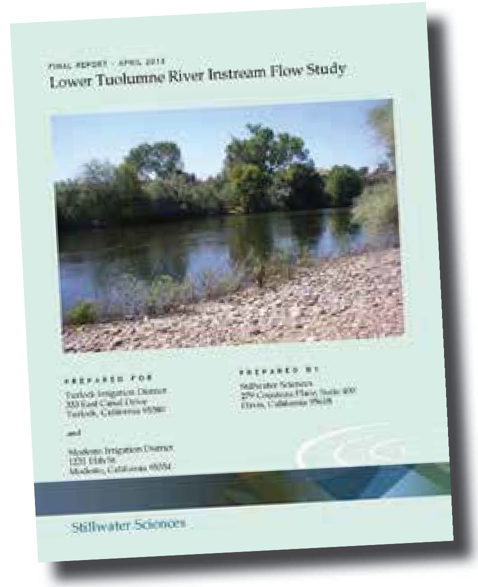
Public workshops are one of many opportunities for public input regarding the relicensing process. Additionally, state and federal agencies, as well as non-governmental organizations, also are involved in the process.

Some examples of such participation occurred in May and June of 2013, when a series of workshops were held. During these workshops, the Districts released analytical models to relicensing participants.

These models, used as tools by the Districts and other participants as part of the relicensing process, include the Lower Tuolumne River Operations Model Base Case, the Don Pedro Reservoir Temperature Model, the Lower Tuolumne River Temperature Model, and the Chinook Salmon Population Model.

At the workshops, which were well-attended, background information and model assumptions were discussed, digital copies of the models were handed out, and participants had the opportunity to test the models and analyze model results based on varying inputs.

More than three years in the making, IFIM study filed



The Districts' Lower Tuolumne River Instream Flow (IFIM) Study Report was filed with FERC on April 29, 2013 after more than three years of study effort, including extensive collaboration with resource agencies and other interested parties.

The instream flow study was to determine instream flows necessary to maximize fall-run Chinook salmon and O. mykiss production, and to maximize survival throughout their various life stages.

In a proceeding underway before relicensing, FERC issued a July 16, 2009 order directing the Districts to develop and implement an Instream Flow Incremental Method/Physical Habitat Simulation (IFIM/PHABSIM) study of the lower Tuolumne River.

Since initiation of the instream flow study, the Districts have initiated the relicensing process for the Don Pedro Project.

It is the Districts' intent to integrate the IFIM study results into all relicensing studies and analyses where pertinent.

Second consecutive dry year

When operating a power plant that is fueled by falling water released from a reservoir, hydrology data and water year status take on increased interest and importance.

Thus is the case with the Don Pedro Project, which receives inflow from the Tuolumne River. The Tuolumne's 2013 water year is shaping up to be dry (among the 25 driest years in over 115 years of record keeping). Its full natural flow this year will not reach 1.1 million acre-feet. Additionally, following a dry 2012, water supply is impacted more during consecutive dry years compared to non-sequential dry years.

Compare those consecutive years to the Department of Water Resources 50-year annual average of about 1.9 million acre-feet, and it's to see why many utilities are hoping for a wet 2014.

Many studies finished, others in works

The Districts completed more than 20 relicensing studies in 2012, and more work is to be completed in 2013 and 2014, leading up to the April 2014 filing of the Districts' Final License Application for the Don Pedro Project.

In its May 21, 2013 Determination on Requests for Study Modifications and New Studies, FERC required that seven of the Districts' studies should be expanded to provide additional information and two new studies should be conducted, both of which had been proposed by the Districts. In addition to following FERC's Determination, the Districts will be conducting a study of the loss of salmon smolts resulting from predation by other fish species (primarily black bass and striped bass) in 2014.

Results of the 23 completed studies, and status reports on the remaining 12 in-progress studies are identified in the Districts' Initial Study Report (ISR). Completed studies include 10 terrestrial studies, three recreation studies, and 10 of the water and aquatic resources studies. The ISR, as well as hundreds of other documents related to the relicensing process, are located on the Documents page at www.donpedro-relicensing.com/documents.

Another major milestone nearing is the filing of the Districts' Draft License Application. This draft application is for the specific purpose of obtaining comments and questions from all interested parties, and is required to be issued prior to November 30, 2013. The Final License Application must be filed before April 30, 2014.

In other news: On June 27, 2013, FERC granted the Districts' request for a time extension related to the La Grange diversion dam. In its order dated Dec. 19, 2012, FERC found that the La Grange diversion dam and TID's small power station was subject to FERC's licensing authority because it included a hydropower generating plant and is located on a navigable stream.

The Districts and conservation groups disagree with the La Grange decision and have sought rehearing. FERC has ordered the Districts to file a licensing plan, which they did on March 19, 2013. FERC is granting an extension of six months to the schedules the Districts' submitted in the licensing plan.

State's flow plan raises concerns

A proposal by the California State Water Resources Control Board is in the works, and could require the Merced, Tuolumne, and Stanislaus rivers to dedicate 35 percent of unimpaired flow to fish and wildlife from February to June each year.

At current, Phase 1 of the board's update to its Bay-Delta Water Quality Control Plan is in the environmental review stages. The board's Substitute Environmental Document was the topic of pubic workshops in March 2013, with water agencies such as the MID and TID opposing the flow proposal, citing the potential harm to water and power customers and the region's economy, agriculture operations and water supply.

Of additional concern to the Districts is the timing of the board's proposal, which conflicts with many aspects of the relicensing process.

Modesto Irrigation District
Water and Power

WATER & POWER
Serving Central California since 1887

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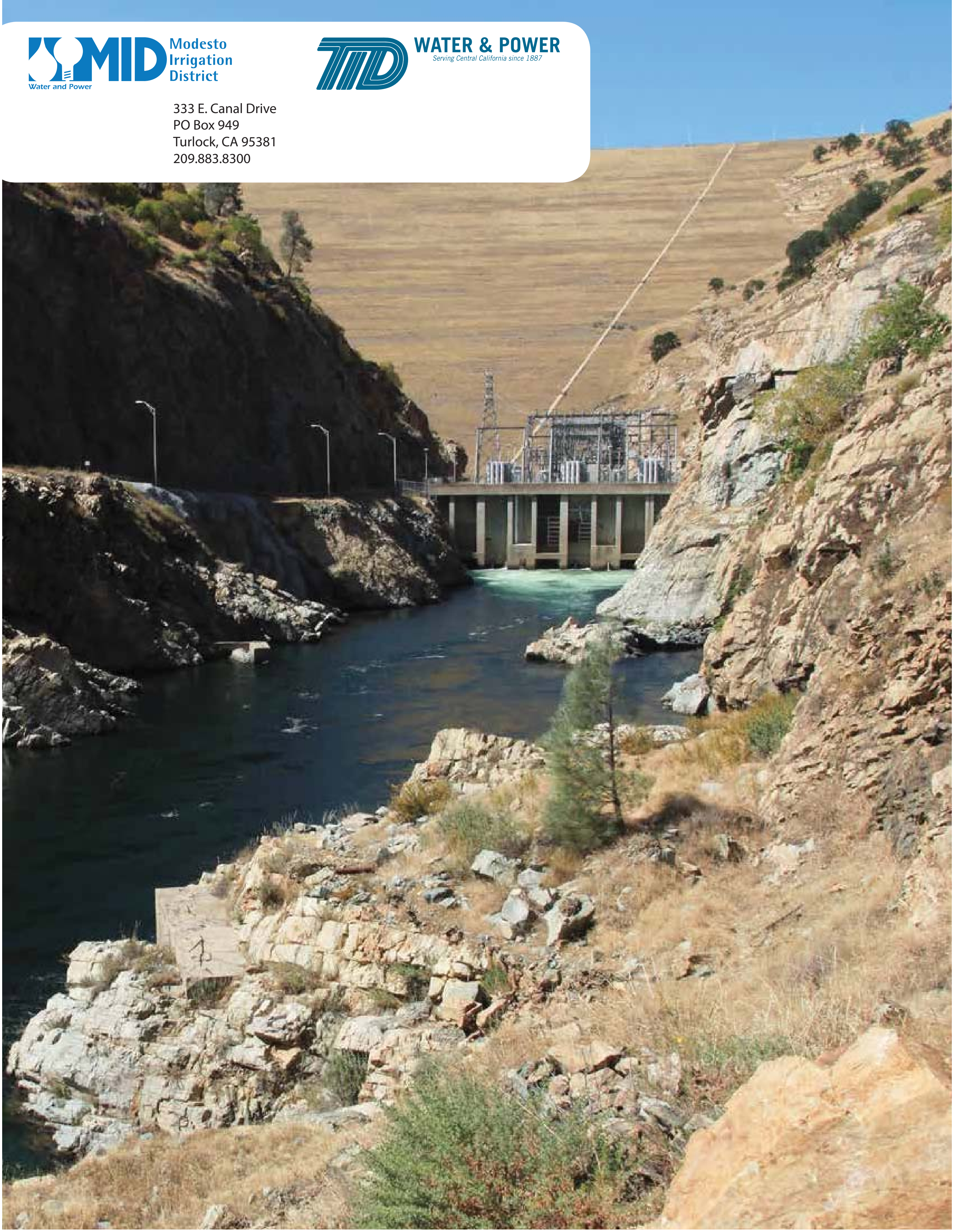

Staples, Rose

From: Staples, Rose
Sent: Thursday, August 08, 2013 6:07 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Draft 2014 Predation Study Plan for 30-Day Review
Attachments: Draft 2014 Predation Study Plan_130808.docx

I am forwarding the following message to you on behalf of Andrea Fuller of FISHBIO:

> As directed in FERC's May 21 Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project ("Determination"), the attached ***Draft 2014 Predation Study Plan*** is being provided for a 30-day review and comment period.
>
> This draft reflects discussions with staff from California Department of Fish and Wildlife, NOAA Fisheries, State Water Resources Control Board, U.S. Fish and Wildlife Service, and Conservation Groups. We are appreciative of the collaborative contributions provided to date, and particularly for the written recommendations provided by Ramon Martin and Zac Jackson of the U.S. Fish and Wildlife Service.

Please provide comments by September 6 to Andrea Fuller at andreafuller@fishbio.com. Thank you.

ROSE STAPLES
CAP-OM
HDR Engineering, Inc.
Executive Assistant, Hydropower Services

STUDY PLAN W&AR-7

TURLOCK IRRIGATION DISTRICT
AND
MODESTO IRRIGATION DISTRICT

DON PEDRO PROJECT
FERC NO. 2299

Draft 2014 Predation Study Plan

August 7, 2013

1.0 Project Nexus

The continued operation and maintenance (O&M) of the Don Pedro Project (Project) may contribute to cumulative effects on the timing and magnitude of stream flow in the lower Tuolumne River. Stream flows, in turn, potentially may contribute to cumulative effects on Chinook salmon (*Oncorhynchus tshawytscha*) outmigrant survival by contributing to changes in velocities, turbidity, and water temperatures that affect the timing and use of in-channel and floodplain habitats by salmon and predatory fish species.

2.0 Resource Agency Management Goals

The Districts believe that four agencies have resource management goals related to Chinook salmon and/or their habitat: (1) U.S. Department of Interior (USDOI), Fish and Wildlife Service (USFWS); (2) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS); (3) California Department of Fish and Wildlife (CDFW); and (4) State Water Resources Control Board, Division of Water Rights (SWRCB).

A goal of the USFWS (2001) Anadromous Fish Restoration Program (AFRP), as stated in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to double the long-term production of anadromous fish in California's Central Valley rivers and streams. Objectives in meeting this long-term goal include: (1) improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat; (2) improve survival rates by reducing or eliminating entrainment of juveniles at diversions; (3) improve the opportunity for adult fish to reach spawning habitats in a timely manner; (4) collect fish population, health, and habitat data to facilitate evaluation of restoration actions; (5) integrate habitat restoration efforts with harvest and hatchery management; and (6) involve partners in the implementation and evaluation of restoration actions.

NMFS has developed Resource Management Goals and Objectives for species listed under the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 et seq.) and the Endangered Species Act (ESA) (16 U.S.C. §1531 et seq.), as well as anadromous species that are not currently listed but may require listing in the future. NMFS' (2009) Public Draft Recovery Plan for Sacramento River Winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and Central Valley steelhead (Draft Recovery Plan) outlines the framework for the recovery of ESA-listed species and populations in California's Central Valley. For Central Valley steelhead, the relevant recovery actions identified for the Tuolumne River are to: (1) Conduct habitat evaluations, and (2) Manage cold water pools behind LaGrange and Don Pedro dams to provide suitable water temperatures for all downstream life stages. For Central Valley fall/late fall-run Chinook, the relevant goals are to enhance the Essential Fish Habitat downstream of the Project and achieve a viable population of Central Valley fall/late fall-run Chinook salmon in the Tuolumne River.

CDFW's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFW's resource management goals, as summarized in restoration planning documents such as "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993), are to restore and protect California's aquatic ecosystems that support fish and wildlife, and to protect threatened and endangered species under California Fish and Game Code (Sections 6920-6924).

3.0 Study Goals

The 2014 predation study will provide information to increase understanding of the current effects of predation on rearing and outmigrating juvenile Chinook salmon and *O. mykiss* in the lower Tuolumne River. Specific information obtained by this study will update and supplement information from prior studies in order to:

- estimate relative abundance of predator fish species using in-channel habitats such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone saxatilis*), during February-May and July between RM 42 and RM 0, and compare to previous studies,
- estimate predation rates by stomach content sampling (e.g., TID/MID 1992) during juvenile Chinook salmon outmigration between RM 42 and RM 0 and compare to previous studies,
- document predator movement and distribution between RM 42 and RM 0 during juvenile salmon outmigration and July,
- identify mortality hot-spots such as individual run-pools and SRPs between RM 42 and RM 0 that potentially result in higher predation mortality on outmigrating juvenile Chinook salmon.

4.0 Existing Information and Need for Additional Information

Interannual variations in seasonal river flow and temperature affect the composition and distribution of the native and non-native fish assemblage, including predators of juvenile salmonids (Baltz and Moyle 1993; Brown and Moyle 1997; Brown 2000; Marchetti and Moyle 2001, Brown and Ford 2002). Surveys of predator species distribution and abundance have been carried out by CDFW and the Districts, and demonstrate increasing predator density downstream of the primary spawning reach of the lower Tuolumne River as well as changes in abundance and habitat use in various water year types (McBain & Trush and Stillwater Sciences 2006). The earliest predation study was conducted in 1987 by CDFW and included the release of 90,000 coded-wire-tagged (CWT) juvenile Chinook salmon from below La Grange Dam (River Mile [RM] 52). Recapture rates of CWT fish indicated only 30 percent of the released fish reached the San Joaquin River confluence (RM 0). Because the most plausible explanation for this observation was mortality by predation, additional predation investigations were undertaken by the Districts.

During 1989, the Districts conducted a follow-up predation study at nine sites in the lower Tuolumne River (TID/MID 1992, App. 22). Although this water year was relatively dry, the main objectives of the study were to obtain preliminary data on (1) the piscivorous predator population (species, abundance), (2) the rates of predation, and (3) the variability inherent in sites, timing of surveys, and numbers of fish examined. Twelve potential Chinook salmon predator species (two of which are native species) were captured during the pilot study. Of these 12 species, only two, one smallmouth and one largemouth bass, were found to contain Chinook juveniles in their stomach content. The estimated rate of predation for smallmouth bass, 0.44 fish per day, was over twice as high as that estimated for largemouth bass, 0.20 fish per day.

Habitat-specific predator abundance was estimated before and after the restoration of special run-pool (SRP) 9 by McBain & Trush and Stillwater Sciences (2006). Monitoring data from September–October 2003 showed that largemouth and smallmouth bass were the most abundant potential salmon predators at all project (SRP 9 and SRP 10) and control (Charles Road) sites. Two other potential salmon predators, Sacramento pikeminnow and striped bass, occurred at very low numbers in the sites sampled. Although no information on predation rate was collected for these species, due to the lower relative abundance of smallmouth bass, predation on Chinook salmon by smallmouth bass was considered to be less important than largemouth bass at that time. However, because relative abundance was shown to be variable between pre- and post-project monitoring assessments of the study sites, there is a need to update this information.

To examine whether water velocity and temperature influence predator and juvenile salmon habitat use at the completed SRP-9 Project discussed above, Stillwater Sciences and McBain & Trush (2006) conducted a predator tracking pilot study of three largemouth bass and one smallmouth bass at the same three sites. Prior habitat suitability modeling conducted at SRP 9 for pre- and post-project conditions using the River 2D model (Steffler and Blackburn 2002) indicated that channel restoration should alter water flows and velocities to provide a "safe-velocity corridor" for outmigrant salmon during relatively low flow conditions. However, juvenile Chinook salmon and piscivore-sized bass captured during the surveys were all found on inundated floodplains or in nearshore areas, and analysis of stomach contents indicated no predation on juvenile salmon and very low feeding rates by all predators examined. The small sample size and non-continuous (weekly) mobile-tracking surveys precluded conclusions regarding habitat use by predators or the relationship between predator location and river flow. Study recommendations included targeting lower flows than occurred during this study (< 7,000 cubic feet per second [cfs]) when mid-channel areas can be more effectively surveyed and higher water temperatures facilitate increased predator feeding rates, and the use of additional observation methods such as electrofishing.

During 2012, the Districts estimated predation rates during March and May, predator abundance during the summer, and relative habitat use of juvenile Chinook salmon and predators to update information from previous predation studies to reflect the predator species composition and distribution in response to current conditions. Predation rates for largemouth bass and smallmouth bass were found to be lower than during the 1989 study, and flow thresholds of 300 cfs and 2,000 were found not to be useful in reducing collocation of Chinook salmon smolts and predators.

Based upon the predation studies reviewed above, predation of juvenile salmonids by introduced species such as striped bass, smallmouth bass, and largemouth bass can be a significant factor affecting Chinook salmon smolt survival in certain years. While the studies to date provide some estimates of predation rate and predator abundance, most sampling has been conducted under relatively dry conditions and more data is needed across years to determine how predator abundance and predation rates may be affected by flow, water temperature, and prey availability. The proposed 2014 predation study seeks to provide additional data to inform our understanding of the potential impacts of predation and mechanisms which may influence these impacts through completion of the following tasks:

- estimate relative abundance of predator fish species using in-channel habitats such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone sax atilis*), during February-May and July between RM 42 and RM 0, and compare to previous studies,
- estimate predation rates by stomach content sampling (e.g., TID/MID 1992) during juvenile Chinook salmon outmigration between RM 42 and RM 0 and compare to previous studies,
- document predator movement and distribution between RM 42 and RM 0 during juvenile salmon outmigration and July,
- estimate juvenile Chinoook salmon mortality in multiple river segments to identify potential mortality hot-spots such as individual run-pools and SRPs between RM 42 and

RM 0 that may result in higher predation mortality on outmigrating juvenile Chinook salmon.

5.0 Study Methods

This study consists of evaluating four components related to salmonid predation by native and non-native species in the lower Tuolumne River:

- estimate relative abundance of predator fish species using in-channel habitats such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone sax atilis*), during February-May and July between RM 42 and RM 0, and compare to previous studies,
- estimate predation rates by stomach content sampling (e.g., TID/MID 1992) during juvenile Chinook salmon outmigration (February-May) between RM 42 and RM 0 and compare to previous studies,
- document predator movement and distribution between RM 42 and RM 0 during juvenile Chinook salmon outmigration (February-May) and July,
- estimate juvenile Chinook salmon mortality in multiple river segments to identify potential mortality hot-spots such as individual run-pools and SRPs between RM 42 and RM 0 that may result in higher predation mortality on outmigrating juvenile Chinook salmon.

5.1 Study Area

The study area includes the Tuolumne River from the La Grange Dam (RM 52) downstream to the confluence with the San Joaquin River (RM 0). Study sites for predator abundance and predation rate sampling will be selected using a stratified random sampling design to select random replicate study sites for major habitat types. The lower Tuolumne River is composed of two general habitat strata. The upper section (RM 52-RM 25) consists of alternating riffle and run-pool habitats (with 7 deep and/or wide pools, termed "special run-pools") while the lower section (RM 25- RM 0) lacks riffles and can be described as uniformly run-pool (TID/MID 1992, Stillwater Sciences and McBain & Trush 2006). These strata will be further divided into four study reaches extending from Turlock Lake State Recreation Area to Hickman Bridge (RM 42-RM 31.6), Hickman Bridge to Charles Road (RM 24), Charles Road to Legion Park (RM 16), and Legion Park to the confluence with the San Joaquin River (RM 0).

5.2 General Concepts and Procedures

The following general concepts apply to the study:

- Personal safety is an important consideration of each fieldwork team. The Districts and their consultants will perform the study in a safe manner; areas considered unsafe in the judgment of field teams will not be surveyed.

- The Districts will make a good faith effort to obtain permission in advance of performance of the study to access private property where needed. Field crews may make minor modifications in the field to adjust to and to accommodate actual field conditions and unforeseeable events. Any modifications made will be documented and reported in the draft study reports.

5.3 Study Methods

Predators will be captured in the lower Tuolumne River in multiple habitat types using a variety of methods to determine the relative abundance of each predator species in each type of habitat.

5.3.1 Predator Abundance

<u>Step 1 – Study Design and Permitting.</u> The Predator Abundance study task is designed to collect data on relative predator abundance in specific habitat types using the most feasible and effective methods available. Between TLSRA (RM 42) and the confluence with the San Joaquin River (RM 0) two habitat types will be electrofished monthly during February-May and during July: (1) "special run pools" or "SRPs") and (2) runs and run-pools. Riffles will not be sampled for three reasons. First, predator abundances in riffle units will likely be low relative to run-pools and special run-pools, and, second, adequately and safely sampling riffle units (at all flows during the study period) using boat-mounted electrofishing units will not be possible. Lastly, both areas and shoreline lengths of riffles make up a relatively small proportion of the total area or shoreline length of the Lower Tuolumne River. Because riffles will not be included, areas and shoreline lengths of riffles will not be used to scale density estimates to abundance estimates (see Step 3). During 2012, sampling was conducted downstream of RM 38.4 during the summer when Chinook salmon are absent from the river and *O. mykiss* are restricted to cooler upstream locations as a means of protecting Chinook salmon and listed Central Valley steelhead from potential harm during sampling. Questions have been raised as to whether summer predator abundance and distribution is representative of conditions during spring. Multiple sampling events during the juvenile Chinook salmon outmigration period and during the summer will document how predator distribution and abundance may change during the juvenile Chinook salmon outmigration period and seasonally from spring to summer to determine if predator abundance and distributionis affected by flow, water temperature, and prey availability, and to determine if estimates collected during summer are representative of distribution and abundance during salmon outmigration.

Primary and alternate sampling locations have been randomly selected in each of the four study reaches extending from Turlock Lake State Recreation Area to Hickman Bridge (RM 42-RM 31.6), Hickman Bridge to Charles Road (RM 24), Charles Road to Legion Park (RM 16), and Legion Park to the confluence with the San Joaquin River (RM 0). The two upper reaches consist of alternating riffle and run-pool habitats (with 7 deep and/or wide pools, termed "special run-pools") while the lower two reaches lack riffles and can be described as uniformly run-pool

(TID/MID 1992, Stillwater Sciences and McBain & Trush 2006). Within each of the two upper reaches three run-pools and 3 special run-pools have been selected, and within each of the two lower reaches three run-pool segments have been selected. Since the lower reaches are essentially a single run-pool, they were broken into ½ mile segments from which sampling locations were randomly selected. A total of 18 units (e.g., twelve RPs and six SRPs) have been randomly selected from all the units available from RM 0 to RM 42 (Table 1). Alternate sites have also been randomly selected and may be sampled if any of the primary sites are found not to be accessible by boat.

Fyke traps will be used in addition to electrofishing to specifically target striped bass and Sacramento pikeminnow which are known to move over large distances, and are more likely to avoid capture by electrofishing than largemouth bass and smallmouth bass. Fyke traps have proven successful in capturing striped bass on the Sacramento River (Dubois et al 2012) and in the San Joaquin River during 2013 (FISHBIO unpublished data). Fyke traps will be used in relatively deep, higher velocity areas where striped bass and Sacramento pikeminnow would be expected. Approximately four traps will be operated near the downstream boundary of each study reach (i.e., near the mouth of the river, near Legion Park, near Charles Rd., and near Hickman Bridge). Traps will be operated concurrent to electrofishing sampling periods, and the specific number of days operated per abundance sampling event will ultimately be dependent upon observed capture rates.

Table 1. Sampling locations randomly selected for predator abundance and predation rate sampling.

Reach	Habitat Type	Unit #	RM	Length (ft)	Area (ft2)	Sample	2012 Sampling
TLSRA-Hickman	RP	RP37	43.3	727	80,153	Alternate	
TLSRA-Hickman	SRP	SRP4	43 3	2,176	463,076	Alternate	

TLSRA-Hickman	RP	RP39	42.3	1,007	79,813	Alternate	
TLSRA-Hickman	RP	RP46	40.3	691	66,129	Alternate	
TLSRA-Hickman	SRP	SRP11	39	585	210,165	Primary	
TLSRA-Hickman	RP	RP50A	38.8	507	51,252	Alternate	
TLSRA-Hickman	RP	RP51	37.9	3,194	342,101	Alternate	
TLSRA-Hickman	RP	RP54B	37	504	48,075	Alternate	Abundance
TLSRA-Hickman	RP	RP56	35 9	237	14,362	Primary	
TLSRA-Hickman	RP	RP58	35.6	621	72,544	Primary	
TLSRA-Hickman	SRP	SRP5 SS1	35.1	1,583	431,989	Primary	
TLSRA-Hickman	SRP	SRP5	34.7	1,401	341,972	Primary	
TLSRA-Hickman	RP	RP59	34.4	877	114,348	Alternate	
TLSRA-Hickman	RP	RP62A	34.1	1,286	164,609	Alternate	
TLSRA-Hickman	RP	RP62B	33.9	145	9,447	Alternate	
TLSRA-Hickman	RP	RP63A	33.6	237	39,242	Primary	
Hickman- Charles	RP	RP65	33 1	716	58,400	Alternate	
Hickman- Charles	RP	RP66	33	1,145	109,508	Primary	
Hickman- Charles	RP	RP66C	32 5	131	5,579	Alternate	
Hickman- Charles	RP	RP66D	32.4	710	54,487	Primary	
Hickman- Charles	SRP	SRP6	32.2	2,873	561,443	Alternate	Pred. Rate
Hickman- Charles	RP	RP67B	31.6	1,429	154,272	Alternate	
Hickman- Charles	RP	RP67C	31 3	276	29,915	Alternate	
Hickman- Charles	SRP	SRP7	30.6	5,900	1,103,099	Primary	Pred. Rate
Hickman- Charles	SRP	SRP7 SS1	29.5	2,646	658,144	Primary	Abundance
Hickman- Charles	RP	RP68A	29.4	333	43,764	Primary	Pred. Rate
Hickman- Charles	SRP	SRP8 SS1	29.1	2,615	808,423	Alternate	Pred. Rate
Hickman- Charles	SRP	SRP8	27.7	6,191	1,553,103	Alternate	
Hickman- Charles	SRP	SRP10	26.9	1,228	415,059	Primary	Abundance/ Pred.
Hickman- Charles	RP	RP70	26.7	665	97,988	Alternate	
Hickman- Charles	RP	RP	26.5	1,568	129,751	Alternate	
Hickman- Charles	RP	RP	26.2	1,411	126,257	Alternate	
Charles Rd - Legion	RP	RP	25.2	3,065	276,001	Alternate	Abundance
Charles Rd - Legion	RP	RP	25	1,280	137,441	Primary	
Charles Rd - Legion	RP	RP	21.5	NA	NA	Primary	
Charles Rd - Legion	RP	RP	21	NA	NA	Alternate	
Charles Rd - Legion	RP	RP	20.5	NA	NA	Primary	
Charles Rd - Legion	RP	RP	20	NA	NA	Alternate	
Charles Rd - Legion	RP	RP	19.5	NA	NA	Alternate	Abundance
Charles Rd - Legion	RP	RP	19	NA	NA	Alternate	
Charles Rd - Legion	RP	RP	18.5	NA	NA	Alternate	
Charles Rd- Legion	RP	RP	17.5	NA	NA	Alternate	Abundance
Legion-Confluence	RP	RP	15	NA	NA	Alternate	
Legion-Confluence	RP	RP	14.5	NA	NA	Alternate	
Legion-Confluence	RP	RP	12.5	NA	NA	Primary	
Legion-Confluence	RP	RP	9.5	NA	NA	Primary	
Legion-Confluence	RP	RP	9	NA	NA	Alternate	
Legion-Confluence	RP	RP	7.5	NA	NA	Alternate	
Legion-Confluence	RP	RP	4	NA	NA	Alternate	
Legion-Confluence	RP	RP	3.5	NA	NA	Alternate	Abundance
Legion-Confluence	RP	RP	2	NA	NA	Alternate	
Legion-Confluence	RP	RP	0	NA	NA	Primary	

We propose to conduct sampling in a fashion that will allow the use of a robust mark-recapture design. In a robust mark-recapture design, primary and secondary sampling events occur at different time intervals, in which the population can be considered as "closed" or "open" (Pollock 1982). Williams et al. (2002) notes that by combining open- and closed-population models, several advantages are gained that would not be possible with either approach used independently. A considerable advantage is that monthly estimates of abundance can be estimated for the first primary period (e.g., February) and the last primary period (e.g., July) using the robust capture-recapture design, something that is not possible with the Jolly-Seber design. Finally, since the secondary events (days) under a robust design are conducted close together on a temporal scale (only a day or two apart), the probability of emigration of marked fish from a pool is likely to be smaller compared to events separated by a month. The greater sampling effort associated with the robust design (e.g., sampling multiple days during secondary events), typically results in more precise abundance estimates than those derived from a single pass Jolly-Seber.

Consider as an example, an initial primary sampling event will be conducted in February at sampling unit #1. The primary sampling event will consist of two or more secondary sampling events conducted in a relatively short time period (e.g., only days apart). During this short time period, the population can be considered essentially "closed", that is, there will be minimal deaths, recruitment, immigration or emigration into or out of that particular unit. However, between primary sampling events (February to March), the population can be considered "open", with relatively higher rates of death, recruitment, immigration and emigration compared with the secondary event. The robust design allows estimation of period-specific abundance estimates during all months (February through May and July).

Because completion of the study as described in this study plan is contingent upon permit approval by CDFW and/or NMFS, the feasibility of the study as well as the accuracy, precision and comparability of the resulting abundance estimates will depend upon the methods and level of effort that is allowed. Permit inquiries and requests will be made well in advance of the proposed study task to allow permit processing and approval. If permits are not granted, the Districts will make a good faith effort to modify study designs, if possible, to comply with permit requirements and proceed with the study.

<u>Step 2 – Data Collection</u>. Electrofishing will take place in pre-selected habitat units (by stratified random selection) mapped onto high-resolution aerial photographs within a GIS. Delineation of habitat units will take place in the field during the Study Design and Permitting Process (Step 1) prior to initiating the sampling. Locations surveyed in each habitat unit will be recorded in the field using Global Positioning System (GPS) receivers to provide the locations of all areas sampled. GPS data will be collected in a manner that meets or exceeds the federal government's "National Map Accuracy Standards" for published maps and stored in Environmental Science Research Institute (ESRI) Shapefile format.

Predators will be captured in two general habitat types described in Step 1 above (i.e., pools/SRPs, and runs and run-pools). Boat electrofishing will be conducted at night when catch per unit effort is typically highest (Paragamian 1989). Electrofishing will be performed in accordance with the *Guidelines for Electrofishing Waters Containing Salmonids Listed Under the Endangered Species Act* (NMFS 2000) and will be used to target territorial species such as largemouth and smallmouth bass that do not range far from their home territory. Predators captured using electrofishing will be identified to species, measured (fork and total length in mm) and weighed (grams), uniquely marked (i.e., PIT tagged and floy tagged), and if permitted by CDFW, scales and otoliths will be collected from largemouth and smallmouth bass (up to 100 per species) to determine age structure. Scales may be collected during all sampling events, but otoliths will only be collected during the final sampling event in July. Fish sampled for otoliths will be euthanized. Fish not sampled for otoliths will be released near the location of capture after all electrofishing passes have been completed.

Each of the selected units will be sampled a minimum of two nights per survey period between February to May and July, as required for the estimation of abundance under a robust capture-recapture design, with each unit sampled one night and then be revisited two nights later. Each sampling event will consist of at least one electrofishing pass through the unit. Sampling events will proceed from downstream to upstream in order to minimize effects to listed salmonids and potential biases associated with short-term tagging related affects that usually result more downstream movement than upstream movement. A tentative schedule of survey periods for estimating predator abundance is shown in Figure 1.

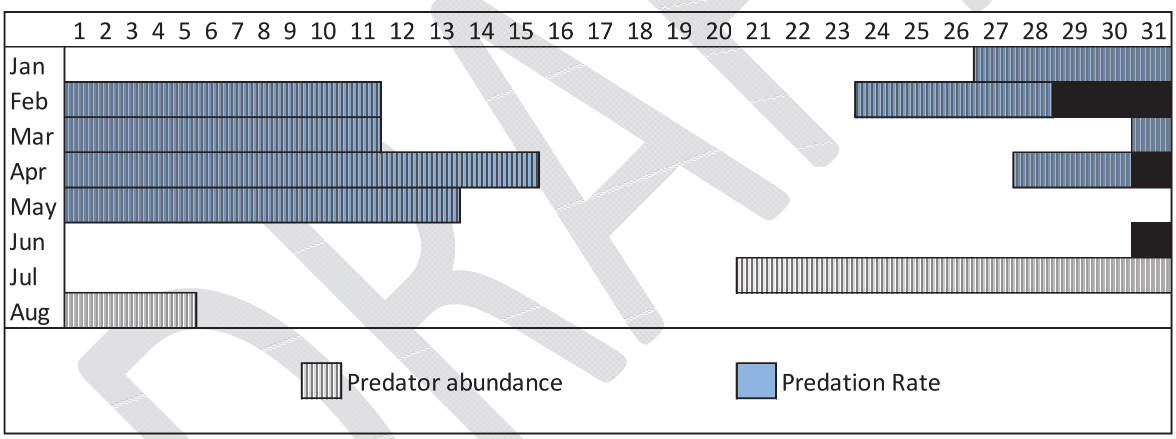

Figure 1. Tentative timing of predator abundance and predation rate sampling events during 2014.

Fyke traps will be used in addition to electrofishing to specifically target striped bass and Sacramento pikeminnow which are known to move over large distances, and are more likely to avoid capture by electrofishing than largemouth bass and smallmouth bass. Fyke traps have proven successful in capturing striped bass on the Sacramento River (Dubois et al 2012) and in the San Joaquin River during 2013 (FISHBIO unpublished data). Fyke traps will be used in relatively deep, higher velocity areas where striped bass and Sacramento pikeminnow would be expected. Approximately four traps will be operated near the downstream boundary of each study reach (i.e., near the mouth of the river, near Legion Park, near Charles Rd., and near Hickman Bridge). Traps will be operated concurrent to electrofishing sampling periods, and the specific number of days operated per abundance sampling event will ultimately be dependent upon observed capture rates.

Use of fyke traps may also provide incidental recaptures of tagged largemouth bass and smallmouth bass. While traps have also been used to capture juvenile largemouth bass (Hayford 1948), the utility of fyke traps in capturing adult largemouth bass is unknown. All untagged predators captured and handled in the fyke traps will be PIT tagged and Floy tagged, and up to 25 striped bass and 25 Sacramento pikeminnow will also be acoustically tagged.

Step 3 – Analysis. Capture-recapture (i.e., mark-recapture) methods are widely used for estimating animal abundances in fisheries (e.g., Seber 1982; Williams et al. 2002). Population models used for estimating abundance are broadly defined as either "closed" or "open" and have various assumptions associated with them. Closed models assume a static population during the study period free of births, deaths, emigration, or immigration. Open models allow for changes in abundance caused by births, deaths, and movements into and out of the sample area. Open models used to estimate abundance, among other things, are more complex, and require larger numbers of marked individuals as well as higher capture probabilities (Pine et al. 2012). Attributes of both the closed and open models may be combined into a model referred to as the "robust" design" (see Step 1), which allows for temporary emigration (Pollock 1982). The robust design functions by linking discrete, closed population studies to estimate population abundance with an open-population model to estimate survival.

Data collected in Step 2 will be used to estimate absolute abundance of each predator species at each site and for each habitat type during each primary event. Data analysis (e.g., estimating abundance and survival) will be conducted using MARK (White and Burnham 1999) or other software packages (R and "RMark" package; Laake 2013) using methods described in Williams et al. (2002). This particular reference is currently considered the standard reference for mark-recapture models. Assumptions of the closed population portion of the robust design (the secondary period samples) are that (1) the population is closed to gains and losses during the period; (2) marks or tags are not lost, missed, or incorrectly recorded; (3) capture probability over the secondary periods varies according to specified model; and (4) the fate of each fish is independent with respect to capture probability (Williams et al. 2002; p. 531). Assumptions associated with the open portion of the robust design are: (1) marks or tags are not lost, missed, or incorrectly recorded; (2) conditional probabilities of capture and survival during each primary period is the same for each marked fish; and (3) fates of fish (in terms of survival and capture probabilities) are independent.

Additional auxiliary information may also be included in the robust design to improve precision of abundance estimates (Kendall et al. 2013). Information about marked predators collected from acoustic telemetry arrays (see Predator Movement Tracking below), anglers, instream PIT tag antennas, fyke traps, instream cameras, and/or other surveys can also be used to improve abundance estimates. Fyke traps may also serve as an additional tagging location in addition to electrofishing surveys.

Sampling gear, fish size, and stream habitat have all been shown to influence capture probabilities of stream fishes (Anderson 1995; Peterson et al. 2004). The electrofishing power density, generally regarded as the best measure of electrofishing effectiveness (Reynolds 1996), will be estimated for each channel unit based on generator peak voltage and water conductivity (Dauwalter and Fisher 2007). If sufficient numbers of predators are captured representing different size classes, abundance estimates will be separated into year classes. Confidence intervals (95%) will be computed using parametric bootstrapping. We will examine the influence of covariates such as fish size, sampling procedures, and stream habitat variables on the individual capture probabilities for smallmouth bass and largemouth bass. All available predators deemed to be in good condition at capture (>150 mm in fork length) will be tagged and used in the capture-recapture study.

From the localized abundance estimates, two population densities can be computed for each site sampled: (1) a linear density based on the bank length of the site sampled and (2) an areal density based on the total area of the site sampled (including any pelagic areas not sampled). Overall abundance estimates by habitat type will be estimated by expansion of the sampled portions of the Tuolumne River to unsampled portions using a multistage method using GIS (Toepfer et al. 2000). Specifically, estimates from multiple sample sites will be averaged for each habitat type within each of two reach strata (i.e., TLSRA to Charles Road and Charles Road to the confluence with the San Joaquin). When estimates are averaged over four samples within a strata, there is typically a two-fold improvement in the relative precision associated with the resulting abundance estimates. If there is no longitudinal trend in fish abundance, or no longitudinal trend is detected, we recommend that mean population estimates for each habitat type be applied to the unsampled units of each habitat type. In cases where an abundance function is created, habitat data generated by the GIS can be input into the predictive model. Densities predicted for each habitat unit are then combined with the area of each unit in the GIS to calculate the predicted abundance of fish within each unit. The GIS can be used to calculate a fish abundance estimate for the entire stream, or the data can be exported to a statistical software package to calculate abundance and a confidence interval. Expansion of the localized abundance estimates from sampled areas to unsampled areas is necessary because only temporary emigration from sampled units is expected and marked fish are not expected to distribute riverwide. Acoustic tracking and recaptures of marked predators will provide important information to address the extent to which predators move.

Density and abundance estimates will be compared with the results from prior studies, including the 2012 predation study estimates derived from depletion methods. It should be noted that in the event that electrofishing permits cannot be obtained in Step 1 above, relicensing participants will be consulted to determine appropriate methodologies to estimate abundance in slow-water habitats from gill netting, fyke trapping, direct snorkel observations, and/or other methods. A discussion of the comparability of the resulting estimates from differing observational/sampling methods will be included as necessary as well as a discussion of inter-annual variability documented in previous restoration project monitoring (e.g., McBain & Trush and Stillwater Sciences 2006, Appendix A for SRP 9 monitoring conducted in 1998, 1999, and 2003).

In the event that the robust capture-recapture design does not allow estimation of abundances for primary events (e.g., months) for any reason (primarily low capture probabilities) or does not provide satisfactory confidence intervals, we propose to use sequential Bayesian mark-recapture analysis for closed populations (Nelson et al. 2013 & 2004, Gazey and Staley 1986). The sequential Bayesian analysis is more robust to small sample sizes and to low recapture probabilities than standard capture-recapture models (described above). Briefly, a distribution of population size is obtained directly by calculating the probability of observing the data at all feasible population sizes. The final result describes both the estimate and the uncertainty around the estimate and a probability can be calculated to test whether the estimated population size is greater than a hypothesized number of individuals.

Step 4 – Prepare Report. The Districts will prepare a study task report that includes the following sections: (1) Study Goals, (2) Methods and Analysis, (3) Results, (4) Discussion, and (5) Conclusions. The report will contain relevant summary data, tables and graphs as well as GIS-based maps of sampled habitats. At the request of Relicensing Participants a separate discussion of available predator control methods will be included in the report.

5.3.2 Predation Rate

Step 1 – Study Design and Permitting. The study task is designed to collect data on predation rate by largemouth bass, smallmouth bass, striped bass, and Sacramento pikeminnow within Special Run Pools and pools/run-pools between Turlock Lake State Recreation Area (RM 42) and the confluence of the Tuolumne River with the San Joaquin River (RM 0) during the Chinook salmon rearing and outmigration period (February-May). All predatory fish sampled during the predator abundance estimation component of this study will be sampled to estimate predation rate by habitat type.

Successful completion of this study is contingent upon permit approval by CDFW and NMFS. Permit inquiries and requests will be made well in advance of the proposed study task to allow permit review, modification, and processing. If permits are not granted, the Districts will make a good faith effort to modify study designs, if possible, to comply with permit requirements and proceed with the study.

Step 2 – Data Collection. Stomach samples from all predatory fish >150 mm that are captured and handled during the predator abundance estimation component of this study will be collected to estimate predation rate by habitat type during the juvenile salmon outmigration period (February-May). Stomach lavage or, if necessary, removal of the stomach, will be used to recover stomach contents from all predators >150 mm TL. Although 180 mm total length has been previously identified as the lower size limit for likely salmon predators (TID/MID 1992), using a lower size limit of 150 mm will serve as a validation of these results. Stomach contents will be preserved in 70% ethanol, marked with predator species, predator tag ID, predator total length (mm) and weight (g), capture location, and date/time, and transported to the laboratory for examination. If a stomach sample is collected during the second pass of a sampling period from an individual that had already been sampled during the initial pass of the sampling period (i.e., recaptured after sampling two nights prior), the sample will not be used for estimation of predation rates given potential bias from recent handling. Depending on the number collected, a stratified (by length category), random sub-sample of the stomach samples may be analyzed.

Water temperature data will be obtained from continuously recording thermographs deployed at each study site, whereas turbidity will be recorded at the time of sampling at each study site. Salmon catch data from the ongoing rotary screw trap and seine surveys will be used to provide an index of the size of the potential prey population (i.e., outmigrant salmon) during the study period.

<u>Step 3 – Analysis</u>. In the laboratory, all identifiable prey items found in predator stomachs will be classified (i.e., fish, insect, crustacean, etc.) and enumerated. Fish found in predator stomachs will be identified to species when possible, and intact fish will be measured. The number of Chinook salmon consumed will be used together with water temperature data and published information on gastric evacuation rate to calculate a predation rate (e.g., number of salmon consumed per day) in two steps. First, a predation ratio (by species) will be calculated by dividing the total number of juvenile salmon in the stomachs of predators by the total number of predators captured within a particular habitat type or study reach. The second step in calculating the daily predation rate is to adjust this predation ratio with the gastric evacuation rate for the prey items using simple exponential models for each species (e.g., Eggers 1977, Elliott and Persson, 1978) with application of parameter adjustments for temperature and fish size or other available methods.

The resulting predation rate estimates will be used to identify differences in predation rates among predator species, predator size, habitat types, and environmental conditions at the time of sampling (e.g., temperature, turbidity, flow). An assessment of predation effects upon reach-scale or riverwide Chinook salmon production will be made by expansion of predation rate estimates using methods described in Rieman et. al. (1991). Estimated consumption rates of juvenile Chinook salmon will be compared between survey periods to evaluate predation prior, during, and after the spring pulse flow period (April 15-May 15); between each of the four survey reaches; and habitat types. Comparison of the results of the current study with results of prior Tuolumne River studies (e.g., TID/MID 1992, TID/MID 2013) will provide a basis to evaluate the magnitude of current vs. prior predation levels on juvenile salmonid populations in the lower Tuolumne River.

Step 4 – Prepare Report. The Districts will prepare a study report that includes the following sections: (1) Study Goals, (2) Methods and Analysis, (3) Results, (4) Discussion, and (5) Conclusions. The report will contain relevant summary data, tables and graphs as well as GIS-based maps.

5.3.3 Predator Movement Tracking

Step 1 – Study Design and Permitting. The study is designed to collect data on predator movement in response to flow and water temperatures occurring during the juvenile salmon migration season. The study will document movements of acoustically tagged predators relative to tagging locations and a network of hydrophones.

Because completion of the study as described in this Proposal is contingent upon permit approval by CDFW, permit inquiries and requests will be made well in advance of the proposed studies to allow permit processing and approval. In the event permits are not granted, the Districts will make a good faith effort to modify study designs, if possible, to comply with permit conditions and proceed with the study.

Step 2 – Data Collection. Up to 25 piscivore-sized predators (> 175 mm TL) for each of the four target species (i.e., largemouth bass, smallmouth bass, striped bass, and Sacramento pikeminnow) captured during predator abundance and predation rate suveyswill be tagged externally using HTI Lg transmitters (4.5 g) with an expected battery life >6 months. Acoustic tagged predators will be held for up to 4 hours and monitored to ensure proper recovery and tag operation before being released in the same habitat unit where they were captured.

A network of fixed receivers will be deployed and used to document movement patterns of acoustic tagged predators following release. Tentative locations of fixed receivers to track both predator movements and to identify potential juvenile Chinook salmon mortality hot-spots (see section 5.3.4) are identified in Table 2 and in Figures 2-5.

Water temperature during sampling will be recorded with continuous recording thermographs maintained at or near each site. Thermographs will be removed when sampling is completed and returned to the laboratory for data download and analysis.

Table 2. Tentative locations of acoustic receivers during 2014.

Reach	Location	River Mile	Array Type
TLSRA-Hickman	TLSRA	42	Dual
TLSRA-Hickman	SRP 11 - u/s	36.8	Single
TLSRA-Hickman	SRP 11 - d/s		Single
TLSRA-Hickman	George Reed run-pool u/s	35	Single
TLSRA-Hickman	George Reed run-pool d/s		Single
TLSRA-Hickman	SRP 5 - u/s	33	Single
TLSRA-Hickman	SRP 5 - d/s		Single
Hickman-Charles Rd	SRP 6 - u/s	30.5	Dual
Hickman-Charles Rd	SRP 6 - d/s		Single
Hickman-Charles Rd	RP 67 - d/s	30	Single
Hickman-Charles Rd	SRP 7 - u/s	29	Single
Hickman-Charles Rd	SRP 7 - d/s	28	Single
Hickman-Charles Rd	SRP 8 - d/s	27	Single
Hickman-Charles Rd	SRP 10 - u/s	26	Single
Hickman-Charles Rd	SRP 10 - d/s	25.5	Single
Charles Rd - Legion	Santa Fe u/s	23	Dual
Charles Rd - Legion	Santa Fe d/s	22	Single
Charles Rd - Legion	Mitchell Rd u/s	20	Single
Charles Rd - Legion	Mitchell Rd d/s	19	Single
Legion - Confluence	Legion Park u/s	17	Single
Legion - Confluence	Legion Park d/s	15	Single
Legion - Confluence	Riverdale	12	Single
Legion - Confluence	Grayson	5	Single
Legion - Confluence	Confluence	0	Dual

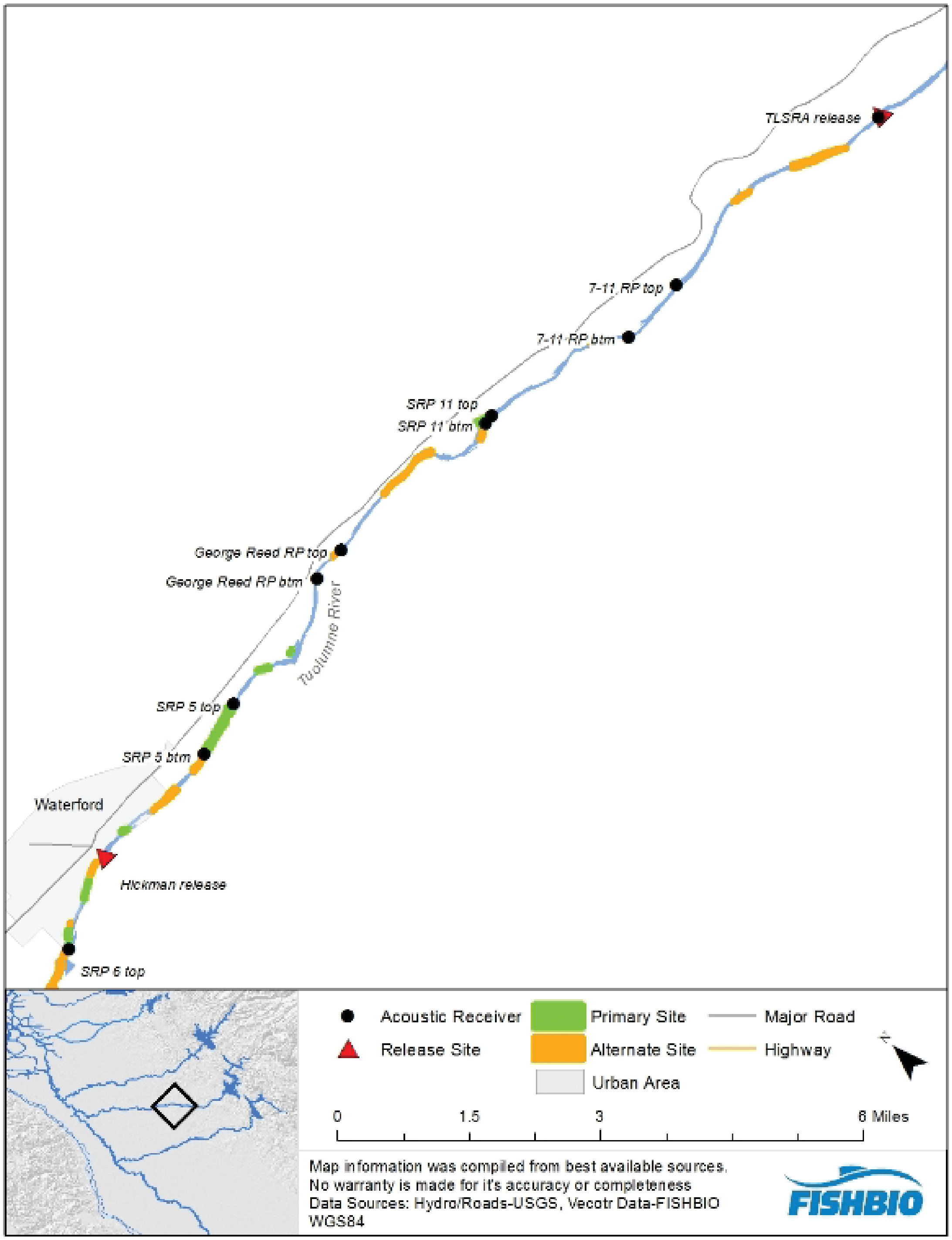

Figure 2. Sampling locations between Turlock Lake State Recreation Area and Hickman Bridge.

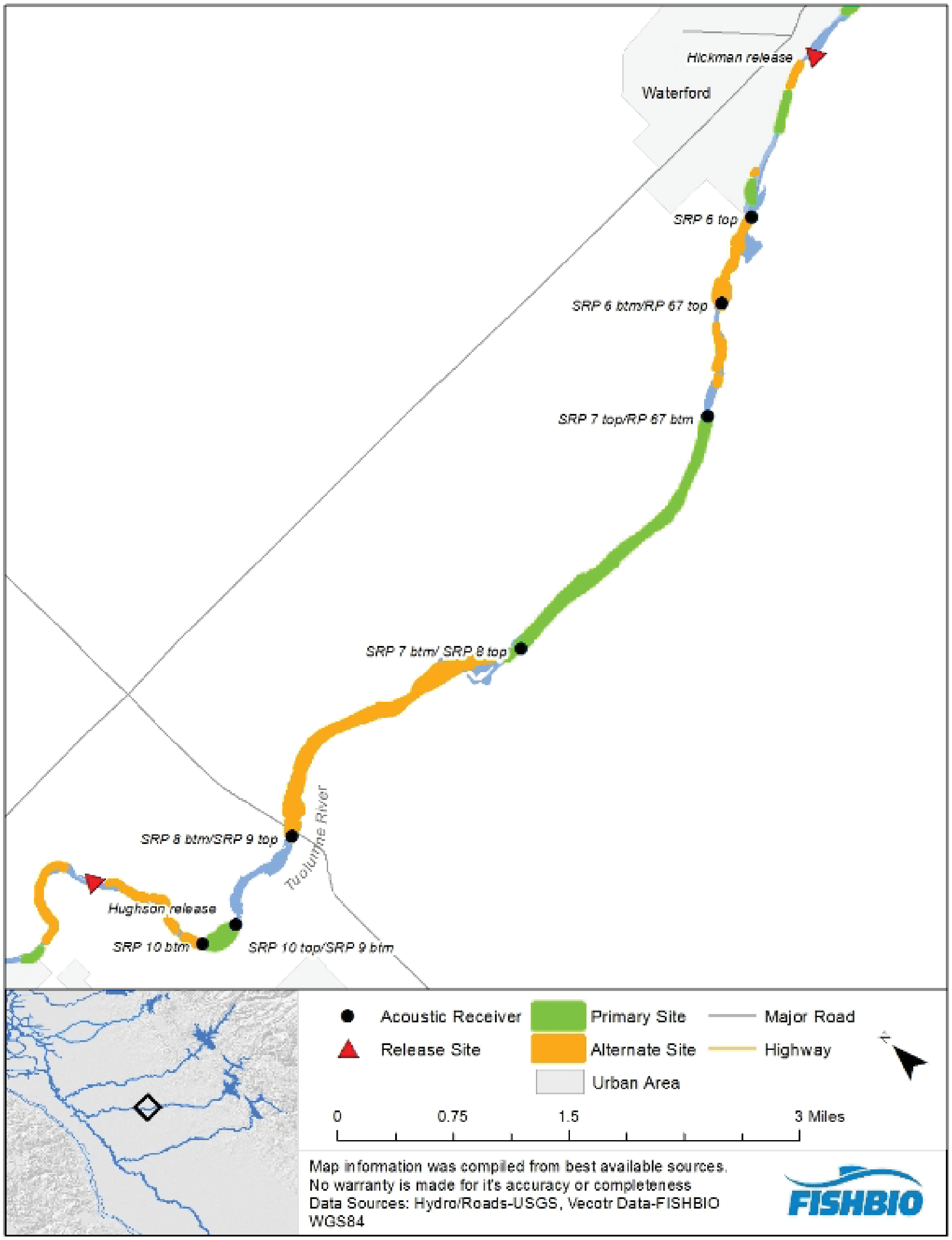

Figure 3. Sampling locations between Hickman Bridge and Charles Road.

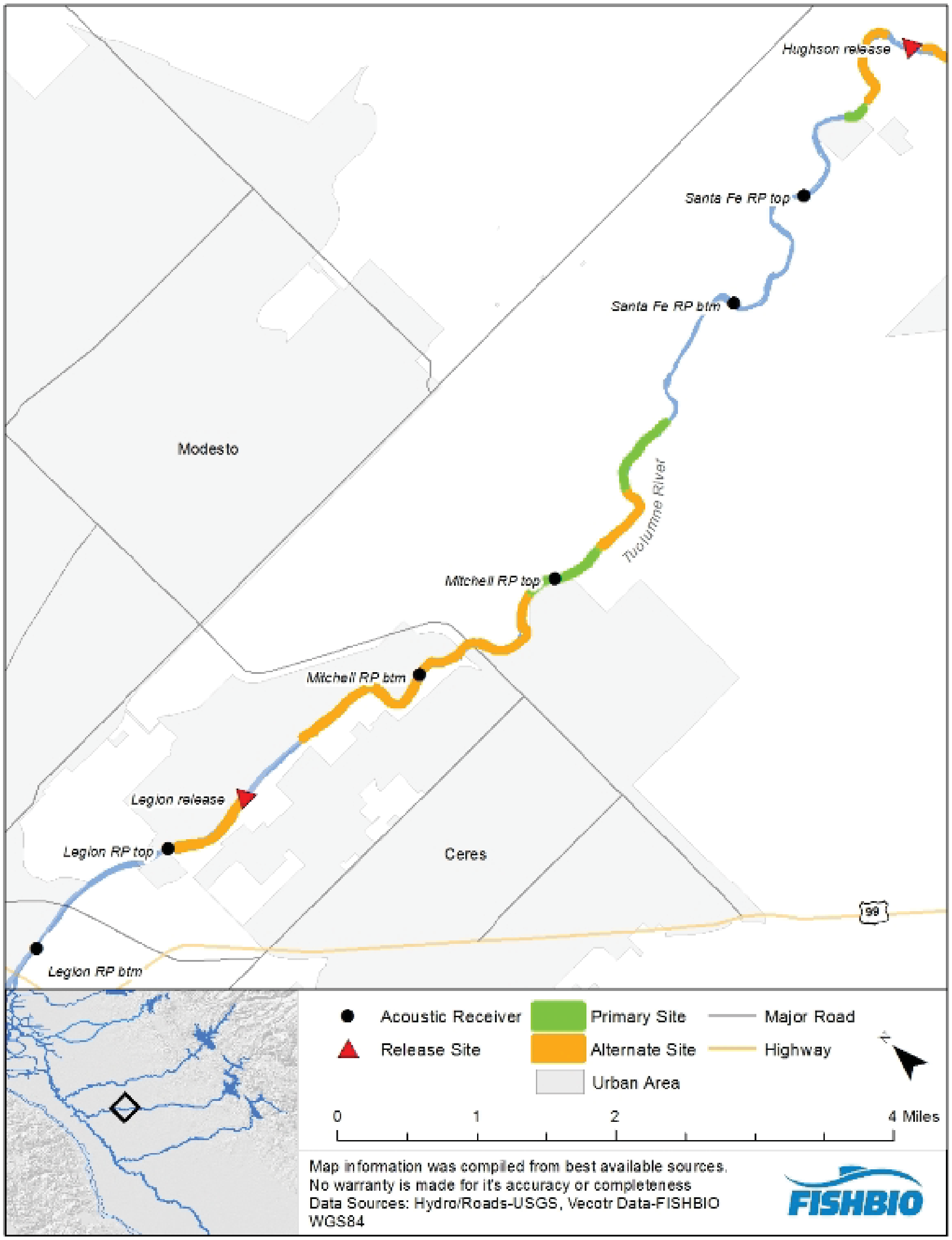

Figure 4. Sampling locations between Charles Road and Legion Park.

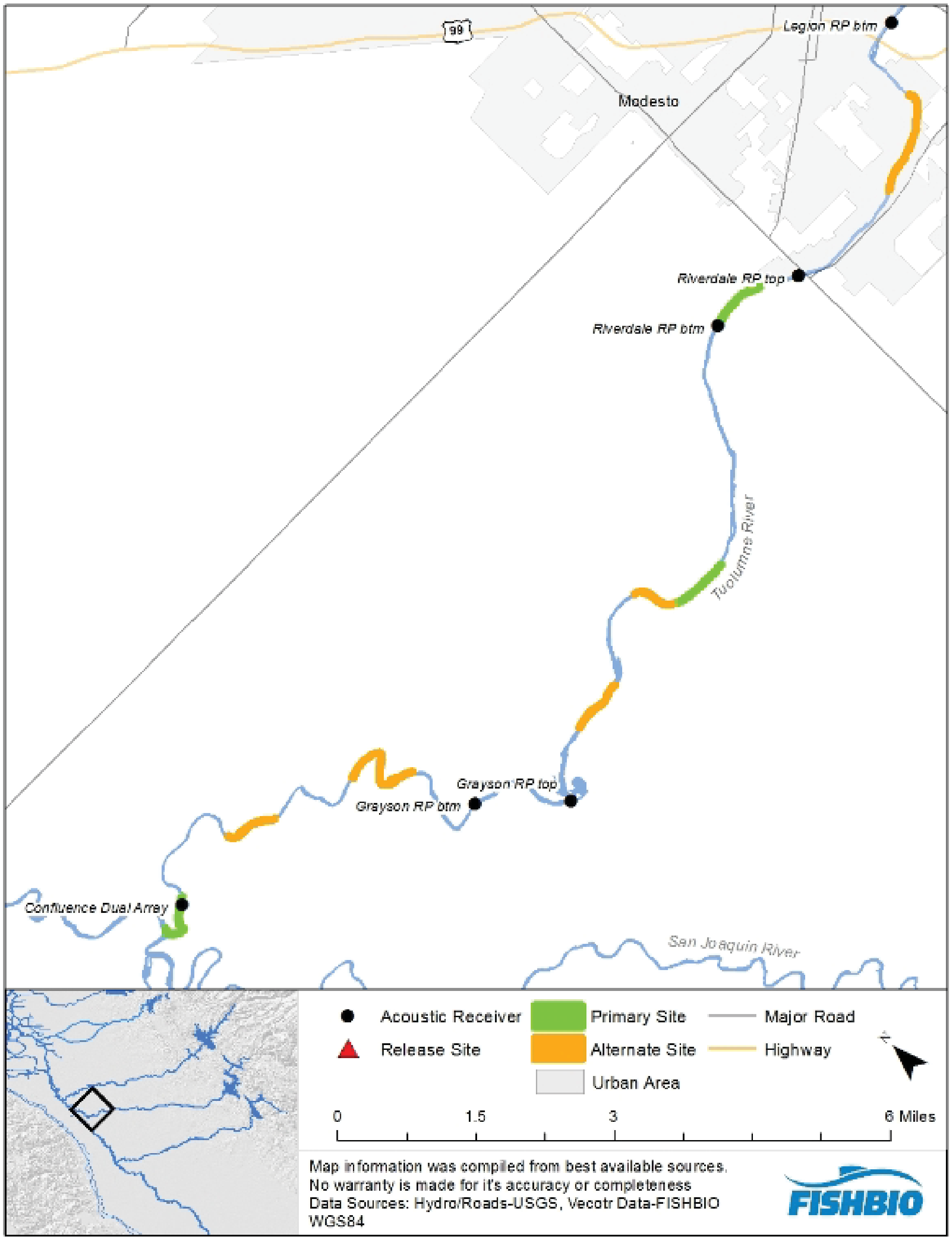

Figure 5. Sampling locations between Legion Park and the confluence with the San Joaquin River.

Step 3 – Analysis. To relate predator movements in response to river flow, water temperature, sampling activities, and season, and to inform predator abundance estimation, movement patterns of predators will be assessed and comparisons made between varying flow levels, water temperatures, sampling activities, and season. River flow data from the U.S. Geological Survey stream gage near La Grange (upstream of the study area) will be used to calculate minimum, maximum, and mean daily flow for the study period. Predator tracking results will also be compared with sampling and tracking data from prior Tuolumne River studies (McBain & Trush and Stillwater Sciences 1999, 2006; Stillwater Sciences and McBain & Trush 2006; TID/MID 2013).

Step 4 – Prepare Report. The Districts will prepare a study report that includes the following sections: (1) Study Goals, (2) Methods and Analysis, (3) Results, (4) Discussion, and (5) Conclusions. The report will contain relevant summary data, tables and graphs as well as GIS-based maps.

5.3.4 Identify Mortality Hot-spots

Step 1 – Study Design and Permitting. An intensive network of fixed receivers combined with releases of acoustically tagged salmon smolts at four locations during at least two events will allow for estimation of Chinook salmon mortality from RM 42 to RM 0, and on a reach, sub-reach scale within defined segments of the 42 mile study area under at least two flow conditions.

Step 2 – Data Collection. HTI Lm (0.65 g) acoustic tags will be surgically implanted in approximately 600 Chinook salmon smolts obtained from the Merced River Hatchery to be released during two release events occurring between April 15 and May 15. Tag weight to body weight ratios will not exceed 5%. Specific timing of releases will be identified during development of the 2014 spring pulse flow schedule and in coordination with relicensing participants.

Each of the two release events will consist of approximately 75 acoustic tagged salmon smolts released near the upper end of four study reaches: 1) Turlock Lake State Recreation Area, 2) Hickman Bridge, 3) Charles Rd., and 4) Legion Park. Tagging and release procedures will be similar to the 2012 study (TID/MID 2013), and salmon will be detected using the expanded network of acoustic receivers previously described for tracking predator movement (Figure 2). Dual receiver arrays will be placed at the first site downstream of each release location and at the confluence to calculate detection probabilities.

A tag life study will be conducted in the laboratory to determine the lifespan of the specific tag lots used for the study. A stratified (by tag lot) random sample of 30 tags (5% of tags to be released) will be selected for the tag life study.

Step 3 – Analysis. Relative losses of acoustically tagged Chinook salmon smolts will be compared between habitat types (i.e., SRPs and pools/run-pools) and between reaches. The intensive network of fixed receivers will allow for estimation of juvenile Chinook salmon mortality from RM 42 to RM 0, and on a reach, sub-reach scale within defined segments of the 42 mile study area. Juvenile Chinook salmon mortality rates will be estimating using complete capture histories for all individuals (Burnham et al 1987; Skalski et al 1998) and adjustment for tag failure will be made if warranted (Townsend et al 2006). Acoustic telemetry studies conducted in the San Joaquin River and Delta have identified that mortality estimates can be biased when predators containing consumed tags are detected and predator filters may be used if similar observations are made in the Tuolumne River (Buchanan et al 2013).

Step 4 – Prepare Report. The Districts will prepare a study task report that includes the following sections: (1) Study Goals, (2) Methods and Analysis, (3) Results, (4) Discussion, and (5) Conclusions. The report will contain relevant summary data, tables and graphs as well as GIS-based maps of sampled habitats.

6.0 Schedule

The Districts anticipate the schedule to complete the study proposal as follows:

- Study Design and Permitting .... July 2013 – January 2014
- Provide Interim Study Updates……………………………………….....January – July 2014
- Field Data Collection (Predator Abundance) .... January – July 2014
- Field Data Collection (Predation Rate) .... January – July 2014
- Field Data Collection (Estimate Juvenile Chinook Mortality)……………..April - May 2014
- Field Data Collection (Predator Movement Tracking) .... January – July 2014
- Data Entry Processing, and QA/QC .... February –September 2014
- Data Analysis……………………………………………...September 2014 – January 2015
- Report Preparation .... December 2014- March 2015
- Report Issuance .... March 2015

7.0 Consistency of Methodology with Generally Accepted Scientific Practices

Sampling methods proposed for the Predation study tasks are generally accepted and commonly used methods for scientific sampling as noted in sections above for electrofishing (e.g., Reynolds 1996; NMFS 2000) and for estimating abundance using mark-recapture (e.g., Seber 1982; Williams et al. 2002).

8.0 Deliverables

The Districts will prepare a report, which will document the methodology and results of the study tasks.

9.0 Level of Effort and Cost

The cost to complete this study is somewhat dependent upon the expectation that approximately 30 acoustic receivers and hydrophones will be available to the study on loan from the USFWS. A final cost estimate will be provided in the final draft study plan.

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Staples, Rose

From: Staples, Rose
Sent: Friday, August 09, 2013 2:30 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Draft Floodplain Hydraulic Assessment for the Lower Tuolumne River Study Plan for Review and Comments
Attachments: W-AR-21_Lower_Tuolumne_Floodplain_Inundation_Study_Plan_RP REVIEW DRAFT_130809.pdf

Please find attached a draft study plan for the ***Floodplain Hydraulic Assessment for the Lower Tuolumne River***. The Districts were directed by FERC in its May 21, 2013 Determination on Study Modifications and New Studies to prepare a study plan for conducting a hydraulic analysis of floodplain inundation and frequency from RM 52.2 to 21.5. This draft study plan describes the scope of work, methods, and schedule for conducting the study. The draft study plan is being issued for a 30-day review and comment period. Comments are due on or before Monday, September 9. We look forward to your comments. Please send them to my attention at rose.staples@hdrinc.com. Thank you.

ROSE STAPLES
CAP-OM

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TURLOCK IRRIGATION DISTRICT & MODESTO IRRIGATION DISTRICT
DON PEDRO PROJECT
FERC NO. 2299

Review Draft
Study Plan W&AR-21
Lower Tuolumne Floodplain Hydraulic Assessment
August 2013

1.0 Project Nexus

The continued operation and maintenance (O&M) of the Don Pedro Project (Project) may contribute to cumulative effects on habitat availability and production of in-river life stages of Central Valley fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and *O. mykiss* in the lower Tuolumne River. FERC's May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Project (Determination) required the Turlock and Modesto irrigation districts (collectively, the Districts) to undertake a study of floodplain inundation flows on the lower Tuolumne River from River Mile (RM) 52.2 to RM 21.5. This study describes the methods and scope of study proposed by the Districts to complete the floodplain hydraulic assessment. The assessment will result in the estimation of the areal coverage, depths and velocities of water upon the floodplain of the lower Tuolumne River for a range of flows from 1,000 to 9,000 cfs. The information developed by this study will be used to prepare an addendum to the Districts Pulse Flow Study Report (Stillwater Sciences 2012) filed with FERC as part of the Instream Flow (IFIM) Studies required by Ordering Paragraph (D) of FERC's May 12, 2010 Order.

The Pulse Flow Study component of the FERC-approved October, 2009 IFIM Study Plan examined potential responses of salmonid and predator species to spatial variations in inundation area, velocities, and depths in relation to the pulse flows specified in the Order within both in-channel areas as well as temporarily inundated portions of the Tuolumne River floodplain. W&AR-21 will expand the range of flows investigated as well as the area covered in the 2012 Pulse Flow Study report.

2.0 Resource Agency Management Goals

The Districts believe that four agencies have resource management goals related to lower Tuolumne River salmonids and/or their habitat: (1) U.S. Department of Interior (USDOI), Fish and Wildlife Service (USFWS); (2) U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service (NMFS); (3) California Department of Fish and Wildlife (CDFW); and (4) California State Water Resources Control Board, Division of Water Rights (SWRCB).

A goal of the USFWS (2001) Anadromous Fish Restoration Program, as stated in Section 3406(b)(1) of the Central Valley Project Improvement Act, is to double the long-term production of anadromous fish in California's Central Valley rivers and streams. Objectives in meeting this long-term goal include: (1) improve habitat for all life stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, and improved physical habitat; (2) improve survival rates by reducing or eliminating entrainment of juveniles at diversions; (3) improve the opportunity for adult fish to reach spawning habitats in a timely manner; (4) collect fish population, health, and habitat data to facilitate evaluation of restoration actions; (5) integrate habitat restoration efforts with harvest and hatchery management; and (6) involve partners in the implementation and evaluation of restoration actions.

NMFS has developed Resource Management Goals and Objectives for species listed under the Magnuson-Stevens Fishery Conservation and Management Act (16 U.S.C. §1801 et seq.) and the Endangered Species Act (ESA) (16 U.S.C. §1531 et seq.), as well as anadromous species that are not currently listed but may require listing in the future. NMFS' (2009) Public *Draft* Recovery Plan for Sacramento River Winter-run Chinook salmon, Central Valley Spring-run Chinook salmon, and Central Valley steelhead (Draft Recovery Plan) outlines the framework for the recovery of ESA-listed species and populations in California's Central Valley. For the Tuolumne River, the relevant goals are to enhance the Essential Fish Habitat downstream of the Don Pedro Project and achieve a viable population of Central Valley fall/late fall-run Chinook salmon.

CDFW's mission is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. CDFW's resource management goals, as summarized in restoration planning documents such as "Restoring Central Valley Streams: A Plan for Action" (Reynolds et al. 1993), are to restore and protect California's aquatic ecosystems that support fish and wildlife, and to protect threatened and endangered species under California Fish and Game Code (Sections 6920–6924).

SWRCB has responsibility under the federal Clean Water Act (33 U.S.C. §11251–1357) to preserve and maintain the chemical, physical and biological integrity of the State's waters and to protect water quality and the beneficial uses of stream reaches consistent with Section 401 of the federal Clean Water Act, the Regional Water Quality Control Board Basin Plans, State Water Board regulations, the California Environmental Quality Act, and any other applicable state law.

3.0 Study Goals

In its May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Project, FERC staff recommended that the Districts develop a study plan to conduct and incorporate into the existing license IFIM study (Stillwater Sciences 2012, 2013) a hydraulic analysis of the amount of floodplain inundated between RM 52.2 and 21.5 of the Tuolumne River at flows between approximately 1,000 cfs and 9,000 cfs. This information will expand the flow range evaluated in the 2012 Pulse Flow Study and update analyses of the USFWS (2008) assessment of floodplain inundation. USFWS (2008) noted that its evaluation of off-channel habitat was limited to a small number of flows corresponding to digitized aerial imagery previously developed by the Districts (TID/MID 1997, Report 96-14). USFWS recommended further analysis was necessary to assess off-channel habitat availability. FERC staff recommended that the study also evaluate the frequency and period of inundation over a range of Project operations representing baseline conditions and alternative operating scenarios.

4.0 Existing Information and Need for Additional Information

FERC's May 21, 2013 Determination noted that the Districts' in-channel IFIM report submitted on April 26, 2013 did not consider floodplain inundation. Although floodplain inundation was previously evaluated in the 2012 Pulse Flow Study report, FERC directed the Districts to obtain additional data and hydraulic analyses of floodplain inundation frequency and duration to assist in the identification of potential Project effects to off-channel salmonid rearing areas. This study will update 2-dimensional (2D) modeling of overbank habitats conducted as part of the 2012 Pulse Flow Study to provide more accurate representation of hydraulic conditions in floodplain areas along the lower Tuolumne River corridor. In addition, this study will examine the seasonal timing and duration of suitable overbank rearing habitat, It is envisioned that an addendum to the Districts' previously submitted IFIM study reports (Stillwater Sciences 2012, 2013) will be completed using the results of this W&AR-21 investigation.

Geospatial sources used for model development will come from the most recent data sources including (1) LiDAR data flown in March, 2012, at an approximate streamflow of 300 cfs, (2) riparian vegetation coverage shapefiles developed in conjunction with the *Lower Tuolumne River Riparian Information and Synthesis Study* (W&AR-19), (3) channel and floodplain cross sections developed as part of the *Lower Tuolumne Temperature Model* (W&AR-16:), and (4) the final GIS mapping layers used in the USFWS (2008) report or, if the USFWS files are not available, the original TID/MID (1997) GIS files used in the USFWS (2008) study as supplemented by any newer information collected by the Districts since that time.

5.0 Study Methods

5.1 Study Area

The study area includes the specific reaches in the lower Tuolumne River between RM 52.2 and River Mile 21.5, consistent with the USFWS (2008) study area and in accordance with FERC's May 21, 2013 Determination.

5.2 Study Methods

Hydraulic modeling will be developed and executed using TUFLOW hydraulic modeling software (BMT Group Ltd 2013). TUFLOW uses both one-dimensional (1D) and two-dimensional (2D) modeling to simulate the interaction between flow within the main channel and within the inundated floodplain. This is an essential capability to represent in a reasonable manner the dynamics of overbank flows and their interaction with flows in the main channel.

The study will consist of six steps:

Step 1 – Model Input Development

The TUFLOW 1D model is used to model flows in the main river channel. Geo-referenced channel geometry will be developed from previously developed cross-sections used in the Lower Tuolumne Temperature Model (WA&R-16) study. Additional in-channel cross sections may be needed for this study to adequately represent the river hydraulics if interpolated cross-sections are determined to be insufficient to achieve model convergence or a solution to water surface elevations.

Flow occurring outside the main channel in the overbank inundation area will be modeled using TUFLOW's 2D calculations capability. The TUFLOW 2D model performs calculations based on a grid system. A digital elevation model (DEM) will be created from the 2012 LiDAR. Alterations to the surface may be necessary to properly represent or model the river. Within GIS, three-dimensional break lines will be created to delineate the left and right bank of the main channel, as well as any levees or embankments, including bridge crossings or lateral embankments of off-channel ponds.

Both the TUFLOW 1D and 2D models require Manning's roughness coefficients. For overbank areas, an existing aquatic plant survey GIS file with full coverage of the reach shall be used. Manning's roughness coefficients will be assigned from established ranges by vegetation density and type.

As part of this step, the Districts will conduct a consultation meeting with relicensing participants to describe and review the suite of data to be used in developing the TUFLOW model and describing the physical configuration of the channel and floodplain.

Step 2 – Hydraulic Model Development

The TUFLOW 1D hydraulic model will be constructed, run, and undergo quality assurance procedures. Once the 1D model is operational, the TUFLOW 2D model will be developed and quality-checked. Then the combined 1D/2D model will be compiled, run, and undergo quality assurance procedures. The model will be developed under the following basis and considerations:

- Bridges will not be modeled as study flows shall not reach bridge chord elevations and any increase in inundation due to the bridge piers is considered negligible.
- Input hydrograph for each run is set as a constant flow value for the entire reach.
- The upstream boundary condition shall be modeled as normal flow entering at RM 52.2.
- The downstream boundary condition will be modeled as normal flow if it is determined that there is not a backwater affect from the San Joaquin River at RM 21.5 under the flows considered. If a backwater affect is determined, the model will extend to where normal flow is considered to occur. The hydraulic model of the San Joaquin River currently under development by the California Department of Water Resources (DWR) for the Central Valley Floodplain Evaluation and Delineation (CVFED) program will be checked to establish the extent of backwater effects for flows likely to occur in combination with the flows being considered under this study. Backwater effects are not anticipated.

Step 3 – Calibrate/Validate 2D Model

After confirmation of flow conditions occurring at the time of air photo collection used in the inundation mapping (TID/MID 1997) for the USFWS (2008) study, the TUFLOW model calibration/validation shall be undertaken by comparing the water surface inundation surfaces for select sub-reaches at nominal flows of 300 cfs, 1,100 cfs, 3,100 cfs, 5,300 cfs, and 8,400 cfs. Calibration will be completed by adjusting manning's roughness coefficients, grid cell size, and geometry within the TUFLOW 1D and 2D models.

Calibration/validation sub-reaches shall be located where minimal changes in the channel geometry are considered to have occurred between the original aerial photograph dates in the 1990s (TID/MID 1997, Report 96-14), and the 2012 air photos and accompanying LiDAR surface.

The grid size used within the TUFLOW 2D model will be selected to be small enough to adequately calibrate the model using the steps above while not being so small that model run-time becomes excessive.

As part of Step 3, once the model is calibrated and validated, Districts will meet with relicensing participants to share the resulting model, describe the process used, and seek review and comment on the calibrated model.

Step 4 – Inundation Mapping

Overbank inundation will be modeled to estimate the inundation extent at 500 cfs intervals between 1,000 cfs and 9,000 cfs, resulting in a total of approximately 20 model runs when including the calibration runs at 1,100 cfs, 3,100 cfs, 5,300 cfs, and 8,400 cfs. TUFLOW directly outputs GIS shapefiles of the inundation area for evaluation and calculation of area.

Step 5 – Inundation Frequency and Period Under Baseline Conditions and Alternative Operating Scenarios

Inundation frequency, period and duration shall be evaluated at range of flows. Area-duration-frequency (ADF) curves and inundation area versus annual frequency plots will be created for the baseline (WY 1971-2009) conditions. Future analyses will compare the frequency analysis results of the baseline conditions to those of alternative operations scenarios. It is expected that these alternative scenarios would be consistent with scenarios that are also evaluated in the *Tuolumne River Operations Model* (W&AR-2). The schedule for assessing inundation frequency and duration under alternative scenarios is not included in the schedule below, or in the cost estimate, as these proposed operations would likely involve additional consultation with relicensing participants.

Step 6 – Prepare Report

A report will be prepared that includes the following: (1) Study goals; (2) Study methods; (3) Results; (4) Conclusions; and (5) Description of variances from the study plan, if any. A draft report will be provided to relicensing participants for review and comment. The final report, model and resulting GIS files will be provided to relicensing participants upon study completion.

The information developed through the conduct of this study will be used to prepare an addendum to the Districts' March 2013 Pulse Flow Study component of the existing license IFIM studies. The results of this study may also be used to update the juvenile salmonid population models being developed under W&AR-6 and W&AR-10.

6.0 Schedule

The Districts anticipate the schedule to complete the study as follows:

Step 1 - Model Input Development and RP Consultation ....September-December 2013
Step 2 - Model Hydraulic Development .... December 2013-January 2014
Step 3 – Model Calibration/Validation and RP Consultation January-February2014
Step 4 - Map Inundation Extents .... March 2014
Step 5 – Evaluate Inundation Frequency, Period, Duration April-May2014
Step 6 – Report Preparation ....May-June 2014

A draft report will be issued to relicensing participants for review and comment by the end of June 2014. The final report will be filed with FERC by the end of September 2014. Draft addendum to the Pulse Flow Study would be completed by December 2014.

7.0 Consistency of Methodology with Generally Accepted Scientific Practices

The TUFLOW model is widely used for the floodplain modeling, and is accepted by the California Department of Water Resources and other governmental agencies involved with floodplain investigations.

8.0 Deliverables

Products from this study will be the above mentioned report, model and GIS files.

9.0 Level of Effort and Cost

The estimated cost to complete this study is $110,000, not including the cost of modeling alternative scenarios.

10.0 References

BMT Group Ltd. 2013. TUFLOW software. Available online at: <http://www.tuflow.com>.

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Central Valley Spring-Run Chinook Salmon and the Distinct Population Segment of Central Valley Steelhead. Available online at: <http://swr.nmfs.noaa.gov/recovery/centralvalleyplan.htm>.

Reynolds, F. L., Mills, T. J., Benthin, R., and A. Low. 1993. Restoring Central Valley streams: a plan for action. Inland Fisheries Div., Calif. Dept. of Fish and Game. Sacramento CA. 184 p.

Stillwater Sciences. 2012. Lower Tuolumne River Instream Flow Studies: Pulse Flow Study Report. Final. Prepared by Stillwater Sciences, Berkeley, California for Turlock Irrigation District and Modesto Irrigation District, California. June.

______. 2013. Lower Tuolumne River Instream Flow Study. Prepared by Stillwater Sciences, Davis, California for Turlock and Irrigation District and Modesto Irrigation District, California. February. April.

Turlock Irrigation District and Modesto Irrigation District (TID/MID). 1997. 1996 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. 6 Volumes. March.

_____. 2005. 2005 Ten Year Summary Report pursuant to Paragraph (G) of the 1996 FERC Order issued July 31, 1996. Report to Federal Energy Regulatory Commission for FERC Project No. 2299-024.

U.S. Department of Interior, Fish and Wildlife Service (USFWS). 2001. Final restoration plan for the Anadromous Fish Restoration Program. A Plan to increase Natural Production of Anadromous Fish in the Central Valley of California. Report of the Anadromous Fish Restoration Program Core Group, Central Valley Project Improvement Act to the Secretary of the Interior. Stockton, CA.

______. 2008. Flow-overbank inundation relationship for potential fall-run Chinook salmon and steelhead/rainbow trout juvenile outmigration habitat in the Tuolumne River. U.S. Fish and Wildlife Service, Sacramento, CA.

Staples, Rose

From: Staples, Rose
Sent: Monday, August 12, 2013 6:57 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Volunteers Needed-Don Pedro Lower Tuolumne River Lowest Boatable Flow Study

Reminder Notice

Please reply to Nancy Craig (928- 273-5772 or nancy.craig@hdrinc.com) if you are interested in participating in this study.

Upcoming Boater Survey Beginning August 17, 2013
Volunteers Needed!
Lower Tuolumne River Lowest Boatable Flow Study

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) continue to seek volunteers for the Lowest Boatable Flow Study on the Lower Tuolumne River. The primary goal of the study is to determine if the Don Pedro Hydroelectric Project's minimum flows result in boatable flows for non-motorized, recreational river boating in portions of the lower Tuolumne River where put-ins and take-outs are available. We are seeking participation from boaters in two types of non-motorized watercraft – (1) hardshell kayaks, inflatable kayaks, and canoes and; (2) drift boat/rafts.

The study is scheduled to begin on Saturday, August 17, 2013, and continue on subsequent Saturday's as needed to fulfill the study's primary goal*.

From: Staples, Rose
Sent: Monday, September 16, 2013 6:21 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; Villalobos, Amber; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro 2014 Predation SP and LT Floodplain Hydraulic Analysis SP Filed with FERC Today

We have filed with FERC today on behalf of the Districts the 2014 Predation and the Lower Tuolumne Floodplain Hydraulic Analysis Study Plans. Copies of each of these study plans are available on the FERC e-library (www.ferc.gov) and also on the Don Pedro Relicensing Website (www.donpedro-relicensing.com), both under the ANNOUNCEMENT tab and attached to the calendar date of September 16.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

From: Staples, Rose
Sent: Wednesday, October 30, 2013 5:35 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; Cooke, Michael; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; Reynolds, Garner; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; Villalobos, Amber; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Cc: Scott Wilcox (Scott@stillwatersci.com); Russell Liebig (russ@stillwatersci.com)
Subject: For Your Review-Available HSC for Don Pedro Assessment Pacific lamprey-Sacramento Splittail-Non Native Predatory Fish Habitat
Attachments: Tuolumne_Splittail-Lamprey-Bass_HSC_Transmittal_TechMemo_30OCT2013.pdf

The attached Technical Memorandum from Stillwater Sciences (summarizing the HSC available for Pacific lamprey, Sacramento splittail, and non-native predatory fish habitat assessment) is being provided to you today for a 30-day review. Please provide any comments by close of business on Friday, November 29, 2013. Thank you.

October 30, 2013

RE: Lower Tuolumne River Instream Flow Study — Pacific lamprey, Sacramento splittail, and non-native predatory fish habitat assessment: 1-D PHABSIM habitat suitability criteria review. Don Pedro Hydroelectric Project, FERC Project No. 2299

Dear Don Pedro Hydroelectric Project Relicensing Participants:

Per the Commission's 16 July 2009 Order (128 FERC ¶ 61,035), Turlock Irrigation District and Modesto Irrigation District ("Districts") conducted an instream flow study on the lower Tuolumne River. Initial chapters of the draft report for this study were included in the Initial Study Report (ISR) filed on 17 January 2013 for the relicensing of the Don Pedro Project, and a summary presentation on the study was provided at the ISR meeting on 30 January 2013. The results of this study were filed with the Commission on 26 April 2013.

Subsequent to the original Study Plan approval, the Commission, in their 22 December 2011 Study Plan Determination for the Don Pedro Hydroelectric Project, expanded the scope of the Lower Tuolumne Instream Flow Study to include Pacific lamprey and Sacramento splittail, and in their May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project, further expanded the scope to assess habitat for non-native predatory fish, including smallmouth bass, largemouth bass, and striped bass, using existing habitat suitability criteria (HSC) data, where available.

The attached Technical Memorandum summarizes the HSC available for the above species for inclusion into the Lower Tuolumne River Instream Flow Study model results. The proposed HSC are being distributed for 30-day Relicensing Participant review. Please provide any comments by COB on Friday, 29 November 2013.

Thank you for your participation and interest in this study,

MODESTO IRRIGATION DISTRICT	TURLOCK IRRIGATION DISTRICT
Greg Dias	Steve Boyd
Project Manager	Assistant General Manager

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DRAFT TECHNICAL MEMORANDUM

DATE:	October 30, 2013
TO:	Steve Boyd, Turlock Irrigation District and Greg Dias, Modesto Irrigation District
FROM:	Scott Wilcox and Wayne Swaney, Stillwater Sciences
SUBJECT:	Lower Tuolumne River Instream Flow Study — Pacific lamprey, Sacramento splittail, and non-native predatory fish habitat assessment: 1-D PHABSIM habitat suitability criteria review

1 BACKGROUND

The *Lower Tuolumne River Instream Flow Studies – Final Study Plan* (Stillwater Sciences 2009a) was filed with the Federal Energy Regulatory Commission (Commission) on October 14, 2009. The Study Plan was approved, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 order. In order to examine the broad flow ranges identified in the Commission's July 16, 2009 Order, the Study Plan separated the study into two separate investigations: (1) A conventional 1-D PHABSIM model ("Instream flow Study"), which examines in-channel habitat conditions at flows from approximately 100–1,000 cfs, and (2) a 2-D hydraulic model of overbank areas, as well as adjacent in-channel locations, for flows of 1,000–5,000 cfs, developed as part of the Pulse Flow Study. The *Lower Tuolumne River Instream Flow Study–Final Report* was filed with the Commission on April 26, 2013 (Stillwater Sciences 2013). The *Pulse Flow Study Report* was submitted to the Commission on June 18, 2012 (Stillwater Sciences 2012).

Subsequent to the original Study Plan approval, the Commission, in their December 22, 2011 Study Plan Determination for the Don Pedro Hydroelectric Project relicensing studies, required the scope of the Lower Tuolumne Instream Flow Study be expanded to include Pacific lamprey (*Entosphenus tridentatus*) and Sacramento splittail (*Pogonichthys macrolepidotus*), if existing habitat suitability criteria (HSC) were available. Within their April 8, 2013 comments on the *Draft Instream Flow Study Report*, the USFWS provided references to existing criteria, developed for the Lower Merced River. More recently, in the Commission's May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project, the Commission required the scope of the Lower Tuolumne Instream Flow Study be expanded to assess habitat for non-native predatory fish, including smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and striped bass (*Moronide saxatilis*) using existing habitat suitability criteria data, where available. The Districts have compiled existing suitability criteria for the above species and, in a letter filed with the Commission on October 4, 2013, outlined a review and filing schedule with Relicensing Participants and the Commission.

This Technical Memorandum summarizes the suitability criteria available for Pacific lamprey, Sacramento splittail, smallmouth bass, largemouth bass, and striped bass for inclusion into the Lower Tuolumne River Instream Flow Study model results.

2 METHODS

2.1 Habitat Suitability Criteria Availability

Use of the PHABSIM model requires application of HSC to the results of the hydraulic model in order to generate an index of habitat suitability (weighted usable area, or WUA) versus flow. Pursuant to the Commission-approved Study Plan, HSC screening criteria included the following, although no single criterion would qualify or disqualify a curve from further consideration.

- Minimum of 150 observations
- Clear identification of fish size classes
- Depth and velocity HSC
- Category II or III data (Bovee 1986)
- Comparable stream size and morphology (e.g., hydrology, stream width and depth, gradient, geomorphology, etc.)
- Source data from the lower Tuolumne River (or other Central Valley streams)
- Habitat availability data collected
- Data collected at high enough flow that depths and velocities are not biased by flow availability
- Availability of presence/absence data

The target species and life stages include:

- Pacific lamprey*:* spawning and ammocoete
- Sacramento splittail: juvenile and spawning
- Smallmouth bass: adult
- Largemouth bass: adult
- Striped bass: adult

Unfortunately, the available HSC for Pacific lamprey, Sacramento splittail, smallmouth bass, largemouth bass, and striped bass are very limited. Available HSC for Pacific lamprey and Sacramento splittail, referenced by the USFWS, were developed for the Merced Hydroelectric Project relicensing (Merced ID 2011 and 2013) (Table 1). The Merced Category I (binary consensus curves) data were based on species habitat descriptions from literature, and not from site-specific surveys. Pacific lamprey HSC were based on habitat preference descriptions of Pacific lamprey and Kern brook lamprey (*Lampetra hubbsi*) from Close et al. (2002), Gard (2009), and Gunckel et al. (2009) (Figures 1–6). The splittail HSC were derived from habitat descriptions from Feyrer et al. (2005), Moyle et al. (2004, 2007), Sommer et al. (2002, 2008), and Young and Cech (1996) (Figures 7–11).

Available HSC for smallmouth bass (Edwards et al. 1983), largemouth bass (Stuber et al. 1982), and striped bass (Crance 1984) include limited Category I (binary consensus curves) data based on species habitat descriptions from literature and professional judgment (Table 1). These HSC were recently used in the overbank habitat assessment, reported in the *Lower Tuolumne River Instream Flow Studies: Pulse Flow Study Report* (Stillwater Sciences 2012), and the HSC for smallmouth bass (Edwards et al. 1983) and largemouth bass (Stuber et al. 1982) were previously used in the 2-D modeling for the special run-pool (SRP) 9 channel reconstruction project on the Lower Tuolumne River at river mile 25.9–25.7 (McBain & Trush and Stillwater Sciences 2006). However, because depth HSC for largemouth bass is not described in Stuber et al. (1982), the prior studies on the Lower Tuolumne River substituted smallmouth bass depth HSC from Edwards et al. (1983) for largemouth bass (Figures12–15).

Similarly, striped bass depth HSC is described in Crance et al. (1984); however, no velocity HSC were provided. Striped bass are reported to tolerate a wide range of velocities, from 0.0 to 16.4 feet per second (fps), with an optimum range between 0.0 and 3.28 fps (Hassler 1988). For this study, velocity HSC for striped bass were developed using these reported ranges by assigning an index value of 1.0 to velocities within the optimal range (0.0–3.28 fps) and an index value of 0.0 to all velocities beyond the tolerance range (>16.4 fps); intermediate values between the upper optimal range and the upper tolerance range were defined by a straight line between the two points (Figures 16–17).

Table 1. Habitat suitability criteria summary for target species and life stages.

Species	Life stage	Depth	Velocity	Substrate	Cover	Source
Pacific lamprey	Ammocoete	Yes	Yes	Yes	No	Merced ID 2011
Pacific lamprey	Spawning	Yes	Yes	Yes	No	Merced ID 2011
Sacramento splittail	Juvenile	Yes	Yes	No	No	Merced ID 2013
Sacramento splittail	Spawning	Yes	Yes	Yes	Yes	Merced ID 2013
Smallmouth bass	Adult	Yes	Yes	Yes	No	Edwards et al. 1983
Largemouth bass	Adult	No[1]	Yes	No	No	Stuber et al. 1982 (velocity) Edwards et al. 1983 (depth from smallmouth bass)
Striped bass	Adult	Yes	Yes	No	No	Crance 1984 (depth) Hassler 1988 (velocity)

[1] Largemouth bass HSC for depth was not available in the literature; however, smallmouth bass HSC for depth were substituted for largemouth bass in prior lower Tuolumne River studies (McBain & Trush and Stillwater Sciences 2006, Stillwater Sciences 2012).

2.2 Species Occurrences in the Tuolumne River

As part of HSC development for the lower Tuolumne River instream flow study, site-specific HSC validation surveys were conducted in the lower Tuolumne River from just below La Grange Dam (RM 52) downstream to Waterford (RM 31). Neither Pacific lamprey nor Sacramento splittail were observed during those surveys, which were conducted across a range of seasons (winter, spring, and summer) and a range of flow conditions (100 cfs, 350 cfs, and 2,000 cfs). However, Pacific lamprey have been observed during snorkel surveys conducted between La Grange Dam (RM 51.8) and Waterford (RM 31) (Stillwater Sciences 2009b, 2010), and Sacramento splittail have been reported to spawn in the lower 6.8 miles of the Tuolumne River during wet years (Moyle et al. 1995). Smallmouth bass, largemouth bass, and striped bass are commonly observed in the lower Tuolumne River (Stillwater Sciences 2009b, 2011; FISHBIO 2012a, 2012b); however, bass were not encountered at the HSC study sites.

2.3 Habitat Suitability Criteria Selection

The lamprey and splittail depth, velocity, and substrate HSC developed for Merced ID were usable for the Lower Tuolumne PHABSIM model. However, the cover criteria used by Merced ID for splittail spawning was based on a coding system that was incompatible with the cover data collected for the lower Tuolumne River. Therefore, cover criteria were not applied for this species/life stage. All bass HSC were usable for the Lower Tuolumne PHABSIM model.

Selected HSC for Pacific lamprey, Sacramento splittail, smallmouth bass, largemouth bass, and striped bass are shown below in Figures 1–17 and listed in Tables 2–8.

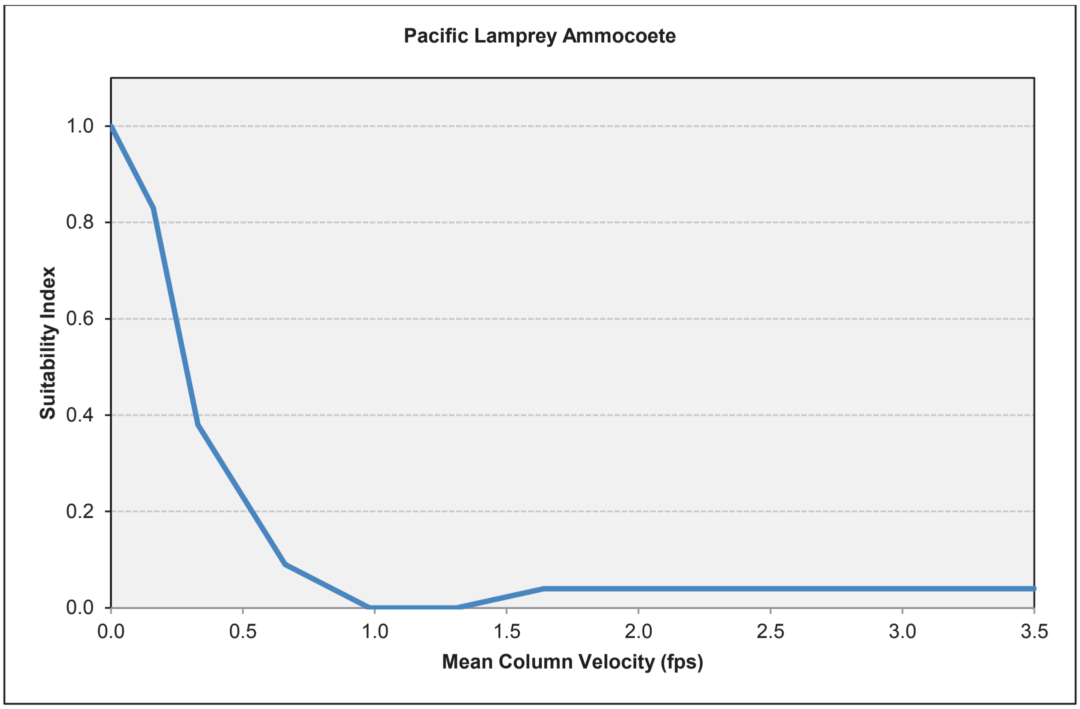

Figure 1. Pacific lamprey ammocoete velocity suitability criteria for the lower Tuolumne River.

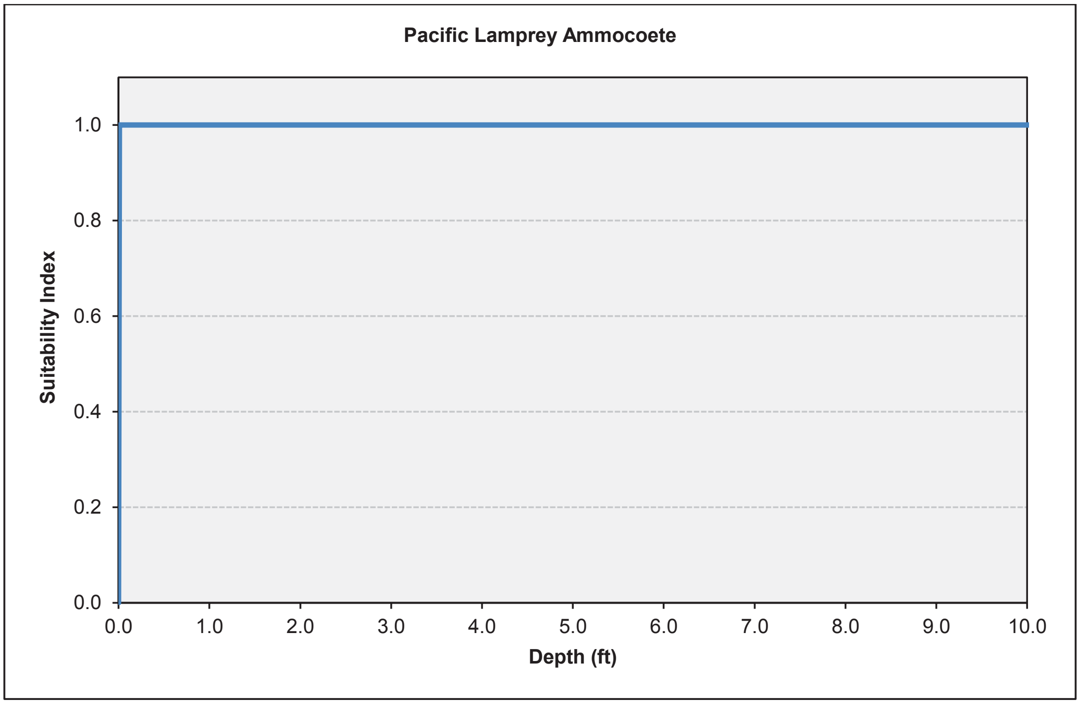

Figure 2. Pacific lamprey ammocoete depth suitability criteria for the lower Tuolumne River.

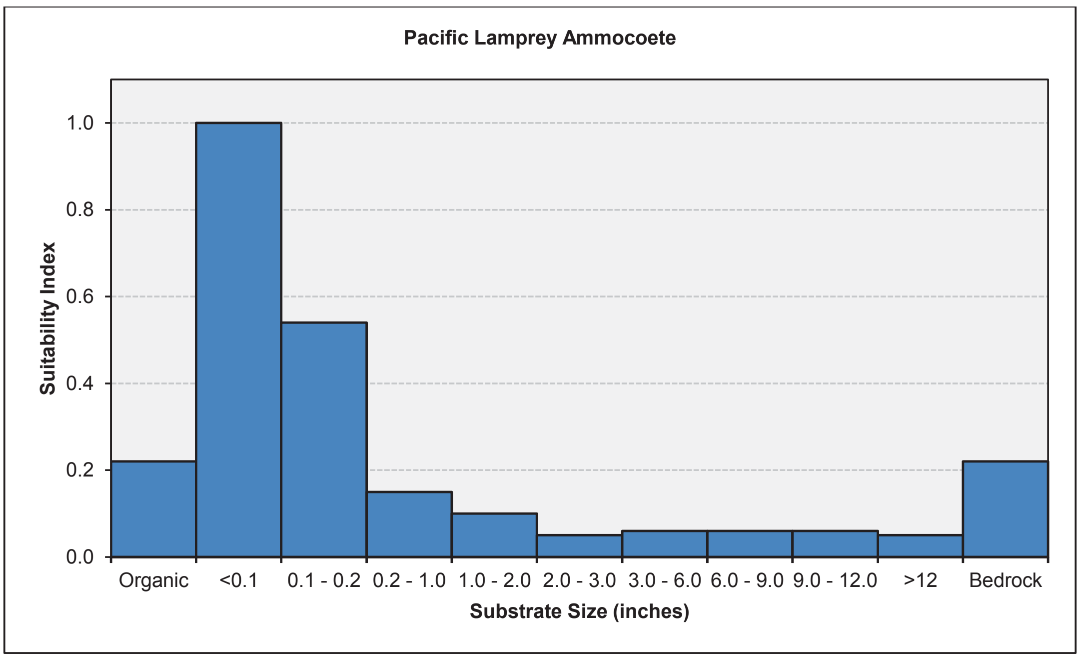

Figure 3. Pacific lamprey ammocoete dominant substrate suitability criteria for the lower Tuolumne River.

Table 2. Pacific lamprey ammocoete suitability criteria.

Velocity		Depth		Substrate		
(fps)	**Index[1]**	**(ft)**	**Index[1]**	**Type**	**Size (inches)**	**Index[1]**
0.00	1.00	0.00	0.00	Organic	N/A	0.22
0.16	0.83	0.01	1.00	Silt	0-0.1	1.00
0.33	0.38	--	--	Sand	0.1-0.2	0.54
0.66	0.09	--	--	Small gravel	0.2-1	0.15
0.98	0.00	--	--	Gravel	1-2	0.10
1.31	0.00	--	--	Large gravel	2-3	0.05
1.64	0.04	--	--	Small cobble	3-6	0.06
--	--	--	--	cobble	6-9	0.06
--	--	--	--	Large cobble	9-12	0.06
--	--	--	--	Boulder	>12	0.05
--	--	--	--	Bedrock	N/A	0.22

[1] Merced ID 2011

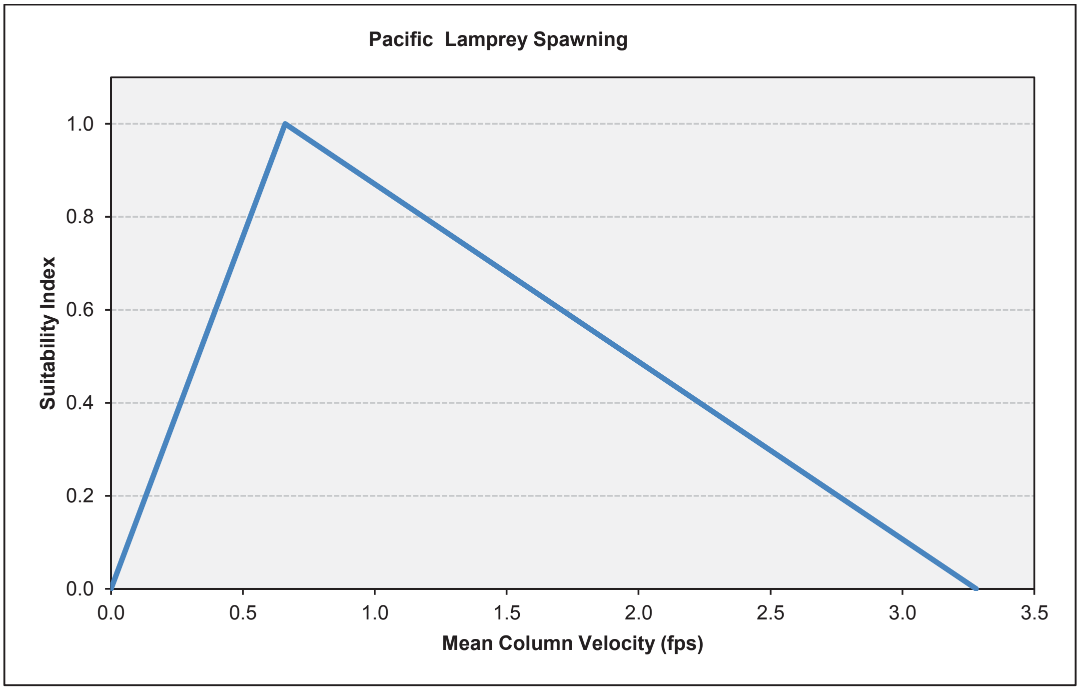

Figure 4. Pacific lamprey spawning velocity suitability criteria for the lower Tuolumne River.

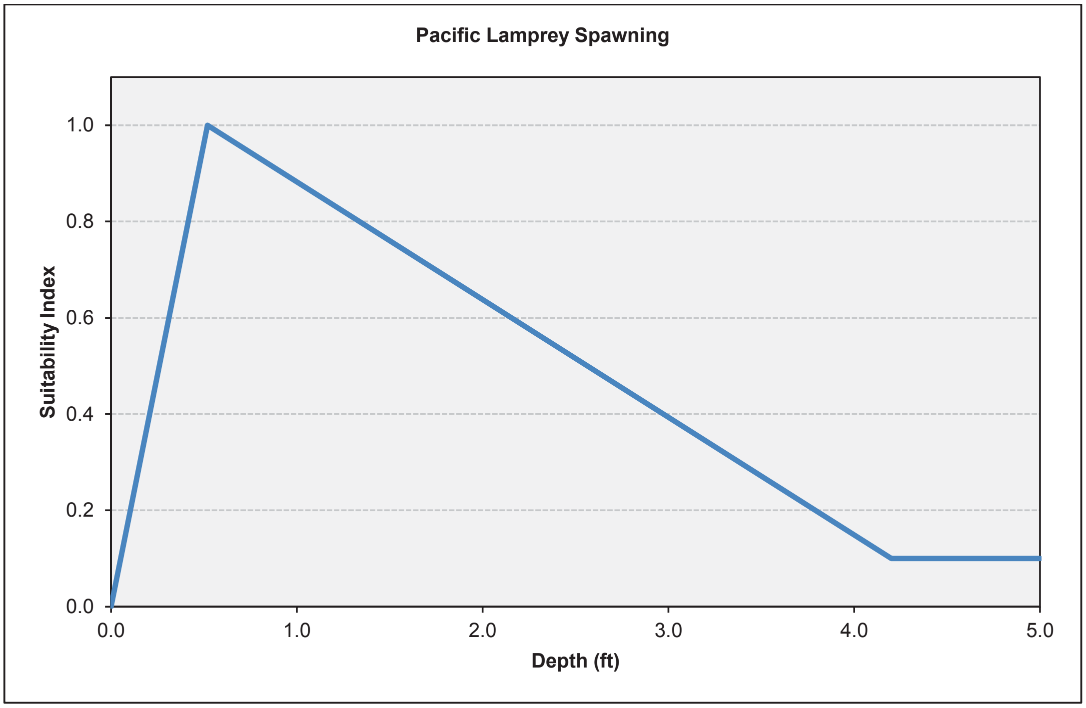

Figure 5. Pacific lamprey spawning depth suitability criteria for the lower Tuolumne River.

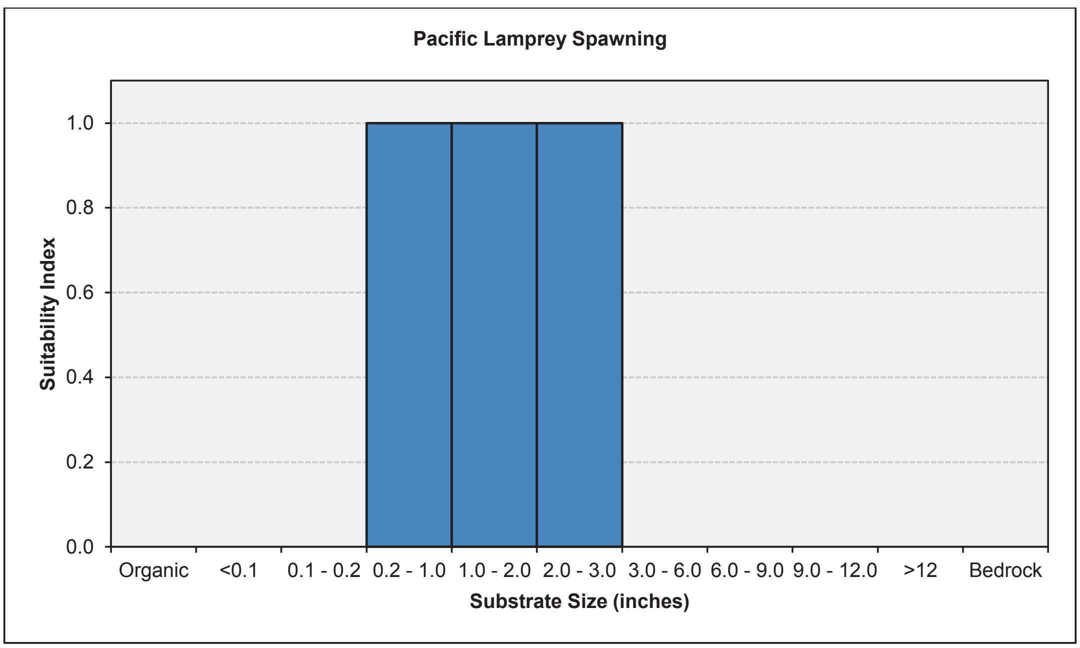

Figure 6. Pacific lamprey spawning dominant substrate suitability criteria for the lower Tuolumne River.

Table 3. Pacific lamprey spawning suitability criteria.

Velocity		Depth		Substrate		
(fps)	**Index**[1]	**(ft)**	**Index**[1]	**Type**	**Size (inches)**	**Index**[1]
0.00	0.00	0.00	0.00	Organic	N/A	0.00
0.66	1.00	0.52	1.00	Silt	<0.1	0.00
3.28	0.00	4.20	0.10	Sand	0.1–0.2	0.00
--	--	--	--	Small gravel	0.2–1	1.00
--	--	--	--	Gravel	1–2	1.00
--	--	--	--	Large gravel	2–3	1.00
--	--	--	--	Small cobble	3–6	0.00
--	--	--	--	cobble	6–9	0.00
--	--	--	--	Large cobble	9–12	0.00
--	--	--	--	Boulder	>12	0.00
--	--	--	--	Bedrock	N/A	0.00

[1] Merced ID 2011

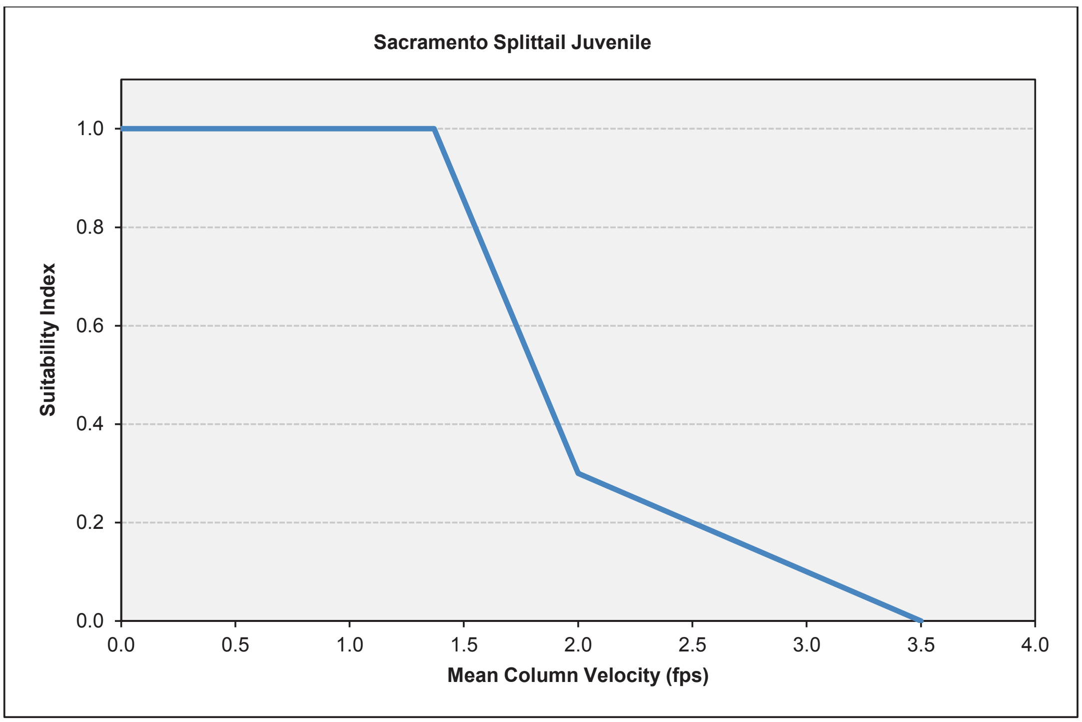

Figure 7. Sacramento splittail juvenile velocity suitability criteria for the lower Tuolumne River.

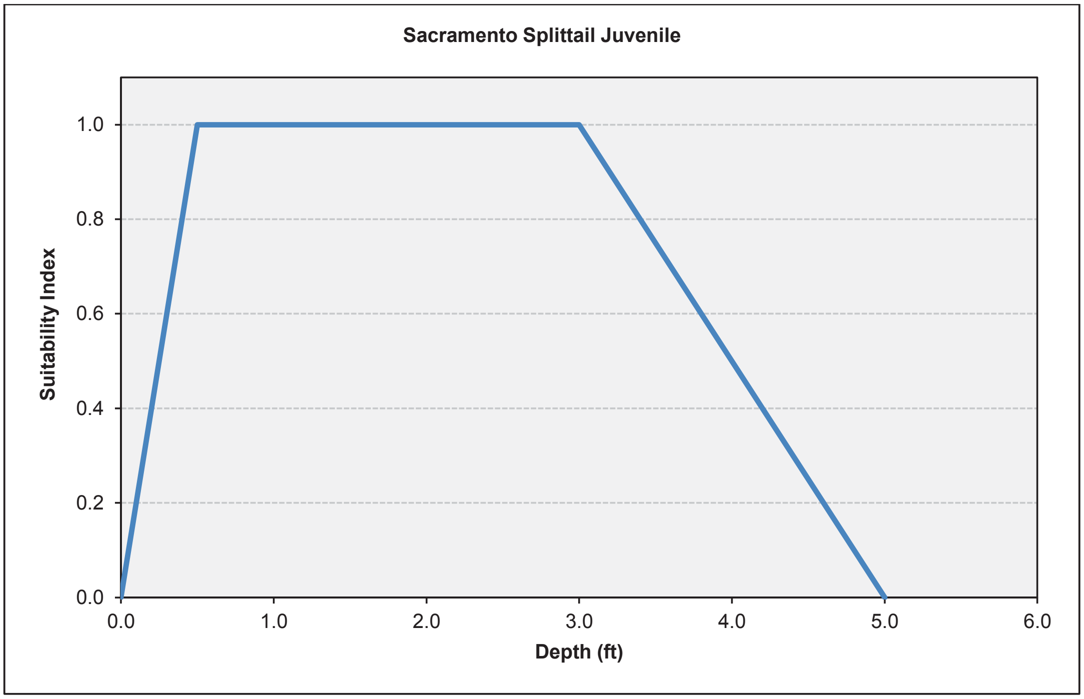

Figure 8. Sacramento splittail juvenile depth suitability criteria for the lower Tuolumne River.

Table 4. Sacramento splittail juvenile suitability criteria.

Velocity		Depth	
(fps)	**Index[1]**	**(ft)**	**Index[1]**
0.00	1.00	0.00	0.00
0.40	1.00	0.50	1.00
1.37	1.00	1.30	1.00
2.00	0.30	3.00	1.00
3.50	0.00	5.00	0.00

[1] Merced ID 2013

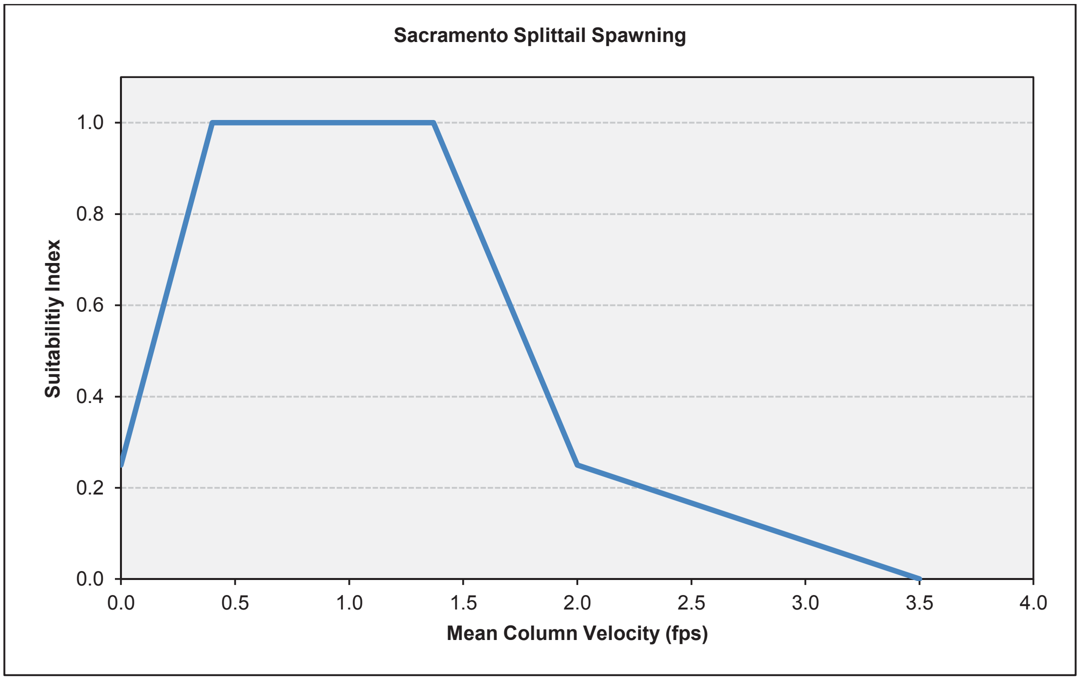

Figure 9. Sacramento splittail spawning velocity suitability criteria for the lower Tuolumne River.

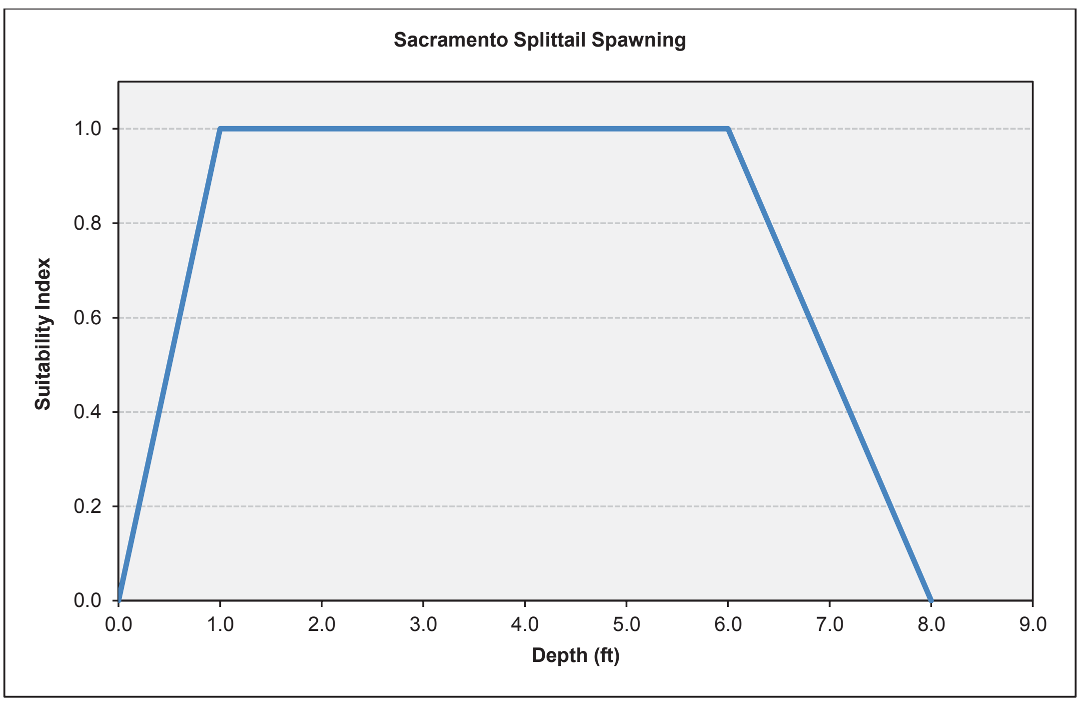

Figure 10. Sacramento splittail spawning depth suitability criteria for the lower Tuolumne River.

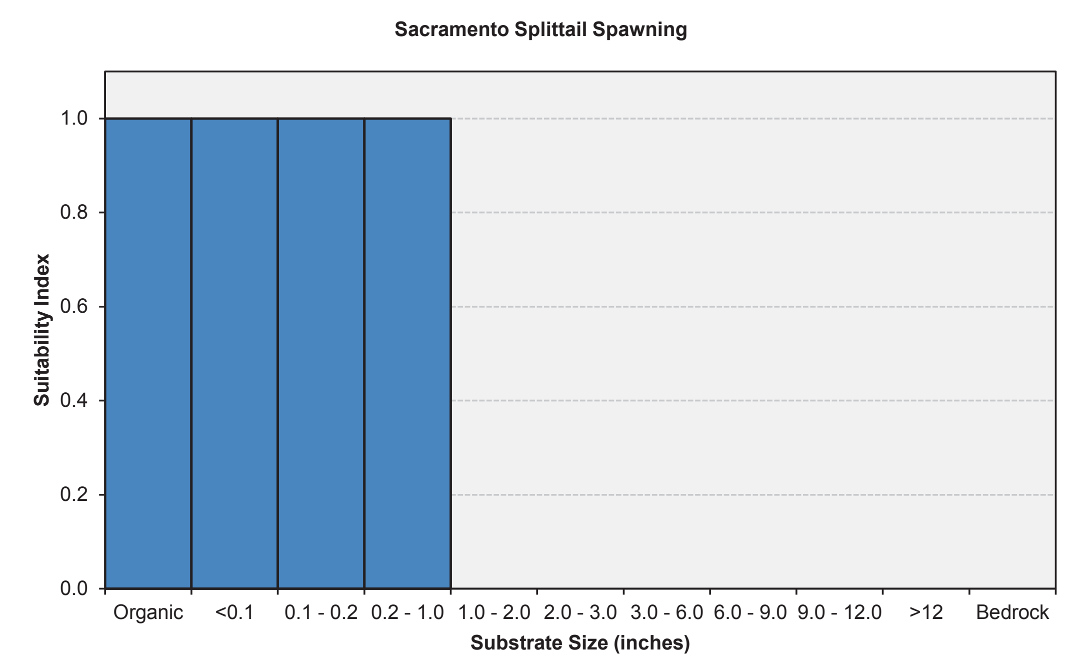

Figure 11. Sacramento splittail spawning dominant substrate suitability criteria for the lower Tuolumne River.

Table 5. Sacramento splittail spawning suitability criteria.

Velocity		Depth		Substrate		
(fps)	**Index**[1]	**(ft)**	**Index**[1]	**Type**	**Size (inches)**	**Index**[1]
0.00	0.25	0.00	0.00	Organic	N/A	1.00
0.40	1.00	1.00	1.00	Silt	<0.1	1.00
1.37	1.00	6.00	1.00	Sand	0.1–0.2	1.00
2.00	0.25	8.00	0.00	Small gravel	0.2–1	1.00
3.50	0.00	--	--	Gravel	1–2	0.00
--	--	--	--	Large gravel	2–3	0.00
--	--	--	--	Small cobble	3–6	0.00
--	--	--	--	Cobble	6–9	0.00
--	--	--	--	Large cobble	9–12	0.00
--	--	--	--	Boulder	>12	0.00
--	--	--	--	Bedrock	N/A	0.00

[1] Merced ID 2013

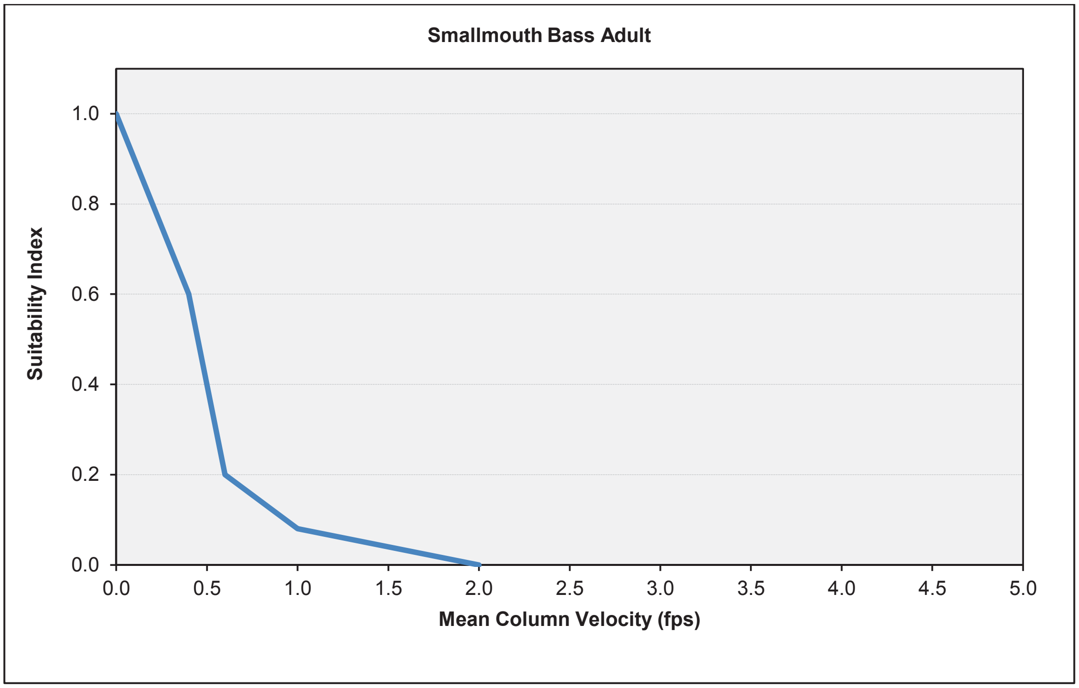

Figure 12. Smallmouth bass adult velocity suitability criteria for the lower Tuolumne River.

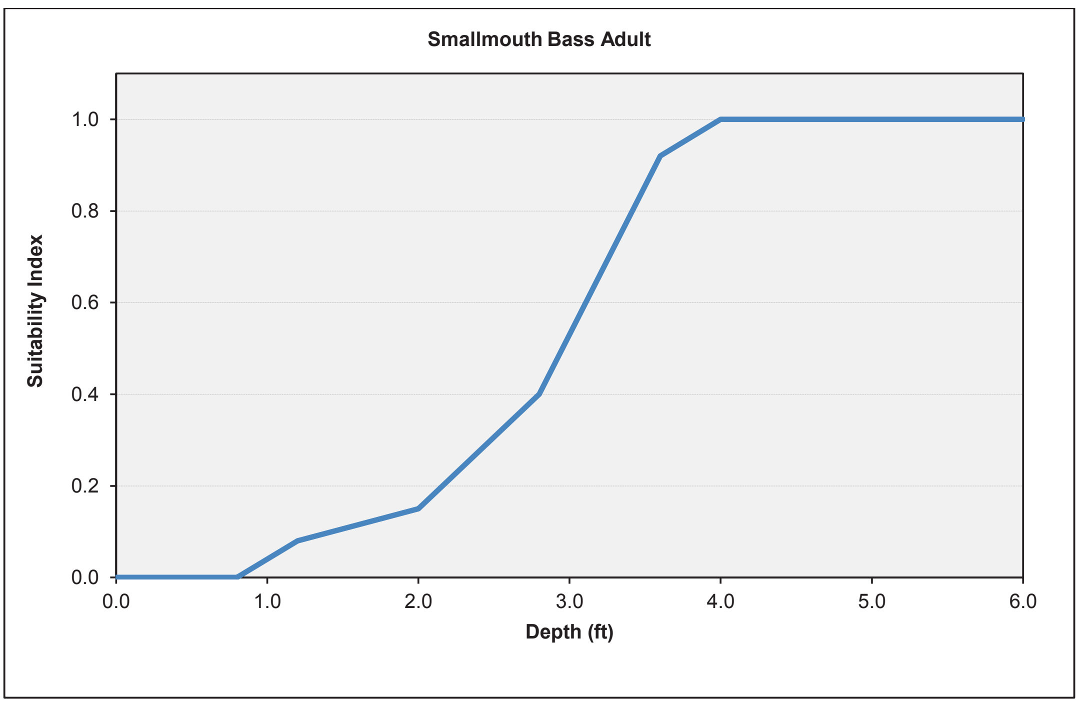

Figure 13. Smallmouth bass adult depth suitability criteria for the lower Tuolumne River.

Table 6. Smallmouth bass adult suitability criteria.

Velocity		Depth	
(fps)	**Index**[1]	**(ft)**	**Index**[1]
0.00	1.00	0.00	0.00
0.40	0.60	0.80	0.00
0.60	0.20	1.20	0.08
1.00	0.08	2.00	0.15
2.00	0.00	2.80	0.40
--	--	3.60	0.92
--	--	4.00	1.00

[1] Edwards et al. 1983

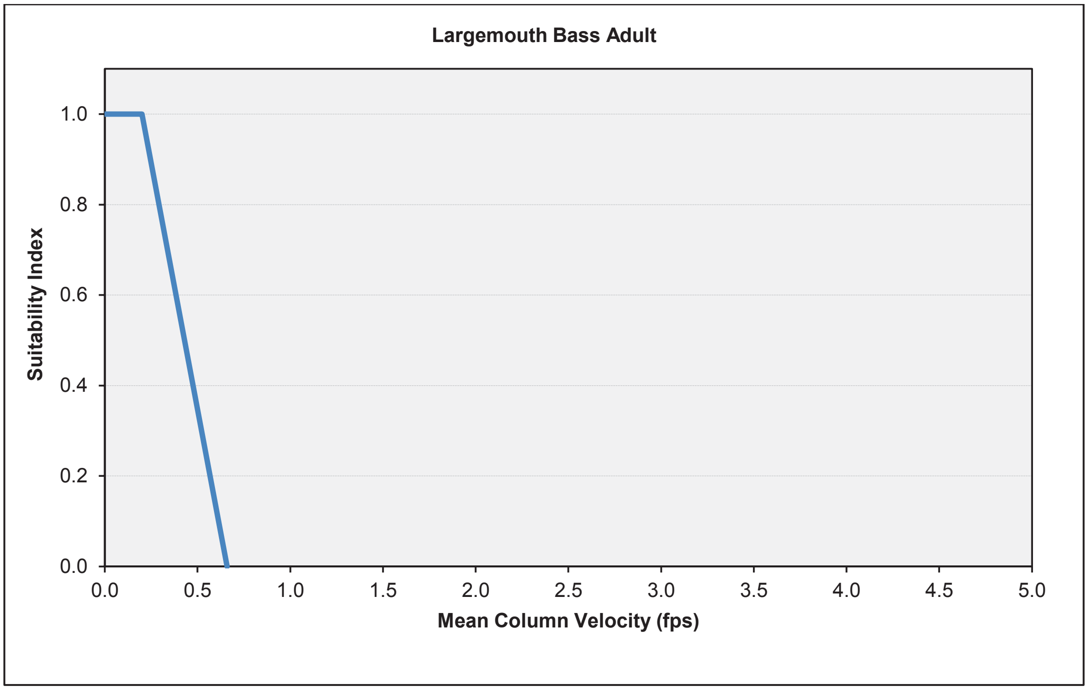

Figure 14. Largemouth bass adult velocity suitability criteria for the lower Tuolumne River.

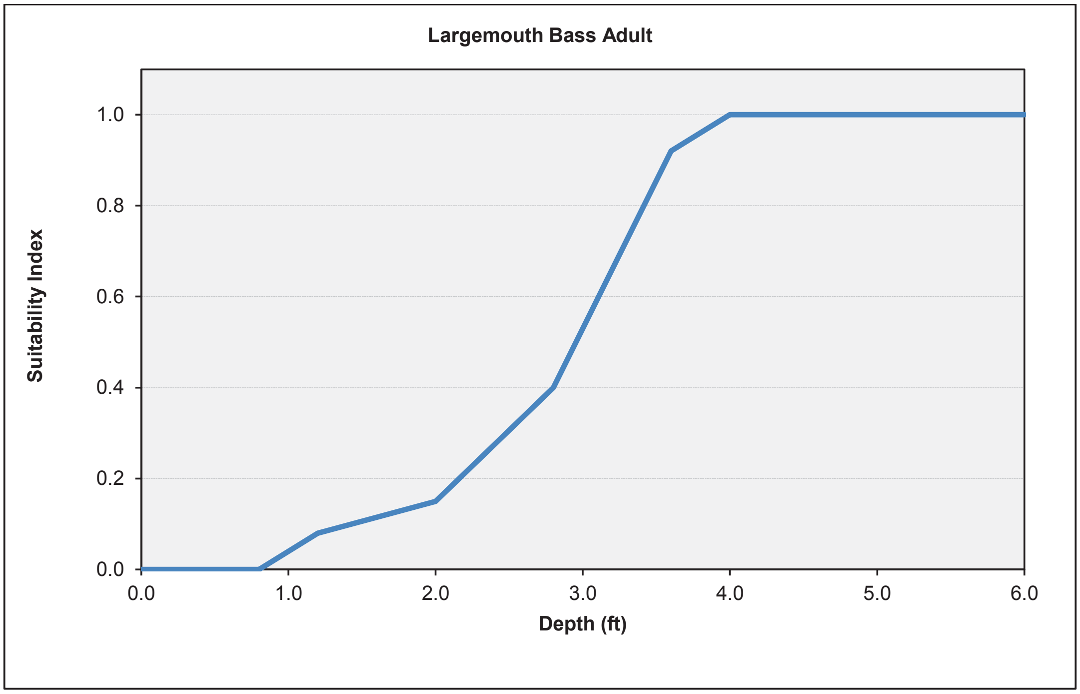

Figure 15. Largemouth bass adult depth suitability criteria for the lower Tuolumne River.

Table 7. Largemouth bass adult suitability criteria.

Velocity[1]		Depth[2]	
(fps	**Index**	**(ft)**	**Index**
0.00	1.00	0.00	0.00
0.20	1.00	0.80	0.00
0.66	0.00	1.20	0.08
--	--	2.00	0.15
--	--	2.80	0.40
--	--	3.60	0.92
		4.00	1.00

1 Stuber et al. 1982
2 HSC for smallmouth bass (Edwards et al. 1983), as used in previous lower Tuolumne studies (McBain and Trush and Stillwater Sciences 2006; Stillwater Sciences 2012)

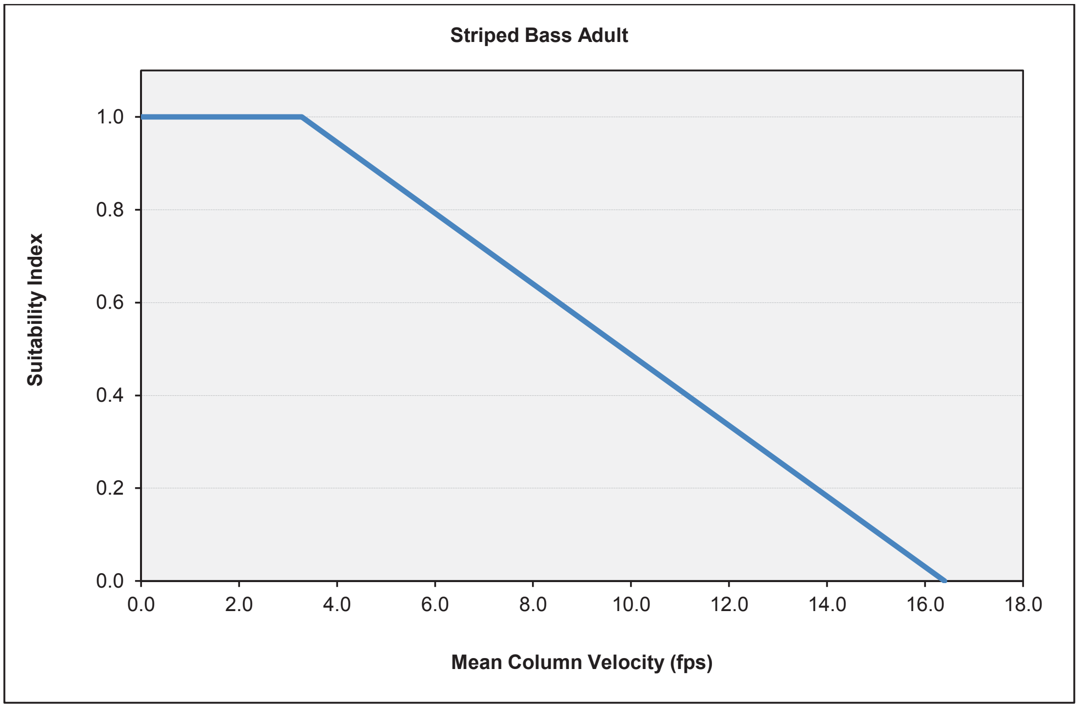

Figure 16. Striped bass adult velocity suitability criteria for the lower Tuolumne River.

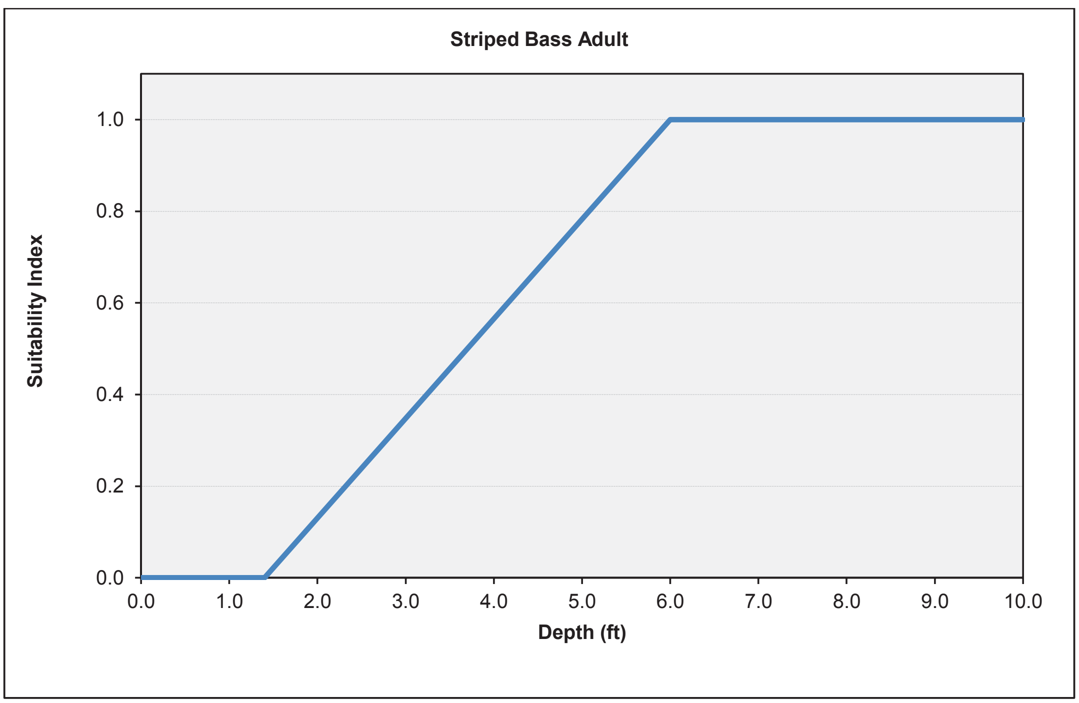

Figure 17. Striped bass adult depth suitability criteria for the lower Tuolumne River.

Table 8. Striped bass adult suitability criteria.

Velocity		Depth	
(fps)	**Index[1]**	**(ft)**	**Index[2]**
0.00	1.00	0.0	0.00
3.00	1.00	1.4	0.00
3.28	1.00	6.0	1.00
16.40	0.00	--	--

[1] Developed using existing literature sources from Hassler (1988)
[2] Crance et al. (1984)

2.4 Habitat Time Series

A Habitat Time Series (HTS) analysis will be conducted to assess how habitat values for each species and life stage vary over time, under different water year type scenarios. Water year types selected for analysis are the five San Joaquin Basin 60-20-20 Index types: Critical, Dry, Below Normal, Above Normal, and Wet, as represented by Water Years 2008-2012 (the most recent years of these index types) and presented in Table 9.

Table 9. San Joaquin Basin 60-20-20 Index, corresponding water year types, and representative water years used for habitat time series analysis in the lower Tuolumne River instream flow study.

San Joaquin Basin 60-20-20 Index[1]	Water Year Type	Representative Water Year
2.06	Critical	2008
2.18	Dry	2012
2.73	Below Normal	2009
3.55	Above Normal	2010
5.59	Wet	2011

[1] DWR Bulletin 132 calculated index

Daily flow values for the lower Tuolumne River were obtained from the USGS gaging station at La Grange (No. 11289560) and were compiled for all Water Year types. No downstream adjustments for accretion or depletion are required in the IFIM assessment reach (RM 51.7 to RM 29.0).[1] The associated WUA values will be assigned based on the daily flows using a lookup table of WUA values from the PHABSIM results, interpolated to 5 cfs intervals.

The periodicity of Pacific lamprey and Sacramento splittail was adapted from the Merced River hydroelectric relicensing project due to its close proximity to the lower Tuolumne River (Merced ID 2011, 2013) (Table 10); the Sacramento splittail spawning periodicity was modified to indicate the spawning period for the lower Tuolumne River (Moyle et al. 2004). Smallmouth bass, largemouth bass, and striped bass have been documented in the lower Tuolumne River during each season of the year (FISHBIO 2012a, 2012b; Stillwater Sciences 2009b, 2011).

[1] The reach represented in the IFIM assessment includes RM 51.7 to RM 29.0. Accretion/depletion studies performed by the Districts suggest that flow changes along the study reach (which is upstream of Dry Creek and does not contain major tributaries) are relatively small compared to the scale of most HTS flows and the associated WUA reporting increments, and therefore the HTS results are not adjusted for these changes.

Periodicity for adult bass species includes all months of the year, since the species are resident (Table 10).

Table 10. Species/life stage periodicity for the lower Tuolumne River.

Species	Life stage	Fall			Winter			Spring			Summer		
		O	N	D	J	F	M	A	M	J	J	A	S
Pacific lamprey	Ammocoete	■	■	■	■	■	■	■	■	■	■	■	■
	Spawning						■	■	■	■			
Sacramento splittail	Juvenile						■	■	■	■	■	■	■
	Spawning					■	■	■	■				
Smallmouth bass	Adult	■	■	■	■	■	■	■	■	■	■	■	■
Largemouth bass	Adult	■	■	■	■	■	■	■	■	■	■	■	■
Striped bass	Adult	■	■	■	■	■	■	■	■	■	■	■	■

3 DISCUSSION

3.1 Next Steps

This report complies with requirements of the Commission's December 22, 2011 Study Plan Determination for the Don Pedro Project relicensing studies and the Commission's May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project, which collectively expanded the flow-habitat assessments to be undertaken to include lamprey, splittail, and three bass species. Following the HSC review, any subsequent modifications to the HSC will be completed and provided in the Districts' Updated Study Report (USR), scheduled to be issued on December 6, 2013. The Districts will to submit the results of the five species assessments as separately bound supplements to the prior filings and as part of the Districts' upcoming license application for the relicensing the Project, in accordance with the following schedules.

Habitat assessments (e.g., WUA versus flow relationships) using the final HSC for Pacific lamprey and Sacramento splittail will be completed by the Districts and submitted to relicensing participants for a 30-day review and comment period by January 16, 2014. The final report will be provided in the Districts' Final License Application to be filed with FERC by April 30, 2014.

Habitat assessments for non-native predatory fish, including smallmouth bass, largemouth bass, and striped bass will be completed by the Districts and submitted to relicensing participants in conjunction with the Districts' 2014 Predation Study. The Districts will submit both studies to relicensing participants for a 30-day review and comment period in December 2014 or January 2015. The final report will be provided as an Additional Information filing to FERC to supplement the Final License Application.

The one remaining component of the *Lower Tuolumne River Instream Flow Studies* 1-D PHABSIM investigation includes an effective habitat analysis to be completed following the completion of the *Lower Tuolumne River Temperature Model* (relicensing study W&AR-16). The river temperature model report will be submitted to relicensing participants for review and comment as part of the Districts' USR. The effective habitat analysis evaluation is expected to be complete within six months (including a 30-day resource agency review period) following the completion of relicensing participants' review and comment on W&AR-16. Therefore, the effective weighted usable area assessment would be completed and filed with FERC by August 2014.

4 REFERENCES

Bovee, K. D. 1986. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. Instream Flow Information Paper No. 21. Instream Flow Group. U.S. Fish and Wildlife Service, Fort Collins, CO.

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From: Allison Boucher <abouche[redacted]>
Sent: Tuesday, November 05, 2013 8:07 PM
To: Staples, Rose; 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; 'Cooke, Michael'; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Donaldson, Milford Wayne'; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Art'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; Le, Bao; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Marshall, Mike'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; 'Reynolds, Garner'; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; 'Simsiman, Theresa'; 'Slay, Ron'; 'Smith, Jim'; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; 'Villalobos, Amber'; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Cc: 'Scott Wilcox'; 'Russell Liebig'
Subject: RE: For Your Review-Available HSC for Don Pedro Assessment Pacific lamprey-Sacramento Splittail-Non Native Predatory Fish Habitat

Don't we need temperature requirements for these fish? Isn't temperature part of the habitat?
Allison Boucher
Tuolumne River Conservancy, Inc.

From: Staples, Rose [mailto:Rose.Staples@hdrinc.com]
Sent: Wednesday, October 30, 2013 2:37 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack;

Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Cc: Scott Wilcox (Scott@stillwatersci.com); Russell Liebig (russ@stillwatersci.com)
Subject: For Your Review-Available HSC for Don Pedro Assessment Pacific lamprey-Sacramento Splittail-Non Native Predatory Fish Habitat

The attached Technical Memorandum from Stillwater Sciences (summarizing the HSC available for Pacific lamprey, Sacramento splittail, and non-native predatory fish habitat assessment) is being provided to you today for a 30-day review. Please provide any comments by close of business on Friday, November 29, 2013. Thank you.

ROSE STAPLES
CAP-OM

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From: Staples, Rose
Sent: Tuesday, November 05, 2013 8:08 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Donaldson, Milford Wayne; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Art; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Marshall, Mike; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Project Relicensing Draft License Application

The Don Pedro Project Relicensing ***DRAFT License Application*** ("DLA") is due to be filed with FERC later this month. Once filed, this document will be available for viewing / downloading from FERC's E-Library and it will also be uploaded into the DOCUMENT section of the Don Pedro Relicensing website at www.donpedro-relicensing.com.

However, if you would prefer receiving a CD copy of the DLA, please send me an email with your current mailing address, and we will forward you the CD once the DLA has been filed with FERC. Thank you.

From: Staples, Rose
Sent: Friday, November 15, 2013 9:44 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Project Relicensing USR Filing and USR Meeting Date

For your information, please note that the Don Pedro Updated Study Report (USR) will be filed with FERC on December 10, 2013—and the USR Meeting will be held on Thursday, December 19, 2013 from 9:00 a.m. to 4:00 p.m. at the MID Offices in Modesto. A more detailed agenda will be forthcoming.

ROSE STAPLES
CAP-OM

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From: Staples, Rose
Sent: Friday, November 15, 2013 6:46 PM
To: Staples, Rose; Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter@Waterboards; Barrera, Linda@Wildlife; Blake, Martin; Bond, Jack; Borovansky, Jenna; abouche[redacted] Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy[redacted]; mcooke@turlock.ca.us; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; steve.edmondson@noaa.gov; Eicher, James; Fargo, James@FERC; Fernandes, Jesse; Ferranti, Annee@Wildlife; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim@Wildlife; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert@Wildlife; Hume, Noah; zachary_jackson@fws.gov; Jauregui, Julia; deltakeep[redacted] Jensen, Laura; Johannis, Mary; Johnson, Brian; christy.a.jones@usace.army.mil; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; maperanch@aol.com; Madden, Dan; Marko, Paul; Martin, Michael; ramon_martin@fws.gov; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen@Wildlife; Murray, Shana; O'Brien, Jennifer@Wildlife; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; rbpool@protroll.com; Porter, Ruth; Powell, Melissa; Puccini, Stephen@Wildlife; Raeder, Jessie; tramirez@sfwater.org; Rea, Maria@NOAA; Reed, Ronda@noaa; Reynolds, Garner; Richardson, Daniel; Kevin.A.Richardson@usace.army.mil; jridenour@modestogov.com; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan@Parks; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; rstork@friendsoftheriver.org; Stratton, Susan@Parks; Taylor, Mary Jane@Wildlife; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; chris.vierra@ci.ceres.ca.us; Villalobos, Amber@Waterboards; richard.wantuck@noaa.gov; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff@Waterboards; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David@NOAA; scott@stillwatersci.com; Williamson, Harry; Willy, Alison; Wilson, Bryan; Winchell, Frank; Wooster, John; Michelle_Workman@fws.gov; rmyoshiyama@ucdavis.edu; Zipser, Wayne
Subject: Don Pedro Project USR Meeting Date Change

As Annie Manji has alerted us to the December 19-20 dates of the already scheduled Merced Hydroelectric Project meetings, we have therefore changed the Don Pedro Project Updated Study Report (USR) Meeting to Wednesday, December 18, 2013 from 9:00 a.m. to 4:00 p.m. at the MID Offices in Modesto.

ROSE STAPLES | **HDR Engineering, Inc.**

From: Staples, Rose
Sent: Monday, November 25, 2013 11:39 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Districts File Today Don Pedro USR Schedule Extension Request

Please be aware that the Districts have filed this morning a Request for Extension with FERC to reschedule the December 18, 2013 Updated Study Report meeting for the Don Pedro Project to Thursday, January 16, 2014. The USR document will be filed with FERC and available to relicensing participants on January 6, 2014. The USR Meeting Summary will be filed by the Districts with FERC by January 24, 2014, and relicensing participants will have until March 3, 2014 to file any comments, requests for study modifications, or requests for new studies. FERC's schedule for resolving any disagreements over the meeting summary or study requests would shift from April 20 to April 24, 2014. A copy of this Request for Schedule Extension will be uploaded shortly to the Don Pedro relicensing website (www.donpedro-relicensing) as an ANNOUNCEMENT.

The request to reschedule the USR meeting is being made because there are a number of relicensing meetings on other California projects scheduled for the week of December 16th. The Districts are anticipating that FERC will grant the extension because of the overall minor delay in the ILP as a whole. The USR meeting will still be held in Modesto at MID's offices from 9 am to 4 pm. A detailed agenda will be provided once the Districts hear from FERC on the request. In the meantime, please mark the date on your calendar. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Tuesday, November 26, 2013 2:41 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro DLA has been filed with FERC

The Don Pedro Draft License Application (DLA) has been filed with FERC day; and is already available on FERC's E-Library at www.ferc.gov. Copies of the DLA documents (32 in all) have been uploaded to the Don Pedro relicensing website at www.donpedro-relicensing.com, attached to today's date in the meeting CALENDAR. I will also be uploading copies to the DOCUMENTS tab a little later today. And, as noted in my previous email of November 5th, a CD copy of the DLA is available upon request by contacting me at rose.staples@hdrinc.com with your mailing address. If you have any difficulties accessing and/or downloading any of these files, please do let me know. Thank you.

ROSE STAPLES
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HDR Engineering, Inc.
Executive Assistant, Hydropower Services

From: Staples, Rose
Sent: Tuesday, December 03, 2013 1:48 PM
To: 'Julie Rentner'
Subject: RE: Don Pedro Relicensing

Thank you for your query. I have forwarded your contact information to the staff who is handling the distribution of the Don Pedro Project relicensing newsletter, so that you get added to the mailing list for the next issue. And I am also forwarding this email to the Districts' relicensing team, regarding your interest in integration. Thank you.

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From: Julie Rentner [mailto:jrentner@riverpartners.org]
Sent: Wednesday, November 27, 2013 4:17 PM
To: Staples, Rose
Subject: Don Pedro Relicensing

Hello Ms Staples,

I noticed in the recent newsletter on Don Pedro Relicensing that the team reports performing a study regarding the relationships between flow and habitat in the lower Tuolumne.

My NGO is a landowner in the Lower Tuolumne River (RM 0-3) and we are actively planning and permitting floodplain habitat restoration on our property.
We are interested in hearing from your study team to ensure our plans are consistent and complimentary with (as well as integrated into) the studies being conducted.
Please contact me directly to discuss integration.

Also, I'd like to be added to the mailing list for the newsletter.
Thanks!

Happy Thanksgiving!

Julie Rentner
Director of Special Projects
River Partners
912 11th Street, Suite LL2
Modesto Ca 95354
(209) 639-2012
Fax: (209) 521-7327
jrentner@riverpartners.org
www.riverpartners.org

From: Staples, Rose
Sent: Thursday, December 05, 2013 5:51 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro Relicensing Newsletter Vol 3 Issue 2 Uploaded to Relicensing Website

A copy of the newest Don Pedro Relicensing Newsletter (Volume 3-Issue 2, December 2013) has been uploaded to the Relicensing website (www.donpedro-relicensing.com) under the COMMUNICATIONS tab. Please scroll down to the bottom of the page to see the Newsletter Section.

ROSE STAPLES
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Volume 3 | Issue 2

Don Pedro

December 2013

A newsletter about the relicensing of the Don Pedro Project

Draft License Application filed with FERC

November 26 marked a major milestone in the relicensing of the Don Pedro Project. That is when the Modesto Irrigation District and Turlock Irrigation District filed their Draft License Application (DLA) with the Federal Energy Regulatory Commission (FERC).

The purpose of the DLA is to provide an opportunity for public review and comment on the application prior to filing of the Final License Application (FLA), to be filed by April 30, 2014.

The relicensing process chosen by the Districts, FERC's Integrated Licensing Process (ILP), requires that the applicant for a new license file a Draft License Application with FERC and interested parties no later than 150 days prior to the date of filing the final license application.

The DLA is a compilation of the information and studies accumulated since the start of the relicensing process and includes proposals for future plans for operating the Don Pedro Project in the next license term. However, because some relicensing studies remain in progress, there are a limited number of firm proposals for future operations contained in the draft. Relicensing participants have 90 days to comment on the DLA. The plans proposed in the DLA include development of a Bald Eagle Management Plan, Historic Properties Management Plan and a Vegetation Management Plan.

The Districts are continuing with the development of the FLA, which will include detailed proposals for future Project operations.

The Relicensing Process

The joint MID-TID relicensing of the Don Pedro Project formally began in 2011. Below are some of the major stages of the process.

1. Districts filed PAD and Notice of Intent in February 2011.
2. FERC conducts scoping in May 2011.
3. Interested parties discuss issues and develop study requests.
4. Districts file Proposed Study Plan (PSP) in July 2011 and undertake a series of meetings with relicensing participants to discuss study plans.
5. FERC issues Study Plan Determination in Dec. 2011.
6. Studies begin in 2012.
7. Initial Study Report issued for review and comment in Jan 2013.
8. **Districts file Draft License Application with FERC on Nov. 26, 2013.**
9. Districts file Final License Application with FERC by April 30, 2014.
10. FERC issues new license with new terms and conditions in 2016.

Important dates

Nov. 26, 2013
Draft License Application filed with FERC

Dec. 10, 2013
Updated Study Report filed with FERC

Jan. 16, 2013
Updated Study Report Meeting at MID, 9 a.m.

by April 30, 2014
Final License Application to be filed with FERC

What's inside

- Updated Study Report meeting set for Jan. 16
- Study statuses
- Additional study notes
- Flow proposal update

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Effort for river flows progresses

The State Water Resources Control Board is looking for water to benefit fish, as well as to control salinity in the south Delta – and it's targeting three tributaries of the San Joaquin River.

Citing a preferred alternative of 35 percent unimpaired flow from each of the Merced, Stanislaus and Tuolumne rivers from February to June annually, the Substitute Environmental Document (SED) is part of Phase 1 of the Board's update to its Bay-Delta Water Quality Control Plan.

MID, TID and many others opposed the flow proposal at a March 2013 public hearing in Sacramento, citing potential harm to water and power customers and the region's economy, as well as implications on groundwater and domestic water supply.

State Board staff is modifying the SED and expects to have a revised document released for comment around February 2014.

A Chinook salmon smolt is removed from the stomach of a striped bass. A 2014 Predation Study (W&AR-07) will be conducted to learn more about fish predators of salmon and predation hot spots.

2014 study to further focus on predation

The Districts will undertake a second, extensive effort to study predation of salmon smolts and juveniles in the lower Tuolumne River in 2014. This will be done in compliance with FERC's May 21, 2013 Study Plan Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project.

Extensive field work on Water & Aquatic Resources (W&AR)-07 will be conducted from January to July and a report will be filed by March 2015. The Districts' 2014 predation study proposal was approved by FERC with few modifications. The 2014 study is dependent upon approval of the necessary permits from the California Department of Fish and Wildlife and the National Marine Fisheries Service.

The 2014 study comes on the heels of the 2012 predation study. The 2014 study will provide data to further understanding of predation effects on rearing and outmigrating juvenile Chinook salmon and O. mykiss in the lower Tuolumne River.

Data obtained from the 2014 study will supplement existing information to estimate relative abundance of predator fish species (such as bass) using in-channel habitats, estimate predation rates by stomach content sampling, document predator movement, and identify hot-spots that potentially result in higher predation mortality on outmigrating juvenile Chinook salmon on the Tuolumne River from River Mile 42 to the confluence with the San Joaquin River.

STUDY NOTES

O. mykiss Workshop No. 2

The Districts hosted a second public workshop on Nov. 5 regarding the modeling effort as part of the W&AR-10 study. The purpose of the workshop was to update relicensing participants on study progress, review a model that evaluates all life stages of O. mykiss in the lower Tuolumne River, and solicit input regarding the study.

Lowest Boatable Flow Study

In accordance FERC's May 21, 2013 Determination, the Districts conducted an additional volunteer boater study in 2013 as part of the Lower Tuolumne River Lowest Boatable Flow Study (Recreational Resources - 03).

A previous river boating study was conducted in Spring 2012 with flows ranging from 171 cubic-feet per second (cfs) to 256 cfs. The 2012 study concluded that 100 cfs is boatable and lower flows would not provide enjoyable boating in inflatable kayaks or any other craft.

During the second iteration of the study requested by FERC's May 21, 2013 Determination, flows of approximately 200 cfs, 175 cfs, 150 cfs, and 125 cfs were employed in August and September 2013. A revised study report presenting results of the 2012 and 2013 volunteer boater effort is to be filed with the Updated Study Report.

Status of Relicensing Studies

Study No.	Study Name	Status
Cultural Resources (CR) -01	Historic Properties Study	Field work complete; Report in progress
CR-02	Native American Traditional Cultural Properties Study	Field work complete; Report in progress
Recreational Resources (RR)-01	Recreation Facility and Public Accessibility Assessment	Complete
RR-02	Whitewater Boating Take Out Improvement Feasibility	Complete
RR-03	Lower Tuolumne River Boatable Flow Study	Complete
RR-04	Visual Quality Study	Complete
Terrestrial Resources (TR)-01	Special-Status Plants	Complete
TR-02	ESA- and CESA-Listed Plants Study	Complete
TR-03	Wetland Habitats Associated with Don Pedro Reservoir	Complete
TR-04	Noxious Weed Survey	Complete
TR-05	ESA-Listed Wildlife - Valley Elderberry Longhorn Beetle (VELB)	Complete
TR-06	Special-Status Amphibians and Aquatic Reptiles	Complete
TR-07	ESA-Listed Amphibians - California Red-Legged Frog (CRLF)	Complete
TR-08	ESA-List Amphibians - California Tiger Salamander (CTS)	Complete
TR-09	Special-Status Bats	Complete
TR-10	Bald Eagle Study	Complete
Water & Aquatic Resources (W&AR)-01	Water Quality Assessment	Complete
W&AR-02	Project Operations/Water Balance Model	In progress
W&AR-03	Reservoir Temperature Model	In progress
W&AR-04	Spawning Gravel Study	In progress
W&AR-05	Salmonid Populations Information Integration	Complete
W&AR-06	Tuolumne River Chinook Salmon Population Model	Report in progress
W&AR-07	2012 Predation Study	Complete
W&AR-07	2014 Predation Study	Field work planning in progress
W&AR-08	Salmonid Redd Mapping	Complete
W&AR-10	Oncorhynchus mykiss Population Study	Report in progress
W&AR-11	Chinook Salmon Otolith Study	Study in progress
W&AR-12	Oncorhynchus mykiss Habitat Assessment	Complete
W&AR-13	Fish Assemblage and Population Study	Complete
W&AR-14	Temperature Criteria Assessment	Report in progress
W&AR-15	Socioeconomics Study	Complete
W&AR- 16	Lower Tuolumne River Temperature Model	Complete
W&AR-17	Don Pedro Reservoir Fish Population Study	Complete
W&AR- 18	Sturgeon	Complete
W&AR- 19	Riparian Information Synthesis	Complete
W&AR-20	O. mykiss scale & age	Complete
—	Lower Tuolumne Instream Flow (IFIM)	Complete; supplemental analysis in progress
W&AR-21	Floodplain Hydraulic Assessment	Study in progress

Work conducted on a range of relicensing studies, such as the terrestrial study above, will be discussed at a Jan. 16 meeting held at Modesto Irrigation District.

Jan. 16 meeting to focus on Study Report

As part of FERC's Integrated Licensing Process (ILP), the Districts as co-applicants will file an Updated Study Report (USR) with FERC on Dec. 10.

The USR is a compilation of all the studies completed in the second year of studies as part of relicensing. The USR includes a second year of bald eagle studies, a study of salmon and steelhead/rainbow trout (O. mykiss) spawning redds, the development of a computer model of O. mykiss populations in the lower Tuolumne River, the completion of the Operations Model, and two water temperature models.

Additionally, the USR updates several other relicensing studies, such as studies of boating flows in the lower Tuolumne River, with new information.

Following the filing, a public meeting will be held to review the USR on Jan. 16 at MID beginning at 9 a.m. Study work will be summarized and questions will be answered.

Updated Study Report Meeting

When: *January 16, 2013 | 9 a.m. to 4 p.m.*

Where: *MID Multipurpose Room, 1231 11th St., Modesto, CA*

What: *Work on studies will be summarized and questions about studies will be answered.*

www.donpedro-relicensing.com

Modesto Irrigation District
Water and Power

WATER & POWER
Serving Central California since 1887

333 E. Canal Drive
PO Box 949
Turlock, CA 95381
209.883.8300

From: Staples, Rose
Sent: Thursday, December 19, 2013 10:29 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Reminder for your 2014 Calendar: Don Pedro USR Meeting January 16 at MID Offices

Reminder for your 2014 calendar that the Don Pedro Project **Updated Study Report (USR) meeting** is scheduled for Thursday, January 16, 2014 at the MID Offices in Modesto. Detailed agenda to be released by January 7, 2014. Thank you.

ROSE STAPLES
CAP-OM

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From: Staples, Rose
Sent: Monday, January 06, 2014 6:33 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro USR Meeting Filed Today

The Districts have filed the UPDATED STUDY REPORT today with FERC; and it can be downloaded from FERC's E-Library at www.ferc.gov. I am also in the process of uploading the individual files making up the UPDATED STUDY REPORT to the Don Pedro Relicensing website at www.donpedro-relicensing.com. The first file in the report (with the Transmittal Letter) also contains the agenda for the January 16, 2014 UPDATED STUDY REPORT MEETING scheduled to be held at the MID Offices in Modesto. If you have any problems accessing the files, please do let me know. Thank you.

ROSE STAPLES
CAP-OM

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From:	Staples, Rose
Sent:	Tuesday, January 07, 2014 6:19 PM
To:	'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; Beeco, Adam; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; Cooke, Michael; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; 'Mills, John'; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; Reynolds, Garner; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; Villalobos, Amber; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject:	Revised Schedule for Jan 16 Don Pedro USR Meeting
Attachments:	USR Meeting AGENDA_140107.doc

Please find attached a **newly-revised AGENDA for the USR Meeting** scheduled for **Thursday, January 16th** at the MID Offices in Modesto**. Times for some of the individual Study Report discussions have changed from the original agenda filed with FERC yesterday as part of the Updated Study Report.** If you have any questions about the new schedule, please let me know. Thank you!

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

REVISED SCHEDULE

Updated Study Report Meeting Agenda

Thursday, January 16, 8:30 am – 4:30 pm – MID Offices, Modesto

(Times are approximate and subject to change*)

Call-In Number 866-994-6437 / Conference Code 5424697994

Time*	Topic	
8:30	**SIGN-IN**	
9:00	Agenda Review, Purpose of Meeting	
9:15	W&AR-15	Socioeconomics Study
9:45	W&AR-02	Tuolumne River Operations Model – Version 3.0 Update
10:00	CR-01	Progress Report and Schedule for Historic Properties Study
	CR-02	Progress Report and Schedule for Native American Traditional Cultural Properties Study
10:30	**BREAK**	
10:45	TR-10	Bald Eagle Study
11:00	RR-01	Recreation Facility Condition, Public Accessibility, and Recreation Use Assessment Study
11:15	RR-02	Whitewater Boating Take Out Improvement Feasibility Study
11:30	RR-03	Lower Tuolumne River Lowest Boatable Flow Study
Noon	**LUNCH BREAK (Lunch is on your own)**	
1:00	W&AR-03	Reservoir Temperature Model
	W&AR-16	Lower Tuolumne River Temperature Model
1:30	W&AR-04	Spawning Gravel in the Lower Tuolumne River Study
2:00	W&AR-06	Tuolumne River Chinook Salmon Population Model
	W&AR-10	*Oncorhynchus mykiss* Population Study
2:30	W&AR-07	Predation Study (2012 Report and 2014 Study)
3:00	W&AR-08	Salmonid Redd Mapping Study
3:15	W&AR-11	Chinook Salmon Otolith Study
3:30	W&AR-12	*Oncorhynchus mykiss* Habitat Assessment
3:45	IFIM	HSC Curves and Analysis for Splittail and Lamprey
4:00	Additional Information	NMFS Data Request (NMFS-1, Elements 3 and 6) Description of La Grange Facilities and Potentially Affected Environment of Anadromous Fish in the Vicinity of the La Grange Dam Districts' Response to NMFS-4, Element 1 through 6 Effects of Don Pedro Project and Related Facilities on Hydrology for Anadromous Fish: Magnitude, Timing, Duration, and Rate of Change
4:15	Closing Summary and Relicensing Schedule	
4:30	**ADJOURNMENT**	

From: Staples, Rose
Sent: Thursday, January 09, 2014 10:29 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills, John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro FLA Distribution List

As the time for the filing of the Don Pedro Project Final License Application (FLA) draws near, I need to refresh my list of MAILING ADDRESSES for all relicensing participants. This list will be published in the FLA, and will also be used to distribute CD copies of the Final License Application. By return email, could you please provide me with this information? Thank you. P.S.: And if there are other people in your offices and/or organizations who should be receiving a CD copy, please also advise their mailing addresses.

ROSE STAPLES
CAP-OM

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Walker, Colleen

From: Staples, Rose
Sent: Thursday, January 16, 2014 10:24 AM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; Beeco, Adam; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; Cooke, Michael; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; Mills John; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; Reynolds, Garner; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; Villalobos, Amber; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'White, David K'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro Draft Technical Memorandum Pacific lamprey Sacramento splittail for Review Comment
Attachments: Tuolumne_Splittail-Lamprey_InstreamFlow_DraftTM_16Jan2014.pdf

Attached is the Don Pedro Project DRAFT TECHNICAL MEMORANDUM on the **Pacific lamprey and Sacramento splittail 1-D PHABSIM Habitat Assessment** for your review and comments. Comments are due by Wednesday, February 26, 2014. A copy of the draft document is also being uploaded to the relicensing website at www.donpedro-relicensing.com under the ANNOUNCEMENTS Tab. Thank you.

ROSE STAPLES | **HDR Engineering, Inc.**

Stillwater Sciences
279 Cousteau Place, Suite 400, Davis, CA 95618
phone 530.756.7550 fax 530.756.7586

DRAFT TECHNICAL MEMORANDUM

DATE: January 16, 2014

TO: Steve Boyd, Turlock Irrigation District and Greg Dias, Modesto Irrigation District

FROM: Wayne Swaney, Russ Liebig, and Scott Wilcox, Stillwater Sciences

SUBJECT: Lower Tuolumne River Instream Flow Study — Pacific lamprey and Sacramento splittail 1-D PHABSIM habitat assessment

This Technical Memo has been updated with additional information that was developed since the document was last distributed for comment to relicensing participants on October 30, 2013. No comments were received from relicensing participants. Any new text provided in the Technical Memo is shaded. Any changed or new figures have shaded captions and any changed or new tables have shaded table titles. Suitability criteria for bass species have been removed from this Technical Memo, and will subsequently be reported separately.

1 BACKGROUND

The *Lower Tuolumne River Instream Flow Studies – Final Study Plan* (Stillwater Sciences 2009a) was filed with the Federal Energy Regulatory Commission (Commission) on October 14, 2009. The Study Plan was approved, pursuant to Ordering paragraphs (A) through (E) of the Commission's May 12, 2010 order. In order to examine the broad flow ranges identified in the Commission's July 16, 2009 Order, the Study Plan separated the study into two separate investigations: (1) A conventional 1-D PHABSIM model ("Instream flow Study"), which examines in-channel habitat conditions at flows from approximately 100–1,000 cfs, and (2) a 2-D hydraulic model of overbank areas, as well as adjacent in-channel locations, for flows of 1,000–5,000 cfs, developed as part of the Pulse Flow Study. The *Lower Tuolumne River Instream Flow Study–Final Report* was filed with the Commission on April 26, 2013 (Stillwater Sciences 2013). The *Pulse Flow Study Report* was submitted to the Commission on June 18, 2012 (Stillwater Sciences 2012).

Subsequent to the original Study Plan approval, the Commission, in their December 22, 2011 Study Plan Determination for the Don Pedro Hydroelectric Project relicensing studies, required the scope of the Lower Tuolumne Instream Flow Study be expanded to include Pacific lamprey (*Entosphenus tridentatus*) and Sacramento splittail (*Pogonichthys macrolepidotus*), if existing habitat suitability criteria (HSC) were available. Within their April 8, 2013 comments on the *Draft Instream Flow Study Report*, the USFWS provided references to existing criteria, developed for the Lower Merced River. More recently, in the Commission's May 21, 2013 Determination on Requests for Study Modifications and New Studies for the Don Pedro Hydroelectric Project, the Commission required the scope of the Lower Tuolumne Instream Flow Study be expanded to assess habitat for non-native predatory fish, including smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and striped bass (*Moronide saxatilis*) using existing habitat suitability criteria data, where available. The Districts compiled existing suitability criteria for the above species and distributed the draft criteria for relicensing participant review on October 30, 2013. No comments were received on the proposed HSC for splittail and lamprey. However, in their November 21, 2013 letter to the Districts, the USFWS requested that the scope of the bass analyses be expanded to include temperature criteria and early life stages (e.g., spawning/incubation, juvenile) of striped bass, largemouth bass, and smallmouth bass.

This Technical Memorandum includes the final suitability criteria and habitat assessment for Pacific lamprey and Sacramento splittail. The additional bass HSC are being included in the Districts' Updated Study Report being filed with FERC in January, 2014, and the habitat assessment for bass is scheduled for completion in conjunction with the District's Predation Study, scheduled for circa December 2014.[1]

2 METHODS

2.1 Habitat Suitability Criteria Availability

Use of the PHABSIM model requires application of HSC to the results of the hydraulic model in order to generate an index of habitat suitability (weighted usable area, or WUA) versus flow. Pursuant to the Commission-approved Study Plan, HSC screening criteria included the following, although no single criterion would qualify or disqualify a curve from further consideration.

- Minimum of 150 observations
- Clear identification of fish size classes
- Depth and velocity HSC
- Category II or III data (Bovee 1986)
- Comparable stream size and morphology (e.g., hydrology, stream width and depth, gradient, geomorphology, etc.)
- Source data from the lower Tuolumne River (or other Central Valley streams)
- Habitat availability data collected
- Data collected at high enough flow that depths and velocities are not biased by flow availability
- Availability of presence/absence data

The target species and life stages include:

- Pacific lamprey*:* spawning and ammocoete
- Sacramento splittail: juvenile and spawning

Unfortunately, the available HSC for Pacific lamprey and Sacramento splittail are very limited. Available HSC for Pacific lamprey and Sacramento splittail, referenced by the USFWS, were developed for the Merced Hydroelectric Project relicensing (Merced ID 2011 and 2013) (Table 1). The Merced Category I (binary consensus curves) data were based on species habitat descriptions from literature, and not from site-specific surveys. Pacific lamprey HSC were based on habitat preference descriptions of Pacific lamprey and Kern brook lamprey (*Lampetra hubbsi*) from Close et al. (2002), Gard (2009), and Gunckel et al. (2009) (Figures 1–6). The splittail HSC

[1] Pursuant to the *Additional Fish Species Flow/Habitat Assessments Schedule Update*, filed with FERC on October 4, 2013.

were derived from habitat descriptions from Feyrer et al. (2005), Moyle et al. (2004, 2007), Sommer et al. (2002, 2008), and Young and Cech (1996) (Figures 7–11).

Table 1. Habitat suitability criteria summary for target species and life stages.

Species	Life stage	Depth	Velocity	Substrate	Cover	Source
Pacific lamprey	Ammocoete	Yes	Yes	Yes	No	Merced ID 2011
Pacific lamprey	Spawning	Yes	Yes	Yes	No	Merced ID 2011
Sacramento splittail	Juvenile	Yes	Yes	No	No	Merced ID 2013
Sacramento splittail	Spawning	Yes	Yes	Yes	Yes	Merced ID 2013

2.2 Species Occurrences in the Tuolumne River

As part of salmonid HSC development for the lower Tuolumne River instream flow study, site-specific HSC validation surveys were conducted in the lower Tuolumne River from just below La Grange Dam (RM 52) downstream to Waterford (RM 31). Neither Pacific lamprey nor Sacramento splittail were observed during those surveys, which were conducted across a range of seasons (winter, spring, and summer) and a range of flow conditions (100 cfs, 350 cfs, and 2,000 cfs) (Stillwater Sciences 2013). However, Pacific lamprey have been observed during snorkel surveys conducted between La Grange Dam (RM 52) and Waterford (RM 31) (Stillwater Sciences 2009b, 2010), and Sacramento splittail have been reported to spawn in the lower 6.8 miles of the Tuolumne River during wet years (Moyle et al. 1995).

2.3 Effective Habitat

An “effective” WUA (eWUA) analysis will be conducted after current water temperature model data review has been completed. The Don Pedro Relicensing temperature model is being included in the Districts’ Updated Study Report to be filed with FERC in January, 2014, and the eWUA assessment is scheduled to be completed and filed with FERC by August 2014 (including a 30-day resource agency review period). The eWUA analysis relates to summertime water temperature suitability for *O. mykiss*, and integrates both micro- and macro-habitat considerations. The results from the current water temperature model (in development) over a range of flows will be combined with the summer WUA results so that areas (“macrohabitats”) with unsuitable water temperatures are excluded from the total WUA sum. In other words, if a given reach has 100,000 square feet of suitable habitat (i.e., WUA) based on hydraulic microhabitat conditions at flow ‘X’, but 30 percent of the reach at flow ‘X’ is above a critical temperature threshold for the species and life stage of interest, the eWUA would be 70,000 square feet. This type of analysis was previously conducted at a coarser level by Stillwater Sciences (2003), using a combination of the 1992 IFIM evaluation for the lower Tuolumne River (USFWS 1995) and the earlier SNTEMP model results (TID/MID 1992).

2.4 Habitat Suitability Criteria Selection

The lamprey and splittail depth, velocity, and substrate HSC developed for Merced ID were applicable for the Lower Tuolumne PHABSIM model. However, the cover criteria used by Merced ID for splittail spawning was based on a coding system that was incompatible with the cover data collected for the lower Tuolumne River. Therefore, cover criteria were not applied for this species/life stage. Selected HSC for Pacific lamprey and Sacramento splittail are shown below in Figures 1–11 and listed in Tables 2–7.

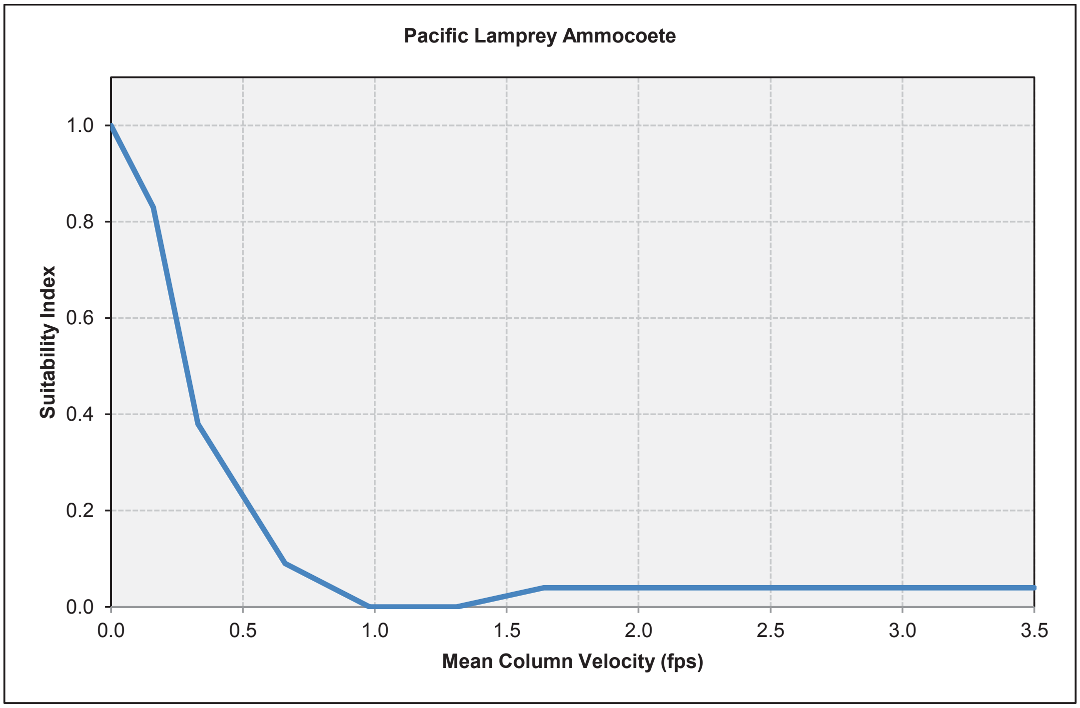

Figure 1. Pacific lamprey ammocoete velocity suitability criteria for the lower Tuolumne River.

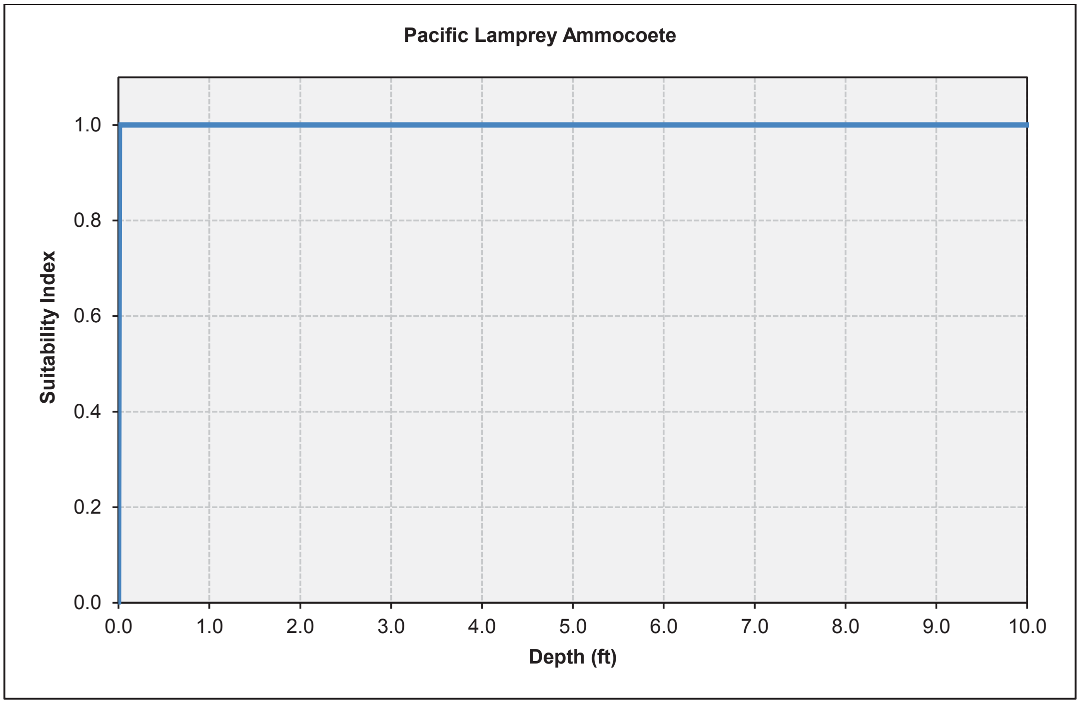

Figure 2. Pacific lamprey ammocoete depth suitability criteria for the lower Tuolumne River.

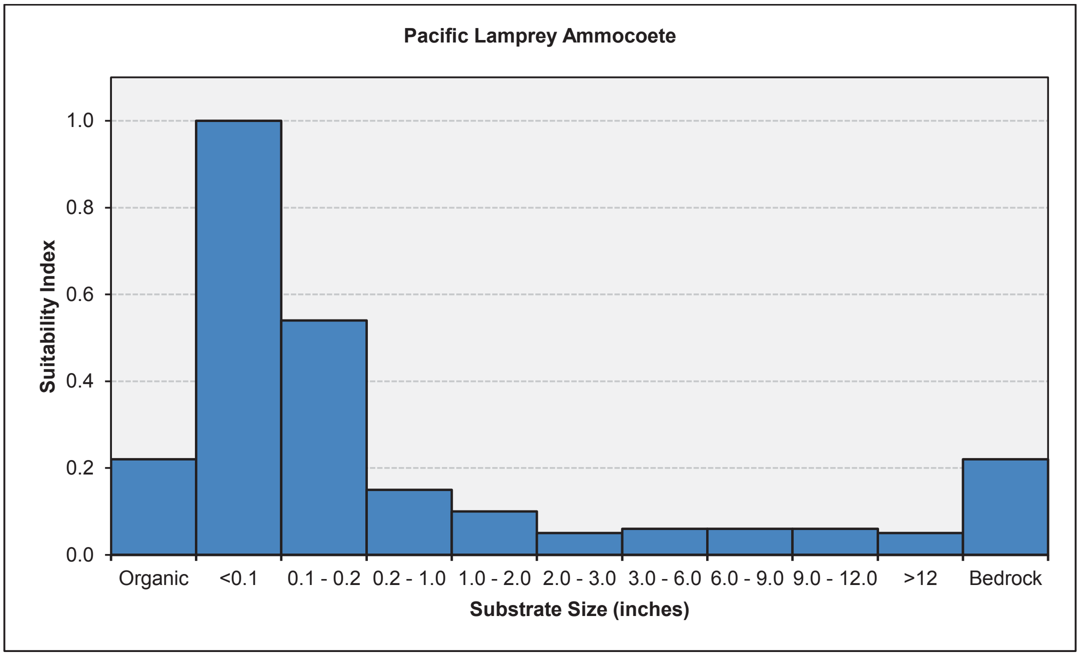

Figure 3. Pacific lamprey ammocoete dominant substrate suitability criteria for the lower Tuolumne River.

Table 2. Pacific lamprey ammocoete suitability criteria.

Velocity		Depth		Substrate		
(fps)	**Index[1]**	**(ft)**	**Index[1]**	**Type**	**Size (inches)**	**Index[1]**
0.00	1.00	0.00	0.00	Organic	N/A	0.22
0.16	0.83	0.01	1.00	Silt	0-0.1	1.00
0.33	0.38	--	--	Sand	0.1-0.2	0.54
0.66	0.09	--	--	Small gravel	0.2-1	0.15
0.98	0.00	--	--	Gravel	1-2	0.10
1.31	0.00	--	--	Large gravel	2-3	0.05
1.64	0.04	--	--	Small cobble	3-6	0.06
--	--	--	--	cobble	6-9	0.06
--	--	--	--	Large cobble	9-12	0.06
--	--	--	--	Boulder	>12	0.05
--	--	--	--	Bedrock	N/A	0.22

[1] Merced ID 2011

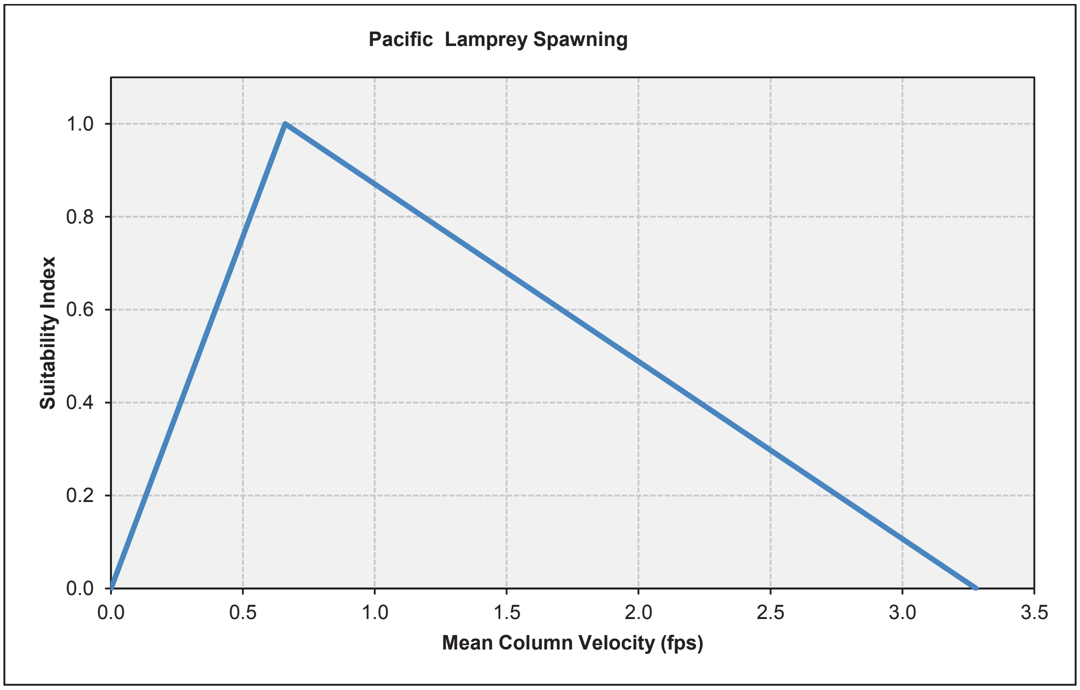

Figure 4. Pacific lamprey spawning velocity suitability criteria for the lower Tuolumne River.

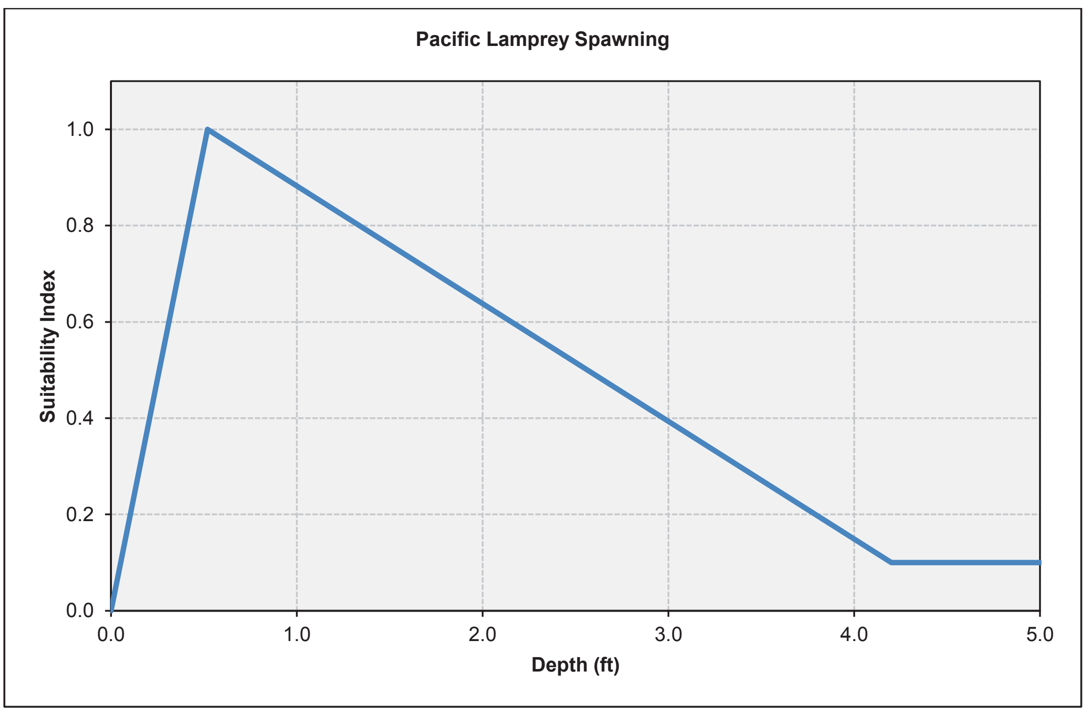

Figure 5. Pacific lamprey spawning depth suitability criteria for the lower Tuolumne River.

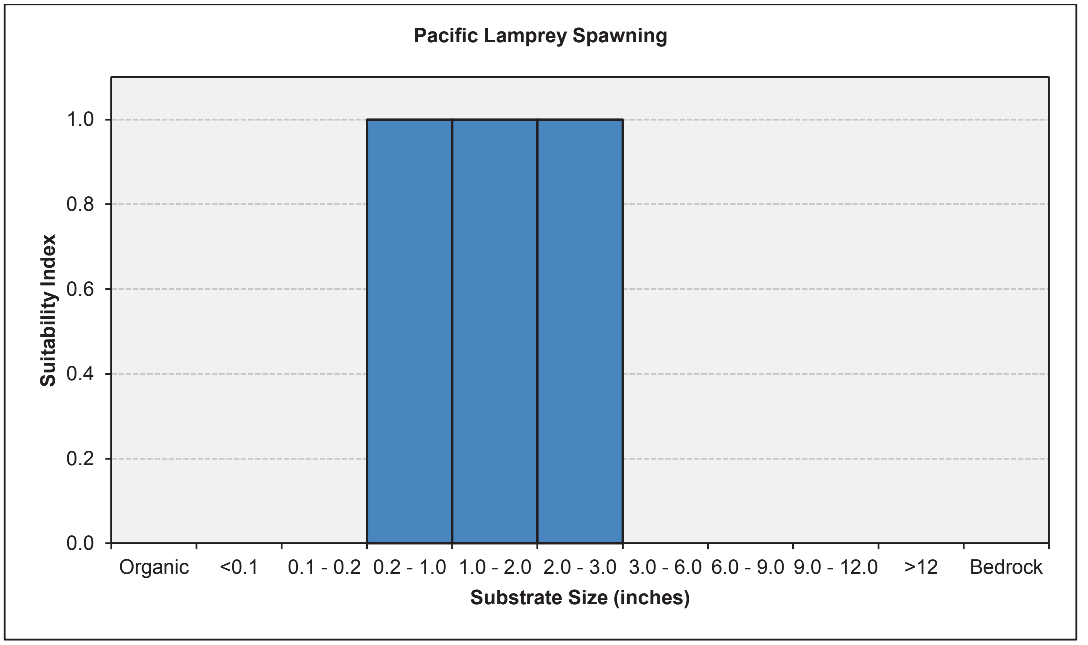

Figure 6. Pacific lamprey spawning dominant substrate suitability criteria for the lower Tuolumne River.

Table 3. Pacific lamprey spawning suitability criteria.

Velocity		Depth		Substrate		
(fps)	**Index**[1]	**(ft)**	**Index**[1]	**Type**	**Size (inches)**	**Index**[1]
0.00	0.00	0.00	0.00	Organic	N/A	0.00
0.66	1.00	0.52	1.00	Silt	<0.1	0.00
3.28	0.00	4.20	0.10	Sand	0.1–0.2	0.00
--	--	--	--	Small gravel	0.2–1	1.00
--	--	--	--	Gravel	1–2	1.00
--	--	--	--	Large gravel	2–3	1.00
--	--	--	--	Small cobble	3–6	0.00
--	--	--	--	cobble	6–9	0.00
--	--	--	--	Large cobble	9–12	0.00
--	--	--	--	Boulder	>12	0.00
--	--	--	--	Bedrock	N/A	0.00

[1] Merced ID 2011

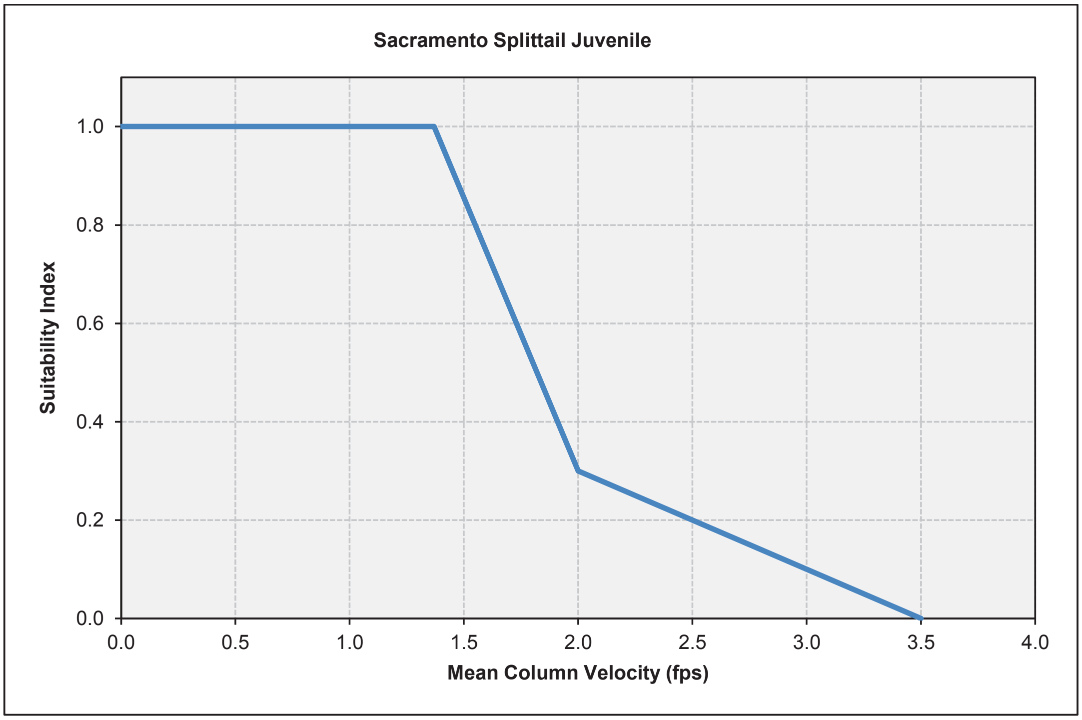

Figure 7. Sacramento splittail juvenile velocity suitability criteria for the lower Tuolumne River.

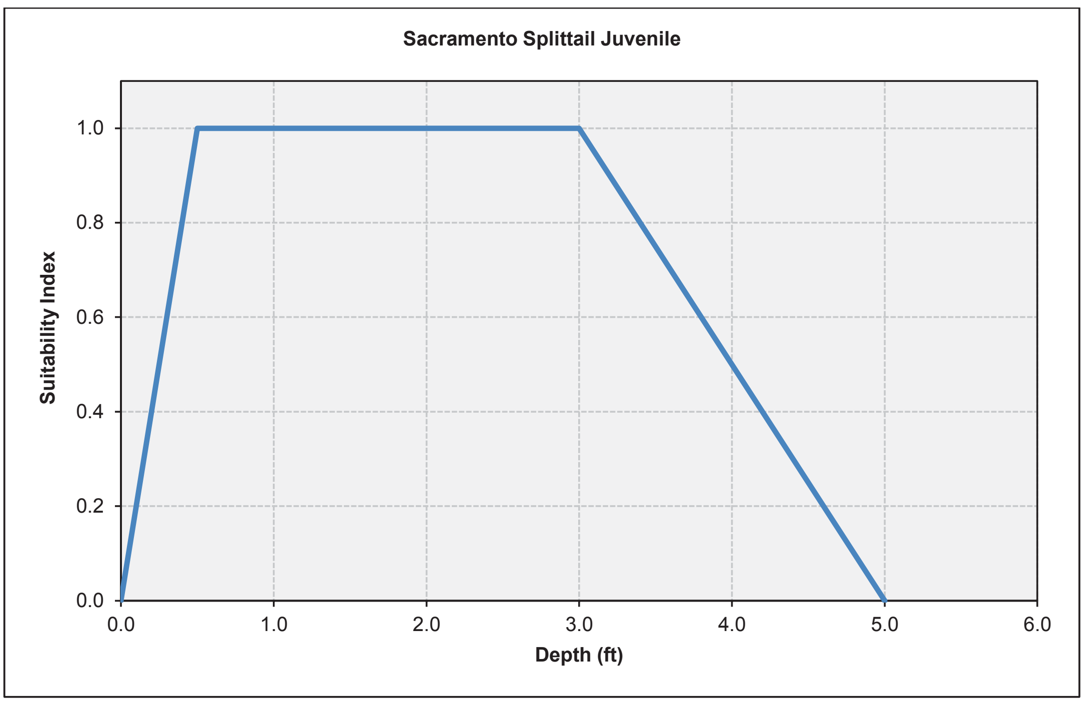

Figure 8. Sacramento splittail juvenile depth suitability criteria for the lower Tuolumne River.

Table 4. Sacramento splittail juvenile suitability criteria.

Velocity		Depth	
(fps)	**Index**[1]	**(ft)**	**Index**[1]
0.00	1.00	0.00	0.00
0.40	1.00	0.50	1.00
1.37	1.00	1.30	1.00
2.00	0.30	3.00	1.00
3.50	0.00	5.00	0.00

[1] Merced ID 2013

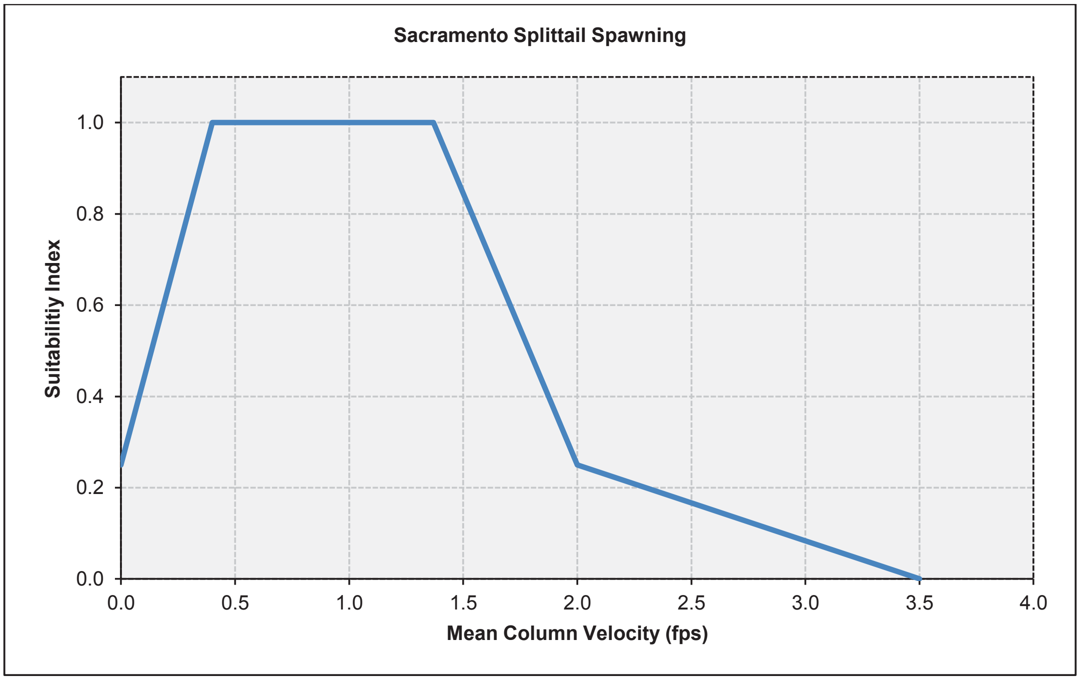

Figure 9. Sacramento splittail spawning velocity suitability criteria for the lower Tuolumne River.

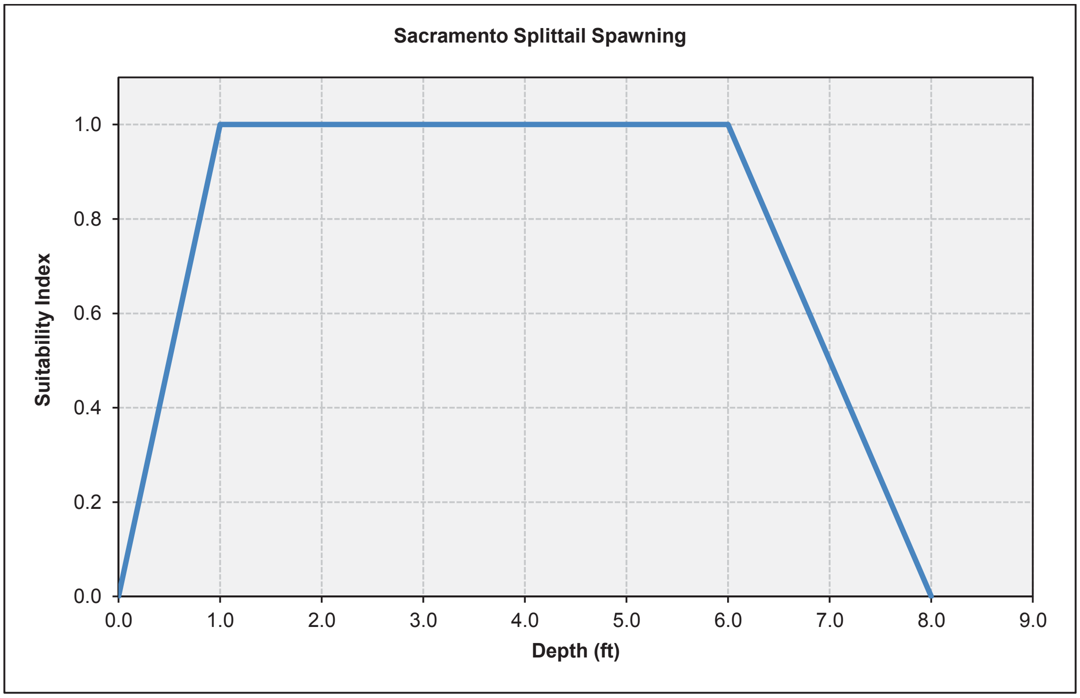

Figure 10. Sacramento splittail spawning depth suitability criteria for the lower Tuolumne River.

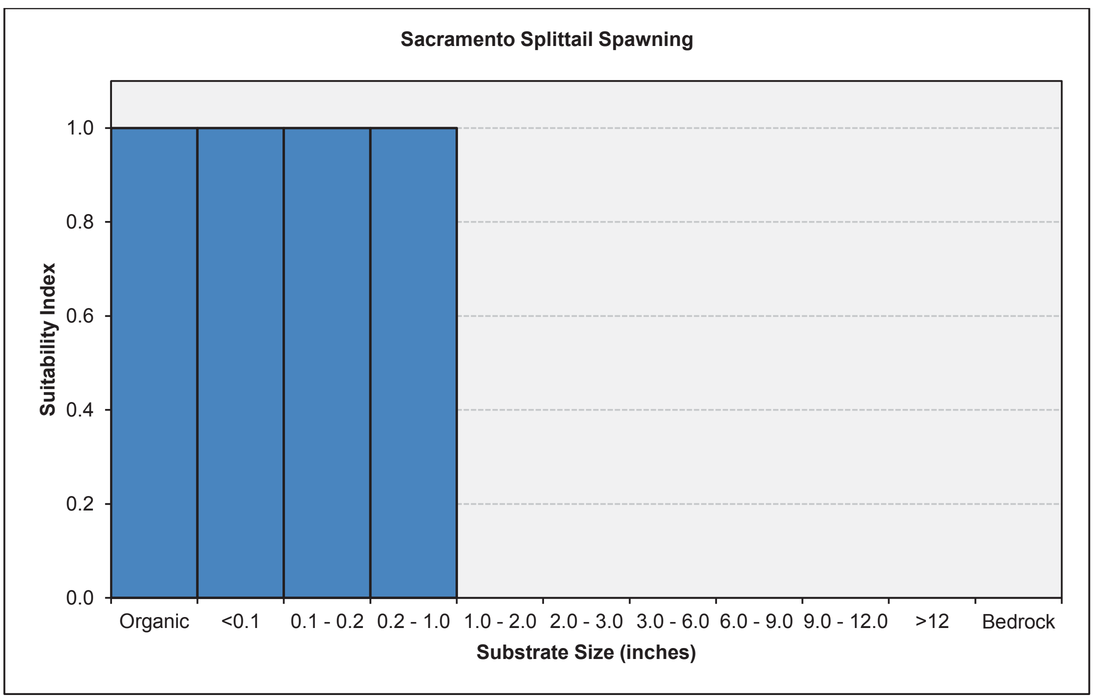

Figure 11. Sacramento splittail spawning dominant substrate suitability criteria for the lower Tuolumne River.

Table 5. Sacramento splittail spawning suitability criteria.

Velocity		Depth		Substrate		
(fps)	**Index[1]**	**(ft)**	**Index[1]**	**Type**	**Size (inches)**	**Index[1]**
0.00	0.25	0.00	0.00	Organic	N/A	1.00
0.40	1.00	1.00	1.00	Silt	<0.1	1.00
1.37	1.00	6.00	1.00	Sand	0.1–0.2	1.00
2.00	0.25	8.00	0.00	Small gravel	0.2–1	1.00
3.50	0.00	--	--	Gravel	1–2	0.00
--	--	--	--	Large gravel	2–3	0.00
--	--	--	--	Small cobble	3–6	0.00
--	--	--	--	Cobble	6–9	0.00
--	--	--	--	Large cobble	9–12	0.00
--	--	--	--	Boulder	>12	0.00
--	--	--	--	Bedrock	N/A	0.00

[1] Merced ID 2013

2.5 Habitat Time Series

A Habitat Time Series (HTS) analysis was conducted to assess how habitat values for each species and life stage vary over time, under different water year type scenarios. Water year types selected for analysis are the five San Joaquin Basin 60-20-20 Index types: Critical, Dry, Below Normal, Above Normal, and Wet, as represented by Water Years 2008-2012 (the most recent years of these index types) and presented in Table 6.

Table 6. San Joaquin Basin 60-20-20 Index, corresponding water year types, and representative water years used for habitat time series analysis in the lower Tuolumne River instream flow study.

San Joaquin Basin 60-20-20 Index[1]	Water Year Type	Representative Water Year
2.06	Critical	2008
2.18	Dry	2012
2.73	Below Normal	2009
3.55	Above Normal	2010
5.59	Wet	2011

[1] DWR Bulletin 132 calculated index

Daily flow values for the lower Tuolumne River were obtained from the USGS gaging station at La Grange Dam (No. 11289560) and were compiled for all Water Year types. No downstream adjustments for accretion or depletion are required in the PHABSIM assessment reach (RM 51.7 to RM 29.0).[2] The associated WUA values were assigned based on the daily flows using a lookup table of WUA values from the PHABSIM results, interpolated to 5 cfs intervals.

[2] The reach represented in the PHABSIM assessment includes RM 51.7 to RM 29.0. Accretion/depletion studies performed by the Districts suggest that flow changes along the study reach (which is upstream of Dry Creek and does not contain major tributaries) are relatively small compared to the scale of most HTS flows and the associated WUA reporting increments, and therefore the HTS results are not adjusted for these changes.

The periodicity of Pacific lamprey and Sacramento splittail was adapted from the Merced River hydroelectric relicensing project due to its close proximity to the lower Tuolumne River (Merced ID 2011, 2013) (Table 7); the Sacramento splittail spawning periodicity was modified to indicate the spawning period for the lower Tuolumne River (Moyle et al. 2004).

Table 7. Species/life stage periodicity for the lower Tuolumne River.

Species	Life stage	Fall			Winter			Spring			Summer		
		O	N	D	J	F	M	A	M	J	J	A	S
Pacific lamprey	Ammocoete												
	Spawning												
Sacramento splittail	Juvenile												
	Spawning												

3 RESULTS

3.1 Weighted Usable Area

Results of the PHABSIM analysis of WUA versus flow relationships for each species and life stage are presented in Figures 12–15 and Tables 8–9. In order to facilitate comparison and analysis, the results are presented and discussed based on a normalized y-axis scale representing "percent of maximum" WUA (Figures 12 and 14).

Results for Pacific lamprey ammocoetes show that their potential habitat is maximized at low flows, with peak WUA values (≥95% of maximum) at flows less than approximately 150 cfs, followed by a slight decline, but still relatively high WUA values (≥80% of maximum) near 450 cfs and then remaining stable over the remaining range of simulated flows (Figures 12 and 13). Results for Pacific lamprey spawning show peak WUA values at approximately 75–150 cfs, with a steady decline, but still relatively high WUA values up to near 250 cfs, followed by a more gradual decline over the remaining range of simulated flows (Figures 12 and 13).

Results for Sacramento splittail juveniles show peak WUA values at approximately 50–175 cfs, with relatively high WUA values below 300 cfs (Figures 14 and 15). Results for Sacramento splittail spawning show high WUA values at about 300-400 cfs, with relatively small increases in WUA values over the remaining simulation range (Figures 14 and 15).

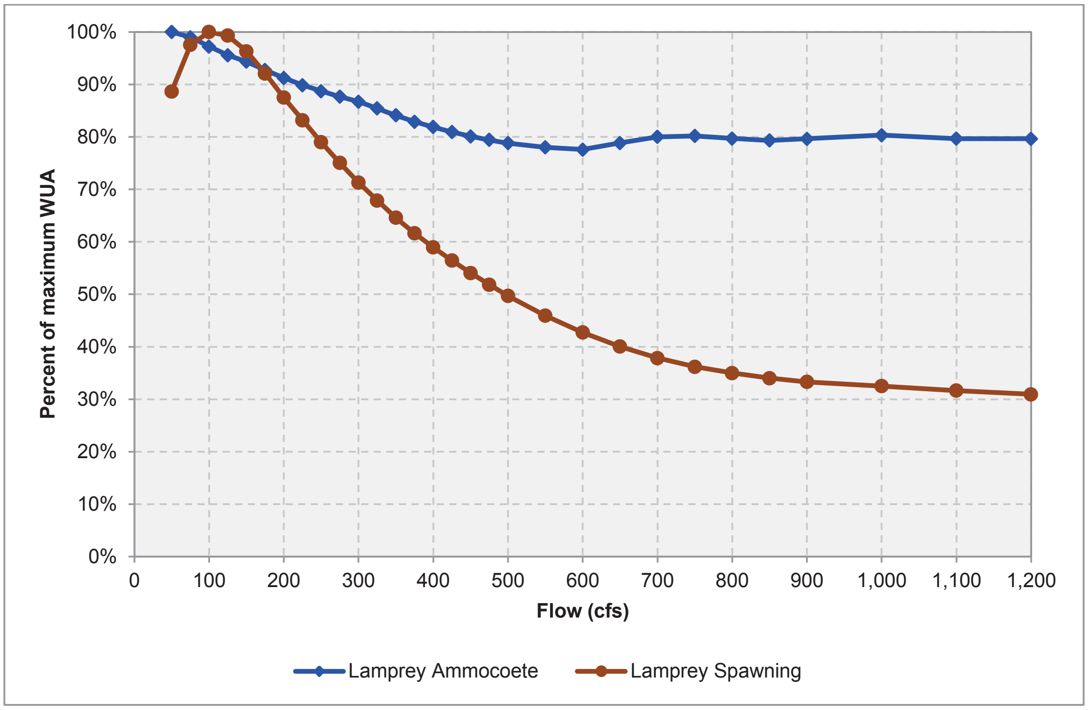

Figure 12. Pacific lamprey WUA results (percent of maximum) for the lower Tuolumne River.

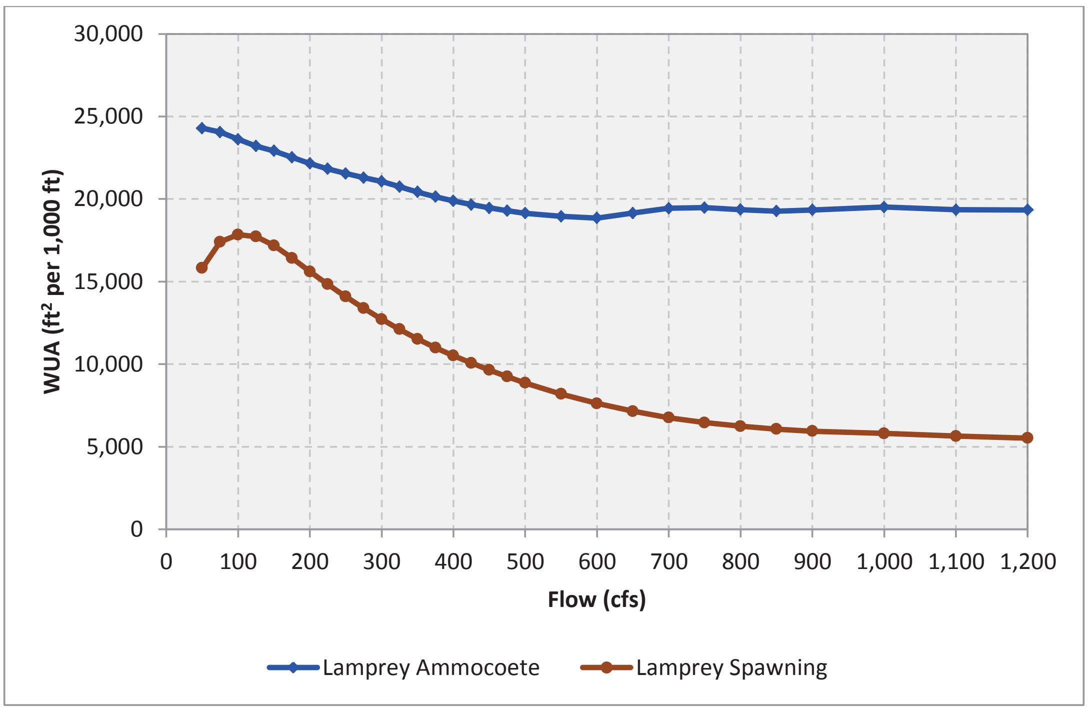

Figure 13. Pacific lamprey WUA results for the lower Tuolumne River.

Table 8. Pacific lamprey WUA results for the lower Tuolumne River.

Simulated discharge (cfs)	Pacific lamprey ammocoete (ft^2 per 1,000 ft)	Pacific lamprey spawning (ft^2 per 1,000 ft)
50	24288.57	15818.00
75	24047.28	17404.11
100	23614.99	17842.49
125	23210.65	17720.25
150	22913.44	17186.22
175	22529.14	16429.56
200	22157.69	15611.94
225	21826.53	14841.16
250	21547.09	14095.15
275	21294.25	13388.09
300	21064.09	12725.28
325	20748.99	12111.84
350	20431.54	11525.86
375	20135.56	10999.58
400	19894.20	10517.03
425	19659.51	10075.10
450	19453.41	9646.10
475	19296.72	9248.33
500	19141.19	8867.14
550	18946.11	8196.07
600	18846.54	7623.26
650	19147.85	7148.60
700	19435.35	6755.09
750	19474.64	6457.57
800	19355.70	6244.06
850	19267.14	6072.78
900	19343.99	5945.62
1000	19508.92	5803.41
1100	19351.98	5646.98
1200	19342.67	5522.68

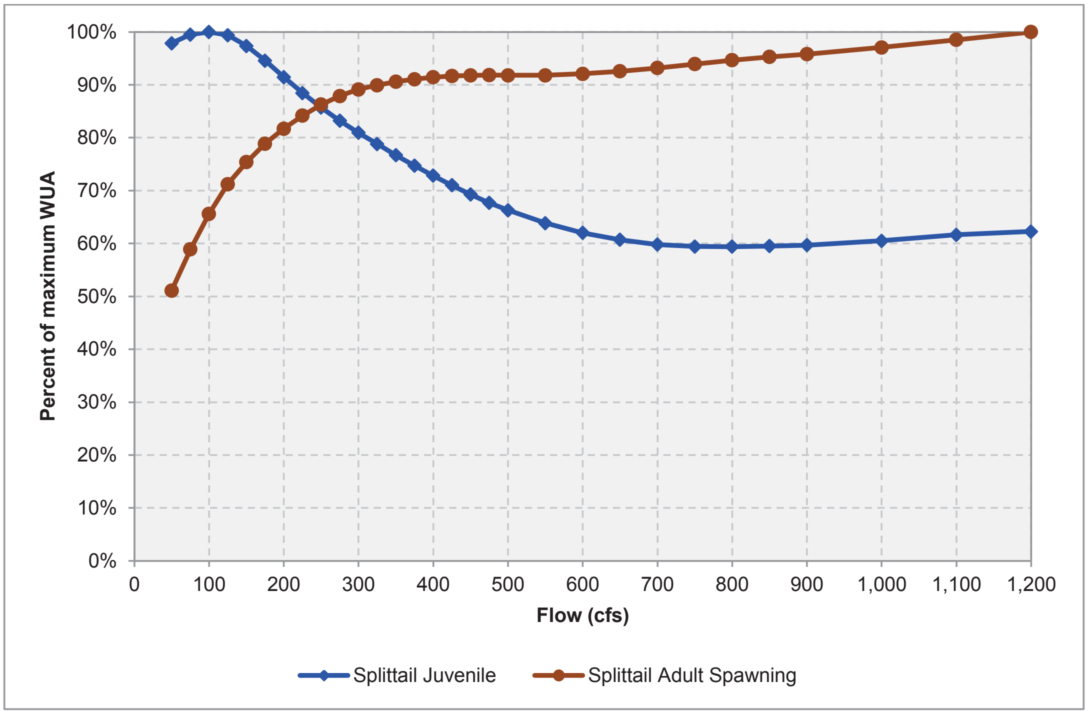

Figure 14. Sacramento splittail WUA results (percent of maximum) for the lower Tuolumne River.

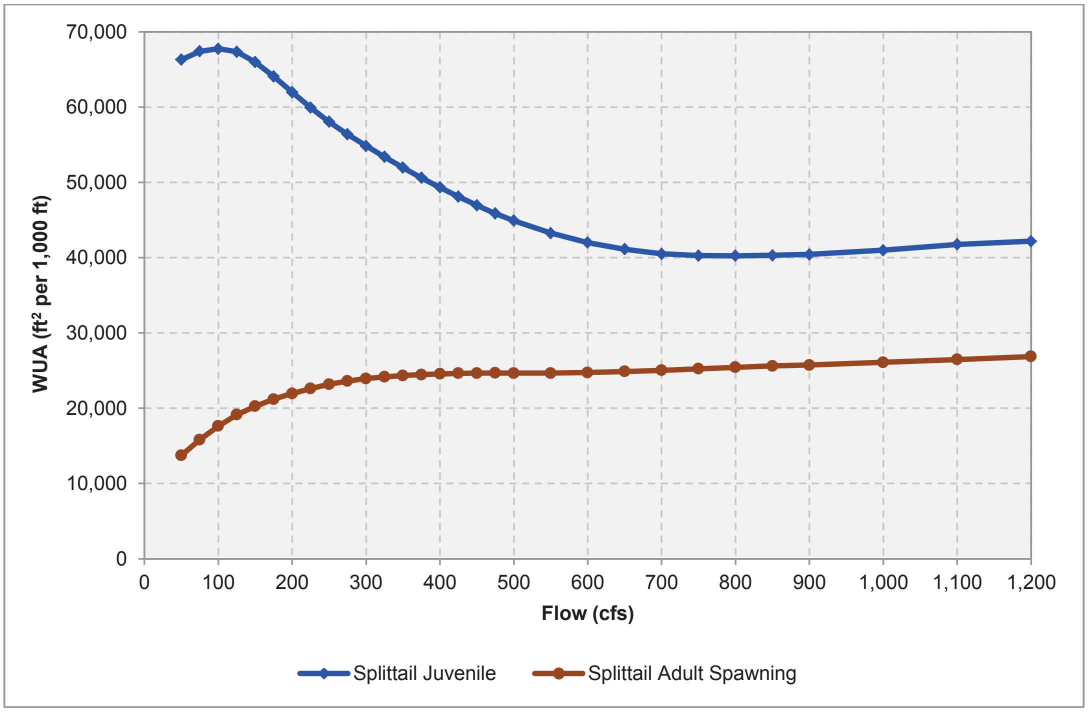

Figure 15. Sacramento splittail WUA results for the lower Tuolumne River.

Table 9. Sacramento splittail WUA results for the lower Tuolumne River.

Simulated discharge (cfs)	Sacramento splittail spawning (ft^2 per 1,000 ft)	Sacramento splittail juvenile (ft^2 per 1,000 ft)
50	13730.95	66296.36
75	15830.43	67407.02
100	17629.23	67745.97
125	19141.98	67343.51
150	20259.21	65966.16
175	21198.40	64075.29
200	21959.39	61966.49
225	22619.46	59919.42
250	23187.14	58058.00
275	23615.71	56379.65
300	23953.35	54844.25
325	24168.83	53399.74
350	24343.61	51967.60
375	24460.33	50607.40
400	24569.94	49339.50
425	24640.72	48118.83
450	24660.87	46937.17
475	24674.46	45858.11
500	24668.73	44906.92
550	24670.27	43254.15
600	24743.66	42006.93
650	24875.21	41122.02
700	25040.35	40507.25
750	25242.78	40266.80
800	25434.96	40244.34
850	25609.38	40315.27
900	25744.88	40437.44
1000	26087.91	40987.27
1100	26474.78	41768.93
1200	26871.41	42183.33

3.2 Habitat Time Series

Habitat Time Series (HTS) results for each of five water year types (using the San Joaquin River 60-20-20 Index) and four species and life stage combinations are presented in Figures 16–25. The time periods used in the habitat time series analysis are when individual life stages are most typically observed, or could theoretically be present, within the study reach based on the periodicity shown in Table 7.

Consistent with the HTS analysis of Chinook salmon and *O. mykiss* (Stillwater Sciences 2013), WUA values were maintained at the 1,200 cfs level for flows over the WUA extrapolation limit of 1,200 cfs. This approach assumes that in-channel WUA will not get significantly higher (or will get higher, then descend again) or lower (or go lower and rise again or level off) than where it was at 1,200 cfs. This is a more conservative approach, but it does have the drawback that all flows above 1,200 cfs will return the same WUA value (e.g "flatline") and a depiction of potential variability at higher flows is lost. Figures 26 and 27 present HTS results across all water year types for Pacific lamprey and Sacramento splittail, respectively, and facilitate comparisons of patterns between water year types.

Under Critical, Dry, and Below Normal year scenarios, Pacific lamprey ammocoete WUA remains relatively stable. Pacific lamprey spawning WUA fluctuates with flow until flow nears 1,200 cfs, where WUA is minimized. Sacramento splittail juvenile WUA is maximized during periods of low flow and quickly drops when flow increases. In contrast, Sacramento splittail spawning WUA is minimized at lower flows and increases as flows increase above 1,000 cfs.

Under Above Normal and Wet year scenarios, Pacific lamprey ammocoete WUA remains relatively stable. Pacific lamprey spawning WUA decreases with increased flow, until flow nears 1,200 cfs where WUA is minimized. Sacramento splittail juvenile WUA are minimized when flow increases above approximately 600 cfs. Sacramento splittail spawning WUA is maximized as flow increases up to 1,200 cfs.

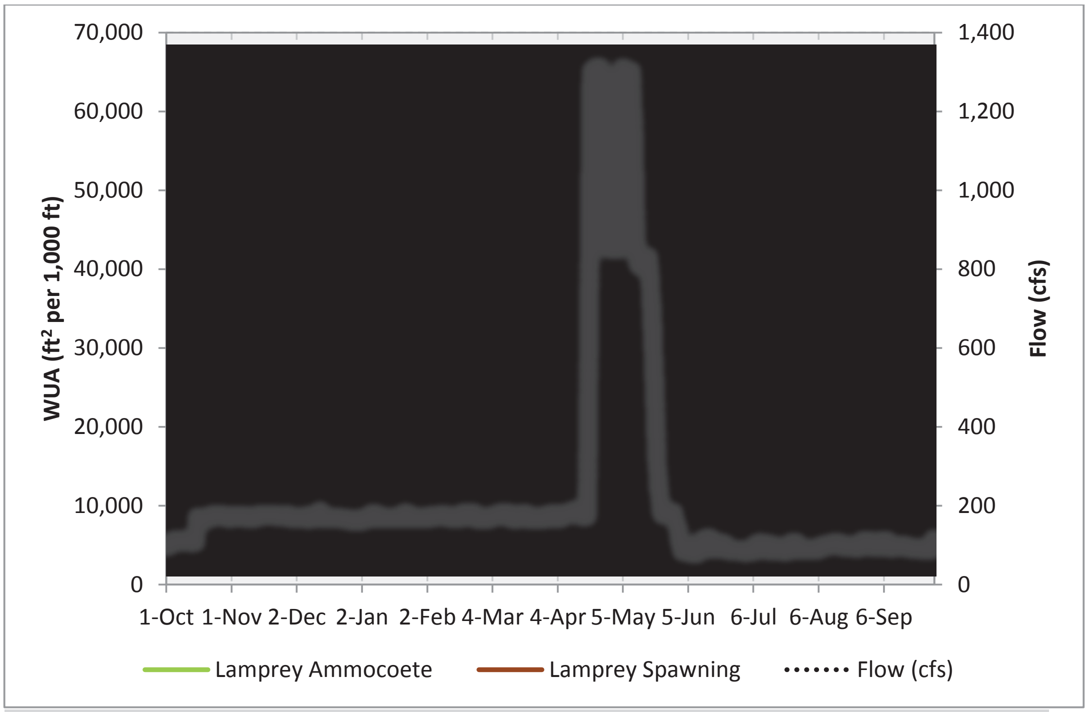

Figure 16. Habitat Time Series results for lower Tuolumne River Pacific lamprey in a Critical water year (2008).

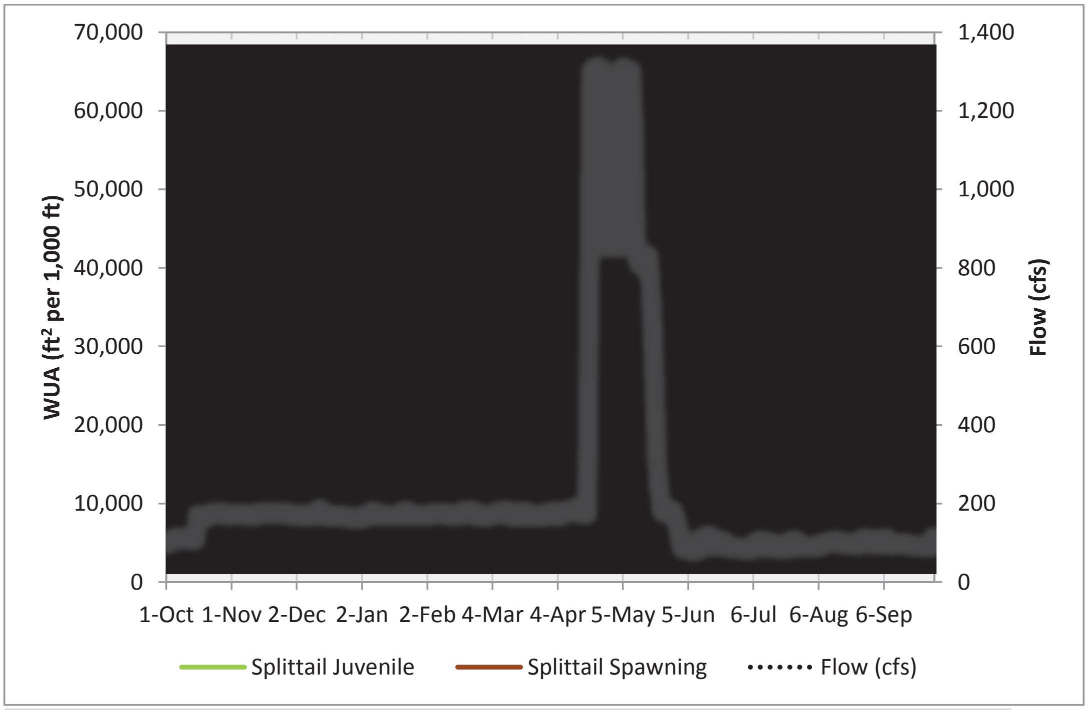

Figure 17. Habitat Time Series results for lower Tuolumne River Sacramento splittail in a Critical water year (2008).

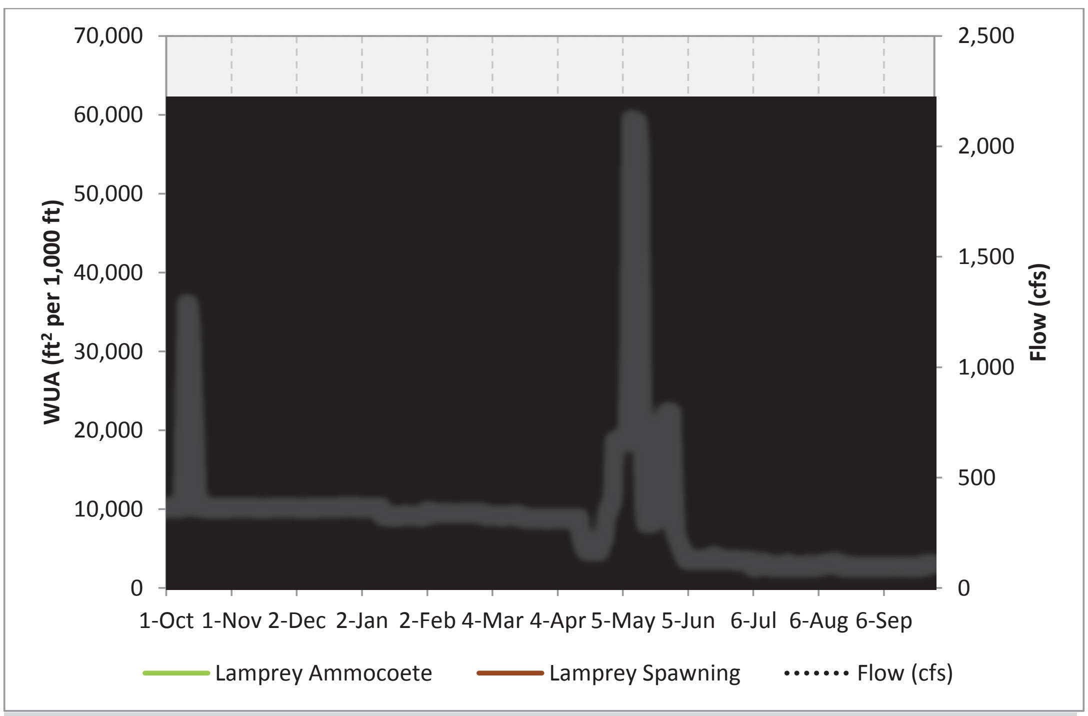

Figure 18. Habitat Time Series results for lower Tuolumne River Pacific lamprey in a Dry water year (2012).

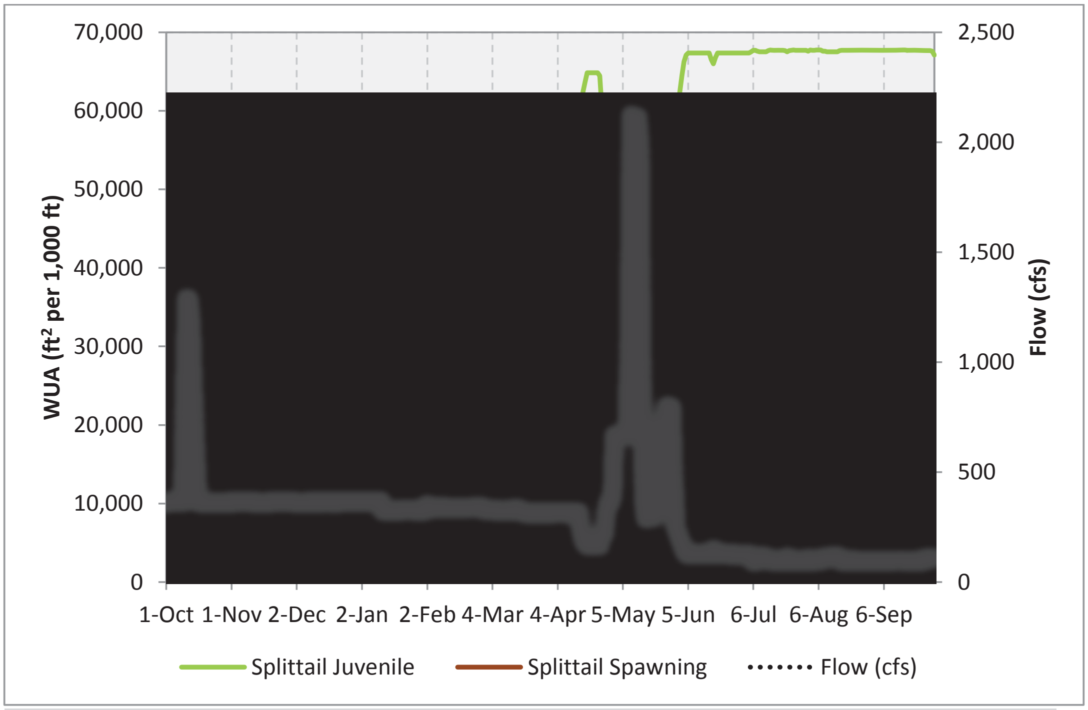

Figure 19. Habitat Time Series results for lower Tuolumne River Sacramento splittail in a Dry water year (2012).

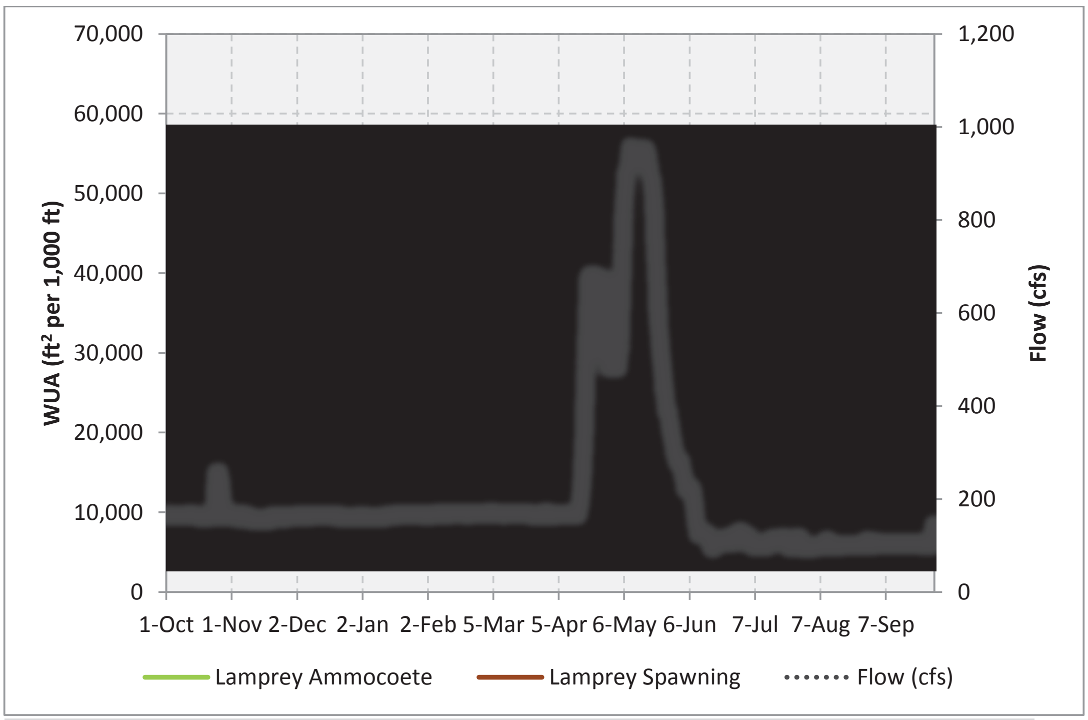

Figure 20. Habitat Time Series results for lower Tuolumne River Pacific lamprey in a Below Normal water year (2009).

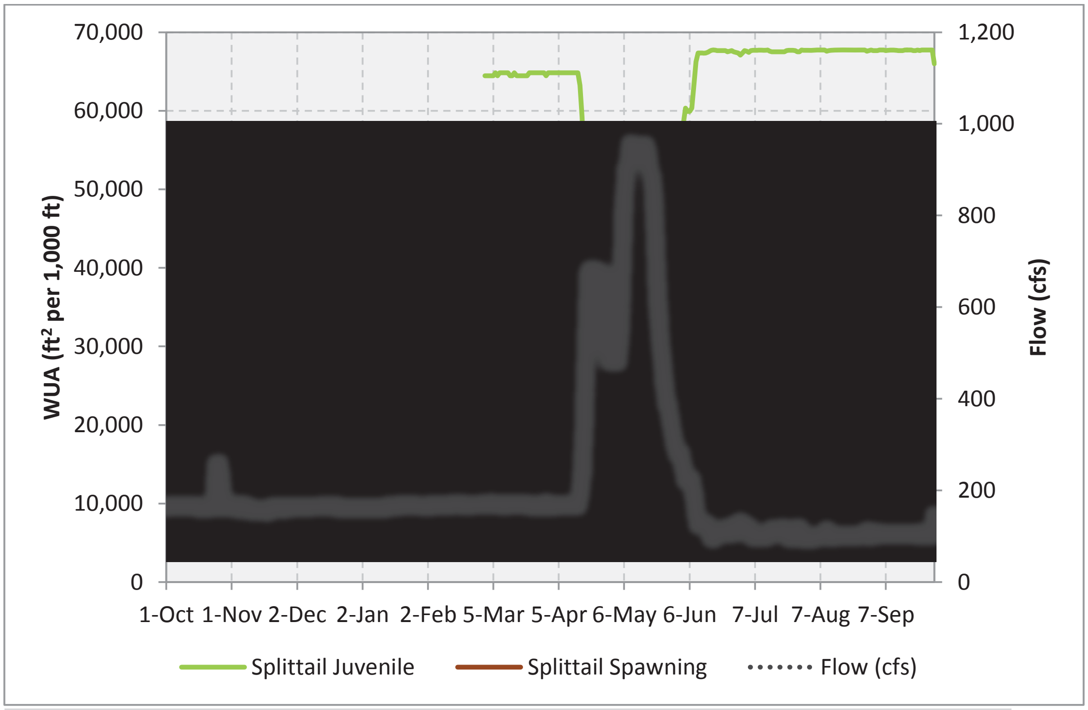

Figure 21. Habitat Time Series results for lower Tuolumne River Sacramento splittail in a Below Normal water year (2009).

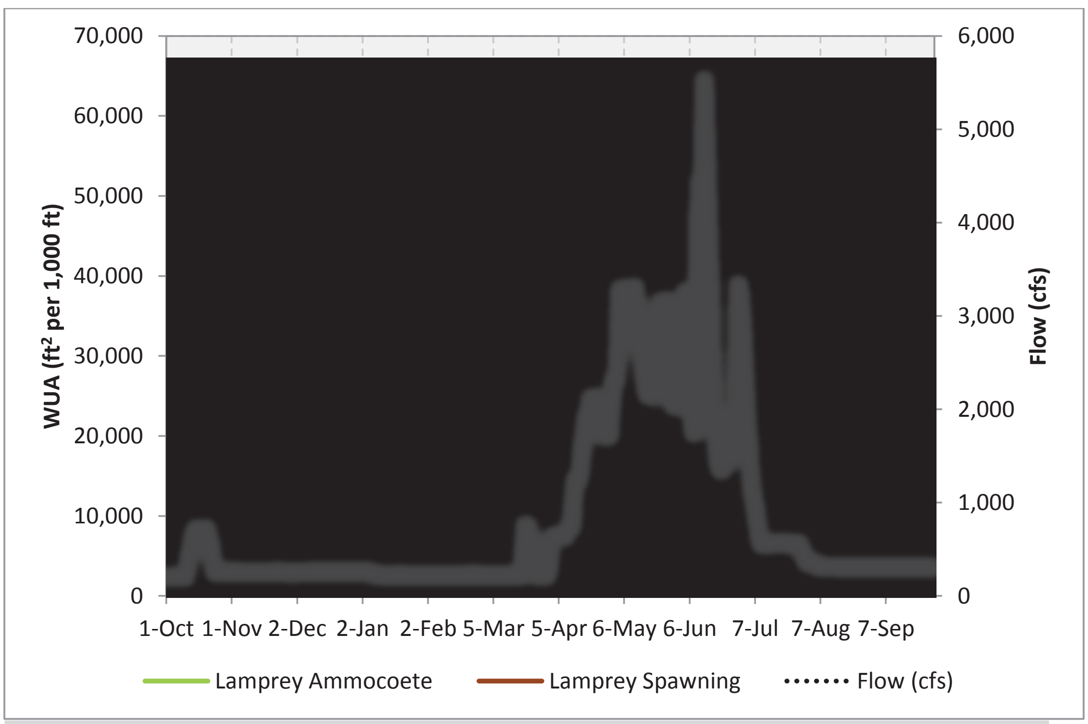

Figure 22. Habitat Time Series results for lower Tuolumne River Pacific lamprey in an Above Normal water year (2010).

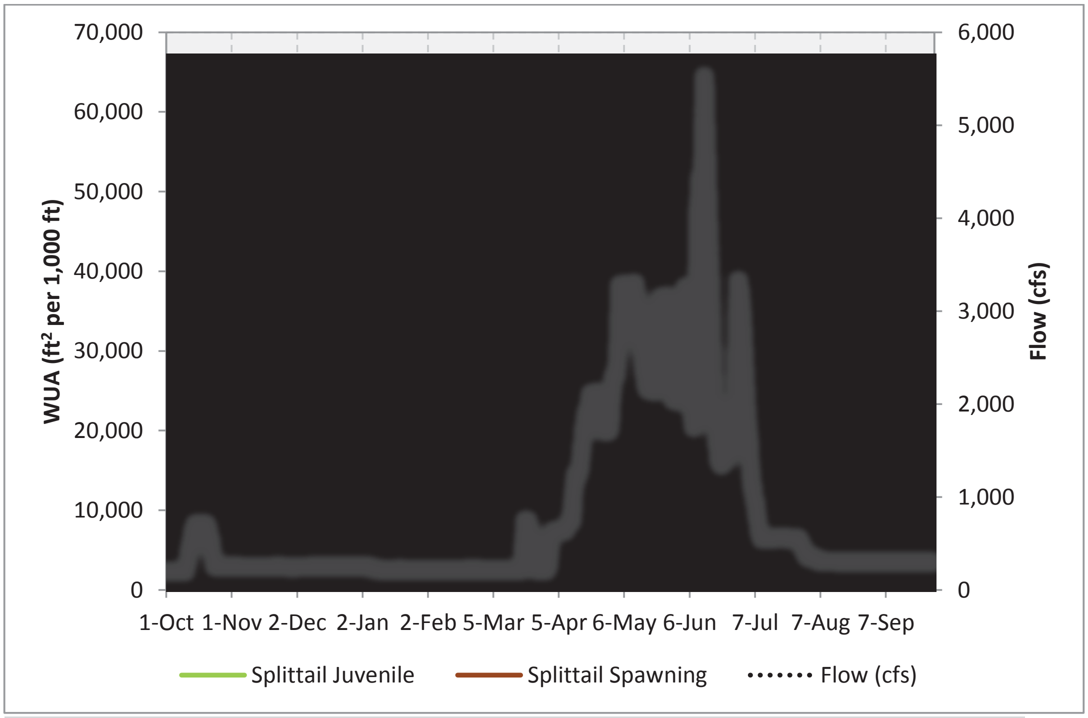

Figure 23. Habitat Time Series results for lower Tuolumne River Sacramento splittail in an Above Normal water year (2010).

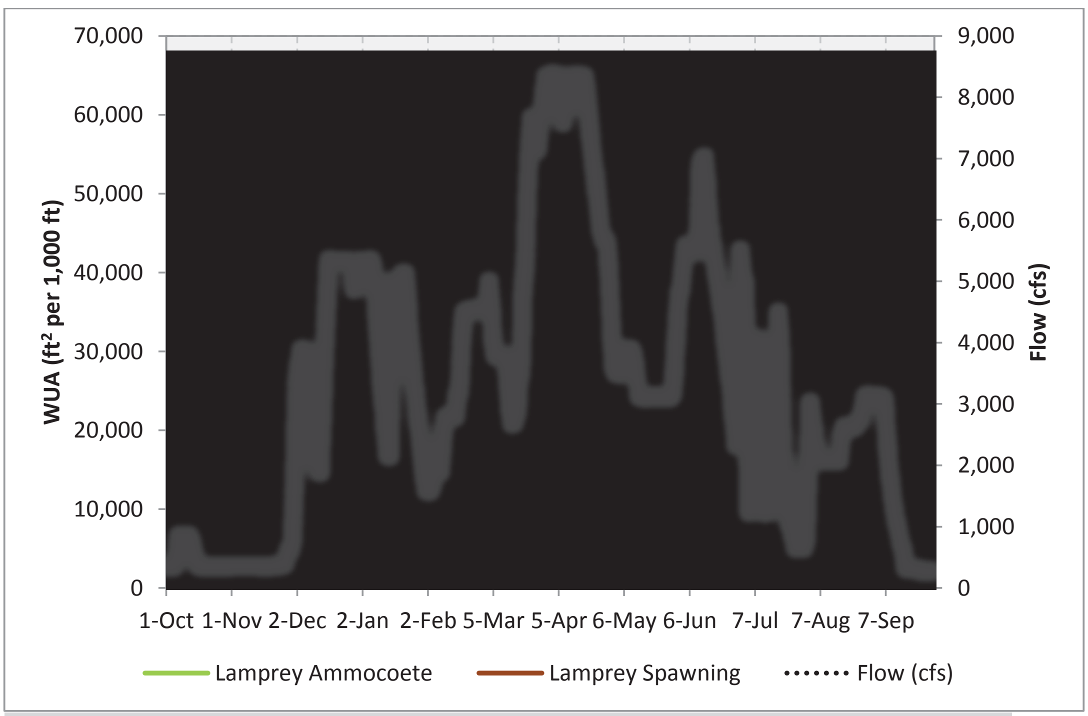

Figure 24. Habitat Time Series results for lower Tuolumne River Pacific lamprey in a Wet water year (2011).

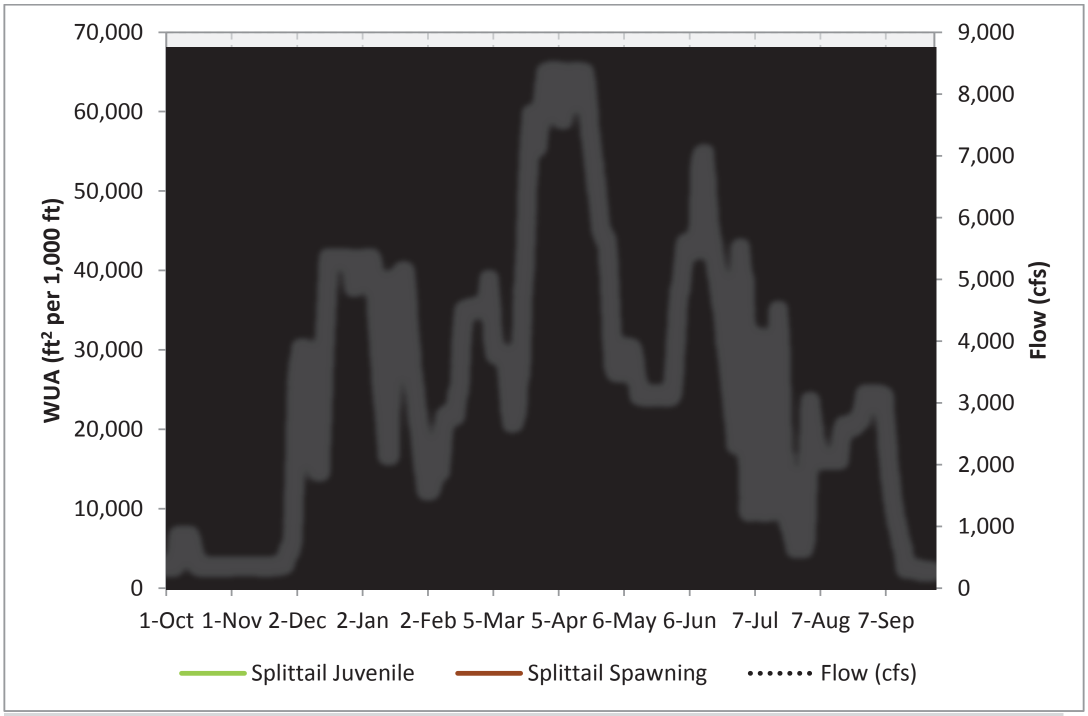

Figure 25. Habitat Time Series results for lower Tuolumne River Sacramento splittail in a Wet water year (2011).

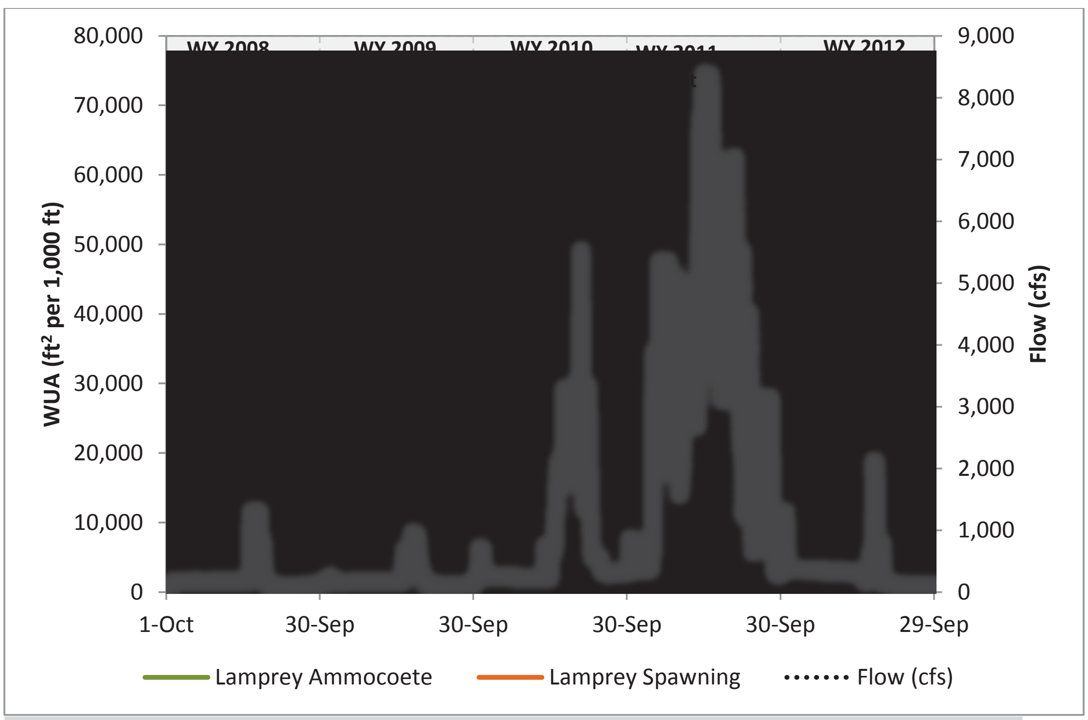

Figure 26. Habitat Time Series results for lower Tuolumne River Pacific lamprey across all water year types.

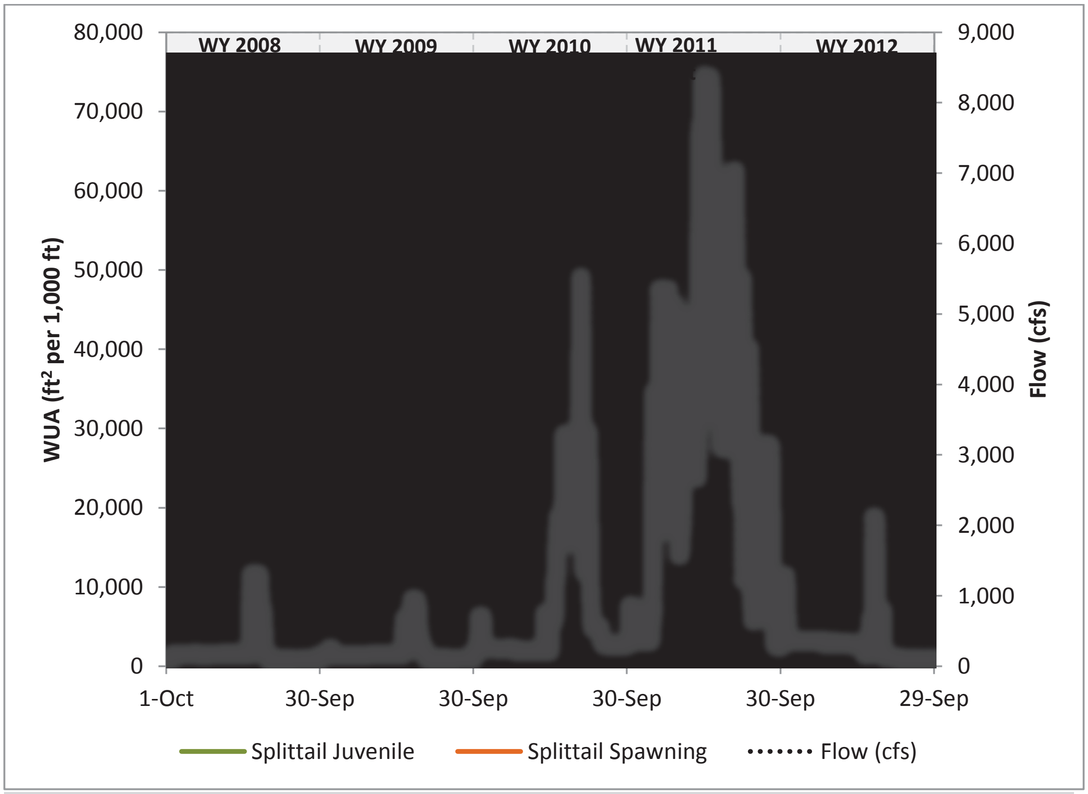

Figure 27. Habitat Time Series results for lower Tuolumne River Sacramento splittail across all water year types.

4 DISCUSSION

4.1 Pacific Lamprey in the Lower Tuolumne River

Pacific lamprey are present in the study reach between La Grange Dam (RM 52) and below Waterford (RM 29). Lamprey ammocoetes are present year-round and typically prefer slow backwater or edgewater habitat, which is available in the study reach across all of the modeled flows. Subsequently, habitat availability (as measured by WUA) for ammocoetes is consistent across a range of flows. In contrast, lamprey spawning may be limited by higher flows in the late winter and spring, as habitat availability decreases with increases in flow. As a result, lamprey spawning habitat declines during flood control or other high flow releases in the spring.

4.2 Sacramento Splittail in the Lower Tuolumne River

Sacramento splittail have not been observed in the study reach between La Grange Dam (RM 52) and below Waterford (RM 29). Splittail inhabit low gradient valley-floor estuaries and streams, and can tolerate a broad range of salinities and temperatures. They have been observed in the lower Tuolumne River as far up as the City of Modesto during wet years, and have been reported to spawn in the lower 6.8 miles of the river (Moyle et al. 1995). Adults are expected to gradually move into the lower Tuolumne in the winter and spring but may migrate more rapidly during flood periods. Adult splittail will forage and opportunistically spawn in flooded areas, after which the young-of-year/juveniles migrate downstream into the estuary by summer (Moyle 2002).

The section of the Tuolumne River where splittail have been observed is within the slow-moving, low-gradient, sand-bedded reach. Water temperatures in this reach are generally influenced by ambient air temperatures, as opposed to releases from Don Pedro Dam. The instream flow study reach (RM 29–52) is within the higher-gradient, gravel-bedded reach further upstream, and generally contains cooler stream temperatures.

The WUA results were extrapolated to the study reach only (RM 29–52). As a result, shallow depths and low velocities preferred by juvenile splittail are maximized at lower flows in this higher gradient reach. However, the WUA results are not directly applicable to the portion of the river (RM 0.0–6.8) where the species is known to occur. .

4.3 Next Steps

This draft report complies with requirements of the Commission's December 22, 2011 Study Plan Determination for the Don Pedro Project relicensing studies, which expanded the flow-habitat assessments to be undertaken to include lamprey and splittail. Following a 30-day review and comment period on the results, the final report will be provided in the Districts' Final License Application to be filed with FERC by April 30, 2014.

A remaining component of the *Lower Tuolumne River Instream Flow Studies* 1-D PHABSIM investigation includes an effective habitat analysis, to be completed following the completion of the *Lower Tuolumne River Temperature Model* (relicensing study W&AR-16). The river temperature model report was submitted to relicensing participants for review and comment as part of the Districts' USR. The effective habitat analysis evaluation is expected to be completed (including a 30-day resource agency review period) following the relicensing participants' review and comment on W&AR-16 and will be filed with FERC by August 2014.

Habitat assessments for non-native predatory fish, including smallmouth bass, largemouth bass, and striped bass will be completed by the Districts and submitted to relicensing participants in conjunction with the Districts' 2014 Predation Study. The Districts will submit both studies to relicensing participants for a 30-day review and comment period in December 2014 or January 2015. The final report will be submitted to FERC to supplement the Final License Application.

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Walker, Colleen

From: Staples, Rose
Sent: Thursday, January 16, 2014 9:43 AM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; White, David K; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Don Pedro USR Meeting Presentations Available on Relicensing Website

Copies of the PowerPoint presentations being used at today's Don Pedro Updated Study Report (USR) meeting in Modesto at the MID Offices have been uploaded to the Don Pedro Project Relicensing Website at www.donpedro-relicensing.com. Click on the CALENDAR tab and then click on the USR meeting announcement for January 16th. You will find the copies attached to that announcement. If you have any problems locating and/or accessing the files, please let me know. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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207.239.3857 | f: 207.775.1742
rose.staples@hdrinc.com | hdrinc.com

From: Staples, Rose
Sent: Tuesday, January 28, 2014 2:36 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Costa, Jan; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Hurley, Michael; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Martin, Ramon; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Paul, Duane; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Ulm, Richard; Vasquez, Sandy; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject: Upcoming February 2014 Don Pedro Training Sessions

In response to requests made at the January 16, 2014, Updated Study Report (USR) meeting, the Districts are proposing to hold **training sessions** on use of the Reservoir Temperature Model and the two fish population models. The Districts are also proposing to conduct a Workshop/meeting on the Floodplain Hydraulic Assessment (W&AR-21) model development.

Also, related to the La Grange licensing, please be aware that the PAD is to be issued and filed this Wednesday, January 29, 2014, to initiate that licensing process. We would like to hold a meeting with parties interested in the La Grange licensing to discuss possible use of the Traditional Licensing Process (TLP) instead of the ILP.

All of these meeting dates are provided below and all meetings are to be held in HDR's Sacramento office. The Districts have tried to schedule these meetings so they occur on a timely basis and to limit conflicts. We recognize that there is a Yuba Forum meeting on Thursday, February 13 (also at HDR's office), and this may present a conflict for a few people. The Districts are hopeful that any affected party might be able to arrange to join either the Don Pedro morning or afternoon session on the 13th as your interests allow.

- **Thursday, Feb 13, 2014 - 9 am to Noon**: **Reservoir Temperature Model Training,** as requested at the January 16, 2014, USR Meeting. Please bring your computer. We'll load the model on each computer and navigate its use. There will also be instructions for accessing the dedicated Citrix server located in HDR, but due to the same limitations discovered during the last training session of trying to connect individual, non-HDR computers through the HDR – Sacramento server and then on to the Citrix server, we suggest each individual attempt access to Citrix through your own systems some time before the meeting, then let us know if you are having any difficulty.

- **Thursday, Feb 13, 2014 - 1:30 pm to 4:30 pm**: **Floodplain Hydraulic Assessment Workshop**. The Districts have established the topography/bathymetry for a multi-mile pilot reach for the TUFLOW model and would like to share the resulting terrain model with relicensing participants. Therefore, the primary purpose of the meeting will be to share the model geometry and consult on the demarcation of the in-stream portion of the model (I-D flow portion of TUFLOW) and the overbank portion of the model (the 2-D flow portion) prior to the start of any modeling.

- **Monday, Feb 24, 2014 - 9 am to Noon**: **Fish Population Models training.** Stillwater's GUI is complete and the meeting will provide an opportunity for training in its use. Please bring your own computer and we will load the model and GUI.

- **Monday, Feb 24, 2014 - 1:30 pm to 3:30 pm**: **La Grange Licensing.** The Districts would like to discuss possible use of the TLP instead of the ILP for the La Grange licensing. The Districts believe this would be less burdensome on all parties, especially over the next 12 months; and given that it is likely that most, but certainly not all, of the necessary studies have been conducted as part of the Don Pedro relicensing, use of the TLP may be a better use of everyone's limited resources.

Please respond to me at rose.staples@hdrinc.com by Friday, January 31, 2014, as to which meetings you anticipate attending. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

From: Staples, Rose
Sent: Tuesday, January 28, 2014 8:33 PM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; Beeco, Adam; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; Cooke, Michael; 'Costa, Jan'; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; Hurley, Michael; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Martin, Michael'; 'Martin, Ramon'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; Mills John; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Paul, Duane'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; Reynolds, Garner; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Ulm, Richard'; 'Vasquez, Sandy'; 'Verkuil, Colette'; 'Vierra, Chris'; Villalobos, Amber; 'Wantuck, Richard'; 'Welch, Steve'; 'Wenger, Jack'; 'Wesselman, Eric'; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject: Don Pedro USR Meeting Summary Filed With FERC Jan 27

The Districts have filed with FERC the Don Pedro Project Relicensing *USR Meeting Summary***,** from the USR meeting held on January 16th. A copy of the document can be viewed / downloaded from FERC's E-Library at www.ferc.gov – and a copy has also been uploaded to the Don Pedro Relicensing website at www.donpedro-relicensing.com, under the CALENDAR tab as an attachment to the January 27 calendar date. If you have any problems accessing and/or downloading the document, please let me know. Thank you.

ROSE STAPLES
CAP-OM

HDR Engineering, Inc.
Executive Assistant, Hydropower Services

From: Staples, Rose
Sent: Tuesday, February 11, 2014 12:23 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Hurley, Michael; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Ward, Walt; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject:Upcoming Don Pedro Model Training Sessions
Attachments: Computer Requirements for Feb 24 Training_140211.docx

This is a reminder of upcoming model trainings (Feb 13 and 24) for the Don Pedro relicensing (to be held at the HDR Office in Sacramento). If you have not already RSVP'd, please do so to Rose.Staples@hdrinc.com to ensure we have the appropriate computer equipment available for you.

* Thursday, Feb 13, 2014 - 9 am to Noon: Reservoir Temperature Model Training. Please attempt to log-on to the HDR Citrix server from your own system prior to the meeting with the password you previously set up (if you

attended the prior MIKE3 model training). Let us know if you have any difficulties using the log-in procedures so we can address those. If you do not have credentials for log-in, we will provide you with new credentials at the meeting and will be reviewing the entire log-in process. However, you will not need to log-in to the Citrix server for the training session, nor will you need to bring your own computer to the workshop. HDR will have computers available pre-loaded with the MIKE3 model available for use during the training. If you do prefer to bring your own computer to the training, please contact jesse.fernandes@hdrinc as soon as possible today for instructions for downloading the MIKE3 software from DHI.

* Thursday, Feb 13, 2014 - 1:30 pm to 4:30 pm: Floodplain Hydraulic Assessment Workshop. No software is required. The Districts have established the topography/bathymetry for a multi-mile pilot reach for the TUFLOW model and would like to share the resulting terrain model with relicensing participants. Therefore, the primary purpose of the meeting will be to share the model geometry and consult on the demarcation of the in-stream portion of the model (I-D flow portion of TUFLOW) and the overbank portion of the model (the 2-D flow portion) prior to the start of any modeling.

* Monday, Feb 24, 2014 - 9 am to Noon: Fish Population Models training. The instructions for downloading the software required for this training are attached to this email. Stillwater's GUI is complete and the meeting will provide an opportunity for training in its use. Please bring your own computer and we will load the model and GUI.

* Monday, Feb 24, 2014 - 1:30 pm to 3:30 pm: La Grange Licensing. No software or computer required. The Districts would like to discuss possible use of the TLP instead of the ILP for the La Grange licensing. The Districts believe this would be less burdensome on all parties, especially over the next 12 months; and given that it is likely that most, but certainly not all, of the necessary studies have been conducted as part of the Don Pedro relicensing, use of the TLP may be a better use of everyone's limited resources.

ROSE STAPLES
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HDR Engineering, Inc.
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970 Baxter Boulevard, Suite 301 | Portland, ME 04103
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rose.staples@hdrinc.com| hdrinc.com

FINAL Population Model Training Computer Requirements
February 2014

Individuals planning to attend the Population Model Training on Monday, February 24 are encouraged to bring their personal computers to the training session. To run the population models, each computer must have (a) **a current web browser** and (b) **R**, which is a language and environment for statistical computing and graphics. Once R is installed, the "shiny" package must be installed.

A. **A current web browser**. To run the population models, your computer must have a current version of a web browser. We recommend that your computer have a current version of Google Chrome (version 14.0 or higher), Mozilla Firefox (version 26.0 or higher), or Internet Explorer (version 10.0 or higher).

B. **R**. To run the population models, your computer must have R. R may be downloaded for free from the internet. If your computer has Microsoft Windows, please follow the steps below. If your computer has Linux or (Mac) OS X, please follow Steps 1 through Step 3, at which point you will choose the link that is appropriate for your operating system.

1. Go to www.r-project.org.
2. In the left scrollbar, click on **CRAN**.
3. Under CRAN Mirrors, scroll down to USA and click on the link for the University of California, Berkeley, CA (http://cran.cnr.Berkeley.edu).
4. Under Download and Install R, there are three download links to choose from. Please choose the link applicable to your computer. Steps 5 through 11 assume you choose to download R for Windows.
5. Click on **Download R for Windows**.
6. Click on **base**.
7. Click on **Download R 3.0.2 for Windows**.
8. A box will appear asking if you want to run or save the file. Choose Save.
9. Save the file to your computer.
10. Once R is saved to your computer, R must be run to complete the installation. Completing the setup for R likely requires administrative privileges.
11. Complete the R Setup.
12. Last, you will need to install the package "Shiny"
    1. Open R.
    2. Type `install.packages("shiny")`
    3. A box will appear asking if you would like to use a personal library instead. Click **Yes**.
    4. A box will appear asking if you would like to create a personal library to install packages into. Click **Yes**.
    5. A box containing a list of CRAN mirrors will appear. Click **USA (CA 2)**.
    6. Once the package is finished downloading, R will be ready to use.

If you have any questions or problems downloading R, please contact Jesse Fernandes at jesse.fernandes@hdrinc.com.

From: Staples, Rose
Sent: Tuesday, February 25, 2014 2:40 PM
To: Alves, Jim; Amerine, Bill; Asay, Lynette; Barnes, James; Barnes, Peter; Barrera, Linda; Beeco, Adam; Blake, Martin; Bond, Jack; Borovansky, Jenna; Boucher, Allison; Bowes, Stephen; Bowman, Art; Brenneman, Beth; Buckley, John; Buckley, Mark; Burke, Steve; Burt, Charles; Byrd, Tim; Cadagan, Jerry; Carlin, Michael; Charles, Cindy; Cooke, Michael; Cowan, Jeffrey; Cox, Stanley Rob; Cranston, Peggy; Cremeen, Rebecca; Damin Nicole; Day, Kevin; Day, P; Denean; Derwin, Maryann Moise; Devine, John; Dowd, Maggie; Drake, Emerson; Drekmeier, Peter; Edmondson, Steve; Eicher, James; Fargo, James; Fernandes, Jesse; Ferranti, Annee; Ferrari, Chandra; Findley, Timothy; Fleming, Mike; Fuller, Reba; Furman, Donn W; Ganteinbein, Julie; Giglio, Deborah; Gorman, Elaine; Grader, Zeke; Gutierrez, Monica; Hackamack, Robert; Hastreiter, James; Hatch, Jenny; Hayden, Ann; Hellam, Anita; Heyne, Tim; Holley, Thomas; Holm, Lisa; Horn, Jeff; Horn, Timi; Hudelson, Bill; Hughes, Noah; Hughes, Robert; Hume, Noah; Hurley, Michael; Jackson, Zac; Jauregui, Julia; Jennings, William; Jensen, Laura; Johannis, Mary; Johnson, Brian; Jones, Christy; Jsansley; Justin; Keating, Janice; Kempton, Kathryn; Kinney, Teresa; Koepele, Patrick; Kordella, Lesley; Le, Bao; Levin, Ellen; Linkard, David; Loy, Carin; Lwenya, Roselynn; Lyons, Bill; Madden, Dan; Manji, Annie; Marko, Paul; Martin, Michael; Mathiesen, Lloyd; McDaniel, Dan; McDevitt, Ray; McDonnell, Marty; Mein Janis; Mills John; Morningstar Pope, Rhonda; Motola, Mary; Murphey, Gretchen; Murray, Shana; O'Brien, Jennifer; Orvis, Tom; Ott, Bob; Ott, Chris; Pavich, Steve; Pool, Richard; Porter, Ruth; Powell, Melissa; Puccini, Stephen; Raeder, Jessie; Ramirez, Tim; Rea, Maria; Reed, Rhonda; Reynolds, Garner; Richardson, Daniel; Richardson, Kevin; Ridenour, Jim; Riggs T; Robbins, Royal; Romano, David O; Roos-Collins, Richard; Rosekrans, Spreck; Roseman, Jesse; Rothert, Steve; Sandkulla, Nicole; Saunders, Jenan; Schutte, Allison; Sears, William; Shakal, Sarah; Shipley, Robert; Shumway, Vern; Shutes, Chris; Sill, Todd; Simsiman, Theresa; Slay, Ron; Smith, Jim; Staples, Rose; Stapley, Garth; Steindorf, Dave; Steiner, Dan; Stender, John; Stone, Vicki; Stork, Ron; Stratton, Susan; Taylor, Mary Jane; Terpstra, Thomas; TeVelde, George; Thompson, Larry; Tmberliner; Ulibarri, Nicola; Verkuil, Colette; Vierra, Chris; Villalobos, Amber; Wantuck, Richard; Ward, Walt; Welch, Steve; Wenger, Jack; Wesselman, Eric; Wetzel, Jeff; Wheeler, Dan; Wheeler, Dave; Wheeler, Douglas; Wilcox, Scott; Williamson, Harry; Willy, Allison; Wilson, Bryan; Winchell, Frank; Wooster, John; Workman, Michelle; Yoshiyama, Ron; Zipser, Wayne
Subject:CCSF Meeting March 24 2014 in San Francisco - Regarding Assessment of Socioeconomic Effects of Water Shortages on Its Regional Water System

CCSF is holding a meeting on Monday, March 24th for FERC Don Pedro Project Relicensing Participants to review the methodology and results of CCSF's assessment of the socioeconomic effects of water shortages on its regional water system. The meeting will be held from 10:30 a.m. to Noon at the San Francisco Public Utilities Commission headquarters in San Francisco at 525 Golden Gate Avenue, 2nd floor, O'Shaugnessy Conference Room. Would suggest you arrive a few minutes early (10:15 a.m.) for sign-in procedures.

For those not able to participate in person, the meeting will also be broadcast via web (details will be provided closer to the meeting date).

The draft report will be available to Relicensing Participants at least 10 days prior to the meeting.

ROSE STAPLES
CAP-OM
HDR Engineering, Inc.
Executive Assistant, Hydropower Services

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From: Staples, Rose
Sent: Tuesday, March 04, 2014 11:52 AM
To: 'Alves, Jim'; 'Amerine, Bill'; 'Asay, Lynette'; 'Barnes, James'; 'Barnes, Peter'; 'Barrera, Linda'; Beeco, Adam; 'Blake, Martin'; 'Bond, Jack'; Borovansky, Jenna; 'Boucher, Allison'; 'Bowes, Stephen'; 'Bowman, Art'; 'Brenneman, Beth'; 'Buckley, John'; 'Buckley, Mark'; 'Burke, Steve'; 'Burt, Charles'; 'Byrd, Tim'; 'Cadagan, Jerry'; 'Carlin, Michael'; 'Charles, Cindy'; Cooke, Michael; 'Cowan, Jeffrey'; 'Cox, Stanley Rob'; 'Cranston, Peggy'; 'Cremeen, Rebecca'; 'Damin Nicole'; 'Day, Kevin'; 'Day, P'; 'Denean'; 'Derwin, Maryann Moise'; Devine, John; 'Dowd, Maggie'; 'Drake, Emerson'; 'Drekmeier, Peter'; 'Edmondson, Steve'; 'Eicher, James'; 'Fargo, James'; Fernandes, Jesse; 'Ferranti, Annee'; 'Ferrari, Chandra'; 'Findley, Timothy'; 'Fleming, Mike'; 'Fuller, Reba'; 'Furman, Donn W'; 'Ganteinbein, Julie'; 'Giglio, Deborah'; 'Gorman, Elaine'; 'Grader, Zeke'; 'Gutierrez, Monica'; 'Hackamack, Robert'; 'Hastreiter, James'; 'Hatch, Jenny'; 'Hayden, Ann'; 'Hellam, Anita'; 'Heyne, Tim'; 'Holley, Thomas'; 'Holm, Lisa'; 'Horn, Jeff'; 'Horn, Timi'; 'Hudelson, Bill'; 'Hughes, Noah'; 'Hughes, Robert'; 'Hume, Noah'; Hurley, Michael; 'Jackson, Zac'; 'Jauregui, Julia'; 'Jennings, William'; 'Jensen, Laura'; 'Johannis, Mary'; 'Johnson, Brian'; 'Jones, Christy'; 'Jsansley'; 'Justin'; 'Keating, Janice'; 'Kempton, Kathryn'; 'Kinney, Teresa'; 'Koepele, Patrick'; 'Kordella, Lesley'; 'Le, Bao'; 'Levin, Ellen'; 'Linkard, David'; Loy, Carin; 'Lwenya, Roselynn'; 'Lyons, Bill'; 'Madden, Dan'; 'Manji, Annie'; 'Marko, Paul'; 'Martin, Michael'; 'Mathiesen, Lloyd'; 'McDaniel, Dan'; 'McDevitt, Ray'; 'McDonnell, Marty'; 'Mein Janis'; Mills John; 'Morningstar Pope, Rhonda'; 'Motola, Mary'; 'Murphey, Gretchen'; 'Murray, Shana'; 'O'Brien, Jennifer'; 'Orvis, Tom'; 'Ott, Bob'; 'Ott, Chris'; 'Pavich, Steve'; 'Pool, Richard'; 'Porter, Ruth'; 'Powell, Melissa'; 'Puccini, Stephen'; 'Raeder, Jessie'; 'Ramirez, Tim'; 'Rea, Maria'; 'Reed, Rhonda'; Reynolds, Garner; 'Richardson, Daniel'; 'Richardson, Kevin'; 'Ridenour, Jim'; 'Riggs T'; 'Robbins, Royal'; 'Romano, David O'; 'Roos-Collins, Richard'; 'Rosekrans, Spreck'; 'Roseman, Jesse'; 'Rothert, Steve'; 'Sandkulla, Nicole'; 'Saunders, Jenan'; 'Schutte, Allison'; 'Sears, William'; 'Shakal, Sarah'; 'Shipley, Robert'; 'Shumway, Vern'; 'Shutes, Chris'; 'Sill, Todd'; Simsiman, Theresa; 'Slay, Ron'; 'Smith, Jim'; Staples, Rose; 'Stapley, Garth'; 'Steindorf, Dave'; 'Steiner, Dan'; 'Stender, John'; 'Stone, Vicki'; 'Stork, Ron'; 'Stratton, Susan'; 'Taylor, Mary Jane'; 'Terpstra, Thomas'; 'TeVelde, George'; 'Thompson, Larry'; 'Tmberliner'; 'Ulibarri, Nicola'; 'Verkuil, Colette'; 'Vierra, Chris'; Villalobos, Amber; 'Wantuck, Richard'; Ward, Walt; 'Welch, Steve'; 'Wenger, Jack'; Wesselman, Eric; 'Wetzel, Jeff'; 'Wheeler, Dan'; 'Wheeler, Dave'; 'Wheeler, Douglas'; 'Wilcox, Scott'; 'Williamson, Harry'; 'Willy, Allison'; 'Wilson, Bryan'; 'Winchell, Frank'; 'Wooster, John'; 'Workman, Michelle'; 'Yoshiyama, Ron'; 'Zipser, Wayne'
Subject:Don Pedro W-AR-21 Floodplain Hydraulic Assessment Workshop Notes Ready for 30-Day Review-Comment
Attachments: 2014-02-13 W-AR21 MtgNotes_Draft_140304.pdf

Attached for your review and comment are the DRAFT meeting notes from the February 13, 2014 Don Pedro Relicensing W&AR-21 Floodplain Hydraulic Assessment Workshop No. 1 Meeting. As Attachment A to the notes, the PowerPoint slides used at the meeting, is over 10

MB, I have uploaded the slides (as well as a copy of the draft meeting notes) to the www.donpedro-relicensing website, under both ANNOUNCEMENT and CALENDAR tabs. If you have any difficulties accessing and/or downloading the files, please let me know.

Comments are due by Thursday, April 3, 2014. Thank you.

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Don Pedro Project Relicensing (FERC No. 2299)
W&AR-21 Floodplain Hydraulic Analysis Study
Workshop No. 1
HDR Office in Sacramento
Draft Meeting Notes

Thursday, February 13, 2014
1:30 PM to 4:30 PM

Attendees

Nolan Adams	HDR, Inc.
Peter Barnes	State Water Resources Conservation Board
Jenna Borovansky	HDR, Inc.
Allison Boucher	Tuolumne River Conservancy
Dave Boucher	Tuolumne River Conservancy
Steve Boyd	Turlock Irrigation District
Anna Brathwaite (by phone)	Modesto Irrigation District
Jesse Fernandes (by phone)	HDR, Inc.
Noah Hume	Stillwater Sciences
Matt Moses	San Francisco Public Utilities Commission
Bill Paris (by phone)	Modesto Irrigation District
Pani Ramalingam	HDR, Inc.
Bill Sears (by phone)	City and County of San Francisco
Rob Sherrick	HDR, Inc.
Maia Singer	Stillwater Sciences
Ron Yoshiyama	City and County of San Francisco

On February 13, 2014, the Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) conducted Workshop No. 1 for the Don Pedro Hydroelectric Project Floodplain Hydraulic Analysis Study (W&AR-21). This document summarizes items discussed in the Workshop. It is not intended to be a transcript of the meeting. Attachment A provides the slides presented during the Workshop.

Following introductions, Jenna Borovansky of HDR, Inc. (HDR), consultant to the Districts, provided background on the study process to date. She noted that, in accordance with the study schedule, this is a Workshop for the W&AR-21 modeling effort and will follow the Consultation Workshop protocols. In January 2013, the Districts received comments on the ISR, including a request for additional information. The Districts agreed to conduct a floodplain study. She added that the study plan was developed during the spring and summer of 2013. Ms. Borovansky said that the W&AR-21 study goals build on past information and that the purpose of this Workshop is to present the 2D hydraulic and habitat modeling approach, and provide a first cut at describing the demarcation between in-river and overbank habitat.

Noah Hume of Stillwater Sciences, consultant to the Districts, reviewed previous floodplain studies on the lower Tuolumne River. Mr. Hume noted that the 2012 2D Pulse Flow Study focused on in-channel predictions of habitat availability. He then presented the W&AR-21 study objectives.

Pani Ramalingam of HDR reviewed the existing topographic data. He noted that there are no breaks in the 2011 LiDAR data, but that there are some breaks in the floodplain ponds. He said that the study team is currently working to fill these few data gaps. Mr. Ramalingam then presented the calibration data.

During the remainder of the Workshop, Mr. Hume and Mr. Ramalingam alternated as presenter. They explained the advantages of using the model TUFLOW for this study, noting that TUFLOW has been used in numerous river hydraulic modeling studies in Europe and Australia and in multiple studies by the U.S. Army Corps of Engineers and California Department of Water Resources. Mr. Hume and Mr. Ramalingam said that TUFLOW is advantageous because the study will model low to moderate flows in the Tuolumne River, rather than high flows, and will attempt to link hydraulic conditions to fish habitat availability, which requires a hydraulic model that realistically represents a flow path from main channel to the 2D floodplain flows and that has a flexible grid size. They also noted that TUFLOW allows changes to be made to local topography and also has a good 1D in-channel modeling component, an attribute that distinguishes TUFLOW from most other 2D models.

Mr. Hume and Mr. Ramalingam said that the computational efficiency of TUFLOW decreases with smaller grid size. TUFLOW was run for a Pilot Reach (RM 40-52) to determine water surface elevation (WSEL) sensitivity to grid size and the results indicate that there is no benefit to running the model at a grid size lower than 30 ft^2. Mr. Hume and Mr. Ramalingam said that the results for Riffle 4A/4B indicate that the smaller the grid size, the higher the estimated area of suitable rearing habitat. This is particularly evident for fry. Balancing this with the decreasing computational efficiency as grid size gets smaller, the sensitivity analysis indicates that 30 ft^2 also represents an appropriate grid size for habitat predictions. Mr. Hume and Mr. Ramalingam said the grid size in particular areas can be reduced, if needed.

Allison Boucher of the Tuolumne River Conservancy asked if the model distinguishes between inundated areas that have active flow/velocity and areas that do not have flow/velocity. As an example, she said that when Legion Park floods, there is no flow. The water just sits on the grass and does not appear to create good habitat. Mr. Hume replied that the model considers both velocity and depth. Based on the habitat suitability criteria (HSC), areas with no flow would not be considered suitable habitat by the model.

Mr. Hume and Mr. Ramalingam said that the existing IFIM Study (2012) is a 1D study and covers in-channel habitat at flows up to 1,200 cfs. They also said that the TUFLOW 1D-2D domain boundary is set in locations that will maximize the quantity of potential 2D habitat to be analyzed. Mr. Ramalingam provided example images of the 1D-2D domain boundary location within the Pilot Reach.

Mr. Ramalingam presented the TUFLOW modeling plan and Mr. Hume presented the conceptual steps in the habitat analysis, whereby TUFLOW provides cell-specific velocity and depth predictions. He added that the velocity and depth predictions are modeled using the habitat suitability criteria (HSC) developed in the 2012 IFIM study and combined with discharge recurrence probabilities to generate area-duration-frequency curves. Ms. Boucher asked if the results include consideration of suitable habitat in different sections of the river (i.e., reach-by-reach). Mr. Hume affirmed that the model has that capability.

Mr. Hume and Mr. Ramalingam said the study team will distribute electronic links to an updated map book of the lower Tuolumne River, which will show the proposed location of the TUFLOW 1D-2D domain boundary. They requested that relicensing participants provide feedback on the model domain delineation approach. They noted that a follow-up conference call to discuss feedback could be scheduled, if desired.

Ms. Boucher asked if the W&AR-21 study report will provide information on the four different fish life stages (i.e., fry and juvenile salmon; fry and juvenile *O. mykiss*). These species require different habitat types and the modeling approach would need to consider these differences. Mr. Hume replied that life history timing for each species is specific. For example, fry and juveniles for each species use the habitats at slightly different times in the year. He said this is an inherent screening tool in the model.

Ms. Boucher said that landowners may like to know what is happening on their property and asked if it would be possible to provide this information. Ms. Borovansky replied that it may be possible to provide this information with respect to habitat, but reiterated that the purpose of the study is not to predict when or which properties will flood.

Ms. Boucher asked how the model predicts the velocity for a particular floodplain location. Mr. Ramalingam replied that TUFLOW models velocity on a cell-by-cell basis.

Ms. Boucher asked how the model deals with velocity in off-channel areas like flooded roads and bends. She noted that there is a property downstream of new La Grange Bridge where she had observed large eddies during high flows. Mr. Ramalingam replied by showing the model results at 3,000 cfs. He noted that the velocity and depth vectors shift with each time step and that flow eddies are represented.

Ms. Boucher asked how roughness is associated with different vegetation types, such as willow. Mr. Ramalingam and Nolan Adams of HDR replied that the study team is working on this and at this time uses the best available information, such as from survey data and aerial imagery, to make distinctions between vegetation types.

Ms. Boucher asked what the study output is and if the model could be run under different scenarios. Mr. Hume replied that the study report will include plots and tabulations of inundated area. He noted that the model will be available for relicensing participants (RPs) to use to run different scenarios. RPs may also use the study report output to extrapolate results at a range of flows or request that the Districts run the model for a specific scenario.

Mr. Ramalingam showed how a recently restored floodplain surface might respond to flows of 8,400 cfs based on TUFLOW predictions. Dave Boucher of the Tuolumne River Conservancy and Ms. Boucher noted that the predicted flow re-routing appears to mimic what actually occurs in the area they are familiar with, which provided positive feedback on the calibration. They said that the TUFLOW model appears to be a reliable tool that would really help the decision-making process in relicensing.

Attachments

Attachment 1: W&AR-21 Workshop No. 1 Slides

ATTACHMENT 1

W&AR-21 Workshop No. 1 Slides

ATTACHMENT B
CONSULTATION RECORD

APPENDIX B
AGENCY CONSULTATION RECORD DOCUMENTS

From: Patrick Koepele <patrick@tuolumne.org>
Sent: Wednesday, May 18, 2011 6:34 PM
To: Devine, John; Craig, Nancy
Cc: Stephen_Bowes@nps.gov
Subject: Lower Tuolumne River Parkway
Attachments: Parkway Framework.pdf

As requested, I am attaching a copy of "The Lower Tuolumne River Parkway: A Framework for the Future."

Please note this was developed through a collaborative effort which included the districts.

I request that you let the broader group know that you have received this document. I would have sent it to the group email list, but didn't want to clog inboxes with a large file. It would probably be useful to have on the Don Pedro website.

Also, the NPS is leading an effort to develop a lower Tuolumne Boat Trail. I believe Stephen Bowes at NPS could provide additional information.

Thanks,
Patrick

Patrick Koepele
Deputy Executive Director
Tuolumne River Trust
ph: 209-588-8636
fax: 209-588-8019

The Lower Tuolumne River Parkway

A Framework for the Future

The Lower Tuolumne River:

A Framework for the Future

April 2005

www.tuolumnerivercoalition.org

Prepared by
Tuolumne River Coalition:

City of Ceres
City of Modesto
City of Waterford
East Stanislaus Resource Conservation District
Friends of the Tuolumne, Inc.
Modesto Irrigation District
San Francisco Public Utilities Commission
Sierra Club, Yokuts Group
Stanislaus County Parks & Recreation
Tuolumne River Regional Park
Tuolumne River Trust
Turlock Irrigation District

Environmental Planning Consultant:

Moore Iacofano Goltsman (MIG), Inc.
Berkeley, California

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CHAPTER V: IMPLEMENTATION ACTIONS AND TOOLS FOR MOVING FORWARD

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WHO WE ARE

The Tuolumne River Coalition ("Coalition") formed in the autumn of 2000 to act as a forum for local organizations to discuss and promote a variety of restoration and recreation projects in the Lower Tuolumne River corridor. The Coalition is a voluntary, local group that represents a balance of interested and affected persons and entities, including local agencies, non-profit organizations, individuals and property owners, as well as cooperating federal and state agencies. The Coalition has come together to develop the Lower Tuolumne River Parkway, and its members will continue to act as the steward of the Parkway.

THE LOWER TUOLUMNE PARKWAY

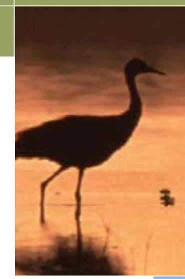
The Lower Tuolumne River Parkway is a mosaic of projects that combines private and public enhancement activities to provide habitat and public use opportunities. Together, existing projects of individual Coalition members include over 28 river miles and over 1,500 acres in the Parkway. These diverse projects incorporate elements such as water quality improvement, floodplain management, access and recreation facilities enhancements, riparian habitat restoration, education, and stewardship.

The Coalition's vision for the Lower Tuolumne River Parkway is grounded in sound ecological principles, sensible design approach to park development and river habitat enhancements, and a significant interest in enhancing public interaction in the outdoor environment through diverse recreation and open space opportunities, while respecting current development and private lands.

The Lower Tuolumne River Parkway is a vibrant, healthy river corridor providing multiple community benefits.

Tuolumne River Coalition Common Goals

- Enhance, protect and restore habitat that supports natural resources and river function consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor
- Extend and protect open space along the river
- Expand and enhance public access and recreational opportunities where appropriate
- Protect the floodplain from intensive development
- Respect existing development, land ownership and water supply uses
- Support and develop riparian buffers
- Provide flood management benefits
- Enhance water quality
- Build upon and integrate existing plans relevant to the Lower Tuolumne River
- Support the development of a mosaic of public and private projects and programs
- Increase river-focused educational programs



TOOLS FOR MOVING FORWARD

The development of the Framework for the Future is a major accomplishment, but only the first in a long series of steps necessary to turn the vision of the Lower Tuolumne River Parkway into a reality.

In order to narrow the gap between the present reality and the future of the Lower Tuolumne River Parkway, the Coalition must also focus attention on **funding opportunities** from local grants, state propositions and federal appropriations; **organizational development** to continue to strengthen and define the role of the Tuolumne River Coalition; **scientific and technical studies** to support the development of information and resources and to analyze the impacts and benefits of the Lower Tuolumne River Parkway; and compiling **best management practices** on issues such as water quality management, floodplain management, recreation and other elements affecting the river.

The Framework must continue to align with the Coalition's mission and vision, contribute to the multi-objective development of the Lower Tuolumne River Parkway, and support Coalition activities and efforts. The Coalition will establish protocols for periodic updates to the Framework and the prioritization of strategies and action steps. As a primary tenet of its work, the Coalition will continue its efforts in fostering the involvement of stakeholders and the public.

Our actions and ability to work collaboratively will determine the future health of the Lower Tuolumne River, the communities it supports, and the habitat at its banks. It is critical that we build on past successful projects and continue to integrate recreation and habitat restoration with a clean and abundant water supply—ensuring a reliable water source for farmers and developed communities in the region, as well as a thriving ecosystem to support all those that grow, live or recreate along this truly spectacular natural resource.

Tuolumne River Coalition

Coalition Steering Committee Members

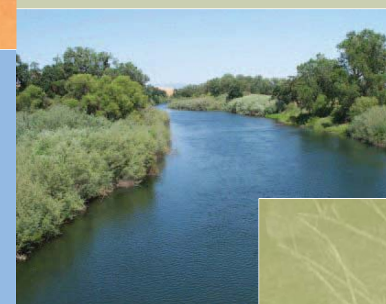
City of Ceres
City of Modesto
City of Waterford
East Stanislaus Resource Conservation District
Friends of Tuolumne, Inc.
Modesto Irrigation District
San Francisco Public Utilities Commission
Sierra Club, Yokuts Group
Stanislaus County Parks and Recreation
Tuolumne River Regional Park
Tuolumne River Trust
Turlock Irrigation District

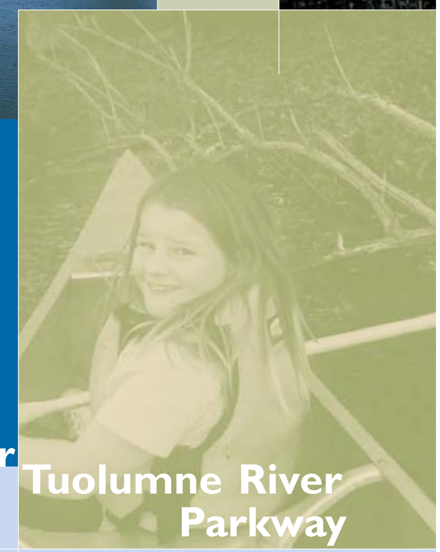
Environmental Planning Consultant

Moore Iacofano Goltsman (MIG), Inc.

For more information and to get a copy of the complete document, "The Lower Tuolumne River Parkway: A Framework for the Future," please visit our website:

www.tuolumnerivercoalition.org





The Lower Tuolumne River Parkway

A Framework for the Future

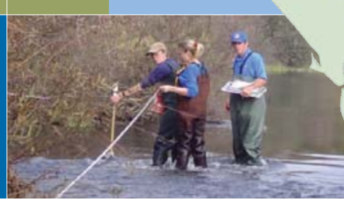
The Lower Tuolumne River is one of the most significant natural resources in California's Great Central Valley. A jewel of the region, the river spills from the foothills of the Sierra Nevada and flows through 52 miles of varied watershed, exceptional wildlife habitat and recreational areas. The river provides water for farmers and municipal water supplies and electricity for communities in the local area. Thousands of Chinook salmon return each fall to spawn on the lower river, which supports many wildlife and plant species, including Swainson's Hawk, San Joaquin Valley Kit fox, rare and threatened willow, cottonwood, and other hardwoods. A critical natural resource, the Lower Tuolumne River is one of the larger river systems in the region.

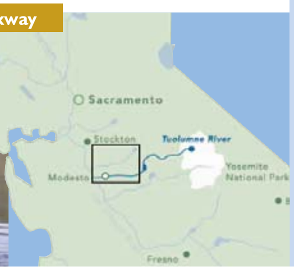
The Lower Tuolumne River Parkway: A Framework for the Future is intended to support, enhance and encourage a concurrent planning process for the Lower Tuolumne River that will ensure the health of this important ecosystem. Drafted by the Tuolumne River Coalition, the aim of the Framework is to facilitate greater cooperation and involvement in the future of this magnificent river. The Framework will be a guiding document for the Coalition as it works in partnership with other stakeholders to develop the Lower Tuolumne River Parkway.

The Framework, funded by the California Bay Delta's (CALFED) Watershed Program, focuses on four key tasks:

- **Provide documentation of Parkway projects** and other Coalition activities and accomplishments
- **Analyze existing plans and reports** concerning the Lower Tuolumne River and its floodplain to identify shared goals and potential conflicts across policies
- **Identify strategies and actions** to meet the multi-objective goals of the Coalition
- **Develop implementation actions** that facilitate the Coalition's coordination of multiple projects along the river

The Lower Tuolumne River Parkway





CURRENT PLANNING EFFORTS ALONG THE RIVER

Current projects underway along the Lower Tuolumne River highlight both the opportunities and the challenges inherent in creating a river corridor that will support populations of native plant and animal species while connecting people to nature through recreation, open space and educational opportunities. The development of a thriving Lower Tuolumne River Parkway will be an on-going task.

In addition to supporting current projects, the Coalition conducts fundraising activities, including meeting with legislators; outreach activities, including stakeholder interviews and community workshops, meetings with state and federal representatives, and project tours and canoe trips to increase awareness of the river; community and volunteer events; policy collaborations; and continued collaborations with cooperating agencies and private companies.

In the Framework for the Future, the Coalition has conducted an inventory of over 40 plans, reports and studies relevant to the Tuolumne River and its floodplain in order to identify shared goals, potential conflicts, and opportunities across the reports. The Framework provides a detailed summary of these shared goals, potential conflicts and opportunities for the following categories:

- Aquatic Species
- Balanced River Management
- Floodplain Management
- Geomorphology
- Information Needs
- Land Use
- Lower River Reaches
- Recreation and Access
- Riparian Habitat
- Stewardship and Education
- Terrestrial Species
- Upper River Reaches
- Urban Reaches
- Water Quality
- Water Supply

A Multi-Objective Approach

As of this publication, the current projects of the Tuolumne River Coalition and its cooperating agencies include:

1. San Joaquin River National Wildlife Refuge Expansion
2. Dos Rios Working Landscape
3. Shiloh Fishing Access
4. Grayson River Ranch Restoration
5. Big Bend Habitat Restoration
6. Riverdale County Park
7. Tuolumne River Regional Park
8. Ceres River Bluff Regional Park
9. Special Run Pools 9 and 10
10. Fox Grove County Park
11. Waterford Percolation Pond Restoration
12. Waterford Urban River Park
13. Gravel Mining Reach Habitat Restoration, Phases I – IV
14. Bobcat Flat Floodplain and Channel Restoration
15. La Grange Regional Park
16. Fine Sediment Reduction and Spawning Gravel Additions
17. Basso Bridge County Park

STRATEGIES FOR THE FUTURE

The Framework identifies specific strategies to assist the Coalition as a whole to meet its multi-objective goals. Strategies and action steps outlined in this document are recommendations for the future work of the Coalition. They are not meant as directives or commitments on the part of individual member organizations. Rather, the Framework is intended to support, enhance and encourage concurrent planning process along the Lower Tuolumne River. The strategies and action steps uphold the goals of the Coalition, build upon the shared goals, address the potential conflicts and/or seize opportunities identified in the analysis of existing reports.

An overarching goal for the Coalition is to facilitate and encourage implementation of projects and programs that are both consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor and that also balance and address the needs of diverse users and uses. The strategies presented in the Framework are an attempt to address some of the challenges while offering suggestions for balancing land uses and coordinating Parkway projects that are complimentary to each other. Proposed strategies, and the resulting projects, must be designed to be appropriate for their given context.

Strategies for Success

- Identify Multi-Objective Projects in the Urban and Rural Reaches of the River
- Support the Coordination of a Water Quality Monitoring and Enhancement Program
- Identify Potential Natural Areas and Working Landscape Projects
- Implement Habitat Restoration Projects
- Increase Recreational Opportunities
- Enhance and Expand Public River Access Points
- Provide Information and Support for a Scenic Trailway Compatible with Private Interests
- Study and Recommend Best Management Practices Regarding the Use of Boats on the Lower Tuolumne
- Create Lower Tuolumne River Parkway Maps and Signage
- Develop a Lower Tuolumne River Parkway Interpretive Program
- Enhance Cleanliness, Safety, and Security for the Users of the Lower Tuolumne River Parkway and Surrounding Communities
- Continue Public Outreach and Involvement

Chapter 1

INTRODUCTION

"The value of a healthy river is immeasurable."

—TUOLUMNE RIVER COALITION MEMBER

1.1 PURPOSE OF THE FRAMEWORK FOR THE FUTURE

This Framework for the Future for the Lower Tuolumne River is intended to facilitate greater cooperation and involvement of stakeholders in the Lower Tuolumne River ("river"), a significant asset to the communities through which it flows in California's Central Valley. With increased interest and more unified goals, policies, projects, and actions, the many values of the Tuolumne can be enhanced for the benefit of all who rely upon it, including agriculture, businesses, wildlife, and the people who visit, live or work near the river.

The Framework for the Future ("Framework") encourages planning for projects along the Lower Tuolumne River that carry multiple benefits and build community interest and involvement in the Tuolumne. The Framework is the guiding document for the Tuolumne River Coalition (Coalition), a group of local public and private entities, as it works in partnership with other stakeholders to develop a Lower Tuolumne River Parkway (Parkway), a collection of private and public projects to enhance habitat and provide public use opportunities that are compatible with existing private land.

To accomplish these purposes, the Framework will focus on four key elements:

- Provide documentation of Parkway projects and other Coalition activities and accomplishments.
- Analyze existing plans and reports concerning the Lower Tuolumne River and its floodplain to identify shared goals and potential conflicts across policies.
- Identify strategies and actions to meet the multi-objective goals of the Coalition.
- Develop implementation actions that facilitate the Coalition's coordination of multiple projects along the river.

These four elements are addressed, respectively, in Chapters Two, Three, Four, and Five of this document. The review of on-the-ground Parkway projects in Chapter One is followed by an analysis of current policies affecting the river in Chapter Two. Together, the information in these chapters provides the foundation and direction for key strategies laid out in Chapter Four by revealing common goals to build upon and gaps to address. The Framework concludes in Chapter Five with an overview of tools necessary to turn these strategies into thriving projects and programs.

The Tuolumne River Coalition's efforts and development of this Framework were funded by the California Bay Delta (CALFED) Program's Watershed Program. Intended outcomes for the Framework identified in the scope of work for this project include:

- Build upon the scientific and technical basis provided in the Habitat Restoration Plan for the Lower Tuolumne River Corridor[1] with social and political aspects provided in other plans and reports that pertain to the Lower Tuolumne River and its floodplain.
- Improve and coordinate implementation of projects.
- Clarify the Coalition's goals and identify opportunities to maximize multiple benefits.
- Recommend and prioritize actions to meet the multi-objective goals of the Coalition.
- Build community interest and involvement.

1. See Page 3-2 for a description of the Habitat Restoration Plan

Finally, this Framework is a "living document." The thoughts, projects, and ideas explored in this document are intended to further the dialogue about key issues surrounding the Lower Tuolumne, so that the on-going enhancement of the Lower Tuolumne River reflects and includes the values of residents, visitors, and other supporters.

Scope of the Framework for the Future

The scope of this document, and of the work of the Tuolumne River Coalition in general, is the area within the floodplain boundaries[2] of the Lower Tuolumne River. This document presents a roadmap with potential strategies and actions for the Tuolumne River Coalition as it develops the Lower Tuolumne River Parkway. However, these strategies are recommendations for the Coalition's work and are not a commitment to perform these actions. Nor do they suggest that the Coalition holds any legal jurisdiction over any member or other existing agency. The Framework is not a Master Plan for the river and therefore does not require environmental review. **Rather, the Framework is intended to support, enhance and encourage concurrent and complimentary planning processes along the Lower Tuolumne.**

MAP 1.1: THE TUOLUMNE RIVER AND STATE OF CALIFORNIA

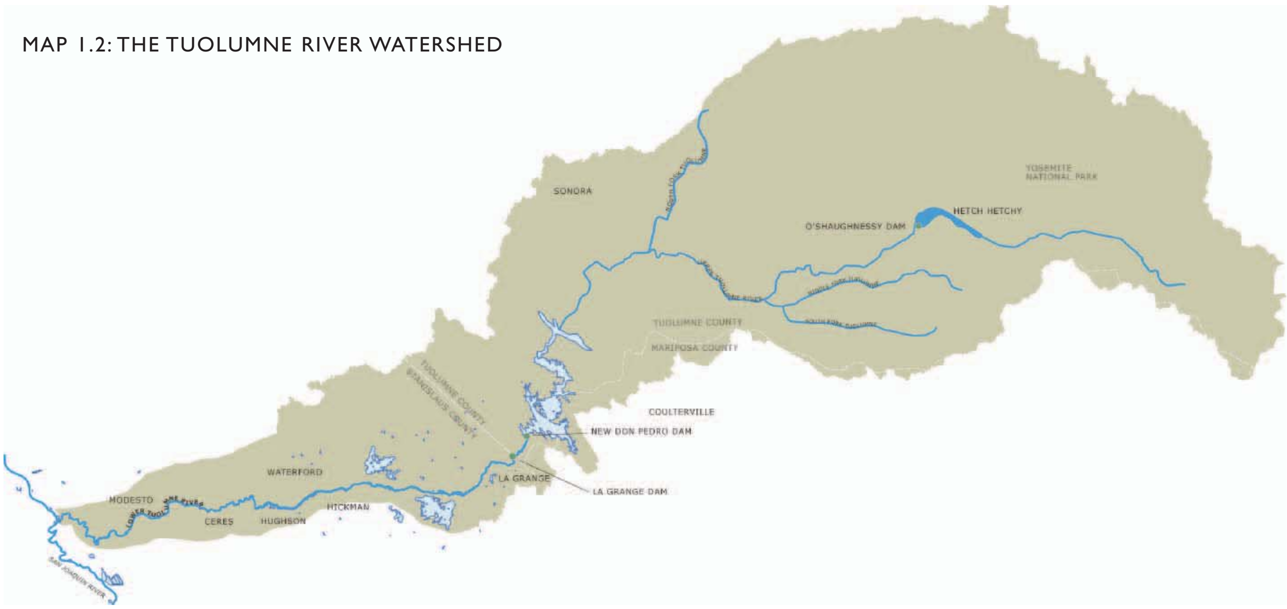
1.2 THE TUOLUMNE RIVER WATERSHED

The Tuolumne River is one of the largest rivers in California's San Joaquin Valley and is the largest tributary of the San Joaquin River (see Map 1.1: The Tuolumne River and State of California). The Tuolumne River, which originates at an elevation of over 13,000 feet in the Sierra Nevada range, flows westerly between the Merced River watershed to the south and Stanislaus River watershed to the north, draining a 1,958 square-mile watershed that includes the northern half of Yosemite National Park (See Map 1.2: The Tuolumne River Watershed, on page 1-4). Runoff from the Tuolumne River is typified by brief winter storm runoff peaks followed by prolonged late spring and early summer snowmelt.

Like many Sierra Nevada rivers, the Tuolumne River is managed to provide multiple beneficial uses to a local and regional population and economy. These uses include water for irrigation and drinking, hydropower, flood control, recreation, and in-stream water for river habitats. These benefits have come at

2. A floodplain is the part of a river valley made of unconsolidated, river-borne sediment that is periodically flooded. In the case of the lower Tuolumne, this area generally extends from bluff to bluff across the incised river valley, becoming less distinct as the river floodplain merges with the San Joaquin River floodplain west of Modesto.

MAP 1.2: THE TUOLUMNE RIVER WATERSHED



a cost to some of the natural capital inherent in a wild river system, as is characteristic of many developed river systems in California. The development of reservoirs, powerhouses, and diversion facilities in the Tuolumne watershed has affected the lower river and its riparian characteristics.

The two primary reservoir impoundments in the Tuolumne River watershed are Hetch Hetchy and Don Pedro reservoirs. O'Shaughnessy Dam, completed in 1923 in Yosemite National Park, forms the Hetchy Hetchy Reservoir, capturing up to 360, 360 acre-feet and diverting approximately 230,00 acre-feet of water from the upper reaches of the Tuolumne watershed. The Hetch Hetchy system is owned by the City and County of San Francisco and is operated by the San Francisco Public Utilities Commission (SFPUC). This system provides approximately 85% of the total SFPUC system water supply, up to 300 million gallons per day. (The remaining 15% comes from local bay area sources.) Water from Hetch Hetchy provides high quality drinking water, as well as water for other municipal and industrial purposes, hydropower, and is released to meet instream fishery water requirements below SFPUC's impoundments on the Tuolumne and its tributaries. The regional significance of the Tuolumne River is demonstrated by the fact that over 2.4 million people in the Bay Area of California rely entirely or in part on water from the SFPUC system.[3]

The Don Pedro Dam, completed in 1971 near the base of the Sierra Nevada (replacing the smaller Don Pedro Dam built in 1923) forms Don Pedro Reservoir, the sixth largest body of water in the state, with a capacity of 2.03 million acre-feet. The dam is jointly owned by the Turlock and Modesto Irrigation Districts (Districts). Like Hetch Hetchy

3. San Francisco Public Utilities Commission-Bay Area Water Users Association Water Supply Master Plan, April 2000.

above it, Don Pedro provides water for multiple uses including drinking and irrigation water supplies, power generation, flood control and recreation.

Below Don Pedro Reservoir, the Districts divert water from the river at La Grange Dam, completed in 1893. The Modesto Irrigation District (MID) diverts water north of the Tuolumne River, providing irrigation supply to 60,000 acres for the area agriculture industry, 30 million gallons of drinking water per day, and electricity for over 100,000 accounts. Turlock Irrigation District (TID) diverts water south of the river, providing irrigation supply to 150,000 acres and electric service to over 73,000 accounts.

1.3 ATTRIBUTES OF THE LOWER TUOLUMNE RIVER

The Lower Tuolumne River emerges from the foothills of the Sierra Nevada at La Grange Dam and travels 52 miles to the confluence of the San Joaquin River, approximately 15 miles west of the city of Modesto, carrying agricultural, recreational, environmental, and municipal water supplies. The lands that border the Lower Tuolumne River are primarily rural, privately owned agricultural land, but also include scattered local, state, and federal public lands. Portions of the cities of Waterford, Ceres, and Modesto lie along the river's edge, as do lands held by Stanislaus County and Modesto and Turlock irrigation districts.

La Grange Dam is considered the uppermost limit of the "lower" river. At the downstream end of the Lower Tuolumne River lies the San Joaquin River National Wildlife Refuge. The Refuge encompasses a vast 12,887 acres of land that lies primarily to the northwest and southwest of the confluence of the Tuolumne and San Joaquin. Although the Refuge primarily borders the San Joaquin River, it does include lands along the north bank of the Tuolumne from its confluence with the San Joaquin extending approximately 1.5 miles upstream. This section of the Refuge contains approximately 300 acres of historic Tuolumne/San Joaquin River floodplain.

The Lower Tuolumne River supports a developed and diversified economy, important recreational opportunities, and a diverse biological community.

Healthy Regional Economy. Activities that depend upon the river and dominate the region's economy include agriculture (row crops, vineyards, and orchards), gravel mining, ranching, tourism, and other regional activities that rely upon water supplied by the Tuolumne.

Extensive Recreation Opportunities. The Lower Tuolumne runs through Stanislaus County (population 446,997 in 2000) and the Cities of Modesto (population 203,300), Waterford (population 6,924), and Ceres (population 34,609).[4] The river provides numerous open space and recreation opportunities available to the rapidly growing populations of these river towns, as well as all of Stanislaus County.

Diverse Biological Communities. The river supports a naturally reproducing population of Chinook salmon as well as other anadromous[5] fish, a wide variety of resident fish species, migratory and resident birds, and other river-dependent wildlife. The Lower Tuolumne River corridor

4. 2000 US Census, SF-1 Data
5. Anadromous fish spawn in freshwater streams or rivers and migrate early in their life cycle to the ocean where the mature. They return as mature adults to spawn in the fresh water of their origin.

continues to support riparian habitat that includes several willow species, Fremont cottonwood, white alder, valley oak, and other native tree species.

The Lower Tuolumne River is 52 miles long, beginning with "river mile" 0 at the confluence with the San Joaquin River, and ending at river mile 52 at the La Grange Dam. The river can be divided into two zones that intergrade, but are defined by the dominant channel sediment: the sand-bedded zone (river miles 0 to 24) and the gravel-bedded zone (river miles 24 to 52). The entire Lower Tuolumne River is further subdivided into seven distinct reaches based on present and historic land uses and channel characteristics.[6] These river miles and reaches are noted on Map C: The Lower Tuolumne River Parkway, on page 1-10, below.

The river reaches are:

- **Reach 1: Lower Sand-bedded Reach** (river miles 0.0-10.5)
- **Reach 2: Urban Sand-bedded Reach** (river miles 10.5-19.3)
- **Reach 3: Upper Sand-bedded Reach** (river miles 19.3-24.0)
- **Reach 4: In-Channel Gravel Mining Reach** (river miles 24.0-34.2)
- **Reach 5: Gravel Mining Reach** (river miles 34.2-40.3)
- **Reach 6: Dredger Tailing Reach** (river miles 40.3-45.5)
- **Reach 7: Dominant Salmon Spawning Reach** (river miles 45.5-52.1)

River stakeholders include the Steering Committee members and Cooperating Agencies of the Tuolumne River Coalition as described in Section 1.6, below, as well as the National Marine Fisheries Service, San Francisco Public Utilities Commission, Bay Area Water Supply and Conservation Agency (representing the 28 agencies that purchase water from the SFPUC), local communities, landowners and residents, people who benefit from or use the river from other areas, and others.

1.4 ENVIRONMENTAL AND CULTURAL HISTORY OF THE RIVER[7]

The first known Native American inhabitants along the Tuolumne River are the Northern Valley Yokuts. The Northern Valley Yokuts relied on the wildlife and vegetation found within the Tuolumne River corridor for hunting, fishing, and the gathering of acorns, roots, bulbs, blackberries, and tall grasses and other food and fibers for daily uses-much use was made of the salmon for food. They lived as one of the highest regional population densities in pre-European North America.

By the late 1700s the Spanish mission at San Jose was already sending out parties to obtain Yokuts to work at the mission. However, significant populations remained in the area until an epidemic in 1833 killed many of the Northern Valley Yokuts in what is now Stanislaus County.

At this time, prior to major Euro-American settlement and land development in the Central Valley, the Lower Tuolumne River was a dynamic, meandering alluvial river, characterized by broad flood-

6. McBain and Trush for the Tuolumne River Technical Advisory Committee. *Habitat Restoration Plan for the Lower Tuolumne River Corridor.* March 2000

7. Tuolumne River Technical Advisory Committee. *Habitat Restoration Plan for the Lower Tuolumne River Corridor.* March 2000; EDAW, Inc. *Tuolumne River Regional Park Master Plan Existing Conditions Technical Memorandum #4.* 2000.

plains and terraces, large gravel bar deposits, and extensive riparian wetlands and forests. Streamflows within a given year and between years varied from as low as 100 cfs in late summer months to peak winter floods exceeding 40,000 cfs. Valley walls confined the river corridor to as narrow as 500 feet near Waterford, while reaches downstream of Modesto were unconfined.

Historically, extensive Fremont cottonwood and valley oak riparian forests surrounded the banks of the Lower Tuolumne River. These forests were several miles wide near the San Joaquin River, merging into riparian forests of the neighboring Merced and Stanislaus rivers. These forests provided foraging and breeding habitat for diverse resident and migratory bird and wildlife populations. Particularly large populations of wintering waterfowl were associated with the valley floodplain area that contained extensive tule marshes. A partial list of native species historically found in or along the river corridor is included in Appendix D.

By the 1840's, a few large Spanish land grant ranchos were established in the region. However, the importance of the Tuolumne River's resources to the region's new economy was not established until the 1850's, starting with the California Gold Rush. Soon after the 1849 discovery of gold in the Sierra foothills, the river became a steamboat route for miners and in 1854 Stanislaus County was organized. The remaining Northern Valley Yokuts were largely extirpated in the onrush.

Table 1.1 on page 1-9 provides an historical outline of the various land uses that have altered the channel morphology and impacted the riparian ecosystem surrounding the river. The major land uses include placer mining for gold, dredger mining for gold, streamflow regulation and diversion, live-

Native Valley Oaks on Bobcat Flat.

stock grazing, urban growth, agriculture, and commercial aggregate (gravel) mining. The development of hydraulic mining posed particular challenges to anadromous fish populations as it caused sedimentation of spawning grounds. Between 1850 and 1885 hydraulic mining in the Sierra washed tons of silt, sand, and gravel into the Sacramento and San Joaquin Valleys, including the Tuolumne. Gold dredging up to the 1950's vastly altered the river and floodplain in the 15-mile reach below La Grange and sand and gravel mining of the river channel up to the 1970's converted about 10 miles of river into lake-like reaches. Such mining continues next to the river and in much of the floodplain in this reach.

Settlements that became the major cities along the Tuolumne (La Grange, Waterford, Modesto and Ceres) were founded in the late 1850s and 1860s, predominantly by European immigrants. These cities emerged due to the influx of people during the Gold Rush, in areas where passage across the river became necessary, and in areas where agriculture was developing. Before the end of the century, agriculture was quickly established as the driver of the regional economy. The abundance of fertile soils unique to the Central Valley led to the domi-

Historic La Grange.

nance of grazing and later crops in the valley around the Tuolumne River. Ranchers and farmers and steamboat operations cleared much of the native vegetation to the river's edge in many locations throughout Stanislaus County.

The Wheaton Dam, built in 1871 near La Grange, became the first primary fish barrier constructed on the Tuolumne River. The formation of the Modesto Irrigation District (MID) and Turlock Irrigation District (TID) was in 1887. Together, they constructed La Grange Dam in 1893 at the site of Wheaton Dam to divert water from the Tuolumne River for irrigation in part of Stanislaus and Merced counties. At that time, La Grange Dam at 128 feet was the highest overflow dam in the country.

Water diversion projects continued on the Tuolumne, with the construction of the O'Shaughnessy Dam and Hetch Hetchy Reservoir upstream in Yosemite National Park in April 1923, the Don Pedro Powerhouse in 1923, and the New Don Pedro Dam and Powerhouse (still the 9th-tallest dam in the United States) in 1970 (see also page 1-4). Simultaneously, private landowners and public agencies built miles of levees along rivers all across the Central Valley, including the Tuolumne, to protect farmlands, with most of the river's floodplains being restricted from inundation by the beginning of the 20th century.

Mining, farming, ranching and the diversion and control of water supplies have been the foundation for a strong and diverse regional economy, provided residents with a steady water supply and afforded numerous people the opportunity to live nearer the Lower Tuolumne River than they would have otherwise. These activities have also altered the river and its corridor by blocking access to upstream spawning areas, decreasing the overall river volume and frequency of large floods, changing the channel morphology, eliminating gravel supply, reducing riparian vegetation, and introducing non-native plant and animal species.

The regional changes to the river and riparian ecosystem have greatly affected the fish and wildlife that depend on it. For example, spring- run Chinook salmon were once abundant and lived in river reaches much further into the Sierra, such as between Don Pedro and Hetch Hetchy reservoirs. Many of the large wildlife species native to the region of the lower Tuolumne River, such as tule

Agriculture along the Tuolumne River.

TABLE 1.1[8] LAND USES AND EFFECTS ON THE LOWER TUOLUMNE RIVER FROM 1848 TO PRESENT

LAND USE	TIME PERIOD	LOCATION	DISTURBANCE	EFFECTS ON CHANNEL
Placer Mining	1848-1880	La Grange and upstream (RM 50)	Turned over floodplains and terraces; spoil placement on fertile areas	Destroyed natural channel morphology, increased sediment supply, destroyed instream habitat, removed riparian forests
Urban Growth	1850-present	Modesto to Waterford (RM 15 to 30)	Need for commercial lumber, space and aesthetic value	Confined river corridor (reduced width), constructed dikes, removed riparian vegetation, increased pollution loading into river
Dredger Mining	1880-1952	Robert's Ferry to La Grange (RM 38 to 50)	Turned over entire riparian corridor valley-wall to valley-wall, spoil placement on fertile areas	Destroyed natural channel morphology, increased sediment supply, destroyed instream habitat, removed riparian habitat
Grazing	1850-present	San Joaquin confluence to La Grange (RM 0-50)	Young riparian vegetation is grazed, water sources become feces conduits	Destabilized banks, discouraged natural riparian regeneration
Farming	1860-present	San Joaquin confluence to La Grange (RM 0 to 50)	Mature and establishing riparian vegetation is cleared, channel location stabilized	Confined river corridor (reduced width), constructed dikes, removed riparian vegetation, increased pollution and fine sediment loading into river
Flow Regulation	1890-present	Downstream of La Grange (RM 0 to 52)	Magnitude, duration, frequency and timing of high flow regime is altered and reduced, reduced/eliminated sediment supply from upstream watershed	Bed coarsening and downcutting, fine sediment accumulation in channel, channel fossilized by encroaching riparian vegetation, channel migration and bar building virtually eliminated, floodplain construction and deposition reduced, quantity and quality of instream and riparian habitat greatly reduced
Aggregate Mining	1930-present	Hughson to La Grange (RM 24 to 50)	Large instream and off channel pits, dredger tailing removal	Historic floodplains are left as deep ponds, floodway narrowed by dikes separating ponds from river, riparian vegetation is cleared, regeneration is prevented and mature stands eliminated

8. Source: McBain and Trush for the Tuolumne River Technical Advisory Committee. *Habitat Restoration Plan for the Lower Tuolumne River Corridor.* March 2000

elk, pronghorn, and grizzly bear were extirpated soon after the gold rush. Fall-run Chinook salmon remain, but their diminished populations are affected by many factors both within and outside the Tuolumne River, including the San Joaquin River, the Bay-Delta region, and the ocean. Riparian vegetation has similarly decreased throughout the river corridor. Virtually all native wildlife species and other natural habitats of the region have been dramatically diminished over the last 200 years.

Guided canoe and kayak trips down the river.

1.5 THE LOWER TUOLUMNE RIVER PARKWAY

The Lower Tuolumne River Parkway is a mosaic of projects that are not contiguous, from La Grange Dam to the River's confluence with the San Joaquin River in Stanislaus County. The Parkway integrates current uses of the river and emphasizes the natural characteristics of the river by combining private and public enhancement activities to provide habitat and public use opportunities that are compatible with existing private interests. Map 1.3: Reaches of the Lower Tuolumne River on page 1-10 provides a view of the Parkway and the various multiple-benefit projects already proposed or in place.

Currently, the projects of individual Tuolumne River Coalition members together include over 28 river miles and over 1,500 acres along the river. These projects incorporate elements such as water quality improvement, floodplain management, recreation facilities and access enhancement, riparian habitat restoration, education and stewardship along the Lower Tuolumne River. With the development of this mosaic of projects, the Coalition approaches river-oriented planning to balance interactions among people, current uses, the river and riparian corridor, and the preservation or restoration of habitat, plant species and wildlife.

1.6 THE TUOLUMNE RIVER COALITION

Tuolumne River Coalition

The Tuolumne River Coalition ("Coalition") formed in the autumn of 2000 to act as a forum for local organizations to discuss and promote a variety of restoration and recreation projects of the Lower Tuolumne River corridor. The Coalition is a voluntary, local group that represents a balance of interested and affected persons and entities within the watershed, including local agencies, non-profit organizations, individuals and property owners, as well as cooperating federal and state agencies. The Coalition has come together to develop the Lower Tuolumne River Parkway, a collection of Coalition member projects, and its members will continue to act as the steward of the Parkway.

The Coalition seeks to identify common goals, coordinate stakeholder involvement, provide support, increase public awareness and involvement, and assist in obtaining federal, state, local, and private funds, where appropriate, for Coalition projects and programs. Through this coordination, the Coalition intends to better understand and integrate existing plans and achieve efficiency, effectiveness, and multiple benefits. More information about the Coalition and its on-going activities and accomplishments are discussed in Chapter Two.

The Mission of the Coalition is "To develop a mosaic of projects for improving habitat and recreation compatible with existing private interests."

City of Ceres	City of Modesto	City of Waterford
East Stanislaus Resource Conservation District	Friends of the Tuolumne, Inc.	Modesto Irrigation District
The San Francisco Public Utilities Commission (SFPUC)	Sierra Club, Yokuts Group	Stanislaus County Parks and Recreation
Tuolumne River Regional Park	Tuolumne River Trust	Turlock Irrigation District

Coalition Steering Committee Members.

Steering Committee Members

Detailed profiles of Steering Committee members, including contact information and opportunities for involvement, are listed in Appendix A.

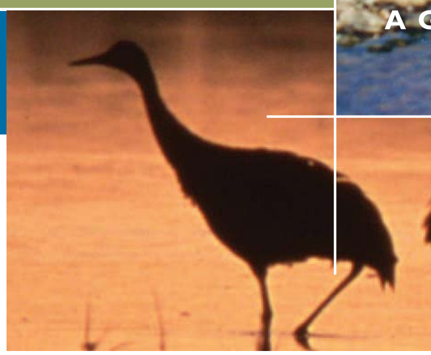
Cooperating Agencies

Cooperating Agencies include those listed below. Detailed profiles of Coalition Cooperating Agencies are also included in Appendix A.

- California Bay-Delta Authority (CALFED)
- California Department of Fish and Game (DFG)
- California Department of Parks and Recreation
- Stanislaus County Council of Governments (StanCOG)
- United States Department of Agriculture-Natural Resources Conservation Service (NRCS)
- United States Department of Commerce-National Oceanic and Atmospheric Administration (NOAA Fisheries)
- United States Fish and Wildlife Service-Anadromous Fish Restoration Program (AFRP)
- United States Fish and Wildlife Service-San Joaquin River National Wildlife Refuge

Chapter 2

A GUIDING VISION FOR THE LOWER TUOLUMNE



"Our success will be measured by the community's attitude toward the river and our river parks."

—TUOLUMNE RIVER COALITION MEMBER

2.1 INTRODUCTION

The Tuolumne River Coalition's vision for the Lower Tuolumne River Parkway is grounded in sound ecological principles, sensible design approaches to park development and river habitat enhancements, and a significant interest in enhancing the public's interaction with the outdoor environment through diverse recreation and open space opportunities, while respecting development and private interests.

This chapter presents the guiding vision and common goals for the Parkway, highlights the natural river and riparian processes, and discusses the social and cultural context surrounding the Tuolumne River Coalition's efforts.

This chapter concludes by describing the "building blocks" of the Parkway: the existing and proposed on-the-ground projects, and other on-going activities of the Tuolumne River Coalition. Together, these projects and programs address the vision for the Lower Tuolumne River Parkway by emphasizing instream and floodplain restoration, recreation and access opportunities, increased river awareness, and water quality enhancements.

Environmental education at Big Bend.

River otter (Reach 1).

2.2 TUOLUMNE RIVER COALITION VISION AND COMMON GOALS FOR THE LOWER TUOLUMNE RIVER PARKWAY

Tuolumne River Coalition Vision for the future of the Lower Tuolumne River Parkway

Vision:

The Lower Tuolumne River Parkway is a vibrant, healthy river corridor providing multiple community benefits.

Tuolumne River Coalition Common Goals for the Lower Tuolumne River Parkway

The following goals have guided and will continue to guide the work of Coalition member organizations along the Lower Tuolumne River. The Framework for the Future provides a roadmap to put these goals into action. All recommendations put forth in this document adhere to and support these goals. Figure 1 on the following page illustrates the relationship between the Coalition's guiding vision, mission, primary goals, and key strategy areas for achieving those goals.

- Enhance, protect and restore habitat that supports natural resources and river function consistent with the *Habitat Restoration Plan for the Lower Tuolumne River Corridor*

Riffle at Bobcat Flat.

- Extend and protect open space along the river
- Expand and enhance public access and recreational opportunities where appropriate
- Protect the floodplain from intensive development
- Respect existing development, land ownership, and water use
- Support and develop riparian buffers
- Provide flood management benefits
- Enhance water quality
- Build upon and integrate existing plans relevant to the Lower Tuolumne River
- Support the development of a mosaic of public and private projects and programs
- Increase river-focused educational programs

2.3 MULTI-OBJECTIVE APPROACH OF THE TUOLUMNE RIVER COALITION

Local and scientific knowledge of the physical and biological processes of the river as well as of human interactions with the river form the basis for the Coalition's development of the Parkway.

Physical and Biological Processes of the River[1]

The Lower Tuolumne River, in its natural state, is an alluvial river. An alluvial river has riverbed, banks, and floodplains composed of coarse and fine sediments (sand, gravel, and cobble). A natural river is dynamic in that it is able to frequently move the channelbed and banks and scour coarse sediments, which are then replaced by comparable materials transported from upstream. The morphology or shape of the river is thus maintained over time.

This dynamic balance creates a river and riparian ecosystem upon which native plants depend for seed dispersal, germination, and growth. Likewise, animal species depend upon it for feeding and foraging, nesting, roosting, migrating, and protection.

The Central Valley's riparian corridors are dominated by winter-deciduous hardwood trees such as cottonwood, willow and valley oak, which survive within the particular conditions available within the river corridor. Although the Tuolumne and its floodplain have been altered over the past century, the river still plays an integral role in supporting a unique biological community. In California, the native amphibian, bird, and mammalian species diversity in Central Valley riparian zones represents the highest biodiversity found anywhere in the state. In general, riparian zones in the Central Valley support 50 amphibians and reptile species, 147 bird species, 55 mammalian species, and 60 native tree and plant species. Appendix G provides a partial list of all plant and animal species, both native and non-native, found in and along the Lower Tuolumne River.

1. Tuolumne River Technical Advisory Committee. *Habitat Restoration Plan for the Lower Tuolumne River Corridor.* March 2000

THE TUOLUMNE RIVER COALITION'S GUIDING FRAMEWORK FOR THE LOWER TUOLUMNE RIVER PARKWAY

VISION

The Lower Tuolumne River Parkway is a vibrant, healthy river corridor providing multiple community benefits

GOALS

- ***Enhance, protect*** *and* ***restore*** *habitat that supports natural resources and river function*
- ***Extend*** *and* ***protect*** *open space along the river*
- ***Expand*** *and* ***enhance*** *public access and recreational opportunities where appropriate*
- ***Protect*** *the floodplain from intensive development*
- ***Respect*** *existing development, land ownership, and water use*
- ***Support*** *and* ***develop*** *riparian buffers*
- ***Provide*** *flood management benefits*
- ***Enhance*** *water quality*
- ***Build upon*** *and* ***integrate*** *existing plans relevant to the Lower Tuolumne River*
- ***Support*** *the development of a mosaic of public and private projects and programs*
- ***Increase*** *river-focused educational programs*

RIVER ENHANCEMENT STRATEGIES

- ***Identify*** *Multi-Objective Projects in Urban and Rural Reaches of the River*
- ***Support*** *the Coordination of a Water Quality Monitoring and Enhancement Program*
- ***Identify*** *Potential Natural Area and Working Landscapes Opportunities*
- ***Implement*** *Habitat Restoration Projects*
- ***Increase*** *Recreation Opportunities*
- ***Enhance*** *and* ***Expand*** *Public River Access Points*
- ***Provide*** *Information and Support for a Scenic Trailway Compatible with Private Interests*
- ***Study*** *and Recommend Best Management Practices Regarding the Use of Boats*
- ***Create*** *Lower Tuolumne River Parkway Maps and Signage*
- ***Develop*** *a Lower Tuolumne River Parkway Interpretive Program*
- ***Enhance*** *Cleanliness, Safety, and Security for the Users of the Lower Tuolumne River Parkway and Surrounding Communities*
- ***Continue*** *Public Outreach and Involvement*

Human Interactions with the River

Archaeological studies demonstrate that humans have relied on the Tuolumne River for sustenance, travel, and other resources for thousands of years. As the history of the river in Chapter One demonstrates, however, the environmental qualities of the river and riparian corridor have been largely modified over the past century and a half. Comprehensive efforts to preserve the river environment for people and wildlife were rare until the past decade, while intensive activities such as placer and dredger mining for gold, streamflow regulation and diversion, livestock grazing, urban growth, agriculture, and commercial aggregate (gravel) mining dominated land uses along the river throughout much of the 19th and 20th centuries.

Recent enhanced efforts (such as those introduced below and discussed in greater detail in Chapter Four) to maintain a healthy river channel, floodplain and watershed, balance the abundance of recreation and economic development opportunities of the Lower Tuolumne River. The river continues to support agriculture, mining, urban development, wildlife viewing and other tourist activities, and serves as a regional outdoor destination. As we move into the 21st century, renewed efforts and increased interest in the river will help highlight the river as a centerpiece of the regional community, for its economic, recreational, and environmental resources.

Background on Recent River Enhancements: The FERC Settlement Agreement

Throughout the 20th century, the Lower Tuolumne River provided residents with water supplies and area wildlife with habitat for feeding, traveling, and nesting. More recently, the 1995 dam license review agreement (the FERC Settlement Agreement, described below) focused attention on river management. Shortly thereafter, the 1997 flood severely impacted water supply, farmland, parklands, and urban areas. Together, these events increased the interest of local governments and community groups, with state and federal encouragement, to re-envision the Tuolumne as a centerpiece of Stanislaus County.

Birdwatching - a popular activity along the Tuolumne River.

As part of the process of re-evaluating the 1964 Federal Regulatory Energy Commission (FERC) license for the Don Pedro Project, several stakeholders entered into an historic agreement, known as the 1995 FERC Settlement Agreement (FSA) that outlined several key strategies for increasing naturally reproducing fall-run Chinook salmon and their habitat in the Lower Tuolumne River. The FSA outlined a comprehensive approach that included 1) Higher minimum instream flow requirements below La Grange Dam, 2) Expanded fishery monitoring, 3) Development and implementation of a Lower Tuolumne River Chinook salmon habitat restoration program, 4) Foundation of a Tuolumne River Technical Advisory Committee (TRTAC), composed of stakeholder organizations, to oversee monitoring and restoration activities laid out in the FSA and 5) Specified funding to conduct the program. The FSA was adopted as part of the Don Pedro Project license in a FERC Order issued in 1996. The ensuing activity has resulted in many unique collaborations along the river. The FSA led to the creation of the "Habitat Restoration Plan for the Lower Tuolumne River Corridor (Restoration Plan)", which identified a basic approach to Lower Tuolumne river restoration based on achieving natural functions while still providing for human uses such as irrigation and domestic supply. The Restoration Plan identified numerous restoration projects (a requirement of the Settlement Agreement) and 10 of those were selected by the TRTAC for implementation by the Districts in fulfillment of the FSA.

Local artist Al Perry painting in Tuolumne River Regional Park.

Population and Economic Characteristics

To better envision Stanislaus County's direction in the coming years and to offer assistance in developing future policies and programs for a healthy Tuolumne River corridor, it is important to understand the existing demographics of the community. Assessing the age, ethnicity, and other cultural factors of the population will provide insight into the recreation needs and other interests of the area's population.

In general, the region's population is: growing rapidly, fairly young, and increasingly diverse in terms of ethnicity. These characteristics will affect the relationship residents have with the river, and their preferred recreation activities. Stanislaus County's population was 446,997 in 2000, but this is projected to increase to over 890,000 by 2020, representing an increase of over 62%.[2]

Table 2.1 on page 2-7 provides an overview of general demographic characteristics of the County in 1990 and 2000. Although the County's population has grown considerably, the only significant change in general demographics since 1990 has been the growth in the Latino population and corresponding decrease in the percent of the White population.

Economic Development Resources[3]

The economic base of Stanislaus County is diverse, and continuously diversifying. The California Employment Development Department expects total non-farm employment in Stanislaus County to grow by 22,900 jobs (125.3%) between 2001 and 2008. The trade, transportation and utilities indus-

2. United States Fish and Wildlife Service. *San Joaquin River National Wildlife Refuge Study Report for Proposed Acquisitions.* 2004
3. California Employment Development Department Labor Market Information Division; http://www.calmis.ca.gov

TABLE 2.1[4] DEMOGRAPHIC CHARACTERISTIC OF STANISLAUS COUNTY, 1990 AND 2000

	1990 DATA	2000 DATA
Gender		
Males	49%	49%
Females	51%	51%
Age		
0-17 years	31%	31%
18-64 years	58%	59%
65 year and over	11%	10%
Race and Ethnicity*		
White	80%	69%
Black/African American	2%	3%
American Indian/Native	1%	1%
Asian or Pacific Islander	5%	5%
Other or Two or More Races	12%	22%
Latino (of any race)	22%	32%

*The percentages listed here do not add up to 100% due to the fact that a respondent could select both "Latino" and any other race.

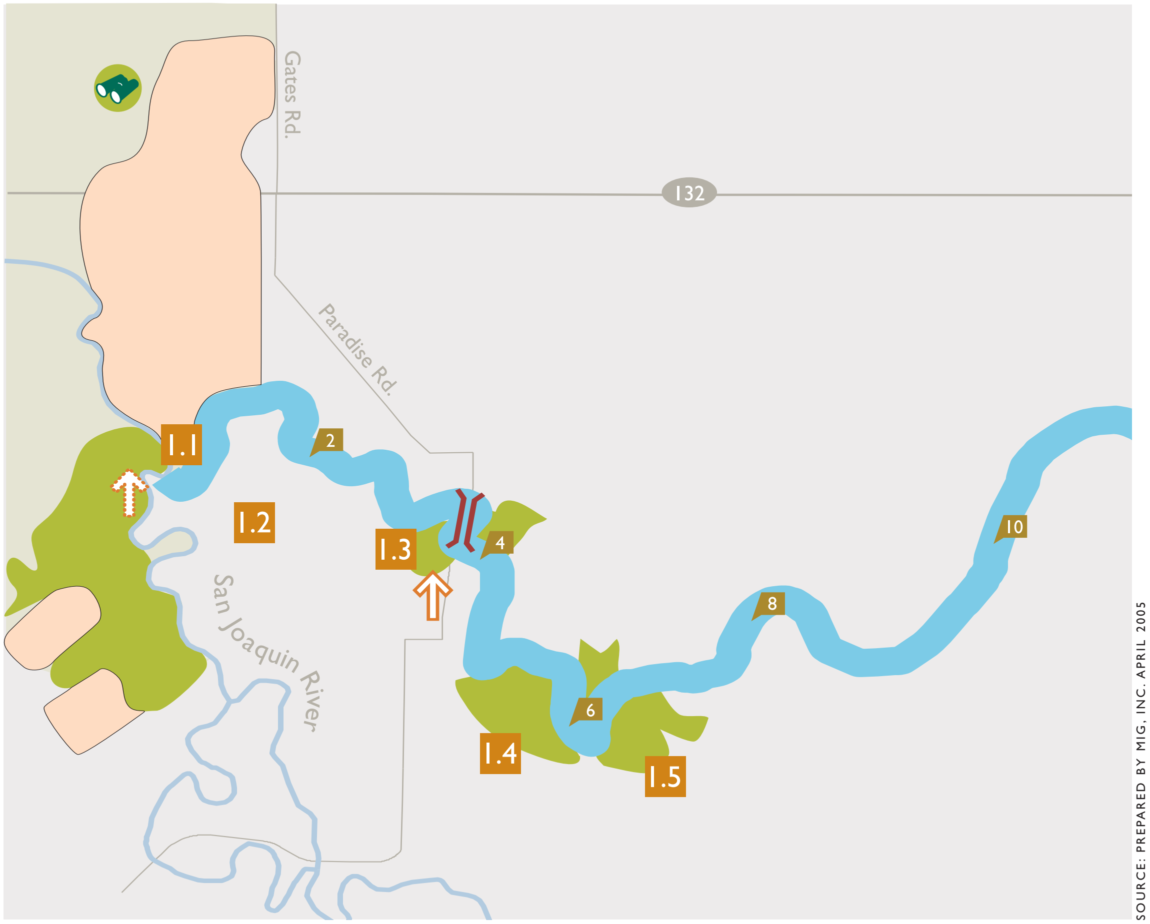
try accounted for the largest single share of industry employment in 2002, at 19.2% of all employment. Other major employers included government (with 15.3% share of all employment), manufacturing (13.6%), educational and health services (10.8%), professional and business services (9.7%), agriculture (8.6%), and leisure and hospitality (8.3%).

Through its municipal and agricultural water supplies, the Lower Tuolumne River contributes to the region's growing economy. The river also directly contributes to economic development through both tourism (visitors recreating in regional parks, boating in the river, and viewing spawning salmon and other wildlife) and resource extraction (aggregate mining).

4. United States Census Bureau. 1990 and 2000 SF-1 Data

2.4 PROJECTS OF TUOLUMNE RIVER COALITION MEMBERS AND COOPERATING AGENCIES

The maps and text presented on the following pages demonstrate how the Tuolumne River Coalition has implemented, and will continue to implement, their vision for the Parkway, while considering and incorporating the dynamic human and natural elements discussed above. These maps, organized by river reach, are followed by detailed project descriptions of each existing and/or proposed Coalition member organization project shown on the maps. These maps provide a visual tour of the Coalition's multi-objective efforts. The maps and projects are organized in a downstream to upstream manner.



Reach 1: Lower Sand-bedded Reach (river miles 0 - 10.5)

TUOLUMNE RIVER COALITION MEMBER PROJECTS

- 1.1 San Joaquin River National Wildlife Refuge Habitat Restoration
- 1.2 Dos Rios Working Landscape (Planned)
- 1.3 Shiloh Fishing Access
- 1.4 Grayson River Ranch Floodplain Restoration Project
- 1.5 Big Bend Floodplain Protection & Restoration Project

Tuolumne River
Other Stanislaus County Rivers
Existing Lower Tuolumne River Parkway Project Site
Planned Lower Tuolumne River Parkway Project Site
Bridges
Public Access Point
Planned Public Access Point
11 *River Mile Marker*

N
Miles
0 1.5

Tuolumne River Coalition Member Projects

Lower Tuolumne River Parkway Framework for the Future

Map 2.1. Reach 1: Lower Sand-bedded reach.

1.1 *San Joaquin River National Wildlife Refuge Expansion*

Lead Organization: U.S. Fish & Wildlife Service, P.O. Box 2176, Los Banos, CA 95635. Contact: Kim Forrest, Refuge Manager, (209) 826-3508

Project Description

LOCATION

The San Joaquin River National Wildlife Refuge is located at river mile 0 of the Lower Tuolumne River, at the confluence of the Tuolumne and San Joaquin Rivers. The Refuge includes extensive lands along the San Joaquin River as well as lands along the north bank of the Tuolumne from its confluence with the San Joaquin extending approximately 1.5 miles upstream. This area consists of approximately 300 acres of historic Tuolumne/San Joaquin River floodplain.

PROJECT OVERVIEW

This12,887-acre refuge was established in 1987 to protect endangered and threatened species, restore and protect wetland habitat for migratory waterfowl and waterbirds, and to provide winter forage for Aleutian Canada Geese and sandhill cranes. The project includes modifying existing flood control levees, restoring historic floodplains, and restoring wetland and riparian forest. Currently there is approximately 3,272 acres within the approved refuge boundary to acquire. There are plans to construct additional public use facilities that will enhance refuge access and interpretive signage. All environmental reviews have been completed for land acquisitions. Approximately 2-3 months (per acquisition) would be needed to complete land appraisal, title work, and contaminants survey.

MULTIPLE BENEFITS

Phase I involves land acquisition, and riparian and wetland habitat restoration. Phase two will entail the development of public use facilities. The project will have multiple regional benefits including public recreation, natural resource stewardship and education, endangered species recovery, open space, flood management, and benefits to the local economy from ecotourism.

KEY PARTNERS

Working Partners: River Partners, CSU Stanislaus — Endangered Species Restoration Program, Point Reyes Bird Observatory, Ducks Unlimited.

Funding Partners: CALFED, U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, Natural Resources Conservation Service, The Resources Agency/Proposition 13 funding, DWR/Flood Protection Corridor Program

Confluence of the Tuolumne and San Joaquin Rivers.

1.2 *Dos Rios Working Landscape Project*

Project Title: Dos Rios Working Landscape Project

Lead Organization: Tuolumne River Trust, 914 Thirteenth Street, Modesto, CA 95354. Contact: Patrick Koepele, (209) 236-0330.

Project Description:

LOCATION

The project is located east of the San Joaquin River in Stanislaus County, approximately 9 miles west of the City of Modesto. The project site is located between river miles 0 and 3 of the Lower Tuolumne River, at the confluence of the San Joaquin and Tuolumne Rivers adjacent to the San Joaquin River National Wildlife Refuge's eastern boundary. The project includes approximately 1,064 acres of unprotected historic floodplain and 545 acres of protected historic floodplain.

PROJECT OVERVIEW

The Dos Rios project is a working landscape, floodplain protection, and riparian restoration project. The project will have direct benefits to the critically endangered riparian brush rabbit (*Sylvilagus bachmani riparus*) by developing riparian brush rabbit habitat and establishing a brush rabbit colony within the riparian corridor on the property. The riparian brush rabbit is California- and Federally-listed as an endangered species. Through purchase of perpetual habitat and agricultural conservation easements, we expect to increase the riparian zone up to 1000 feet wide, restrict development of the properties, including dairies, orchards, and vineyards, and confined animal facilities while protecting other agricultural uses of the land in perpetuity.

The project will result in the following ecologic benefits:

- Establishment of a self-sustaining colony of critically endangered riparian brush rabbits thus contributing directly towards the recovery and eventual delisting of the species from Endangered Species Act protections.
- The project will result in the permanent protection of 6 miles of river front;
- Up to 700 acres of riparian forest will be restored;
- Up to 800 additional acres of floodplain will be permanently protected from development, use by dairies, confined animal facilities, orchards, and vineyards;
- Up to 800 acres of farmland will be permanently protected;
- Connection of the San Joaquin River National Wildlife Refuge with several upstream habitat restoration projects on the Tuolumne River;
- Improved rearing and spawning habitat for native fish including Chinook salmon, steelhead trout, and Sacramento Splittail;
- Improved nesting and migrating habitat for birds.

KEY PARTNERS

California Rangeland Trust

1.3 *Shiloh Fishing Access*

Lead Organization: Stanislaus County Parks & Recreation, 3800 Cornucopia Way, Suite C, Modesto, CA 95358. Contact: Sonya Harrigfeld, Director, (209) 525-6750

Project Description:

LOCATION

The Shiloh Fishing Access is located in Reach One of the river, and is managed by Stanislaus County Parks and Recreation. The Fishing Access, located along the Shiloh Bridge.

PROJECT OVERVIEW

All of the facilities previously at this site were washed away in the floods of the winter of 1996-1997. Due to the nature of the river in this location, it is recommend that the improvements to the access point be nominal, such as a parking area, small boat launch, as well as removable picnic facilities and portable restrooms.

MULTIPLE BENEFITS

Enhance appearance of the area while providing river facilities with opportunities for boating, places for passive recreation, picnic, and informal play.

KEY PARTNERS

Working Partners: California Department of Fish and Game

View from Shiloh Bridge.

1.4 *Grayson River Ranch*

Lead Organization: Friends of the Tuolumne, Inc., 7523 Meadow Avenue Stockton, CA 95207. Contact: Allison Boucher, (209) 477-9033, www.friendsofthetuolumne.org

Project Description:

LOCATION

The project is located approximately four miles upstream of the confluence of the Tuolumne River with the San Joaquin River. The 140-acre project extends for one mile along the river.

PROJECT OVERVIEW

Restoration of this floodplain is reestablishing the oak and willow forest. A variety of nearly 7,000 native trees and grasses were planted representing the natural mix of trees that originally grew in this section of the river. Creeping wild rye grass was seeded on approximately 40 acres as an experiment. Sloughs were carved into the floodplain to improve floodwater interface with the project area and provide floodwater refuge for fish. Monitoring shows increased use by birds and animals. The landowner is actively involved in planning, planting, and maintenance of this perpetual conservation easement. The wide floodplain contouring and planting is complete; maintenance and monitoring will continue for several years.

The project carries many benefits. Riparian birds and mammals are benefiting for breeding, rearing, and winter habitat (migratory birds). Floodwaters are being stored during high water events thereby reducing flood impacts downstream. The channels are providing refuge for Chinook salmon and steelhead during flood events. Natural geomorphic and ecological processes are happening.

Plantings at Grayson River Ranch.

Construction and planting are complete. Funds are being sought for continued monitoring and maintenance.

KEY PARTNERS

Friends of the Tuolumne, Inc. worked in coordination with the East Stanislaus Resource Conservation District, the USDA Natural Resources Conservation Service, U.S. Fish and Wildlife Service, Anadromous Fish Restoration Program, California Department of Fish and Game, the Bay Delta Authority, Tuolumne River Technical Advisory Committee, and the property owner.

1.5 Big Bend Habitat Floodplain Protection and Restoration

Lead Organization: Tuolumne River Trust, 914 Thirteenth Street, Modesto, CA 95354. Contact: Patrick Koepele, (209) 236-0330.

Project Description:

LOCATION

The project is located along river miles 6 and 7 of the Lower Tuolumne River, east of the San Joaquin River in Stanislaus County approximately 7 miles southwest of the City of Modesto.

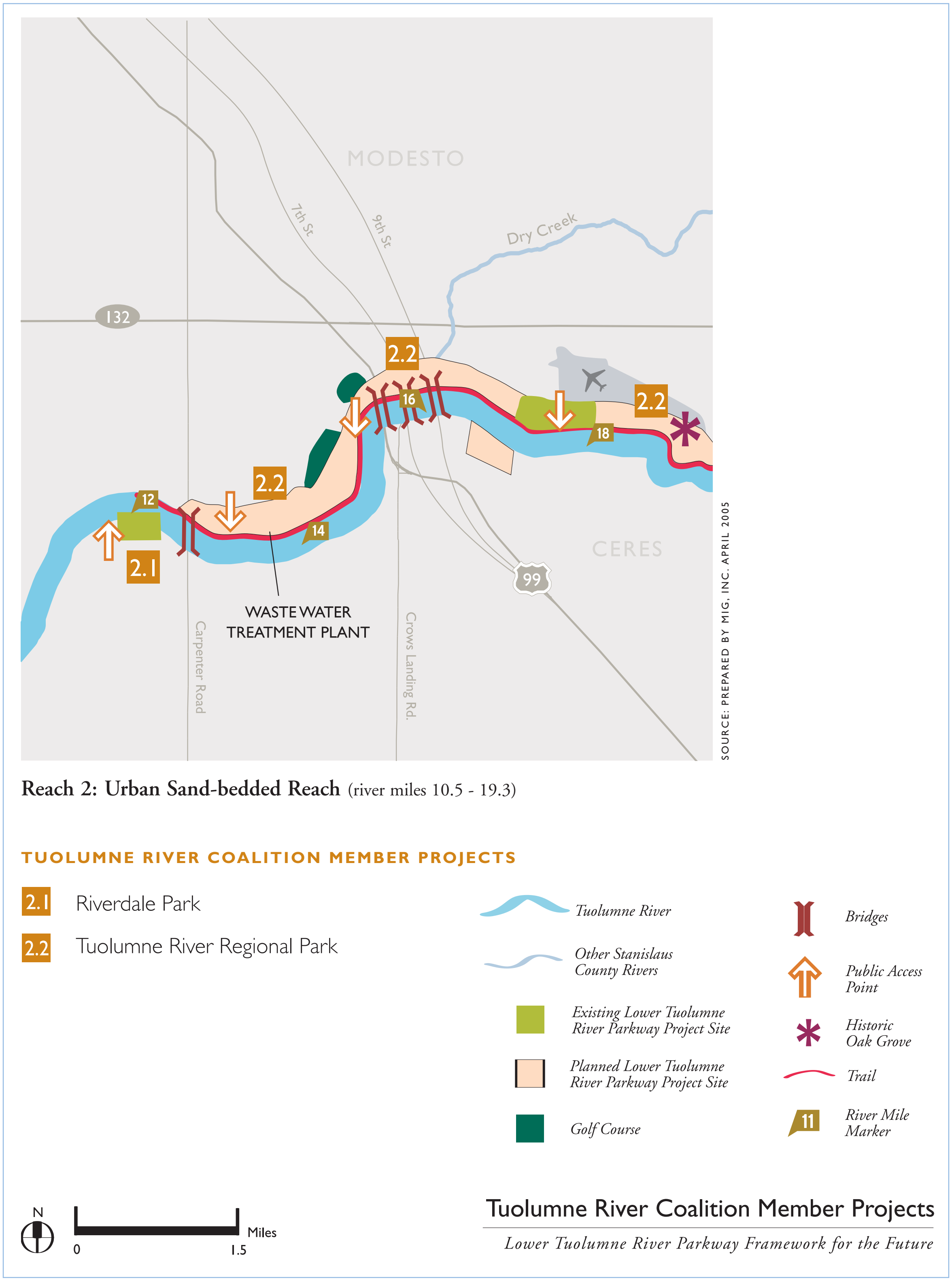
PROJECT OVERVIEW

The Big Bend project is a riparian habitat restoration project along the Tuolumne River west of the City of Modesto. The properties have been protected through the purchase of permanent conservation easements held by the USDA-Natural Resources Conservation Service. Restoration activities will include earthwork and planting to encourage natural floodplain function and improve habitat on approximately 239 acres of river bottom. Earthwork, including notching of private berms to improve channel-floodplain connectivity was completed in autumn 2004. Revegetation of the site commenced in autumn 2004. CEQA/NEPA review has been completed, and all required federal, state, and local permits have been secured. Project plans and designs have been completed. Earthwork and initial planting has been completed.

MULTIPLE BENEFITS

The goals of the restoration project are to improve the functionality of the Tuolumne River floodplain to support riparian plant species, juvenile Chinook salmon and steelhead by restoring approximately 240 acres of floodplain. The objectives for the restoration project are:

Floodplain plantings at Big Bend.



Map 2.2. Reach 2: Urban Sand-bedded reach.

- Improve channel-floodplain connectivity by increasing the frequency of floodplain inundation on the project site, improve natural regeneration of native riparian plant species, and improve rearing habitat for juvenile Chinook and steelhead. Spawning, rearing, and migrating habitat of other native fishes will also be improved.
- Preserve existing riparian vegetation and plant native riparian species on floodway surfaces appropriate for each species' life history.
- Remove invasive exotic vegetation.
- Provide for public education and involvement in the restoration activities on the northern property (owned by the ESRCD).

KEY PARTNERS

California Department of Water Resources — Flood Protection Corridor Program, United States Department of Agriculture — Natural Resources Conservation Service, NOAA Fisheries, East Stanislaus Resource Conservation District — San Francisco FERC Riparian Fund.

2.1 *Riverdale Park*

Lead Organization: Stanislaus County Parks & Recreation, 3800 Cornucopia Way, Suite C, Modesto, CA 95358. Contact: Sonya Harrigfeld, Director, (209) 525-6750

Project Description:

LOCATION

The project is located on the Tuolumne River off Parkdale Drive, north west of the intersection of Hatch Road and Carpenter Road. The access is approximately three acres in size with a river oriented put-in facilities aimed at non-motorized or car top boats.

Riverdale Park.

PROJECT OVERVIEW

The project will enhance the riparian habitat and restore native vegetation (particularly native grasses) in the flood corridor area of this Stanislaus County Park. This project will provide open space in an urban area and provide the community with an area for passive recreation, including a picnic area with tables, barbeques, security lighting, and a small parking area. The Riverdale Park and Fishing Access Project will also include an active recreation area (playground equipment and informal play area) in the upper quadrant of the park, not in the riparian area. Additionally, there is a storm drain basin in the middle quadrant on this site that will be used in dual use as a turfed informal play area.

MULTIPLE BENEFITS

Public access will be improved, providing pedestrian trails through the park to the Tuolumne River for nature walks, fishing and non-motorized boat carry-in opportunities.

KEY PARTNERS

Working Partners: California Department of Fish and Game, Friends of the Tuolumne

Funding Partners: State of California, Proposition 40 River Parkways Grant, Park Bond Act of 2000

(Proposition 12, Per Capita), Park Bond Act of 2002 (Proposition 40, Roberti-Z'Berg-Harris), and the East Stanislaus Resource Conservation District.

2.2 *Tuolumne River Regional Park*

Lead Organization: City of Modesto, 1010 Tenth Street, Suite 4400, P.O. Box 642, Modesto, CA, 95353. Contact: Doug Critchfield, Project Manager, (209) 571-5141

Project Description:

LOCATION

The Tuolumne River Regional Park (TRRP) is located in the cities of Modesto and Ceres. TRRP contains approximately 7 miles of river front park space between river miles 12.4 and 19.3. A centerpiece of TRRP is the Gateway Parcel, located next to the Modesto and Ceres downtown areas.

PROJECT OVERVIEW

The Tuolumne River Regional Park Gateway Parcel creates a green space through the heart of these growing urbanized communities. The intent of the design to create a place where people can enjoy the Tuolumne River, gain access to its multiple benefits, gather for community events, operate educational venues, and attract regional interest to the park. By virtue of its location under Highway 99, the Seventh Street and Ninth Street Bridges, this parcel is highly visible. The intent of the design is to enhance the river corridor, improve circulation, improve recreational opportunities, improve water quality, and create a connection between the urban and river environments. This development is consistent with the Tuolumne River Regional Park MEIR (SCH #2000022028), adopted September 2001 by the TRRP Joint Powers Authority. The project is set to begin work on the permitting and construction documentation. Work will commence in late spring 2006 and be completed in fall of 2006, followed by a 3-year monitoring and maintenance program.

Future view of the Tuolumne River Regional Park.

MULTIPLE BENEFITS

The Gateway Parcel will provide recreation, gathering areas, habitat restoration, bank stabilization, improved flood conveyance, and a softening of the urban landscape. It will function as a destination location for river access, regional events, wildlife viewing, trails, and educational venue. It will also serve as a water cleansing facility as it will displace some of the run-off from the Modesto Downtown into a wetlands area and treat it through natural processes before it enters the Tuolumne River. Also included will be a significant improvement to floodway conveyance for both Dry Creek and the Tuolumne Rivers.

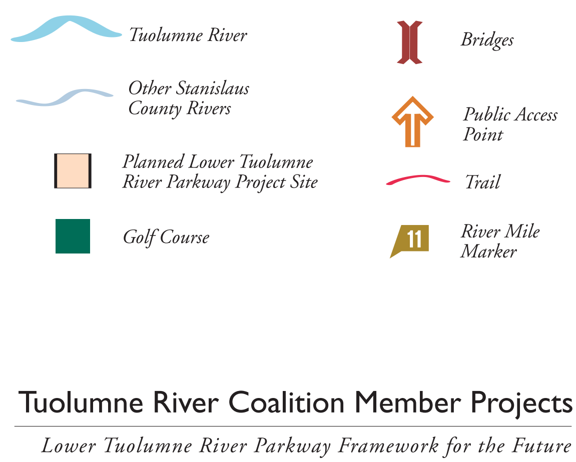
KEY PARTNERS

A Joint Powers Authority made up of the Cities of Modesto and Ceres and Stanislaus County develops and manages the Tuolumne River Regional Park. This JPA is administered by the TRRP commission, whose membership consists of representatives from each of the three agencies. Contributing agen-

Reach 3: Upper Sand-bedded Reach (river miles 19.3 - 24.0)

TUOLUMNE RIVER COALITION MEMBER PROJECTS

3.1 Ceres River Bluff Regional Park



Tuolumne River Coalition Member Projects

Lower Tuolumne River Parkway Framework for the Future

Map 2.3. Reach 3: Upper Sand-bedded reach.

cies also include the California Department of Fish and Game, the Trust for Public Land, the Land and Water Conservation Fund, the U.S. Army Corp of Engineers, California Department of Transportation, and the Regional Water Quality Control Board.

3.1 *Ceres River Bluff Regional Park — Lower Terrace*

Lead Organization: City of Ceres Parks, Recreation and Facilities Department. Contact: Doug Lemcke, Director, Parks, Recreation & Facilities; 2720 2nd Street, Ceres, CA 95307

Project Description:

LOCATION

Located within the city limits, north of Hatch Road and adjacent to River Oaks Golf Course, between Mitchell and Faith Home Roads, the parcel is divided into an upper and lower terrace.

PROJECT OVERVIEW

The city of Ceres purchased 76 acres of land in 2001 for approximately $1 million to construct a regional park. The upper terrace is 38 acres which will include a sports complex and 2.5 acres are zoned commercial. The lower terrace, in the flood zone, is also 38 acres and will be restored to a native riparian habitat, including a wetland area. The lower terrace will consist of 2 phases. Currently, the design and construction of Phase I is being completed which includes 19 of the 38 acres. Phase II will include the remaining 19 acres of the lower terrace. The intent is to protect established trees and vegetation, such as valley oaks and elderberry bushes and preserve the existing wildlife habitat and food sources. Open space will be planted with native meadow grasses and other plants that will increase habitat and food sources for a variety of birds and mammals. The environment review for the entire 76 acres regional park, including the lower terrace 38 acres was completed with a successful Mitigated Negative Declaration in 2003. Phase I of the lower terrace is projected to be completed by March 2006. We are applying for Phase II and if funds are approved, design work could start in January 2006 and construction completed in March 2007.

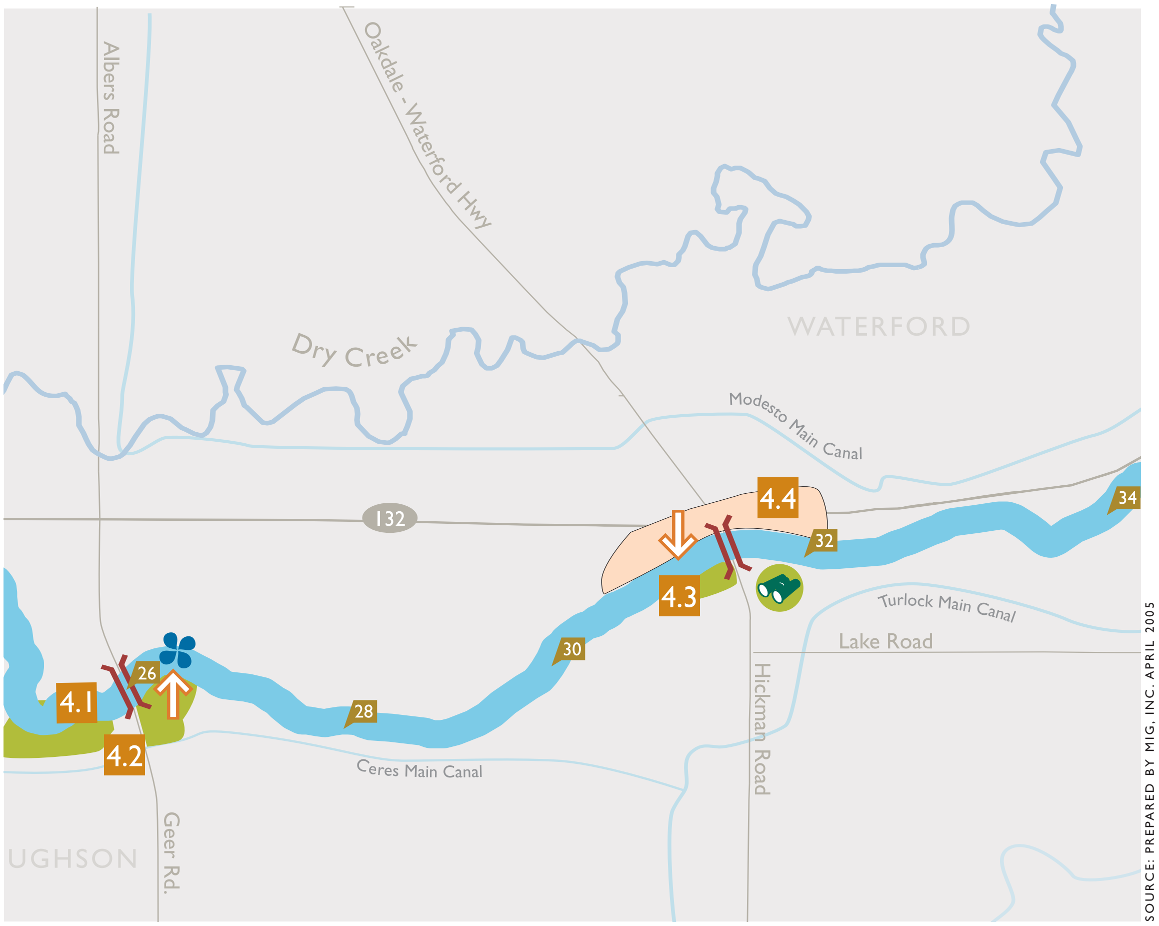
Ceres River Bluff Regional Park.

MULTIPLE BENEFITS

In this restored habitat educational activities will be emphasized. Trails and viewing boardwalks will be constructed within the lower terrace. Trees will be planted to provide an environment for terrestrial species and a canopy along the Tuolumne River edge to benefit fish habitat.

KEY PARTNERS

Friends of the Tuolumne and the Ceres Garden Club



Reach 4: In-Channel Gravel Mining Reach (river miles 24.0 - 34.2)

TUOLUMNE RIVER COALITION MEMBER PROJECTS

- **4.1** Special Run Pools 9 (complete) & 10 (planned) Restoration Projects
- **4.2** Fox Grove County Park
- **4.3** Waterford Percolation Pond Restoration
- **4.4** Waterford Urban River Park

Tuolumne River

Other Stanislaus County Rivers

Existing Lower Tuolumne River Parkway Project Site

Planned Lower Tuolumne River Parkway Project Site

Bridges

Public Access Point

Motorized Boat Access

Wildlife Viewing

11 *River Mile Marker*

N

0 1.5 Miles

Tuolumne River Coalition Member Projects

Lower Tuolumne River Parkway Framework for the Future

Map 2.4. Reach 4: In-channel gravel mining reach.

SRP 9 and SRP 10.

4.1a Special Run Pool 9

Lead Organization: Turlock Irrigation District.
Contact: Wilton Fryer, (209) 883-8317

Project Description:

LOCATION

The project is located at river mile 25.9 of the Lower Tuolumne River, just west of the Geer Road Bridge.

PROJECT OVERVIEW

Special Run Pools 9 and 10, adjacent to Fox Grove Park, represent large-scale restoration projects designed to enhance fall run Chinook salmonid habitat. SRP 9 became an extension of the Fox Grove Park when it was completed in December 2001.

The SRP 9 Project was the first in-stream mining pit to be restored. The restoration project goal is to reduce bass predation on salmon fry and smolts and provide improved rearing habitat during their out migration. The TID is the sponsor for the SRP 9 Project on behalf of the Tuolumne River Technical Advisory Committee (TRTAC). The Project had three phases, with Phase I covering design, environmental permits, and pre project monitoring to establish a basis for both the SRP 9 Project and future SRP 10 project downstream. The TRTAC and AFRP funded design, permits, some construction and monitoring while CBDA, through the Metropolitan Water District of Southern California, funded the construction and revegetation.

The in-channel restoration required over 144,000 cubic yards of material to fill a 1,200 foot long by 500 foot wide mining pit that reached 19 feet deep. The project created five acres of additional floodplain lands and added an upland bench with old valley oaks to the lands already in Fox Grove Park. The Turlock Irrigation District also installed an infiltration gallery under the new river channel to provide a future option to augment existing fishery releases by enabling flows up to 100 cfs, that would normally be diverted at La grange, to be left in the upper 26 miles of the river and then withdrawn through the gallery for delivery into the irrigation system to the south of the SRP 9 Project.

MULTIPLE BENEFITS

The County manages the Fox Grove Park on behalf of the Wildlife Conservation Board. The monitoring from the SRP 9 Project has lead to enhancements to be incorporated into the design for the downstream SRP 10 Project.

KEY PARTNERS

Anadramous Fish Restoration Program, California Bay-Delta Authority (Metropolitan Water District), Stanislaus County Parks Department, Wildlife Conservation Board.

4.1b *Special Run Pool 10*

Lead Organization: Turlock Irrigation District. Contact: Wilton Fryer, (209) 883-8317

Project Description:

LOCATION

The project is located at river mile 25.3 of the Lower Tuolumne River, about ? mile west of the Geer Road Bridge.

PROJECT OVERVIEW

Special Run Pools 9 and 10, adjacent to Fox Grove Park, represent large-scale restoration projects designed to enhance fall run Chinook salmonid habitat. SRP 9 became an extension of the Fox Grove Park, and is now complete.

The SRP 10 Project will be the second in-stream mining pit to be restored, similar in concept, but larger in scope to the work recently completed upstream on the SRP 9 Project at Fox Grove Park. The restoration project goal is to reduce predation on salmon fry and smolts and provide improved rearing habitat during their out migration. The TID is the sponsor for the SRP 10 Project on behalf of the Tuolumne River Technical Advisory Committee (TRTAC). The Project has been divided into two phases, with Phase I covering design, land appraisal, environmental permits and monitoring that is currently fully funded by CBDA and Phase II covering land acquisition and construction that has not been funded.

The in-channel restoration requires over 350,000 cubic yards of material. The land acquisition would be 84 acres. A 15-acre portion will be used to supply materials to create the in-channel restoration and added riparian floodplain. The remaining land consists of 22 acres of riparian land along a 1.2-mile long river frontage and 47 acres of an upland bench currently in walnuts. The walnut orchard has a well and could be used for parkland. All the orchard land is adjacent to the closed County owned Geer Road landfill. The County also owns the parcel north of the project land.

MULTIPLE BENEFITS

The walnut orchard has a well and could be used for parkland. All the orchard land is adjacent to the closed County owned Geer Road landfill. The County also owns the parcel north of the project land. The County has indicated an interest in managing the land as park and public access to the river after the restoration work is complete.

KEY PARTNERS

Anadramous Fish Restoration Program (w/o funding), California Bay-Delta Authority funding of Phase I, and Stanislaus County Parks Department.

4.2 *Fox Grove*

Lead Organization: Stanislaus County Parks & Recreation, 3800 Cornucopia Way, Suite C, Modesto, CA 95358. Contact: Sonya Harrigfeld, Director, (209) 525-6750

Fox Grove County Park

Project Description:

LOCATION

The project is located on the Tuolumne River at Geer Road. The river access is approximately sixty-four acres in size on one mile of river frontage with parking area, restrooms, boat ramp, swimming, barbecues, picnic tables, and handicapped access.

PROJECT OVERVIEW

Proposed improvements include upgrade of many of these facilities to comply with ADA and better serve the number of visitors. New features include habitat enhancement with native plant materials and an educational nature trail, new play equipment and an informal play field. The shelter cove should be investigated for a new swimming hole.

MULTIPLE BENEFITS

The intent of the design to create a place where people can enjoy the Tuolumne River, by creating nature trails and habitat enhancement, including native plant material for educational purposes. Provide safe water access and an increase in amenities for family outings will draw more of the public to the park.

KEY PARTNERS

Working Partners: Wildlife Conservation Board, California Department of Fish and Game.

©Modesto Bee. Volunteer planting at Waterford Percolation Ponds.

Funding Partners: Wildlife Conservation Board and California State Off-Highway Vehicle Park

4.3 *Waterford Percolation Ponds Restoration*

Lead Organization: City of Waterford, P.O. Box 199, Waterford, CA 95386. Contact: Chuck Deschenes, City Administrator, (209) 874.2329, admin@cityofwaterford.org

Project Description:

LOCATION

Waterford Area, South Bank of Tuolumne River

PROJECT OVERVIEW

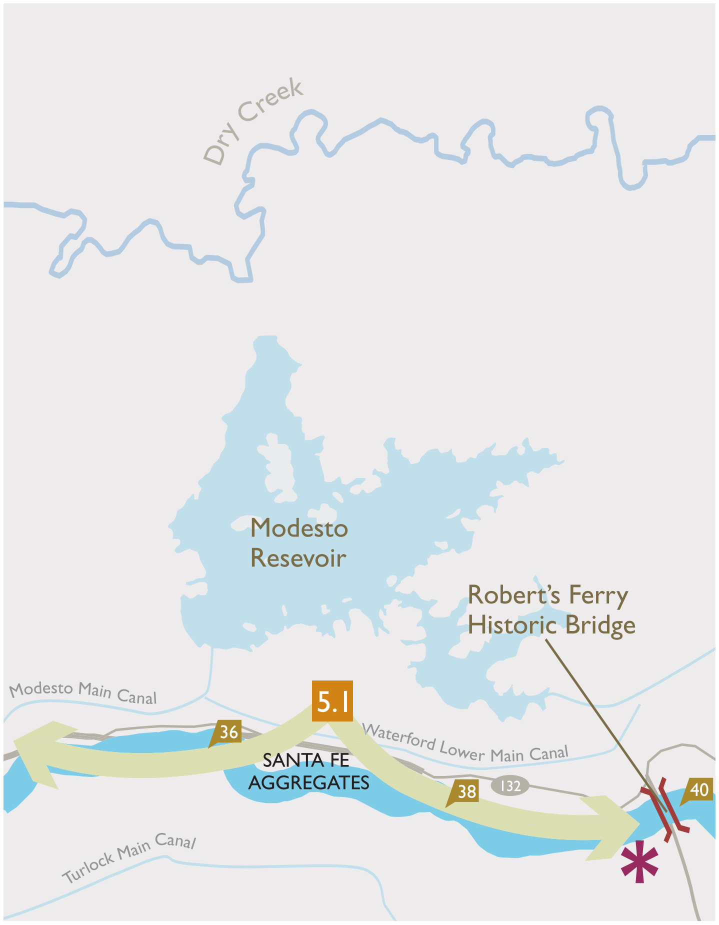
Restoration of native vegetation of the lower portion, adjacent to the river. Project is ready to implement using a phased approach to maximize community involvement and spread out the irrigation and maintenance workload that is needed to get vegetation established in this area.

Multiple Benefits

Water quality improvement, Air quality improvement, Enhanced appearance of area, wildlife habitat, better river shading to help maintain cooler water in hot times of the year, better storm water runoff timing and filtration, less noxious weeds and non-native vegetation.

KEY PARTNERS

Friends of the Tuolumne, local schools and civic organizations.



SOURCE: PREPARED BY MIG, INC. APRIL 2005

Reach 5: Gravel Mining Reach (river miles 34.2 - 40.3)

TUOLUMNE RIVER COALITION MEMBER PROJECTS

5.1 Gravel Mining Reach Habitat Restoration Phases I-IV

Tuolumne River

Bridges

Other Stanislaus County Rivers

Historical/ Cultural Site

Lakes and Water Bodies

11 *River Mile Marker*

Existing Lower Tuolumne River Parkway Project Site

N

Miles
0 1.5

Tuolumne River Coalition Member Projects

Lower Tuolumne River Parkway Framework for the Future

Map 2.5. Reach 5: Gravel mining reach.

Volunteer clean-up at Waterford Urban Park.

4.4 *Waterford Urban Park*

Project Title: City of Waterford Urban Park

Lead Organization: City of Waterford

Project Description:

LOCATION

City of Waterford, river miles 31-32

PROJECT OVERVIEW

This project includes acquisition of land along the Tuolumne River in and around the City of Waterford. Project includes the vegetation of parcels that have been disturbed, but not developed, with native vegetation where feasible to create open space and passive use parkland, wildlife habitat, and river shading which will also improve water and air quality. The project will also include the development of a non-motorized boat launch, parking, picnic areas and restrooms on parcels that have already been developed or significantly disturbed.

The acquisition, passive amenities and vegetation work is ready to be implemented on most parcels. Some environmental work may be needed for non-passive use activities contemplated.

MULTIPLE BENEFITS

Recreation, Education, River access, non-motorized boat launch, alleviation of eyesores, removal of non-native and non-native noxious plants, improved wildlife habitat, improved water quality, improved air quality.

KEY PARTNERS

Ongoing, feel free to join up! Current and immediate past partners are members of the Tuolumne River Coalition, State of California Department of Resources, The Friends of the Tuolumne, San Francisco FERC Riparian funds administered by the East Stanislaus Resource Conservation District, Grupe Development Company, Hickman School and the Waterford Unified School District.

5.1 *Gravel Mining Reach Habitat Restoration, Phases I-IV*

Lead Organization: Turlock Irrigation District; Wilton Fryer (209) 883-8317

Project Description:

LOCATION

The project is located between River Mile 40.2 and 34.3 with Roberts Ferry Bridge located a River Mile 39.5.

PROJECT OVERVIEW

In total, the Gravel Mining Reach Restoration Project encompasses a 6.1-mile stretch of salmonid habitat restoration in the reach of the river with active terrace mining. The restoration work involves channel reconstruction, setting back existing dikes between the mining pits and the river to widen the floodway, reconstruction of riffle pool sequences to increase spawning and rearing area, and planting riparian forest on the newly created floodway benches. These are considered large-scale projects

Gravel mining reach restoration.

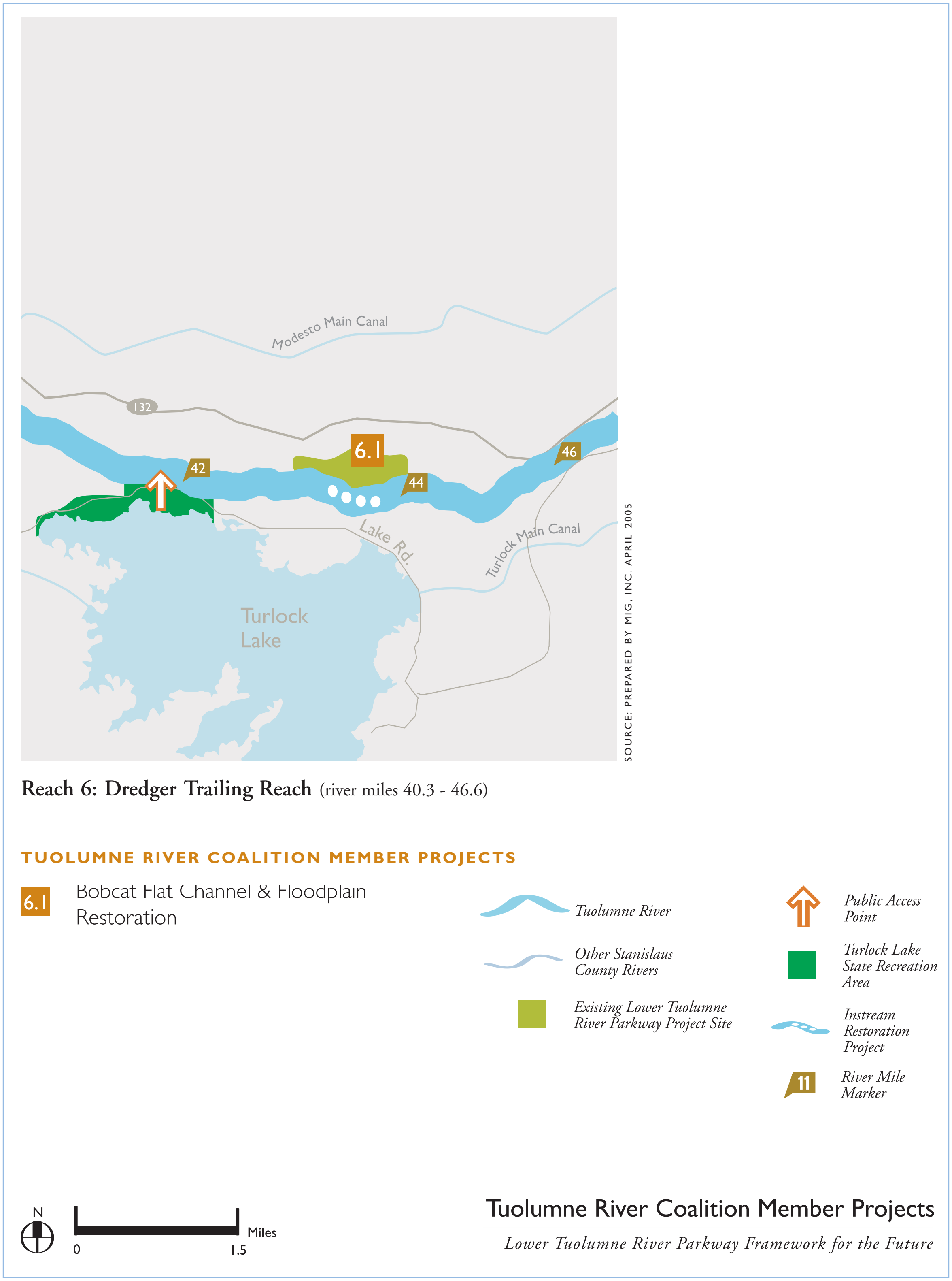
given the 6.1-mile length of the river and the magnitude of the materials used for the restoration construction. The project includes planting of over 150 acres of riparian forest and the construction of a 500 -foot wide riparian floodway with setback dikes as part of channel reconstruction. There is no public access at these sites. The Project is divided into four segments, 7\11, MJ Ruddy, Warner-Deardorff, and Reed, to be funded and constructed sequentially.

The first segment, 7\11, is 2.2 miles long covering 87.4 acres, 31.4 acres of which were reforested. Construction and planting occurred between April 2002 and March 2003 at a cost of $6,747,812, including purchase of aggregate mining rights within the footprint of the project. Approximately 540,000 cubic yards of aggregate and topsoil were moved and five new riffles were constructed.

The second segment, MJ Ruddy, is 1.1 miles long covering 56.8 acres. Approximately 36.4 acres of floodplain will be created or modified to increase the floodway capacity, and native riparian habitat will be increased from 18.6 acres to 42.2 acres Approximately 465,000 cubic yards of aggregate and topsoil will be moved in this project. The Project has been fully funded in the amount of $7,737,000 with $115,000 from the Districts and $7,622,000 from the US Fish & Wildlife AFRP. The design work is complete, ROW acquisition is underway, and construction in anticipated to begin in the spring of 2005 with revegetation in the fall of 2005. Maintenance of the revegetation planting will extend through September 2006.

The third segment, Warner Deardorff, is 1.4 miles long covering 75 acres. The project will involve 500,000 cubic yards of material nearly all of which can be generated on site because historic floodplains on the Deardorff parcel will be lowered and the remainder of the Tulare Pond deepened to supply the materials. This phase will also create approximately 63.6 acres of floodplain. Native riparian vegetation will increase from 56.9 acres to 67.5 acres. The Project has been fully funded with $518,670 from the US Fish & Wildlife AFRP and $10,800,000 from the CBDA. The design and permitting of the MJ Ruddy and Warner Deardorff segments has been done as one project under the District's contribution for the MJ Ruddy Segment. The design work is 90% complete; ROW acquisition will commence after completion of the MJ Ruddy ROW acquisition, and construction is anticipated to begin in the spring of 2006 with revegetation in the fall of 2006. Maintenance of the revegetation planting will extend through September 2007.

The fourth segment, Reed, is 1.4 miles long covering 50 acres. In a manner similar to Segment III, the Reed segment restoration was originally intended to use on-site materials for channel and floodplain reconstruction to avoid the need for imported materials. Extensive mining at the site in recent years may now require importation of



Map 2.6. Reach 6: Dredger training reach.

materials to complete the restoration. Restoration will create approximately 48.2 acres of floodplain. Native riparian vegetation will be increased from 35.9 acres to 47.5 acres. While the Reed Segment has been identified as the fourth project in the Mining Reach there has been no funding by the State, Federal, or District pledged or awarded for the project at this time. In 1999 the estimated cost for this project was $3,340,000. The funding Agencies have asked to see the first three segments completed first before considering funding for the Reed Segment.

MULTIPLE BENEFITS

The projects increase salmon spawning and rearing habitat, increase riparian forest available for avian & terrestrial species and future shaded riverine habitat, provide continuity of fluvial processes within the Mining Reach, remove flow constrictions for improved upstream fluvial processes, and reduce entrapment of salmon fry & smolts by increasing flow capacity of the floodway.

Bobcat Flat restoration.

KEY PARTNERS

Funding came from Anadramous Fish Restoration Program, CBDA (including MWD), and Districts (TID, MID, CCSF). Other partners are local aggregate mining companies, local landowners, and TRTAC.

6.1 *Bobcat Flat Floodplain and Channel Restoration*

Lead Organization: Friends of the Tuolumne, Inc., 7523 Meadow Avenue Stockton, CA 95207. Contact: Allison Boucher, (209) 477-9033 www.friendsofthetuolumne.org

Project Description:

LOCATION

Approximately 12 miles upstream from Waterford in the salmon spawning reach.

Project Overview

Coarse spawning gravel is available on site and from a willing seller neighbor. Placing this gravel in spawning riffles would complete the restoration phase started during summer of 2005.

Project Readiness

Permits and environmental documentation for excavation and placement of spawning gravel will be completed before construction begins in 2005. The current CALFED budget provides for excavation, placing 5,000 cubic yards of gravel, and replanting of the floodplain. Additional funding is being requested to place another 5,000 cubic yards for spawning riffles. This additional 5,000 cubic yards will be ready for placement along with additional gravel available from a neighbor. The second stage will begin as soon as funding is available.

SOURCE: PREPARED BY MIG, INC. APRIL 2005

Reach 7: Dominant Salmon Spawning Reach (river miles 46.6 - 52.1)

TUOLUMNE RIVER COALITION MEMBER PROJECTS

- 7.1 La Grange Regional Park
- 7.2 Basso Bridge Fishing Access
- 7.3 Fine Sediment Reduction & Spawning Gravel Additions

Tuolumne River
Other Stanislaus County Rivers
Existing Lower Tuolumne River Parkway Project Site
Bridges
California Department of Fish & Game—La Grange Field Station
Instream Restoration Project
Public Access Point
Historical/ Cultural Site
La Grange Dam
Wildlife Viewing
River Mile Marker

N
0 1.5 Miles

Tuolumne River Coalition Member Projects
Lower Tuolumne River Parkway Framework for the Future

Map 2.7. Reach 7: Dominant salmon spawning reach.

La Grange Regional Park.

Multiple Benefits

The instream fishery restoration will benefit both Chinook salmon and steelhead trout for spawning and juvenile rearing. Non-native predator fish habitat will be reduced. The floodplain replanting will benefit birds and mammals that depend on streamside vegetation. The damage from the gold dredgers will be repaired and the floodplain will be able to once again accommodate seasonal inundation and floods. A more natural setting will promote geomorphic and ecological processes. Instream restoration will apply the principles of the AFRP and Tuolumne River Technical Advisory Committee's "Coarse Sediment Management Plan for the Lower Tuolumne River."

KEY PARTNERS

CALFED ($2 million) funded the acquisition and first phase of the restoration. Turlock Irrigation District also partnered with us bringing $300,000 for instream salmon riffle restoration funded by California Department of Water Resources/ Department of Fish and Game. Matching funds for the land acquisition ($138,467) were contributed from the San Francisco FERC Riparian Fund administered by the ESRCD. Stanislaus Fly Fisherman also contributed $1,000 from their conservation fund for this project.

7.1 *La Grange Regional Park*

Lead Organization: Stanislaus County Parks & Recreation, 3800 Cornucopia Way, Suite C, Modesto, CA 95358. Contact: Sonya Harrigfeld, Director, (209) 525-6750

Project Description:

LOCATION

This project is the most diverse regional park in the County, with over 700 acres located at 11 sites in the La Grange area, including 225 acres of river bottom along the Tuolumne River.

PROJECT OVERVIEW

The Town of La Grange

The project will include nature programs incorporating various components of the park with information on cultural, as well as natural history of the area. The area around the Old La Grange Bridge may include a trailhead with fishing access, picnic area and parking for a loop nature trail connecting the bridge, town and river bottom. The historic bridge will continue to be open only to pedestrian and bicycle traffic.

River-bottom Area

Along Yosemite Boulevard between the town of La Grange and Basso Bridge, the county owns approximately 225 acres of river bottom along the Tuolumne River. Most of this area is currently undeveloped. A river access point has been developed at Basso Bridge. Plans recommend a trail system and loop nature trail, but also recommend keeping these improvements low-impact. Improvements to the restroom/showers, as well as future site furnishings (picnic tables, barbecues) at the Basso Bridge area will need to incorporate features to bring the park into compliance with ADA.

MULTIPLE BENEFITS

This project will provide a safe and unique environment for picnicking, hiking, bird watching, possibly biking, camping, fishing and small boating (non-motorized). Native plant restoration programs should promote the restoration of the oak woodlands, wetlands and native grass stands.

KEY PARTNERS

Working Partners: California Department of Fish and Game, Turlock Irrigation District (TID)

7.2 *Basso Bridge*

Lead Organization: Stanislaus County Parks & Recreation, 3800 Cornucopia Way, Suite C, Modesto, CA 95358. Contact: Sonya Harrigfeld, Director, (209) 525-6750

Project Description:

LOCATION

The Basso Bridge river access is located off Highway 132 west of the town of La Grange, on the upper reach of the Lower Tuolumne River. This improved access is a part of La Grange Regional Park and currently includes a parking lot, restrooms, boat launch, gravel beach area, and picnic facilities.

PROJECT OVERVIEW

Proposed improvements include upgrade of many of these facilities to comply with ADA and better serve the number of visitors. Trail connections to the adjacent areas should be expanded. New signage and interpretive materials should also inform

Basso Bridge.

the visitors not only of the opportunities and precautions relating to the river, but also of the other nearby park resources.

MULTIPLE BENEFITS

Public access will be improved, providing pedestrian trails to adjacent areas. Improvements will provide safe public access, open space, opportunities for boating, passive recreation, picnic, informal play, and educational opportunities regarding river wildlife and vegetation.

KEY PARTNERS

Working Partners: California Department of Fish and Game, Tuolumne River Trust, Friends of the Tuolumne, Inc.

7.3 *Fine Sediment Reduction and Spawning Gravel Additions*

Lead Organization: Turlock Irrigation District. Contact: Wilton Fryer, (209) 883-8317

Project Description:

The sediment management projects are intended to improve quantity and quality of spawning riffles. The projects range from cleaning fine sediments deposited in existing riffles, reducing transport of

Gravel stockpiled for a spawning riffle reconstruction project.

fine sediments into the principle spawning areas between Basso Bridge and La Grange, and gravel additions or infusions to create more riffles and to provide improved continuity of sediment transport for the long term maintenance of natural fluvial process in segments of the river. There were four sediment management projects identified by the TRTAC.

1. The riffle-cleaning project involves evaluating several methodologies for gravel cleaning to improve the survival to emergence associated with the existing gravel quality of the spawning riffles. The objectives are to: (1) quantify the relationship between substrate permeability and Chinook salmon survival-to-emergence and (2) reduce the volume of sand stored in the mainstem channel and, hence, increase substrate permeability by implementing five riffle-cleaning projects. The project implemented a field experiment to quantify the relationship between permeability and salmon survival-to-emergence to provide guidance on the level of gravel cleaning the project should work towards. Sand storage in riffles throughout the spawning reach has been assessed by the TRTAC monitoring program

Project Status: The riffle-cleaning project has been funded by CBDA in the amount of $404,230. The survival to emergence study and pool sand volume assessment has been conducted. The methods and equipment for cleaning sand is currently under evaluation. It is anticipated sand cleaning work will be conducted in the summer of 2005.

2. The Gasburg Creek Project has three elements to reduce the transport of fine sediment into the primary spawning reach of the river. These were an assessment of the Gasburg Creek watershed to evaluate the contribution of sediment from Gasburg Creek to the Tuolumne River, identify major sediment sources within the Gasburg Creek watershed, and provide recommendations for reducing sediment delivery from the watershed. The study found two locations within the basin where remedial action is recommended to reduce the amount of sediment to be handled in a sedimentation basin to be constructed on property owned by the California Department of Fish & Game (CDFG) in La Grange. The construction of a sedimentation basin includes channel restoration design and implementation for a 300-foot reach of the creek downstream of the sedimentation basin.

Project Status: The project has been funded by CBDA in the amount of $590,880. The watershed assessment and design work are complete. Construction of the sedimentation basin is scheduled for the summer of 2005 pending approval of the design by CDFG.

3. The third project is the Gravel Augmentation Project. On the Tuolumne River, gravel and cobble are needed to restore degraded sections of river to more productive conditions and to increase salmon spawning habitat. The Gravel Augmentation

Project is implementation of restoration in the priority areas identified in the TRTAC "Coarse Sediment Management Plan". Two important restoration goals in this project are to:

- Continue with large-scale sediment augmentation by placing large volumes of spawning gravel-sized material in the upper gravel-bedded reaches below La Grange Reservoir, to increase spawning habitat availability and improve geomorphic conditions.
- Develop project implementation, monitoring, and adaptive management plans that will facilitate a long-term sediment augmentation program on the Tuolumne River.

The project entails placement of 300,000 cubic yards of screened aggregate to increase salmon spawning habitat by reducing the gradient of existing riffles and by the addition of aggregate in alternate bars within the long runs between existing riffles to further increase available spawning habitat. The project design and implementation process are intended to include protection of existing *O mykiss* habitat while expanding salmon spawning habitat with the aggregate infusion.

Project Status: The project has been funded for $4,400,000 with the FSA contributing $50,000 and the CBDA contributing $4,350,000. The design and permitting work has started. Placement of the aggregate can only be done in the summer period when salmon are not present. It is anticipated the placement will take three years, starting in the summer of 2005.

4. The River Mile 43 Project is a joint project with the Friends of the Tuolumne as part of their Bobcat Flat Project in the Dredger Tailings Reach of the river. The project is designed to demonstrate how to increase available spawning areas in the Dredger reach of the river. Reversing the impacts of the dredge mining require conversion from the current "lake-cascade" morphology back to a more natural pool riffle morphology. This can be accomplished by redistributing the elevation drop in the short steep riffles to create low gradient riffles with a slope less than 0.2%. Adding aggregate in the long lake areas to create new bars and riffle areas can create similar conditions. Reducing the riffle slopes will not only improve the hydraulic conditions within each riffle to increase spawning habitat, but it will also greatly increase the total amount of potential spawning habitat by increasing the riffle surface area.

The River Mile 43 Project involves implementing two gravel addition treatments to reduce the gradient at two riffles and to create a new riffle in between. Approximately 10,000 cubic yards of screened aggregate will be placed in the river. The project includes creation of a high flow bypass channel on the adjacent floodplain as the way to generate the aggregate required for the project. The floodplain work is part of a larger riparian reforestation project conducted by the landowner, The Friends of The Tuolumne.

Project Status: The RM 43 work is fully funded by the California Department of Water Resources (4 Pumps Project mitigation funds) in the amount of $300,000. The design work has been completed. The process for obtaining the permits required to construct the project has started. It is anticipated that inchannel restoration could start in the summer of 2005.

MULTIPLE BENEFITS

The projects increase salmon spawning and rearing habitat and provide continuity of fluvial processes within the spawning reach of the river. The projects are designed to include habitat improvement for *O mykiss*.

KEY PARTNERS

Funding came from Anadramous Fish Restoration Program, CBDA, California Dept. of Fish & Game, Stanislaus County, and Districts (TID, MID, CCSF). Other partners are Friends of the Tuolumne, local landowners, and TRTAC.

2.5 ON-GOING COALITION ACTIVITIES AND ACCOMPLISHMENTS

In addition to the projects described above, Tuolumne River Coalition members increase awareness of the river and its surrounding habitat through a variety of efforts. Examples of other recent collaborations and accomplishments include those described below.

Fundraising Efforts

A joint funding request from Coalition member organizations won $2.625 million in state funding for River Parkways in 2002. The funding is helping to improve habitat and recreation in four projects: Tuolumne River Regional Park, Riverdale County Park, Waterford Urban Parks, and Ceres River Bluff Regional Park.

Outreach Activities

- The Coalition conducted stakeholder interviews and held two community workshops, one in November of 2004 and the second in March 2005. The feedback gathered from stakeholders helped enhance the key strategies presented in this document.
- Tuolumne River Trust has organized annual canoe trips to increase awareness of the river and the Coalition and to view the spawning salmon.
- Coalition members met with State and Federal Representatives including Congressman Cardoza, Assemblymen Cogdill, and Agazarian, and state Senators Poochigian and Denham to discuss the vision of the Coalition.
- The Friends of the Tuolumne, Inc. offer tours of their project sites including Bobcat Flat, Grayson River Ranch, and Waterford Percolation Pond restoration sites.
- Coalition members hosted a visit from Attorney General William Lockyer, including a helicopter tour of the river.
- The Tuolumne River Trust, Cities of Modesto and Waterford, TRRP, Stanislaus County Parks and Recreation, and SFPUC jointly sponsored a canoe trip on November 12th to highlight projects along the Lower Tuolumne River. In attendance were over 50 state and federal agency and elected officials. Congressman Cardoza provided opening remarks at Old La Grange Bridge. Participants then went to Mape's Ranch for lunch and project presentations, followed by a tour of the National Wildlife Refuge.

Community and Volunteer Events

- The Hispanic Youth Leadership Council, Great Valley Museum, Friends of Johnny Poppy Seed, Boy Scouts of America, Girl Scouts, Airport Neighborhood United, and several religious and service organizations contribute time, materials and financial support to the Tuolumne River Regional Park. In the good weather months, several volunteer projects are occurring at any given weekend throughout the Regional Park System (from tree planting to refurbishing picnic areas, to painting bollards, to clean-up days) all play a significant role in developing and maintaining TRRP.
- The Yokuts Group of the Sierra Club has worked with the Tuolumne River Trust and Friends of the Tuolumne, Inc. with various river clean-ups and tree-planting efforts at restoration sites.

- Waterford has worked with Friends of the Tuolumne, Inc. and other volunteers for tree plantings at Waterford Percolation Ponds restoration site.
- Members of the Tuolumne River Regional Park (TRRP) Citizen's Advisory Committee volunteer time and labor to the design and public outreach efforts. Members set up booths at Earth Day, Cesar Chavez Celebration, The International Festival and special events. Members of the TRRP staff give presentations to local service organizations such as the Garden Club, Rotary International, Kiwanis, Lions, Soroptomists, the Hispanic Youth Leadership Council and others.

Policy Collaborations

- Coalition members provide on-going feedback to the development of other Coalition member plans.
- In 1995, five Coalition member organizations[5] and supporters signed on to the FERC Settlement Agreement.
- The development of the Habitat Restoration Plan for the Lower Tuolumne River Corridor was a joint effort that included multiple Coalition members and supporters such as Turlock Irrigation District, Modesto Irrigation District, the Department of Fish and Game, San Francisco Public Utilities Commission, Fish and Wildlife Service, the Tuolumne River Trust, and Friends of the Tuolumne, Inc.
- There are 10 priority projects that have been selected per the FERC Settlement Agreement through the Tuolumne River Technical Advisory Committee.
- The TRRP staff assisted the City of Ceres in the development of River Bluff Park.

The Tuolumne River Coalition will continue to plan for and host activities such as Parkway project tours, canoe trips, natural history and environmental interpretation tours, volunteer tree planting days and river clean-ups that increase the awareness of the river and of Parkway projects.

5. Tuolumne River Trust, Friends of the Tuolumne, Inc., Turlock Irrigation District, Modesto Irrigation District, San Francisco Public Utilities Commission

2.6 OTHER ENHANCEMENT, RECREATION AND MANAGEMENT EFFORTS

In addition to the on-going efforts of the Coalition member organizations, many state, federal, and private agencies continue to influence the Lower Tuolumne River corridor with their activities.

Public

Public agencies involved with land management along the Lower Tuolumne include the California Department of Fish and Game, which operates a restoration field office in Reach 7 near La Grange, and the USDA's Natural Resources Conservation Service (NRCS), which works with local leadership provided by ESRCD to conserve, improve, and sustain natural resources, the environment and the economy of the river. The NRCS has purchased 5 conservation easements with many parties near Shiloh Road Bridge, including Grayson River Ranch and Big Bend.

California State Parks has also published "California State Parks and the Great Central Valley" in April 2004. The report identifies unique recreation opportunities in the Central Valley, particularly along rivers, and a great recreation need due to booming population growth. California State Parks is actively exploring opportunities to contribute to the Tuolumne River Parkway.

Region-wide efforts that encompass or may encompass the Lower Tuolumne River in the future include several San Joaquin Basin water quality studies. The Central Valley Regional Water Quality

Control Board (RWQCB) will be releasing an updated San Joaquin Basin Water Quality Assessment in 2005. The U.S. Geological Survey also coordinates the San Joaquin Basin National Water Quality Assessment (NAWQA) Program. Also, the San Joaquin River Water Quality Management Program is an informal collaborative of technical consultants that provides mitigation recommendations in response to Total Maximum Daily Loads (see page 3-9) in the Central Valley Regional Water Quality Control Board's plan for the Bay-Delta.

Other regional efforts that affect the Lower Tuolumne River include the CALFED Bay-Delta Program and the Anadromous Fish Restoration Program (AFRP) of the U.S. Fish and Wildlife Service. The CALFED Bay-Delta Program aims to develop and implement a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta System, while the AFRP has a mission to make all reasonable efforts to at least double natural production of anadromous fish in California's Central Valley streams on a long-term, sustainable basis.

Private

Primary biological, engineering, and environmental consultants actively assisting projects on the Lower Tuolumne River include Trust for Public Land, McBain and Trush, Stillwater Sciences, Hart Restoration Team, and River Partners.

Aggregate mining companies are now required by multiple regulatory agencies to accompany gravel mining activities with channel and riparian mitigation or reclamation efforts. Bridge construction will also trigger restoration or mitigation efforts as required by relevant regulatory agencies.

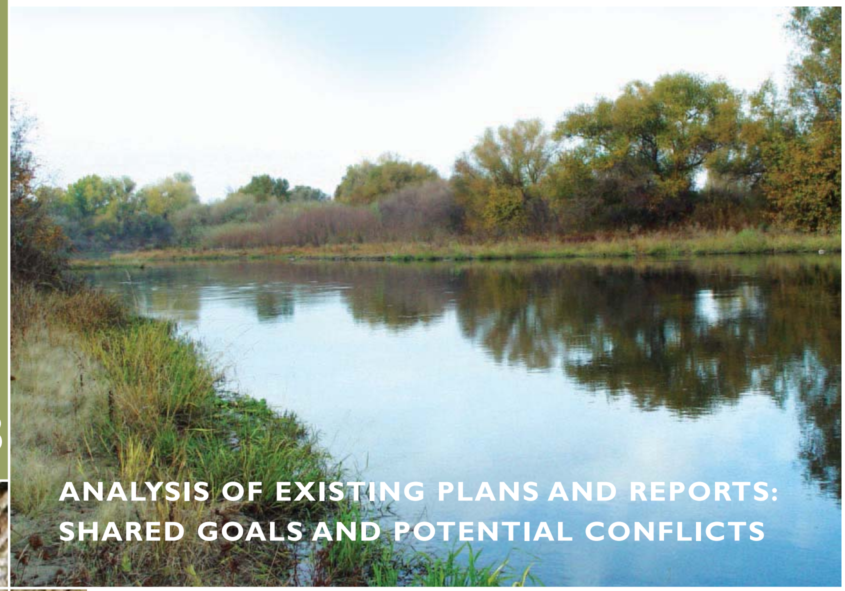
2.7 SUMMARY

This review of the river (and the people, wildlife and vegetation it sustains) highlights the many opportunities and challenges inherent to creating a river corridor that will support self-sustaining populations of native species while connecting people to nature through recreation, open space, and educational opportunities and continuing to support a diverse regional economy. Finding and securing funding and other support for Lower Tuolumne River Parkway projects will be an on-going task. The lack of a clear perception of the Lower Tuolumne River's assets and multiple values by the general public also poses a significant challenge.

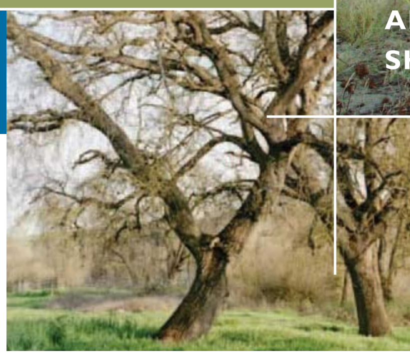
The Tuolumne River corridor's assets include acres of riparian habitat rich in diverse species, developed parklands and public access points for recreational uses, and special interest groups, governmental bodies and regulatory agencies that have invested significant resources in studies, restoration, and management of the river corridor. There are economic and agricultural uses that depend on the river for sustenance. The dynamic between these interests, as well as those yet unrevealed, play a significant role.

Although there are several uses of the river that require further study and understanding, a review of the river today reveals that there is an emerging relationship between people and the river, which will result in highlighting the river as a centerpiece in the community for those who live, work, and recreate near it. Recent efforts are realizing a new level of environmental values and quality of life along the Lower Tuolumne River corridor.

Chapter 3



ANALYSIS OF EXISTING PLANS AND REPORTS: SHARED GOALS AND POTENTIAL CONFLICTS



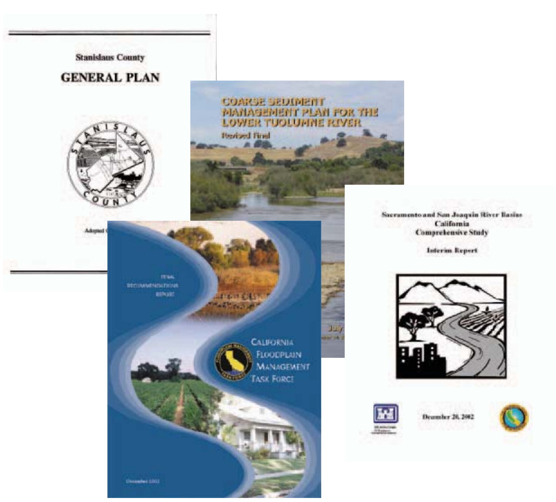
"Preservation insures that future generations will continue to enjoy the natural ecology of our river."

—TUOLUMNE RIVER COALITION MEMBER

3.1 INTRODUCTION

This chapter addresses the second of four tasks identified in the first chapter: to analyze existing plans and reports concerning the Lower Tuolumne River and its floodplain, building upon the Habitat Restoration Plan for the Lower Tuolumne River Corridor (described in greater detail below).

The Tuolumne River Coalition is guided by the vision and approach outlined in the previous chapter, yet also recognizes the complex policies that affect planning along the river. For example, in addition to all of the Coalition members, many local, state and Federal agencies hold jurisdiction along the river, and their policies wield considerable influence on planning related to the river. These include the California-Bay Delta Authority (CALFED), the US Fish and Wildlife Service Anadromous Fish Restoration Program, California Department of Fish and Game (DFG), Stanislaus County, the US Department of Agriculture-Natural Resources Conservation Service (NRCS), and the US Department of Commerce-National Oceanic and Atmospheric Administration (NOAA Fisheries).



In order to address the diverse array of policies that affect the river in this complex environment, the Coalition has adopted three primary approaches: 1) Analyze current plans, reports and studies that pertain to or affect the Lower Tuolumne River; 2) Create a forum, in the form of the monthly Coalition meetings, for on-going discussion of projects and issues concerning the river; 3) Conduct outreach and education to stakeholders and the public to gather and disseminate information (including a Lower Tuolumne River community workshop in November 2004 and on-going communication with stakeholders).

The results of the Coalition's analysis of plans and reports are presented in this chapter. The Coalition conducted an inventory of many plans, reports, and studies relevant to the Tuolumne River and its floodplain. In all, the Coalition collected more than 40 different documents and conducted an analysis of each of these plans, with special emphasis on identifying shared goals across plans, potential conflicts identified in the plans or between plans, and opportunities revealed in the reports.

The shared goals, potential conflicts, and opportunities from existing reports presented here describe current policies that have helped to shape the projects described in Chapter Two. These goals, conflicts and opportunities provide insight into future policy concerning the Lower Tuolumne and build the foundation for the strategies and actions put forth in Chapter Four. These strategies and actions strengthen the common goals and address the needs and gaps identified in this chapter.

Although the strategies proposed by the coalition build upon or address these common goals and potential conflicts, the statements included in this chapter are simply findings. They reflect the wording and approach of existing reports and are not necessarily statements that are endorsed by the Coalition.

Appendix B includes a detailed table of all plans and reports considered in this analysis. The table lists key river elements contained in each document, cites which of the document's policies or goals were referenced in the development of the Framework for the Future, and lists a website (if applicable) where the document is available. Appendix C is a comprehensive inventory of state-

TABLE 3.1 LIST OF EXISTING PLANS, REPORTS AND STUDIES CONSIDERED IN THIS ANALYSIS

AGENCY/ORGANIZATION	PLAN, REPORT OR STUDY
California Bay-Delta Authority	• Ecosystem Restoration (ERP) Multi-Year Program Plan (Years 5-8) • Lower Tuolumne River Adaptive Management Forum Report. October 1, 2001 • Watershed Program Multi-Year Program Plan (years 5-8)
California Department of Fish & Game	• Restoring Central Valley Streams: A Plan for Action. November 1993
California Department of Water Resources*	• Bulletin 118 – Update 2003, California's Groundwater • California Model Floodplain Management Ordinance, December 2001
California Floodplain Management Task Force	• California Floodplain Management Report. December 12, 2002
California Partners in Flight	• Riparian Bird Conservation Plan: A Strategy for reversing the decline of riparian associated birds in California. (Riparian Habitat Joint Venture). August 2000
California Regional Water Quality Control Board, Central Valley Region	• Water Quality Control Plan for the Sacramento and San Joaquin Basins, 1998
California State Parks	• California State Parks and The Great Central Valley, April 2004 • Performance Management Report 2004 • California Outdoor Recreation Plan 2002
Ceres, City of	• Hatch Road Regional Park Master Plan. July 2002 • City of Ceres General Plan

TABLE 3.1 LIST OF EXISTING PLANS, REPORTS AND STUDIES CONSIDERED IN THIS ANALYSIS (CONTINUED)

AGENCY/ORGANIZATION	PLAN, REPORT OR STUDY
Department of Commerce, National Oceanic and Atmospheric Administration	• Federal Register Part IJ 50 CUR Parts 223 and 224
Federal Emergency Management Agency Revised as of October 1, 1994	• National Flood Insurance Program and Related Regulations,
Federal Energy Regulatory Commission	• Federal Energy Regulatory Commission Order Amending Articles 37 & 58 of License for Project Number 2299-024 & –031 • New Don Pedro Proceeding Settlement Agreement. 1995
Friends of the Tuolumne, Inc	• Bobcat Flat Conceptual Restoration Plan
Modesto, City of	• City of Modesto General Plan. 1995, updated 2001 • City of Modesto General Plan, Tuolumne River Comprehensive Planning District • County and City-wide Visioning Statements and Related County Policies, February 5, 2002
River Partners	• Annual Report 2003
San Francisco Public Utilities Commission	• Capital Improvement Program, February 25, 2002 • SFPUC Master Plan
Stanislaus County	• Countywide Visioning Statements and Related County Policies, February 5, 2002 • Stanislaus County General Plan. 1994 • Stanislaus County Agricultural Elements of the General Plan, 1994 • Stanislaus County Parks Master Plan. August 24, 1999 • County of Stanislaus Policy Regarding Agricultural Lands Transaction
Tuolumne River Regional Park	• Tuolumne River Regional Park Master Plan and Master Environmental Impact Report (SCH# 2000022028) • CEQA Findings of Fact and Statement of Overriding Conditions for the Tuolumne River Regional Park Master Plan (Joint Powers Authority, also including City of Modesto and County of Stanislaus). October 2001

TABLE 3.1 LIST OF EXISTING PLANS, REPORTS AND STUDIES CONSIDERED IN THIS ANALYSIS (CONTINUED)

AGENCY/ORGANIZATION	PLAN, REPORT OR STUDY
Tuolumne River Technical Advisory Committee	• Habitat Restoration Plan for the Lower Tuolumne River Corridor. March 2000
U.S. Army Corps of Engineers	• Tuolumne River & Tributaries Feasibility Study Project Management Plan (currently developing work plan and project schedule). October 31, 2001 • Sacramento & San Joaquin River Basins Comprehensive Study for Flood Damage Reduction & Ecosystem Restoration Post-Flood Assessment, December 20, 2002
U.S. Fish & Wildlife Service	• Environmental Assessment and Land Protection Plan. Proposed Addition to the San Joaquin River National Wildlife Refuge Stanislaus County, CA. (for the establishment/expansion of the riparian wildlife refuge in 1998), April 1998 • Final Restoration Plan for the Anadromous Fish Restoration Program: A Plan to Increase Natural Protection of Anadromous Fish in the Central Valley of California, January 9, 2001 • Central Valley Habitat Joint Venture Implementation Plan, February 1990 • The Economic Impact on Stanislaus County of Public land Acquisitions and Conservation Easements on Floodplain Lands Along the Lower Tuolumne and San Joaquin Rivers. Revised Draft Report, December 2002 • AFRP Tuolumne River Watershed Data • Workplan for Fiscal Year 2003, September 20, 2002 • San Joaquin National Wildlife Refuge Comprehensive Conservation Plan • Coarse Sediment Management Plan for the Lower Tuolumne River, Revised Final, July 20, 2004[1] • Tiered Environmental Assessment. 1998[2]
Waterford, City of	• City of Waterford General Plan. November 1991

1. This report was co-authored by the U.S. Fish and Wildlife Service and Tuolumne River Technical Advisory Committee.

2. This report was co-authored by the U.S. Fish and Wildlife Service and Turlock Irrigation District.

ments excepted from existing plans and reports that was used as the basis for analysis. A list of agencies and their documents considered in this analysis include those listed in Table 3.1 on page 3.3.

Overview and Role of the Habitat Restoration Plan for the Lower Tuolumne River

The Habitat Restoration Plan for the Lower Tuolumne River is a document prepared by consultants McBain and Trush under the direction of the TRTAC, including the irrigation districts, federal agencies, and local non-profits (see page 2-33 for a list). The Restoration Plan was finalized in 2000.

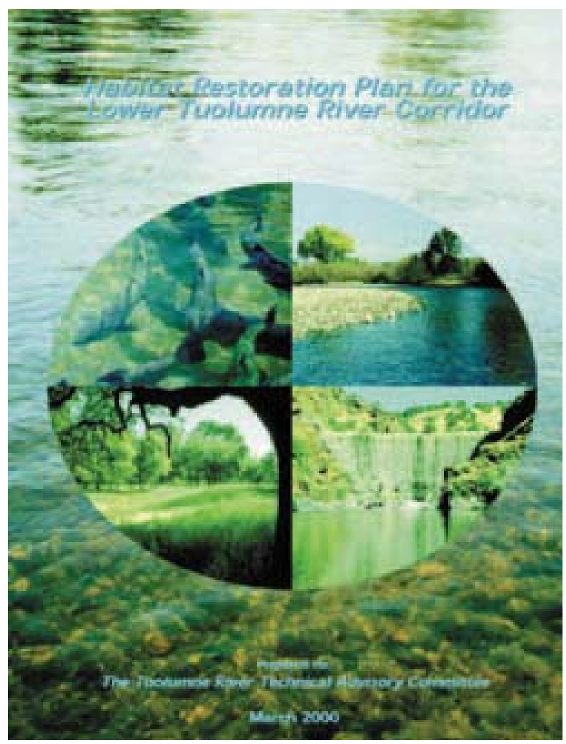
The Restoration Plan is based on the assumption that many human and economic uses depend upon the Tuolumne River and a strategy for restoring the river must recognizes these uses. The Restoration Plan provides extensive technical information about restoring the Lower Tuolumne river channel and riparian corridor, especially to improve Chinook salmon and wildlife habitat. It provides information about the history of the Tuolumne River, anadromous fish, riparian vegetation, and fluvial morphology. It also established the boundaries of the seven reaches of the river referred to in this document.

The Framework for the Future builds upon the technical foundation of the Restoration Plan through the examination of other plans and policies concerning the Lower Tuolumne River and its floodplain. The Restoration Plan focuses on restoring riverine and riparian habitats and presents more limited information concerning the social and cultural environment surrounding the river. The Framework for the Future addresses more fully those aspects and will act as an advisory document to the work of the Tuolumne River Coalition.

The Habitat Restoration Plan for the Lower Tuolumne River Corridor (Restoration Plan) combines knowledge of salmon ecology with information about the fluvial geomorphic and hydrologic processes, presents results from extensive fluvial geomorphic and riparian vegetation investigations, develops river-wide as well as reach-specific restoration goals and strategies, and proposes an adaptive management monitoring approach for restoration projects.

The primary goals for restoring the Lower Tuolumne River laid out in the Restoration Plan include:

- A continuous river floodway along the Lower Tuolumne River with capacity that safely conveys at least 15,000 cfs above Dry Creek and 20,000 cfs below Dry Creek



Habitat Restoration Plan for the Lower Tuolumne River Corridor.

- A continuous riparian corridor along the Lower Tuolumne River, with a width exceeding 500ft minimum in the gravel-bedded reaches to a width up to 2,000ft near the San Joaquin River.
- A dynamic alluvial channel, maintained by flood hydrographs of variable magnitude and frequency adequate to periodically initiate fluvial geomorphic processes (e.g. mobilize channel bed surface, scour and replenish gravel bars, inundate floodplains and promote channel migration).
- Variable streamflows, such as during Chinook spawning, rearing and emigration, to benefit salmon and other aquatic resources.
- A secure gravel supply to replace gravel transported by the high flow regime, thus maintaining the quantity and quality of alluvial deposits that provide Chinook salmon habitat.
- Bedload transport continuity throughout all reaches.
- Chinook salmon habitat created and (once re-established) maintained by natural processes, sustaining a resilient, naturally reproducing Chinook salmon population.
- Self-sustaining, dynamic, native woody riparian vegetation and reduced extent of exotic plants.
- Continual revision of project management to ensure adaptive management, addressing areas of scientific uncertainty that will improve our understanding of river ecosystem processes and refine future restoration and management.
- Increased public awareness and involvement in the Tuolumne River restoration effort.
- A clean river. Community's perception of a river's intrinsic value is largely based on visual aesthetics. To most people, a clean river is worth caring for, and the public will be more conscious of keeping it clean.

3.2 SHARED GOALS AND POTENTIAL CONFLICTS FROM THE ANALYSIS OF EXISTING PLANS, REPORTS AND STUDIES

The analysis of existing plans, reports, and studies involved cataloguing and comparing goal and policy statements from within these documents that relate to the Tuolumne River. Small groups within the Tuolumne River Coalition analyzed the goal and policy statements to identify those that communicated shared goals, called out potential conflicts, or identified common opportunities relating to the river. In many cases, statements from documents were recorded word for word; in others, they were summarized or consolidated.

Coalition members then organized the goal and policy statements into categories characterized by either a river element (such as water supply or habitat restoration) or river location (such as the upper reaches of the river). This section discusses the analysis by river element first, and then by river location. **They are not presented in priority order.**

Each element or category begins with a discussion of the current status of the element, followed by statements concerning shared goals across existing reports, potential conflicts across existing reports, or identified by the reports, and/or opportunities revealed in the analysis of existing documents. Each statement is numbered, so that the first statement for "Water Supply", for example, is called "WS-1" and the second "WS-2" and so on. These statements of analysis are summarized in Appendix D. Appendix F links specific strategies (as outlined in the Chapter Four) to the specific statements of analysis they address.

The categories of river elements or location are as follows:

3.3 WATER SUPPLY[3]

The Lower Tuolumne River, along with three major reservoirs, provides drinking and irrigation water to Stanislaus County. Currently, the water supply from the Lower Tuolumne River is regulated through a variety of mechanisms. Don Pedro Dam regulates releases of stored runoff (for example, seasonal rainfall and snowpack melt) that continually re-charge the Tuolumne River. Modesto and Turlock Irrigation Districts are responsible for maintaining river flows below La Grange Dam to meet the needs of fisheries and for the purposes of flood management. As discussed in Chapter One, water diversions from the Upper Tuolumne River also impact the river and riparian characteristics of the lower section. Runoff from the Upper Tuolumne supplies the Hetch Hetchy system, which is the largest water supply and conveyance system of the San Francisco Public Utilities Commission (SFPUC), providing about 85% of the total SFPUC system water supply.

Irrigated fields.

Water from the Lower Tuolumne River not only supports many plant and animal species, but also provides for industrial, environmental, recreational and agricultural uses as well. River flows, whether high or low, affect habitat conditions as well as recreation, while high flows can pose potential threats to some residents, businesses, and farms, they are necessary at times to sustain certain types of riparian vegetation, and may also be unavoidable. Low flows can affect fish ecology and distribution, riparian habitat, and recreation opportunities.

Shared Goals, Potential Conflicts and Opportunities

WS-1: Analysis of existing plans and reports indicates a shared goal to enhance support for innovative means to accommodate diverse water uses.

3. San Francisco Public Utilities Commission Water Supply Master Plan; Tuolumne River Technical Advisory Committee. Habitat Restoration Plan for the Lower Tuolumne River Corridor. March 2000; Modesto Irrigation District: http://www.mid.org/

MID Main Canal, near Reach 7.

- Commonly proposed approaches focus on water conservation, reclaimed wastewater, and groundwater management programs.

WS-2: The analysis of plans reveals there may be conflicts and competition for limited water resources for diverse urban, agricultural, environmental, and recreational needs.

- Water management may affect the degree to which a natural functioning river ecosystem is restored to the Lower Tuolumne.
- Boating and other recreational opportunities are affected by river flows
- Flow affects water temperatures which influence the status (e.g., health and numbers) of aquatic species.

3.4 WATER QUALITY (WQ)[4]

Areas of concern along the Lower Tuolumne include the confluence with Dry Creek and other areas where urban and agricultural run-off enters the river. There also exist several land uses of potential concern located near the river, including three sewage treatment sites, a tallow factory, a junkyard, chlorine storage, gravel mining activities, adjoining residential development, and various industrial uses in the urban areas. In recent years, cities and the County have begun various mitigation efforts to control storm-water run-off.

The Tuolumne is included in the geographic area of the State Water Resources Control Board's Organophosphorous Pesticide and Salt and Boron TMDL[5]s. The Lower Tuolumne is also on the 303(d) list[6] for impairment by diazinon, Group A Pesticides, and unknown toxicity.

The Central Valley Regional Water Quality Control Board's (RWQCB) Intensive Basin Unit, in conjunction with its Surface Water Ambient Monitoring Program (SWAMP) Unit monitors specific sites along the Tuolumne and Dry Creek for Total Coliform, E. coli, Total Suspended Solids (TSS), Total Organic Carbon (TOC), Trace Elements (TE), Partial Mineral, Nutrients A and B, and Toxicity in addition to conductivity (EC), pH, Dissolved Oxygen (DO) and temperature.

The sites that are monitored by the RWQCB are as follows: Tuolumne at Old La Grange Bridge; Tuolumne at Legion Park; Tuolumne at Riverdale Fishing Access; Tuolumne at Shiloh Fishing Access; and Dry Creek at La Loma Rd. The pesticides unit

4. Central Valley Regional Water Quality Control Board: Tuolumne River Technical Advisory Committee. *Habitat Restoration Plan for the Lower Tuolumne River Corridor.* March 2000

5. "TMDL"s are "Total Maximum Daily Loads", a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. By law, EPA must approve or disapprove lists and TMDLs established by states, territories, and authorized tribes. If a state, territory, or authorized tribe submission is inadequate, EPA must establish the list or the TMDL. EPA issued regulations in 1985 and 1992 that implement section 303(d) of the Clean Water Act - the TMDL provisions.

6. Section 303(d) of the Clean Water Act requires water departments to develop prioritized lists of streams and lakes that do not support their designated uses, and to provide information on the pollutants and sources that are the causes of non-support.

Tuolumne River, Downstream of Waterford

also monitors the following sites most frequently for Diazinon and Chlorpyrifos: Tuolumne at Santa Fe Road near Empire; Tuolumne at Modesto; Dry Creek at Gallo Bridge; and Dry Creek at Modesto.

Several region-wide water quality efforts were identified in Chapter 2.

Shared Goals, Potential Conflicts and Opportunities

WQ-1: A common goal across plans and reports is to maintain or improve current water quality of the Lower Tuolumne and its tributaries to support human uses and diverse aquatic ecosystems.

- There is support for the implementation of practices to improve water quality and floodplain restoration. Approaches include Best Management Practices such as water quality and wastewater planning, monitoring, management of agricultural and urban run-off, and riverbank restoration.
- There is widespread support for significant efforts to address dumping of refuse in the river.

WQ-2: The study of plans reveals that there may be conflicts between upstream water diversions that decrease flows in the river and water quality (temperature, dissolved oxygen, cleanliness).

WQ-3: Plan analysis points to other potential conflicts when land uses and water diversions may lead to excessive sedimentation therefore limiting water quality improvement efforts.

WQ-4: The examination of existing plans indicates that a lack of coordination across cities and other entities that manage land along the river may inhibit water quality improvement efforts.

3.5 FLOODPLAIN AND FLOODWATER MANAGEMENT (FM)

Currently, floodplains along the Lower Tuolumne are managed and maintained through a variety of mechanisms including agricultural practices, flood control (flow restrictions and levees), private mining and agricultural berms, riparian habitat restoration, open space and park/golf course designation, and controlled land use (such as restricting building within the floodplain). These mechanisms represent diverse, and at times conflicting, approaches to flood and floodplain management.

Shared Goals, Potential Conflicts and Opportunities

FM-1: A common goal across several of the plans and reports analyzed is to manage floods to protect people, developed areas, and habitat through diverse mechanisms.

- Flood management approaches include non-structural approaches (utilizing the natural floodplain to accommodate flood waters).
- Flood management approaches include allowing inundation where it could contribute to the ecological value of the corridor and not threaten people or development.

Flooding near Modesto.

- Filling, dredging, or grading that could increase flood damage can be controlled.

FM-2: Through the analysis of plans, it appears that there may be conflicts or limitations between existing land uses and flood management approaches.

- Safety of residential developments must be of primary concern in considering any floodplain management approach.
- Existing mining practices may intensify flood damage.
- Natural floodplain and channel processes may be limited by urban development and other land uses.
- Existing or potential development may restrict the use of non-structural approaches to flood damage reduction.
- Some flood management approaches may limit habitat restoration opportunities.

3.6 GEOMORPHOLOGY (GM)

Geomorphology is defined as the evolution and configuration of rocks, soils, and landforms. The geomorphology, or physical configuration, of the river (or "fluvial" environment) determines, in part, what plants and animals will be found in and near the river.

The Lower Tuolumne River is an alluvial river. An alluvial river has riverbed, banks, and floodplains composed of coarse and fine sediments (sand, gravel, and cobble). A natural river is dynamic in that it is able to frequently move the channelbed and banks and scour coarse sediments, which are then replaced by comparable materials transported from upstream. The morphology or shape of the river is thus maintained over time in what is called a "dynamic quasi-equilibrium".

Floodplain near Waterford.

Shared Goals, Potential Conflicts and Opportunities

GM-1: Several of the plans and reports share goals to attain an active and vegetated floodplain that supports multiple uses and resources.

- Natural river processes could be achieved through managing coarse sediment supplies and flood management that contributes to the ecological value of the river corridor.

GM-2: The examination of plans indicates that finite sediment resources may lead to competition between gravel mining, habitat restoration, natural river processes, and flood management.

GM-3: Plans and reports call out that conflicts may occur because upstream water management may limit the potential to achieve naturally functioning processes, such as a balance of coarse and fine sediments.

3.7 RIPARIAN HABITAT (RH)

The area of riparian vegetation along the Lower Tuolumne River has been greatly reduced as reviewed in Chapter 2. Like the rest of the Central Valley, much of the riparian forest along the river corridor has been eliminated.[7] The main terrestrial vegetation communities represented along the Tuolumne River are: grasslands, riparian woodland, agriculture land, and wetlands. The most abundant and significant native species remaining today are the Narrow-leaf willow (and willow species in general), the Fremont Cottonwood, and the Valley oak. Both native and non-native plant species are listed in Appendix G.

Riparian vegetation serves as habitat for diverse breeding and migratory songbirds, provides nesting sites for birds of prey and colonial nesting waterbirds, and acts as home and travel corridors for forest-dependent wildlife.

Shared Goals, Potential Conflicts and Opportunities

RH-1: Goals shared across several plans and reports are to protect and conserve riparian habitat.

- Native, sensitive, and self-sustaining habitats are prioritized for protection.

7. United States Fish and Wildlife Service. *San Joaquin River National Wildlife Refuge Comprehensive Conservation Plan.* 2004

Bobcat Flat Preserve.

- Valley oak and Fremont cottonwood stands in particular are identified for protection.
- Emphasis is placed on preserving habitat for both ecological and public values.

RH-2: The analysis of plans reveals that the Habitiat Restoration Plan Goal to establish a riparian corridor of 500-2,000 ft along the Lower Tuolumne may conflict with other existing or projected land uses.

RH-3: The analysis highlights that multiple plans and reports identify opportunities to restore habitat through a multi-pronged approach.

- Adequate flows and floods could assist in restoration.
- Restoration could include mitigation from new development as well as restoration in undeveloped areas.

Studying Riparian brush rabbits at the Refuge.

Aleutian cackling geese arrive at the Refuge.

- Restoration could be assisted, where possible, by widening of the river corridor.
- Individual volunteers, especially landowners along the river, could significantly enhance habitat improvements through restoration of their properties.

3.8 TERRESTRIAL SPECIES[8] (TS)

Mammals

Endangered or Threatened mammalian species potentially found in the Lower Tuolumne River corridor include the San Joaquin Kit Fox, the San Joaquin Valley (Riparian) Woodrat, and the Riparian Brush Rabbit. There are now multiple known sites of the Riparian Brush Rabbit in or near the San Joaquin River National Wildlife Refuge, and the Refuge is expanding their habitat. There may also be bat species present that are Species of Concern.

8. San Joaquin River National Wildlife Refuge Study Report; San Joaquin River National Wildlife Refuge Comprehensive Conservation Report; Stanislaus Audubon; Central Valley Habitat Joint Venture Implementation Plan; TRRP Master Plan Existing Conditions Technical Memorandum #4; Habitat Restoration Plan for the Lower Tuolumne River Corridor; Mitigated Negative Declaration for Special Run Pool 9 (TID)

River Otters have been sighted in both the lower and upper reaches of the river. Other river-oriented mammals found in the river corridor include mink, muskrat (introduced), weasel (long-tailed) and beaver. Many terrestrial mammal species rely on the riparian corridor. The disruption of the riparian corridor in the urban reaches has restricted the location of certain larger mammals, such as deer, to the upper reaches of the river.

Birds

California supports more than 60 percent of all waterfowl (excluding sea ducks) wintering in the Pacific Flyway and about 20 percent in the entire United States, with the Central Valley playing the most significant role of all regions. The Lower Tuolumne River corridor provides habitat for many bird species, and supports approximately 23 bird species of concern. With increasing wetlands restoration projects, the National Wildlife Refuge at the confluence of the Tuolumne and San Joaquin Rivers supports significant waterfowl and waterbird resources and is capable of providing habitat for an even greater abundance of these resources.

Specifically, riparian birds found in the Lower Tuolumne River corridor include Swainson's hawk, Willow flycatcher, Yellow warbler, Osprey, Belted kingfisher, and colonial nesting birds such as herons, egrets, and cormorants. The Bank swallow and Yellow-billed cuckoo are riparian bird species that have become locally extinct in the northern San Joaquin Valley, but whose populations could recover with habitat restoration efforts.

Spawning salmon in Reach 7.

Other Species

Other Endangered or Threatened species currently living within the Lower Tuolumne River corridor include the Valley Elderberry Longhorn Beetle and other Species of Concern include the Western Pond Turtle and the Silvery Legless lizard. Appendix G contains a more comprehensive list of all species found in the Lower Tuolumne River region.

Shared Goals, Potential Conflicts and Opportunities

TS-1: The analysis of plans reveals a common goal across many plans to enhance the river corridor as bird habitat for native bird species.

TS-2: The analysis indicates that achieving species recovery through habitat restoration efforts is also a mutual goal.

- Emphasis is placed on protecting wildlife habitat through working with public and private landowners.
- The recovery and protection of federal and state listed endangered, threatened, sensitive and rare wildlife is prioritized.

3.9 AQUATIC SPECIES[9] (AS)

NOAA Fisheries has proposed that the Central Valley steelhead trout remain a Federally-listed Threatened species. Currently, the fall-run Chinook salmon is a candidate species. Both steelhead and salmon are anadromous.[10] Other fish species of concern found in the river include Pacific lamprey and river lamprey.

Chinook salmon provide an illustrative example of the life cycle of an anadromous fish. Chinook salmon are the largest of the five anadromous North American Pacific salmon species. The life cycle of the Chinook salmon begins and ends on the spawning grounds. In the San Joaquin basin, adults typically arrive at the spawning grounds from October into December, peaking in early- to mid-November. Spawning takes place from mid-October through late-December. Fry, about 1.5 inches long, emerge mostly from January to March. Fry may emigrate from the river into San Joaquin river and the Bay Delta estuary soon after emergence, but some rear in the river for several months before migrating, mostly in April to May as 3-4 inch smolts. Tuolumne River Chinook salmon return to spawn when they are between two- and five-years old.

The life cycle of Central Valley steelhead is similar to that of the salmon in that they are anadromous fish, migrating to sea as juveniles and returning to inland waterways to spawn, as two- to four- year olds. Upstream migration of steelhead occurs in August through March, altered from native patterns as a result of interbreeding with hatchery strains and altered flow and temperature conditions below major dams. Steelhead spawning typically occurs December through April. Unlike Chinook salmon, most steelhead do not die after spawning, and many live on to be repeat spawners. Females have a higher survival rate, and some spawn up to four times. Steelhead that survive spawning return to the sea between April and June. Juveniles generally rear in fresh water for over a year before emigrating as larger smolts, often 8-12 inches long in December through May.[11]

9. Habitat Restoration Plan for the Lower Tuolumne River Corridor; Adaptive Management Forum Report; Mitigated Negative Declaration for Special Run Pool 9 (TID)

10. Anadromous fish spawn in freshwater streams or rivers and migrate early in their life cycle to the ocean where the mature. They return as mature adults to spawn in the fresh water of their origin.

Shared Goals, Potential Conflicts and Opportunities

AS-1: Mutual goals revealed through the analysis of plans include enhancing and maintaining fisheries, particularly for native anadromous fish.

- Common goals focus on maintaining or improving overall instream habitat, water quality and river flows that support species recovery.

AS-2: Plans and reports indicate that simultaneous demands for increased water supply for fish species, especially steelhead, and other uses such as irrigation may conflict.

AS-3: The plan analysis highlights opportunities to share information regarding annual anadromous fish counts more broadly in order to integrate the community into observing and tracking fish species.

AS-4: Plans also indicate that there are opportunities to examine fisheries projects with an ecosystem perspective when possible.

- Develop complementary and linked fish habitat and riparian habitat restoration efforts.
- Upstream and downstream projects should be integrated to the greatest degree possible.

11. United States Fish and Wildlife Service. *Working Paper on Restoration Needs*

Above Grayson River Ranch and Big Bend (Reach 1).

3.10 LAND USE[12] (LU)

Agriculture in the Great Central Valley

Agriculture continues to be a major industry in Stanislaus County and the entire Central Valley. A number of the largest employers in Stanislaus County produce agricultural related commodities. Principal agriculture includes dairy, almonds, poultry and grapes. Much of this farmland is classified as "Important Farmland", meaning that the land meets certain land use and soil requirements. A 2000 inventory found that over 280,000 acres in Stanislaus County qualified as Important Farmlands, almost 30% of the County. Stanislaus County was, however, also one of the top 10 counties in terms of urbanization of irrigated farmlands throughout the 1990s. The San Joaquin Valley as a whole has been the leading region in California in terms of conversion of irrigated farmland to urban lands for at least two decades.

12. Habitat Restoration Plan for the Lower Tuolumne River Corridor; ;The Economic Impact on Stanislaus County of Public Land Acquisitions and Conservation Easements on Floodplain Lands Along the Lower Tuolumne and San Joaquin Rivers; Department of Conservation Division of Land Resource Protection Farmland Mapping and Monitoring Program

Along the Tuolumne River, agriculture is still prevalent in all but the urban reach (Reach 2), which includes the Cities of Modesto and Ceres. Agriculture is a major contributor to the local economy and an important aspect of regional identity. Agricultural land use on the terraces above the floodplain includes field crops, livestock grazing, orchards and vineyards. Agricultural use in the floodplain is typically considered marginal because of frequent flooding.

Most of the agricultural lands within the Tuolumne River floodplain are in private ownership. Agencies such as USFWS and NRCS have programs to acquire marginal agricultural lands with additional benefits of habitat restoration and riparian buffers.

All current acquisition and easement programs operate in a "willing seller" basis. A 1998 study, "The Economic Impact Stanislaus County of Public Land Acquisition and Conservation Easements on Floodplain Lands along the Lower Tuolumne and San Joaquin Rivers" found that the application of public land acquisition and easements are not likely to have a significant impact on the economy of Stanislaus County.

Other Land Uses

A broad array of diverse land uses is found along the river, including agricultural (as discussed above) as well as park and recreation, natural, residential, and industrial areas.

The majority of publicly-owned and accessible areas bordering the river are parks or recreation areas, such as those presented below in Table 3.2. These areas are well planned, involve community input into the design, are managed to facilitate and regulate the general public, provide opportunities for various recreational activities, and are generally linked by public access points. Restored and protected areas along the river include Lower Tuolumne River Parkway projects such as Bobcat Flat and NRCS floodplain easements near Shiloh Bridge such as Grayson River Ranch and Big Bend. Other non-park or agriculture open space areas include multiple private and public golf courses located next to the river (there are two golf courses along the river in Reach 2 and two in Reach 3), and the large Lakewood Memorial Cemetery in Reach 3.

Residential and industrial lands are mostly found in the cities of Modesto, Ceres, and Waterford and adjacent County lands (Reaches 2-4). The residential areas along the river are predominantly single-family homes. In some areas, residential facilities such as private homes, backyards and swimming pools are located near the river's edge.

The industrial areas along the river include light and heavy industry such as waste treatment and gravel mining operations. Specifically, in Reach 2, the Modesto Airport, Modesto Wastewater Treatment Plant, and rendering and truss plants border the river. The Hughson sewage disposal ponds border Reach 3 of the river, the Waterford sewage disposal ponds are in Reach 4, and aggregate mining operations are located in Reaches 4-6.

Shared Goals, Potential Conflicts and Opportunities

LU-1: Common goals across several plans revealed in the analysis include supporting continued land use controls to help guide growth.

- The use of urban boundaries so that the County will grow in a compact and efficient manner is highly supported.
- Priority is placed on the continued use of the Williamson Act and other mechanisms such as easements to preserve agricultural lands to conserve agriculture as open space, and to conserve open space for itself.

LU-2: The review of plans highlights mutual goals across plans to maintain, expand and link open space.

- Priority is placed on preserving open space in the floodway.
- Open space can provide buffers between the river and urban environments.
- Open space can provide scenic corridors.
- Open space provides recreation opportunities.
- Open space provides sensitive habitat protection.

LU-3: The analysis of plans indicates shared goals across many plans to preserve Important Farmland (such as prime farmland and farmland of local and statewide importance) from conversion and urbanization.

LU-4: The analysis of plans reveals joint goals to maintain farm and ranch land as important components in open space networks of wildlife habitat and scenic corridors.

LU-5: Common goals stressed in many plans are to collaborate and partner with farmers and landowners concerning water quality and supply enhancements as well as habitat restoration and other efforts.

LU-6: Through the analysis of plans, it appears that conflicts may arise when there are real and perceived effects of removing crops from production on individual profitability, the County's economy, and a sense of identity.

LU-7: The examination of plans demonstrates that conflicts may arise due to poorly defined and balanced types of open space.

LU-8: The analysis of plans shows that there is a need and opportunity to define riparian "buffers" and how they function in different roles.

3.11 RECREATION AND ACCESS (RA)

The responsibility of maintaining parks and recreation facilities in Stanislaus County falls primarily upon local and state agencies. These agencies ensure that the general public has access to the Tuolumne River. Twelve access points and many public facilities currently border the river.

TABLE 3.2 PUBLIC FACILITIES ON THE LOWER TUOLUMNE RIVER

PUBLIC FACILITIES	RESPONSIBLE AGENCIES	PUBLIC RIVER ACCESS SITES
La Grange Dam, River Mile 52	Modesto Irrigation District Turlock Irrigation District	No No
DFG Research Site, River Mile 50.5	California Department of Fish and Game	No
La Grange Regional Park, River Mile 50-51	Stanislaus County Parks and Recreation	Yes
Basso Bridge, River Mile 48	Stanislaus County Parks and Recreation	Yes
Fox Grove County Park, River Mile 26	Stanislaus County Parks and Recreation	Yes
Riverdale Park, River Mile 12	Stanislaus County Parks and Recreation	Yes
Shiloh Bridge, River Mile 3.5	Stanislaus County Parks and Recreation	Yes
California Department of Fish & Game at La Grange Field Station, River Mile 49	California Department of Fish and Game	No
Turlock Lake State Recreation Area, River Mile 42	California State Parks	Yes
Waterford Urban River Park, River Mile 31.5	City of Waterford	Yes
Ceres River Bluff Regional Park, River Mile 19	City of Ceres Parks, Recreation, & Facilities	Yes
Tuolumne River Regional Park, River Miles 12-19	Tuolumne River Regional Park JPA (Ceres, Modesto, and Stanislaus County)	Yes
SJR National Wildlife Refuge, River Mile 1	U.S. Fish and Wildlife Service	Yes

Multiple parks and open space areas are located along the river from La Grange to the San Joaquin River National Wildlife Refuge. The largest and closest to downtown Modesto is the Tuolumne River Regional Park (TRRP), which borders the river for seven continuous miles through the cities of Modesto and Ceres. A Joint Powers Authority between the Cities of Ceres and Modesto and Stanislaus County manages TRRP. TRRP provides extensive passive and active recreation opportunities in the urbanized river reach and offers a template for linking river trails and other open space areas with neighboring parks and open space.

Table 3.2 presents a list of responsible agencies and the public facilities they maintain that border the Lower Tuolumne River, along with general public access sites.

Shared Goals, Potential Conflicts and Opportunities

RA-1: The examination of plans and reports shows shared goals to enhance human interactions with the river.

RA-2: Goals common to several plans include linking bicycle and pedestrian trails along or near the river on public lands.

Stanislaus County Parks Boat Launch.

RA-3: Analysis reveals that multiple plans include the goal to increase collaborations across agencies to discuss multi-purpose and appropriate recreation opportunities along and near the river.

RA-4: The review of plans shows that there is a goal to conduct a region-wide recreation needs assessment.

RA-5: The analysis if plans reveal a shared goal to support the use of non-motorized boat access to the river as an existing and future beneficial use.

RA-6: The study of existing plans demonstrates a shared goal to enhance existing river access sites.

RA-7: Many plans and reports were revealed to share the goal of managing access in order to reduce or eliminate potential threats to sensitive habitats and private properties, through increased security or other means.

RA-8: The analysis indicates that several of the plans and reports have a goal to provide recreation and access opportunities to all residents. (Public agencies must ensure ADA compliance.)

RA-9: Through the analysis, it appears that a goal of many plans is to enhance the aesthetics and attractiveness of the river by addressing dumping, trespassing, drug use and other illegal activities along the river.

RA-10: The analysis of plans reveals that current management practices and land uses have not sufficiently addressed issues of public safety along the river including drug use, trespassing, homeless encampments, and the dumping of refuse.

RA-11: Existing plans and reports point out that types of recreation may limit or conflict with each other.

- Motorized boating may not be compatible with non-motorized boating and other activities on the river.
- Passive and active recreation may compete for limited space and resources.

RA-12: The analysis of plans shows that there is a need and opportunity to define passive and active recreation.

- Plans often call for passive recreation at some locations and active recreation in others.

RA-13: The analysis of plans shows that there is a need and opportunity to plan for increased maintenance needs that will be required by enhanced river accesses.

RA-14: The analysis of plans shows that there is a need and opportunity to increase public access and park patrols to reduce trespassing and improve safety.

3.12 STEWARDSHIP AND EDUCATION (SE)

The existing educational and stewardship opportunities (such as field-trips for schools, volunteer planting days, informal educational programs and so on), can be enhanced and expanded to expose more residents to the river, educate more people about it, and involve more people in caring for it.

Concepts for Tuolumne River Regional Park.

Awareness of the river and an emerging dialogue between the public and local governments is being fostered by public workshops presented by the City of Ceres and the Tuolumne River Regional Park. Private landowners have also increasingly integrated restoration into their river front properties. Groups such as the Friends of the Tuolumne, Inc., East Stanislaus Resource Conservation District, Sierra Club and Tuolumne River Trust have assisted in the restoration of and education about these properties.

Multiple sites along the river also offer recreational amenities, viewing of wildlife and hands-on educational programs. For example, the San Joaquin River National Wildlife Refuge continues to enhance and expand environmental education about native California wildlife, their habitat, and their conservation. Visitors to the Refuge can also view multiple wildlife species, as well as experience traditional area activities, including waterfowl hunting and fishing. Recreational access points, such as the Old La Grange Bridge, allow for interaction with the river by the general public.

Shared Goals, Potential Conflicts and Opportunities

SE-1: Analysis shows that many plans share the goal to increase access to and awareness of the river to increase stewardship.

- Stewardship is encouraged through public participation in design workshops, educational venue and classes, volunteerism and frequent access to the river and its multiple values.
- Stewardship would be encouraged through the development of interpretive centers and interpre-

Reach 7.

tive trails, community monitoring and research projects, and the preservation of the area's archaeological and historical legacy.

SE-2: A common goal across multiple plans is to continue to provide information to private landowners on the river about stewardship opportunities, such as conservation easements and funding for habitat projects.

SE-3: Through the review of plans, it appears that there are shared goals to further develop sites for environmental education along the river and corresponding school outreach programs.

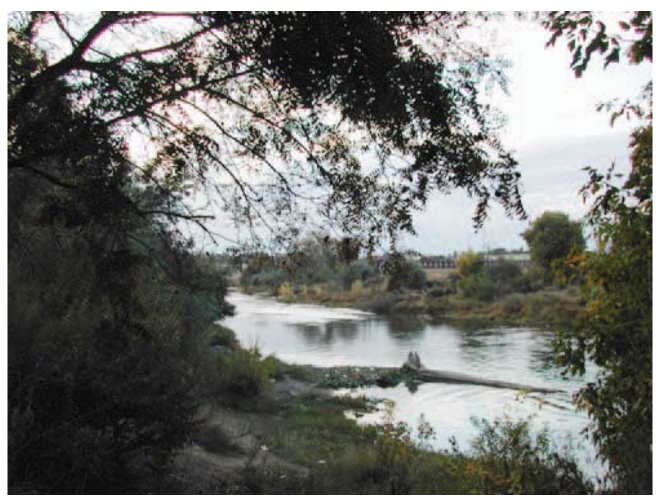
SE-4: The analysis of plans shows that there is a need and opportunity to integrate evaluation and monitoring into the planning and development of projects in the Lower Tuolumne River Parkway as a means for sustaining on-going involvement and stewardship of river-oriented projects.

3.13 UPPER REACHES (UR)

The upper reaches of the Lower Tuolumne River span from the town of La Grange to just below Gee Road. These reaches are unique in terms of instream sediment composition, floodplain width, and surrounding land uses. The upper reaches are defined as being the gravel-bedded reaches of the river (river miles 24 to 52) and include Reach 7 (Dominant Salmon Spawning Reach), Reach 6 (Dredger Tailing Reach), Reach 5 (Gravel Mining Reach), and Reach 4 (In-channel Gravel Mining Reach).

Sediment composition of the upper reaches is characterized by gravel riffles between runs and pools containing beds ranging from sand to bedrock. Problems include excessive sand in gravel riffles and a lack of adequate gravel. This need for coarse sediment supplies also highlights the potential competition amongst instream restoration needs and the needs of gravel mining businesses and other habitat restoration activities that use gravel.

The surrounding areas are characterized by low-density development such as the town of La Grange and a mix of intensive agriculture and ranching.



Under 9th St. Bridge in Modesto.

Shared Goals, Potential Conflicts and Opportunities

UR-1: The examination of plans and reports indicates a mutual goal to improve anadromous fish spawning and rearing habitat in the upper reaches.

- Improving fish habitat can include securing gravel supply, reducing fine sediment influx, adding spawning gravel, and reducing stranding potential.

UR-2: A common goal across many plans is to reduce impacts on water quality and riparian habitat from surrounding land uses.

- There are common goals to reduce grazing along the banks of the upper reaches and tributaries.

UR-3: The analysis of plans indicates that proposed active recreation in the upper reaches and recommendations to widen the riparian corridor may be incompatible with goals to reduce impacts on habitat restoration.

- There may be conflicts between: existing grazing; County plans for active recreation sites near La Grange (interpretive center, camps, sports field, and trails); potential linked trail systems near Waterford; and Habitat Restoration Plan recommendations to widen the riparian corridor to 500 feet.

UR-4: The analysis of plans shows that there is a need and opportunity to address the effects of activities that remove or deposit sediment and alter the balance of coarse and fine river sediment, including: aggregate mining, the use of gravel for spawning habitat, land uses in the floodplain, flows, and flood management.

UR-5: The analysis of plans shows that there is a need an opportunity to develop additional information on the water quality of the upper reaches.

3.14 URBAN REACHES (URB)

The most significant urban reach along the river is Reach 2 (Urban Sand-Bedded Reach), which is dominated by the Cities of Modesto and Ceres. Reach 3 (Upper Sand-Bedded Reach) is also influenced somewhat by outlying areas of Modesto, Ceres, and the City of Hughson, as well as the unincorporated community of Empire. A two-mile stretch of Reach 4 (In-Channel Gravel Mining Reach) is influenced by the City of Waterford. The urban reaches provide unique opportunities and challenges for balancing river-oriented recreation and restoration.

Shared Goals, Potential Conflicts and Opportunities

URB-1: The review of plans and reports demonstrates a shared goal to preserve and/or extend riparian buffers, existing setbacks, and scenic corridors around urban growth and development.

URB-2: A common goal revealed in the analysis of plans is to enhance and promote key river access sites near urbanized areas in order to provide access where residents need it most and to preserve other less developed areas as such.

The confluence of the Tuolumne and San Joaquin Rivers

URB-3: The examination of plans indicates that future urban growth/development and open space preservation may conflict where each focuses on the river corridor.

URB-4: The analysis of plans reveals that existing urban and industrial land uses may limit restoration opportunities.

URB-5: Analysis of plans highlights the opportunity to protect an active and vegetated floodplain while supporting multiple uses and accommodating current and expected urban development.

URB-6: The review of plans demonstrates that several promote opportunities to integrate storm-water runoff and reclaimed wastewater programs.

URB-7: The analysis of plans shows that there is a need and opportunity to uphold diverse passive and active recreation opportunities that minimize impact on surrounding habitat restoration and water quality.

URB-8: Analysis of plans highlights the opportunity to explore the possibility for economic development opportunities built around parks and open space, in keeping with the parks and open space character.

3.15 LOWER REACH (LR)

The lower reaches include Reach 3 (Upper Sand-bedded Reach), Reach 2 (Urban Sand-bedded Reach), and Reach 1 (Lower Sand-bedded Reach). However, the opportunities and challenges will be primarily applicable to Reaches 1 and 3 because Reach 2 is so dominated by urbanization and is addressed in the previous section. Also, as noted in the previous section, some of the opportunities and challenges of the urban zones apply to Reach 3.

The lower reaches span from the confluence of the Tuolumne and San Joaquin Rivers at RMA 0 to RMA 24, and are defined as the sand-bedded portion of the river. Reach 1 is characterized by extensive riparian, floodplain, and wetland restoration and education opportunities. Reach 1 is anchored by the San Joaquin River National Wildlife Refuge, contains only one public access site and is bordered almost exclusively by orchards and other farmland. Reach 3 extends from Mitchell Road Bridge to the gravel-bedded reaches at RMA 24. These reaches are relatively undeveloped and therefore offer many opportunities for partnering with farmers and other landowners, expanding open space and/or maintaining minimally disturbed habitat.

Shared Goals, Potential Conflicts and Opportunities

LR-1: Analysis across multiple plans reveals a common goal to maintain land uses in the lower reach as primarily agricultural lands or open space, with minimal public river access sites.

LR-2: The analysis of plans indicates a shared goal to revegetate and restore floodplains and terraces along the lower reach.

LR-3: Multiple plans highlight their goal to stress the role of the San Joaquin River National Wildlife Refuge as a key link in the Pacific Flyway.

LR-4: The review of plans demonstrates a mutual goal to support the restoration of off-channel wetlands to increase and support wildlife habitat.

LR-5: The analysis of plans reveals that Habitat Restoration Plan recommendations to widen the riparian corridor up to 2,000 feet in lower reach areas may conflict with existing agricultural and other private and public uses along the lower reaches.

LR-6: Analysis of plans highlights the opportunity to expand the riparian corridor and wetlands surrounding San Joaquin River National Wildlife Refuge through conservation easements and land acquisition.

3.16 BALANCED RIVER MANAGEMENT (BRM)

A primary theme emerging from the analysis of existing plans and community dialogue is to balance diverse uses and needs along the river. What defines a "balance" of activities and uses may take on very different interpretations for different people. At times, there may even be a need to balance uses of land among different restoration projects, or among various recreation-oriented projects.

Overall, however, this Framework for the Future highlights existing efforts to balance the need for land, materials, and funding across different projects, and identifies areas where a balance of these necessary elements is still needed. The findings presented below represent some specific directions and needs concerning balanced river management.

Shared Goals, Potential Conflicts and Opportunities

The assessment of existing plans and reports revealed the following recommendations for stakeholders concerned with establishing a balance of uses and users for the entire river.

BRM-1: Balance diverse efforts (e.g., channel, floodplain restoration, and riparian habitat restoration) that may compete for limited water supply and sediment.

BRM-2: Explore management of run-off from land uses (grazing, farming, urban) that impact the river and its tributaries.

BRM-3: Engage and encourage diverse voices and interests.

BRM-4: Consider the following existing or potential land uses and their impacts on each other when reaching a balance:

- Riparian corridor of up to 500-2000 feet in some areas
- Passive and active recreation opportunities.
- Population growth in Stanislaus County
- Reduction of riparian encroachment
- Marginality of certain farmland in the floodplain due to frequent flooding
- Riparian habitat restoration opportunities

BRM-5: An abundance of opportunities exist along the river, and recent efforts represent a positive movement in enhancing habitat, recreation, and other river corridor enhancements.

3.17 INFORMATION NEEDS (IN)

The Coalition identified the following information needs, based on group discussions, public feedback, and the review of existing reports:

IN-1: Comprehensive water quality assessments for the Lower Tuolumne and its tributaries to identify specific pollutants and their sources, as well as barriers to improving water quality.

IN-2: Additional information about the impacts of restoration on urban uses and vice versa, to balance these uses with one another, spatially and temporally.

IN-3: Mapping of current locations of key wildlife species along the river that rely on a riparian corridor (such as river otters, coyotes, and deer) or are Threatened, Endangered, or Species of Concern (such as Riparian Brush Rabbits, and others).

IN-4: Information regarding the effects of current or projected flows on wildlife and vegetation.

IN-5: Information on feeding, resting, nesting, and rooting patterns in the Lower Tuolumne River floodplain, and how human activities impact these activities.

IN-6: Additional information concerning regional recreation needs, such as through a river-oriented recreation needs assessment survey.

IN-7: Additional evaluation and monitoring of key efforts as outlined in the Habitat Restoration Plan for the Lower Tuolumne River Corridor relating to channel and floodplain morphology.

- It is necessary to understand how changes to channel and floodplain morphology impact fish recovery, what the positive and negative effects might be from various flows, and to assess ecosystem response in general through on-going monitoring and criteria for success.

Chapter 4

RIVER ENHANCEMENT STRATEGIES AND FUTURE PROJECT OPPORTUNITIES

"Protection of the natural environment is an important aspect of outdoor recreation."

—TUOLUMNE RIVER COALITION MEMBER

4.1 INTRODUCTION

This chapter describes strategies for moving the Tuolumne River Coalition forward and fulfills the third key task of this document (as described in Chapter One): to identify strategies to meet the multi-objective goals of the Coalition. This chapter identifies specific strategies that together achieve the Coalition's primary goals and provides detailed action steps for each strategy.

The strategies (and their strategy action steps) emerged directly from the analysis in Chapter Three and fulfill two primary requirements: 1) to meet and exceed the goals of the Tuolumne River Coalition (as presented in the graphic below); and 2) to build upon the shared goals, address the potential conflicts, and/or seize opportunities as presented in the analysis of Chapter Three.

The strategies and strategy action steps presented here are intended as a reference for existing and future work of the Coalition and Coalition member organizations. However, this document is not a commitment to perform these actions. Nor does it suggest that the Coalition or this document holds any legal jurisdiction over any member or other existing agency regarding these strategies or action steps. The Framework is not a Master Plan for the river and therefore does not require environmental review. **Rather, the Framework is intended to support, enhance and encourage concurrent planning processes along the Lower Tuolumne.**

Volunteer planting at the Refuge.

The Tuolumne River Coalition at work.

An overarching goal for the Lower Tuolumne River Parkway is to facilitate and encourage implementation of projects and programs that are consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor and that balance and address the needs of diverse users and uses. The strategies presented here are an attempt to address some of the challenges while offering suggestions for balanced land uses and coordinating Parkway projects that are complementary to each other. Proposed strategies, and the resulting projects, must be designed to be appropriate for their given context.

THE TUOLUMNE RIVER COALITION'S GUIDING FRAMEWORK FOR THE LOWER TUOLUMNE RIVER PARKWAY

VISION

The Lower Tuolumne River Parkway is a vibrant, healthy river corridor providing multiple community benefits

GOALS

- ***Enhance, protect** and **restore** habitat that supports natural resources and river function*
- ***Extend** and **protect** open space along the river*
- ***Expand** and **enhance** public access and recreational opportunities where appropriate*
- ***Protect** the floodplain from intensive development*
- ***Respect** existing development, land ownership, and water use*
- ***Support** and **develop** riparian buffers*
- ***Provide** flood management benefits*
- ***Enhance** water quality*
- ***Build upon** and **integrate** existing plans relevant to the Lower Tuolumne River*
- ***Support** the development of a mosaic of public and private projects and programs*
- ***Increase** river-focused educational programs*

RIVER ENHANCEMENT STRATEGIES

- ***Identify** Multi-Objective Projects in Urban and Rural Reaches of the River*
- ***Support** the Coordination of a Water Quality Monitoring and Enhancement Program*
- ***Identify** Potential Natural Area and Working Landscapes Opportunities*
- ***Implement** Habitat Restoration Projects*
- ***Increase** Recreation Opportunities*
- ***Enhance** and **Expand** Public River Access Points*
- ***Provide** Information and Support for a Scenic Trailway Compatible with Private Interests*
- ***Study** and Recommend Best Management Practices Regarding the Use of Boats*
- ***Create** Lower Tuolumne River Parkway Maps and Signage*
- ***Develop** a Lower Tuolumne River Parkway Interpretive Program*
- ***Enhance** Cleanliness, Safety, and Security for the Users of the Lower Tuolumne River Parkway and Surrounding Communities*
- ***Continue** Public Outreach and Involvement*

The on-going execution of these strategies is detailed in the next (and final) chapter, Chapter Five. The strategies and action steps are also laid out in Appendix E, which provides broad prioritization for the action steps and identifies key partners for each strategy. The priorities do not necessarily reflect the priorities of individual member organizations but those of the Coalition as a whole at this time. The Coalition intends to revisit and amend the strategies, action steps, and prioritizations regularly to update and adapt them as the river, community, and circumstances change.

4.2 RIVER ENHANCEMENT STRATEGIES AND STRATEGY ACTION STEPS

The Tuolumne River Parkway aims to facilitate and encourage implementation of projects and programs that are consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor and that balance and address the needs of diverse users and uses. However, finding this balance is complicated by a range of issues, as the analysis in Chapter Three revealed. For example, balancing water quality, habitat, supply, floodplain management, and recreation can be influenced by surrounding land uses, existing habitat types, and residents' desires. The strategies presented below address these complications and offer a direction for crafting a balance through the development of complementary projects.

Concepts for the Tuolumne River Regional Park.

Strategy 1: Identify Multi-objective Projects in the Urban and Rural Reaches of the River (S1)

Both the urban and rural reaches of the Tuolumne have characteristics compatible with different types of projects. The urban reaches, close to developed areas, provide exceptional opportunities for access and recreation with less extensive habitat elements. The rural reaches of the river, with fewer developed areas close to the river, offer significant opportunities for habitat restoration with less active recreational elements. Projects in both reaches can address other objectives such as flood management or water quality. The Coalition aims to better define a balanced approach appropriate to the Tuolumne and its communities by reaching out to landowners and expanding community outreach.

S1.1: Compile case studies and Best Management Practices concerning the co-existence of recreational uses and habitat. Provide specific information on how to enhance and/or restore natural river processes where urban development and river accesses exist, and vice versa.

S1.2: Develop an outreach program targeted to landowners along the river corridor to learn about landowner concerns and to educate them about natural river processes.

S1.3: Encourage a comprehensive and on-going assessment of water quality in Dry Creek, a major polluter to the urban reaches of the Lower Tuolumne River.

S1.4: Identify key river access sites in the urban reaches for enhancement and expansion.

Strategy 2: Support the Coordination of a Water Quality Monitoring and Enhancement Program (S2)

Cities, residents, agriculture, recreationists, wildlife and plants all depend upon high quality water for their needs. Municipal and agricultural water supplies are carefully monitored by several jurisdictional agencies (see page 3-9 for more information). Given that the Tuolumne River is listed as an impaired water body for certain contaminants, the Coalition could undertake the action steps listed below, partnering with existing water quality monitoring efforts to compile information, develop additional monitoring efforts, and create reference information.

S2.1: Encourage a comprehensive, on-going assessment of water quality in the Tuolumne and its tributaries.

S2.2: Compile and distribute Best Management Practices for water quality enhancement that include: bank protection, riparian restoration and constructed wetlands as filters, and management of run-off from various land uses.

S2.3: Continue to integrate water reclamation, filter, and riverbank restoration projects in Lower Tuolumne River Parkway projects where possible.

S2.4: Initiate a tributary restoration program with nearby landowners to manage run-off for Dry Creek.

S2.5: Spearhead or partner with a stream-watcher program for local volunteers and schools.

S2.6: Encourage Sewage Treatment plans to complement Lower Tuolumne River Parkway projects.

Riparian corridor near Waterford.

Strategy 3: Identify Potential Natural Area and Working Landscapes Projects Along the Lower Tuolumne River (S3)

Natural areas and working landscapes provide recreation, environmental education, habitat protection, and riparian buffers, and can include parklands as well as working farms. Building upon existing efforts of the CALFED Working Landscapes Program and the NRCS Conservation Security Program, the Coalition can identify possible locations where such areas could be preserved within the corridor. Approaches include those outlined below.

S3.1: Inventory and map all existing open space areas of the Lower Tuolumne River, delineating between type of ownership and management, including public and private lands and those preserved as open space through the Williamson Act or conservation easements.

S3.2: Compile and distribute potential criteria for prioritizing open space preservation for the Lower

Tuolumne River Corridor, as resources and opportunities arise.

S3.3: Compile and make available guidelines for acquisition and maintenance of open space areas, such as facilitating voluntary land acquisition, developing floodplain zoning, and supporting the use of fees.

Strategy 4: Implement Habitat Restoration Projects (S4)

The Lower Tuolumne supports a variety of instream and riparian habitats and has opportunities for expanding or enhancing habitat. Habitat restoration strategies could include the development of guidelines for restoration approaches and identification of priority areas. Habitat restoration opportunities will also continue to reflect the unique circumstances of various locations along the river. Some of these strategies are listed below.

S4.1: Develop criteria for prioritizing habitat restoration or mitigation opportunities. These could include:

Grey fox near Bobcat Flat.

- Location (Can this site be linked to other restoration sites? What will the positive and negative effects be on surrounding land uses, recreation and restoration opportunities? What is the habitat type?)
- Potential to be a self-sustaining corridor
- Availability of public land, potential of acquiring private land, or potential to partner with the existing landowner
- Ability to integrate and allow for natural flow and flooding processes
- Potential to protect rare, threatened, endangered or otherwise sensitive species or habitat (such as those listed in the riparian inventory of the Habitat Restoration Plan for the Lower Tuolumne River Corridor)

S4.2: Review and update as needed the identified habitat restoration opportunities of the Restoration Plan.

- Compile information on potential opportunities for securing off-river gravel sources for gravel augmentation.
- Gather Best Management Practices regarding issues such as incorporating restoration into gravel-mining permits and alternative grazing strategies, especially ways to eliminate illegal cattle grazing on County land at La Grange.
- Support implementing operation of the Geer Road irrigation water diversion and the Turlock Area Drinking Water Project.

S4.3: Develop recommendations to reduce potential conflicts with public and private landowners.

S4.4: Encourage project demonstration sites of natural river processes (e.g., through passive levee breaches) and low-impact design (e.g., alternative bank protection mechanisms) at the San Joaquin River National Wildlife Refuge.

Canoeing for all ages down the Tuolumne.

Strategy 5: Increase Recreation Opportunities (S5)

The Lower Tuolumne River Parkway aims to increase opportunities for residents and visitors to recreate on or near the river in a safe, clean environment, in a way that does not place additional stress on surrounding sensitive habitat. The Coalition could help to provide information on recreation needs and potential solutions for park and recreation areas by moving forward with the actions listed below.

S5.1: Support a river-oriented region-wide recreation needs survey, focusing on uses of and interest in the river corridor.

S5.2: Identify areas along the river where additional recreational lands could be acquired in areas least impactful to sensitive habitats.

Strategy 6: Enhance and Expand Public River Access Points (S6)

Improving existing access as well as adding additional ones along the Lower Tuolumne River could enhance recreation, environmental education and public engagement opportunities. Through the action steps listed below, the Coalition could prioritize the maintenance, enhancement, and promotion of existing public access sites for all users on the river, while working to identify additional access needs and potential areas for accommodating those needs.

S6.1: Use public outreach and information strategies (described below in Strategy 8) to help clean, maintain, and promote existing river access sites.

S6.2: Assess key issues of safety at river access sites and support the implementation of enhanced security and patrols at access sites.

S6.3: Sponsor or support activities and other community events at existing access sites that highlight recreational opportunities unique to the Lower Tuolumne River Parkway.

Strategy 7: Provide Information and Support for a Scenic Trailway Compatible with Private Interests (S7)

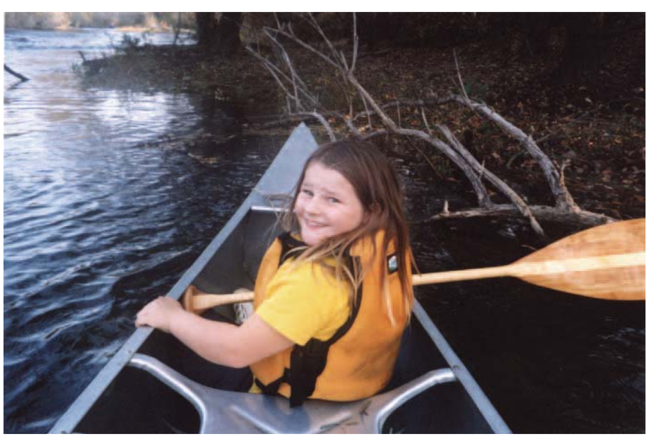
A scenic trailway could include route maps, signage, and controlled access points to the river to highlight trails, roads, bike and pedestrian paths that already exist on public lands. Bike lanes and

Historic Robert's Ferry Bridge.

pedestrian trails offer a pleasant, human-scale and non-disruptive means for enjoying the river corridor in a way that protects sensitive areas of the river. This Trailway, which would not cross private lands except under special agreements or easements with the property owner, could emphasize the various projects, parks, residential, commercial and regional uses of the river through partnerships with transportation agencies, community advocacy groups and public and private land developers. Potential action steps for moving forward with this strategy include those listed below.

S7.1: Support the development of a Class I trail along Scenic Highway 132 and potential connections between this trail and other trails that lead to the river on public lands. Support the development of Class II bike lanes on Highway 132 where Class I trails are not feasible.

S7.2: Identify all existing and potential bicycle and pedestrian paths or trails bordering the Lower Tuolumne River by identifying areas where trails could be linked without negatively impacting sensitive habitat or private property, including through the use of existing public rights-of-way.



Enjoying a ride down the Tuolumne River.

S7.3: Create a trailway map and identify the trailway sections on Lower Tuolumne River Parkway signage (e.g., establish wayfinding signs along bike lanes and pedestrian paths that identify mileage, directions to points of interest, river overlooks, viewpoints, or other sites where visitors interact with the river).

Strategy 8: Study and Recommend Best Management Practices Regarding the Use of Boats on the Lower Tuolumne (S8)

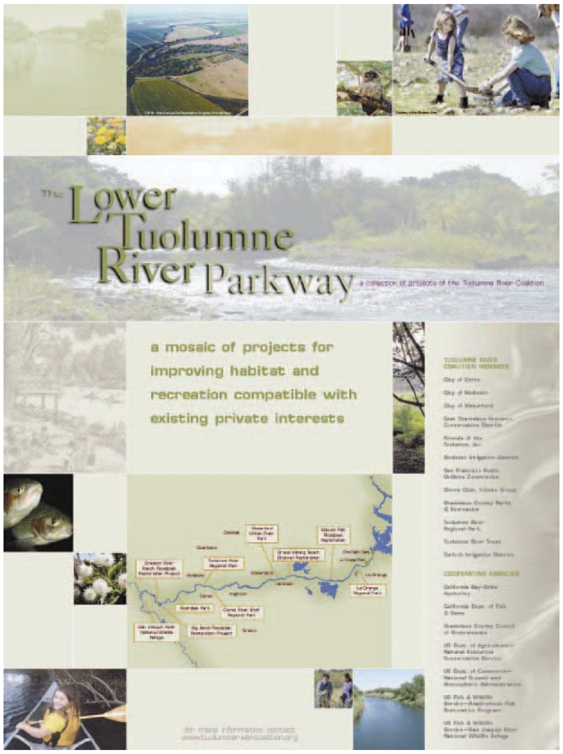
Boating provides a very direct way to experience and observe the river and all that the river sustains. Some types of boating may be better suited to different parts of the river, and the Tuolumne River Coalition could help analyze this issue by moving forward with the steps listed below.

S8.1: Evaluate policies regarding watercraft use (e.g., use of motorized or non-motorized craft, speeds allowed) on the Tuolumne and other local rivers and support the implementation of boating laws.

S8.2: Improve and/or support the development of additional non-motorized access sites to expand the "canoe trail" that does not conflict with private property or sensitive habitats.

S8.3: Identify all put-in or take-out sites for canoes on Lower Tuolumne River Parkway maps, signs, and guidebooks.

S8.4: Host fall canoe trips to view spawning salmon and other trips when possible to educate stakeholders about the river, the Coalition and Parkway projects.



The Lower Tuolumne River Parkway Poster.

Strategy 9: Create Lower Tuolumne River Parkway Maps and Signage (S9)

Key to increasing public awareness, gaining landowner support, and securing financial backing is a clearly identified Parkway. A comprehensive signage program ("way-finding") can demonstrate the unique mosaic of projects throughout the Lower Tuolumne River. Such an approach could include a common logo design, maps identifying key access points and viewpoints, as well as a corresponding Lower Tuolumne River Parkway guidebook.

S9.1: Create a Parkway image and identity program including a common logo and graphics for way-finding signage, and place at key locations.

S9.2: Develop and distribute a Parkway recreation and use guidebook that highlights:

- Parks, paths, trails, public recreation and access areas, overlooks, and public facilities.
- Habitat and wildlife information and other significant areas on the river.
- Information, if applicable, on how and when private properties can be accessed by the public.

Strategy 10: Develop a Lower Tuolumne River Parkway Interpretive Program (S10)

A comprehensive interpretive program can increase the sense of place and stewardship of the river. Simple informational signage and other written and graphic materials could provide a quick, cost-efficient yet impactful approach to complement people's experience of a place. Other potential action steps include those listed below.

S10.1: Support the development of an interpretive center(s) about the river.

S10.2: Support interpretive trails in and along the river corridor that link existing and proposed trails, where appropriate, on public lands.

Native Button Brush.

S10.3: Develop interpretive signage for unique features along the river corridor.

S10.4: Compile written educational materials that illustrate the important roles of unique and native plant and animal species.

Strategy 11: Enhance Cleanliness, Safety, and Security for the Users of the Lower Tuolumne River Parkway and Surrounding Communities (S11)

A primary barrier to further river enhancements is the community's lack of involvement with the river and the fear and reality of illegal activities and dumping along the riverside. In order to ensure long-term community involvement in and support of recreation, education and restoration activities along the Lower Tuolumne River, the Coalition could sponsor and support community outreach activities, in tandem with other outreach as described in Strategy 12 below, specifically designed to address issues of illegal activities and dumping along the river.

Volunteer river planting near Waterford.

11.1: Develop education and outreach programs in partnership with law enforcement to protect open space areas, habitat, and quality of experience for visitors.

11.2: Integrate river clean-ups and adopt-a-river-mile efforts into a Tuolumne River Coalition Volunteer Program (see S12.2, below)

11.3: Develop a Lower Tuolumne River Parkway security and patrol program by advocating for increased river policing and developing a community-based monitoring program.

Strategy 12: Continue Public Outreach and Involvement (S12)

A comprehensive outreach and education program could include programs for students, landowners, and the general community. A multi-pronged communication approach could include tools such as a newsletter, advertising through the media and the website, and the use of graphics such as a master map of the Parkway. These efforts could be sustained through a formalized Parkway volunteer program.

S12.1: Develop education and outreach programs in partnership with, and specifically targeted for, the following groups:

- Students and youth groups.
- California State University-Stanislaus Biology and other students for research projects.
- Community organizations such as the Great Valley Museum to educate the community about the river and its ecology.
- Farmers and other landowners.

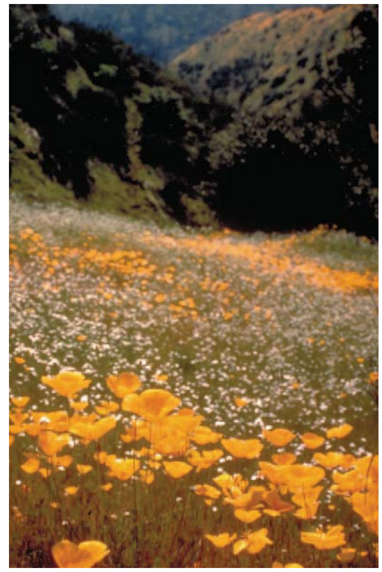
S12.2: Structure an on-going Tuolumne River Coalition Volunteer Program that could include a Stream-watcher Program, and project monitoring.

S12.3: Update the public about on-going meetings and community forums through the use of a Tuolumne River Newsletter as well as the Coalition website, brochure, and other outreach materials.

S12.4: Appeal to print and news media to produce or write public interest pieces concerning the river (e.g., request a slot on the television show "Valley Mosaic" and submit information to the Modesto View website).

S12.5: Place Coalition projects and efforts on relevant regional and statewide inventories, such as the EPA's Watershed site and the Natural Resource Projects Inventory.

S12.6: Publish a master map of the Lower Tuolumne River Parkway (with pedestrian trails, bike lanes and paths, the canoe trail, access sites, interpretive centers and trails, and all Coalition projects).



Native California Poppy.

Chapter 5

IMPLEMENTATION ACTIONS AND TOOLS FOR MOVING FORWARD

“River public access adds to quality of life.”

—TUOLUMNE RIVER COALITION MEMBER

5.1 INTRODUCTION

Although the development of this Framework for the Future is a major achievement, it remains only the first in a long series of steps necessary to turn the vision of the Lower Tuolumne River Parkway into a reality.

This chapter introduces some of the components required to narrow the gap between the present reality and the future of the Lower Tuolumne River Parkway, and addresses the fourth key task for this document: to develop implementation actions that facilitate the Coalition's coordination of multiple projects along the river. These implementation actions are necessary to turn the strategies presented in the previous chapter into thriving projects and programs.

Appendix E expands on these implementation actions. This appendix presents an action plan for moving forward and outlines prioritization and key partners for specific strategies. As the action plan indicates, the implementation of the strategies put forward here will not be the sole responsibility of any single organizational entity. It will instead result from the collective endeavors of many public and private organizations pursuing a variety of projects over time, but guided by this Framework for the Future.

River bend near La Grange County Park.

The implementation actions discussed in this chapter cover a variety of approaches and steps that will help the Coalition develop or compile the following:

5.2.1 Funding Opportunities

5.2.2 Organizational Development

5.2.3 Scientific and Technical Studies

5.2.4 Best Management Practices

This chapter also includes tools for the Coalition to move forward with their project work such as Guidelines for Amending the Framework for the Future Document.

5.2 IMPLEMENTATION STRATEGIES

5.2.1 Funding Opportunities[1]

Funding Action 1: Work with CALFED Bay-Delta Program officials to determine a coordinated approach to the award of new CALFED Bay-Delta Program Funds.

The CALFED Bay-Delta Program has recently been re-authorized at the Federal level and the State's Proposition 50 was passed by voters and provides resources to continue funding its programs as outlined in the 2004 Program Plans Report adopted by the California Bay-Delta Authority in the Fall of 2004. The CALFED Bay-Delta Program 10-Year Finance Plan tables are available on the

1. See Appendix H for a project funding matrix that includes all Parkway projects.

Authority's website at http://www.calwater.ca.gov. CALFED programs include:

Watershed Program:
The grant is expected to focus on projects that address **watershed assessment**, **watershed planning**, **education,** and **increasing the local capacity** of entities to engage in watershed management.

Within these broad categories of eligibility projects should address one or more of the following:

- Broaden participation in existing watershed partnerships
- Initiate new partnerships dedicated to watershed management
- Advance the application and use of science in assessing, planning, and managing watersheds and in increasing public understanding of watershed characteristics, functions, and conditions
- Foster and support strategies to ensure long term sustainability of watershed management and local stewardship groups
- Maintain or enhance the network of communication among watershed stakeholders

This program may be the best opportunity for funding continued Coalition activities and for a Coalition Program Coordinator position.

Ecosystem Restoration Program—State Proposition 50
Project Solicitation Package is under development at the State Department of Water Resources for the next round of environmental restoration projects. Coalition projects, which address Eco-System Restoration should be identified for funding applications.

Volunteer planting near Waterford.

Funding Action 2: Continue to pursue Federal appropriations.

Continue to work with Congressman Dennis Cardoza to coordinate, prepare, submit and advocate for annual Federal Appropriations for selected Coalition projects. House Appropriation Subcommittees and programs to be targeted include:

Water and Energy Development Committee:

- Central Valley Project Conservation Program; Central Valley Project Improvement Act-Habitat Restoration Program (CVPIA PL 102-575 Section 3406(b)(1) and Section 3407);
- California-Bay Delta Authorization Act, PL108-361 Section 103 (f) (2).

Interior and Environment Committee:

- Land and Water Conservation Fund (LWCF); Multinational Species Conservation Fund-Migratory Bird Conservation Fund.
- National Parks Service

Funding Action 3: Support the preparation of an Integrated Regional Water Management Plan under the State of California's Proposition 50 and identify implementation projects for funding.

Coalition members could help participate in the development an Integrated Regional Water Resources Management Plan to maximize the region's competitiveness for Proposition 50 IRWMP funding for planning and implementation of key river projects.

- Develop strategy among Coalition members, including water supply agencies, to compete for Proposition 50 IRWMP Planning and Implementation grants over the next two (2) years.
- Prepare IRWMP Implementation grant applications for strategic and competitive projects by individual agencies.

Funding Action 4: Coordinate application for upcoming 2005-2006 State Water Resources Control Board (SWRCB) Clean Water Act programs and mandated water quality programs.

Develop and refine strategy among Coalition members to compete for next round of Consolidated Grant Programs of the SWRCB water quality and Non-Point Source programs.

The next funding cycle is expected at the end of 2005.

Funding Action 5: Pursue California River Parkways Program-Proposition 50 funds.

This program has been established in the office of the Secretary of the Resources Agency. Regulations are under development for Proposition 50 funded River Parkway projects Statewide, which are anticipated to provide up to $100 million in new River Parkway Projects in 2005 and 2006.

To be eligible for a grant, a project must provide public access **or be a component of a larger parkway plan that provides public access and, at a minimum,** meet two of the following conditions:

- Provide compatible recreational opportunities such as trails for strolling, hiking, bicycling, and equestrian uses along rivers and streams.
- Protect, improve, or restore riverine or riparian habitat, including benefits to wildlife habitat and water quality.
- Maintain or restore the open-space character of lands along rivers and streams so that they are compatible with periodic flooding as part of a flood management plan or project.
- Convert existing developed riverfront land uses into uses consistent with river parkways.

Provide facilities to support or interpret river or stream restoration or other conservation activities.

5.2.2 Organizational Development[2]

Organization Development Action 1: Continue to Strengthen and Define the Tuolumne River Coalition Goals and Objectives.

1. Define the future organizational structure of the Tuolumne River Coalition:
   - Consider a Memorandum of Understanding to formalize membership of the Coalition
   - Seek funding for and hire a Tuolumne River Coalition Project Coordinator

2. See Appendix J for a review of organizational structure options and guidelines for developing Memorandums of Understanding and 501(c)3 status.

2. Establish roles and responsibilities for the Coalition:
    - *Leadership:* Continue voluntary rotations of internal project leaders (e.g., Chair, Vice-chair, Secretary)
    - *Steering Committee*
    - *Subcommittees* (recommended 2-3 members each): Funding Development Subcommittee; Education and Outreach Subcommittee; Scientific Information Subcommittee; Social and Cultural Subcommittee
    - *Volunteer Base*
3. Research opportunities to expand the Coalition's membership through partnerships with regional groups such as the San Joaquin Regional Watershed Program, San Joaquin Conservancy, the American River Parkway Foundation and others than can provide regional resources and organizational models.
4. Explore the possibility of partnering and coordinating efforts with regional groups such as the Downtown Modesto Blueprint Committee that are affecting change in neighborhoods surrounding the Tuolumne River.
5. Identify roles for Coalition representation at City and County hearings, and other forums on issues that relate to the river.

5.2.3 Scientific and Technical Studies

Scientific and Technical Studies Action 1: Support the Development of Needed Information and Resources

The Coalition will actively encourage, seek out and support the development of new or additional technical studies covering topics that will help and strengthen projects of the Lower Tuolumne River Parkway. The following subject areas are of interest to Coalition members:

1. Habitat requirements for wildlife and natural processes (e.g., the Point Reyes Bird Observatory's Riparian Bird Conservation Plan).
2. Effects of channel improvements on habitat and wildlife.
3. Interactions between wildlife and human uses temporally and spatially.
4. Links between instream and riparian habitat restoration efforts.
5. Effects of current and potential flows on river processes, vegetation, and wildlife.
6. Sediment analysis.
7. Recreation needs analysis.
8. Benefits to human health due to interaction with the river (especially in urban environments).
9. The river environment as a community asset.
10. Public investment as a tool for access, improvement and public stewardship of the river corridor.

Scientific and Technical Studies Action 2: Analyze Impacts and Benefits of the Lower Tuolumne River Parkway

1. Build upon existing evaluation efforts of Coalition members to develop comprehensive baseline information for the entire Lower Tuolumne River Parkway and continue on-going evaluations over time. Efforts could include:
    - Existing conditions of the Lower Tuolumne River Parkway through extensive photographic, mapping, and written assessments.

Chinook salmon spawning riffle survey.

- Studies of human uses of the river corridor (e.g., increased park visits, canoe trips, partnerships with educational institutions)
- Integration of adaptive management protocol into restoration efforts.
- Implementation and integration of a biotic resources evaluation, including species and habitat surveys (Bird and other species population data may be available through partnerships with the San Joaquin River National Wildlife Refuge, California State University-Stanislaus, Stanislaus County Parks and Recreation bird monitoring program, and others such as Stanislaus Audubon Society).
- Map the locations of key species (river otters, deer), and Endangered or Threatened species (Riparian Brush Rabbit, Swainson's Hawk, and others).

2. Create a community-based, volunteer-driven program to monitor and observe visitation patterns and habitat changes as the Parkway develops.

5.2.4 Best Management Practices

Best Management Practices Action 1: Compile and Support the Use of Best Management Practices for the Lower Tuolumne River

The Coalition can act as a clearinghouse for information regarding current best practices for water quality management, habitat restoration, recreation enhancement, floodplain management, open space conservation, and other elements affecting the river. These could include but are not limited to the following:

1. Recreation Use Guidelines that evaluate policy guidelines regarding watercraft use on the Tuolumne; promote good recreational stewardship; promote means for ensuring universal access to river recreation sites; and support best management practices at facilities along the river.
2. Summary of key mechanisms to maintain open space along the river corridor.
3. Guidelines regarding flow and flood management, and its effects on water quality, recreation, open space, and ecological restoration.
4. Overview and illustrations of diverse quality enhancement approaches including: erosion control, riparian restoration and constructed wetlands as filters, and management of run-off from various land uses.
5. Model floodplain management ordinances that include standards for construction, development, non-structural approaches, and floodways.
6. Guidelines for facilitating voluntary land acquisition, working in partnership with landowners and the public.
7. Effective habitat restoration practices in urbanized and highly developed or developing areas.
8. Summary of key recommendations from the Restoration Plan concerning geomorphic processes and the effects of channel improvements on habitat.
9. Design recommendations and opportunities for experimentation from the Adaptive Management Forum Report's review of large channel restoration projects.
10. Explanations of the different functions or types of open space and buffers.

5.3 RECOMMENDED STEPS FOR UPDATING AND AMENDING THE FRAMEWORK

In order to proceed with the strategies and action steps outlined in this document in an efficient and consistent manner, the coalition will need to adopt a set of criteria for project and process endorsement. Such criteria could include the following:

1. In order to be fully endorsed or initiated by the Coalition, a project must: align with the Coalition Mission and Vision Statements; contribute to the multi-objective development of the Lower Tuolumne River Parkway; and, support Coalition activities efforts.
2. Structure a working group or subcommittee to further prioritize strategies and action steps, as outlined in the Framework. Identify those strategies and actions steps that can be implemented immediately, and establish timelines for the achievement of each strategy. Formalize these timelines as an appendix to this document.
3. Establish protocols for periodic updates of the Framework (e.g., devote one meeting annually to reviewing and amending strategies and action steps). From these updates, develop a memorandum that lists which strategies and

specific action steps have been accomplished in the previous year and which will be addressed in the following year. This memorandum should also identify specific barriers and potential solutions for each strategy and should list any new or removed strategies.

4. Assess Coalition membership based upon the review of strategies. Consider expanding Steering Committee or general membership in order to accomplish strategies.

5. Refine the action plan (provided in Appendix E) as needed based upon periodic updates.

6. Use the action plan as a tool in promoting on-going collaborations with key partners listed (e.g., provide updates to key partners by distributing the memorandum on strategy updates and the refined action plan).

7. Adhere to the public outreach and involvement strategy and formalize community feedback on the Framework (e.g., hold a community workshop to review strategies every other year).

8. Use these updates as a means for continuously communicating with potential funding sources.

APPENDICES

Appendices

Appendix A: Organizational Profiles of Tuolumne River Coalition Members

City of Ceres

Guided by the principle "Together We Achieve," the City of Ceres exists to provide current and future citizens with the best municipal services, which improve quality of life, prosperity and safety. We will do this in a compassionate, professional and cost-effective manner, promoting fairness and inclusion of all citizens.

The 5-person Ceres City Council hires the City Manager who leads and manages all staff, finances, contracts, and CIP projects. There are 6 Departments including: the Parks, Recreation, and Facilities Department, Management Services, Public Safety, Public Works Department, and the Planning and Finance Department. There are approximately 220 full-time employees working for the City of Ceres.

Major On-going Projects: Presently a Task Force is working on the conceptual design and construction drawings of the lower 38 acres. The City of Ceres is seeking input from the public regarding habitat restoration of the lower terrace leading to the Tuolumne River.
Meetings or other forums: Please call the Ceres Parks, Recreation and Facilities Department regarding future public meetings.
Contact:
Doug Lemcke, Director of Parks, Recreation, and Facilities
2720 2nd Street
Modesto, CA 95356
(209) 538-5628

City of Modesto

On-going Projects: The City of Modesto participates in the Tuolumne River Regional Park, a 500-acre river park running through the Modesto Urban Area. Currently Modesto operates Dryden Municipal Golf Course and owns property in the floodplain that is slated for neighborhood parkland. These sites are being reviewed for irrigation and future improvements.
Meetings or other forums: Future public meetings are scheduled as parkland is planned.
On-going volunteer activities: The City of Modesto is working closely with volunteer organizations that work in the floodplain areas to clean up and beautify City owned property.
Contact:
Doug Critchfield
1010 10th Street, Modesto, CA 95354 / P.O. Box 642, Modesto, CA 95353
(209) 577-5200

City of Waterford

Contact:
Chuck Deschenes
PO Box 199
Waterford, CA 95386
(209) 874-2328

East Stanislaus Resource Conservation District

Across the United States, nearly 3,000 conservation districts are helping local people to conserve land, water, forests, wildlife, and related natural resources. The RCD is committed to local control, believing the more we learn about our resources, the more we control our own backyard. The more we work with our neighbors, the less we face outside regulatory solutions that don't work. To this end, we are working to integrate resource management solutions that will:

- Bring together parties with common goals and interests.
- Create integrated management models to encourage best "multiple" resource use.
- Prevent pollution of waterways and groundwater from pesticide run-off, sediment, and nutrient buildup.
- Reduce losses of habitat and diversity, both in wildlife and plant species.

The East Stanislaus RCD includes the area east of the San Joaquin River to the Tuolumne and Calaveras County lines and is bordered by San Joaquin County to the North and Merced County to the South. The communities of Modesto, Ceres, Turlock, Oakdale, Salida, Hughson, Hickman, Riverbank, Denair and Waterford are included within the District. The East Stanislaus Resource Conservation District encompasses 984 square miles.

Contact:
Martin Reyes
3800 Cornucopia Way Suite E
Tuolumne Building
Modesto, CA 95358
(209) 491-9320

Friends of the Tuolumne, Inc.

The Friends is a local grassroots, 501(c)(3) land trust focusing only on the lower 52 miles of the Tuolumne River. We have been working to foster and promote conservation, preservation, and restoration of natural resources on the Lower Tuolumne River since 1994.

The mission of the Friends of the Tuolumne, Inc. is the restoration of a riparian habitat corridor along the Tuolumne River in Stanislaus County. Activities shall foster and promote conservation, preservation and restoration of natural resources which are consistent with agricultural and other relevant adjacent land uses, including appropriate recreational uses.

On-going Projects: Bobcat Flat (300 acre restoration); Grayson River Ranch (133 acre restoration); Waterford Percolation Ponds Restoration (approx 9 acres); Advocacy for the river at the Technical Advisory Committee (Don Pedro Dam license agreement) and other available opportunities
Meetings or other forums: We schedule meetings and workshops for our projects as they progress.
On-going volunteer activities: We offer numerous tours and planting parties. Please contact us for dates.
Contact:
Allison Boucher
7523 Meadow Avenue
Stockton, CA 95207
(209) 477-9033
www.friendsofthetuolumne.org

Modesto Irrigation District

The Modesto Irrigation District (MID) provides electricity and irrigation water and treats surface water for drinking water supply. MID is an independent, publicly owned utility with business operation on a not-for-profit basis. MID serves over 100,000 electrical accounts in the greater Modesto area (north of the Tuolumne River, Waterford, Salida, Mountain House (Northwest of Tracy) and parts of Ripon, Escalon, Oakdale and Riverbank. MID provides irrigation water to 60,000 acres and is a partner in the Don Pedro Project with the Turlock Irrigation District (see on-going projects listed under TID).

The MID mission is to deliver superior value to our irrigation, electric and domestic water customers through teamwork, technology, and innovation.
Contact:
Tim Ford
PO Box 949
Turlock, CA 95381
(209) 883-8275

San Francisco Public Utilities Commission

The San Francisco Public Utilities Commission ("SFPUC") provides 2.4 million Bay Area residents and businesses with reliable, high quality and affordable water from local and Tuolumne River watersheds. The SFPUC also has charge of power operations, the City's Clean Water Program, and management of natural resources under its care.

The SFPUC is a party signatory to the FERC settlement agreement for the New Don Pedro Project, which enhanced instream flows in the lower Tuolumne River and created funding for monitoring and restoration projects. Through the FERC settlement agreement and associated agreements with Turlock and Modesto Irrigation Districts, the SFPUC makes annual payments for fish flows in the lower Tuolumne, and provided over $2.4 million dollars in additional funding for lower Tuolumne River habitat restoration and improvement projects.

Contact:
John Chester
1000 El Camino Real
Millbrae, CA 94030
(650) 871-2027

Sierra Club, Yokuts Group

The mission of the Sierra Club is to preserve the environment – for our families, for our future.

As part of the Mother Lode Chapter of the Sierra Club, the Yokuts Group has about 900 members, drawn from all of Stanislaus County. The Yokuts Group holds 9 general meetings a year and mails out 1,400 copies of "The Valley Habitat" newsletter 9 times a year.

On-going activities of the Yokuts Group include concern to protect the Tuolumne River from inappropriate development. The Group is prepared to organize and present testimony to prevent such development so that the river can be rehabilitated. Conversely, the Group also presents testimony in support of restoration projects or for acquisition for restoration or parkland.

On-going Projects: Outings and hikes, for all levels from strolls along the river to several-day hikes in the Sierras. Sierra Club monitors and comments on landfill, land-use, air pollution, recycling, and other activities.
Meetings or other forums: General meetings are held the third Friday of the month from September through May, except for December. There is socializing with snacks at 7:00 pm, and the meeting starts at

7:30pm. Program includes slides of others' travels or talks of local activities, such as land use or recycling. Meetings are held in the Modesto Police Department Community Room (600 10th St).
On-going volunteer activities: Annual activities including Earth Day, Garage sale, and cleanups and tree plantings when requested.

Contact:
Caroline Mitton
1120 Tasmania Way
Modesto, CA 95356
(209) 577-3086
www.motherlode.sierraclub.org/yokuts

Stanislaus County Parks and Recreation

The mission of the Parks and Recreation Department is to implement the policies established by the Board of Supervisors pertaining to Parks which include acquiring, developing and maintaining recreation areas serving every segment of society, including the disabled and the economically disadvantaged; providing the leadership necessary to develop and manage parks and recreation facilities in ways that will provide the best possible experience for people to enjoy the out-of-doors at the most reasonable costs.

The Department of Parks and Recreation employs approximately 60 staff members and is responsible for the maintenance and operations of over 8,000 acres of County Parks and for grounds maintenance of county facilities. The County currently operates a system of 25 Parks encompassing 16,487 acres of land and water. The Parks can be divided into three primary types: Regional Parks, Fishing Accesses, and Neighborhood Parks.

Contact:
Terri Sanders, Manager, Parks and Recreation
3800 Cornucopia Way, Suite C
Modesto, CA 95358
(209) 525-6771

Tuolumne River Regional Park

Tuolumne River Regional Park

The Tuolumne River Regional Park consists of over 500 acres of land along a 7-mile stretch of river generally bounded by Mitchell Road to the east and Carpenter Road to the west. Of the land acquired by the TRRP Joint Powers Authority (comprised of Stanislaus County and the cities of Ceres and Modesto), only approximately 180 acres have been developed for recreational purposes. In 1995, the TRRP Joint Powers Authority acquired a pivotal property along the park corridor. This remnant walnut orchard at the foot of 10th Street, referred to as the "Gateway Parcel", completed the missing link in the chain of park land along the Tuolumne and provided significant focus to the regional park.

On-going Projects: The Tuolumne River Regional Park (TRRP) is operated by a Joint Powers Authority consisting of the City of Ceres, City of Modesto and Stanislaus County. TRRP owns and maintains over 500 acres of land adjacent to the Tuolumne River. The TRRP JPA recently certified the TRRP Master Plan and MEIR, which created a blueprint and gave environmental clearance for future park improvements. Currently, TRRP is working on developing a 90-acre site located in the heart of the regional park and adjacent to the City of Ceres and Downtown Modesto. Identified as the 'Gateway Project', it will consist of river restoration, wetlands, trails, boardwalks, river access, gathering areas, amphimeadow, and picnic facilities. The cost for development of the Gateway Project is over $20 Million. Recently, TRRP received a Proposition 40 line item grant in the amount of $1,140,000 for the development of this project.
Meetings or other forums: TRRP is administered by the TRRP Commission, consisting of elected representatives from the City of Ceres, City of Modesto and Stanislaus County. Meetings are regularly scheduled for the 3rd Monday of every other month. The TRRP Citizen's Advisory Committee meets the third Wednesday of every month to review plans and make recommendations to the TRRP Commission. When plans are in the development stage, TRRP organizes public workshops for input. Information about upcoming events and meeting agendas is posted on the TRRP sponsored website at www.trrp.info
On-going volunteer activities: Boy Scout and Girl Scout service projects, the Hispanic Youth League Council's semi-annual volunteer project, The Tuolumne School Park Partners, education and grassroots volunteer projects and many other projects are performed for the Tuolumne River Regional Park.

Contact:
Jim Niskanen
1010 10th Street
Modesto, CA 95354
P.O. Box 642
Modesto, CA 95353
(209) 577-5200
www.trrp.info

Tuolumne River Trust

Tuolumne River Trust

The Tuolumne River Trust works to promote the stewardship of the Tuolumne River and its tributaries to ensure a healthy watershed.

The Tuolumne River Trust is a nonprofit public benefit corporation organized and operated exclusively for charitable and educational purposes within the meaning of Section 501(c)(3) of the Internal Revenue Code. The Trust currently has 14 Board members, 16 advisors, and five staff, including an Executive Director, Central Valley Program Director, and Sierra Nevada Program Director.

The Trust protects and conserves critical natural areas in the Tuolumne watershed, with offices in Groveland, Modesto, and San Francisco. The Trust links Sierra and Valley conservation issues and communities together and forges strong ties with the San Francisco Bay urban areas that rely on and recreate near the river.

On-going volunteer activities and events: Spring 2005 Big Bend volunteer planting day; Summer 2005 Hikes and Educational Events in Sierra Nevada; Fall 2005 Canoe trips
Contact:
Jenna Olsen, Executive Director
917 13th Street
Modesto, CA 95354
(209) 236-0330
www.tuolumne.org

Turlock Irrigation District

TID WATER & POWER

Turlock Irrigation District is the oldest continuously operating irrigation district in California, delivering water to 150,000 acres of land and low cost electrical energy to over 65,000 customers.
The TID is the manager of the Don Pedro Project on behalf of the Turlock and Modesto Irrigation Districts and both are members of the Tuolumne River Technical Advisory Committee (TRTAC).

The Turlock Irrigation District mission is to provide dependable, competitively prices water and electricity in an environmentally responsible manner that is consistent with the interest of our customers.

On-going Projects: Predator Reduction Projects: SRP 9 at Fox Grove complete. SRP 10 adjacent to SRP 9 in design stage. Mining Reach channel restoration Projects: 7\11 Segment No. 1 complete; MJ Ruddy Segment No. 2 in ROW acquisition; Warner-Deardorff Segment No. 3 in final design. Sediment Management Projects: RM 43 in permitting stage; Fine Sediment Management (a) Gasburg Creek sediment control basin designed ready for construction & (b) spawning gravel cleaning systems under design; Gravel Infusion Project under design.
On-going volunteer activities: None planned.

Contact:
Wilton B. Fryer, P.E., Turlock Irrigation District
333 East Canal Dr.
Turlock CA 95380
(209) 883-8316

Cooperating Agencies

California Bay-Delta Authority
Dan Wermiel, (916) 445-5398

California Department of Fish and Game
Contact: Pat Brantley, (209) 772-0703

Stanislaus County Council of Governments
Contact: Bruce Abanathie, (209) 558-4762

United States Department of Agriculture-Natural Resources Conservation Service
Contact: Michael A. McElhiney, District Conservationist, (209) 491-9320 x. 102

United States Department of Commerce-National Oceanic and Atmospheric Administration (NOAA) Fisheries
Contact: Madelyn Martinez or Jeff McLain (916) 930-3600

United States Fish and Wildlife Service-Anadramous Fish Restoration Program
Contact: Carl Mesick (209) 946-6400

United States Fish and Wildlife Service-San Joaquin National Wildlife Refuge
Contact:

Eric Hopson	Kim Forrest
Assistant Refuge Manager	Refuge Manager
San Joaquin River NWR	San Luis National Wildlife Refuge Complex
2714 Dairy Road	947 West Pacheco Blvd., Ste C
Vernalis, CA 95385	Los Banos, CA 93635
(209) 587-5532 cell	(209) 826-3508
(209) 832-9035 office	

http://sanluis.fws.gov/sanjoaquin_info.htm
On-going Projects: Endangered Riparian Brush Rabbit Recovery; Wetland and Riparian habitat restoration; Floodplain Hydrology Restoration
Meetings or other forums: Meeting to discuss and comment on the Refuge's Draft Comprehensive Conservation Plan; (fall/winter 2004/5); Modesto (Time and location TBA)
Other volunteer activities: On-going volunteer projects are developed and tailored to fit individual experience and interest levels. Contact Eric Hopson, 587-5532; Docents are needed to lead third grade wildlife interpretation field trips through the Faith Ranch and Refuge Lands. Contact John Hertle, 545-0815;
Guided bird watching trips are conducted on the Refuge by the Stanislaus Audubon Society one or two times per month. Contact Bill Amundsen 521-8256, or Dave Froba 521-5890.

Appendix B: Table of Existing Plans, Reports and Studies

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
1	CALFED	**1a.** Ecosystem Restoration (ERP) Multi-Year Program Plan (Years 5-8)	▪ Riparian Habitat ▪ Floodplain/Run-off management	Strategic Goals 1-6, and corresponding objectives	http://calwater.ca.gov/Programs/EcosystemRestoration/Ecosystem.shtml
		1b. Lower Tuolumne River Adaptive Management Forum Report. October 1, 2001.	▪ Riparian Habitat ▪ Floodplain & Run-off management	Key Recommendations (p. 8-26)	http://calwater.ca.gov/Programs/Science/adobe_pdf/LowerTuolumneForumReport.pdf
		1c. Watershed Program Multi-Year Program Plan (years 5-8)	▪ Coordination with ERP		http://baydeltawatershed.org/
2	California Department of Fish & Game	Restoring Central Valley Streams: A Plan for Action. November 1993.	▪ Riparian Habitat ▪ Floodplain/Run-off management	Central Valley Action Plan: San Joaquin Region: Tuolumne River (p. VII-113)	

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
3	California Department of Water Resources*	**3a.** Bulletin 118 – Update 2003, California's Groundwater	▪ Floodplain/Run-off management	Major Recommendations	http://www.groundwater.water.ca.gov/bulletin118/update2003/index.cfm
		3b. California Model Floodplain Management Ordinance, December 2001	▪ Floodplain/Run-off management	Section 1.4; Sections 5.1, 5.2, 5.3, 5.4, 5.4, 5.6, 5.8, and 5.9	http://www.fpm.water.ca.gov/ordinance/Ordinance01.doc
4	California Floodplain Management Task Force	California Floodplain Management Report. December 12, 2002.	▪ Floodplain/Run-off management ▪ Land use ▪ Stewardship & Education ▪ Riparian Habitat	Floodplain Management Actions & Key Recommendations	http://fpmtaskforce.water.ca.gov/
5	California Partners in Flight	Riparian Bird Conservation Plan: A Strategy for reversing the decline of riparian associated birds in California. (Riparian Habitat Joint Venture). August 2000.	▪ Riparian Habitat ▪ Floodplain/ Run-off management ▪ Stewardship & Education	Conservation Recommendations Objectives 1-13	http://www.prbo.org/calpif/pdfs/riparian_v-2.pdf

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
6	California Regional Water Quality Control Board, Central Valley Region	Water Quality Control Plan for the Sacramento and San Joaquin Basins, 1998	▪ Water Quality ▪ Water Supply	Surface Water Bodies and Beneficial Uses; Specific Dissolved Oxygen Water Quality Objectives	http://www.epa.gov/ost/standards/wqslibrary/ca/ca_9_central_valley.pdf
7	California State Parks	**7a.** California State Parks and The Great Central Valley, April 2004	▪ Land Use ▪ Riparian Habitat ▪ Recreation ▪ Stewardship & Education ▪ Terrestrial Species	Acquisition and Development Strategies; Key Recommendations	http://www.parks.ca.gov/
		7b. Performance Management Report 2004	▪ Land Use ▪ Riparian Habitat ▪ Recreation ▪ Stewardship & Education ▪ Terrestrial Species	Core Programs and Outcome Measures	http://www.parks.ca.gov/

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
		7c. California Outdoor Recreation Plan 2002	▪ Land Use ▪ Riparian Habitat ▪ Recreation ▪ Stewardship & Education ▪ Terrestrial Species	Actions (Issues 1-6)	http://www.parks.ca.gov/
8	Ceres, City of	**8a.** Hatch Road Regional Park Master Plan. July 2002.	▪ Water Quality ▪ Land Use ▪ Recreation ▪ Access	Program Elements and Phasing Plan	
		8b. City of Ceres General Plan.	▪ Land Use ▪ Water Quality ▪ Water Supply ▪ Riparian Habitat ▪ Terrestrial Species	Policies 1.A.2, 1.A.3, 1.A.4, 1.A.5; 4.C.1, 4.C.3, 4.C.4, 4.D.1, 4.D.4, 4.E.1, 4E.3, 4.E.6, 4.E.10; 5.A.1, 5.A.6, 5.A.7, 5.B.1, 5.B.2, 5.C.1; 6.A.1, 6.A.2, 6.A.5, 6.A.6, 6.B.1, 6.B.2, 6.B.3, 6.B.4, 6.B.5, 6.C.1, 6.C.2, 6.C.3, 6.C.4, 6.C.5; Goals 6D, 6E, and 7B and all Policies;	http://www.ci.ceres.ca.us/GeneralPlan.pdf

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
9	Department of commerce, National Oceanic and Atmospheric Administration	Federal Register Part II 50 CFR Parts 223 and 224	▪ Aquatic Species		
10	Federal Emergency Management Agency	National Flood Insurance Program and Related Regulations, Revised as of October 1, 1994	▪ Floodplain/Run-off management ▪ Land Use	Part 60: 60.2-60.26	
11	Federal Energy Regulatory Commission	**11a.** Federal Energy Regulatory Commission Order Amending Articles 37 & 58 of License for Project Number 2299-024 & –031	▪ Riparian Habitat ▪ Land use ▪ Floodplain/Run-off management ▪ Aquatic Species		
		11b. New Don Pedro Proceeding Settlement Agreement. 1995.	▪ Riparian Habitat ▪ Land use ▪ Floodplain/Run-off management ▪ Aquatic Species		

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
12	Friends of the Tuolumne, Inc.	**Bobcat Flat Conceptual Restoration Plan**	▪ Riparian Habitat ▪ Floodplain/Run-off management ▪ Terrestrial Species ▪ Aquatic Species		
13	Modesto, City of	**13a.** City of Modesto General Plan. 1995, updated 2001.	▪ Riparian Habitat ▪ Land Use ▪ Access ▪ Floodplain/Run-off management	Community Facilities Policies C.2, C.3; D.2, D.3; E.2, E.3; G.2, G.3; Public Safety Policies C.2, C.3; Environmental Resources and Open Space Policies B.1-B.7; D.2, D.3E.2, E.3; F.2, F.3	http://www.modestogov.com/cdd/Planning/documents/generalplan.asp
		13b. City of Modesto General Plan, Tuolumne River Comprehensive Planning District	▪ Land Use	Land Use Policies	
		13c. County and City- wide Visioning Statements and Related County Policies, February 5, 2002	▪ Land Use ▪ Water Quality ▪ Water Supply ▪ Access	Strategy (and corresponding actions) V.A.6, XI.A, I.B.1.a, I.B.1.b, I.B.1.c	

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
14	River Partners	Annual Report 2003	▪ Riparian Habitat	Tuolumne River Project Facts	http://www.riverpartners.org/documents/2003AnnualReport.pdf
15	San Francisco Public Utilities Commission	**15a.** Capital Improvement Program, February 25, 2002	▪ Water Supply ▪ Water Quality	Capital Improvement Planning Programs	http://sfwater.org/detail.cfm/MSC_ID/6/MTO_ID/NULL/MC_ID/7/C_ID/452/holdSession/1
		15b. SFPUC Master Plan	▪ Water Supply ▪ Water Quality		
16	Stanislaus County	**16a.** Countywide Visioning Statements and Related County Policies, February 5, 2002	▪ Land Use	Land Use Action Items; Environment Action Items;	
		16b. Stanislaus County General Plan. 1994.	▪ Riparian Habitat ▪ Land Use ▪ Access ▪ Floodplain/Run-off management	**Chapter One:** Goal 1: Policies 2, Goal 2: Policies 4, 7, 10, 12; **Chapter Three:** Goal 1: Policies 1-4; Goal 2: Policies 5,6,8,9; Goal 3: Policies 10-11; Goal 4: Policies 12-15; Goal 5: Policy 16; Goal 8: Policies 24; Goal 9: Policies 26-28; Goals 10: Policies 29-30; **Chapter 5**: Goal 1: Policy 2	http://ceres.ca.gov/planning/counties/Stanislaus/plans.html

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
		16c. Stanislaus County Agricultural Elements of the General Plan, 1994	▪ Land Use ▪ Water Quality ▪ Water Supply	Goal 1, Policies 1.1, 1.2, 1.3, 1.10, 1.11, 1.12, 1.26 Goal 2, Policies 2.1 to 2.14 Goal 3, Policies 3.5 to 3.7	http://ceres.ca.gov/planning/counties/Stanislaus/plans.html
		16d. Stanislaus County Parks Master Plan. August 24, 1999.	▪ Access ▪ Recreation ▪ Land use ▪ Stewardship & Education	Design Recommendations; Future Planning: New Regional Parks, New River Accesses and Geer Landfill; Specific Park Plans; Economic Development Opportunities: County Resources	http://www.co.stanislaus.ca.us/er/Execsum.htm
		16e. County of Stanislaus Policy Regarding Agricultural Lands Transaction	▪ Land Use	Criteria A to D	Great Valley Center
17	Tuolumne River Regional Park	**17a.** Tuolumne River Regional Park Master Plan	▪ Recreation ▪ Access ▪ Land Use ▪ Riparian Habitat ▪ Stewardship & Education ▪ Terrestrial Species	Preliminary Goals & Objectives; Chapters 3,4,5; Implementation Action Plan	

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
		17b. CEQA Findings of Fact and Statement of Overriding Conditions for the Tuolumne River Regional Park Master Plan (Joint Powers Authority, also including City of Modesto and County of Stanislaus). October 2001.	▪ Recreation ▪ Access ▪ Land Use ▪ Riparian Habitat ▪ Stewardship & Education		
18	Tuolumne River Technical Advisory Committee	Habitat Restoration Plan for the Lower Tuolumne River Corridor. March 2000.	▪ Riparian Habitat ▪ Land Use ▪ Floodplain/Run-off management ▪ Aquatic Species	Restoration Goals & Objectives; Restoration Strategies; Restoration & Preservation Approaches; Riparian Inventory	http://www.delta.dfg.ca.gov/afrp/documents/tuolplan2.pdf
19	U.S. Army Corps of Engineers	**19a.** Tuolumne River & Tributaries Feasibility Study Project Management Plan (currently developing work plan and project schedule). October 31, 2001.	▪ Floodplain/Run-off management ▪ Riparian Habitat	Plan Formulation & Planning Objectives; Chapter 3 Phase I: Measures 1-6	
		19b. Sacramento & San Joaquin River Basins Comprehensive Study for Flood Damage Reduction & Ecosystem Restoration Post-Flood Assessment. December 20, 2002.	▪ Riparian Habitat ▪ Floodplain/Run-off management	Policies on Agriculture in the Floodplain; Guiding Principles; Approach for Project Development; The Lower San Joaquin River Region	http://www.compstudy.org/docs/interimreport20021220/interimrpt-cover.pdf

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
19	U.S. Fish & Wildlife Service	**20a.** Environmental Assessment and Land Protection Plan. Proposed Addition to the San Joaquin River National Wildlife Refuge Stanislaus County, CA. (for the establishment/expansion of the riparian wildlife refuge in 1998). April 1998.	▪ Riparian Habitat ▪ Land Use ▪ Terrestrial Species	Purpose & Need; Guiding Principles; Goals; Habitat & Land Acquisition Process	
		20b. Final Restoration Plan for the Anadromous Fish Restoration Program: A Plan to Increase Natural Protection of Anadromous Fish in the Central Valley of California. January 9, 2001.	▪ Riparian Habitat ▪ Stewardship & Education	Central Valley and Tuolumne-Specific Action and Evaluation Items	www.delta.dfg.ca.gov/afrp/restplan_final.asp
20	U.S. Fish & Wildlife Service, Cont'd	**20c.** Central Valley Habitat Joint Venture Implementation Plan. February 1990.	▪ Riparian Habitat ▪ Terrestrial Species ▪ Floodplain/run-off management ▪ Stewardship & Education	Six Primary Objectives	

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
		20d. The Economic Impact on Stanislaus County of Public land Acquisitions and Conservation Easements on Floodplain Lands Along the Lower Tuolumne and San Joaquin Rivers. Revised Draft Report	▪ Land Use	Past and Future Acquisitions and Easements	http://www.deltadfg.ca.gov/afrp/documents/Rev_Report-12-16.pdf
		20e, AFRP Tuolumne River Watershed Data	▪ Water Quality ▪ Aquatic Species		http://www.deltadfg.ca.gov/afrp/ws_stats.asp?code=TUOLR
		20f. Workplan for Fiscal Year 2003, September 20, 2002	▪ Aquatic Species	Central Valley and Tuolumne Specific Program Objectives	http://www.deltadfg.ca.gov/afrp/documents/AWP2003Final.pdf
		20g. San Joaquin National Wildlife Refuge Comprehensive Conservation Plan	▪ Riparian Habitat ▪ Terrestrial Species	Chapter One	
		20h. Coarse Sediment Management Plan for the Lower Tuolumne River, Revised Final, July 20, 2004	▪ Aquatic Species ▪ Riparian Habitat	6.3; 6.4; 7.2; 7.3; 7.4; 7.5;	

	Agency/ Organization	Plan, Report or Study	Plan Elements	Plan, Goals, Policies Cited	Contact Information & Availability
21	Waterford, City of	City of Waterford General Plan. November 1991.	▪ Riparian Habitat ▪ Access ▪ Land use ▪ Floodplain/run-off management ▪ Water Quality ▪ Water Supply	Land Use Element: Policies 4.1.4, 4.1.5, 4.1.6; 4.2.4; Open Space and Conservation Element: Policies 7.1.17.3.5, Goal 7.4 and all Policies; Goal 7.6 and all Policies; Policy 7.7.1; Safety Element: Policy 8.1.5; Parks and Recreation Element: Goal 10.1 and all Policies; Goal10.4 and all Policies	

Appendix C: Inventory of Detailed Plan Elements and Objectives

Plan Elements & Objectives for the Lower Tuolumne River

The following table includes excerpts from over 40 plans and documents that pertain to or affect the Lower Tuolumne River. The table is organized by "river element", such as recreation or water quality. In addition, the table includes references to river location, if any elements addressed specific reaches of the river (see the Key). All statements are followed by a citation of the original source document. Refer to Appendices B for more information about the documents referenced here.

KEY:

Elements unique to Reaches 1-7	**1-7**
Elements common to the Lower (sand bed) Reaches	**8**
Elements common to the Upper (gravel bed) Reaches	**9**
Elements common to all Reaches	**10**

Element:	Objectives:
✓Recreation	▪ Formal recreation (sports fields, concessions, picnicking, river overlooks) as well as passive recreation (wetlands restoration, trail development, river overlooks, natural recreation) (*source: City of Ceres General Plan*) **[2]** ▪ Walking and biking along the River and enjoying the natural beauty of the River through the development of the Tuolumne River Regional Park (*source: Friends of the Tuolumne, City of Ceres General Plan*) **[2]** ▪ Focus on multi-purpose recreation: enhancing a trail system (riverwalk), river overlooks, pedestrian bridges, outdoor classrooms, beaches, small piers, amphimeadow, canoe and kayak launches, regional sports complex, and interpretive center. Specifically, passive recreation oriented to the River East and West of the Gateway Parcel; Active recreation and facilities in the Gateway Parcel (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Consideration and use of natural forces affecting sites; Avoid permanent structures in the floodplain if possible (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Develop Phases I-III of the Ceres River Bluff Regional Park to include soccer fields, paths and fencing, parking lots, basketball courts, play areas, restrooms, softball facilities, other formal recreation elements, and pathways and overlooks on this upper-bluff area. Develop Phase IV along the lower terrace to include a natural recreation area with river cleanup, removal of the existing orchard to restore natural riparian habitat, seasonal wetlands constructed as water detention areas, trail systems, overlooks, picnic areas, other native and riparian plantings, and enhanced vehicular access and a parking lot for the non-motorized boating access (*source: Hatch Road Regional Park Master Plan*) **[2]** ▪ Develop resources that attract regional visitors (regional river park), and parkways and greenbelts (*source: City of Waterford General Plan, Tuolumne River Regional Park Master Plan*) **[4]** ▪ Maintain City's open space for passive and active recreational use accessible to everyone by developing a recreation guide, mapping trails and parks and their

	connections with other communities, and plans for sensitive habitat areas that include trail systems, access, and interpretive centers (*source: City of Waterford General Plan*) **[4]** ▪ Develop an interpretive center, camps, amphitheater, sports fields and other facilities, trail systems, and fishing access at La Grange and connections of pedestrian, bike, and equestrian trails near Waterford (*source: Stanislaus County Parks Master Plan*) **[7]** ▪ Canoeing and rafting (*source: Central Valley Regional Water Quality Control Board*) **[10]** ▪ Fishing access, boating, picnicking, informal play, camping, river trails, and other passive recreation along the River to create a "string of pearls" of access sites. (*source: Stanislaus County Parks Master Plan*) **[10]** ▪ Maintain the natural environment in areas dedicated as parks and open space and include provisions in County parks for native vegetation conservation (*source: Stanislaus County General Plan*) **[10]** ▪ Provide open space and recreation needs of residents through a system of local and regional parks, by acquiring open space where future growth is planned, and by creating an interconnection of recreation areas and open spaces that are oriented to bike and pedestrian use while making parks more universally accessible (*source: Stanislaus County General Plan*) **[10]** ▪ Provide diverse recreational opportunities such as horseback riding, hiking trails, and bikeways (*source: Stanislaus County General Plan*) **[10]** ▪ Coordinate provision of recreation opportunities with other providers such as the Army Corps of Engineers, State Resource Agency, school districts, river rafters, horse stables, and private organizations such as the Sierra Club and Audubon Society (*source: Stanislaus County General Plan*) **[10]** ▪ California State Parks has outlined the following Strategic Initiatives: Increase Diversity; Increase Leadership in Parks and Recreation; Focus on Cultural resources; Utilize Technology; Increase Leadership in Natural Resource Management; Develop a New Image (to communicate a clear message); Create an Urban Connection; Expand Recreational Opportunities (to keep pace with California's divers ad changing lifestyles) (*California State Parks Performance Management Report 2004*) **[10]** ▪ Key outcomes for California State Parks' 6 Core Program (Natural Resource Protection, Cultural Resource Protection, Facilities, Education/Interpretation, Public Safety, and Recreation) are that ecosystems and constituent elements are in a desired condition; significant cultural sites, features, structures, and collections are protected and preserved; quality infrastructure is provided and maintained; the public understands the significance and value of the State's natural and cultural resources through education, interpretation, and leadership; a safe environment is provided within parks; and the quality of life for Californians is improved through the provision of diverse, high-quality recreation experiences and opportunities. (*California State Parks Performance Management Report 2004*) **[10]** ▪ Natural Resource Protection is measured through securing lands that contribute to sustainable ecosystems (providing or creating linkages to existing protected areas, contributing to complete watershed protection, provide buffers from urban impacts); the control and management of exotic species; continuing the Inventory, Monitoring, and Assessment Program for flora and

	fauna; restoring natural processes (e.g. prescribed fires); increasing visitor satisfaction; and Paleontological Resource Management (*California State Parks Performance Management Report 2004*) **[10]** ▪ Cultural Resource Protection is measured through cataloging, scanning, and documenting objects and photographs; continuing archaeological site assessment, protection, and maintenance; conducting condition assessments of historic buildings and structures; securing appropriate housing for artifacts; conducting the Cultural Stewardship Program; securing land of cultural resources; and increasing visitor satisfaction (*California State Parks Performance Management Report 2004*) **[10]** ▪ Facilities are measures through increasing visitor satisfaction; documentation of repair and maintenance; and the accessibility of facilities (compliance with ADA) (*California State Parks Performance Management Report 2004*) **[10]** ▪ Education and interpretation are measured by increasing visitor satisfaction; participant hours in education and interpretation programs; and congruity with educational curricula (*California State Parks Performance Management Report 2004*) **[10]** ▪ Public Safety is measured by ratio of accidents and crimes to visitors; and increasing visitor satisfaction/perceptions of safety (*California State Parks Performance Management Report 2004*) **[10]** ▪ Recreation is measured by increasing visitor satisfaction; visitor attendance rates; and accessibility (recreational activities are ADA compliant) (*California State Parks Performance Management Report 2004*) **[10]** ▪ The California Outdoor Recreation Plan prioritized the following 6 issues: the status of parks and recreation; financing parks and outdoor recreation; access to public parks and recreation resources; protecting and managing natural resource values; preserving and protecting California's cultural heritage; and statewide leadership in parks and outdoor recreation (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Actions to enhance the status of parks and recreation: Document and publicize benefits related to parks and outdoor recreation; Raise public awareness of elected official's decisions; Develop statewide political action committee; Introduce legislation mandating General Plan recreation element; Expand California Roundtable membership to expand legislative and advocacy efforts; Develop a State/Federal healthy lifestyle initiative; Emphasize elements of parks and recreation field most valued by public (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Actions to improve financing: Support full stateside funding from the Land and Water Conservation Fund based on State population and level of recreation-related travel; Sponsor/support legislation to create a professionally managed statewide endowment for acquisition, capital outlay, and extraordinary maintenance; Conduct statewide inventory rating needs for infrastructure maintenance and new facilities; Advocate for State legislation to allocate new or existing tax revenues towards parks and recreation; Coordinate technical assistance for obtaining grants and identifying funding sources; Design a standard interpretive template for promoting acquisitions, new and rehabilitated facilities (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Actions to improve access: Complete statewide inventory of federal, state, county, city and special district outdoor recreation facilities; Track emerging

	outdoor recreation trends and conduct research for access, relevance, safety, ad barriers; Develop statewide parks and recreation area standards; Establish a multicultural advocacy council to promote parks ad recreation benefits to youth; Create inclusive camping areas for educational and recreational experiences; Have every K-12 student visit a resource-based park during their school career (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Actions protect natural resource values: Complete gap analysis of biological diversity, bio-corridors and linkages; and sustainable landscapes; Develop a coordinated land acquisition strategy for under-represented ecosystems and additional resource-based recreational properties; Establish a Council on Carrying Capacity to minimize the social and environmental carrying capacities of park and recreation areas; Adopt a statewide environmental education program and code of outdoor recreation ethics; Create partnerships with education providers on educating youth about preserving and protecting natural resources; Identify a funding source and prioritize natural systems for restoration projects (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Actions to preserve cultural heritage: Increase the number of significant private and public historic resources following a gap analysis of missing or under-represented cultural themes; Incorporate historic preservation into public policy at all levels of government; Provide technical, financial, and leadership assistance to state agencies and local governments; Increase the understanding of historic preservation in those individuals; organizations, and local governments who influence public opinion and the planning process; Promote historic preservation through education, training and outreach programs; Stimulate California's economy through historic preservation incentives that promote jobs, community investments, and heritage tourism (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Actions to increase leadership: convene a Parks and Recreation Summit to establish a common vision, an Outdoor Code of Ethics, a set of guiding principles, long range goals and a plan to achieve them; NPS resumes technical assistance to park and recreation service providers; DPR re-establish technical assistance to park and recreation service providers; Federal, state and local provider adopt relevant project goals from the Vision Insight Planning team to meet their specific needs; Expand private sector and non-traditional California Roundtable membership; Post park and recreation research findings on a central website; Create a Leadership Academy to identify and mentor future parks and recreation leaders (*California Outdoor Recreation Plan 2002*) **[10]** ▪ Expand recreational facilities for camping, day use, fishing, boating, and trails to accommodate larger families and groups in existing parks along river corridors, at Valley reservoirs and in the Delta (*California State Parks and the Great Central Valley, 2004*) **[10]** ▪ Expand landholdings at existing parks and acquire new parklands along major river corridors such as the Sacramento, Tuolumne, Stanislaus, San Joaquin and Merced Rivers, particularly where an opportunity exists to link state parks and other lands in public ownership (*California State Parks and the Great Central Valley, 2004*) **[10]** ▪ Acquire lands that preserve and protect vanishing natural resources once more abundantly evident in the CV, such as blue oak and sycamore

	woodlands, riparian habitat, and native grasslands (*California State Parks and the Great Central Valley, 2004*) **[10]** ▪ Better preserve and interpret the rich history associated with the CV's past, including the full sweep of agricultural history, Native American past and continuing life ways; Highway 99, the Valley's oil industry, and the stories of immigrant workers from around the world, of Depression-era dust bowl refugees, and of California's country and western music artists (*California State Parks and the Great Central Valley, 2004*) **[10]** ▪ Acquisition and development opportunities (to acquire and expand state parks) should focus on lands containing under-represented natural or historical resources; lands with water features to support a multitude of uses and interests; river corridors and parkways; lands that have the capacity for high demand recreational activities such as camping, day use, trails and youth activities; Lands that link large blocks of protected habitat resulting in combined acreage; Lands that serve growing communities and a diversity of interests; Lands that offer the possibility of partnerships with other organizations (*California State Parks and the Great Central Valley, 2004*) **[10]** ▪ Habitat: Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics. (*source: CALFED Ecosystem Restoration Plan*) ▪ Water and sediment quality: Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed, and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people (*source: CALFED Ecosystem Restoration Program*) ▪ Coordinate the AFRP with appropriate activities supported by the Riparian and Recreation Improvement fund that was established by the New Don Pedro Settlement Agreement (*source: AFRP Final Restoration Plan*)
✓ **Floodplain & Run-off Management**	▪ Reduce flood damages in the Modesto area in compliance with local land use plans in an efficient manner (contributing to NED) with on-going environmental restoration and management plans. (*source: ACOE Feasibility Study Project Management Plan. Habitat Restoration Plan for the Lower Tuolumne*) **[2]** ▪ Mitigate increases in peak storm water flow and volume (positive drainages, drainage ponds, on-site drainage, irrigation facilities), consider using higher quality storm water to replenish groundwater basin, restore wetlands and riparian habitat, irrigate agriculture, or as open space and recreation enhancements, and develop floodway zoning (*source: City of Ceres General Plan*) **[2]** ▪ Purification of urban stormwater runoff using constructed wetlands (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Focus on non-structural approaches to flood control and prevention (e.g. preserve undeveloped floodway/floodplain areas for non-urban use, permit new development when proved to be protected from 100-year floods, and restrict amount of new development run-off from exceeding current conditions) (*source: City of Modesto General Plan*) **[2]** ▪ Minimize local flooding and reduce burden on sanitary system (construct lines to River from various watersheds, add storm drainage basins and use Modesto Irrigation Canal system to increase volume of water carried by River), and

	designate floodway along river with standards for building within 100- and 500- year floodplains (*source: City of Waterford General Plan*) **[4]** ▪ Prioritize potential coarse sediment supplies for sediment augmentation, as well as channel/floodplain reconstruction projects, to minimize additional demands on commercial aggregate supplies (*source: Course Sediment Management Plan*) **[9]** ▪ General flood management that contributes to ecological values of River corridor (*source: ACOE Feasibility Study Project Management Plan. Habitat Restoration Plan for the Lower Tuolumne*) **[10]** ▪ Explore future flood damage reduction and ecosystem restoration projects in cooperation with state and federal agencies (e.g. passive levee breaches near confluence with San Joaquin River, control weirs, improve effectiveness of Don Pedro reservoir through physical improvements, coordinated pre-releases, or strategic releases to support more natural hydrologic regime, riparian vegetation, and ecosystem functioning) (*source: ACOE Sacramento and San Joaquin River Basins Comprehensive Study*) **[10]** ▪ Reserve lands subject to natural disaster as open space: development will not be permitted in the floodplain unless otherwise approved by the State Recreation Board and information will be provided to anyone interested in creating a Flood Control District (*source: Stanislaus County General Plan*) **[10]** ▪ The California Model Floodplain Management Ordinance contains methods and provisions to: Restrict or prohibit uses which are dangerous to health, safety, and property due to water or erosion hazards, or which results in damaging increases in erosion or flood heights or velocities; Require that uses vulnerable to floods, including facilities which serve such uses, be protected against flood damage at the time of initial construction; Control the alteration of natural floodplains, stream channels, and natural protective barriers, which help accommodate or channel flood waters; Control filling, dredging, grading, and other development which may increase flood damage; Prevent or regulate the construction of flood barriers which will unnaturally divert flood waters or which may increase flood hazards in other areas. (*source: California Model Floodplain Management Ordinance, DWR*) ▪ Implement provisions for flood hazard reduction including standards for construction, standards for utilities, standards for subdivisions, standards for manufactured homes, standards for recreational vehicles, prohibit encroachments, including fill, new construction, substantial improvement, or other new development, in the floodway unless certified by a registered engineer; standards for mudslide prone areas, and standards for flood-related erosion-prone areas (*source: California Model Floodplain Management Ordinance, DWR*) ▪ Flood plain management criteria for flood-prone areas are detailed depending upon how much data is available. The Administrator will provide the data upon which floodplain management regulations shall be based. If the Administrator has not provided sufficient data to furnish a basis for these regulations in a particular community, the community shall obtain, review, and reasonable utilize data available from other Federal, State, or other sources pending receipt of data from the Administrator. However, when special flood hazard area designations and water surface elevations have been furbished by the Administrator, they shall apply In all cases the minimum requirements

	governing the adequacy of the flood plain management regulations for flood-prone areas adopted by a particular community depend on the amount of technical data formally provided to the community by the Administrator. (Minimum standards for communities are outlined in subchapter 60.3) Flood plain management criteria and planning considerations for mudslide-prone areas, for erosion-prone areas, for State-owned properties in special hazard areas, and guidelines for local coordination are also outlined. (*source: FEMA National Flood Insurance Program and Related Regulations*) ▪ Better understanding of and reducing risks from reasonable foreseeable flooding: expand State Awareness Floodplain Mapping; prepare floodplain maps that consider future build-out and are based on watersheds; develop cross-agency compatible GIS flood maps; map alluvial fan floodplains; installation of real-time gages and monitorig in priority locations; identify repeatedly-flooded structrures; increase flood warning and local community flood response systems; use other resources in addition to FIRMS; exceed NFIP floodplain management requirements; update the Governor's 1977 Executive Order for Floodplain Management; coordinate State Multi-Hazard Mitigation Plan and FEMA requirements; coordinate across various multi-hazard mapping efforts to develop GIS-based advisory maps; ensure that State Building Codes meet or exceed NFIP requirements. (*source: California Floodplain Management Task Force*) **[10]** ▪ Multi-Objective Management Approach for Floodplains: promote a Multi-Objective Management approach to flood management projects; flood management projects should maximize opportunities for agricultural conservation and ecosystem protection and restoration; integrate non-structural approaches, restoration and conservation of agricultural natural lands into flood management programs; develop tools to protect flood-compatible uses; protect floodplain groundwater recharge areas; consider the costs and impacts of vector control; encourage multi-jurisdictional partnerships; monitor projects on the watershed level; manage floodplains proactively and adaptively; work with stakeholders to identify BMPs; develop training, education and professional certification in multi-objective floodplain management; coordinate across agencies and groups; update the Sate General Plan guidelines according to these recommendations; coordinate across federal, state, local and nongovernmental sources to fund multi-objective floodplain management (*source: California Floodplain Management Task Force*) **[10]**
✓Geomorphology	▪ Floodplain as resource to be used for waterfowl, habitat, aquifer recharge, fishery enhancement, agricultural water supply (*source: City of Ceres General Plan*) **[2]** ▪ Permanently protect (as open space) areas of natural resource value such as wetlands, riparian corridors, and floodplains to full extent possible (*source: City of Ceres General Plan*) **[2]** ▪ Design strategies consistent with natural hydrologic processes; riparian restoration and restoration of riparian terraces along Gateway Parcel and Carpenter Road area (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Reconstruct remnant channel left by gold dredger operations to a natural river and floodplain form; Secure remnant dredger tailings for future restoration; Increase floodway width to at least 500 feet; Restore a natural river and

	floodplain morphology; Restore and maintain riparian corridor through gravel mining zones (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[9]** ▪ Continue to focus on the area of the river between La Grange and Waterford as an "Aggregate Resource Area". Manage extractive mineral resources to ensure an adequate supply without degrading the environment (e.g. surface mining will be encouraged in areas classified by State Division of Mines and Geology, permits will not be supplied four uses that threaten the potential to extract minerals, and land used for extraction shall be reclaimed) (*source: Stanislaus County General Plan*) **[9]** ▪ A secure gravel supply to replace gravel transported by the high flow regime, thus maintaining the quantity and quality of alluvial deposits that provide salmonid habitat. *(Sources: Habitat Restoration Plan for the Lower Tuolumne River Corridor; CALFED Ecosystem Restoration Program)* **[10]** ▪ Restore and improve opportunities to inundate the floodplain on a seasonal basis, conduct a feasibility study to construct setback levees in the floodplain, restore stream channel and overflow basin configuration, minimize effects of structures (bridges, etc.) on floodplain process and develop a floodplain management plan. *(Sources: Habitat Restoration Plan for the Lower Tuolumne River Corridor; CALFED Ecosystem Restoration Program)* **[10]** ▪ Restore, expand, and protect floodplain (modify levees, restore floodplain width, restore wetlands and riparian forest), lower floodplains to be wetted by spring flows (*sources: Proposed Addition to the San Joaquin National Wildlife Refuge, Friends of the Tuolumne, Inc, City of Ceres, Habitat Restoration Plan for the Lower Tuolumne*) **[10]** ▪ Restructure channel and floodplain morphology to an active and vegetated floodplain in order to restore natural ecosystem functioning and the survival of key channel and floodplain species – principally the fall-run Chinook salmon (*source: AFRP, Habitat Restoration Plan for the Lower Tuolumne*) **[10]** ▪ Salmonid habitat created and maintained by natural processes, sustaining a resilient, naturally reproducing populations (*sources: AFRP, Habitat Restoration Plan for the Lower Tuolumne)* ▪ Design and implement in-stream, channel, and floodplain projects with a tributary-scale, ecosystem perspective: Develop conceptual models for the Lower Tuolumne River which integrate the models for the gravel-bedded reach with the models for the sand-bedded reach; Define a project's success in terms of its contribution to overall ecosystem functions at the tributary scale; Determine and identify the metrics of ecosystem response to the Lower Tuolumne River restoration efforts (Adaptive Management Forum Report) ▪ Integrate a monitoring plan into the HRP that defines a monitoring network, sampling methods, or data processing protocol that integrates required monitoring with proposed monitoring: Collect sufficient baseline data to detect change (hydraulic modeling, topographic map of river bottom and overbanks, vegetation map); Stronger commitment to monitoring (include a list of variables, monitor predation at a scale to detect change, expand and improve river-wide monitoring, early collection of adequate information on salmon survival or bass predation rates); Consider monitoring invertebrate production; Avoid monitoring activities that could harm the ecosystem; Develop O&M plans regarding monitoring; Consider multivariate design and

	analysis; Document failures and lessons learned (Adaptive Management Forum Report) ▪ For project design and implementation, identify gains and losses of river flow and ensure that ecological objectives of restoration projects are adequately captured in the engineering design and are the primary consideration during construction (Adaptive Management Forum Report) ▪ Identify and integrate opportunities for experiments, with low-flow investigations; Riparian vegetation ecology experiments (physical sites factors and seeding and planting); Predation experiments for the SRPs; Spawner distribution; Nursery habitat- fry retention; Gravel augmentation/infusion; Riparian vegetation as fish nursery habitat (Adaptive Management Forum Report) ▪ Ecological processes: Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities (*source: CALFED Ecosystem Restoration Plan*) ▪ Improve watershed management and restore and protect instream and riparian habitat, including consideration of restoring and replenishing spawning gravel and performing an integrated evaluation of biological and geomorphic processes (*source: AFRP Final Restoration Plan*) ▪ Utilize an integrative approach to reestablish critical ecological functions, processes and characteristics tat, under regulated flow and sediment conditions, best promotes recovery and maintenance of a resilient, naturally reproducing salmon population and the river's natural animal and plant communities (*source: AFRP*) ▪ Protect, enhance or recreate natural riparian processes, particularly hydrology and associated high-water events, to promote the natural cycle of channel movement, sediment deposition, and scouring that create a diverse mosaic of riparian vegetation types (control all nonnative species, manage flows and avoid impacts on the natural hydrology of river channels) (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Restore coarse sediment supply and Chinook salmon and O. mykiss spawning gravels to the gravel-bedded reaches below La Grange Dam in a manner that protects existing habitat values for both salmon and O. mykiss (*source: Course Sediment Management Plan*) **[9]** ▪ Introduce coarse sediment to create immediately usable spawning habitat for both Chinook salmon and O. mykiss to supplement existing degraded habitat and/or create new habitat where none currently exists (*source: Course Sediment Management Plan*) **[9]** ▪ Prioritize potential coarse sediment supplies for sediment augmentation, as well as channel/floodplain reconstruction projects, to minimize additional demands on commercial aggregate supplies (*source: Course Sediment Management Plan*) **[9]** ▪ Identify alternative strategies for the environmental compliance process for coarse sediment management and other large-scale restoration projects (*source: Course Sediment Management Plan*) **[9]** ▪ Establish monitoring and adaptive management guidelines for evaluating the long-term coarse sediment management needs and the success of this

	program in restoring coarse sediment supply equilibrium, geomorphic processes, spawning gravel availability, and spawning habitat quality (*source: Course Sediment Management Plan*) **[9]**
✓Water Quality	▪ Improve water quality to protect public health and ensure a healthy aquatic community by minimizing or eliminating use of pesticides and fertilizers that may run off into the River, maintaining or restoring streambanks to minimize erosion and siltation into the River, and treat storm water runoff on-site using constructed wetlands and vegetated swales where possible (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Maintain standards for effluent water and biosolids as established by the Central Valley RWQCB by exploring land application of biosolids, encouraging regional beneficial reuse of reclaimed water, focusing on source control and demand management for wastewater management, developing positive storm drainage systems in new development areas, and preventing water pollution from urban storm run-off as established by the Central Valley RWQCB (surface water) and the EPA (ground water) (*source: City of Modesto General Plan*) **[2]** ▪ Focus storm water drainage facilities on rehabilitation, remediation of developed areas with inadequate levels of drainage, and expansion of the system for future development (with a dual-use focus) (*source: City of Modesto General Plan*) **[2]** ▪ Form regional partnerships for water and wastewater development, develop a comprehensive water and wastewater strategy, and protect water supply from storm drainage contamination (*source: City of Modesto Visioning Project 2000*) **[2]** ▪ Preserve, manage, and enhance the quality and quantity of ground and surface waters of the Tuolumne and other wetlands; Quality and quantity of surface water runoff from properties will not exceed existing flows or quality standards and will comply with City standards for off-site drainage (*source: City of Waterford General Plan*) **[4]** ▪ Increase the amount of Dissolved Oxygen in the region of the River from La Grange to Waterford (*source: Central Valley Regional Water Quality Control Board*) **[9]** ▪ Support state-wide water quality planning and water resource management and monitor and protect existing beneficial uses and plan for potential beneficial uses of water in the San Joaquin Basin. Potential beneficial uses of surface waters from the Lower Tuolumne River include Municipal Domestic Supply. Existing beneficial uses include irrigation, stock watering, river access, canoeing and rafting, warm and cold freshwater habitat, cold water salmon and steelhead spawning, and wildlife habitat. (*source: Central Valley Regional Water Quality Control Board*) **[10]** ▪ Policies or plans for the San Joaquin Basin include: Urban Runoff, Wastewater Reuse, Controllable (human) Factors, Water Quality Limited Segments, San Joaquin River Agricultural Subsurface Drainage (a Valley-wide drain to carry salts generated by agricultural irrigation out of the Central Valley), Antidegradation Implementation, Application of Water Quality Objectives, Investigation and Clean up of Contaminated Sites, Policy for Obtaining Salt Balance in the San Joaquin Valley, and Watershed Proposal (supports the implementation of a watershed-based approach to addressing water quality problems) (*source: Central Valley Regional Water Quality Control*

	Board) **[10]** ▪ Manage agricultural drain water (pesticides and other toxic substances) in the San Joaquin Basin and require use of feasible Best Management Practices to protect waters from the adverse effects of construction and urban runoff (*source: Central Valley Habitat Joint Venture Implementation Plan)* **[10]** ▪ Conserve water resources and protect water quality by protecting groundwater aquifers and recharge areas by exploring pollution control, water conservation measures, water-conserving landscapes, and alternative irrigation methods and by expanding the Water Quality Monitoring Program (*source: Stanislaus County General Plan*) **[10]** ▪ Water and sediment quality: Improve and/or maintain water and sediment quality conditions that fully support healthy and diverse aquatic ecosystems in the Bay-Delta estuary and watershed, and eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people (*source: CALFED Ecosystem Restoration Program*) ▪ Reduce toxic chemical and trace element contamination (*source: AFRP Final Restoration Plan*)
✓Water Supply	▪ Maintain an adequate supply of high quality water for urban uses and stabilize groundwater levels by viewing water sources such as groundwater, surface water, and recycled wastewater as an integrated hydrologic system, by establishing guidelines, policies, and programs to implement water conservation to the maximum extent feasible, and through local management of groundwater resources (*source: City of Modesto General Plan*) **[2]** ▪ Protect the water supply and the quality of the River, investigate use of surface water supplies fir domestic uses, promote efficient water use and explore use of reclaimed wastewater and ground water management program (*source: City of Ceres General Plan*) **[2]** ▪ Expand and improve domestic water supply to accommodate growth and reduce water consumption through water conservation measures (*source: City of Waterford General Plan*) **[4]** ▪ River supplies water for diverse uses, including irrigation and municipal uses (source: Friends of the Tuolumne, Central Valley Regional Water Quality Control Board, others) **[10]** ▪ Secure adequate water supply for wetlands restoration, acquisition, and easements (e.g. 402,450 ac-ft for National Wildlife Refuges in the Central Valley) (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Meet increase in demand of SFPUC customers through recycled water, groundwater development, conservation and demand management, and construction of additional water transmittal and storage facilities; Improve SFPUC infrastructure to address increasing demand, aging infrastructure, natural threats, changing regulations (*source: SFPUC Capital Improvements Program*) **[10]** ▪ Conserve water resources and protect water quality by protecting groundwater aquifers and recharge areas by exploring pollution control, water conservation measures, water-conserving landscapes, and alternative irrigation methods and

	ensuring new development can access water supplies without adversely impacting existing water resources by investigating additional water sources such as developing surface water or other potential sources (*source: Stanislaus County General Plan*) **[10]** ▪ Protect, conserve, and develop water resources for local domestic use and irrigation, and support the operation of the Tuolumne River Groundwater Basin Association as well as the San Joaquin Valley Water Coalition Council (*source: Stanislaus County Visioning Statements*) **[10]** ▪ Protect water resources by encouraging water conservation for both agricultural and urban uses through increasing education about irrigation methods and Best Practices and coordinated conservation efforts with key soil and farmland partners, cities, irrigation and water districts, as well as considering water-conserving elements when reviewing proposed developments and using conserved water locally *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ One opportunity for meeting the projected need of additional 71mgd of delivery capability could come from water supplies made available from the Tuolumne River system through transfers from senior Tuolumne water rights holders or increased storage under existing SFPUC water rights. Additional storage capacity opportunities could include expansion of Hetch Hetchy or other reservoirs, groundwater banking in the Central Valley along the San Joaquin Pipelines, new surface reservoirs such as Corral Hollow Reservoir along the San Joaquin Pipelines. SFPUC could also convert grave quarries in the Sunol Valley to water storage reservoirs or expand Crystal Springs and/or San Antonio Reservoirs. The SFPUC could also acquire water from MID/TID or could participate in conservation and/or groundwater banking programs. The Sunol Quarries Project is expected to generate about 6mgd of firm delivery, so about 65mgd of firm Tuolumne River supply must be acquired. (*source: SFPUC Water Supply Master Plan*) **[10]**

✓Land Use (Urban Buffers; Open Space; Agriculture)	▪ Establish urban limit lines to preserve open space, farmland, natural beauty, historic buildings, and critical environmental areas (*source: City of Modesto Visioning Project 2000*) **[2]** ▪ Future Urban Growth Boundary; Current very-low density urban development along River (*source: City of Ceres General Plan*) **[2]** ▪ Maintain agricultural areas around Waterford to set Waterford apart from surrounding urban areas (*source: City of Waterford General Plan*) **[4]** ▪ Create and maintain riparian buffer (corridor) along urban/agricultural zones in Reaches 2,3, and 4; Preserve existing urban setback from river (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[8]** ▪ Acquire lands that where growth is likely in and surrounding wetlands (*source: Central Valley Habitat Joint Venture Implementation Plan)* **[10]** ▪ Review zoning regulations for compatibility between development and natural areas and review all development requests to ensure that sensitive areas including riparian habitat are undisturbed or mitigation measures are put in place (*source: Stanislaus County General Plan*) **[10]** ▪ Urban growth shall be discouraged in areas with growth-limiting factors such as high water table, poor soil percolation, and prohibited in geological fault and hazard areas, floodplains, riparian areas, and airport hazard areas unless measure to mitigate the problems are included in application (e.g. development next to riparian areas that require discretionary approval must include measures for protecting that habitat) (*source: Stanislaus County General Plan*) **[10]** ▪ Create urban limit lines, providing for areas of open space, agriculture, very low density, rural development, or greenbelts in which urban development cannot occur (*source: Stanislaus County Visioning Statements*) **[10]** ▪ Reduce development pressures on agricultural lands by encouraging high-density infill development in built-up areas of the County, encouraging clustering of development on agricultural land when necessary, directing development away from the most agriculturally productive areas, limiting new development to areas of less productive agricultural land (generally the East and West sides of the County), and excluding agricultural lands from assessments to pay for infrastructure needed to accommodate new development *(source: Stanislaus County General Plan Agricultural Element)* **[10]**

	▪ Protect open space qualities of the River such as riverbluffs (*source: City of Ceres General Plan*) **[2]** ▪ Open space will be provided through a comprehensive network of regional, community, and neighborhood parks (*source: City of Modesto General Plan*) **[2]** ▪ Visual corridors of the River will be protected and enhanced and all scenic resources will be protected as resources of public importance (*source: City of Modesto General Plan*) **[2]** ▪ 1,380 acres will be designated as "open space" along the River in the Tuolumne River Comprehensive Planning District and will comprise a public park which will be represented by the TRRP Master Plan (*source: City of Modesto General Plan*) **[2]** ▪ Continue to focus open space preservation on: preservation of natural resources, public health and safety, managed production of resources, and outdoor recreation. The River is considered open space for the preservation of natural resources as the areas is required for the preservation of plant and animal life and for ecological and other scientific study purposes (*source: City of Modesto General Plan*) **[2]** ▪ Create open space corridors along the River by adopting a scenic corridor plan, preserve riparian vegetation, define sensitive habitat and open spaces by public access ways, encourage landowners to consolidate habitat and open spaces, establish City standards and plans for designating and maintaining sensitive habitat areas, and acquire and preserve City's open spaces for passive and active use (*source: City of Waterford General Plan*) **[4]** ▪ Maintain natural areas as open space through native plantings and continue to use the Williamson Act (*source: Stanislaus County General Plan*) **[10]** ▪ Preserve and expand stream meander belts by adding riparian lands in the meander zone by purchase from willing sellers, incentives to preserve and manage private riparian areas, establish property owner reimbursement mechanism for lands lost to meander processes, and develop a program to remove riprap and relocate other structures that impair stream meander. *(Source: CALFED Ecosystem Restoration Program)* **[10]** ▪ Natural Resource Protection is measured through securing lands that contribute to sustainable ecosystems (providing or creating linkages to existing protected areas, contributing to complete watershed protection, provide buffers from urban impacts); the control and management of exotic species; continuing the Inventory, Monitoring, and Assessment Program for flora and fauna; restoring natural processes (e.g. prescribed fires); increasing visitor satisfaction; and Paleontological Resource Management (*California State Parks Performance Management Report 2004*) **[10]**
✓Agriculture	▪ Support efforts to promote location of new agriculture-related businesses and industries throughout the County *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ Continue to implement right-to-farm ordinance *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ Protect agricultural operations from conflicts with and adverse impacts of non- agricultural uses by requiring buffers between proposed non-agricultural uses and adjacent agricultural operations and establishing setbacks from agricultural area *(source: Stanislaus County General Plan Agricultural Element)* **[10]**

	▪ Continue to work with local, state, and federal agencies to regulate the application of agricultural chemicals to prevent air and water quality problems, while ensuring the economic viability of agriculture *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ Provide property tax relief to agricultural landowners by participating in the Williamson Act (which is intended to conserve opens space and agricultural land by providing property owners with tax relief) and support reasonable measures to strengthen the Act, making it a more effective tool for protecting agricultural land, such as encouraging State legislators to increase Act subvention payments to local governments based on Cost of Living Adjustments and implementing the Act aloing with other conservation tools *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ When considering amendments to the General Plan for conversions of agricultural land, include adjacent uses, proposed methods for sewage treatment, availability of water, impacts on air and water quality, wildlife habitat, endangered species, and sensitive lands and other elements to enhance the evaluation process *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ When the proposed conversion of agricultural land to non-agricultural uses could have a significant effect on the environment, the County shall evaluate the direct, indirect, and cumulative effects on a site-specific basis, enhancing the standards outlined in the EIR process and requiring mitigation by including elements in the evaluation process such as destruction or fragmentation of native ecological communities, loss of nesting or foraging habitat, adverse impacts on rare species, impediments to wildlife migration patterns, reductions in the availability of water supplies or beneficial uses of water, and other impacts resulting from air and water pollution *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ Land designated agricultural shall be restricted to uses that are compatible with agricultural practices, including natural resources management, open space, outdoor recreation, and enjoyment of scenic beauty (*source: Stanislaus County General Plan*) **[10]** ▪ Agricultural land conservation efforts must be on the best soils – prime farmland or farmland of statewide importance (*source: Stanislaus County Policy Regarding Criteria for Agricultural Lands Transactions*) ▪ Eligible property (for conversation easements) must be close to urban boundaries and subject to urbanization pressure, but not substantially surrounded by urban development and not within the urban boundary (*source: Stanislaus County Policy Regarding Criteria for Agricultural Lands Transactions*) ▪ Eligible property (for conservation easements) must have access to high quality and economical water resources that would ensure its continued agricultural productivity (*source: Stanislaus County Policy Regarding Criteria for Agricultural Lands Transactions*) ▪ Eligible property (for conservation easements) must be large enough to sustain commercial agricultural production (*source: Stanislaus County Policy Regarding Criteria for Agricultural Lands Transactions*) ▪ Public acquisitions and easements on the San Joaquin and Tuolumne Rivers impose no significant economic impacts on Stanislaus County. While there is an adverse effect on the county economy from reduced agricultural

	production, the sum of the positive impacts from channel and habitat restoration, recreational use by residents and visitors, and the value of non-user benefits offset the agricultural income losses (*source: The Economic Impact on Stanislaus County of Public Land Acquisitions and Conservation Easements on Flood plain Lands Along the Lower Tuolumne and San Joaquin Rivers)* ▪ Promote more compact and clearly defined urban boundaries that avoid unnecessary conversion of farmlands (*source: Approve an Update on the Countywide Visioning Statements and Related County Policies*) ▪ Encourage protection of farmland outside the urban boundaries (i.e., continuation of the Williamson Act; discussions with Riverbank and Oakdale about a community separator, that protects farmland beyond urban boundaries) (*source: Approve an Update on the Countywide Visioning Statements and Related County Policies*) ▪ Support the creation of the Stanislaus Farmland Trust (*source: Approve an Update on the Countywide Visioning Statements and Related County Policies*) ▪ **Promote the expansion of other major economic sectors that are compatible with agriculture (s*ource: Approve an Update on the Countywide Visioning Statements and Related County Policies*)** ▪ **Preserve farming, food processing and agricultural business services (*source: Approve an Update on the Countywide Visioning Statements and Related County Policies*)** ▪ Purchase agricultural development rights outside the ultimate sewer service boundary of the city *(source: City of Modesto, Visioning Project 2000)* ▪ Encourage the use of voluntary agricultural land trust methods *(source: City of Modesto, Visioning Project 2000)* ▪ Identify and prioritize farmland/open space areas for preservation as community buffers *(source: City of Modesto, Visioning Project 2000)* ▪ Agricultural Lands Enhancement: Enhance 332,300 acres of privately owned grain fields and 110,800 acres of upland nesting habitat through existing programs, incentive payments to cooperating landowners who conduct land use practices favorable to waterfowl, outreach extension and education programs (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Use information gathered in avian monitoring programs to improve the effects of agricultural and land management techniques on birds (work with agricultural researchers to asses potential of ag adjacent to riparian habitat to be more "bird friendly") (*source: RHJV Riparian Bird Conservation Plan*) **[10]**
✓Riparian Habitat	▪ The NWR will support a variety of native habitats ranging from valley oak gallery and mixed riparian forests/woodlands to seasonal and permanent wetlands, to native grasslands as well as modified habitats (*source: San Joaquin NWR Comprehensive Conservation Plan*) **[1]** ▪ Restore floodplain land along the river to improve channel-floodplain connectivity to allow inundation at a greater frequency, improve regeneration of native riparian species, and improve spawning habitat for Sacramento splittail and rearing habitat for juvenile Chinook salmon and steelhead; remove invasive vegetation; preserve existing riparian vegetation and plant native riparian hardwoods on floodway surfaces appropriate for each species' life history; and provide public education and involvement opportunities in the replanting project; Maintain compatibility with the HRP and NRCS Floodplain Easement Program (*source: River Partners*) **[1]**

	▪ Implement a biotic resources evaluation to identify and preserve rare, threatened, or endangered plant species and support management or wetland and riparian plant communities for passive recreation, groundwater recharge, nutrient catchments and habitat (*source: City of Ceres General Plan*) **[2]** ▪ Develop Phases I-III of the Ceres River Bluff Regional Park to include soccer fields, paths and fencing, parking lots, basketball courts, play areas, restrooms, softball facilities, other formal recreation elements, and pathways and overlooks on this upper-bluff area. Develop Phase IV along the lower terrace to include a natural recreation area with river cleanup, removal of the existing orchard to restore natural riparian habitat, seasonal wetlands constructed as water detention areas, trail systems, overlooks, picnic areas, other native and riparian plantings, and enhanced vehicular access and a parking lot for the non-motorized boating access (*source: Hatch Road Regional Park Master Plan*) **[2]** ▪ Improve Tuolumne River Regional Park by increasing area of native riparian trees (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[2]** ▪ Riverfront vegetation will be maintained to be consistent with riparian habitat zones (*source: City of Modesto General Plan*) **[2]** ▪ Protect and conserve sensitive habitats, restore native riparian plantings, preserve and enhance existing mature trees, encouraged native plantings in landscaping, and remove invasives (*sources: Friends of the Tuolumne, Inc, City of Ceres General Plan, Tuolumne River Regional Park Master Plan*) **[2, 10]** ▪ Protect and restore self-sustaining, dynamic, native riparian habitat and enhance the existing public and private wetlands of the Central Valley *(sources: Habitat Restoration Plan for the Lower Tuolumne River Corridor; AFRP; Central Valley Habitat Joint Venture)* **[10]** ▪ Discretionary projects with potential impacts are to have an oak woodland management plan and for adoption of an ordinance for protection of oak woodlands. *(source: Stanislaus County General Plan)* **[10]** ▪ Adoption of an ordinance for protection of trees with historic significance including heritage trees. *(source: Stanislaus County General Plan)* **[10]** ▪ Discretionary projects adjacent to or within riparian habitat include measures for protecting that habitat and riparian habitat along rivers and natural waterways of the County will to the extent possible be protected. *(source: Stanislaus County General Plan)* **[10]** ▪ Reduce riparian encroachment onto active channel; Reduce grazing impacts to promote riparian regeneration of floodplains (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Restore functional floodplains and native riparian forests (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Create vegetative buffer to reduce soil erosion and filter agricultural runoff (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Areas of sensitive wildlife and plant habitat shall be protected from development (*source: Stanislaus County General Plan*) **[10]** ▪ Preserve vegetation to protect waterways from bank erosion and siltation (*source: Stanislaus County General Plan*) **[10]** ▪ Develop a minimum 500-ft wide riparian corridor and floodway along the entire river that is protected by conservation easements, private ownership, and/or public ownership (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]**

	▪ Preserve remaining valley oak and Fremont cottonwood stands to provide future seed sources (e.g. the valley oak stand at RM 38.1-34.2, valley oak and cottonwood stands at RM 47.3, the cottonwood stand at RM 6.8) (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Reconstruct floodplains and terraces at an elevation inundated by flows exceeding 4,000 cfs to 6,000 cfs (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Incorporate silt importation on floodplain restoration projects wherever possible to improve oil moisture retention and promote natural regeneration (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Reconstruct floodplains and terraces that are topographically variable, to allow some depressions a longer period of saturated soil conditions (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Encourage channel migration at all sites where no human structures are at risk so the channel can construct a contemporary floodplain (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Target Fremont cottonwood and valley oak at riparian restoration projects to replace dying pre-NDPP generations (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Remove exotic plants wherever possible (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Encourage floodplain inundation during flood control releases to deposit fine sediment and saturate floodplain soils (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Increase flood flow magnitude and variability over different water years to create and maintain topographic diversity on bars and floodplains (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ During springtime flood control releases in wetter years, maintain dam ramping rates less than 8cm/day to facilitate cottonwood seedling survival (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Improve management of riparian zones that would encourage natural regeneration (e.g. eliminate grazing, landscaping maintenance in parks, etc.) (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Endangered and other at-risk species and native biotic communities: Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step in establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in SF Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed (*source: CALFED Ecosystem Restoration Plan*) ▪ Ecological processes: Rehabilitate natural processes in the Bay-Delta estuary and its watershed to fully support, with minimal ongoing human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native members of those communities (*source: CALFED Ecosystem Restoration Plan*) ▪ Habitat: Protect and/or restore functional habitat types in the Bay-Delta estuary and its watershed for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics. (*source: CALFED Ecosystem Restoration Plan*)

	▪ Nonnative invasive species: Prevent the establishment of additional nonnative invasive species and reduce the negative ecological and economic impacts of established nonnative species in the Bay-Delta estuary and its watershed. (*source: CALFED Ecosystem Restoration Plan*) ▪ Commitment to a science-based, adaptive management approach to ecosystem restoration (*source: CALFED Ecosystem Restoration Plan*) ▪ Improve watershed management and restore and protect instream and riparian habitat, including consideration of restoring and replenishing spawning gravel and performing an integrated evaluation of biological and geomorphic processes (*source: AFRP Final Restoration Plan*) ▪ Coordinate the AFRP with appropriate activities supported by the Riparian and Recreation Improvement fund that was established by the New Don Pedro Settlement Agreement (*source: AFRP Final Restoration Plan*) ▪ Prioritize riparian sites for protection and restoration according to current avian health, proximity to high quality sites, lands adjacent to upland habitats, presence of intact natural hydrology, surrounding land uses (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Promote riparian ecosystem health (i.e. a self-sustaining functioning system) by ensuring patch size, configuration and connectivity support desired populations and by restoring natural hydrological processes (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Increase the value of ongoing restoration projects for bird species by restoring riparian fprests to promote structural diversity and volume of understory and restoring the width of the riparian corridor (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Ensure that large landscape-scale management and flood control projects maximize benefits to wildlife while benefiting agriculture and urban populations. Achieving multiple goals simultaneously enhances the overall value of such projects to residents (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Design and implement cultivated restoration projects that mimic the diversity and structure of a natural riparian habitat community through planting native species, increasing shrub richness and density, planting early successional species in a mosaic design, retaining some trees, connecting patches of habitat with dense vegetation areas, cultivate shrubs that benefit Central Valley birds and provide valley oak and shrub cover for open-cup nesters. (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Implement and time land management activities to increase avian reproductive success and enhance populations (maintain diverse and vigorous understory and herbaceous layer, create "soft" edges, avoid structures or plantings that attract brown-headed cow birds, influence management at the landscape level, limit restoration activities and disturbance events to non-breeding seasons or minimize its length) (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Protect, enhance or recreate natural riparian processes, particularly hydrology and associated high-water events, to promote the natural cycle of channel movement, sediment deposition, and scouring that create a diverse mosaic of riparian vegetation types (control all nonnative species, manage flows and avoid impacts on the natural hydrology of river channels) (*source: RHJV*

	Riparian Bird Conservation Plan) **[10]**
✓Fish	▪ Support native habitats that support a wide variety of native fish (anadromous fish) (*source: San Joaquin NWR Comprehensive Conservation Plan*) **[1]** ▪ Restore floodplain land along the river to improve channel-floodplain connectivity to allow inundation at a greater frequency, improve regeneration of native riparian species, and improve spawning habitat for Sacramento splittail and rearing habitat for juvenile Chinook salmon and steelhead; remove invasive vegetation; preserve existing riparian vegetation and plant native riparian hardwoods on floodway surfaces appropriate for each species' life history; and provide public education and involvement opportunities in the replanting project; Maintain compatibility with the HRP and NRCS Floodplain Easement Program (*source: River Partners*) **[1]** ▪ Support the California Department of Fish and Game to maintain and enhance the productivity of fisheries in the River (*source: City of Ceres General Plan*) **[2]** ▪ Restore coarse sediment supply and Chinook salmon and O. mykiss spawning gravels to the gravel-bedded reaches below La Grange Dam in a manner that protects existing habitat values for both salmon and O. mykiss (*source: Course Sediment Management Plan*) **[9]** ▪ Introduce coarse sediment to create immediately usable spawning habitat for both Chinook salmon and O. mykiss to supplement existing degraded habitat and/or create new habitat where none currently exists (*source: Course Sediment Management Plan*) **[9]** ▪ Prioritize potential coarse sediment supplies for sediment augmentation, as well as channel/floodplain reconstruction projects, to minimize additional demands on commercial aggregate supplies (*source: Course Sediment Management Plan*) **[9]** ▪ Identify alternative strategies for the environmental compliance process for coarse sediment management and other large-scale restoration projects (*source: Course Sediment Management Plan*) **[9]** ▪ Establish monitoring and adaptive management guidelines for evaluating the long-term coarse sediment management needs and the success of this program in restoring coarse sediment supply equilibrium, geomorphic processes, spawning gravel availability, and spawning habitat quality (*source: Course Sediment Management Plan*) **[9]** ▪ Instream gravel augmentation improvements for spawning and fish rearing habitat; Slough construction, Enforcing fishing regulations (catch and release) (*source: Friends of the Tuolumne, Inc*) **[9]** ▪ Reduce sand input into river and storage in riverbed (especially in spawning gravels); Increase and maintain spawning gravel supply; Restore riffles to increase salmon spawning and rearing habitat; Regrade floodplains to reduce salmon stranding and promote riparian regeneration; Isolate off-channel mining pits to prevent river connection during floods up to 15,000 cfs to reduce salmon stranding and bass predation on juvenile salmon (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[9]** ▪ Spawning (salmon and steelhead) (*source: Central Valley Regional Water Quality Control Board*) **[10]** ▪ Implement measures to improve and increase habitat and populations through eComplete evaluatingion and implementing measures forof spawning, rearing,

	and migration habitat restoration needs *(sources: FERC Settlement Agreement)* **[10]** ▪ Evaluate spawning gravel quality and renovate or supplement gravel supplies to enhance substrate quality and employ actions to reduce predation on juvenile salmon, including actions to reduce or isolate "ponded" sections. *(sources: FERC Settlement Agreement; Habitat Restoration Plan for the Lower Tuolumne River Corridor; CALFED Ecosystem Restoration Program; AFRP)* **[10]** ▪ Restore and improve opportunities to inundate the floodplain on a seasonal basis. *(sources: FERC Settlement Agreement; Habitat Restoration Plan for the Lower Tuolumne River Corridor; CALFED Ecosystem Restoration Program; AFRP)* **[10]** ▪ Increase naturally occurring and naturally reproducing populations (*sources: CALFED Ecosystem Restoration Program; FERC Settlement Agreement*) **[10]** ▪ Increase the naturally occurring salmon population, protect the remaining genetic distinction, and improve salmon habitat through the use of flow and non-flow (habitat rehabilitation and improvement) measures (*source: FERC Settlement Agreement*) **[10]** ▪ AFRP-CVPIA Program objectives include: Improve habitat for all stages of anadromous fish through provision of flows of suitable quality, quantity, and timing, And improved physical habitat; Improve survival rates by reducing or eliminating entrainment of juveniles at diversions; Improve the opportunity for adult fish to reach their spawning habitats in a timely manner; Collect fish population, health, and habitat data to facilitate evaluation of restoration actions; Integrate habitat restoration efforts with harvest and hatchery management and involve partners in the implementation and evaluation of restoration actions (*AFRP-CVPIA Workplan for Fiscal Year 2003*) **[10]** ▪ AFRP-CVPIA objectives for the Central Valley include: Understand salmon and steelhead life history characteristics and population structures in CV streams; Expand distribution of steelhead in CV; Reduce loss of Chinook salmon smolts due to predation; Increase natural production of anadromous fish through educational outreach programs; Insure continued long-term salmonid life history evaluations both within and beyond the CV; Insure continued long-term life history evaluations of green sturgeon both within and beyond the CV; Increase natural production of anadromous fish through improved spawning and rearing habitat quality and quantity; Reduce detrimental effects of introduced fish on anadromous fish (*AFRP-CVPIA Workplan for Fiscal Year 2003*) **[10]** ▪ AFRP-CVPIA objectives specific to the Tuolumne River include: Enhance stream flow for Chinook and steelhead life history requirements to increase natural production of salmonids (Tuolumne river flow supplementation and determine the effectiveness of pulse flows); Provide suitable water temperatures for Chinook salmon and steelhead (temperature monitoring and adjustment); Enhance river management by better understanding life history requirements of Chinook salmon and steelhead (juvenile salmon habitat utilization and ecology and steelhead trout abundance and distribution); Restore proper river function and improve spawning and rearing habitat for anadromous salmonids (Warner-Deardorff, Big Bend, Bobcat Flat restoration); Prevent losses of juvenile fish due to pump diversion intakes (diversion screening); Increase public involvement in river management(stakeholder group development and facilitation to establish a

	"streamwatch" program) (*AFRP-CVPIA Workplan for Fiscal Year 2003*) **[10]** ▪ Integrated restoration and a tributary-scale, ecosystem perspective: link projects in the gravel bed to projects downstream and eventually other parts of fall-run Chinook salmon system with restoration efforts of other rivers (passive or active adaptive management) (*source: Lower Tuolumne River Adaptive Management Forum Report -AFRP*) **[10]** ▪ Study additional experiments that relate to or include: low-flow investigations, riparian vegetations ecology, physical site factors, predation for the SRPs, spawner distribution, nursery habitat-fry retention, gravel augmentation/infusion, and riparian vegetation as fish nursery habitat (*source: Lower Tuolumne River Adaptive Management Forum Report - AFRP*) **[10]** ▪ Focus on restoring natural pattern of periodic disturbance and continual re-growth that creates a mosaic of high quality habitat for many species, including salmon (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Attributes of river integrity: spatially complex channel shape, variable streamflow patterns, frequently disturbed riverbed surface, periodic riverbed scour and fill, balanced fine and course sediment volumes, periodic channel migration and/or avulsion, a functional floodplain, infrequent channel resetting floods, self-sustaining, diverse riparian corridor, naturally fluctuating groundwater table (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Protect fish species by ensuring adequate water flows to support the salmon migration and protecting habitats of rare and endangered fish and wildlife species (*source: Stanislaus County General Plan*) **[10]** ▪ Design and implement in-stream, channel, and floodplain projects with a tributary-scale, ecosystem perspective: Develop conceptual models for the Lower Tuolumne River which integrate the models for the gravel-bedded reach with the models for the sand-bedded reach; Define a project's success in terms of its contribution to overall ecosystem functions at the tributary scale; Determine and identify the metrics of ecosystem response to the Lower Tuolumne River restoration efforts (Adaptive Management Forum Report) ▪ Integrate a monitoring plan into the HRP that defines a monitoring network, sampling methods, or data processing protocol that integrates required monitoring with proposed monitoring: Collect sufficient baseline data to detect change (hydraulic modeling, topographic map of river bottom and overbanks, vegetation map); Stronger commitment to monitoring (include a list of variables, monitor predation at a scale to detect change, expand and improve river-wide monitoring, early collection of adequate information on salmon survival or bass predation rates); Consider monitoring invertebrate production; Avoid monitoring activities that could harm the ecosystem; Develop O&M plans regarding monitoring; Consider multivariate design and analysis; Document failures and lessons learned (Adaptive Management Forum Report) ▪ For project design and implementation, identify gains and losses of river flow and ensure that ecological objectives of restoration projects are adequately captured in the engineering design and are the primary consideration during construction (Adaptive Management Forum Report) ▪ Endangered and other at-risk species and native biotic communities: Achieve

	recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step in establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in SF Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed (*source: CALFED Ecosystem Restoration Plan*) ▪ Harvested species: Maintain and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with other ERP strategic goals (*source: CALFED Ecosystem Restoration Plan*) ▪ Nonnative invasive species: Prevent the establishment of additional nonnative invasive species and reduce the negative ecological and economic impacts of established nonnative species in the Bay-Delta estuary and its watershed. (*source: CALFED Ecosystem Restoration Plan*) ▪ Implement flow schedule as specified in the terms of the FERC proceeding. Supplement these flows with water acquired from willing sellers consistent with applicable guidelines or negotiate agreements as needed to improve condition for all life history stages of Chinook salmon (*source: AFRP Final Restoration Plan*) ▪ Improve watershed management and restore and protect instream and riparian habitat, including consideration of restoring and replenishing spawning gravel and performing an integrated evaluation of biological and geomorphic processes (*source: AFRP Final Restoration Plan*) ▪ Screen all diversions to protect all life history stages of anadramous fish (*source: AFRP Final Restoration Plan*) ▪ Utilize an integrative approach to reestablish critical ecological functions, processes and characteristics tat, under regulated flow and sediment conditions, best promotes recovery and maintenance of a resilient, naturally reproducing salmon population and the river's natural animal and plant communities (*source: AFRP*) ▪ Evaluation: Identify and implement actions to provide suitable water temperatures for all life stages of Chinook salmon; Evaluate and implement actions to reduce predation on juvenile Chinook salmon, including actions to isolate ponded sections of the river; Evaluate the effects of flow fluctuations established by the guidelines of the FERC settlement Agreement on spawning, incubation, and rearing of Chinook salmon, and modify guidelines if adverse effects are indicates; Evaluate fall pulse flows for attraction and passage benefits to Chinook salmon and steelhead; Implement all Central-Valley wide evaluation recommendations as well (*source: AFRP Final Restoration Plan*)
✓Birds	▪ Management emphasis on native wildlife and actions that focus on the recovery of Federal and State listed endangered/threatened species and other species of special concern, protection and/or enhancement of migratory bird resources, as well as serving as part of a riparian corridor for natural resources in the Central Valley (*source: San Joaquin NWR Comprehensive Conservation Plan*) **[1]** ▪ Management priorities will be waterfowl and other waterbirds, in particular the Aleutian Canada goose, and neotropical migratory birds. The NWR will be a key link in the Pacific Flyway (*source: San Joaquin NWR Comprehensive Conservation Plan*) **[1, 10]**

	▪ Restore, acquire, or establish easements for seasonal wetlands and other riparian habitat; Revegetate with native plantings and restore floodplains (*sources: Central Valley Habitat Joint Venture Implementation Plan, Proposed Addition to the San Joaquin National Wildlife Refuge*) **[10]** ▪ Attain key peak population objectives for the Central Valley (4.7M ducks, 865,000 geese & swans), and key breeding populations (490,00 ducks) **[10]** ▪ Increase wetlands area in Central Valley to total of 412,000 acres including acquiring or placing easements on 80,000 acres (acquire 52,500 acres in the San Joaquin Basin out of 67,000 unprotected acres); Enhance wetlands on 291,555 acres in the Central Valley and enhance waterfowl habitat on 443,000 agricultural acres (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Habitat acquisitions: Protect 62,060 acres in the Central Valley through conservation easements. Prioritize habitat with high waterfowl value, wetlands with lower waterfowl use adjacent to restorable wetlands, and wetlands with lower waterfowl use not adjacent to restorable wetlands (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Water and Power: address severe water shortages, initiate legislation to reauthorize CVP to include wildlife as a project purpose (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Wetland Restoration: Restore and protect an additional 112,700 acres of wetlands. 75% through perpetual conservation easements and 25% through fee title acquisition by USFWS ad DFG. (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Expand research and monitoring of selected special-status species to address pressing conservation issues (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Use information gathered in avian monitoring programs to improve the effects of agricultural and land management techniques on birds (work with agricultural researchers to asses potential of ag adjacent to riparian habitat to be more "bird friendly") (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Encourage regulatory and land management agencies to recognize that avian productivity is a prime criterion for determining protected status of specific habitats, mitigation requirements for environmental impacts, and preferred land managed practices (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Increase protection and management actions to benefit severely declining or locally extirpated bird species (through research committees, maping of existing riparian and associated oak woodland habitats) (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Wetland Enhancement: Enhance an additional 291,555 acres through supplemental incentive payments to private landowners, disease control, technical assistance, and coordination with other agencies such as agricultural departments and irrigation districts (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Agricultural Lands Enhancement: Enhance 332,300 acres of privately owned grain fields and 110,800 acres of upland nesting habitat through existing programs, incentive payments to cooperating landowners who conduct land use practices favorable to waterfowl, outreach extension and education programs (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Conduct on-going monitoring and evaluation of habitat and waterfowl

	population objectives(*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Harvested species: Maintains and/or enhance populations of selected species for sustainable commercial and recreational harvest, consistent with other ERP strategic goals (*source: CALFED Ecosystem Restoration Plan*)
✓Mammals (general wildlife habitat)	▪ Conserve, protect, and enhance native communities of the San Joaquin Valley with a focus on wildlife and the ecological processes on which they depend (*source: San Joaquin NWR Comprehensive Conservation Plan*) **[1, 10]** ▪ Establish wildlife corridors and preserve habitat features where possible (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Land acquisition and easements for floodplain restoration and native re-vegetation; Protect and restore habitats to maintain viable fish and wildlife populations (*sources: City of Ceres General Plan, Friends of the Tuolumne, Inc*) **[10]** ▪ Enhance riparian habitat areas (balanced with active restoration) and active management for River's ecological health (*source: Stanislaus County Parks Master Plan*) **[10]** ▪ Restore off-channel wetlands to increase wildlife habitat (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Areas of sensitive, rare, and endangered wildlife and habitat shall be protected from development (*source: Stanislaus County General Plan*) **[10]** ▪ Endangered and other at-risk species and native biotic communities: Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step in establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in SF Bay and the watershed above the estuary; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed (*source: CALFED Ecosystem Restoration Plan*) ▪ Utilize an integrative approach to reestablish critical ecological functions, processes and characteristics tat, under regulated flow and sediment conditions, best promotes recovery and maintenance of a resilient, naturally reproducing salmon population and the river's natural animal and plant communities (*source: AFRP*)
✓Stewardship & Education	▪ The NWR will provide an ideal location for environmental education on native California habitats/wildlife and their conservation/restoration, and will provide the public with excellent wildlife viewing and photographic opportunities as well as offering traditional areas activities such as waterfowl hunting and fishing (*source: San Joaquin NWR Comprehensive Conservation Plan*) **[1]** ▪ Restore floodplain land along the river to improve channel-floodplain connectivity to allow inundation at a greater frequency, improve regeneration of native riparian species, and improve spawning habitat for Sacramento splittail and rearing habitat for juvenile Chinook salmon and steelhead; remove invasive vegetation; preserve existing riparian vegetation and plant native riparian hardwoods on floodway surfaces appropriate for each species' life history; and provide public education and involvement opportunities in the replanting project; Maintain compatibility with the HRP and NRCS Floodplain Easement Program (*source: River Partners*) **[1]** ▪ Emphasize individual and community responsibility for appreciation, protection, and conservation of the River through: scientific studies of the

	river, natural resource education programs, interpretive programs for the entire San Joaquin Basin and the Anadromous fish cycle, community work days, and the production of maps, brochures, and signage; Use ecologically compatible construction materials and adopt ecologically appropriate maintenance practices (*source: Tuolumne River Regional Park Master Plan*) **[2]** ▪ Environmentally sensitive habitat areas shall be protected against any significant disruption, and only uses dependent upon such resources will be allowed (e.g. nature education, research, fishing, and habitat protection) (*source: City of Modesto General Plan*) **[2]** ▪ Habitat sites, burials, and concentration of artifacts will be protected and preserved (*source: City of Modesto General Plan*) **[2]** ▪ Evaluation and monitoring (*sources: Central Valley Regional Water Quality Control Board, Central Valley Habitat Joint Venture Implementation Plan, AFRP, FERC Settlement Agreement*) **[10]** ▪ Continual revision of the Adaptive Management Program, addressing areas of scientific uncertainty that will improve our understanding of river ecosystem processes and refine future restoration and management. *(Source: Habitat Restoration Plan for the Lower Tuolumne River Corridor)* **[10]** ▪ Conduct a detailed annual review to assess progress toward meeting the goals. *(Source: FERC Settlement Agreement)* **[10]** ▪ Establish a "streamwatch" program to increase public participation in river management. *(source: AFRP)* **[10]** ▪ Support an Interpretive Center. *(source: AFRP)* **[10]** ▪ 8 Control illegal harvest and protect habitat through increased enforcement *(source: CALFED Ecosystem Restoration Program)* **[10]** ▪ Use an Adaptive Management Strategy, initially employing feasible measures with a high chance of success. (*sources: FERC Settlement Agreement; CALFED Ecosystem Restoration Program)* **[10]** ▪ Public awareness and involvement in the ecosystem restoration effort (*sources: Habitat Restoration Plan for the Lower Tuolumne River Corridor; CALFED Ecosystem Restoration Program)* **[10]** ▪ Increase access and ADA compliance **[10]** ▪ Encourage more recreational use to protect unique resources (*source: Stanislaus County Parks Master Plan*) **[10]** ▪ Encourage and facilitate easements (*sources: Friends of the Tuolumne, Inc, Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Interpretive centers and trails systems (*sources: cities of Waterford and Ceres, and Stanislaus County*) **[10]** ▪ Improve inter-agency coordination, produce written materials, and develop incentive funds and education for farmers to enhance wetlands (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Enhancements that benefit all existing riparian habitat (multi-purpose) and encourages recreation and access (*source: FERC Settlement Agreement*) **[10]** ▪ Increase public awareness of the Tuolumne and promote cleanup, restoration, and monitoring; Remove trash and debris, eliminate chronic sources of pollution, and actively prohibit illegal dumping (*source: Habitat Restoration Plan for the Lower Tuolumne River Corridor*) **[10]** ▪ Support the preservation of the County's cultural legacy of historical and

	archaeological resources and preserve historic buildings for future generations (e.g. continue to use historic suite zoning at La Grange to protect the historical character) (*source: Stanislaus County General Plan*) **[10]** ▪ Coordinate provision of recreation opportunities with other providers such as the Army Corps of Engineers, State Resource Agency, school districts, river rafters, horse stables, and private organizations such as the Sierra Club and Audubon Society (*source: Stanislaus County General Plan*) **[10]** ▪ Encourage the establishment of voluntary regional government associations of governments for the Central Valley to coordinate planning and development activities of counties and cities *(source: Stanislaus County General Plan Agricultural Element)* **[10]** ▪ Education and interpretation are measured by increasing visitor satisfaction; participant hours in education and interpretation programs; and congruity with educational curricula (*California State Parks Performance Management Report 2004*) **[10]** ▪ Cultural Resource Protection is measured through cataloging, scanning, and documenting objects and photographs; continuing archaeological site assessment, protection, and maintenance; conducting condition assessments of historic buildings and structures; securing appropriate housing for artifacts; conducting the Cultural Stewardship Program; securing land of cultural resources; and increasing visitor satisfaction (*California State Parks Performance Management Report 2004*) **[10]** ▪ Increase public involvement in river management(stakeholder group development and facilitation to establish a "streamwatch" program) (*AFRP-CVPIA Workplan for Fiscal Year 2003*) **[10]** ▪ On-going coordination between ERP and the Science Program, Environmental Justice Subcommittee, Tribal Forum, and other CALFED programs and efforts to ensure plan integration and consistent collaboration. (*source: CALFED Ecosystem Restoration Program*) ▪ Support programs to provide educational outreach and local involvement in restoration, including programs like Salmonids in the Classroom, Aquatic Wild, and Adopt a Watersehd and school district environmental camps (*source: AFRP Final Restoration Plan*) ▪ Develop programs to educate the public about anadramous fish issues, such as the effects of poaching and environmental contaminants, especially contaminants I urban runoff (*source: AFRP Final Restoration Plan*) ▪ Provide additional funding for increased law enforcement to reduce illegal take of anadramous fish, stream alteration, and water pollution and to ensure adequate protection for juvenile fish at pumps and diversions (*source: AFRP Final Restoration Plan*) ▪ Agricultural Lands Enhancement: Enhance 332,300 acres of privately owned grain fields and 110,800 acres of upland nesting habitat through existing programs, incentive payments to cooperating landowners who conduct land use practices favorable to waterfowl, outreach extension and education programs (*source: Central Valley Habitat Joint Venture Implementation Plan*) **[10]** ▪ Provide data on pressing conservation issues affecting birds through targeted and long-term monitoring and research (*source: RHJV Riparian Bird Conservation Plan*) **[10]** ▪ Maximize the effectiveness of ongoing monitoring and management efforts

	through increasing coordination between land managers, and incorporating a monitoring program to assess avian response to riparian habitat restoration into CALFED (*source: RHJV Riparian Bird Conservation Plan*) **[10]**
✓Access	▪ Visual corridors and access points along the Riverfront will be re-created through redevelopment; Public access points and linear footpaths and bike paths will be incorporated into residential development; Development of a Riverfront Greenway trail element identifying access points and interconnection with other pathways as well as operation and maintenance standards and land dedications to guarantee access is permanent (*source: City of Modesto General Plan*) **[2]** ▪ Increase overall access to the river; Comply with ADA standards; Establish bike and pedestrian trail systems, develop connections with neighboring communities, build additional motorized and non-motorized boat access and increase parking and road access where needed for cars and public transit (*sources: all*) **[10]** ▪ Restore riparian environments and preserve river corridors for public access and use, including regional park facilities and trail systems (*source: Stanislaus County Visioning Statements and City of Modesto Visioning Project 2000*) **[10]** ▪ Purchase riparian properties along the Tuolumne River, and the development and/or restoration of existing river accesses (see Capital Improvement Plan) (*source: Stanislaus County Visioning Statements*) **[10]** ▪ Recreation is measured by increasing visitor satisfaction; visitor attendance rates; and accessibility (recreational activities are ADA compliant) (*California State Parks Performance Management Report 2004*) **[10]** ▪ Facilities are measures through increasing visitor satisfaction; documentation of repair and maintenance; and the accessibility of facilities (compliance with ADA) (*California State Parks Performance Management Report 2004*) **[10]**

Appendix D: Summary of Shared Goals, Potential Conflicts and Opportunities From Existing Plans and Reports[1]

Water Supply	
WS-1	Enhance support for innovative means to accommodate diverse water uses. ▪ Commonly proposed approaches focus on water conservation, reclaimed wastewater groundwater management, and conjunctive-use programs.
WS-2	Limited water resources across diverse urban, agricultural, environmental, and recreational needs often lead to competition for resources. ▪ Water management may affect the degree to which a natural functioning river ecosystem is restored to the Lower Tuolumne. ▪ Boating and other recreational opportunities are affected by river flows ▪ Flow and water temperatures influence the status (e.g., health, numbers) of aquatic species.
Water Quality	
WQ-1	Maintain or improve current water quality of the Lower Tuolumne and its tributaries to support human uses and diverse aquatic ecosystems. ▪ Approaches to enhancing water quality include developing and integrating Best Management Practices such as water quality and wastewater planning, monitoring, management of agricultural and urban run-off, and riverbank restoration. ▪ There is widespread support for significant efforts to address dumping of refuse in the river.
WQ-2	Water quality (temperature, dissolved oxygen, cleanliness) may be decreased due to water diversions that decrease flows in the river.
WQ-3	Excessive sedimentation in the river due to land uses and water diversions may be limiting water quality improvement efforts.
WQ-4	Water quality improvement efforts may be inhibited by a lack of coordination across cities and other entities that manage land along the river.

[1] Although the strategies proposed by the Coalition build upon or address these common goals or potential conflicts, the statements included in this table are simply findings. They reflect the wording and approach of existing reports and are not necessarily statements that are endorsed by the Coalition.

Floodplain and Floodwater Management	
FM-1	Manage floodwaters to protect people and developed areas, and enhance habitat through diverse mechanisms. ▪ Flood management approaches include non-structural approaches (utilizing the natural floodplain to accommodate flood waters). ▪ Possible flood management approaches include allowing inundation where it could contribute to the ecological value of the corridor and not threaten people or development. ▪ Filling, dredging, or grading that could increase flood damage can be controlled.
FM-2	Existing land uses will influence floodplain management approaches. ▪ Existing mining practices may intensify flood damage. ▪ Natural floodplain and channel processes may be limited by urban development and other land uses. ▪ Existing or potential development may restrict the use of non-structural approaches to flood damage reduction. ▪ Safety of residential developments must be of primary concern in considering alternative floodplain management approaches. ▪ Some floodplain management approaches may limit habitat restoration opportunities.
Geomorphology	
GM-1	Achieve an active and vegetated floodplain that supports multiple uses and resources.Natural river processes could be achieved through managing coarse sediment supplies and flood management that contributes to the ecological value of the river corridor.
GM-2	Potential competition for finite sediment resources between gravel mining, habitat restoration, natural river processes, and flood management.
GM-3	Upstream water management may limit the potential to achieve naturally functioning processes (such as a balance of coarse and fine sediments.
Riparian Habitat	
RH-1	Protect and conserve riparian habitat. ▪ Native, sensitive, and self-sustaining habitats are prioritized for protection. ▪ Valley oak and Fremont cottonwood stands in particular are identified for protection. ▪ Emphasis is placed on preserving habitat for both ecological and public values.
RH-2	Habitat Restoration Plan Goals to establish a riparian corridor of 500-2,000ft along the Lower Tuolumne and other existing or projected land uses.
RH-3	Habitat restoration could require a multi-pronged approach.

	▪ Adequate flows and managed floods could assist in restoration. ▪ Restoration could include mitigation from neighboring land uses. ▪ Restoration could be assisted, where possible, by widening of the river corridor. ▪ Individual volunteers, especially landowners along the river, could significantly enhance habitat improvements through restoration of their properties.
Terrestrial Species	
TS-1	Enhance the river corridor as a bird habitat for native bird species.
TS-2	Achieve species recovery through habitat restoration efforts.. ▪ Emphasis is placed on protecting wildlife habitat through working with public and private landowners. ▪ The recovery and protection of Federally and State listed endangered, threatened, sensitive and rare wildlife is prioritized.
Aquatic Species	
AS-1	Enhance fisheries, particularly native anadromous fish. ▪ Common goals focus on maintaining or improving overall instream habitat, water quality and river flows that support species recovery.
AS-2	There are simultaneous demands for water for fish species, especially steelhead, and other uses such as irrigation.
AS-3	Broadly share information regarding annual anadromous fish counts to integrate the community into observing and tracking fish species.
AS-4	Examine fisheries projects with an ecosystem perspective. ▪ There is a need to develop complementary and linked fish habitat and riparian habitat restoration efforts. ▪ Upstream and downstream projects should be integrated to the greatest degree possible.
Land Use	
LU-1	Support continued land use controls to help guide growth. ▪ The use of urban boundaries so that the County will grow in a compact and efficient manner is highly supported. ▪ Priority is placed on the continued use of the Williamson Act and other mechanisms such as easements to preserve agricultural lands, to conserve agriculture as open space, and preserve open space itself.

LU-2	Maintain, expand and link open space. ▪ Priority is placed in preserving open space in the floodway. ▪ Open space can provide urban and riparian buffers. ▪ Open space can provide scenic corridors. ▪ Open space provides recreation opportunities. ▪ Open space provides sensitive habitat protection.
LU-3	Preserve Important Farmland (such as prime farmland and farmland of local and statewide importance) from conversion and urbanization.
LU-4	Recognize farm and ranch land as an important component in open space networks of wildlife habitat and scenic corridors.
LU-5	Collaborate and partner with farmers and landowners concerning water quality and supply enhancements as well as habitat restoration and other efforts.
LU-6	There are real and perceived effects of removing crops from production owith regards to individual profitability, the County's economy, and a sense of community identity.
LU-7	Define and balance different types of open space.
LU-8	Define urban and riparian "buffers" and how they function in different roles.

Recreation and Access

RA-1	Enhance human interactions with the river.
RA-2	Develop linked systems of bicycle and pedestrian trails along or near the river on public lands.
RA-3	Support increasing collaborations across agencies to discuss multi-purpose and appropriate recreation opportunities along and near the river.
RA-4	Conduct a region-wide recreation needs assessment.
RA-5	Emphasize the role of non-motorized boat access to the river as an existing and future beneficial use.
RA-6	Support the enhancement of existing river access sites.
RA-7	Manage access to reduce or eliminate potential threats to very sensitive habitats and to private properties, through increased security or other means.
RA-8	Provide recreation and access opportunities to all residents, by complying with ADA regulations and recommendations (public agencies must ensure this at all locations).
RA-9	Enhance the aesthetics and attractiveness of the river by addressing dumping, trespassing, drug use and other illegal activities along the river.
RA-10	Current management practices and land uses have not sufficiently addressed issues of public safety along the river including drug use, trespassing, homeless encampments, and the dumping of refuse.
RA-11	Types of recreation may limit or conflict with each other. ▪ Motorized boating may not be compatible with non-motorized boating and other activities on the river. ▪ Passive and active recreation may compete for limited space and resources.
RA-12	Improve clarity between passive and active recreation. ▪ Plans often call for passive recreation at some locations and active recreation in others.

RA-13	Plan for increased maintenance needs that will be required by enhanced river accesses.
RA-14	Increase opportunities for public access and park patrols to decrease trespass and improve safety.
Stewardship and Education	
SE-1	Support for increasing access to and awareness of the river to increase stewardship. ▪ Stewardship is encouraged through public participation in design workshops, educational venues and classes, volunteerism and frequent access to the river and its multiple values. ▪ Stewardship would be encouraged through the development of interpretive centers and interpretive trails, community monitoring and research projects, and the preservation of the area's archaeological and historical legacy.
SE-2	Provide information to private landowners on the river about stewardship opportunities, including the use of conservation easements.
SE-3	Further develop sites for environmental education along the river and corresponding school outreach programs.
SE-4	Integrate evaluation into the planning and development of projects in the Lower Tuolumne River Parkway as a means for sustaining on-going involvement and stewardship of river-oriented projects.
Upper Reach	
UR-1	Emphasize improving anadromous fish spawning and rearing habitat in the upper (gravel-bedded) reaches. Improving fish habitat can include securing gravel supply, reducing fine sediment influx, adding spawning gravel, and reducing stranding potential.
UR-2	Reduce impacts on water quality and riparian habitat from surrounding land uses. There are common goals to reduce grazing along the banks of the upper reaches and tributaries
UR-3	Proposed active recreation in the upper reaches and recommendations to widen the riparian corridor and reduce land use impacts on habitat restoration may be incompatible. ▪ There may be conflicts between existing grazing along the upper reaches, County plans for an amphitheater, interpretive center, camps, sports field, and trails near La Grange, plans for linked trail systems near Waterford, and Habitat Restoration Plan recommendations to widen the riparian corridor to 500 feet in some areas of the upper reaches.
UR-4	Address and balance the effects of activities in the upper reaches that remove or deposit sediment in ways that may alter the delicate balance of river sediment: aggregate mining, the use of gravel for spawning habitat, land uses in the floodplain, flows allowed, and flood management.
UR-5	Develop additional information on the water quality of the upper reaches.
Urban Reach	
URB-1	Focus on the importance of preserving and/or extending riparian buffers, existing setbacks, and scenic corridors around urban growth and development.

URB-2	Enhance and promote key river access sites near urbanized areas in order to provide access where residents need it most and to preserve other less developed areas as such.
URB-3	Future urban growth and development as well as open space preservation may focus on the river corridor.
URB-4	Existing urban and industrial land uses may limit restoration opportunities.
URB-5	Protect an active and vegetated floodplain that supports multiple uses and accommodates current and expected urban development.
URB-6	Make the most of opportunities for storm-water run-off and reclaimed wastewater programs.
URB-7	Uphold diverse passive and active recreation opportunities that minimize impact on surrounding habitat restoration and water quality.
URB-8	Explore the possibility for economic development opportunities built around parks and open space.
Lower Reach	
LR-1	Maintain land uses in the lower reach as primarily agricultural lands or open space, with minimal public river access sites.
LR-2	Revegetate restored floodplains and terraces along the lower reach.
LR-3	Enhance the role of the San Joaquin River National Wildlife Refuge as a key link in the Pacific Flyway.
LR-4	Restore functional floodplains and off-channel wetlands to increase and support wildlife habitat.
LR-5	Habitat Restoration Plan recommendations to widen the riparian corridor up to 2,000 feet in lower reach areas may conflict with existing agricultural and other private and public uses along the lower reaches.
LR-6	Expand the riparian corridor and wetlands surrounding San Joaquin River National Wildlife Refuge through conservation easements and land acquisition.
Balanced River Management	
BRM-1	Balance diverse efforts (including fish habitat restoration, floodplain restoration, and riparian habitat restoration that may compete for limited water supply, sediment, and other resources.
BRM-2	Explore management of run-off from land uses (grazing, farming, urban) that impact the river and its tributaries.
BRM-3	Engage and encourage diverse voices and interests.
BRM-4	Key land uses to consider in reaching a balance: ▪ Riparian corridor of up to 500-2000 feet in some areas ▪ Passive and active recreation opportunities. ▪ Population growth in Stanislaus County ▪ Reduction of riparian encroachment ▪ Riparian habitat restoration opportunities ▪ Marginality of certain farmland in the floodplain due to frequent flooding
BRM-5	An abundance of opportunities exist along the river, and recent efforts represent a positive movement in enhancing habitat, recreation, and other enhancement of the river corridor.

Information Needs	
IN-1	Comprehensive water quality assessments for the Lower Tuolumne and its tributaries to identify specific pollutants and their sources, as well as barriers to improving water quality.
IN-2	Additional information about the impacts of restoration on urban uses and vice versa, to inform balancing these uses with one another, spatially and temporally.
IN-3	Mapping of current locations of key wildlife species along the river that rely on a riparian corridor (such as river otters, coyotes, and deer) or are Threatened, Endangered, or Species of Concern (such as Riparian Brush Rabbits, San Joaquin Kit Fox, and others).
IN-4	Information regarding the effects of current or projected flows on wildlife and vegetation.
IN-5	Information on feeding, resting, nesting, and roosting patterns in the Lower Tuolumne River floodplain, and how human activities impact these activities.
IN-6	Additional information concerning regional recreation needs, such as through a river-oriented recreation needs assessment survey.
IN-7	Additional evaluation and monitoring of key efforts as outlined in the Habitat Restoration Plan for the Lower Tuolumne River Corridor relating to channel and floodplain morphology. ▪ It is necessary to understand how changes to channel and floodplain morphology impact fish recovery, what the positive and negative effects are from various flows, and to assess ecosystem response in general through on-going monitoring and criteria for success.

Appendix E: Action Plans for River Enhancement Strategies and Implementation Tools[2]

Strategy 1 (S1): Identify Multi-Objective Projects in Urban and Rural Reaches of the River	**Project Lead:** **TBD**	**Partners:** RWQCB; Cities; County; Landowners
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
1.1 Compile case studies and Best Management Practices concerning the co-existence of recreational uses and habitat. Provide specific information on how to enhance and/or restore natural river processes where urban development and river accesses exist, and vice versa.	**M**	**L**
1.2 Develop an outreach program targeted to landowners along the river corridor to learn about landowner concerns and to educate them about natural river processes.	**M**	**L**
1.3 Encourage and facilitate a comprehensive and on-going assessment of water quality in Dry Creek, a major polluter to the urban reaches of the Lower Tuolumne River.	**M**	**L**
1.4 Identify key river access sites in the urban reaches for enhancement and expansion.	**M**	**L**

[2] This action plan provides broad prioritization for the action steps and identifies key partners for each strategy. The priorities do not necessarily reflect the priorities of individual member organizations but those of the Coalition as a whole at this time. The Coalition intends to revisit and amend the strategies, action steps, and prioritizations regularly to update and adapt them as the river, community, and circumstances change.

Strategy 2(S2): Support the Coordination of a Water Quality Monitoring and Enhancement Program	**Project Lead: SWRCB**	**Partners:** RWQCB; San Joaquin River Water Quality Management Group; San Joaquin Basin National Water Quality Assessment Program, Stanislaus County CURES Program. City of Hughson; SJRNWR; ESRCD; Landowners; Local educational institutions
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
2.1 Encourage a comprehensive, on-going assessment of water quality in the Tuolumne and its tributaries.	**H**	**L; On-going**
2.2 Compile and distribute Best Management Practices for water quality enhancement that include: bank protection, riparian restoration and constructed wetlands as filters, and management of run-off from various land uses.	**M**	**L**
2.3 Continue to integrate water reclamation, filter, and riverbank restoration projects in Lower Tuolumne River Parkway projects where possible.	**M**	**L**
2.4 Initiate a tributary restoration program with nearby landowners to manage run-off for Dry Creek.	**M**	**L**
2.5 Spearhead or partner with a stream-watcher program for local volunteers and schools.	**M**	**L**
2.6 Encourage Sewage Treatment plans to complement Lower Tuolumne River Parkway projects.	**M**	**L**

S3: Identify Potential Natural Area and Working Landscapes Projects Along the Lower Tuolumne River	**Project Lead:** **TBD**	**Partners:** CALFED Working Landscapes; NRCS Conservation Security; Cities and County; Landowners
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
3.1 Inventory and map all existing open space areas of the Lower Tuolumne River	**H**	**S**
3.2 Compile and distribute potential criteria for prioritizing open space preservation for the Lower Tuolumne River Corridor	**H**	**S**
3.3 Compile and distribute guidelines for acquisition and maintenance of open space areas	**M**	**L**

S4: Implement Habitat Restoration Projects	**Project Lead:** TID/MID; Tuolumne River Trust; Sierra Club; Friends of the Tuolumne, Inc.,	**Partners:** TRTAC; ESRCD; Landowners; SJRNWR; TID; MID; County
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
4.1 Develop criteria for prioritizing habitat restoration or mitigation opportunities. These could include: ▪ Location (Can this site be linked to other restoration sites? What will the positive and negative effects be on surrounding land uses, recreation and restoration opportunities? What is the habitat type?) ▪ Potential to be a self-sustaining corridor ▪ Availability of public land, potential of acquiring private land, or potential to partner with the existing landowner ▪ Ability to integrate and allow for natural flow and flooding processes ▪ Potential to protect rare, threatened, endangered or otherwise sensitive species or habitat (such as those listed in the riparian inventory of the Habitat Restoration Plan for the Lower Tuolumne River Corridor)	**M**	**L**

4.2 Review and update as needed the identified habitat restoration opportunities from the Restoration Plan ▪ Compile information on potential opportunities for securing off-river gravel sources for gravel augmentation. ▪ Gather Best Management Practices regarding issues such as incorporating restoration into gravel-mining permits and alternative grazing strategies, especially ways to eliminate illegal cattle grazing on County land at La Grange. ▪ Support implementing operation of the Geer Road irrigation water diversion and the Turlock Area Drinking Water Project.	**L**	**L**
4.3 Develop recommendations to reduce potential conflicts with public and private landowners.	**M**	**L**
4.4 Encourage project demonstration sites of natural river processes (e.g., through passive levee breaches) and low-impact design (e.g., alternative bank protection mechanisms) at the San Joaquin River National Wildlife Refuge.	**M**	**L**

S5: Increase Recreation Opportunities	**Project Lead: City of Ceres, TRRP JPA; Stanislaus County Parks and Recreation**	**Partners:**
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
5.1 Support or conduct a region-wide recreation needs survey, focusing on uses of and interest in the river corridor.	**H**	**S**
5.2 Identify areas along the river where additional recreational lands could be acquired in areas least impactful to sensitive habitats.	**H**	**L**

S6: Enhance and Expand Public River Access Points	**Project Lead: City of Ceres, TRRP JPA; Stanislaus County Parks and Recreation**	**Partners:** Fishing and sports groups; Local police: City and County Parks maintenance and security staff; Restorationists; Public landholders
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
6.1 Use public outreach and information strategies (described below in Strategy 8) to help clean, maintain, and promote existing river access sites.	**H**	**S**
6.2 Assess key issues of safety at river access sites and support the implementation of enhanced security and patrols at access sites.	**H**	**L**
6.3 Sponsor or support activities and other community events at existing access sites that highlight recreational opportunities unique to the Lower Tuolumne River Parkway.	**L**	**L**

S7: Provide Information and Support for a Scenic Trailway Area Compatible with Private Interests	**Project Lead: TBD**	**Partners:** Caltrans; Cities; County; Developers; Bicycle and pedestrian advocacy groups; Transit agencies
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
7.1 Support the the planned development of a bike lane along Scenic Highway 132 and potential connections between this bike lane and other trails that lead to the river on public lands.	**M**	**L**
7.2 Identify all existing and potential bicycle and pedestrian paths or trails bordering the Lower Tuolumne River by identifying areas where trails could be linked without negatively impacting sensitive habitat or private property, including through the use of existing public rights-of-way.	**M**	**L**
7.3 Create a trailway map and identify the trailway sections on Lower Tuolumne River Parkway signage (e.g., establish wayfinding signs along bike lanes and pedestrian paths that identify mileage, directions to points of interest, river overlooks, viewpoints, or other sites where visitors interact with the river).	**L**	**L**

S8: Study and Recommend Best Management Practices Regarding the Use of Boats on the Lower Tuolumne	**Project Lead:** TBD	**Partners:** Recreation groups
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
8.1 Evaluate policies regarding watercraft use (e.g., use of motorized or non-motorized craft, speeds allowed) on the Tuolumne and other local rivers and support the implementation of boating laws.	**H**	**S**
8.2 Improve and/or support the development of additional non-motorized access sites to expand the "canoe trail" that does not conflict with private property or sensitive habitats.	**M**	**L**
8.3 Identify all put-in or take-out sites for canoes on Lower Tuolumne River Parkway maps, signs, and guidebooks.	**M**	**S**
8.4 Host fall canoe trips to view spawning salmon and other trips when possible to educate stakeholders about the river, the Coalition and Parkway projects.	**H**	**S; On-going**

S9: Create Lower Tuolumne River Parkway Maps and Signage	**Project Lead: TBD**	**Partners:**
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
9.1 Create a Parkway image and identity program including a common logo and graphics for way-finding signage, and place at key locations.	**M**	**L**
9.2 Develop and distribute a Parkway recreation and use guidebook that highlights: ▪ Parks, paths, trails, public recreation and access areas, overlooks, and public facilities. ▪ Habitat and wildlife information and other significant areas on the river. ▪ Information, if applicable, on how and when private properties can be accessed by the public.	**M**	**L**

S10: Develop a Lower Tuolumne River Parkway Interpretive Program	**Project Lead:** **TBD**	**Partners:** City and County Planning Agencies; Town of La Grange; Department of Fish and Game
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
10.1 Support the development of an interpretive center along the river.	**L**	**L**
10.2 Support interpretive trails in and along the river corridor that link existing and proposed trails, where appropriate, on public lands.	**M**	**L**
10.3 Develop interpretive signage for unique features along the river corridor.	**L**	**L**
10.4 Compile written educational materials that illustrate the important roles of unique and native plant and animal species.	**M**	**L**

S11: Enhance Cleanliness, Safety, and Security for the Users of the Lower Tuolumne River Parkway and Surrounding Communities	**Project Lead:** TBD	**Partners:** City and County Planning Agencies; Town of La Grange; Department of Fish and Game
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
11.1 Develop education and outreach programs in partnership with law enforcement to protect open space areas, habitat, and quality of experience for visitors.	**M**	**L**
11.2 Integrate river clean-ups and adopt-a-river-mile efforts into a Tuolumne River Coalition Volunteer Program (see S12.2, below)	**M**	**L**
11.3 Develop a Lower Tuolumne River Parkway security and patrol program by advocating for increased river policing and developing a community-based monitoring program.	**M**	**L**

S12: Continue Public Outreach and Involvement	**Lead: TBD**	**Partners:** Regional media; CSU-Stanislaus; Great Valley Museum; Local educational and community institutions; Landowners
Potential Strategy Actions	**Priority** (High, Medium, Low)	**Timeline** (Short-term=1-3 years; Long-term=3-10 years)
12.1 Develop education and outreach programs in partnership with, and specifically targeted for, the following groups: ▪ Students and youth groups. ▪ California State University-Stanislaus Biology and other students for research projects. ▪ Community organizations such as the Great Valley Museum to educate the community about the river and its ecology. ▪ Farmers and other landowners.	**M**	**L**
12.2 Structure an on-going Tuolumne River Coalition Volunteer Program that could include a Stream-watcher Program and project monitoring.	**M**	**L**
12.3 Update the public on on-going meetings and community forums through the use of a Tuolumne River Newsletter as well as the Coalition website, brochure, and other outreach materials.	**M**	**L**
12.4 Appeal to print and news media to produce or write public interest pieces concerning the river (e.g., request a slot on the television show "Valley Mosaic" and submit information to the Modesto View website).	**M**	**L**
12.5 Place Coalition projects and efforts on relevant regional and statewide inventories, such as the EPA's Watershed site and the Natural Resource Projects Inventory.	**H**	**S**
12.6 Publish a master map of the Lower Tuolumne River Parkway (with pedestrian trails, bike lanes and paths, the canoe trail, access sites, interpretive centers and trails, and all Coalition projects).	**H**	**S**

Appendix F: Summary of Strategies and Goals or Conflicts Addressed

Strategy[3]	Goals or Conflicts Addressed[4]
S1: Identify Multi-Objective Projects in Urban and Rural Reaches of the River	WS-1; WS-2; FM-2; LU-1; LU-3; LU-4; LU-8; RA-1; RA-6; RA-7; RA-9; RA-10; RA-11; SE-2; SE-1; URB-1; URB-2; URB-3; URB-4; URB-5; URB-6; URB-7; URB-8
S2: Support the Coordination of Water Quality Monitoring and Enhancement Program	WS-1; WS-2; WQ-1; WQ-2; WQ-3; WQ-4; BM-2; IN-1
S3: Identify Potential Natural Area and Working Landscapes Projects Along the Lower Tuolumne River	FM-1; RH-2; LU-1; LU-2; LU-3; LU-4; LU-5; LU-6; LU-7; LU-8; RA-7; RA-9; RA-10; LR-6
S4: Implement Habitat Restoration Projects	GM-1; GM-2; AS-1; AS-2; AS-3; AS-4; LU-4; LU-5; SE-2; UR-1; UR-2; UR-3; UR-4; UR-5; BRM-2; BRM-5; WS-1; WS-2; WQ-1; FM-1; FM-2; TS-1; LU-4; SE-2; SE-3; LR-3; LR-4; LR-5; LR-6; RH-1; RH-2; RH-3; TS-1; TS-2;
S5: Increase Recreation Opportunities	RA-1; RA-4; RA-7; URB-8: SE-1; LU-2; BRM-5
S6: Enhance and Expand Public River Access Points	RA-1; RA-3; RA-6; RA-8; RA-9; RA-10; RA-134; RA-14; SE-1; LU-2; UR-3; URB-3; URB-5; BRM-1; BRM-5
S7: Provide Information and Support for a Scenic Trailway Area Compatible with Private Interests	LU-2; RA-2; RA-3; RA-8; SE-1; BRM-4
S8: Study and Recommend Best Management Practices Regarding the Use of Boats on the Lower Tuolumne	WS-2; RA-1; RA-5; RA-11; SE-1; BRM-5
S9: Create Lower Tuolumne River Parkway Maps and Signage	RA-1; RA-2; RA-3; RA-6; RA-7; RA-8; RA-9; RA-10; SE-1
S10: Develop a Lower Tuolumne River Parkway Interpretive Program	RA-1; RA-5; RA-6; SE-1; SE-3; BRM-5
S11: Enhance Cleanliness, Safety, and Security for the Users of the Lower Tuolumne River Parkway and Surrounding Communities	RA-1; RA-7; RA-9; RA-10; RA-13; RA-14; BRM-5
S12: Continue Public Outreach and Involvement	RH-3; RA-7; RA-9; RA-10; SE-1; SE-2; SE-3; SE-4; BRM-3

[3] See Potential Strategy Actions in Chapter Four for more detail
[4] Refer to Appendix D for a detailed list of all findings

Appendix G: Detailed Species Lists: Species Found in the Lower Tuolumne River Region (A Provisional List)[5]

Note that State or Federal Threatened or Endangered are identified with an asterisk (*) and species of concern with two (**)

Native Plant Species

Trees

- Box Elder
- California Buckeye
- White Alder
- Southern California Walnut
- California Sycamore
- Fremont Cottonwood*
- Blue Oak
- Valley Oak*
- Roble Oak
- Interior Live Oak
- Black Willow
- Red Willow
- Sandbar Willow
- Pacific Willow
- Red Osier Dogwood
- Gray Pine

Shrubs

- Buttonbush
- Bush Lupine
- Narrow-Leaved Willow
- Arroyo Willow
- Dusky Willow
- Blue Elderberry

[5] Habitat Restoration Plan for the Lower Tuolumne River Corridor; TRRP Master Plan; TID Special Run Pool Mitigated Negative Declaration; USFWS Working Paper on Restoration Needs; Stanislaus Audubon

- Poison Oak
- California Coffeeberry
- California Rose
- Coyote Brush

Vines

- California Grape
- Coyote Melon
- California Blackberry

Herbs and Grasses

- Black Cap Raspberry
- Mugwort
- Mule fat
- Seep willow
- Water wally
- Rattlesnake Spurge
- Jimson Weed
- Willow Herb
- Goose Grass
- Everlasting
- Sun Flower
- Blazing Star
- Monkey Flower
- Waterpepper
- Hoary Nettle
- Common Cocklebur
- Turkey Mullien
- Evening Primrose
- California Sweetcicely
- Common Plantain
- Nightshade
- Mullien
- American Vetch

- Hornwort
- Common coon s tail
- Spike Rush
- Common Waterweed
- Duckweed
- Water Primrose
- Western Milfoil
- Tule
- Broad-Leaved Cattail
- Blue wildrye
- Creeping wildrye
- Meadow barley
- Basket sedge
- Dogbane
- Gumplant
- Deergrass
- Purple needlegrass
- Squirreltail

Ferns

- California Maidenhair fern
- Spike Moss
- Golden Backed Fern
- Giant Chain Fern
- Common Horsetail

Parasites

- Dodder
- Poplar Mistletoe

Non-Native Plant Species

Trees

- Tree of Heaven
- Red Gum,
- River Red Gum
- Gum Tree
- Persian or English Walnut
- Fruitless Mulberry
- Foothill Pine
- Black Locust
- Weeping Willow
- Tamarisk
- Silver Maple
- Catalpa
- American Elm

Shrubs

- Edible Fig
- Tree Tobacco

Vines

- Bindweed
- Orchard Morning Glory

Herbs

- Himalayan Berry
- Yellow Star Thistle
- Pig weed
- Lambs Quarters
- Pokeweed
- Pokeberry
- Pigeon Berry
- Plantain
- Curly Dock
- Black Mustard
- Poison Hemlock
- White Sweet Clover
- Yellow Sweet Clover
- Oxallis
- Castor Bean
- Moth Mullien
- Brazilian Waterweed
- Parrots Feather
- Crispate-Leaved Pondweed

Aquatic Plants

- Hydrilla
- Water Hyacinth

Grasses

- Giant Reed
- Wild Oat
- Cheat Grass
- Bermuda Grass
- Beard Grass

Wildlife Species

Fish

- Central Valley Steelhead*
- Fall-run Chinook Salmon*
- Kern Brook Lamprey**
- Hardhead**
- Pacific Lamprey**
- River Lamprey
- Sacramento Splittail**

Invertebrates

- California Linderiella
- Valley Elderberry Longhorn Beetle*
- Moestan Blister Beetle
- Redheaded Sphecid Wasp

Amphibians

- California Tiger Salamander*
- Western Spadefoot
- California Red-legged Frog*
- Foothill Yellow-legged Frog

Reptiles

- Western Pond Turtle**
- California Horned Lizard
- Silvery Legless Lizard
- Giant Garter Snake*
- Western Whip Tail

Birds

Ducks, Geese & Swans:

- Greater White-fronted Goose
- Snow Goose
- Ross's Goose
- Canada Goose
- Cackling Goose
- Aleutian cackling goose**
- Tundra Swan
- Wood Duck
- Gadwall
- Eurasian Wigeon
- American Wigeon
- Mallard
- Blue-winged Teal
- Cinnamon Teal
- Northern Shoveler
- Northern Pintail
- Green-winged Teal
- Canvasback
- Redhead
- Ring-necked Duck
- Greater Scaup
- Lesser Scaup
- Long-tailed Duck
- Bufflehead
- Common Goldeneye
- Hooded Merganser
- Common Merganser
- Ruddy Duck

Pheasants and Turkeys:

- Ring-necked Pheasant -I
- Wild Turkey - I

New World Quail:

- California Quail

Loons:

- Common Loon

Grebes:

- Pied-billed Grebe
- Horned Grebe
- Eared Grebe
- Western Grebe
- Clark's Grebe

Pelicans:

- American White Pelican**

Cormorants:

- Double-crested Cormorant**

Herons, Bitterns, and Allies:

- American Bittern
- Great Blue Heron
- Great Egret
- Snowy Egret*
- Cattle Egret
- Green Heron
- Black-crowned Night-Heron

Ibises:

- White-faced Ibis**

New World Vultures:

- Turkey Vulture

Hawks, Kites, Eagles, and Allies:

- Osprey**
- White-tailed Kite
- Bald Eagle*
- Northern Harrier**
- Sharp-shinned Hawk
- Cooper's Hawk**
- Red-shouldered Hawk
- Swainson's Hawk*
- Red-tailed Hawk
- Ferruginous Hawk**
- Rough-legged Hawk
- Golden Eagle**

Faclons:

- American Kestrel
- Merlin
- Peregrine Falcon*
- Prairie Falcon**

Rails, Galllinules, and Coots:

- Virginia Rail
- Sora
- Common Moorhen
- American Coot

Cranes:

- Sandhill Crane*

Lapwings and Plovers:

- Black-bellied Plover
- Snowy Plover*
- Semipalmated Plover
- Killdeer
- Mountain Plover

Stilts and Avocets:

- Black-necked Stilt
- American Avocet

Sandpipers, Phalaropes, and Allies:

- Greater Yellowlegs
- Lesser Yellowlegs
- Willet
- Spotted Sandpiper
- Whimbrel
- Long-billed Curlew
- Marbled Godwit
- Sanderling
- Western Sandpiper
- Least Sandpiper
- Baird's Sandpiper
- Pectoral Sandpiper
- Dunlin
- Short-billed Dowitcher
- Long-billed Dowitcher
- Wilson's Snipe
- Wilson's Phalarope

Gulls and Terns:

- Bonaparte's Gull
- Mew Gull
- Ring-billed Gull
- California Gull
- Herring Gull
- Thayer's Gull
- Glaucous-winged Gull
- Caspian Tern**
- Forster's Tern**

Pigeons and Doves:

- Rock Pigeon - I
- Band-tailed Pigeon
- Mourning Dove

Barn and Typical Owls:

- Barn Owl
- Western Screech-Owl
- Great Horned Owl
- Northern Pygmy-Owl
- Burrowing Owl**
- Long-eared Owl**
- Short-eared Owl**

Goatsuckers:

- Lesser Nighthawk

Swifts:

- Vaux's Swift
- White-throated Swift

Hummingbirds:

- Black-chinned Hummingbird
- Anna's Hummingbird
- Costa's Hummingbird
- Rufous Hummingbird

Kingfishers:

- Belted Kingfisher

Woodpeckers and Allies:

- Lewis's Woodpecker
- Acorn Woodpecker
- Red-breasted Sapsucker
- Nuttall's Woodpecker
- Downy Woodpecker

Tyrant Flycatchers:

- Northern Flicker

- Olive-sided Flycatcher
- Western Wood-Pewee
- Willow Flycatcher
- Pacific-slope Flycatcher
- Black Phoebe
- Say's Phoebe
- Ash-throated Flycatcher
- Western Kingbird

Shrikes:

- Loggerhead Shrike**

Vireos:

- Cassin's Vireo
- Hutton's Vireo
- Warbling Vireo

Crows and Jays:

- Steller's Jay
- Western Scrub-Jay
- Yellow-billed Magpie
- American Crow
- Common Raven

Larks:

- Horned Lark

Swallows:

- Tree Swallow
- Violet-green Swallow
- N. Rough-wingd Swallow
- Bank Swallow
- Cliff Swallow
- Barn Swallow

Chickadees and Titmice:

- Oak Titmouse

Bushtits:

- Bushtit

Nuthatches:

- Red-breasted Nuthatch
- White-breasted Nuthatch

Creeper:

- Brown Creeper

Wrens:

- Rock Wren
- Canyon Wren
- Bewick's Wren
- House Wren
- Winter Wren
- Marsh Wren

Dippers:

- American Dipper

Kinglets:

- Golden-crowned Kinglet
- Ruby-crowned Kinglet

Gnatcatchers:

- Blue-gray Gnatcatcher

Thrushes:

- Western Bluebird
- Mountain Bluebird
- Townsend's Solitaire
- Swainson's Thrush

- Hermit Thrush
- American Robin
- Varied Thrush

Babblers and Wrentit:

- Wrentit

Mockingbirds and Thrashers:

- Northern Mockingbird
- California Thrasher

Starlings:

- European Starling - I

Pipits:

- American Pipit

Waxwings:

- Cedar Waxwing

Silky-flycathers:

- Phainopepla

Wood-warblers:

- Orange-crowned Warbler
- Nashville Warbler
- Yellow Warbler**
- Yellow-rumped Warbler
- Black-throated Gray Warbler
- Townsend's Warbler
- Hermit Warbler
- MacGillivray's Warbler
- Common Yellowthroat**
- Wilson's Warbler
- Yellow-breasted Chat**

Tanagers:

- Summer Tanager
- Western Tanager

Towhees, Sparrows, and Allies:

- Spotted Towhee
- California Towhee
- Rufous-crowned Sparrow
- Chipping Sparrow
- Vesper Sparrow
- Lark Sparrow
- Sage Sparrow
- Lark Bunting
- Savannah Sparrow
- Fox Sparrow
- Song Sparrow**
- Lincoln's Sparrow
- White-throated Sparrow
- White-crowned Sparrow
- Golden-crowned Sparrow
- Dark-eyed Junco

Grosbeaks and Buntings:

- Black-headed Grosbeak**
- Blue Grosbeak**
- Lazuli Bunting

Blackbirds, Orioles, and Allies:

- Red-winged Blackbird
- Tricolored Blackbird**
- Western Meadowlark
- Yellow-headed Blackbird
- Brewer's Blackbird
- Great-tailed Grackle
- Brown-headed Cowbird

- Hooded Oriole
- Bullock's Oriole

Finches and Allies:

- Purple Finch
- House Finch
- Red Crossbill
- Pine Siskin
- Lesser Goldfinch
- Lawrence's Goldfinch
- American Goldfinch

Old World Sparrows:

- House Sparrow –

Mammals

- Myotis (Long-eared, Fringed, Long-legged and small-footed)
- Townsend's Western Big-eared Bat
- Pallid Bat
- California Mastiff Bat
- Beaver
- River Otter
- Mink
- Long-tailed Weasel
- Striped Skunk
- Raccoon
- Riparian Brush Rabbit
- Desert Cottontail
- Black-tailed Hare
- San Joaquin Pocket Mouse**
- San Joaquin Valley Woodrat*
- San Joaquin Kit Fox*
- Coyote
- Deer (Mule and Black-tailed)
- Mountain Lion
- Bobcat

Tuolumne River Coalition

Tuolumne River Coalition
Project Funding Matrix

● = Primary Plan Element or Opportunity
◐ = Secondary Plan Element or Opportunity
○ = Potential Element or Opportunity

STAKEHOLDER PROJECTS				PLAN ELEMENTS									PROJECT STATUS	PROJECT COSTS	FUNDING
PROJECT INFORMATION															
	Project Name	Project Description	Primary Project Coordinator & Funding Partners	Flood Damage Reduction	Land Acquisition	Habitat	Water Supply	Water Quality	Education	Recreation	Open Space	Land Reclamation/ Economic Dev't		(Estimated Land Acquisition; Predevelopment and Planning; Design & Construction; TOTAL Costs)	(Amount Committed; Funding Gap; Potential Funding Gap Sources)
1	San Joaquin River National Wildlife Refuge **Reach 1** **River mile 0-1**	12,887-acre refuge established to support endangered and threatened species; protect wetland habitat for migratory shorebirds, waterfowl, herons, waterbirds, and other species; and to provide winter forage habitat for Aleutian Canada geese and sandhill cranes. Project includes modifying existing flood control levees, restoring historic floodplains, and restoring wetlands and riparian forest. Currently, there is approximately 3,272 acres within the approved Refuge boundary left to acquire. NWR also plans on constructing additional public use facilities that would include enhanced access and interpretive signage.	U.S. Fish & Wildlife Service, Kim Forrest (209) 826-3508	◐	●	●	○	○	◐	◐	◐		§ Acquisition § Restoration Planning § Restoration Implementation	**Land Acquisition:** $60M Restoration: $11M **Predevelopment & Planning:** $4.5M (including AFRP hydraulic modeling for non-structural alternative at the SJRNWR and refinement of habitat enhancement) **Design & Construction:** $2.5M U.S.ACOE non-structural alternative **Public Use Facilities:** $700,000 **Total Cost:**$78.7M	**Committed:** CALFED ($16.7M riparian and brush rabbit habitat acquisition and restoration); The Resources Agency/Proposition 13 ($5M land acquisition), DWR/Flood Protection Program ($1.7M for 511-acre habitat restoration project with River Partners); USFWS Migratory Bird Conservation Fund ($9.7M); NRCS/Federal Flood Emergency Appropriations ($11.6M); Private funds; USFWS/Anadromous Fish Restoration Program ($0.5M); USACOE ($2.5M); Land & Water Conservation Fund ($6.3M). **Funding Gap:** $20M (land acquisition), $4M (restoration) and $700,000 (Public use facilities) **Potential Funding Gap Sources:** CALFED, State proposition funding, MBCF, LWCF
2	Dos Rios Conservation Easements **Reach 1** **River miles 0-3**	The Dos Rios project is a working landscape, floodplain protection, and riparian restoration project located along the Tuolumne and San Joaquin Rivers. The project will have direct benefits to the critically endangered riparian brush rabbit by developing riparian brush rabbit habitat and establishing a brush rabbit colony within the riparian corridor on the property. Through purchase of perpetual habitat and agricultural conservation easements, we expect to increase the riparian zone up to 1000 feet wide, restrict development of the properties, including dairies, orchards, and vineyards, and confined animal facilities while protecting other agricultural uses of the land in perpetuity. Long-term management will incorporate adaptive management and monitoring and best management practices to ensure long-term success of habitat restoration.	Tuolumne River Trust, Patrick Koepele (209) 236-0330	●	●	●			○		●		§ Acquisition	**Land Acquisition**: $9M **Predevelopment & Planning**:$500,000 **Design & Construction**: $3,000,000 **Total Cost**: $12,500,000	**Committed**: $0 **Funding Gap**: $9M **Potential Funding Gap Sources:** Land and Water Conservation Fund; Farm Bill (various)
3	Shilo Fishing Access **Reach 1** **River mile** 3.7	Provides river facilities with opportunities for boating, places for passive recreation, picnic, informal play, and overnight camping.	Stanislaus County Department of Parks & Recreation, Terri Sanders (209) 525-6771		●					●	●		§ In Master Plan	**Land Acquisition**: **Predevelopment & Planning**: **Design & Construction**: **Total Cost**: $45,764	**Committed**: **$0** **Funding Gap**: $45,764 **Potential Funding Gap Sources:**

STAKEHOLDER PROJECTS				PLAN ELEMENTS									PROJECT STATUS	PROJECT COSTS	FUNDING
PROJECT INFORMATION															
	Project Name	Project Description	Primary Project Coordinator & Funding Partners	Flood Damage Reduction	Land Acquisition	Habitat	Water Supply	Water Quality	Education	Recreation	Open Space	Land Reclamation/ Economic Dev't		(Estimated Land Acquisition; Predevelopment and Planning; Design & Construction; TOTAL Costs)	(Amount Committed; Funding Gap; Potential Funding Gap Sources)
4	Bancroft-Ott **Reach 1** **River mile 4**	NRCS floodplain easement on the Bancroft-Ott property northeast of the Shiloh Bridge. The project will include active floodplain and habitat restoration activities.	East Stanislaus Resource Conservation District, Martin Reyes (209) 605-4079	●	●	●		●						**Land Acquisition**: **Predevelopment & Planning**: **Design & Construction**: **Total Cost**:	**Committed**: Funded by NRCS **Funding Gap**: None **Potential Funding Gap Sources:**
5	Grayson River Ranch **Reach 1** **River mile 5.5**	This is a one-mile long floodplain restoration project on 140 acres downstream near the Tuolumne River confluence with the San Joaquin. Project wide floodplain contouring and extensive native planting have been completed and maintenance and monitoring will continue for several years.	Friends of the Tuolumne, Inc, Allison Boucher (209) 477-9033; CALFED, AFRP, NRCS, SFPUC	●	●	●		◐			●	○	§ Completed (On-going maintenance)	**Land Acquisition**: $377,200 AFRP (acquisition & restoration) **Predevelopment & Planning**: **Design & Construction**: $332,000 CALFED (restoration) and $24,000 NRCS (restoration) **Total Cost**: $1.5M	**Committed**: AFRP, CALFED, NRCS, FERC Settlement **Funding Gap**: On going O&M **Potential Funding Gap Sources:**
6	Big Bend Floodplain Protection and Restoration Project **Reach 1** **River miles 6-7; 250 acres**	The first phase of the project protected flood-prone land of Tuolumne River floodplain west of Modesto through a combination of fee title and conservation easement acquisitions. During the second phase of the project, riparian and floodplain habitat at the project site will be restored. Restoration activities include earthwork to encourage natural floodplain function and planting native vegetation to restore the riparian forest on approximately 254 acres of river bottom.	Tuolumne River Trust, Patrick Koepele (209) 236-0330; CA Dept. of Water Resources, UDSA – Natural Resources Conservation Service, East Stanislaus Resource Conservation	●	●	●		◐	●		●		§ Implementation (revegetation)	**Land Acquisition**: 250 acres **Predevelopment & Planning**: Current phase; Funding from (DWR) Prop 13, NRCS, ESRCD/SFPUC FERC Settlement, and NOAA Community Restoration Program **Design & Construction**: **Total Cost**: $2,928,519	**Committed**: $2,378,519, (some from SFPUC FERC Settlement) **Funding Gap**: $734,700 for Phase II **Potential Funding Gap Sources:** for Revegetation - amount TBD
7	Riverdale Park **Reach 2** **River mile 12-13**	Improvement plans for this currently unimproved 5 acre park include amenities for both regional use as well as neighborhood-type facilities for the surrounding unincorporated community. Near Parkdale Drive are proposed picnic facilities, children's play equipment, an informal play area, as well as security lighting, restrooms, and a small parking area. The river-oriented put-in facilities are aimed at non-motorized or car-top boats.	Stanislaus County Department of Parks & Recreation, David Piper (209) 525-6768; SFPUC							●	●		§ Design phase beginning § Grants paperwork 25% completed	**Land Acquisition**: **Predevelopment & Planning**: **Design & Construction**: **Total Cost**: $282,500	**Committed**: Fully funded. Prop 12; Per capita funds from Prop 13 or 40; FERC settlement (FOTT, INC), 40 Riverway Grant **Funding Gap**: **Potential Funding Gap Sources:**

STAKEHOLDER PROJECTS				PLAN ELEMENTS									PROJECT STATUS	PROJECT COSTS	FUNDING
PROJECT INFORMATION															
	Project Name	Project Description	Primary Project Coordinator & Funding Partners	Flood Damage Reduction	Land Acquisition	Habitat	Water Supply	Water Quality	Education	Recreation	Open Space	Land Reclamation/ Economic Dev't		(Estimated Land Acquisition; Predevelopment and Planning; Design & Construction; TOTAL Costs)	(Amount Committed; Funding Gap; Potential Funding Gap Sources)
8	Tuolumne River Regional Park **Reach 2** **River miles 12.4-19.3**	The Tuolumne River Regional Park Gateway Parcel is located adjacent to the Modesto and Ceres Downtowns. It creates a greenspace through the heart of these growing urbanized communities. The intent of the design to create a place where people can enjoy the Tuolumne River, gain access to it's multple benefits, gather for community events, operate educational venues, and attract regional interest to the park. By virtue of it's location under Highway 99, the Seventh Street and Ninth Street Bridges, this Parcel is highly visible. The intent of the design is to enhance the river corridor, improve circulation, improve recreational opportunities, improve water quality, create a connection between the urban and river environments. The FY 05-06 funding request is for Phase I of the Gateway Precise Plan Development. Phase I will include Site Preparation, Grading and Drainage, Irrigation System and Planting for the entire site. Included is the restoration work on the Tuolumne and Dry Creek areas.	City of Modesto, Doug Critchfied (209) 577-5353	●	●	●		●		●	●		§ Construction § Restoration Planning § Restoration Implementation	**Land Acquisition:** **Predevelopment & Planning:** **Design & Construction:** **Total Cost:** $7,500,000	**Committed**: $1,140,000 from Proposition 40 line item funds, $420,600 annually from the JPA (Ceres, Modesto, Stanislaus); $70,900 annually from revenue-generating facilities and grants **Total -** $7.5 m **Funding Gap**: $6M **Potential Funding Gap Sources:** Cities of Modesto, Ceres; Stanislaus County; Prop 50 Funds; Grants and private donations (Pakard Foundation, GVC - LEGACI Grants); User fee and Development Impact revenues; General Obligation Bond; Land and Water Conservation Fund; Recreational Trails Program (through FHWA/CA Department of Parks and Recreation); Habitat Conservation Fund; California Riparian Habitat Conservation Program (WCB); TEA 21 Grants; Solid Waste Disposal and Cidisposal Site Cleanup Program;
9a	Ceres River Bluff Regional Park **Reach 3** **River mile 20**	Parkway expansion: Future acquisition of neighboring properties	City of Ceres, Doug Lemcke (209)538-5650		●	●			●	●				**Land Acquisition**: **Predevelopment & Planning**: **Design & Construction**: Total Cost: $18 m	**Committed**: $1 million Ceres Redevelopment, $.55 TEA-Trans, State Prop12/40 $.750 Funding Gap: $8.5 m **Potential Funding Gap Sources:** Land and Water Conserve Fund-Federal
9b	Ceres River Bluff Regional Park **Reach 3** **River mile 20**	The lower 38 acres is in a floodplain next to the River and contains outlets for stormwater, as well as a wetlands area and biking and hiking trails.	City of Ceres, Doug Lemcke (209)538-5649		●	●			●		●		§ Partial Design of Lower 38 acres	**Land Acquisition**: $300,000 **Predevelopment & Planning**: $720,000 (Prop 40- includes partial construction); **Design & Construction**: $1,000,000 **Total Cost**: $2,020,000	**Committed**:$300,000 (Ceres Redevelopment); $720,000 from Prop 40 **Funding Gap**:$1,000,000 **Potential Funding Gap Sources:**
9c	Ceres River Bluff Regional Park **Reach 3** **River mile 20**	Recreational sports facilities on the upper 38 acres.	City of Ceres, Doug Lemcke (209)538-5648		●					●			§ Design	**Land Acquisition**:$650,000 (Master Planning) **Predevelopment & Planning**: **Design & Construction**:$1.08M (developer fees); $800,000 (construction) **Total Cost**: $7.4M	**Committed**:$1.0M **Funding Gap**: $6.4M **Potential Funding Gap Sources:** ~$1.4M from the County; Future park development fees; grants, bonds, private donations
10	Special Run Pool 10 **Reach 4** **River mile 25.3**	SRP 10 has the potential to add river access and parklands as an extension of the County owned Geer Road Landfill site.	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8317; CALFED, AFRP		●	●	●			●	●		§ In Design	**Land Acquisition**: $1,200.000 **Predevelopment & Planning**: $543,000 **Total Cost**: $4,593,000	**Committed**: SRP 10 funded to date $543,530 (for Phase 1:design, permits, appraisals, & monitoring); CALFED administered by NFWF **Funding Gap**: $4,200,000 (Phase II - $1.4M for Land Acquisition and $2.8M for construction/revegetation) **Potential Funding Gap Sources:**
11	Special Run Pool 9 **Reach 4** **River mile 25.8**	Large-scale restoration projects adjacent to Fox Grove Park designed to enhance fall run Chinook salmonid habitat. SRP 9 became an extension of the Fox Grove Park.	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8317; CALFED,			●	●			●	●	●	§ Completed-no Request Form	**Land Acquisition**: **Predevelopment & Planning**: $388,000 **Design & Construction**: $2,353,000 **Total Cost**: $2,741,000	**Committed**: FERC Settlement; MID/TID **Funding Gap**: None **Potential Funding Gap Sources:**CALFED/AFRP; FERC Settlement; Drainage Assessment

STAKEHOLDER PROJECTS				PLAN ELEMENTS									PROJECT STATUS	PROJECT COSTS	FUNDING
PROJECT INFORMATION															
	Project Name	Project Description	Primary Project Coordinator & Funding Partners	Flood Damage Reduction	Land Acquisition	Habitat	Water Supply	Water Quality	Education	Recreation	Open Space	Land Reclamation/ Economic Dev't		(Estimated Land Acquisition; Predevelopment and Planning; Design & Construction; TOTAL Costs)	(Amount Committed; Funding Gap; Potential Funding Gap Sources)
12	Foxgrove County Park **Reach 4** **River mile 26**	64-acre site located on the Tuolumne River. It is the largest and most developed river access point with an existing boat ramp, parking areas, restrooms, and picnic facilities. Proposed improvements include upgrade of many of these facilities.	Stanislaus County Department of Parks & Recreation, David Piper		●	○			○	●	●		§ In Master Plan	**Land Acquisition**: $4.1 m **Predevelopment & Planning**: **Design & Construction**: $.750 **Total Cost**:$5.4 m These estimates are for all Stanislaus County New River Accesses @ Fox Grove, Riverdale, Basso Bridge, La Grange Shiloh Appling Way	**Committed**: **$ .282 Prop 40, RCD,** **Funding Gap**: $4.9 million **Potential Funding Gap Sources:**
13	Waterford Percolation Pond Restoration **Reach 4** **River mile 31.5**	Two-phase planting and maintenance along the lower and upper part of this parcel.	City of Waterford, Chuck Deschenes (209) 874-2331; Friends of the Tuolumne, Inc, Allison Boucher (209) 477-9033		●	●			●	●	●		§ Looking for additional funding	**Land Acquisition:** **Predevelopment & Planning:** **Design & Construction:** $205,000 (planting & maintenance, first 2 years); $20,000 (This is designed to be a 5 to 10 year project.) **Needed 04/05 Funding**: $35,000. Estimates may be revised in future years. **Total Cost:**$225,000	**Committed:** $8,000 (Friends of the Tuolumne, Inc) **Funding Gap:** $8,000 (lower parcel) **Potential Funding Gap Sources:**
14	Waterford Urban River Park Acquisitions **Reach 4** **River miles 31-32**		City of Waterford, Chuck Deschenes (209) 874-2328; SFPUC		●			●		●	●			**Land Acquisition:** **Predevelopment & Planning:** **Design & Construction:** **Total Cost:** $14.3 m for Acquisitions and Improvements for all Waterford Projects. Multi-year-per Waterford TRC Request Form (s) State and Fed Combined	**Committed**: State $.625 m, Local $.580 million (some from FERC Settlement) Total $1.2 m **Funding Gap**: **$13.1 m** **Potential Funding Gap Sources:** State $4.8 Fed: $4.7
	Big Bear Park Parcel: Public access, open space, and passive use along the river near river mile 31.95.		City of Waterford, Chuck Deschenes (209) 874-2329		●				●	●	●	●	§ In negotiation	**Land Acquisition:** **Predevelopment & Planning:** **Design & Construction:** **Total Cost:** $150,000	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**
	Caro Parcel: Boat ramp, restrooms, picnic tables as well as road access, trail improvements, and parking improvements near river mile 31.7.		City of Waterford, Chuck Deschenes (209) 874-2330		●				●	●	●	●	§ Parcel in escrow (hope to close at end of year)	**Land Acquisition:** $290,000 **Predevelopment & Planning:** **Design & Construction:** $30,000 (plus additional funds) **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:** Prop 40; FERC Settlement
	Lambert Parcel: Extensive restoration with improved trail, access, and parking near Riverdale 31.65.		City of Waterford, Chuck Deschenes (209) 874-2331		●	●			●	●	●	●	§ In negotiation	**Land Acquisition:** $550,000 -$600,000 (?) **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**
	Lucinda Rae Parcel #1: 7 acres with Wastewater Treatment Plant facilities and open space. Upper area could include restoration and trail improvements. Near river mile 30.9. .		City of Waterford, Chuck Deschenes (209) 874-2332		●	●			●	●	●	●	§ In negotiation	**Land Acquisition:** $300,000 **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**
	Matroni Parcel: Open space and passive use parkland Possible restoration and trail improvements. Near river mile 30.75..		City of Waterford, Chuck Deschenes (209) 874-2333		●	●			●	●	●	●	§ In negotiation	**Land Acquisition:** $100,000 **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**
	Lucinda Rae Parcel #2: Restoration and trail improvements near river mile 30.65.		City of Waterford, Chuck Deschenes (209) 874-2334		●	●			●	●	●	●	§ In negotiation	**Land Acquisition:** $200,000 (?) **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**
	Appling Road ROW: Pedestrian, equestrian, and bicycle access along the old road near river mile 31.72..		City of Waterford, Chuck Deschenes (209) 874-2335							●		●		**Land Acquisition:** **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**

STAKEHOLDER PROJECTS				PLAN ELEMENTS									PROJECT STATUS	PROJECT COSTS	FUNDING
PROJECT INFORMATION															
	Project Name	Project Description	Primary Project Coordinator & Funding Partners	Flood Damage Reduction	Land Acquisition	Habitat	Water Supply	Water Quality	Education	Recreation	Open Space	Land Reclamation/ Economic Dev't		(Estimated Land Acquisition; Predevelopment and Planning; Design & Construction; TOTAL Costs)	(Amount Committed; Funding Gap; Potential Funding Gap Sources)
	Balkey Property: Possible trail construction in conjunction with residential development.		City of Waterford, Chuck Deschenes (209) 874-2336		●				●	●	●	●	§ In negotiation	**Land Acquisition:** $50,000 (?) **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: **Funding Gap**: **Potential Funding Gap Sources:**
15a	Gravel Mining Reach Phase 4: Reed **Reach 5** **River miles 34-35**		Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8318; SFPUC	●	●	○							§ Concept Only	**Land Acquisition:** **Predevelopment & Planning:** **Design & Construction:** **Total Cost:**	**Committed**: FERC Settlement **Funding Gap**: **Potential Funding Gap Sources:** CALFED/AFRP; FERC Settlement; Drainage Assessment?
15b	Gravel Mining Reach Phase 3: Warner-Deardorff **Reach 5** **River miles 35-37**	1.2 miles of salmonid habitat restoration the first segment of the Mining Reach of the river. Includes planting of over 73 acres of riparian forest and the construction of a 500 -foot wide riparian floodway. No public access.	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8316; CALFED, AFRP; SFPUC	●	●	●							§ In pre-design and permitting	**Land Acquisition:** $2,000,000 **Predevelopment & Planning:** $518,670 AFRP **Design & Construction:** $8,800,000 **Total Cost:** $11,318,000	**Committed**: Warner-Deardorff fully funded, but contract issued with only $518,670 (AFRP) for Phase I design, permits, appraisal, & monitoring; FERC Settlement **Funding Gap**: None, pending approval as Directed Action **Funding Sources:** CALFED/AFRP; FERC Settlement; One of 10 projects.
15c	Gravel Mining Reach Phase 2: MJ Ruddy **Reach 5** **River miles 37-38**	1.3 miles of salmonid habitat restoration the first segment of the Mining Reach of the river. Includes planting of over 54 acres of riparian forest and the construction of a 500 -foot wide riparian floodway. No public access.	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8316; CALFED, AFRP; SFPUC	●	●	●							§ In Land Acquisition	**Land Acquisition:** $1,600,000 **Predevelopment & Planning:** $300,000 **Design & Construction:** $5,873,000 **Total Cost:** $7,737,000	**Committed**: Fully funded (some from FERC Settlement), but construction not started **Funding Gap**: none **Potential Funding Gap Sources:** CALFED/AFRP; FERC Settlement
15d	Gravel Mining Reach Phase 1: 7/11 Project **Reach 5** **River miles 38-40**	2.6 miles of salmonid habitat restoration the first segment of the Mining Reach of the river. Includes planting of over 30 acres of riparian forest and the construction of a 500 -foot wide riparian floodway. No public access.	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8316; CALFED, AFRP; SFPUC	●	●	●							§ Completed	**Land Acquisition:** **Predevelopment & Planning:** **$300,000** **Design & Construction:** **Total Cost:** $7,264,000	**Committed**: FERC settlement & CALFED funds **Funding Gap**: None **Funding Sources:** CALFED, USF&W-AFRP; FERC Settlement
16	Bobcat Flat **Reach 6** **River miles 43-44**	This project comprises 1.6 miles (approximately 300 acres) along the river of floodplain and channel restoration. The project includes native tree, shrub & vine replantings to repair dredging damage. It also includes instream steelhead habitat restoration along the spawning reach. The project complements the current TID/MID restoration project at River Mile 43.	Friends of the Tuolumne, Inc, Allison Boucher (209) 477-9033; CALFED; SFPUC; Local	●	●	●		●			●	●		**Land Acquisition**: $2.1M (purchase & Phase I of restoration) **Predevelopment & Planning**: **Design & Construction**:$300,000 (Phase II restoration) **Total Cost**: $6.0M (Restoration=$3.6M)	**Committed**: CALFED **Funding Gap**: $1,000,000 (for implementation) **Potential Funding Gap Sources:** CALFED; USFWS AFRP: Local funds
17	Floodplain Acquisitions **Reach 7** **River mile 50**	Floodplain acquisition and restoration. A small parcel of floodplain is available at River Mile 50. Purchase of this property would cease cattle grazing in the riparian habitat. Minimal restoration will be required once the cattle are fenced out.	Friends of the Tuolumne, Inc, Allison Boucher (209) 477-9033	●	●	●		●			●	○		**Land Acquisition**: $50,000,000 (for acquisitions and restoration) **Predevelopment & Planning**: **Design & Construction**: **Total Cost**: $50,000,000	**Committed**: **Funding Gap**: $50,000,000 **Potential Funding Gap Sources:**
18	Basso Bridge County Park **Reach 7** **River mile** 47.5	Provides river facilities with opportunities for boating, places for passive recreation, picnic, informal play, and overnight camping.	Stanislaus County Department of Parks & Recreation,							●	●		§ In Master Plan	**Land Acquisition**: **Predevelopment & Planning**: **Design & Construction**: **Total Cost**: See total Stanislaus Budget-Above	**Committed**: **$0** **Funding Gap**: **Potential Funding Gap Sources:**

STAKEHOLDER PROJECTS				PLAN ELEMENTS									PROJECT STATUS	PROJECT COSTS	FUNDING
PROJECT INFORMATION															
	Project Name	Project Description	Primary Project Coordinator & Funding Partners	Flood Damage Reduction	Land Acquisition	Habitat	Water Supply	Water Quality	Education	Recreation	Open Space	Land Reclamation/ Economic Dev't		(Estimated Land Acquisition; Predevelopment and Planning; Design & Construction; TOTAL Costs)	(Amount Committed; Funding Gap; Potential Funding Gap Sources)
19	La Grange Spawning Gravel Infusion **Reach 7** **River miles 47-52**	Develop long-term supply of aggregates for infusion in the river a key locations to maintain fluvial processes and improve the quantity and quality of spawning riffles.	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8317; SFPUC			●							§ Major Amendment in scope	**Land Acquisition:** **Predevelopment & Planning:** $300-500,000 **Design & Construction:** $3,900,000 **Total Cost:**$4,400,000	**Committed**: Fully funded at $4.4 M (some from FERC Settlement) **Funding Gap**: **Potential Funding Gap Sources:**CALFED/AFRP; FERC Settlement
20	Gasburg Creek **Reach 7** **River mile 50.2**	Sediment reduction	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8317; SFPUC			●		●					§ Design Only	**Land Acquisition:** **Predevelopment & Planning:** $235,000 **Design & Construction:** $995,000 **Total Cost:** $1,230,000	**Committed**: AFRP & FERC Settlement **Funding Gap**: none **Potential Funding Gap Sources:**CALFED/AFRP; FERC Settlement
21	La Grange Regional Park **Reach 7** **River mile 50-51**	Floodplain and Riparian restoration on 200 acres of county-owned floodplain. Also will improve park facilities, including hiking trail, educational opportunities, picnic areas, etc.	Tuolumne River Trust, Patrick Koepele (209) 236-0330/Stanislaus County Department of		●	●			●	●			§ Looking for Funding (Planning, Design & Implementation)	**Land Acquisition** $0 **Predevelopment & Planning** $185,000 **Design & Construction:** $2,315,000 **Total Cost** **$4.7** $1.5M for projects in the floodplain; $3.2M for projects in the surrounding area	**Committed**: **$.70** (some from FERC Settlement) **Funding Gap**: $1.5M for floodplain projects; $2.5M for other **Potential Funding Gap Sources:** CALFED/AFRP; WCB; County Parks & Recreation
22	Sediment Management Plan	Sediment management planning document for the lower Tuolumne River	Turlock & Modesto Irrigation Districts, Wilton Fryer (209) 883-8318; AFRP, SFPUC			●			●				§ Complete	**Land Acquisition**: **Predevelopment & Planning**: **Design & Construction**: **Total Cost**:	**Committed**: $202,300 AFRP **;** Other from FERC Settlement **Funding Gap**: **Potential Funding Gap Sources:**

Appendix I: Case Studies, Resources and Planning Tools

This section includes case studies, planning resources and tools to assist the Coalition in envisioning and implementing the strategies laid out in the Framework for the Future document. This section begins with six case studies that demonstrate a variety of means to achieving a balance of river restoration, recreation, public involvement, and other objectives. Following these case studies is a list of resources and references that may assist the Coalition in carrying out its primary strategies.

Case Study 1:

The Bresee-Bimini Slough Ecology Park, City of Los Angeles, California

Project Background

Bresee-Bimini Slough Ecology Park was financed by the Bresee Foundation along with a new community center in Koreatown to offer local youth a safe place for after-school activities.

The Bresee- Bimini Slough Ecology Park was designed by the non-profit North East Trees to provide space for play, reflection, and group gatherings while also cleansing stormwater runoff through a biofiltration swale running through the site. The project located adjacent to the community center also involves a street closure; a one-block stretch of 2nd Street is being closed to vehicular traffic for the creation of this park. The project is a unique example where a city-owned street right-of-way was deeded over to a private foundation on the condition that it be developed and maintained solely as a public park.

Project Outcomes

The park development has achieved multiple purposes: 1) public community open space in a park poor urban neighborhood, 2) demonstration of a water quality bio-swale as a focal park element and other sustainable concepts, 3) environmental education and 4) improved pedestrian circulation and traffic-calming.

Several sustainable elements have been incorporated into the park design including a state-of-the-art drip irrigation system, a native/low flow water usage plant palette, recycled broken concrete, permeable surfaces, a 180 foot bio-filtration vegetated swale, and a trash interceptor. The environmentally friendly irrigation and indigenous vegetation minimizes water usage. The bio-swale filters storm water runoff from a 5.85 acre local drainage area, which eliminates some of the gross pollutants and toxins from the water that flows out to the ocean, addressing the Total Maximum Daily Load (TMDL) for trash established for the Ballona Creek watershed, where the park is situated.

The structural design of the swale needed to ensure permeability and swale alignment eliminates the need for concrete retaining walls. The swale banks are retained by the placement of boulders.

Sources:

NorthEast Trees (http://northeastrees.org)
Park2parkLA (www.park2parkla.com)

Case Study 2:

Lititz Run Watershed Alliance – Lancaster County, Pennsylvania*

Project Background

Lancaster County is changing from rural to rural/suburban and community members are concerned about the rate of change and the potential impacts on their natural resources. In particular, the community is concerned about active agricultural lands adjacent to residential properties that surround the historic town of Lititz and resulting non-point source pollution problems now prevalent in Lititz Run. In addition, the community has begun to recognize the degrading effects of converting open space to impervious surfaces associated with suburban sprawl development. In response, community members formed the Lititz Run Watershed Alliance (LRWA) to promote collaborations and participation among citizens, businesses, non-profit affiliations, farmers, and local, county, state and federal governments for the sake of the Lititz Run.

Project Outcomes

In order to improve the water quality in Lititz Run, the community determined that a comprehensive long-term watershed management strategy combining techniques in natural resource management, land use planning, education and community involvement in addressing non-point source pollution was necessary. Today, the LWRA has over 16 projects in various stages of planning and implementation. The map above highlights several of those projects; others include developing agricultural management plans throughout the watershed, designing natural channel design using fluvial geomorphology, planning and constructing a regional water quality facility, creating a GIS database and mapping of mitigation banking sites and water quality monitoring data, stabilizing streambanks and establishing forested riparian buffers along the stream, and disseminating public educational material.

After two years, the group of 15 – 20 community residents continues to meet once a month. The success of the LWRA is largely evident through the receipt of over $400,000 in grants and donations for improving the watershed. Water quality has noticeably improved and has been supported through a monitoring program established by faculty and students from the local high school, sighting of a Black Crowned Night Heron at the created wetland of the regional water quality facility, improved wildlife habitat along a restored section of a stream, and the revegetated banks of Lititz Run. Other benefits associated with the group's efforts include the increase in community awareness regarding the aesthetic beauty of wetlands and natural resource issues.

Source:

National Showcase Watersheds (US EPA)
http://www.epa.gov/owow/showcase/projects.html

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* Recognized as a National Showcase Watershed by the Clean Water Action Plan program; the above information and/or pictures were obtained from the following website: http://www.cleanwater.gov/anniv2/showcase.html.

Case Study 3:

Bear Creek Watershed Project – Story and Hamilton Counties, Iowa*

Project Background

The Bear Creek Watershed encompasses 30 square miles of land and water in the Western Corn Belt Plains Ecoregion of the Midwest. The Bear Creek Restoration Project has merged academic research and development with landowner cooperation in developing a stream restoration approach that has broad applicability to agricultural watersheds. Major components include a multi-species riparian buffer, soil bioengineering and grade control technologies for streambank stabilization, constructed wetlands to intercept and process nonpoint source pollutants in agricultural drainage tile water, and rotational grazing systems that limit livestock access to the stream channel.

Project Outcomes

The challenge faced by the Agroecology Issue Team of the Leopold Center for Sustainable Agriculture and researchers at Iowa University was to develop and implement restoration based management that complement and build upon traditional soil and water conservation and pollution control efforts already in place. The Bear Creek Watershed Project was developed to contribute to a management approach for the environmental enhancement of intensively modified agricultural watersheds in the Midwest. Accordingly, a major goal was to develop a riparian management system that has broad scale applicability to watersheds in the Midwestern agroecosystem. This enables farmers, and other landowners or community members interested in restoring the watershed to select from a pool of restoration measures that are aligned with their objectives, whether they wish to intercept eroding soil and agricultural chemicals from adjacent crop fields, slow floodwaters, stabilize streambanks, improve wildlife habitat, or provide alternative, marketable products.

Restoration efforts in the Bear Creek watershed began in 1990 and focused on the upper half of the watershed. Initial efforts were focused on a 3/5-mile portion of privately owned land along Bear Creek with the implementation of a buffer system. Subsequently, the effort was expanded to 5 miles of Bear Creek across five privately owned farms. The success of this effort supports the need for a system consisting of a variety of components that can be selected for implementation based on the different ecological and agricultural needs within the watershed. Similarly, such a system including its various components can be modified according to different landscape conditions and landowner objectives for application elsewhere.

Source:

National Showcase Watersheds (US EPA)
http://www.epa.gov/owow/showcase/projects.html

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* Recognized as a National Showcase Watershed by the Clean Water Action Plan program; the above information and/or pictures were obtained from the following website: http://www.cleanwater.gov/anniv2/showcase.html.

Case Study 4:

Mattole Restoration Council – Humboldt County, California

Project Background

The Mattole Restoration Council (MRC) is among the oldest citizen-based watershed groups seeking to restore and protect the natural systems within the local watershed. Founded in 1983 to provide community support for restoration projects in the watershed, the not-for-profit organization remains at the forefront of community based watershed restoration. The MRC has shared its successes and failures with other watershed communities and the general public through its website, newsletters, publications and books including *Totem Salmon: Life Lessons From Another Species* by Freeman House, the former MRC Executive Director. In addition, the MRC has filmed a video titled, *Thinking Like a Watershed*, which documents the watershed and salmon restoration efforts that have taken place in the Mattole watershed since the late 1970s.

Project Outcomes

The Mattole River in Humboldt County, California runs parallel to the Eel River and empties into the Pacific Ocean, just above California's Lost Coast. The remote location combined with the geological composition of the area, has resulted in minimal population growth and minor development. However, intensive logging beginning in the 1940's combined with other land use changes created hundreds of miles of poorly built-and later abandoned-roads, and hillsides denuded of the vegetation that holds soil in place. This land use change, compounded by floods in the 1950s and 1960s, increased sedimentation in the watershed beyond the river's carrying capacity. The result has been the filling of many of the deep pools that used to exist in the river, and a flattening and widening of the river channel. These changes in the river's geomorphology have resulted in adverse impacts on the habitats of the Chinook salmon, coho salmon and steelhead trout. The MRC seeks to restore and protect the river by developing watershed-based strategies and assisting landowners to use sustainable management practices on their properties. Currently, the MRC offers free programs and services such as GIS mapping, reforestation and tree planting, resource centers, and forest practice reviews to landowners and residents that promote ecological and economic health in the watershed.

The MRC has recently been recognized in studies of watershed councils for several reasons. The MRC is one of the oldest, continuous watershed groups in California. Unlike other groups, the MRC has implemented actions to treat problems at the watershed level as opposed to more narrowly focused riparian restoration projects. Finally, the MRC is considered unique due to the group's emphasis on data collection regarding aquatic conditions and salmonid populations. The majority of the information about the watershed is available because of the MRC's data collection efforts.

Source:

Mattole Restoration Council
http://www.mattole.org/

Case Study 5:

The Blackfoot Challenge — Missoula, Montana*

Project Background

The Blackfoot Challenge was formerly chartered in 1993 to coordinate the management of the Blackfoot River watershed. However, the concern among the private landowners participating in the grassroots group can be traced back to the 1970's when residents and ranchers in the Blackfoot Valley demanded conservation easement legislation, walk-in hunting areas and recreation corridor management. The group does not have formal membership but operates through committees aligned with the Challenge's mission to enhance, conserve and protect the natural resources and rural lifestyle of the Blackfoot River Valley for present and future generations.

Project Outcomes

The Blackfoot River runs 132 miles in length through some of the most productive fish and wildlife habitat in the Northern Rocky Mountains. The valley floor contains glaciated wetland complexes, native scrub/shrub riparian areas and blue ribbon trout streams. The valley, though sparsely populated by humans, is characterized by the rich diversity of its native species. In particular, the tributary streams emptying into the Blackfoot River provide crucial spawning and rearing habitat for bull trout and the westslope cutthroat trout, both listed under the Federal Endangered Species Act. The valley is at the southern edge of the Northern Continental Divide Ecosystem, which supports the largest population of grizzly bears in the lower 48 states. The biological diversity that remains in the Blackfoot Valley can largely be attributed to the individual management activities of the local ranchers.

The Blackfoot Challenge focuses its restoration efforts in three areas: education, weed management and habitat restoration and protection. The group sponsors annual workshops and maintains a weed calendar contest for youth in schools as one program to involve the community. The Challenge participated in the process of dividing the 350,000 acres comprising the Blackfoot Valley into seven different Weed Management Areas (WMA) and assists the Weed Management Coordinator within each WMA hired to work with the individual landowners on mapping noxious weeds, providing information on the different weeds, coordinating control measures and grant writing. Habitat restoration and protection programs began with comprehensive studies of the watershed and developed into activities targeted toward the restoration of fisheries and the preservation of the landscape surrounding critical wildlife areas.

Source:

National Showcase Watersheds (US EPA)
http://www.epa.gov/owow/showcase/projects.html

* Recognized as a National Showcase Watershed by the Clean Water Action Plan program; the above information and/or pictures were obtained from the following website: http://www.cleanwater.gov/anniv2/showcase.html.

Case Study 6:

The Napa River Flood Management Plan; Napa County, California

Project Background

The Napa River Flood Management Plan, designed by a unique Community Coalition, is a creative solution, to an age-old problem: How to provide flood protection and watershed management to the Napa River Valley while meeting environmental restoration and economic revitalization goals? The Community Coalition's plan was built on a set of "living river" principles, developed and refined by an unprecedented coalition of political and community leaders, private industry, natural resource agencies, non-profit groups, local governments and private citizens.

The Napa River Watershed historically supported a dense riparian forest, significant wetland habitat and spawning areas for fish such as salmon and steelhead. The pressures of urbanization, agriculture, and grazing have degraded the watershed's habitats and drastically increased the rates of erosion and sedimentation. Since 1800, an estimated 6,500 acres of historical valley floor wetlands have been drained or filled, 19,700 acres of the watershed are now under hardened pavement or rooftops and another 26,000 acres have been developed to intensive cultivated agriculture. At the same time, much of the river system has been altered by straightening channels, hardening banks, changing the flow, and constructing levees. These alterations made the natural drainage system insufficient to prevent extensive flooding in the area. Since 1862, more than 27 major floods have plagued Napa Valley, resulting in significant loss of life and property. The 1995 flood damaged 277 businesses and residences at a cost of over $100 million.

In response the U.S. Army Corp of Engineers offered a new plan in 1995 to address the flood control problem. The plan's traditional approach –enlarging the channel and constraining the river within the channel – was met with an underwhelming response in Napa. The Community Coalition came together in 1996, and using the Army Corp as a resource, began the extensive process of formulating an alternative flood control approach. Thousands of hours of meetings later, a "living river" design achieved consensus. Less than one year later, in March 1998, a proposal to add a half-cent to the Napa County sales tax to fund the local share of this Flood Project was put before the voters. A two-thirds majority was required to approve the tax increase. More than 27,000 voters cast a ballot on that election day, and Measure A passed with just 308 votes to spare.

Project Outcomes

Major objectives of the "Living River" design include reconnecting the River to its historic flood plain; maintaining the natural slope and width of the River; allowing the River to meander as much as possible; retaining natural channel features like mud flats, shallows and sandbars; and supporting a continuous fish and riparian corridor along the River.

The measures designed to provide 100-year flood protection include some traditional approaches and many innovative concepts. Old dikes have been breached to restore tidal marshlands; bridges are being replaced to remove obstacles to water flow; riverbank terracing is creating more room for large volumes of water; a new dry bypass channel will provide a shortcut for the River through the slow moving Oxbox; new dikes, levees and floodwalls will be built; bank stabilization will be used in specific areas; and detention basins and pump stations will accommodate runoff behind the floodwalls.

The project is viewed as having three inter-locking elements:

- Increased public safety through flood protection
- Watershed stewardship through environmental remediation and restoration
- Enhanced prosperity through the reduction of insurances costs and flood risk, and stimulation of economic development

The end result is a Living River that can sustain migrating fish and wildlife and a system that will help protect all County residents from damages caused by regular flooding.

Sources:

Clean Water Action Plan (www.cleanwater.gov), Watershed Success Stories: Applying the Principles and Spirit of the Clean Water Action Plan.

Napa County Flood Control and Water Conservation District, The Napa River Flood Protection Project – Progress and Plan Summary 2004

U.S Army Corp of Engineers and Napa County Flood Control and Water Conservation District, A Citizen's Guide to the City of Napa, Napa River, and Napa Creek Flood Protection Project.

Resources and Planning Tools

Project Tools and Resources:

1) California Buffer Initiative
http://www.ca.nrcs.usda.gov/programs/buffer.html
This information and links provide NRCS staff and partners with support to implement the California Buffer Initiative. Conservation buffers and filter strips are small areas or strips of land in permanent vegetation, designed to intercept pollutants and manage other environmental concerns. Strategically placed buffer strips in the agricultural landscape can effectively mitigate the movement of sediment, nutrients, and pesticides within farm fields and from farm fields.

2) Natural Resource Conservation Service-Farm Bill Programs
http://www.nrcs.usda.gov/programs/farmbill/2002/products.html

Inventories:

The inventories listed below provide information on current rivers and watersheds projects. They could provide references and case studies for Lower Tuolumne River Parkway projects and Parkway projects could be included in such inventories.

1) The Natural Resource Projects Inventory
www.ice.ucdavis.edu/nrpi

2) EPA Watersheds: Adopt Your Watershed
http://www.epa.gov/adopt/

3) California State Parks Central Valley Strategy
http://www.parks.ca.gov/default.asp?page_id=23483

Resources for Community Engagement:

1) San Francisco Bay Keeper-DeltaKeeper Chapter
DeltaKeeper offers a model for engaging volunteers in water quality monitoring and could act as a partner organization to assist in mobilizing efforts on the Tuolumne.
http://www.baykeeper.org/html/pages_link_to_index/deltalinks.htm

2) EPA's Kids' Page
EPA's Kids's Page provides tools for involving children and youth in water-related activities and provides a link to their Water Drop Patch Program, as a model and resource for encouraging youth to become watershed stewards.
http://www.epa.gov/owow/kids.html

3) American Rivers' Citizens' Agenda for Rivers
This website provides a "toolkit" for river stewardship and community involvement.
http://www.healthyrivers.org/toolkit.html

4) CREEC Network (California Regional Environmental Education Community)
CREEC is a communication network which provides educators with access to environmental education resources to enhance the environmental literacy of California Students.
http://www.creec.org

5) Getting in Step: Engaging and Involving Stakeholders in Your Watershed (US EPA)
This stakeholder guide provides the tools needed to identify, engage, and involve stakeholders throughout a watershed to restore and maintain healthy environmental conditions.
http://www.epa.gov/owow/watershed/outreach/documents/stakeholderguide.pdf

6) Volunteer Monitoring Tools and Resources (US EPA)
http://www.epa.gov/owow/monitoring/volunteer/

Sources for Promising and Best Management Practices:

1) The California Stormwater Quality Association

www.cabmphandbooks.com

The CSQA has produced a series of four BMP Handbooks for various applications. These handbooks are available for free downloading at www.cabmphandbooks.com.

The four handbooks include information and Best Management Practices for:

- New Development and Redevelopment
- Construction
- Industrial and Commercial
- Municipal Activities

2) The California Rivers Assessment (CARA)
http://endeavor.des.ucdavis.edu/newcara/
CARA is a computer-based data management system designed to give resource managers, policy-makers, landowners, scientists and interested citizens rapid access to essential information and tools with which to make sound decisions about the conservation and use of California's rivers.

3) Protecting and Restoring America's Watersheds: Status, Trends, and Initiatives in Watershed Management (US EPA)
http://www.epa.gov/owow/protecting/restore725.pdf
See unique case studies highlighted throughout the document. Tools and recommendations are included in the section entitled, "What Can Be Done to Improve Progress?" starting on Page 38.

4) Stream Corridor Restoration: Principles, Processes and Practices (Federal Interagency Stream Restoration Working Group)

http://www.nrcs.usda.gov/technical/stream_restoration/newgra.html
This document provides numerous case studies (accessible from the website) and best practices relevant to the strategies adopted by the Coalition in the Framework for the Future. Such practices include "Developing a Monitoring Plan" (page 6-25) and "Designing Urban Stream Buffers" (page 8-12).

5) National Resources Defense Council: Stormwater Strategies
This site provides links to case studies and practices regarding Stormwater run-off management.
http://www.nrdc.org/water/pollution/storm/stoinx.asp

6) Center for Watershed Protection: Urban Subwatershed Restoration Manual Series
This series organizes information needed to restore small urban watersheds into a format that can easily be accessed by watershed groups, municipal staff, environmental consultants and other users.
http://www.cwp.org/USRM_verify.htm

7) California Department of Parks and Recreation Planning Division: Parks and Recreation Technical Services

- Innovative Practices: Case Studies Volume I; Suggested by California Park and Recreation Providers October 2004
- Directory of Grant Funding Sources for California Parks and Recreation Providers June 2004
- Getting a Grip on Grants: A How-to Guide for Park and Recreation Providers 2004

http://www.parks.ca.gov/?page_id=22226

Appendix J: Organizational Development Options Analysis

Introduction and Overview

To date, the Coalition received information about several of the organizational options currently being considered by the group. These options as well as the current structure of the Coalition are noted below in bolded text (summarized information for each is available as an appendix to this document, upon request). The second section of this document contains a preliminary analysis of these organizational options including possible structural models and pros and cons.

The purpose of this handout is to assist the Coalition in thinking about the advantages and strengths as well as the drawback and limitations of each organizational option. The Coalition may decide that more information is needed for the options or other alternatives that need to be tested with the evaluation criteria previously identified by the Coalition Steering Committee.

The organizational options listed below in bold (and examples for each in italics) are analyzed on the following pages of this document:

1. **Informal Alliance — *Tuolumne River Coalition***
2. **Coordinated Resource Management and Planning (CRMP) Group — *San Francisquito Watershed Council***
3. **Memorandum of Understanding (MOU) Collaborative**
4. **Nonprofit Organization / 501(c)(3) — *San Joaquin River Parkway and Conservation Trust***
   - Legal Limitations
   - Reasons to Incorporate a Nonprofit Association
   - 501(c)(3) Organization Classifications

     A. Public Charity

        i. Watershed Conservancy

        ii. Trust

        iii. Regional Watershed Council

     B. Foundation

Preliminary Analysis of Organizational Options

The Role of the Coalition

The Coalition has been formed to fulfill the following roles:

- Educate and inform the State and Federal Governments for political and funding support to implement projects in support of the Vision statement (e.g. restoration, recreation, flood management, buffering productive agriculture, etc.);
- Conduct fundraising activities, as necessary, for project implementation;
- Help implement projects through strong coordination with agencies and other partners;
- Serve as a project, information "clearinghouse" to ensure coordination among agencies and other partners; and
- Develop educational tools and materials to increase public knowledge and community awareness of the Tuolumne River and its multiple values.

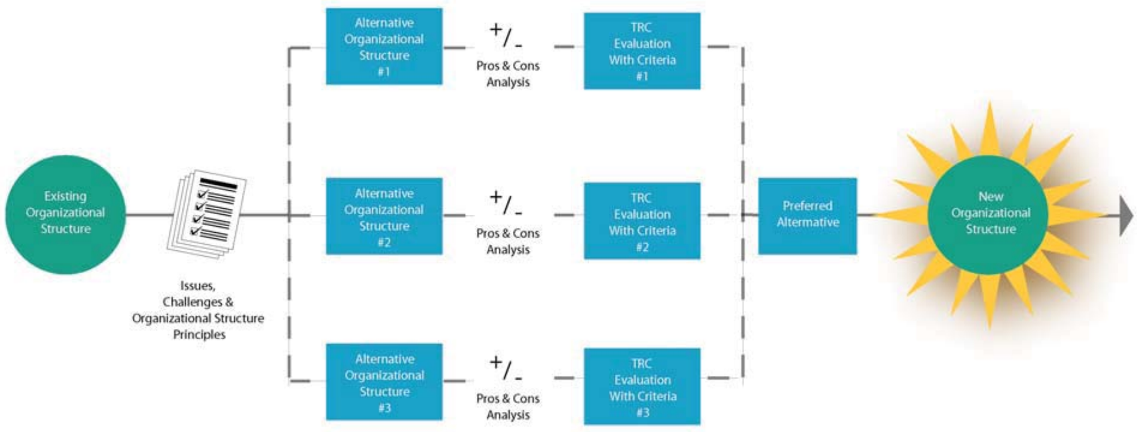
Issues and Challenges

Steering Committee members suggested the following issues and challenges for consideration during the Coalition organizational development process and identification of an alternative organizational structure:

- Establish an organizational structure with legal status to help obtain additional funding and create outreach materials that describe the Coalition as one entity.
- Enhance the Coalition's credibility by supporting restoration of habitat and flood capacity, while supporting sound planning and implementation principles of public use areas.
- Include clear and concise operating procedures outlining new membership guidelines and decision-making processes.

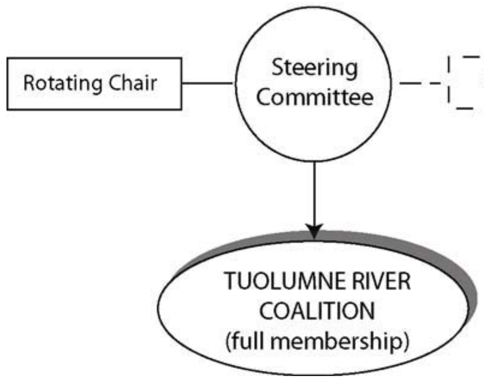
The Process

The diagram below illustrates a process for conducting a preliminary analysis of potential organizational options:



1. *Informal Alliance* — Tuolumne River Coalition

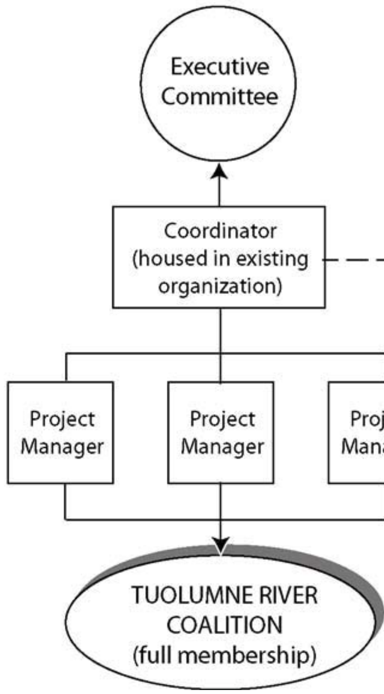
Potential Organizational Structure



Potential Pros	Potential Cons
1. Familiar in that it requires no change	1. Coordination, obtaining information and decision-making is difficult
2. Flexible due to limited bureaucratic processes and procedures	2. Participation/meeting attendance could be less consistent
3.	3. Limited volunteer time is stretched too thin
4.	4. Limited authority to influence policy; Potentially less authority to obtain funding
5.	5. Effectiveness is dependent on a high degree of participant and community commitment, support and good faith or overall trust
6.	6. May requires use of a separate fiscal agent

2. *Coordinated Resource Management and Planning (CRMP) Group* — San Francisquito Watershed Council

Potential Organizational Structure



Potential Pros	Potential Cons
1. Minimal change to current structure	1. No legal authority to influence policy or obtain funding
2. Implementation of model policies and procedures	2. Participation/meeting attendance is inconsistent
3. Existing network of other CRMP's	3. Limited volunteer time is stretched too thin
4. Increased access to federal programs and grants	4. Funding opportunities dependent on socioeconomic status of the community (i.e., tax base)
5. Emphasis on reducing tensions and increasing cooperation between landowners and public agencies	5. Dependent on the commitment, continuous and regular participation, good faith and overall trust of all participants, community support and good information
6. Often housed within an established organization (with designated staff, grant-writing capacity and other existing resources)	6.

3. Writing Memorandums of Understanding

Memorandums of Understanding (MOUs) are typically written as work plans that outline parties' work roles and financial responsibilities. They must be signed and dated by all parties involved.
MOUs will typically include the following:

I. Statement of Work

II. Period of Performance

III. Clarification of Agency Roles & Expectations

IV. Key Deadlines or Dates

V. Confidentiality Agreement

VI. Financial Agreements

VII. Identification of Liaisons or Interagency Coordination

MOUs may also include:

I. Training

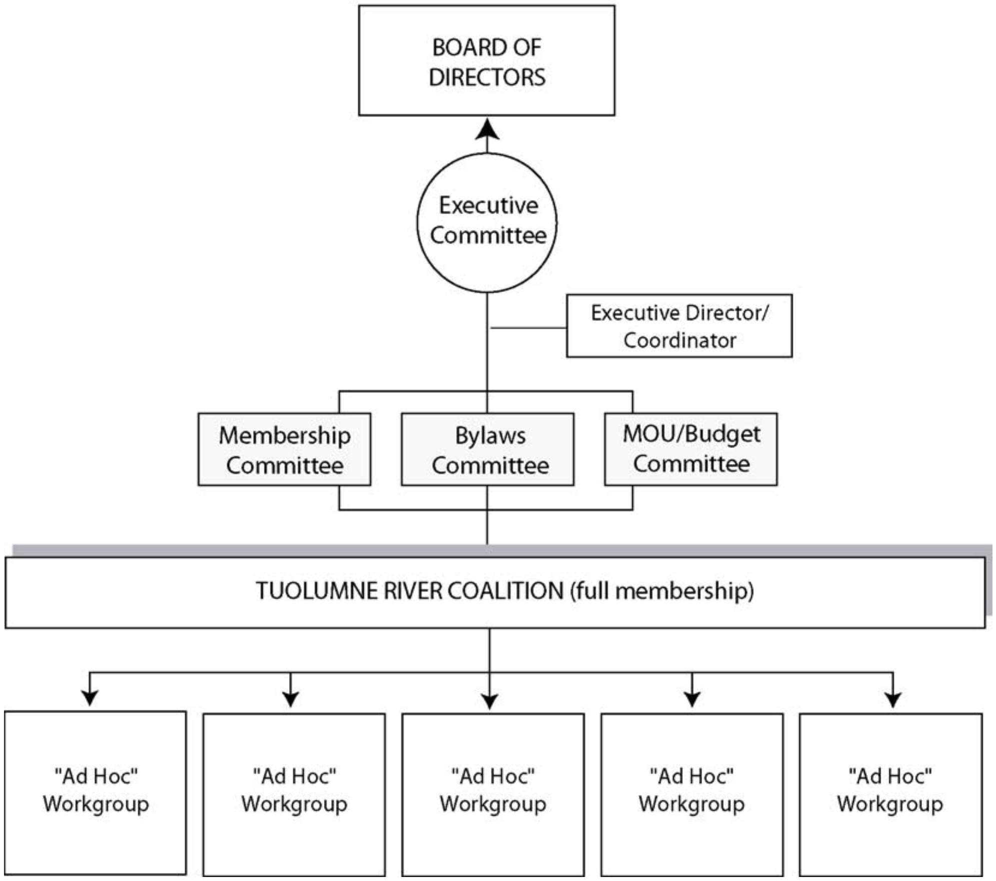
II. Assessment Protocol

III. Process for Resolving Conflict

IV. Periodic Review

4. Nonprofit Organization / 501(c)(3) — San Joaquin River Parkway and Conservation Trust

Potential Organizational Structure



Potential Pros	Potential Cons
2. Easier to obtain private and public grants	1. May be difficult to achieve balanced Board representation
3. Group can fund activities/projects through surpluses	2. Director/Officer liability issues could potentially make it too costly or difficult to form a Board
4. Donations received are tax-deductible	3. Can engage in only limited lobbying activities
5. Protection from personal liability for members' activities and advocacy efforts	4. Cannot contribute money to political campaigns
6.	5. Cannot make substantial profits from unrelated activities
7.	6. Assets must be distributed to another tax-exempt group if group dissolves

Non-Profit Resources

"Get Ready Get Set" is a California-specific book on starting a Non-Profit, from the Center for Non-Profit Management in Southern California:
http://www.cnmsocal.org/Services/GetReadyGetSet.pdf

Nonprofit Start-up Checklist (not California-specific):

The Center for Non-Profit Management (http://www.cnm.org/) provides the following as a way for you to track your progress through the start-up process:

- Has a unique name been selected?
- Have state articles of incorporation been filed? Forms are available from the Secretary of State.
- Have Publication 557 (Tax Exempt Status for Your Organization), Form 1023 and instructions, Form 872-C, and Form 8718 been obtained from the IRS?
- Has a federal employer identification number (EIN) been obtained from the IRS (Use Form SS-4)?
- Has a mission statement been developed which clearly defines the purpose of your organization in terms of why you exist and who you serve?
- Has a narrative of your services been developed that describes what services you provide, how they are delivered, to whom, by whom, and where?
- Have by-laws been developed?
- Do you intend to engage in political activities or lobbying as part of your services?
- Has a board of directors been established?
- Have the sources of funds and volunteers been identified? Will you engage in unrelated activities which will generate revenue?
- Has a plan for fundraising been developed?
- Has paid staff, if any, been hired?
- Have all those with special interests and relationships been identified?
- Has a financial history (3 years) and projection been developed, and has a balance sheet been prepared?
- Has an application been made to the Department of Revenue for a tax exempt certificate? (A copy of the IRS letter of determination is required.)

Appendix K: Glossary of River and Watershed Planning Terms

Adaptive Management:

The process of refining or redefining management actions as a process unfolds and results are obtained. Adaptive management is an interactive and iterative approach to decision making that incorporates feedback loops for evaluating actions and injecting new information as it becomes available.

Anadromous:

Fish that spawn in freshwater streams or rivers and migrate early in their life cycle to the ocean where the mature. They return as mature adults to spawn in the fresh water of their origin.

Anadromous Fish Restoration Program:

Efforts by State and Federal agencies and local irrigation districts to restore anadromous fish populations to recent historical levels.

Baseline Assessment:

An assessment intended to help characterize existing watershed conditions and/or to establish a background for planning or future comparisons.

Beneficial Use:

Actual or reasonable potential use that may be made of waters of the state, including but not limited to domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and propagation and enhancement of fish, wildlife, and other aquatic resources.

Best Management Practices (BMP):

An urban water conservation measure that the California Urban Water Conservation Council agrees to implement among member agencies.

Buffer zones:

Areas where management activities are restricted or prohibited to reduce magnitude of impacts to fish and wildlife habitat, recreational areas, agriculture, or other land uses.

Candidate species:

Any species or subspecies of bird, mammal, fish, amphibian, reptile, or plant that is being considered for listing as endangered or threatened but is not yet the subject of a proposed rule.

Capital cost:

A lump-sum cost that includes those costs associated with the start-up of a project or program. For example: planning, design, construction, power costs for initial filling of reservoirs, activation costs, operation and maintenance costs prior to initial operation.

Conceptual Model:

An explicit description of the critical cause-and-effect pathways in ecosystem function. A conceptual model includes a summary of current knowledge and hypotheses about ecosystem structure and function, and highlights key uncertainties where research might be necessary. Alternative or competing conceptual models illustrate areas of uncertainty, paving the way for suitably-scaled experimental manipulations designed both to restore and explore the ecosystem. Conceptual models also help to define monitoring needs, and bases for quantitative modeling.

Conservation:

Careful preservation and protection of resources, usually referring to land and related natural resources, includes planned management of resources to protect their future integrity and value.

Conveyance:

A pipeline, canal, natural channel or other similar facility that transports water from one location to another.

Critical habitat:

(1) Specific areas within the geographical area occupied by a species at the time it is listed in accordance with the Endangered Species Act; (2) Specific areas outside the geographical area occupied by a species at the time it is listed if there is a determination that such areas are essential for conservation of the species.

Designated floodway:

The channel of the stream and that portion of the adjoining floodplain required to reasonably provide for passage of a design flood.

Diversions:

The action of taking water out of a river system or changing the flow of water in a system for use in another location.

Ecosystem (1):

A recognizable, relatively homogeneous unit that includes organisms, their environment, and all the interactions among them.

Ecosystem (2):

An interactive system that includes the organisms of a natural community in association together with their abiotic physical, chemical, and geochemical environment.

Ecosystem-based Management:

Ecosystem-based management is a resource management concept of achieving species management objectives by sustaining and enhancing the fundamental ecological structures and processes that contribute to the well being of the species.

Ecosystem Management:

Management of land and aquatic resources based on perspective of ecosystem structure, function, and dynamics aimed at long-term sustainability of watershed productivity. Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting ecosystem integrity over the long term.

Ecosystem Element:

An ecosystem element is a basic component or function which, when combined with other ecosystem elements, makeup an ecosystem. An ecosystem element can be categorized as a process, habitat, species, species community, or stressor.

Ecosystem Restoration:

Ecosystem restoration is a term sometimes used to imply the process of recreating the structural and functional configurations of an ecosystem to that present at some agreed to time in the past. Ecosystem restoration is more realistically defined as the process by which resource managers ensure that the capacity of the ecosystem to provide ecological outcomes valued by society is maintained, enhanced, or restored.

Ecological Process:

Ecological processes act directly, indirectly, or in combination, to shape and form the ecosystem. These include streamflow, stream channel, and floodplain processes. Stream channel processes include stream meander, gravel recruitment and transport, water temperature, and hydraulic conditions. Floodplain processes include overbank flooding and sediment retention and deposition.

Endangered species:

Any species or subspecies of bird, mammal, fish, amphibian, reptile, or plant that is in serious danger of becoming extinct throughout all or a significant portion of its range.

Endangered Species Act (ESA):

Federal legislation that provides protection for species that are in danger of extinction.

Exotic Species:

Also called introduced species; refers to plants and animals that originate elsewhere and migrate or are brought into a new area, where they may dominate the local species or in some way negatively impact the environment for native species.

Feasibility study:

The detailed investigation of project alternatives that were not eliminated during reconnaissance investigations.

Floodplain:

Part of a river valley made of unconsolidated, river-borne sediment that is periodically flooded.

Floodway:

The channel of a river or other watercourse and adjacent land areas that convey flood waters.

Fragmentation of habitat:

Division of a large piece of habitat into a number of smaller, isolated patches.

GIS:

Geographical Information System. A specialized form of computerized, geographically referenced data bases that provide for manipulation and summation. A GIS may also be defined as a system of hardware, software, data, and personnel for collecting, storing, analyzing, and disseminating information about geographical areas.

Government Agencies:

Federal, state, county, city and town governments; Native American governments; and special districts.

Habitats:

Habitats are areas that provide specific conditions necessary to support plant, fish, and wildlife communities. Some important habitats include gravel bars and riffles for salmon spawning, winter seasonal floodplains that support juvenile fish and water birds, and shallow near-shore aquatic habitat shaded by overhanging tule marsh and riparian forest.

Heavy metals:

A metal of atomic weight greater than 23 that forms soaps on reaction with fatty acids. Examples are aluminum, lead, cobalt.

Hydrologic Area:

A geographical area representing part or all of a surface drainage basin or distinct hydrologic feature such as a reservoir, lake, etc.

Land retirement:

The process of taking agricultural lands out of production.

Meander Belt:

Protecting and preserving land in the vicinity of a river channel in order to allow the river to meander. Meander belts are a way to allow the development of natural habitat around a river.

Mitigation:

Measures to avoid, minimize, rectify, reduce, or compensate for project impacts.

Monitoring:

The organized collection of information over time to aid the understanding process of a watershed system. The information may be used in watershed assessment, watershed planning, and in overall watershed management decision making. Monitoring is also used to track the implementation accuracy and effectiveness of specific policies and projects.

Restoration:

The reestablishment of processes, functions, and related biological, chemical, and physical linkages between the aquatic and associated riparian ecosystems; it is the repairing of damage caused by human activities.

Riparian:

Pertaining to the banks and other terrestrial environs adjacent to water bodies, watercourses, and surface-emergent aquifers (springs, seeps, and oases) whose water provides soil moisture significantly in excess of that otherwise available through local precipitation. Vegetation typical of this environment depends on availability of excess water.

Riparian Habitat:

The strip of land adjacent to a natural water course such as a river or stream. Often supports vegetation that provides the best fish habitat values when growing large enough to overhang the bank.

Riparian Corridor:

Land adjacent to creeks, rivers, and streams where vegetation is strongly influenced by the presence of water.

River Basin:

A part of the earth's surface which is occupied by a drainage system which consists of a surface stream with all its tributaries and impounded bodies of water. Also known as watershed, catchment area, and drainage area.

Riverine:

Habitat within or alongside a river or channel.

Set-aside lands:

Agricultural lands temporarily not farmed.

Setback Levee:

A constructed embankment to prevent flooding that is positioned some distance from the edge of the river or channel. Setback levees allow wildlife habitat to develop between the levee and the river or stream.

Stakeholder:

Anyone who lives in a watershed or has land management, administrative, or other responsibilities or interests in it. Stakeholders include private individuals, businesses, government agencies, and special interest groups, wildlife and fisheries, among others.

Stressors:

Stressors are natural and unnatural events or activities that adversely affect ecosystem processes, habitats, and species. Environmental stressors include water diversions, water contaminants, levee confinement, stream channelization and bank armoring, mining and dredging in streams and estuaries, excessive harvest of fish and wildlife, introduced predator and competitor species, and invasive plants in aquatic and riparian zones. Some major stressors affecting the ecosystem are permanent features on the landscape, such as large dams and reservoirs that block transport of the natural supply of woody debris and sediment in rivers or alter unimpaired flows.

Total Maximum Daily Loads (TMDL):

A calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. Water quality standards identify the uses for each waterbody, for example, drinking water supply, contact recreation (swimming), and aquatic life support (fishing), and the scientific criteria to support that use. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the State has designated. The calculation must also account for seasonal variation in water quality.

Terrestrial:

Types of species of animal and plant wildlife that live on or grow from the land.

Threatened Species:

Any species or subspecies of bird, mammal, fish, amphibian, reptile, or plant likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

Tributary:

Stream flowing into a lake or larger stream.

Toxins:

Substances that cause damage to a living tissue, impairment of the central nervous system, severe illness, or death when ingested, inhaled, or absorbed by the skin.

Trace Elements:

A chemical element used by organisms in minute quantities and essential to their physiology.

Upland:

Generally a land zone sufficiently above or away from freshwater bodies, watercourses, and surface-emergent aquifers to be largely dependent on precipitation for its water supplies. Also refers to lands other than those that are seasonally or permanently wet.

Water Conservation:

Practices that encourage consumers to reduce the use of water. The extent to which these practices actually create a savings in water depends on the total or basin-wide use of water.

Watershed:

An area that drains ultimately to a particular channel or river, usually bounded peripherally by a natural divide of some kind such as a hill, ridge, or mountain.

Wetlands:

Zone periodically or continuously submerged or having high soil moisture that has aquatic and/or riparian vegetation components and is maintained by water supplies significantly in excess of those otherwise available through local precipitation.

Wildlife Habitat:

Area that provides a water supply and vegetative habitat for wildlife.

Sources of Definitions for Terms in The Glossary

http://wwwdpla.water.ca.gov/sjd/sjrmp/documents/glossary.html
http://cdec.water.ca.gov/glossary.html
http://calfed.ca.gov/Archives/GeneralArchive/Phase_1_FinalReport/glossary.html
http://www.epa.gov/owow/tmdl/intro.html
http://calfed.ca.gov/CALFEDDocuments/July2000_EIS_EIR/312/312-6.pdf
http://www.heritageconservancy.org/publications/glossary.html
http://www.ramsar.org/strp_rest_glossary.htm
CALFED Bay-Delta Program. *Ecosystem Restoration Program Plan, Vol. I*. July 2000.
CALFED Bay-Delta Program. *Watershed Program Plan*. July 2000.

Appendix L: List of Acronyms

AFRP	Anadromous Fish Restoration Program
CALFED	California Bay-Delta Authority
DFG	California Department of Fish and Game
ESRCD	East Stanislaus Resource Conservation District
FERC	Federal Energy Regulation Commission
FSA	FERC Settlement Agreement
MID	Modesto Irrigation District
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
RWQCB	Regional Water Quality Control Board
TID	Turlock Irrigation District
TRRP	Tuolumne River Regional Park
TRTAC	Tuolumne River Technical Advisory Committee
SFPUC	San Francisco Public Utilities Commission
SJRNWR	San Joaquin River National Wildlife Refuge
USFWS	United States Fish and Wildlife Service

Appendix M: Footnote Bibliography

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Turlock Irrigation District. *Mitigated Negative Declaration for Special Run Pool 9*. 2000.

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United States Fish and Wildlife Service. *San Joaquin River National Wildlife Refuge Comprehensive Conservation Plan*. 2004.

United States Fish and Wildlife Service. *San Joaquin River National Wildlife Refuge Study Report for Proposed Acquisitions*. 2004.

United States Fish and Wildlife Service. *Working Paper on Restoration Needs*

Staples, Rose

From:	Stephen_Bowes@nps.gov
Sent:	Thursday, September 08, 2011 7:04 PM
To:	Annie Manji; hbwillia44[redacted] James.Hastreiter@ferc.gov; jhorn@ca.blm.gov; Devine, John; Craig, Nancy; Staples, Rose; jessie@tuolumne.org; peter@tuolumne.org; BHackamack[redacted]; patrick@tuolumne.org; Barbara Rice@nps.gov
Subject:	NPS comments on Studies RR-1, RR-2, and RR-3
Attachments:	Study RR-01 Recreation Facility Condition, NPS 08-29-11.doc; Study RR-02 White Water Boating, NPS 9-1-11.doc; Study RR-03 Boatable Flow.doc; Study RR-01, ATT B, NPS & DFG, 9-7-11.doc

Nancy,

Here are the comments we have on the three recreation study plans.

Stephen M. Bowes
Hydropower Assistance Program
National Park Service
333 Bush Street, Suite 500
San Francisco, CA 94104
Phone: 415-623-2321
Fax: 415-623-2387

(See attached file: Study RR-01 Recreation Facility Condition, NPS 08-29-11.doc)(See attached file: Study RR-02 White Water Boating, NPS 9-1-11.doc)(See attached file: Study RR-03 Boatable Flow.doc)(See attached file: Study RR-01, ATT B, NPS & DFG, 9-7-11.doc)

From: Annie Manji <amanji@dfg.ca.gov>
Sent: Thursday, September 08, 2011 6:04 PM
To: Craig, Nancy
Cc: Jeff Horn; Dean Marston; Jennifer O'Brien; Julie Means; Bob Hughes; Tim Heyne; James.Hastreiter@ferc.gov; Harry Williamson; Devine, John; Staples, Rose; Stephen_Bowes@nps.gov
Subject: Suggested additions to Don Pedro Recreation Resource Study 1 Attachment B
Attachments: RR-1 Attachment B 110824-AManji110908.doc

Nancy

Thank you for the opportunity to comment on the proposed visitor survey. The Calif. Dept. of Fish and Game (CDFG) supports the idea of assessing visitor use at Don Pedro with a survey.

CDFG is particularly interested in assessing angling behavior and success of visitors. I have added a section that approximates a creel survey as an example. Note: CDFG creels usually include physical measurements of any fish in possession if the creel respondents are willing. This might require an extra person to handle the fish while the survey is being administered. This "fish squeezing" component could be focused on areas where anglers are most likely to be encountered, such as boat ramps and fish cleaning stations.

At the last meeting I did not record a complete contact list of the parties interested in this topic (one of the drawbacks to phoning in). Please feel free to circulate these suggestions to additional parties if that helps to prepare for the next recreation meeting.

Thank you,

Annie Manji
Statewide FERC Coordinator
California Department of Fish and Game
601 Locust Street
Redding, CA 96001
(530) 225-2315
amanji@dfg.ca.gov

ATTACHMENT B

SAMPLE VISITOR SURVEY INSTRUMENT

Date ___________ Time _______ Survey No.

Recreation Visitor Survey for the Don Pedro Project (FERC Project No. 2299)

The following survey has been designed to help Modesto Irrigation District and Turlock Irrigation District understand the needs of users of the recreational facilities and opportunities at the Don Pedro Reservoir.

These questions are generally for the **overall recreation area** (*i.e.*, the Don Pedro Reservoir). However, some questions are for the **specific recreation facility or site** you are currently visiting (*e.g.*, Fleming Meadows, Blue Oaks, Moccasin Point). Please be aware of this distinction when reading each question.

Your Trip Characteristics

1. Please write the name of the **recreation site/facility** where you have received this survey: ____ .

2. If you are staying overnight, where are you staying or camping today? (Check One)

- ❑ **Not staying overnight, this is a day visit only**.
- ❑ RV park or campground. If so, what is the name of the campground you are staying at? ______________________________________ .
- ❑ Dispersed shoreline camping
- ❑ Staying at a hotel or motel. If so, which community/town/city? ______________________________________ .
- ❑ Other (please specify): ______________________________________ .

3. When did you **arrive** and **plan to depart** this Don Pedro Reservoir?
(For the time, please specify AM or PM)

Arrival		➡	Estimated Departure	
________	________		________	________
Date	Time (am / pm)		Date	Time (am / pm)

4. A) What year did you **first visit** this Don Pedro Reservoir: ____________.

B) Approximately **how many times** have you visited since your first visit: ___________.

5. Which of the following best describes your recreation group? (Check One)

❑ Alone	❑ Friends	❑ Family & Friends	❑ Other (specify): ______________________________.
❑ Family	❑ Multiple Families	❑ Organized Outing Group	

6. How many people, vehicles, boats, and water-related equipment are included with the **group you traveled with** during your current visit to Don Pedro Reservoir? (Write a number for each)

_____ People (include yourself)

_____ Vehicles used to travel to the area (include trucks, cars, RVs, etc.)

_____ Off-Highway Vehicles (OHVs) – 2, 3, or 4 wheels

_____ Trailer for OHV

_____ Trailer for Boat/PWC/Raft

_____ RV/Camper ➔ Length in ft. ________ *(if more than 1, give range)*

_____ Camper Trailer ➔ Length in ft. ________ *(if more than 1, give range)*

_____ Tents

_____ Powerboats (under 15 horsepower)

_____ Powerboats (15 horsepower or larger)

_____ Personal Watercraft (PWC)

_____ Canoes/kayaks/other non-motorized watercraft

_____ Fishing tubes

_____ River tubes

_____ Other, specify: __________________________

7. Check each of the activities that **you expect to participate in** during your current visit to Don Pedro Reservoir. (Check All That Apply)

- ❑ Camping
- ❑ Driving for pleasure
- ❑ Fishing
- ❑ Houseboating
- ❑ Flat-water, motorized boating
- ❑ Flat-water, non-motorized boating (*e.g.*, kayaks, canoes)
- ❑ Gold panning
- ❑ Hiking or walking
- ❑ Horseback riding
- ❑ Hunting (specify type): ___________________________
- ❑ Mountain biking
- ❑ OHV use
- ❑ Picnicking
- ❑ River/stream boating (*e.g.*, raft, kayak, canoe)
- ❑ Swimming
- ❑ Target Shooting
- ❑ Water skiing
- ❑ Wildlife viewing (birding, etc)
- ❑ Other (specify): __________________________
- ❑ Other (specify): __________________________

8. Please list your **primary recreation activity** for your current visit**:**___________________________________ .

9. Please list (up to 3) other areas in central California where you visit to participate in your **primary recreation activity**.

1) ________________________________ 2) ________________________________ 3) ________________________________

If you have fished or expect to fish in this area on this trip please complete questions F1 through F7. Otherwise skip to the next section.

F1. Have you fished in the Don Pedro Reservoir area before this trip?

- ❑ Yes. If yes, approximately how many times over the past 12 months? _________
- ❑ No

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F2. Have you participated in fishing tournaments in the Don Pedro Reservoir area in the last 12 months?

- ❑ Yes (Which ones? ____
- ❑ No

Formatted: Bullets and Numbering

F3. Please indicate how crowded you felt at the area you fished today.

1-----------2-------------3------------4-------------5-------------6------------7------------8-------------9

Not at all	Slightly	Moderately	Extremely

F4. Please describe your fishing trip today.

# of anglers in your party ____________
Area(s) Fished ____________________
Hours Fished ______________________

F5. Please circle all of the following techniques that apply to your trip today:

Mode:	Boat	Shore	
Lure:	Bait	Artificial	
Method:	Casting	Trolling	Still

F6. Complete the following table about the species you are fishing for today and whether or not you caught any fish. If you have not fished today, skip to Question ___

Are you fishing for:	Number of fish caught in each size category			# Released
	0 -11"	12-24"	>24"	
Black Bass				
Bluegill				
Catfish				
Crappie				
Trout				
Salmon				
Other				

F7. Overall, are you satisfied with you fishing experience on this trip to Don Pedro Reservoir?

1-----------2------------3-------------4-------------5-------------6----------7-----------8-----------9

Dissatisfied — Moderately Satisfied — Extremely Satisfied

Your Thoughts on Existing Conditions at Don Pedro Reservoir …

10. Please indicate whether or not the **level of the reservoir** or **river** was a problem for each of the following at the recreation area you are currently visiting. (Check One For Each Item)

(Circle one number for each)	Not a problem	A small problem	Neither	A moderate problem	A large problem	No Opinion/ Not Applicable
Ability to use beach area	5	4	3	2	1	❑
Ability to safely swim	5	4	3	2	1	❑
Ability to launch or take out boat	5	4	3	2	1	❑
Ability to safely boat	5	4	3	2	1	❑
Ability to utilize trails	5	4	3	2	1	❑
Ability to fish along the shoreline	5	4	3	2	1	❑
Ability to access the shoreline	5	4	3	2	1	❑
Ability to moor or dock boat	5	4	3	2	1	❑
Scenic quality of shoreline	5	4	3	2	1	❑
Other (specify):___________________	5	4	3	2	1	❑

11. A) Did you experience any **conflict** with other recreation users in Don Pedro Reservoir (*i.e.*, anyone who negatively impacted your experience)?

❑ Yes ❑ No

B) If **YES**, what was the activity of the other recreation user? (Check One)

❑ Bird watcher ❑ Motorized boater ❑ OHV (2, 3, or 4 wheels)
❑ Camper ❑ Non-motorized boater ❑ Unsure
❑ Hiker ❑ Mountain biker ❑ Other (specify): ________________________

C) If you experienced conflict, please check the reasons that contributed to the conflict. (Check All That Apply)

❑ Proximity to where we were ❑ Rowdiness ❑ Loudness ❑ Other (specify): __________________________

12. Please rate the **acceptability** of the following **Existing Conditions** at the Recreation Facility / Site you are currently visiting (*this site is identified at the start of the survey*).
Important: Please only circle a number for the items that you used during your visit to this Specific Recreation Facility / Site. Please **check** the "*Did Not Use*" box, if you did not use the item or it does not exist at the Specific Recreation Facility / Site.

FACILITIES	Acceptable	Slightly Acceptable	Neither	Slightly Unacceptable	Unacceptable	Did Not Use/ Not Applicable
Camp sites	5	4	3	2	1	❑
Camp site parking spur size	5	4	3	2	1	❑
Vegetation or screening between camp sites	5	4	3	2	1	❑
Shading of camp sites	5	4	3	2	1	❑
Picnic sites	5	4	3	2	1	❑
Vegetation or screening between picnic sites	5	4	3	2	1	❑
Shading of picnic sites	5	4	3	2	1	❑
Food storage locker	5	4	3	2	1	❑
Restroom	5	4	3	2	1	❑
Potable water	5	4	3	2	1	❑
Trash receptacle	5	4	3	2	1	❑
Vehicle parking areas	5	4	3	2	1	❑
Trailer parking areas	5	4	3	2	1	❑
Boat ramp parking area	5	4	3	2	1	❑
Boat launch/take out	5	4	3	2	1	❑
Boat mooring/docking	5	4	3	2	1	❑
Other (specify):________________________	5	4	3	2	1	❑

If you rated a condition **"unacceptable"**, please identify the item from the table & describe the location and nature of the unacceptable condition:

ACCESS	Acceptable	Slightly Acceptable	Neither	Slightly Unacceptable	Unacceptable	Did Not Use/ Not Applicable
Width of roads within the site	5	4	3	2	1	❑
Condition of roads within the site	5	4	3	2	1	❑
Foot trails to the shoreline	5	4	3	2	1	❑
Foot trails around the shoreline	5	4	3	2	1	❑
Signage to the recreation site	5	4	3	2	1	❑
Signage within the recreation site	5	4	3	2	1	❑
Other (specify):________________________	5	4	3	2	1	❑

If you rated a condition **"unacceptable"**, please identify the item from the table & describe the location and nature of the unacceptable condition

INFORMATION RESOURCES	Acceptable	Slightly Acceptable	Neither	Slightly Unacceptable	Unacceptable	Did Not Use/ Not Applicable
Interpretive/education information	5	4	3	2	1	❑
Recreation visitor information	5	4	3	2	1	❑
Reservoir water surface elevation information	5	4	3	2	1	❑
River/stream flow information	5	4	3	2	1	❑
Other (specify):________________________	5	4	3	2	1	❑

If you rated a condition **"unacceptable"**, please identify the item from the table & describe the location and nature of the unacceptable condition:

13. A) Did/do you feel **crowded** at any of the following locations during your visit to Don Pedro Reservoir today? (Circle One Number For Each Item)

LOCATION/AREA	Not At All Crowded		Slightly Crowded			Moderately Crowded		Extremely Crowded		Did Not Use/ Not Applicable
Campground	1	2	3	4	5	6	7	8	9	❑
Shoreline camping area	1	2	3	4	5	6	7	8	9	❑
Picnic area	1	2	3	4	5	6	7	8	9	❑
Boat launch	1	2	3	4	5	6	7	8	9	❑
Boat docking/mooring	1	2	3	4	5	6	7	8	9	❑
Trail	1	2	3	4	5	6	7	8	9	❑
Trailhead	1	2	3	4	5	6	7	8	9	❑
Other shoreline area	1	2	3	4	5	6	7	8	9	❑
Water surface	1	2	3	4	5	6	7	8	9	❑
Other (specify): ___________________	1	2	3	4	5	6	7	8	9	❑

B) **If you felt crowded**, did you modify your recreation plans because you felt crowded? ❑ Yes ❑ No ❑ Did Not Feel Crowded

C) If **YES,** what did you do? ❑ Moved to a new location ❑ Changed your activity ❑ Did nothing
❑ Changed the time of day ❑ Choose not to recreate ❑ Other (specify): ______________________

14. A) Are you recreating at your preferred location today? ❑ Yes ❑ No

B) If **NOT**, what was your preferred location? ____ .

C) **Why** were you unable to use or go to your preferred location? ____ .

15. A) Are there any places in Don Pedro Reservoir where you feel unsafe? ❑ Yes ❑ No

B) If **YES**, please identify why you feel unsafe. (Check All That Apply)

❑ Wild animals ❑ Unattended campfires ❑ Speeding boats/PWC ❑ Other visitors behavior (specify): _______________________
❑ Unleashed dogs ❑ Firearm discharge ❑ Speeding vehicles ❑ Other (specify): ___________________________________

C) If **YES**, please identify the location where you feel unsafe:____.

16. Are there any barriers that prevent you or a member of your group from participating in desired recreation activities at Don Pedro Reservoir?

❑ Yes ❑ No If **YES**, please identify the location(s), the type of barrier(s) in the space below.

17. A) Please rate the relative uniqueness of the **recreation opportunities** at Don Pedro Reservoir relative to similar to opportunities within central California:

Extremely Common Opportunity ◄				► Extremely Unique Opportunity
1	2	3	4	5

B) Please explain, what, if anything is **special** or **unique** about this recreation area relative to other recreation areas in central California.

About You

18. How did you learn about Don Pedro Reservoir? ❑ Word of mouth ❑ Internet ❑ Don Pedro Recreation Agency ❑ Other: ____________________

19. What is the zip code for your primary residence? _______________ **OR** ___________________.

Any Additional Comments?

20. Please let us know if you have any additional comments regarding your recreation experience during your visit in the space below.

Thank You For Taking The Time To Participate In This Survey!

-----Original Message-----
From: Shelly Schubert [mailto:SSCHUBERT@dfg.ca.gov]
Sent: Monday, October 10, 2011 12:54 PM
To: Vertucci, Charles
Subject: Re: Tuolumne River temps

Charles,

I am sending you the Tuolumne data that we have available. I know our crews have not been able to access a lot of sites until recently because of the high flows. Some of the data has not been entered. I will plan on sending you this data when we process it. I am also sending MGAL2 data for the Merced.

MGAL for the Merced is no longer a site.
A few sites on the Tuolumne are no longer being monitored also: TOLGB, TRST, and TRG2.

Shelly Schubert

>>> "Vertucci, Charles" <Charles.Vertucci@hdrinc.com> 9/29/2011 3:08 PM >>>
Shelly,

I looked at the few stations you provided for the Tuolumne and there were some more data gaps, similar to those on the Merced. I made a table below so you can see the last date from each station.

Thanks for the help.

LOCATION

Station

Start

End

Start of 9/19/11 Data

Tuolumne River at Grayson Rotary Screw Trap

TRST

1/14/00

5/28/01

Tuolumne River at Shiloh Bridge

TRSHILO1

2/16/05

3/28/10

8/9/10

Tuolumne River at Carpenter Road Bridge

TRCRDB

8/12/05

3/28/10

Tuolumne River at 9th Street Bridge

TR9STB

8/12/05

3/28/10

Dry Creek above Tuolumne River

TDRYCK

2/3/06

3/28/10

Tuolumne River above Dry Creek

TRADRY

7/25/06

3/28/10

Tuolumne River at Mitchell Road Bridge

TRMRDB

8/12/05

3/28/10

Tuolumne River above Santa Fe Bridge

TRASFB

8/12/05

2/26/10

Tuolumne River near Fox Grove Bridge

TRFGB

9/9/05

7/27/10

Tuolumne River at Hickman Bridge

THB

7/15/02

1/26/10

Tuolumne River below Hickman Spill

TBHCKSP

3/9/05

7/23/10

Tuolumne River above Hickman Spill

TAHCKSP

3/9/05

7/27/10

Tuolumne River at Riffle Q3

TRQ3

5/31/02

7/27/10

Tuolumne River at Sante Fe Gravel

TSF

5/31/02

7/27/10

Tuolumne River at 7-11 Gravel Company

T7-11

6/16/01

7/27/10

Tuolumne River at Riffle K1

TRK1

6/16/01

7/26/10

Tuolumne River at Riffle I2

TRI2

6/15/01

7/26/10

Tuolumne River at Riffle G3

TRG3

6/15/01

7/26/10

Tuolumne River at Riffle G2

TRG2

9/2/05

8/10/06

Tuolumne River at Basso Bridge

TBAS

Tuolumne River at Riffle D2

TRD2

6/14/01

7/26/10

Tuolumne River at Riffle C1

TRC1

6/14/01

7/26/10

Tuolumne River at Old La Grange Bridge

TOLGB

6/23/00

12/18/02

Tuolumne River at Riffle A1

TRA1

6/18/01

6/14/09

Tuolumne River upstream of Wards Ferry Bridge

TRWARDS

5/24/05

4/6/10

Tuolumne River above the South Fork

TASFRK

4/27/05

2/24/10

Tuolumne River below the South Fork

TBSFRK

4/27/05

7/12/10

2/1/11

Cherry Creek Power House

TCKPH

4/27/05

9/8/09

2/2/11

Tuolumne River at Early Intake

TREARLY

7/19/05

2/24/10

2/2/11

South Fork of the Tuolumne near Confluence

TSFRK

4/27/05

7/9/10

2/1/11

Charles vertucci

HDR Engineering, Inc.
Scientist - Water Resources and Aquatic Biology, Hydropower Services

2379 Gateway Oaks Drive, Suite 200 | Sacramento, CA 95833
O: 916.564.4214 | D: 916.679.8768
charles.vertucci@hdrinc.com<mailto:charles.vertucci@hdrinc.com> |
hdrinc.com<http://www.hdrinc.com/>

From: Imholt, Susan
To: Alison Willy; Cranston, Peggy; Eicher, James M
Cc: Michelle Reimers (mareimers@tid.org); Robert Nees (rmnees@tid.org); Bill Johnston ([redacted]); Steve Boyd (seboyd@tid.org); Melissa Williams (MelissaW@mid.org); Joy Warren (joyw@mid.org); Greg Dias (gregd@mid.org); Regina Cox (reginac@mid.org); Devine, John; Borovansky, Jenna; Malkin, Devin
Subject: Don Pedro Project FERC Relicensing - CRLF Site Assessment Field Notice
Date: Friday, January 06, 2012 4:32:00 PM

ESA-Listed Amphibians – California Red-legged Frog Study (Study TR-7)
Notice of Site Assessment Fieldwork

On behalf of Modesto Irrigation District and Turlock Irrigation District (the Districts), who own and operate the Don Pedro Project, HDR Engineering, Inc. (HDR) is commencing Study TR-7, ESA-Listed Amphibians – California Red-legged Frog, which includes field site assessments of aquatic habitats within the existing FERC Project Boundary and other accessible areas of potentially suitable aquatic habitat within 1.0 mile of the existing FERC Project Boundary.

The FERC-approved study plan requires the Districts provide advance notice of the field assessments and invitation to observe the field work to USFWS. Field work is scheduled to begin February 6-10, 2012, weather permitting. During this first week of fieldwork, it is anticipated that site assessments will be performed at accessible locations in the study area within the FERC Project Boundary.

HDR biologists performing the assessments can be met each day at 8:00 AM at the Best Western in Sonora, CA (19551 Hess Avenue, Sonora, California, 95370-9720, phone: 209-533-4400). Interested observers are asked to please contact Susie Imholt (office: 206-826-4693, cell: 360-318-5333) at least 1 week in advance.

Observers are asked to be prepared for work in the elements with the proper clothing, foot-wear, food, and water. Please also be aware that the terrain may be rigorous. HDR cannot provide transportation for observers due to liability constraints.

Locations and logistics of subsequent site assessments will be provided to USFWS at least 30 days in advance of field work.

If you have any questions regarding this e-mail, please contact Susie Imholt.

SUSAN IMHOLT

HDR Engineering, Inc.
Scientist - Wildlife, Fisheries, Botanical

601 Union St, Suite 700 | Seattle, WA 98101
206.826.4693 | c: 360.318.5333
susan.imholt@hdrinc.com | hdrinc.com

From: Mary Nicholl <mary.nicholl@noaa.gov>
Subject: Re: Modification to 4(d) application
Date: January 20, 2012 11:07:19 AM PST
To: Jason Guignard <Jasonguignard@fishbio.com>

Hey Jason,
That's a by-product of putting it in draft. It probably prompted you do that. I fixed it to be January again. Thanks for letting me know. Have a great weekend.

Mary

On Fri, Jan 20, 2012 at 10:47 AM, Jason Guignard <Jasonguignard@fishbio.com> wrote:
Hi Mary,
One thing that came up yesterday when I was editing the Project info.
On the 1st page it would not allow me to keep the start date as 1/1/2012, so I changed it to 2/2/2012. Don't know if this matters, but thought I should let you know.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Jan 19, 2012, at 12:41 PM, Mary Nicholl wrote:

Awesome, thank you for following up. I am making these changes now. Please review your application and make sure I have incorporated your information as requested.
Mary

On Thu, Jan 19, 2012 at 12:13 PM, Jason Guignard <Jasonguignard@fishbio.com> wrote:
We will not need to anesthetize the adults. They will be placed upside down in the measurement cradle (like we do with adults on our weirs) while samples are taken. This should work for all individuals, so anesthetize can also be removed from our permit.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.

Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Jan 19, 2012, at 12:03 PM, Mary Nicholl wrote:

What is the anesthetizing agent that will be used? Please note that adult salmonids may not be anesthetize with MS-222 because of a 21-day hold.

On Thu, Jan 19, 2012 at 12:00 PM, Jason Guignard <Jasonguignard@fishbio.com> wrote:

Hi Mary,

You can remove the acoustic tagging procedures, and change the Project title to scale collection and age determination. Below are our sampling methods, let me know if you nedd any additional information.

Methods: Juvenile and adult *O. mykiss* will be captured in the Tuolumne River at selected locations from RM 52 (La Grange Dam) downstream to approximately RM 39.5 (Roberts Ferry Bridge), which is the portion of the river where *O. mykiss* have been historically observed (Stillwater Sciences 2011).

The survey crew will record the location (GPS coordinates), habitat type, and length of each captured *O. mykiss*. Fish will be transferred to a measurement cradle and data recorded for all fish meeting the required length criterion, including fork length (FL, mm), total length (TL, mm), and general condition. If possible, the sex of each fish will be determined, and any marks that would aid in determining hatchery vs. wild origin (e.g., adipose fin clip) will be noted.

Scales will be removed from the region between the posterior end of the dorsal fin and the lateral line on the left side, roughly two scale rows above the lateral line. Prior to scale removal, mucous and debris will be cleaned from the sampling location for ease in scale processing. Scales will be removed by scraping a dull knife from the posterior to anterior of the sample area. Approximately 10 scales will be removed per fish.

All collected scales from individual fish will be placed on a square of “Rite in the Rain” paper. The paper will be folded over the blade and pinched to remove the scales. The folded paper will be immediately inserted into an envelope. Each individual envelope will be clearly labeled with species, site location, fork length, weight, date, condition, and any other applicable information. All envelopes will be pressed flat to reduce scale curling and increase analytical accuracy. Only one envelope will be used for each fish. Knives will then be thoroughly cleaned with ethanol to prevent cross-contamination of scale samples.

Jason Guignard

Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Jan 19, 2012, at 11:45 AM, Mary Nicholl wrote:

Hey Crissy,

To clarify you will not be acoustically tagging any fish under this permit, may I remove that procedure from the two lines of take that you have it under? Also, should I remove it from the title of the project and replace it with age data? I will add the scale sampling procedure and anesthetizing to your permit. However, You will need to provide a paragraph for the methods section that details how the fish (each life stage) will be processed as soon as possible. We are trying to avoid moving the applications into draft. Please provide this information as soon as possible I will follow up with you once it is complete.

Mary

On Thu, Jan 19, 2012 at 11:34 AM, Jeffrey Jahn <jeffrey.jahn@noaa.gov> wrote:
Chrissy,
Mary should be able to make the requested updates and will follow up with you if more info is needed.

From,

Jeff

Jeffrey Jahn
Fishery Biologist ~
Regional ESA Research & Enhancement Coordinator

NOAA's National Marine Fisheries Service
Southwest Region, Protected Resources Division
North Central Coast Office
777 Sonoma Avenue, Room 325
Santa Rosa, California 95404

Phone: 707-575-6097, Fax: 707-578-3435

HOME EMAIL ADDRESS REMOVED PER SECTION 2.4.3 DON PEDRO PAD

"Our mission is to conserve and recover NOAA's National Marine Fisheries Service's trust resources and the ecosystems upon which they depend"

On Thu, Jan 19, 2012 at 10:21 AM, Chrissy Sonke <sonke[redacted] > wrote:
Hi Jeff,

How do I go about modifying one of our 2012 4(d) applications? I don't think the on-line system allows for modification requests since the 2012 permit has not yet been issued. The Tuolumne River Acoustic Tracking Study (file # 16875) is currently permitted for a total take of 85 *O. mykiss*. We do not need to increase the take or the method of take, we would just like to change the procedures. Our recent tracking data results indicate a large majority of the Tuolumne River *O. mykiss* reside in-river. We would like to change the focus of the study and collect some age growth data. For this, we are requesting to change the procedures for all fish captured under this permit to allow anesthetize and collect a scale sample for scale sample analysis. We will not acoustically tag any additional fish in 2012. We would only like to obtain scale samples from all fish captured by hook-and-line.

Please let me know if there is anything additional you need from me to complete this request.

Thank you!
Chrissy

Chrissy Sonke
Fisheries Biologist

FISHBIO
9330 E. Lathrop Rd.
Manteca, CA 95336

209.614.0813

www.fishbio.com

--
Mary Nicholl

Contractor - Research Permits
NOAA's National Marine Fisheries Service
Southwest Region, Protected Resources Division
777 Sonoma Avenue, Room 325
Santa Rosa, CA. 95404
(707) 575-6054, Fax (707) 578-3435

From: Sunil Rajappa <SRAJAPPA@dfg.ca.gov>
Subject: Re: SCP amendments
Date: January 26, 2012 10:38:57 AM PST
To: Jason Guignard <jasonguignard@fishbio.com>
Cc: Jamie Cary <JCARY@dfg.ca.gov>

We'll keep an eye out for them.

Jason Guignard <jasonguignard@fishbio.com> 1/26/2012 8:07 AM >>>
Hi Sunil,

We mailed another package of SCP amendments yesterday. These amendments are for a "Tuolumne River Predation Study", which is part of the FERC relicensing of the Don Pedro Project. This Project includes boat electrofishing in the Tuolumne River to determine predator abundance and predation rates on Chinook salmon. We will be working with Stillwater Sciences who has a Section 10 permit (#1282), which allows boat electrofishing during the proposed sampling periods.
Like the previous SCP amendments we submitted, this FERC project has a short timeline which will require us to begin sampling in March (if permitted).

I just wanted to make you aware of these amendments, and hope that these amendments can be pushed through a quickly as possible. The local DFG biologists (Tim Heyne & Steve Tsao, La Grange) are aware of this study, please contact me if you have any questions or concerns.

Thank You,

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

From: Sunil Rajappa <SRAJAPPA@dfg.ca.gov>
Subject: Re: Tuolumne River Predation Study SCP amendments
Date: February 14, 2012 10:20:48 AM PST
To: Jason Guignard <jasonguignard@fishbio.com>
Cc: Jamie Cary <JCARY@dfg.ca.gov>

Jason,

My colleague Jamie is currently working on your permits. I'll have her update us tomorrow.

Sunil

Sunil Rajappa
Scientific Aide
Fisheries Branch
California Department of Fish and Game
830 S Street
Sacramento, CA 95811
916.327.8335

Jason Guignard <jasonguignard@fishbio.com> 2/14/2012 9:56 AM >>>
Hi Sunil,

I wanted to check on the status of the SCP amendment package I submitted for the "Tuolumne River Predation Study". Can you tell me if these are being processed, and possibly a timeframe for us to expect them to be completed?
This study is fairly time sensitive, with sampling scheduled to begin in March.
Any information you could give me regarding the status of these amendments would be very much appreciated.

Thank You

Jason Guignard
Fisheries Biologist

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1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

HOME EMAIL ADDRESS REMOVED PER SECTION 2.4.3 DON PEDRO PAD

From:	Imholt, Susan
To:	Alison Willy; "Cranston, Peggy"; Eicher, James M
Cc:	Michelle Reimers (mareimers@tid.org); Robert Nees (rmnees@tid.org); Bill Johnston (Agengr[redacted]a[redacted]; Steve Boyd (seboyd@tid.org); Melissa Williams (MelissaW@mid.org); Joy Warren (joyw@mid.org); Greg Dias (gregd@mid.org); Regina Cox (reginac@mid.org); Devine, John; Borovansky, Jenna; Malkin, Devin
Subject:	Don Pedro Project FERC Relicensing - CRLF Site Assessment Field Notice
Date:	Tuesday, February 28, 2012 12:16:00 PM

ESA-Listed Amphibians – California Red-legged Frog Study (Study TR-7)
Notice of Continuation of Site Assessment Fieldwork

On behalf of Modesto Irrigation District and Turlock Irrigation District (the Districts), who own and operate the Don Pedro Project, HDR Engineering, Inc. (HDR) is continuing fieldwork for Study TR-7, ESA-Listed Amphibians – California Red-legged Frog Study, which includes field site assessments of aquatic habitats within the existing FERC Project Boundary and other accessible areas of potentially suitable aquatic habitat within 1.0 mile of the existing FERC Project Boundary.

The FERC-approved study plan requires the Districts provide advance notice of the field assessments and invitation to observe the field work to USFWS. Field work is scheduled to occur April 2 - 4, 2012, weather permitting. It is anticipated that site assessments will be performed at accessible locations in the study area outside of the FERC Project Boundary. Site assessment locations have not yet been finalized, but it is anticipated that some locations will be located on BLM land.

HDR biologists performing the assessments can be met each day at 8:00 AM at the Best Western in Sonora, CA (19551 Hess Avenue, Sonora, California, 95370-9720, phone: 209-533-4400). Interested observers are asked to please contact Susie Imholt (office: 206-826-4693, cell: 360-318-5333) at least 1 week in advance.

Observers are asked to be prepared for work in the elements with the proper clothing, footwear, food, and water. Please also be aware that the terrain may be rigorous. HDR cannot provide transportation for observers due to liability constraints.

Locations and logistics of subsequent site assessments will be provided to USFWS at least 30 days in advance of field work.

If you have any questions regarding this e-mail, please contact Susie Imholt.

SUSAN IMHOLT

HDR Engineering, Inc.
Scientist - Wildlife, Fisheries, Botanical

601 Union St, Suite 700 | Seattle, WA 98101
206.826.4693 | c: 360.318.5333
susan.imholt@hdrinc.com | hdrinc.com

From: Jason Guignard <jasonguignard@fishbio.com>
Subject: Re: SCP's
Date: February 29, 2012 2:57:32 PM PST
To: Jamie Cary <JCARY@dfg.ca.gov>, spu@dfg.ca.gov

Attached are the SCP amendments for Jeremy Pombo and Robert Fuller.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Feb 29, 2012, at 2:45 PM, Jamie Cary wrote:

Jason, When you send Jeremy's SCP can you also send Rob Fuller's? I don't have a complete copy of his SCP so LRB can't take what I have.

Sorry for all this.

Jamie

>>> Jason Guignard <jasonguignard@fishbio.com> 2/28/2012 12:08 PM >>>
Thank you Jamie. Jeremy Pombo and Mike Kersten's permits had recently expired, but the renewals have been submitted.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Feb 28, 2012, at 11:51 AM, Jamie Cary wrote:

I did not hear back from the biologist but I had my supervisor review and I am in the process of approving them. It looks like Jeremy Pombo's (8035) was just submitted? Is that right? I've been working off of Robert Fuller's.

They should be done today or tomorrow and then they are in the hands of the LRB to finish processing (not sure how long that takes).

Jamie

>>> Jason Guignard <jasonguignard@fishbio.com> 2/28/2012 10:13 AM >>>
Hi Jamie,
Have you been updated by the regional biologist regarding our SCP amendment? Our proposed sampling start date is quickly approaching, so want to make sure this is still moving forward.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Feb 16, 2012, at 10:18 AM, Jamie Cary wrote:

Hi Jason

I'm working on getting your SCP's processed. They are being reviewed by the regional biologist; who I emailed yesterday asking for an update. I will contact them again and tell them we need to process these quickly.

Thanks

Jamie

From: Jason Guignard <jasonguignard@fishbio.com>
Subject: Re: SCP's
Date: March 5, 2012 3:37:29 PM PST
To: Jamie Cary <JCARY@dfg.ca.gov>, spu@dfg.ca.gov

Attached are the SCPs for Robert Fuller & Jeremy Pombo. Jeremy's SCP expired in October, and his renewal package was mailed in early Feb (also attached).

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Mar 5, 2012, at 1:51 PM, Jamie Cary wrote:

Jason

Hello, I'm so sorry. I don't think I was very clear the last time we spoke. I need a copy of Robert Fuller's **entire** SCP permit sent to the LRB (not just the amendment). For some reason they have no hardcopy of his complete file.

It'll come together soon

Jamie

>>> Jason Guignard <jasonguignard@fishbio.com> 2/29/2012 2:57 PM >>>
Attached are the SCP amendments for Jeremy Pombo and Robert Fuller.

From: Gina De La Rosa <GDELAROSA@dfg.ca.gov>
Subject: Re: SCP's
Date: March 5, 2012 3:42:49 PM PST
To: Jason Guignard <jasonguignard@fishbio.com>

Good news all the SCP's that need to be expedited have been scanned in, this includes Jeremy's also.

Gina de la Rosa
Program Technician II
Special Permits Unit
CA. Dept of Fish and Game
License and Revenue Branch
gdelarosa@dfg.ca.gov
Office 916-928-5849
fax 916-419-7586

>>> Jason Guignard <jasonguignard@fishbio.com> 3/5/2012 3:37 PM >>>
Attached are the SCPs for Robert Fuller & Jeremy Pombo. Jeremy's SCP expired in October, and his renewal package was mailed in early Feb (also attached).

From: Jim Inman <jiminman@fishbio.com>
Subject: Fwd: SCP's
Date: March 6, 2012 9:55:20 AM PST
To: JCARY@dfg.ca.gov
Cc: Jason Guignard <jasonguignard@fishbio.com>

Hi Jamie,

Jason is out of the office today so he asked me to help you with this. I have attached Robert Fuller's current SCP (permanent ID SC-911) pages 1-4. It is valid from 4-13-11 to 4-13-13, it has a CDFG stamp as well as a signature on page 1. Please let me know if you have any other questions.

Jim

Begin forwarded message:

From: Jamie Cary <JCARY@dfg.ca.gov>
Date: March 6, 2012 9:31:07 AM PST
To: Jason Guignard <jasonguignard@fishbio.com>
Subject: Re: SCP's

Was Robert issued a permit w/approval signatures on it? It should also have a stamp saying how long the permit is valid for (on the first page).

>>> Jason Guignard <jasonguignard@fishbio.com> 3/5/2012 8:53 PM >>>
Jaime,
Here is Robert's approved SCP. I believe this is what you are looking for, but if you need something else please let me know.

Jim Inman
Wildlife Biologist
FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 988-2314 cell
www.fishbio.com

From:	Imholt, Susan
To:	"Cranston, Peggy"
Cc:	Eicher, James M; Devine, John; Borovansky, Jenna
Subject:	Don Pedro herp record request
Date:	Thursday, March 08, 2012 3:42:00 PM

Hi Peggy,

I hope you are doing well.

For the Don Pedro Project Special-Status Amphibian and Aquatic Reptiles, CA Red-legged Frog, and CA Tiger Salamander studies, I wanted to ask if BLM has any records of western pond turtle, foothill yellow-legged frog, CRLF or CTS in the vicinity of the project.

If you have GIS shapefiles with this information or locations on a map, that would be wonderful.

Also, we will be conducting reconnaissance for FYLF and WPT in early April (as well as finishing CRLF and CTS habitat assessments); I will send out an email notice of field locations we will be visiting that occur on BLM land prior to that fieldwork.

Thank you,
Susie

SUSAN IMHOLT

HDR Engineering, Inc.
Scientist - Wildlife, Fisheries, Botanical

601 Union St, Suite 700 | Seattle, WA 98101
206.826.4693 | c: 360.318.5333
susan.imholt@hdrinc.com | hdrinc.com

Tortosa, Justin

From: Cranston, Peggy [pcransto@blm.gov]
Sent: Friday, March 09, 2012 12:22 PM
To: Tortosa, Justin
Subject: RE: Don Pedro LTAM site locations

Hi Justin,

These sites seem reasonable.

Take Care

Peggy Cranston
Wildlife Biologist
BLM, Mother Lode Field Office
5152 Hillsdale Circle
El Dorado Hills, CA 95762
(916) 941-3136

From: Tortosa, Justin [mailto:Justin.Tortosa@hdrinc.com]
Sent: Friday, March 09, 2012 12:04 PM
To: Cranston, Peggy
Cc: Borovansky, Jenna
Subject: Don Pedro LTAM site locations

Peggy,

Thanks for Allison's contact information, I will call her right away.

As we discussed, I pulled together some maps (quick and crude) of the LTAM sites, and they are attached. One is an overview map (Don Pedro LTAM sites) and the other two are close-ups of the sites (LTAM below spillway and LTAM at base of Dam tunnel entrance). Like I had mentioned on the phone our choices are pretty limited with respect to equipment security and habitat diversity occurring in such close proximity to each other. I really feel that these two locations offer two very different habitat types (small open body of water and deep canyon) that are common around this project, and yet in this case happen to be close to secure Project facilities. Please let me know if you agree with the two locations.

Respectfully,

JUSTIN TORTOSA | **HDR Engineering, Inc.**
Senior Wildlife Biologist

2379 Gateway Oaks Dr. Suite 200 | Sacramento, CA 95833
D: 916.679.8766
justin.tortosa@hdrinc.com| hdrinc.com

From: Cranston, Peggy [mailto:pcransto@blm.gov]
Sent: Friday, March 09, 2012 11:37 AM

To: Tortosa, Justin
Subject: alison wily contact info

Hi Justin,

Here is Alison Willy's contact information. Alison_Wily@fws.gov and (916) 414—6534.

Take Care

Peggy Cranston
Wildlife Biologist
BLM, Mother Lode Field Office
5152 Hillsdale Circle
El Dorado Hills, CA 95762
(916) 941-3136

From: Tortosa, Justin
To: Cranston, Peggy
Cc: Borovansky, Jenna
Subject: Don Pedro Bald Eagles
Date: Wednesday, March 14, 2012 4:11:57 PM

Peggy,

I just wanted to touch base with you and let you know that we are planning to do our first bald eagle nesting survey next week for the Don Pedro Project. In the study plan there is mention of at least 6 historic nests, most in the southern half of the reservoir. I was wondering if you have any additional information regarding the exact location of these nests so that we can be sure not to miss them during our survey.

Thanks, and I look forward to hearing back from you.

Respectfully,

JUSTIN TORTOSA

HDR Engineering, Inc.
Senior Wildlife Biologist

2379 Gateway Oaks Dr. Suite 200 | Sacramento, CA 95833
D: 916.679.8766
justin.tortosa@hdrinc.com| hdrinc.com

From: Jamie Cary <JCARY@dfg.ca.gov>
Subject: Re: Tuolumne Predation SCP amendment
Date: March 15, 2012 2:15:27 PM PDT
To: <jasonguignard@fishbio.com>

I checked w/my supervisor about the two weeks sampling period and you get two weeks for each of your sampling activities. As for getting you the permits the LRB said that after I finish them tomorrow morning and approve them then they can email them to you tomorrow and you can print them up. So you should be good for your Monday sampling.

Jason Guignard <jasonguignard@fishbio.com> 03/15/12 10:30 AM >>>
Hi Jamie,
I just wanted to check in on the status of our permits and the possibility of us beginning our sampling next week.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Mar 13, 2012, at 4:54 PM, Jamie Cary wrote:

Jason,

I'll check with my supervisor tomorrow about the sampling dates. I've also asked LRB if they can email you the pdf's of your permits once they process them (hopefully on Friday) so that you can have them for Monday. I'll let you know tomorrow once I hear back from everyone.

Jamie

Jason Guignard <jasonguignard@fishbio.com> 03/13/12 10:22 AM >>>
Hi Jamie,
Is the limit of 2 weeks sampling for each activity or for the entire Project? We have 3 sample periods planned (1) predation rate in March, (2) predation rate in April/May, and (3) predator abundance in July-Sept. Each of these activities were scheduled for ~10 days each, but we may have to make changes if we are limited to 2 weeks total.

Also, if you finish processing these today will we have them by monday? If not, is it possible for us to work off of a verbal agreement?

Thank You,

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Mar 12, 2012, at 9:18 AM, Jamie Cary wrote:

Jason

I'm processing the predation study amendments today and tomorrow (they should be done tomorrow). One of the conditions is that you are authorized only 2 weeks of sampling (after your start date). The other one is that you must get written permission from Steve Tsao for EACH electroshocking activity.

Jamie

Jason Guignard <jasonguignard@fishbio.com> 3/12/2012 7:39 AM >>>
Jamie,
What is your phone number? I am in the field today but will try to have someone call you. Pombo and Fuller will only be needed for the predation study.

Jason Guignard
FISHBIO

Sent from my iPhone

On Mar 12, 2012, at 7:36 AM, Jamie Cary <JCARY@dfg.ca.gov> wrote:

Hi Jason,

Would it be possible for you to call me today before 9 am? I have been focusing on your amendments that are for the Don Pedro Project/FERC project since that was the one we received first. I haven't even had a chance to review the predation study yet. I see that Robert Fuller's permit is now in the system but is only for the predation study. Is he not involved with the other project? For the Don Pedro Project I have Tim Leigh, Mike Phillips, and Scott Wucherer. Will you need Pombo and Fuller to have a permit for this study or only the predation study?

Jason Guignard <jasonguignard@fishbio.com> 3/7/2012 3:25 PM >>>
Hi Jaime,

With the problems we have had with Robert's incomplete SCP, do you think there is any chance that we will have the amendment for the Tuolumne River Predation Study in the next week?
The study calls for 2 weeks of sampling in March, so we would need to start sampling on March 19th.
I appreciate your effort to try expediting this process, but I am at a point that I need to call off the march sampling if our permits will no be ready.

Thanks,

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

From: Jamie Cary <JCARY@dfg.ca.gov>
Subject: Re: Tuolumne Predation SCP amendment
Date: March 16, 2012 8:29:12 AM PDT
To: Jason Guignard <jasonguignard@fishbio.com>

Jason

I wanted to give you a heads up regarding the conditions Steve Tsao placed on your permits. You are required to email confirmation from either him or Tim Heyne prior to each electrofishing activty. After your first e-fishing event you need to include all fish caught in subsequent emails. You will also have 2 weeks for each sampling event.

So I'd recommend getting in touch with him today regarding your Monday activites.

Jamie

>>> Jason Guignard <jasonguignard@fishbio.com> 3/13/2012 10:21 AM >>>
Hi Jamie,
Is the limit of 2 weeks sampling for each activity or for the entire Project? We have 3 sample periods planned (1) predation rate in March, (2) predation rate in April/May, and (3) predator abundance in July-Sept. Each of these activities were scheduled for ~10 days each, but we may have to make changes if we are limited to 2 weeks total.
Also, if you finish processing these today will we have them by monday? If not, is it possible for us to work off of a verbal agreement?

Thank You,

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Mar 12, 2012, at 9:18 AM, Jamie Cary wrote:

Jason

I'm processing the predation study amendments today and tomorrow (they should be done tomorrow). One of the conditions is that you are authorized only 2 weeks of sampling (after your start date). The other one is that you must get written permission from Steve Tsao for EACH electroshocking activity.

From: Jason Guignard <JASONGUIGNARD@FISHBIO.COM>
Subject: Re: Amendment Approved!
Date: March 21, 2012 1:04:12 PM PDT
To: Nicole Stowe <NSTOWE@dfg.ca.gov>

Hi Nicole,

Rob Fuller did not receive an SCP amendment for the Tuolumne Predation study in his email. Could you please send a copy of his amendment to me in case it is an issue with his email address.

Thanks You,

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Mar 16, 2012, at 4:39 PM, Nicole Stowe wrote:

Attached is your approved amendment, please read carefully as your amendment may not have been approved for all your requests. Please attach your amendment form to the back of your permit when collecting.

Thanks!

From: Domenic Giudice <dgiudice@dfg.ca.gov>
Subject: Re: Tuolumne predation rate sampling
Date: March 21, 2012 9:43:06 AM PDT
To: Steve Tsao <STSAO@dfg.ca.gov>
Cc: <jasonguignard@fishbio.com>

Sounds good Steve, I will get to the office in Oakdale at 5 and Friday.

Steve Tsao 03/21/12 8:30 AM >>>
Jason,

Domenic Giudice will work with you on Friday night and Gretchen Murphey will work with you on Saturday night.

H. Steve Tsao
Environmental Scientist(Marine/Fisheries)
California Dept. of Fish and Game
Tuolumne River Restoration Center
P.O. Box 10 La Grange, CA 95329
(209) 853-2533 ext. 6#
Fax:(209) 853-9017

Jason Guignard <jasonguignard@fishbio.com> 3/19/2012 11:28 AM >>>
Steve,
We will likely be meeting here at the shop around 5:00 each afternoon, and will likely be out until 2 or 3 am each morning. Please let me know who and when you will have staff coming out ASAP so that we can work them into our schedule.

Thanks

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
(209) 847-6300 office
(209) 840-9019 cell
www.fishbio.com

On Mar 19, 2012, at 11:16 AM, Steve Tsao wrote:

Andrea,

Any staff we send to work with your crew on this sampling will work as hard as your crew. Please provide me with time and place to meet for this sampling. I will let you know who we will send by tomorrow.

Thank you

H. Steve Tsao
Environmental Scientist(Marine/Fisheries)
California Dept. of Fish and Game
Tuolumne River Restoration Center
P.O. Box 10 La Grange, CA 95329
(209) 853-2533 ext. 6#
Fax:(209) 853-9017

Andrea Fuller <andreafuller11@comcast.net> 3/19/2012 10:53 AM >>>
Hi Steve,

All of the sampling will occur at night. Since we are limited on space, anyone participating in the sampling will need to be an active member of the crew for the duration of the sampling that night. Please let us know who and when so we can plan accordingly.

Thanks,
Andrea

-----Original Message-----
From: Steve Tsao [mailto:STSAO@dfg.ca.gov]
Sent: Monday, March 19, 2012 9:48 AM
To: Tim Heyne; Jason Guignard
Cc: Andrea Fuller; John Devine
Subject: Re: Tuolumne predation rate sampling

Jason,

Will all sampling occur at night? We also would like to send some staff out to participate the shocking for few days.

Thanks

H. Steve Tsao
Environmental Scientist(Marine/Fisheries)
California Dept. of Fish and Game
Tuolumne River Restoration Center

P.O. Box 10 La Grange, CA 95329
(209) 853-2533 ext. 6#
Fax:(209) 853-9017

Jason Guignard <jasonguignard@fishbio.com> 3/19/2012 9:35 AM >>>
Hi Steve,

We received our SCP amendment for the Tuolumne Predation Study on Friday. We plan to begin the predation rate sampling on Thursday (3/22), and sample nightly through the 29th. Sampling will occur at 12 sites between Hickman Bridge and Santa Fe Bridge.

Jason Guignard
Fisheries Biologist

FISHBIO
1617 S. Yosemite Ave.
Oakdale, CA 95361
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www.fishbio.com

APPENDIX H

Final Report

Chinook Salmon Otolith Study

E-Filed with FERC February 2016

WATER & POWER
Serving Central California since 1887

Modesto Irrigation District
The Power to Grow

February 8, 2016

Filed via Electronic Submittal (E-File)

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Subject: Don Pedro Hydroelectric Project, FERC Project No. 2299
Submittal of Final Chinook Salmon Otolith Study Report (W&AR-11)

Dear Secretary Bose:

On March 16, 2015, Turlock Irrigation District and Modesto Irrigation District (collectively, the "Districts"), co-licensees of the Don Pedro Hydroelectric Project on the Tuolumne River, provided the draft Chinook Salmon Otolith Study Report (W&AR-11) to relicensing participants for a 30-day review and comment period. On April 14, 2015, comments were received from Dr. Rachel Johnson, who oversaw the Chinook Salmon Otolith Study laboratory analysis. On April 23, 2015, the U.S. Fish and Wildlife Service provided comments. The Districts have reviewed all comments. Responses to comments from Dr. Johnson and the U.S. Fish and Wildlife Service are provided in an errata sheet and Attachment B, respectively. In addition, revisions to the study report were made based on the comments.

The Districts herewith file with FERC the final Chinook Salmon Otolith Study Report. If you have any questions about this filing, please contact the undersigned at the addresses and telephone numbers listed below.

Sincerely,

Steve Boyd
Turlock Irrigation District
P.O. Box 949
Turlock, CA 95381
(209) 883-8364
seboyd@tid.org

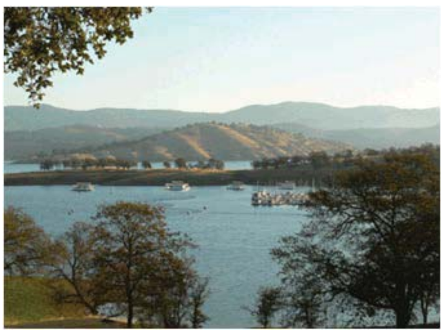
Greg Dias
Modesto Irrigation District
P.O. Box 4060
Modesto, CA 95352
(209) 526-7566
gregd@mid.org

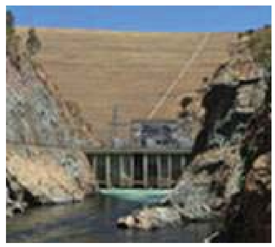
cc: Relicensing Participants E-Mail List

Attachment: Chinook Salmon Otolith Study Report (W&AR-11)

CHINOOK SALMON OTOLITH STUDY

STUDY REPORT
DON PEDRO PROJECT
FERC NO. 2299





Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
Stillwater Sciences

February 2016

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This study has involved the cooperation and participation of the
California Department of Fish and Wildlife
and Dr. Rachel Johnson and Dr. Anna Sturrock
at the University of California Davis,
Department of Animal Science.

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Errata Sheet

The following changes were made to the draft study report in response to comments provided by Dr. Rachel Johnson (University of California, Davis), who oversaw the laboratory analysis conducted for W&AR-11.

Section 5.2, pages 5-11 to 5-12, various. Language to clarify that otolith data have been used to *estimate* juvenile outmigrant age, size, and growth rates, such that the reader does not misinterpret study results as actual juvenile outmigration size data rather than a reconstruction of the early life history of surviving adults.

Section 5.3.2, pages 5-20 to 5-33, including new figures 5.3-4 to 5.3-9. Inclusion of juvenile outmigrant monitoring data corresponding to water years (WYs) represented in the study, in order to better support statements about emigration patterns and variations in phenotypic contributions estimated from otolith data.

Section 6.3, page 6-3. Clarification of study findings regarding the low representation of early emigrating fry contributions to subsequent escapement.

Section 6.3, page 6-3. Reference to recent study results from the Stanislaus River, California, regarding phenotypic contributions to escapement during wet and dry water year types, as further context for the Tuolumne River results reported in this study.

Chinook Salmon Otolith Study
Study Report

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List of Acronyms

ac ....acres
ACEC.........................Area of Critical Environmental Concern
AF ....acre-feet
ACOE.........................U.S. Army Corps of Engineers
AFY............................acre-feet per year
ADA...........................Americans with Disabilities Act
ALJ.............................Administrative Law Judge
APE............................Area of Potential Effect
ARMR........................Archaeological Resource Management Report
BA..............................Biological Assessment
BAWSCA ....Bay Area Water Supply Conservation Agency
BDCP ....Bay-Delta Conservation Plan
BEA............................Bureau of Economic Analysis
BLM...........................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI............................Benthic macroinvertebrates
BMP ....Best Management Practices
BO.............................Biological Opinion
CAISO........................California Independent System Operators
CalEPPC ....California Exotic Pest Plant Council
CalSPA.......................California Sports Fisherman Association
CALVIN ....California Value Integrated Network
CAS............................California Academy of Sciences
CASFMRA ....California Chapter of the American Society of Farm Managers and Rural Appraisers
CCC............................Criterion Continuous Concentrations
CCIC ....Central California Information Center
CCSF..........................City and County of San Francisco
CCVHJV....................California Central Valley Habitat Joint Venture
CD.............................Compact Disc
CDBW........................California Department of Boating and Waterways

CDEC........................California Data Exchange Center
CDFA........................California Department of Food and Agriculture
CDFG........................California Department of Fish and Game (as of January 2013, Department of Fish and Wildlife)
CDMG.......................California Division of Mines and Geology
CDOF........................California Department of Finance
CDP...........................Census Designated Place
CDPH........................California Department of Public Health
CDPR........................California Department of Parks and Recreation
CDSOD.....................California Division of Safety of Dams
CDWR.......................California Department of Water Resources
CE ....California Endangered Species
CEII...........................Critical Energy Infrastructure Information
CEQA........................California Environmental Quality Act
CESA ....California Endangered Species Act
CFR...........................Code of Federal Regulations
cfs..............................cubic feet per second
CGS...........................California Geological Survey
CMAP ....California Monitoring and Assessment Program
CMC..........................Criterion Maximum Concentrations
CNDDB.....................California Natural Diversity Database
CNPS.........................California Native Plant Society
CORP ....California Outdoor Recreation Plan
CPI ....Consumer Price Index
CPUE ....Catch Per Unit Effort
CRAM.......................California Rapid Assessment Method
CRLF.........................California Red-Legged Frog
CRRF ....California Rivers Restoration Fund
CSAS.........................Central Sierra Audubon Society
CSBP.........................California Stream Bioassessment Procedure
CT ....Census Tract
CT ....California Threatened Species
CTR...........................California Toxics Rule

CTS ....California Tiger Salamander
CUWA ....California Urban Water Agency
CV ....Contingent Valuation
CVP............................Central Valley Project
CVPIA........................Central Valley Project Improvement Act
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWD ....Chowchilla Water District
CWHR........................California Wildlife Habitat Relationship
CWT...........................hundredweight
Districts ....Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA.........................Don Pedro Recreation Agency
DO.............................Dissolved Oxygen
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity
EDD ....Employment Development Department
EFH............................Essential Fish Habitat
EIR ....Environmental Impact Report
EIS..............................Environmental Impact Statement
ENSO ....El Nino – Southern Oscillation
EO ....Executive Order
EPA ............................U.S. Environmental Protection Agency
ERS ....Economic Research Service (USDA)
ESA ....Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU ....Evolutionary Significant Unit
ET...............................Evapotranspiration
EVC............................Existing Visual Condition
EWUA........................Effective Weighted Useable Area
FEMA ....Federal Emergency Management Agency
FERC..........................Federal Energy Regulatory Commission

FFS............................Foothills Fault System
FL..............................Fork length
FMU..........................Fire Management Unit
FMV..........................Fair Market Value
FOT...........................Friends of the Tuolumne
FPC...........................Federal Power Commission
FPPA.........................Federal Plant Protection Act
FPC...........................Federal Power Commission
ft................................feet
ft/mi...........................feet per mile
FWCA.......................Fish and Wildlife Coordination Act
FYLF.........................Foothill Yellow-Legged Frog
g.................................grams
GAMS.......................General Algebraic Modeling System
GIS............................Geographic Information System
GLO..........................General Land Office
GPM..........................Gallons per Minute
GPS...........................Global Positioning System
HCP...........................Habitat Conservation Plan
HHWP.......................Hetch Hetchy Water and Power
HORB.......................Head of Old River Barrier
HPMP........................Historic Properties Management Plan
ILP............................Integrated Licensing Process
IMPLAN...................Impact analysis for planning
I-O.............................Input-Output
ISR............................Initial Study Report
ITA............................Indian Trust Assets
kV.............................kilovolt
LTAM.......................Long-Term Acoustic Monitoring
LTR...........................Lower Tuolumne River
m...............................meters
M&I...........................Municipal and Industrial
MCL..........................Maximum Contaminant Level

mg/kg ....milligrams/kilogram
mg/L...........................milligrams per liter
mgd ....million gallons per day
mi ....miles
mi^2 ....square miles
MID............................Modesto Irrigation District
MOU ....Memorandum of Understanding
MRP ....Monitoring and Reporting Program
MRWTP.....................Modesto Regional Water Treatment Plant
MSCS.........................Multi-Species Conservation Strategy
msl..............................mean sea level
MVA ....Megavolt Ampere
MW ....megawatt
MWh ....megawatt hour
mya.............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAICS........................North America Industrial Classification System
NAS............................National Academy of Sciences
NASS ....National Agricultural Statistics Service (USDA)
NAVD 88...................North American Vertical Datum of 1988
NAWQA ....National Water Quality Assessment
NCCP ....Natural Community Conservation Plan
NEPA ....National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NMP...........................Nutrient Management Plan
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent

NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP.........................National Register of Historic Places
NRI.............................Nationwide Rivers Inventory
NTU ....Nephelometric Turbidity Unit
NWI............................National Wetland Inventory
NWIS ....National Water Information System
NWR ....National Wildlife Refuge
NGVD 29 ....National Geodetic Vertical Datum of 1929
O&M ....operation and maintenance
OEHHA......................Office of Environmental Health Hazard Assessment
OID ....Oakdale Irrigation District
ORV ....Outstanding Remarkable Value
PAD............................Pre-Application Document
PDO............................Pacific Decadal Oscillation
PEIR ....Program Environmental Impact Report
PGA............................Peak Ground Acceleration
PHG............................Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF............................Probable Maximum Flood
PMP............................Positive Mathematical Programming
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb.............................parts per billion
ppm ....parts per million
PSP.............................Proposed Study Plan
QA..............................Quality Assurance
QC ....Quality Control
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ...............U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RMP ....Resource Management Plan
RP...............................Relicensing Participant

RR ....Recreation Resources
RSP ....Revised Study Plan
RST ....Rotary Screw Trap
RWF...........................Resource-Specific Work Groups
RWG ....Resource Work Group
RWQCB....................Regional Water Quality Control Board
SC...............................State candidate for listing under CESA
SCD............................State candidate for delisting under CESA
SCE ....State candidate for listing as endangered under CESA
SCT ....State candidate for listing as threatened under CESA
SD1 ....Scoping Document 1
SD2 ....Scoping Document 2
SE...............................State Endangered Species under the CESA
SFP.............................State Fully Protected Species under CESA
SFPUC ....San Francisco Public Utilities Commission
SHPO ....State Historic Preservation Office
SIC ....Standard Industry Classification
SJR.............................San Joaquin River
SJRA ....San Joaquin River Agreement
SJRGA ....San Joaquin River Group Authority
SJTA ....San Joaquin River Tributaries Authority
SPD ....Study Plan Determination
SRA............................State Recreation Area
SRMA ....Special Recreation Management Area or Sierra Resource Management Area (as per use)
SRMP.........................Sierra Resource Management Plan
SRP ....Special Run Pools
SSC ....State species of special concern
ST...............................California Threatened Species under the CESA
STORET ....Storage and Retrieval
SWAMP.....................Surface Water Ambient Monitoring Program
SWAP ....Statewide Agricultural Model
SWE ....Snow-Water Equivalent

SWP ....State Water Project
SWRCB......................State Water Resources Control Board
TAC............................Technical Advisory Committee
TAF ....thousand acre-feet
TC ....Travel Cost
TCP ....Traditional Cultural Properties
TDS ....Total Dissolved Solids
TID ....Turlock Irrigation District
TIN .... Triangular Irregular Network
TMDL ....Total Maximum Daily Load
TOC............................Total Organic Carbon
TPH ....Total Petroleum hydrocarbon
TRT ....Tuolumne River Trust
TRTAC ....Tuolumne River Technical Advisory Committee
UC ....University of California
UCCE.........................University of California Cooperative Extension
USDA.........................U.S. Department of Agriculture
USDOC ......................U.S. Department of Commerce
USDOI .......................U.S. Department of the Interior
USFS ..........................U.S. Department of Agriculture, Forest Service
USFWS ......................U.S. Department of the Interior, Fish and Wildlife Service
USGS .........................U.S. Department of the Interior, Geological Survey
USR............................Updated Study Report
UTM...........................Universal Transverse Mercator
VAMP ....Vernalis Adaptive Management Plan
VELB ....Valley Elderberry Longhorn Beetle
VES ....Visual Encounter Surveys
VRM ....Visual Resource Management
W&AR ....Water & Aquatic Resources
WMP ....Waste Management Plan
WPT ....Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP ....Water System Improvement Program

WTP ....Willingness to Pay

WWTP ....Wastewater Treatment Plant

WY ....water year

μS/cm ....microSiemens per centimeter

1.0 INTRODUCTION

1.1 Background

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir has a normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2). The Project is designated by the Federal Energy Regulatory Commission (FERC) as project no. 2299.

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Don Pedro Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with agreements between the Districts and City and County of San Francisco (CCSF), the Don Pedro Reservoir also includes a “water bank” of up to 570,000 AF of storage which CCSF uses to efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. The “water bank” within Don Pedro Reservoir provides significant benefits for CCSF’s 2.6 million customers in the San Francisco Bay Area.

The Don Pedro Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Don Pedro Project are recreation, protection of aquatic resources in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from RM 53.2, which is one mile below the Don Pedro powerhouse, upstream to RM 80.8 at a water surface elevation of 845 ft (31 FPC ¶ 510 [1964]). The Project Boundary encompasses approximately 18,370 ac with 74 percent of the lands owned jointly by the Districts and the remaining 26 percent (approximately 4,802 ac) owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Don Pedro Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Don Pedro Project and its primary facilities is shown in Figure 1.1-1.

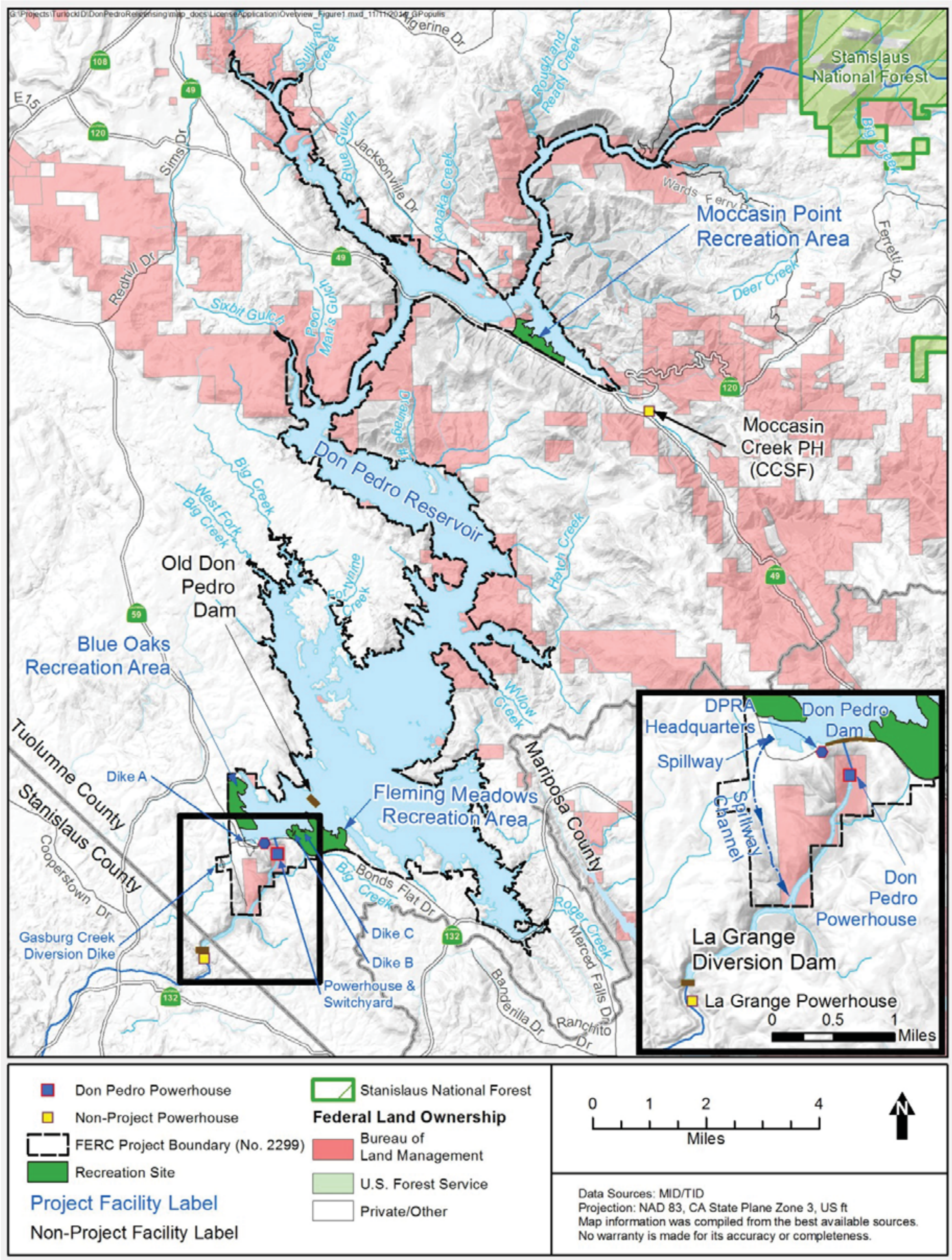

Figure 1.1-1. Don Pedro Project site location map.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts applied for a new license on April 30, 2014. At that time, and consistent with study schedules approved by FERC through the Integrated Licensing Process (ILP) study plan determinations, five important studies involving the resources of the lower Tuolumne River were still in-progress. These studies are scheduled to be completed by April 2016. Once these studies are completed, the Districts will evaluate all data, reports, and models then available for the purpose of identifying appropriate protection, mitigation, and enhancement (PM&E) measures to address the direct, indirect, and cumulative effects of Project operations and maintenance. Upon completion of this evaluation, the Districts will prepare any needed amendments to the license application.

The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, in accordance with the regulations governing the ILP. The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012. The *Chinook Salmon Otolith Study* (W&AR-11) was not a subject of the dispute resolution process.

On January 17, 2013, the Districts issued the Initial Study Report (ISR) and held an ISR meeting on January 30 and 31, 2013. The Districts filed a summary of the ISR meeting with FERC on February 8, 2013. Comments on the meeting summary and requests for new studies and study modifications were filed by relicensing participants on or before March 11, 2013, and the Districts filed reply comments on April 9, 2013. FERC issued the Determination on Requests for

Study Modifications and New Studies on May 21, 2013. The determination did not involve the study plan for the *Chinook Salmon Otolith Study* (W&AR-11).

The Districts filed the Updated Study Report (USR) on January 6, 2014; held a USR meeting on January 16, 2014; and filed a summary of the meeting on January 27, 2014. Relicensing participant comments on the meeting summary and requests for new studies and study modifications were due by February 26, 2014. The Districts filed reply comments on March 28, 2014. FERC issued the Determination on Requests for Study Modifications on April 29, 2014.

This study report describes the objectives, methods, and results of the *Chinook Salmon Otolith Study* (W&AR-11) as implemented by the Districts in accordance with FERC's December 22, 2011 Order. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at http://www.donpedro-relicensing.com/.

1.3 Study Report

Results of laboratory analyses conducted for W&AR-11 are provided in Appendix A of this study report. The draft study report (including Appendix A) was provided to relicensing participants on March 16, 2015, for 30-day review. Comments on the draft report were provided on April 23, 2015 by the U.S. Fish and Wildlife Service (USFWS). Responses to draft study report comments are presented in Appendix B. Additional comments on the draft report were provided by Dr. Rachel Johnson (University of California, Davis), who oversaw the laboratory analysis, on April 14, 2015. Changes made to the draft report based on Dr. Johnson's comments are presented in the errata sheet included above.

2.0 CHINOOK SALMON OTOLITH STUDY GOALS AND OBJECTIVES

Otoliths (commonly referred to as “earstones”) are calcium carbonate structures in the inner ear of fish that grow in proportion to the overall growth of the individual, such that daily or weekly growth increments can be measured to allow the age and fish size at various habitat transitions to be identified. Through analysis of otoliths, the goal of this study was to identify the geographic origin and early life history rearing and emigration patterns of Tuolumne River Chinook salmon during above- and below-normal water year (WY) types. Examination of otolith microstructure has been used to identify differing rearing environments of juvenile salmon (e.g., Neilson et al. 1985) as well as differences in rearing temperatures (Zhang et al. 1995; Volk et al. 1996). Additionally, using one of several methods of microchemical analysis, the concentrations of elements (e.g., strontium, barium, calcium) and proportions of stable strontium (Sr) isotopes in otoliths may be compared to those in the water in which the fish inhabits in order to provide a tracer of the location where the fish has been (e.g., freshwater, saltwater, natal stream) (Campana and Neilson 1985). Otolith microchemistry has been used to examine early life history rearing environments of salmonids to address questions of streams of natal origin (Ingram and Weber 1999; Campana and Thorrold 2001) as well as the timing of entry into estuarine and saline environments (Zimmerman 2005).

This study applies microstructural and microchemical analysis of otoliths to address questions regarding the success of various early life-history emigration patterns of fall-run Chinook salmon originating from the Tuolumne River. Early life history events in juvenile salmonid development, including incubation, emergence, and habitat transitioning, can be linked to otolith microstructural patterns due to the thermal, physical, and chemical regime under which these fish were reared. Identification of the natal streams of adults that spawn in the Tuolumne River may allow additional quantification of straying rates from other rivers and, hence, more accurate assessments of the population size of indigenous Tuolumne River salmon. The relative contribution of emigrant fry, parr and smolts to subsequent escapement may have implications for the magnitude and timing of flow in the Tuolumne River, as well as the timing of operations of barriers and export facilities in the southern Sacramento and San Joaquin River delta (Delta[1]).

In brief, the study objectives were to use otolith microstructural growth patterns and/or microchemistry in order to identify:

- whether returning adults originated from hatcheries or riverine environments other than the Tuolumne River; and,
- growth rates and sizes of ‘wild’ fish at exit from the Tuolumne River and from the freshwater Delta.

[1] The Delta received its first official boundary in 1959 with the passage of the Delta Protection Act (Section 12220 of the California Water Code), with the southern boundary in the San Joaquin River located at Vernalis (RM 69.3) and a western boundary at the confluence of the Sacramento and San Joaquin Rivers (RM 0) near Chipps Island.

3.0 STUDY AREA

The study area consists of locations of Chinook salmon carcass recoveries collected by California Department of Fish and Wildlife (CDFW) from the lower Tuolumne River, typically extending from approximately 0.5 miles downstream of the lower end of the La Grange powerhouse tailrace (RM 51.6) to the end of routine spawning surveys at approximately RM 21.2. The lower San Joaquin River from the Tuolumne River confluence (RM 84) to Vernalis (RM 69.3), Delta, San Francisco Bay Estuary[2], and the Pacific Ocean are also addressed in terms of their use by rearing and emigrant juvenile life stages of Chinook salmon.

[2] The greater San Francisco Bay estuary extends from the Golden Gate Bridge in San Francisco Bay eastwards across salt and brackish water habitats included in San Leandro, Richardson, San Rafael, and San Pablo bays, as well as the Carquinez Strait, Honker, and Suisun bays further to the east near the western edge of the Delta.

4.0 METHODOLOGY

4.1 Existing Data Compilation

This study relied upon the existing inventory of fall-run Chinook salmon otoliths sampled from unmarked carcasses collected by CDFW during annual spawner escapement surveys in the lower Tuolumne River, which are typically conducted from October to early-January. Otoliths were provided cooperatively by CDFW under a memorandum of understanding (MOU) with the Districts and the Department of Animal Science, University of California, Davis (UC Davis). In order to examine potential variations in early life-history emigration patterns, otoliths were selected to represent returning adults that had emigrated during five focus years (1998, 1999, 2000, 2003, and 2009), representing “above normal” or “wet” and “below normal” or “dry” WY types[3]. With a sampling goal of obtaining 100–200 otoliths from each outmigration year for laboratory analysis, these five years were also selected because they represented years with the greatest number of available samples from the existing CDFW inventory. The sampling goal was met for the above normal/wet WY types 1998, 1999, and 2000, but was not met for the below normal/dry WY types 2003 and 2009, which had comparatively fewer samples available (Table 4.2-1). As the otoliths were collected from unmarked fish, the samples did not include known hatchery-origin fish[4].

4.2 Laboratory Otolith Analysis

A summary of the otolith analytical methods is provided below, with additional details provided in Sturrock and Johnson (2014), which is appended to this study report as Appendix A.

4.2.1 Adult sampling and cohort reconstruction

Adult salmon from a given outmigration year typically return between 2 and 5 years later with the greatest proportion returning after 3 and 4 years respectively in historical Tuolumne River spawner surveys (TID/MID 2014a). Thus, for each outmigration year that was examined in this study, otolith samples were recovered from carcasses collected over several escapement years (Table 4.2-1). Experts at CDFW determined the ages of the adult samples by counting scale winter annuli from unmarked adult salmon carcasses in accordance with established and validated techniques (Guignard 2008). Information regarding the date of collection, location, fish length, sex, and estimated age-at-return were provided by CDFW for each otolith sample.

3 CDWR Bulletin 120 estimates unimpaired runoff as TAF for the San Joaquin River and tributaries. The San Joaquin Basin 60-20-20 Index classifies water years (October 1 through September 30) into five basic types (C=Critical, D=Dry, BN=Below Normal, AN=Above Normal, W=Wet) which are further refined under Article 37 of the FERC (1996) license. For the purposes of this report, the broader CDWR Water Year types are used as a basis of discussion.

4 Although the Merced River Fish Facility (MRFF) does not participate in the Constant Fractional Marking Program implemented since 2007, the MRFF historically only marked a proportion of hatchery fish, and that proportion has varied over time.

Table 4.2-1. Otolith sampling inventory by juvenile cohort and outmigration WY type collected from unmarked adult salmon carcasses in the Tuolumne River between 1999 and 2012. Source: Sturrock and Johnson (2014).

Juveniles Represented			Adults Sampled			
Spawning year[1]	**Outmigration year[2]**	**WY type during rearing & outmigration[3]**	**Escapement year[4]**	**Estimated age at return (yr)[5]**	**Number of individuals sampled**	**% of total sample**
1997	1998	Wet	1999	2	0	0%
			2000	3	124	62%
			2001	4	76	38%
			Sum		**200**	**100%**
1998	1999	Above normal	2000	2	9	6%
			2001	3	64	44%
			2002	4	73	50%
			Sum		**146**	**100%**
1999	2000	Above normal	2001	2	31	28%
			2002	3	79	72%
			2003	4	0	0%
			Sum		**110**	**100%**
2002	2003	Below normal	2004	2	0	0%
			2005	3	87	91%
			2006	4	9	9%
			Sum		**96**	**100%**
2008	2009	Below normal	2010	2	14	30%
			2011	3	30	65%
			2012	4	2	4%
			Sum		**46**	**100%**
TOTAL					**598**	

1 Although CDFW uses the term "brood-year" to designate the year in which fry first emerge (typically December), here we simply indicate the year in which the majority of spawning occurred.
2 Outmigration-year designation is based on the timing of the first juveniles' departure from the natal river.
3 CDWR Bulletin 120 estimates unimpaired runoff as TAF for the San Joaquin River and tributaries. The San Joaquin Basin 60-20-20 Index classifies WYs (October 1 through September 30) into five basic types (C=Critical, D=Dry, BN=Below Normal, AN=Above Normal, W=Wet), which are further refined under Article 37 of the FERC (1996) license. For the purposes of this report, the broader CDWR WY types are used as a basis of discussion.
4 Sampled during CDFW annual spawner escapement surveys.
5 Estimated from CDFW scale readings.

4.2.2 Strontium isotope analysis

Adult otoliths were prepared and analyzed for strontium isotopic ($^{87}Sr/^{86}Sr$) ratios using standard techniques described in Sturrock and Johnson (2014). In brief, the technique relies on detecting daily deposition of chemical elements from the surrounding environment in otolith growth rings, producing a distinct and reproducible "chemical fingerprint". In the California Central Valley, strontium isotopes ($^{87}Sr/^{86}Sr$) are ideal markers because the water signature varies with watershed geology, therefore differing among many of the rivers and salmon outmigration paths (Ingram and Weber 1999; Barnett-Johnson et al. 2008).

Otoliths were rinsed and cleaned of adhering tissue, then mounted in resin and polished until each primordial core (i.e., center) was exposed. Each otolith was sampled at multiple spots along a 90° radial transect starting at the primordial core and ending just past the point of ocean entry (also called the "freshwater exit"), in order to ensure inclusion of the full freshwater outmigration period in the analysis (Figure 4.2-1). At each sample spot, $^{87}Sr/^{86}Sr$ ratios were determined by multi-collector laser ablation inductively coupled plasma mass spectrometry (MC-LA-ICPMS) (Barnett-Johnson et al. 2005). To improve the spatial resolution and accuracy of the ocean entry spot identification and outmigration fork length (see also Section 4.2.4), additional $^{87}Sr/^{86}Sr$ sample spots were re-sampled at the region representing an isotope ratio shift (e.g., the Tuolumne-San Joaquin River transition).

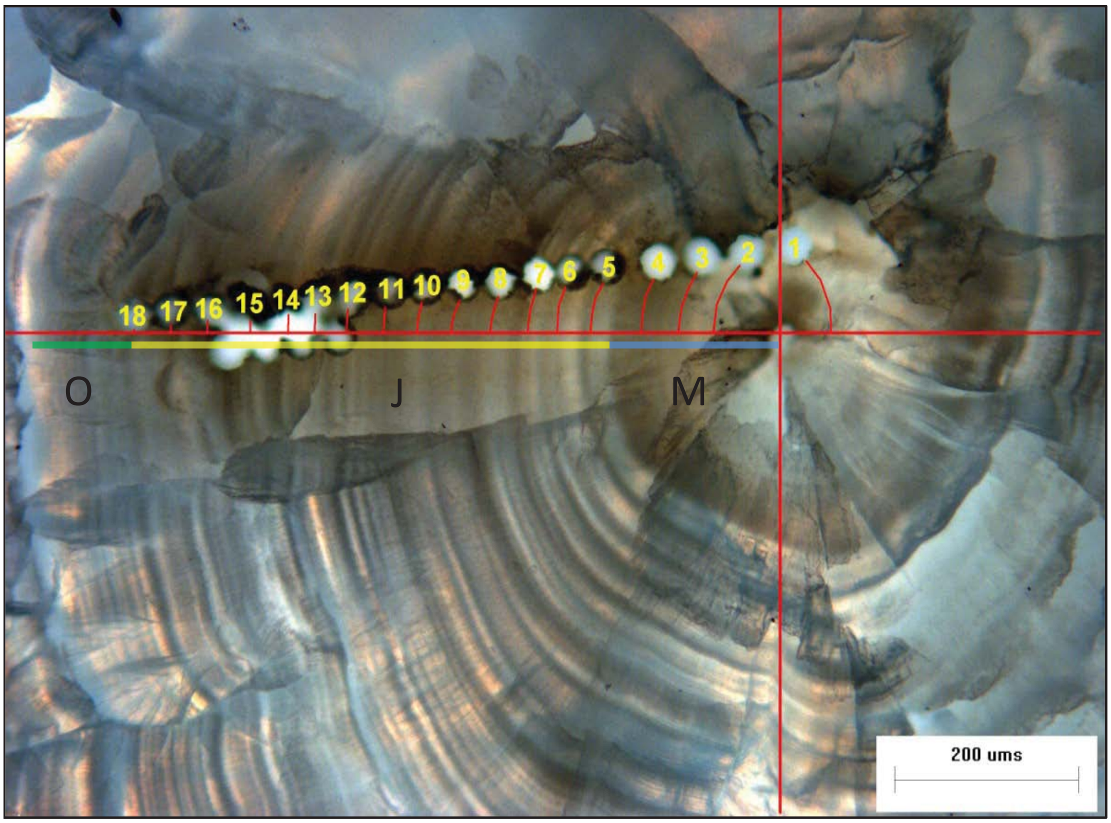

Figure 4.2-1. A typical 87Sr/86Sr transect showing spot analyses (numbered) from the core to ocean entry. The life history stages are indicated by letters: maternal (M), juvenile (J) and ocean (O). The distance at which the final 'natal spot' intersected the 90° transect (indicated by curved red lines) was used to back-calculate size at outmigration. 'Respots' occurred at positions 12.5 to 15.5 used to more accurately identify exit point. Source: Sturrock and Johnson (2014).

4.2.3 Identification of natal origin

To identify the natal origin of the otolith samples, measured $^{87}Sr/^{86}Sr$ ratios were statistically compared to a "strontium isoscape" comprised of the previously published $^{87}Sr/^{86}Sr$ baseline for California Central Valley rivers and hatcheries, additional Sr isotope values of otolith samples from juveniles and coded wire tag (CWT) adults known to originate from the Tuolumne River, and Sr isotope values from Tuolumne River and San Joaquin River water samples collected in 2014 (Ingram and Weber 1999; Sturrock and Johnson 2014). The resulting strontium isoscape included a total of 480 tissue and water samples from all potential natal sources in the California Central Valley, with many sites sampled across multiple years (1998–2013) and hydrologic regimes (Sturrock and Johnson 2014, Table 3).

Given the variability in Sr isotope values in water samples from upper to lower reaches of the lower Tuolumne River (Ingram and Weber 1999; Sturrock and Johnson 2014), juveniles collected in the Tuolumne River tend to exhibit more variable isotopic signatures within and among individuals than in other rivers in the Central Valley (Figure 4.2-2). Additionally, otolith $^{87}Sr/^{86}Sr$ values of known-origin Tuolumne River fish, Mokelumne River Hatchery and Feather River Hatchery can overlap (Figure 4.2-2), increasing the potential of misclassifying Tuolumne-origin fish. To improve assignment accuracy, any otolith samples exhibiting ambiguity in their natal assignment were also analyzed for otolith microstructural features that can discriminate hatchery from wild fish. Following methods developed for California Central Valley Chinook (Barnett-Johnson et al. 2007), individuals were classified as hatchery or wild based on the prominence of the exogenous feeding check (scored blind by 2–3 independent readers) and the mean and variance in increment width around the first 30 daily increments following onset of exogenous feeding after fry emergence from the spawning gravels.

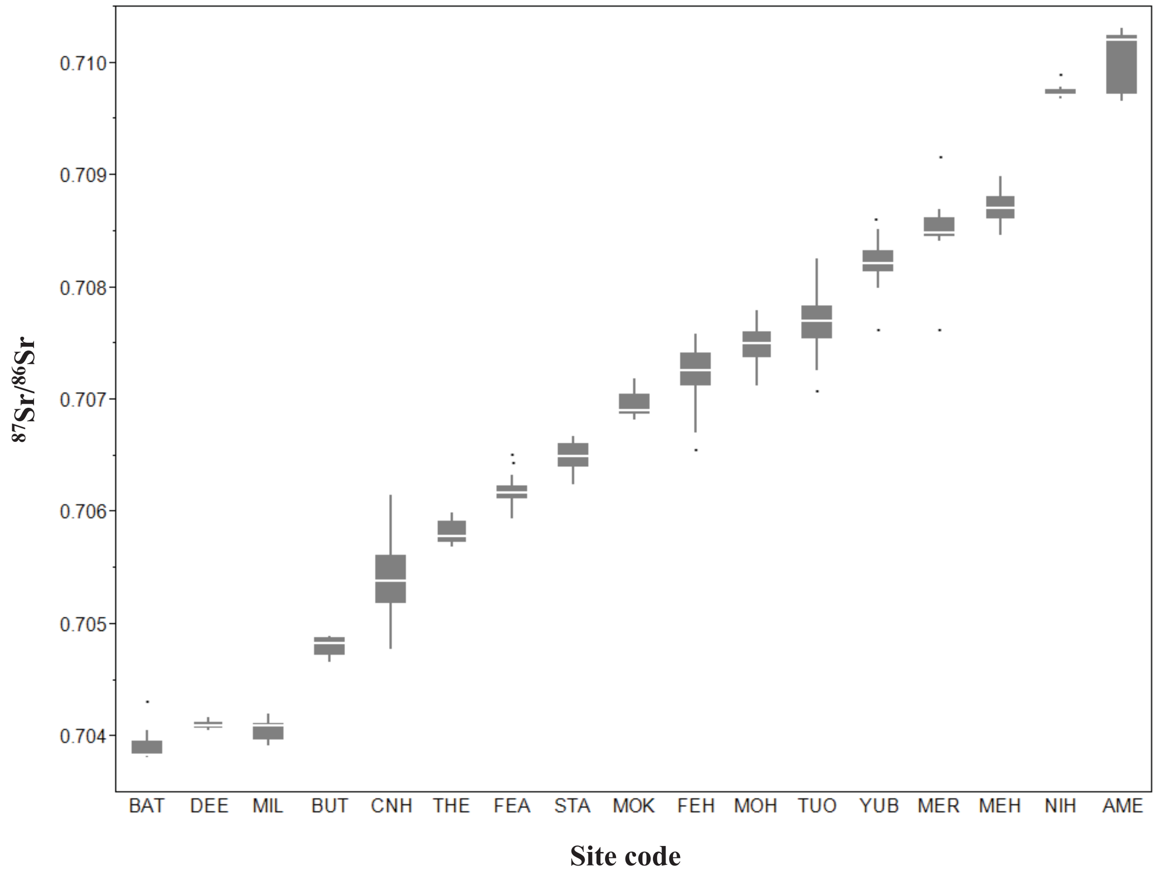

Figure 4.2-2. **Differences in 87Sr/86Sr values among sites in the California Central Valley. Source: Sturrock and Johnson (2014). Due to overlap among the Tuolumne River (TUO), Mokelumne River Hatchery (MOH), and Feather River Hatchery (FEH), all fish identified as potentially originating from the Tuolumne River using Sr isotopes were also assigned to hatchery/wild using otolith microstructure. Other side codes: Battle Creek (BAT), Deer Creek (DEE), Mill Creek (MIL), Butte Creek (BUT), Coleman National Fish Hatchery (CNH), Thermalito Rearing Annex (THE), Feather River (FEA), Stanislaus River (STA), Mokelumne River (MOK), Yuba River (YUB), Merced River (MER), Merced River Hatchery (MEH), Nimbus Hatchery (NIH), American River (AME).**

4.2.4 Reconstructing size and age at outmigration

Variations in the $^{87}Sr/^{86}Sr$ ratio along the sampling transect were used to indicate the location and thus life history timing of emigration from the Tuolumne River ('natal exit') using the distance from the otolith primordial core to the 'last natal spot'. The 'last natal spot' rather than the 'first non-natal spot' was used because to accrete sufficient new otolith material to modify the isotopic composition of the otolith, the fish would have inhabited isotopically distinct (i.e., non-natal) water for several days, after which time it would be a significant distance downstream of the Tuolumne-San Joaquin River confluence. The 'last natal spot' was identified by working backwards from the final inflection point indicative of ocean-bound migration, and using the spot just prior to the lowest point of inflection, where the latter represented likely movement through the San Joaquin River (Sturrock and Johnson 2014, Figure 3, Plots A, B, and C). The only exceptions were on occasions when the lowest point prior to ocean migration was lower than any value measured in the San Joaquin River (Sturrock and Johnson 2014, Figure 3, Plot D); on these occasions the lowest point was assumed to have been deposited while the fish was rearing in the lower Tuolumne River, which has been shown to exhibit $^{87}Sr/^{86}Sr$ values as low as 0.7066 (Sturrock and Johnson 2014).

The point of emigration from freshwater ('freshwater exit') was defined as the distance at which otolith $^{87}Sr/^{86}Sr$ values last reached 0.7080 (equivalent to a salinity of 1ppt based on Hobbs et al. 2010), determined using linear interpolation.

In order to estimate fish size at the natal and freshwater exit points, radial otolith distances to these points were measured for use with an existing relationship between otolith radius and fork length (FL) from the California Central Valley fall run Chinook salmon Evolutionarily Significant Unit (ESU) (Zabel et al. 2010). Juvenile reference samples for the Zabel et al. (2010) relationship were collected at various locations including samples from the Tuolumne River (2003; n = 6), Stanislaus River (2000 and 2002; n = 95), the Coleman National Fish Hatchery (2002; n=40) and in the San Francisco Bay at Golden Gate Bridge (2005; n = 83) (Figure 4.2-3). While the small number of Tuolumne-origin fish included in the relationship tended to sit above the mean regression line (Figure 4.2-3), there was no significant difference between the back-calculated fork length of Tuolumne vs. non-Tuolumne fish, nor any difference in the slopes (Sturrock and Johnson 2014). The uncertainty in the otolith radius-fork length regression was used to estimate 95% confidence intervals (CI) for the estimated juvenile fork lengths associated with individual adult otolith samples.

For each length estimate at natal exit from the Tuolumne River, fish were classified as fry (<50 mm FL), parr (≥50 to <70 mm FL), and smolt (≥70 mm FL) in this report. Although these size cutoffs are 5 mm larger than those from the Mokelumne River (Miller et al. 2010) used in Sturrock and Johnson (2014), the Tuolumne River size cutoffs were re-assigned here based upon operational definitions used in juvenile outmigration studies (TID/MID 2014b). For example, the smallest sized juveniles reported as smolts in historical sampling range as low as 65 mm FL in some years (Stillwater Sciences 2013a).

Fish age at outmigration was determined by counting daily growth bands and measuring widths between daily increments along the same 90° radial transect as the $^{87}Sr/^{86}Sr$ analysis, beginning at the point when the maternal yolk sac is depleted and exogenous feeding begins ("post exogenous feeding check") until freshwater exit from the Delta to the San Francisco Bay and Pacific Ocean. Some otoliths were difficult to age and given low readability scores (1-2); ages were not provided for these individuals. The ages of fish at natal exit from the lower Tuolumne River, freshwater exit from the Delta, and habitat-specific growth rates were obtained for fish with otolith readability scores of 3–5. A subset of otoliths was aged by two independent readers, providing an estimate of error associated with fish aging. The two independent reads of each fish demonstrated high agreement, with an average difference of ± 5 days (range 0–12 days).

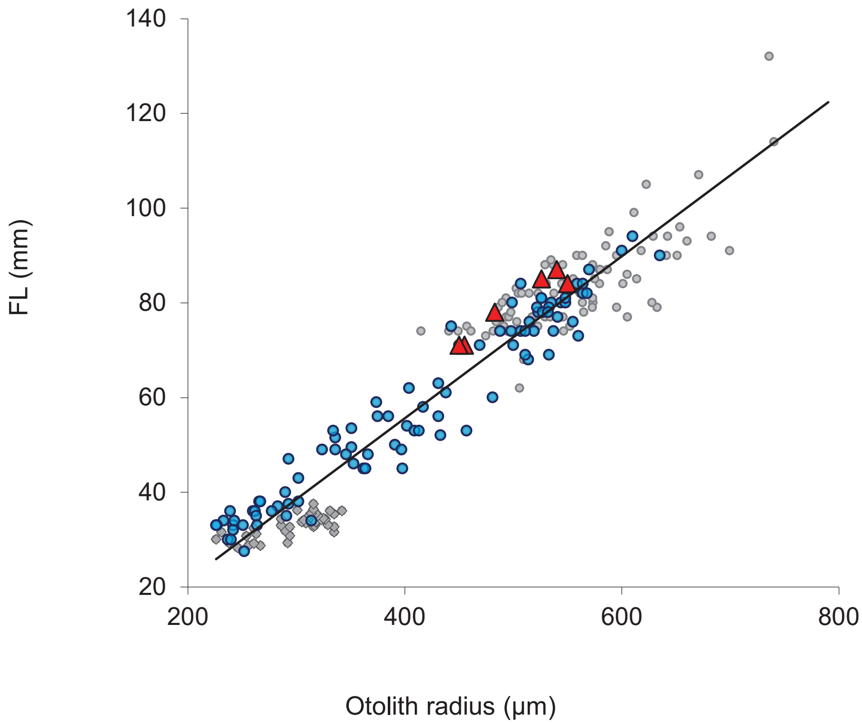

Figure 4.2-3. **Relationship between otolith radius and fork length (FL) of juveniles of known origin from the California Central Valley fall run Chinook salmon Evolutionarily Significant Unit (ESU). (n=224, r2 = 0.92) Red triangles = Tuolumne River (n = 6); blue circles = Stanislaus River (n = 95); grey diamonds = Coleman National Fish Hatchery (n=40); grey circles = San Francisco Bay at Golden Gate Bridge unknown origin (n = 83). Source: Sturrock and Johnson (2014).**

4.3 Analysis of Potential Flow Relationships

Tuolumne River hydrologic patterns were explored for each of the five outmigration years using available flow data for gages at La Grange (USGS #11289650), Modesto (USGS #11290000), and Vernalis (USGS #11303500). Daily flow data were pooled to develop flow metrics at 2-week and monthly intervals from January through June, including minimum, maximum, and mean Tuolumne River discharge. Each of the Tuolumne River flow metrics were used in linear regressions against fish size at natal exit and fish age at natal exit (determined by the otolith analyses) for each of the five outmigration years included in the study (1998, 1999, 2000, 2003, and 2009).

Average daily flow magnitude and timing were also examined in combination with mean fish size and age at exit from the Tuolumne River and the Delta to determine any potential relationships between flow and fish age/size at exit. This exploratory analysis was undertaken to determine whether flow may explain various early life-history emigration patterns of juvenile salmon from differing WY types.

Delta hydrologic patterns were investigated using California Department of Water Resources (CDWR) DAYFLOW data, including 24 flow parameters and indices characterizing the following (CDWR 2015):

- daily river inflows (e.g., Sacramento, Yolo, Cosumnes, Mokelumne, San Joaquin, Calaveras plus other miscellaneous creek flows);
- interior Delta flows (e.g., Delta Cross Channel and Georgiana Slough, Jersey Point, Rio Vista);
- water exports and diversions/transfers (e.g., Central Valley Project at Tracy, Contra Costa Water District Diversions at Middle River, Rock Slough, Old River, North Bay Aqueduct, State Water Project);
- estimates of Delta agriculture depletions; and,
- fish-related flows (i.e., percent water diverted, effective Western/Central Delta inflow, effective percent Western/Central Delta water diverted).

Daily average flow data for each of the DAYFLOW 24 parameters/indices were pooled into aggregated monthly averages from January through June. Each of these averages were used in exploratory linear regressions against fish size at freshwater exit and fish age at freshwater exit for each of the five outmigration years included in the study (1998, 1999, 2000, 2003, and 2009).

5.0 RESULTS

5.1 Natal Origin

Analysis of Sr isotope ratios ($^{87}Sr/^{86}Sr$) and microstructural features (see Section 4.2.3) in otoliths collected from unmarked Chinook salmon carcasses indicated both wild- and hatchery-origin fish in Tuolumne River spawning adults corresponding to outmigration years 1998, 1999, 2000, 2003, and 2009 (Figure 5.1-1). The earliest three years exhibited the highest numbers of Tuolumne River returning wild fish, with smaller numbers of wild fish exhibiting Sr isotope ratios indicating straying from the Stanislaus, Merced, and Mokelumne rivers. The hatchery component in these outmigration years was primarily from the Merced and Mokelumne river hatcheries, with smaller contributions from the Feather River and Nimbus hatcheries. Overall, returning wild fish made up 38–68% of the sample of unmarked fish for outmigration years 1998–2000 (Table 5.1-1). For outmigration years 2003 and 2009, relatively low numbers of returning wild fish were present in the sample, with larger hatchery components primarily from the Mokelumne River Hatchery (2003) and the Coleman National Fish Hatchery (2009) (Table 5.1-1). Overall, returning wild fish made up 9–25% of the sample for outmigration years 2003 and 2009 (Table 5.1-1). Considering all five outmigration years combined (n=598), 54% of the unmarked fish samples were identified as wild and of Tuolumne River origin (n=321), 43% were identified as hatchery-origin (n=255), and 4% were identified as wild strays from other rivers (n=22).

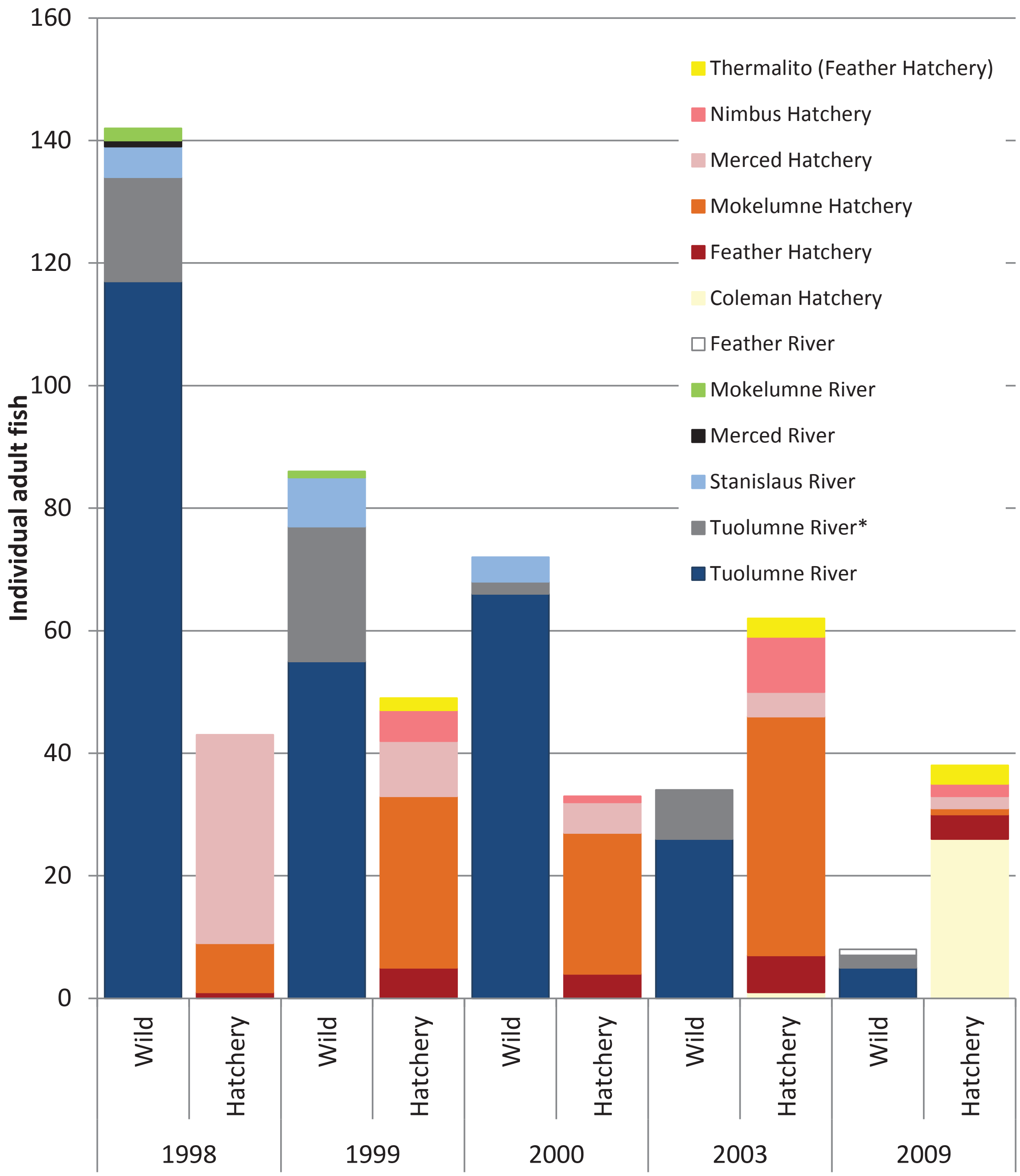

Figure 5.1-1. **Natal origin of all unmarked fish (n=598) analyzed for outmigration years 1998, 1999, 2000, 2003 and 2009. [*] indicates individuals assigned to the Tuolumne River with <0.5 posterior probability based on mean natal 87Sr/86Sr values or individuals assigned to the Tuolumne River, but with inconclusive hatchery/wild assignment based on otolith microstructure. Data from Sturrock and Johnson (2014).**

Table 5.1-1. Summary of straying and return rates to the Tuolumne River for unmarked fish (n=598). Data from Sturrock and Johnson (2014).

Outmigration year	San Joaquin River Index Water Year Type[1]	Sample size	Returns (Wild)[2]	Strays (Wild and Hatchery)[2]	Primary origin of strays
1998	Wet	200	57–68%	33–44%	Merced Hatchery
1999	Above normal	146	38–53%	47–62%	Mokelumne Hatchery
2000	Above normal	110	61–64%	36–39%	Mokelumne Hatchery
2003	Below normal	96	27–35%	65–73%	Mokelumne Hatchery
2009	Below normal	46	9–15%	85–91%	Coleman Hatchery

1 San Joaquin Basin 60-20-20 Index from CDWR Bulletin 120.
2 Range in natal assignment is based on probabilities associated with the isotope-based discriminant function analysis and reference samples from existing or ongoing projects.

5.2 Growth and Residency of Juveniles

Estimated mean fish size at exit from the Tuolumne River based on otolith analyses ranged 63.5–76.0 mm, with the lowest mean size exhibited in outmigration year 2000. The year 2000 mean size was significantly different ($p<0.005$) from that estimated for the other four years of the study. Similarly, estimated age at exit from the Tuolumne River was lower in outmigration year 2000 (68.5 days) as compared with that of other years, although there was generally higher variability in age at exit such that no single year was statistically lowest (Table 5.2-1).

Estimated mean fish size at freshwater exit from the Delta based on otolith analyses ranged 77.4–83.4 mm, with slightly greater variability within years than that of the Tuolumne River (Table 5.2-1). Examination of the distributions of age at exit from the Tuolumne River and the Delta suggests that overall the total days from the end of exogenous feeding (i.e., emergence from gravels) to ocean entry was relatively constant at 99±20 days for each of the five outmigration years, such that fewer days spent rearing in the Tuolumne River resulted in relatively more days rearing in the Delta (Figure 5.2-1).

Table 5.2-1. Summary of estimated fish size, age, and increment widths (mean ±1SD) at natal exit and freshwater exit by outmigration year for juveniles that originated in and returned to the Tuolumne River. Source: Sturrock and Johnson (2014).

Out-migration year (WY Type[2])	Sample Size	Tuolumne River			Delta		
		FL at exit (mm)	No. increments (days)	Increment width[1] (um)	FL at exit (mm)	No. increments (days)	Increment width[1] (um)
1998 (W)	117	73.3 ± 8.5	91.0 ± 16.2	3.07 ± 0.28	80.8 ± 9.0	15.8 ± 7.5	3.24 ± 0.54
1999 (AN)	55	72.6 ± 11.6	82.0 ± 13.6	3.20 ± 0.27	82.3 ± 11.5	16.5 ± 8.7	3.35 ± 0.56
2000 (AN)	66	63.5 ± 8.6	68.5 ± 18.6	3.10 ± 0.26	77.4 ± 6.9	27.6 ± 12.1	3.52 ± 0.52
2003 (BN)	26	71.0 ± 10.6	79.7 ± 17.9	3.39 ± 0.43	80.1 ± 10.0	10.5 ± 5.2	3.65 ± 0.62
2009 (BN)	5	76.0 ± 7.1	88.0 ± 20.3	3.36 ± 0.29	83.4 ± 6.8	16.0 ± 7.5	3.03 ± 0.36

1 Width between daily increments is a measure of growth rate.
2 San Joaquin Basin 60-20-20 Index from CDWR Bulletin 120.

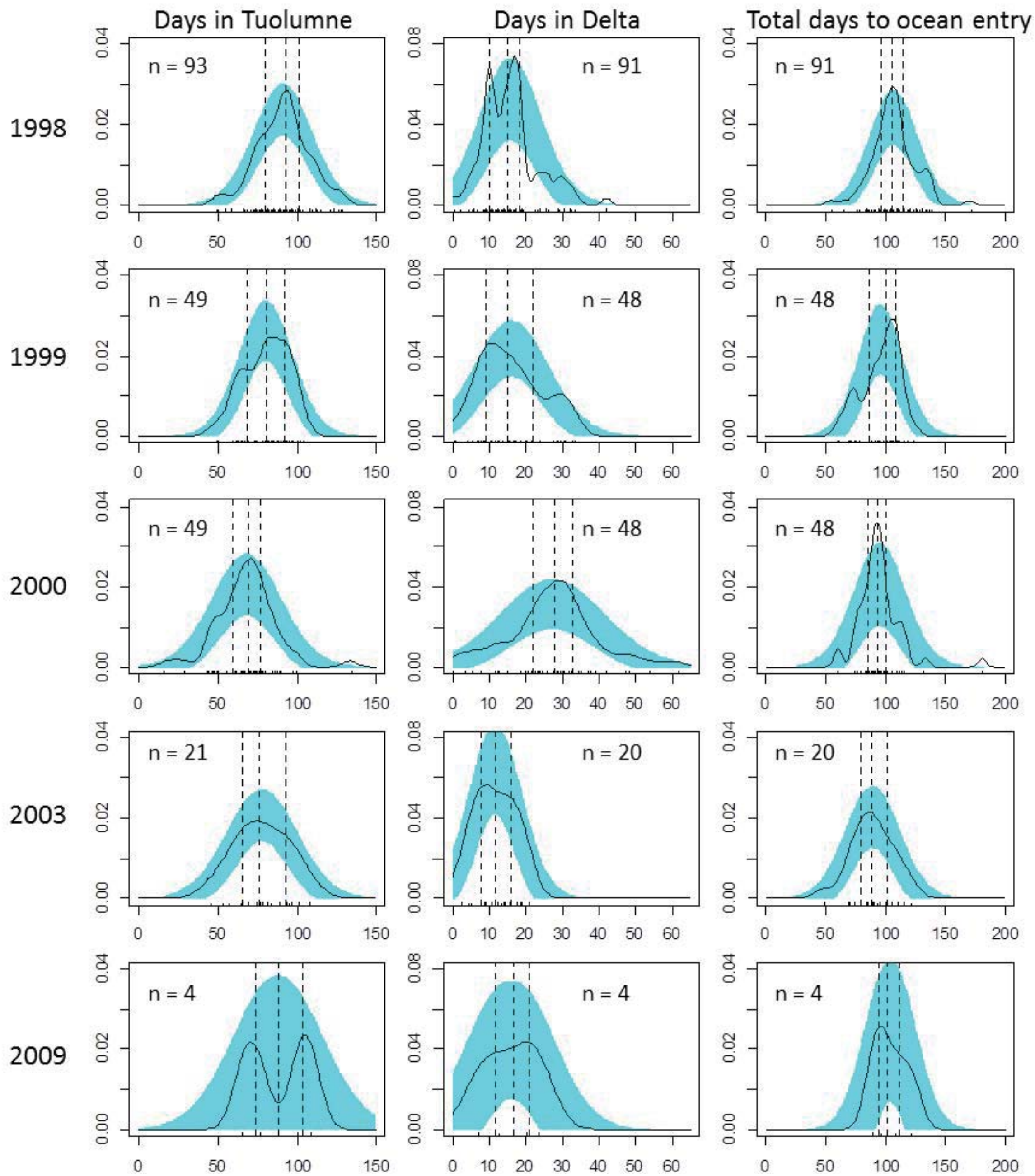

Figure 5.2-1. **Estimated days of development from formation of otolith core to ocean entry. The rug plots show values for individual otoliths from unmarked adult samples. The curves are non-parametric density estimates obtained by kernel smoothing, deliberately under-smoothed. The cyan bands encode a test for normality. The vertical dashed lines mark the data quartiles.**

Table 5.2-1 (and Figure 9 of Sturrock and Johnson 2014) presents the central tendency and general range of increment widths as an indication of growth rates in the Tuolumne River and the Delta for each WY included in this study. It should be noted, however, that Chinook growth rates vary with fish size among other factors (Titus et al 2004). Since juvenile outmigrants will generally have attained a larger size by the time they have reached Delta habitats, average growth rates in the Delta will generally be lower than for samples including a larger proportion of fish that completed the fry/parr transition within the natal river. To remove this potential effect from the analysis, a growth trajectory was created for each otolith sample by plotting increment number against distance along the otolith radial transect (um), with the transition point between Tuolumne River and Delta rearing based upon results of the Sr isotope analysis. The individual growth trajectories exhibit little discernable difference in slope between natal stream and Delta rearing locations for individual fish (Figure 5.2-2).

Additionally, specific otolith growth rates (um/d) were plotted as a function of fish size to allow direct growth rate comparisons between the Tuolumne River and the Delta for each WY included in this study. Figure 5.2-3 shows a high degree of growth rate variability for fish of the same estimated fork length in both riverine and Delta habitats, although some patterns are apparent. In two of the three wet WY types (1998, 1999), estimated growth rates in the Tuolumne River were greater than those of the Delta (95% confidence interval [CI]) for larger parr-sized individuals, corresponding to otolith distances of approximately 475 um (68 mm FL estimate) and greater. However, estimated growth rates of smaller juveniles, corresponding to otolith sizes of 425 um (60 mm FL estimate) and smaller fish, were not different between the river and the Delta during 1998 and 1999. Conversely, for the other above normal/wet WY type represented (2000), estimated growth rates in the Delta were greater than those of the Tuolumne River (95% CI) for parr-sized individuals, corresponding to otolith distances of approximately 425–475 um (60–68 mm FL estimate) and larger fish. The remaining comparisons for other otolith distances during WY 2000 fell within the 95% CI and are not statistically distinguishable. Lastly, in the dry WY types (2003, 2009), estimated growth rates for a given fish size were not different between the Tuolumne River and the Delta (95% CI), save for otolith distances 475−525 um (68−77 mm FL estimate parr and smolts) which exhibited higher estimated growth rates in the Tuolumne River.

Overall, with the exception of parr-sized individuals collected from carcasses originating from outmigration year 2000, size-standardized estimated growth rates for juveniles were generally greater in the Tuolumne River than similar-sized juveniles that reared in Delta habitats, or were not statistically distinguishable between the two rearing locations.

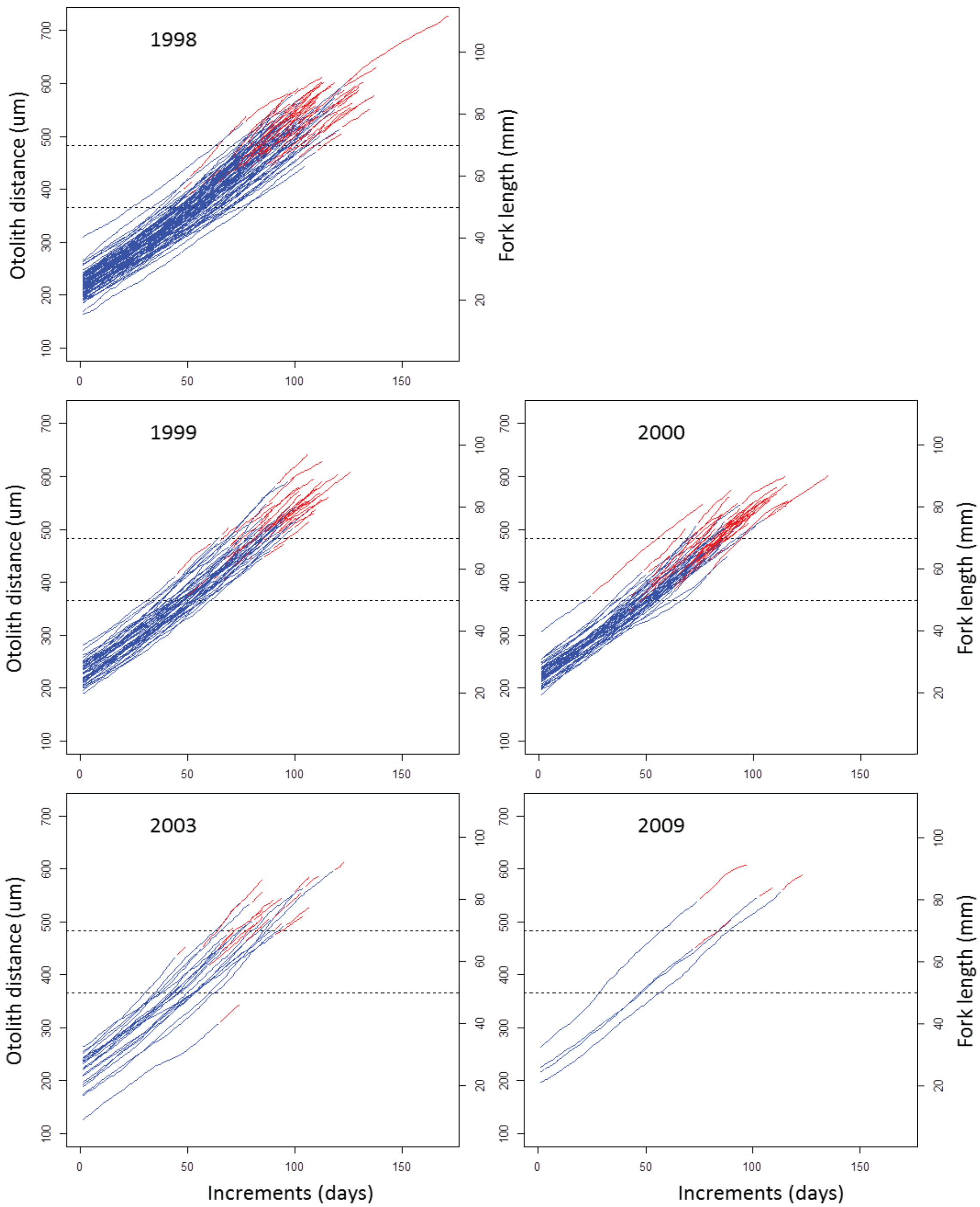

Figure 5.2-2. Tuolumne River individual otolith growth trajectories. Each line shows data for an individual otolith. The blue portion shows growth in the Tuolumne River, the red portion shows growth after leaving the river but before entering salt water. Horizontal dashed lines indicate approximate otolith distances corresponding to the fry/parr (50 mm FL) and parr/smolt (70 mm FL) life stage transitions. Data source: Sturrock and Johnson (2014).

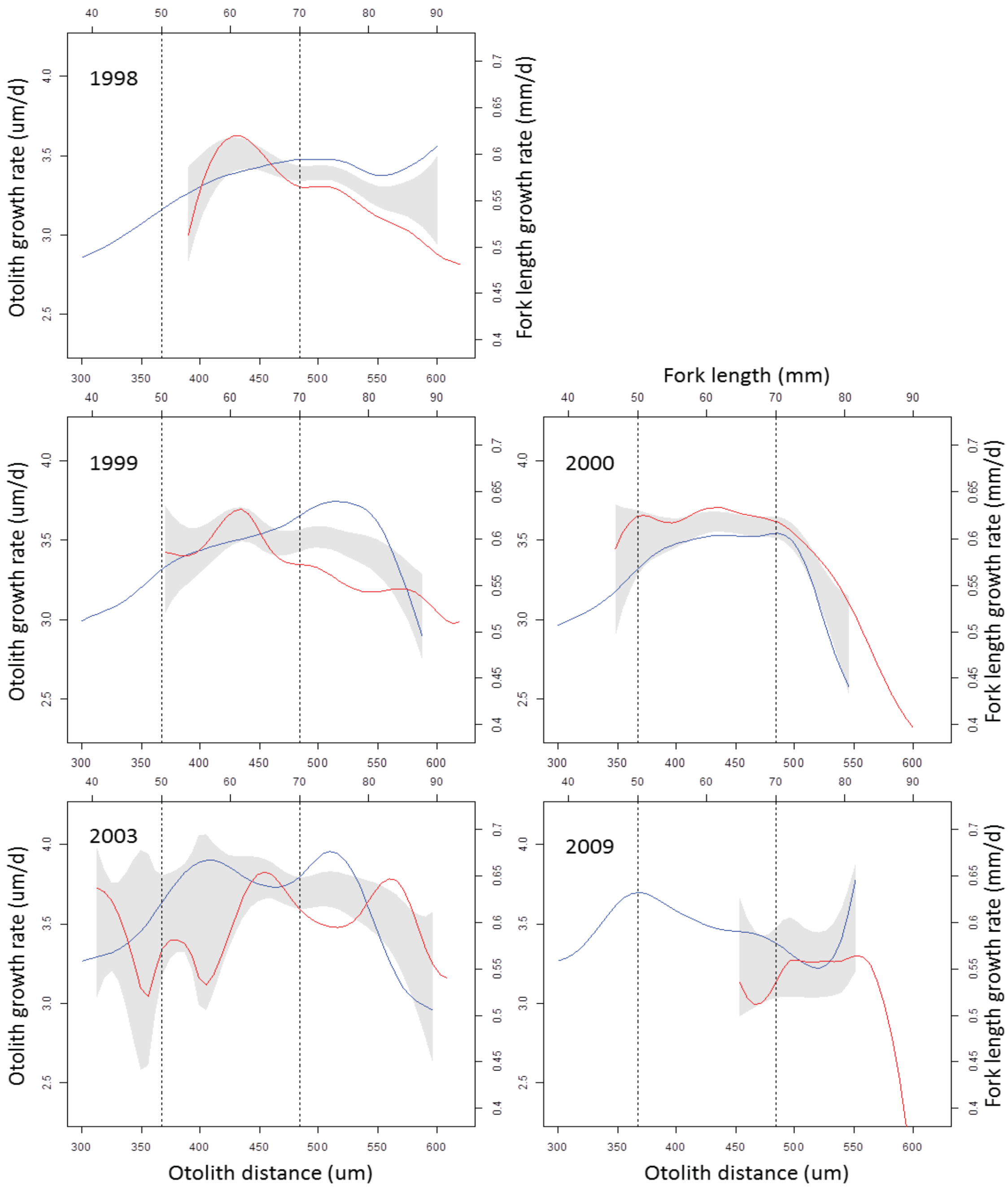

Figure 5.2-3. **Tuolumne River otolith growth rates as a function of fish size. Plots present smoothed (n=20) values of daily growth increments across all samples from a given outmigration year. The grey band encodes an approximate 95% confidence band for equality between samples from the Tuolumne River (blue line) and Delta (red line) habitats. Vertical dashed lines indicate approximate otolith distances corresponding to the fry/parr (50 mm FL) and parr/smolt (70 mm FL) life stage transitions. The fitted lines are clipped to a range in which there is some overlap between the otolith sizes. Data source: Sturrock and Johnson (2014).**

Using size cutoffs for juvenile life stage transitions in the Tuolumne River (fry <50 mm FL, parr ≥50 to <70 mm FL, and smolt ≥70 mm FL), emigrants from all juvenile life stages were represented in the returning adult spawning population. However, Tuolumne-origin adults were overwhelmingly comprised of individuals that had emigrated from the Tuolumne as parr and smolts, with only small contributions from fry-sized emigrants evident in 2000 and 2003 (Table 5.2-2). In 2000, a relatively high percentage of the returning adults had emigrated as parr (70%). In 2009, although the sample size was very low (n=5), an apparently high percentage of the returning adults had emigrated as smolts (80%) (Table 5.2-2).

Table 5.2-2. Water year type and juvenile outmigrant size classes at natal exit for unmarked fish. Life stage size cutoffs revised from fork length data presented in Sturrock and Johnson (2014).

Outmigration year	San Joaquin River Index Water Year Type	N	Fry (< 50 mm)	Parr (50–69 mm)	Smolt (≥ 70 mm)
1998	Wet	117	0%	34%	66%
1999	Above normal	55	0%	38%	62%
2000	Above normal	66[1]	5%	70%	26%
2003	Below normal	26	4%	42%	54%
2009	Below normal	5	0%	20%	80%

[1] Sample size for outmigration year 2000 incorrectly reported as 67 in Sturrock and Johnson (2014).

5.3 Hydrology

5.3.1 Daily flows

Tuolumne River hydrographs for WYs 1998, 1999, 2000, 2003, and 2009 are presented in Figure 5.3-1 and Figure 5.3-2. At the La Grange and Modesto gages, during the three above normal/wet WY types (1998, 1999, 2000), winter flows increased during December through February, typically remaining at or above 2,000 cfs until at least early/mid-summer. In WY 1998, average daily flows increased beginning in mid-January and remained high, exceeding 5,000 cfs multiple times from February through July. In WY 1999, flows increased to 2,000–3,000 cfs in December, and again in mid-January, remaining generally at or near this range through mid-May. WY 2000 experienced a relatively later increase in winter flows than either WY 1998 or 1999, with flow increases occurring in mid-February (Figure 5.3-1 and Figure 5.3-2).

Average daily flows at La Grange during the two below normal/dry WY types (2003, 2009) remained at or below approximately 200 cfs through March, with pulse flow releases peaking in mid-April at 1,500 cfs in WY 2003, and peaking in mid-May at 950 cfs in WY 2009 (Figure 5.3-1). In general, average daily flows were slightly greater further downstream at Modesto, with the exception of a short but relatively large increase in average daily flow (> 1,000 cfs) that occurred during early March in WY 2009 (Figure 5.3-2).

In the San Joaquin River at Vernalis, peak flows during the above normal/wet WY types 1998 and 1999 occurred in mid-February, although their relative magnitudes were opposite those of the Tuolumne River, with 1999 flows exceeding 1998 flows at this location (Figure 5.3-3). WY 2000 flows peaked approximately a month later in mid-March, consistent with hydrology exhibited in the Tuolumne River (Figure 5.3-1 and Figure 5.3-2). Average daily flows at Vernalis for the below normal/dry WY types exhibited the pulse flow releases in mid-April, similar to the Tuolumne River (Figure 5.3-3).

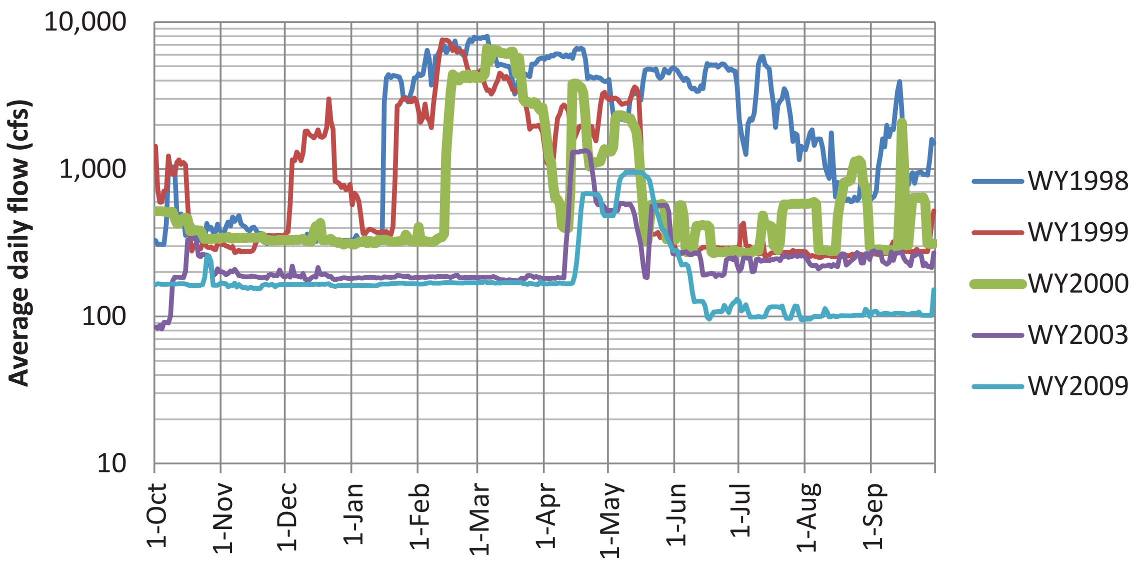

Figure 5.3-1. Tuolumne River average daily flow (cfs). Data from Tuolumne River Below La Grange Dam (USGS gage #11289650).

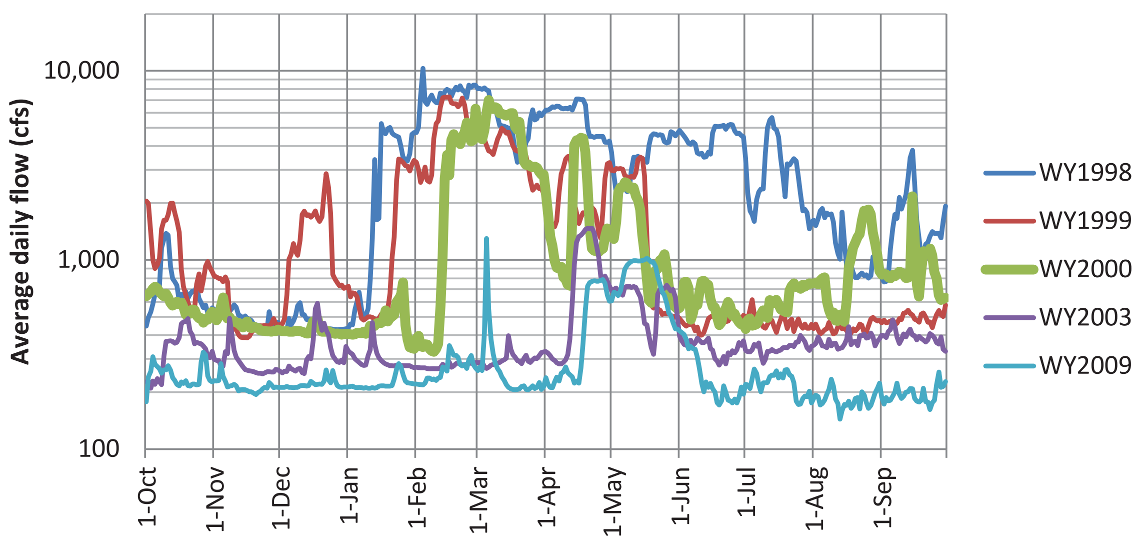

Figure 5.3-2. Tuolumne River average daily flow (cfs). Data from Tuolumne River at Modesto (USGS gage #11290000).

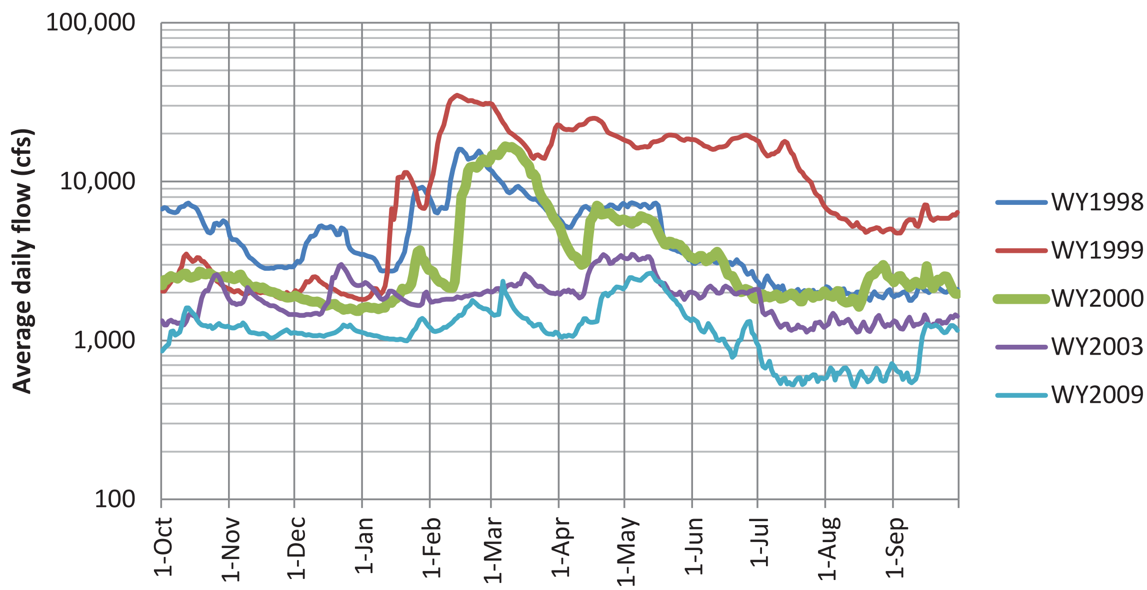

Figure 5.3-3. **San Joaquin River average daily flow (cfs). Data from San Joaquin River at Vernalis (USGS gage #11303500).**

5.3.2 Relationship between average daily flows and juvenile growth and residency

Average daily flow magnitude and timing was examined in relation to estimated mean fish size and age at exit for both the Tuolumne River (at La Grange and Modesto) and the Delta (at Vernalis) across above normal/wet WY types (1998, 1999, 2000) and dry WY types (2003, 2009). In 1998 and 1999, when average daily flows were sustained at relatively high levels during winter through spring months (extending into summer months in 1999), otolith data indicate that mean fish size and age at exit from the Tuolumne River for fish that returned to spawn were also relatively high, at approximately 73 mm FL (both years) corresponding to smolts, 91 days (1998), and 82 days (1999) (Table 5.2-1). Conversely, rotary screw trap data for 1998 and 1999 indicate that the majority of outmigrants were fry (< 50 mm FL) moving downstream during periods of increasing flow, with particularly high numbers (>500 per day) in WY 1999 (Figure 5.3-5 and Figure 5.3-6).

Although the pattern for 1998 and 1999 is consistent with prior observations of relatively larger sizes at emigration for above normal and wet WY types (Stillwater Sciences 2013b), mean fish size and age at natal exit (for fish that returned to spawn) were relatively lower at 64 mm and 69 days (Table 5.2-1) for outmigration year 2000, with the majority of individuals (70%) classified as parr (Figure 5.3-7). In contrast to other above normal and wet WY types examined, daily flows in the Tuolumne River did not increase until later in the winter (mid-February) in 2000, and were generally sustained through mid-May. Again, rotary screw trap data for WY 2000 indicate that the majority of outmigrants during WY 2000 were fry (< 50 mm FL), leaving in late February/early March (Figure 5.3-7).

Similar fish size associations were evident in the Delta as found at exit from the Tuolumne River, with larger mean fish size at ocean entry exhibited in outmigration years 1998–1999 than in 2000. However, the mean number of days spent rearing in the Delta was roughly twice as high in 2000 as in 1998 and 1999. As noted previously (Section 5.2), overall the total days from the end of exogenous feeding (i.e., emergence from gravels) to ocean entry was relatively constant at 99±20 days across all outmigration years included in the study, such that fewer days spent rearing in the Tuolumne River resulted in relatively more days rearing in the Delta (Figure 5.2-1).

Within the below normal WY types (2003, 2009), when average daily flows followed the FERC (1996) minimum flow schedule, including pulse flow releases from La Grange Diversion Dam, estimated mean fish size and age at exit were generally similar to those of the above normal/wet WY types 1998 and 1999. Rotary screw trap (RST) data indicate that very few or no fry were represented in the Shiloh Road RST (RM 3.4) data for the below normal/dry WY types (2003, 2009), in contrast to large number of fry that were observed outmigrating during the three wet WY types included in the study (1998, 1999, 2000) (Figure 5.3-8 and Figure 5.3-9). However, it should be noted that the traps were not installed until April 1 in WY 2003 and early March in WY 2009, so earlier fry emigration during these years would have been missed. Further, confirmation of any relationship between mean fish size and age at exit and below normal/dry WY hydrology should consider the relatively small sample size (n=31) for these WY types and for outmigration year 2009 in particular (n=5).

Lastly, additional exploratory analyses were conducted to determine whether barrier operations in the lower San Joaquin River and south Delta may have influenced the relative survival of early emigrating fry vs. later emigrating smolts. For example, the physical Head of Old River barrier (HORB) was in place in WY 2000 (Figure 5.3-7), corresponding to one of only two years in which there was a fry contribution to escapement (5%). Conversely, this physical (rock) barrier was not in place in WY's 1998 and 1999 when flows were too high to allow installation (Figure 5.3-5 and Figure 5.3-6); the estimated fry contribution to escapement for these years was zero. The physical HORB was in place for smolt outmigration in 2003 (Figure 5.3-8), the second of only two years when there was an estimated fry contribution to escapement (4%). An experimental behavioral barrier ("bubble barrier") was operated intermittently during smolt outmigration in 2009 when the estimated fry contribution was zero (Figure 5.3-9). These data suggest poor through-Delta juvenile survival in the absence of a physical HORB, consistent with prior studies evaluating survival of juvenile emigrants through the south Delta (Newman 2008, NMFS 2012).

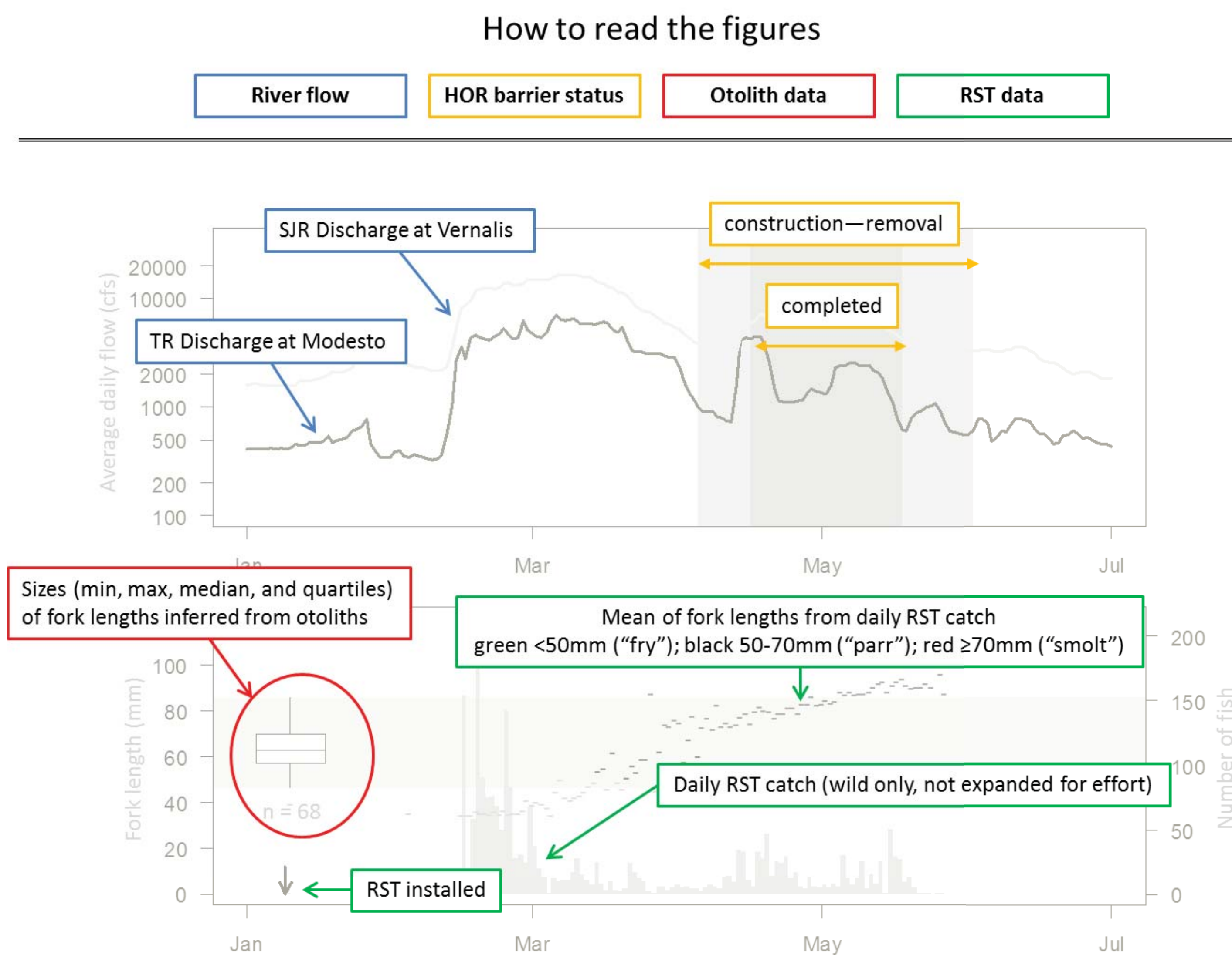

Figure 5.3-4. **Key for hydrology, rotary screw trap (RST) data, and of size-at-exit of returning fish (from otolith analysis).**

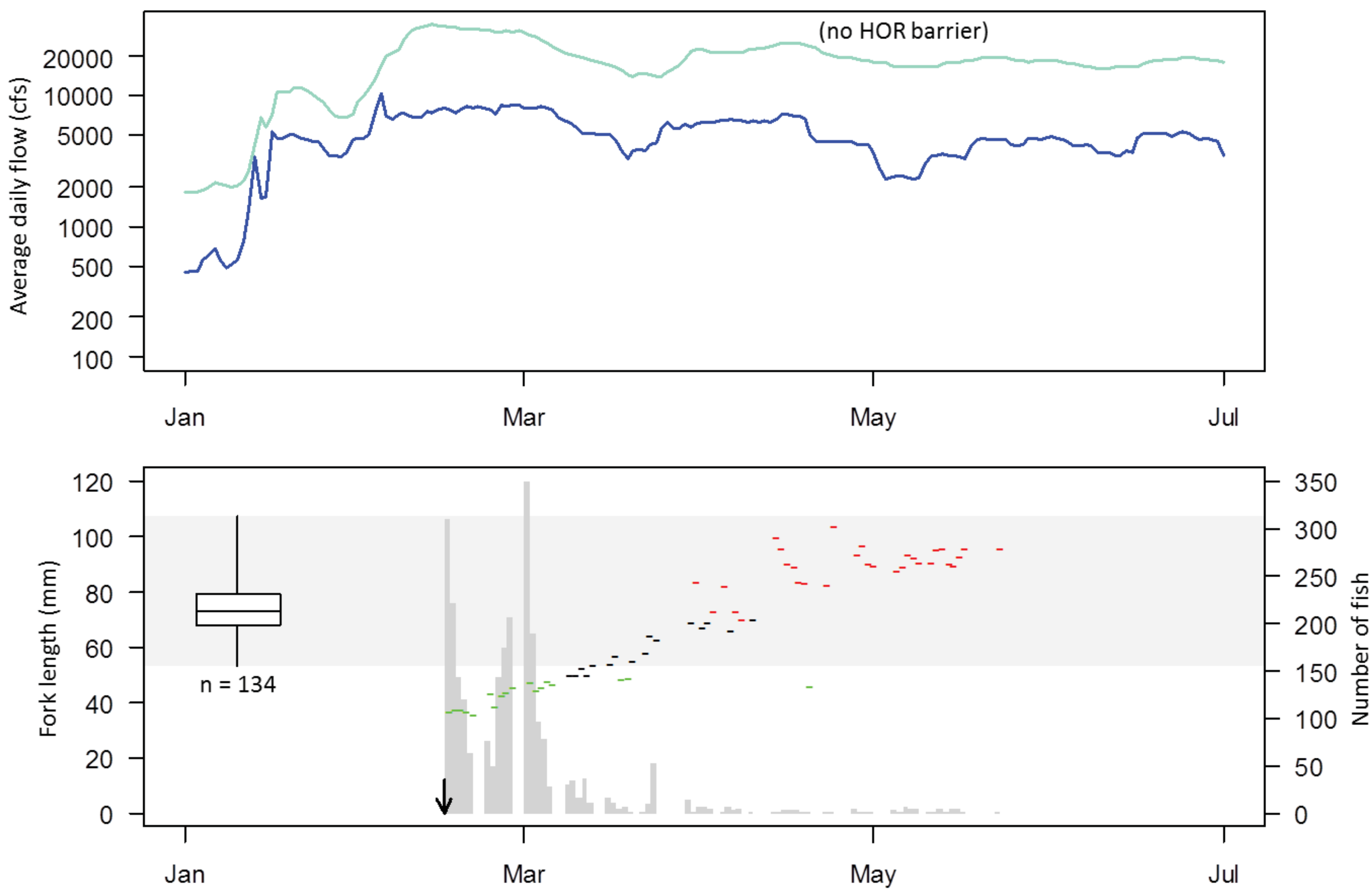

Figure 5.3-5. **1998 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

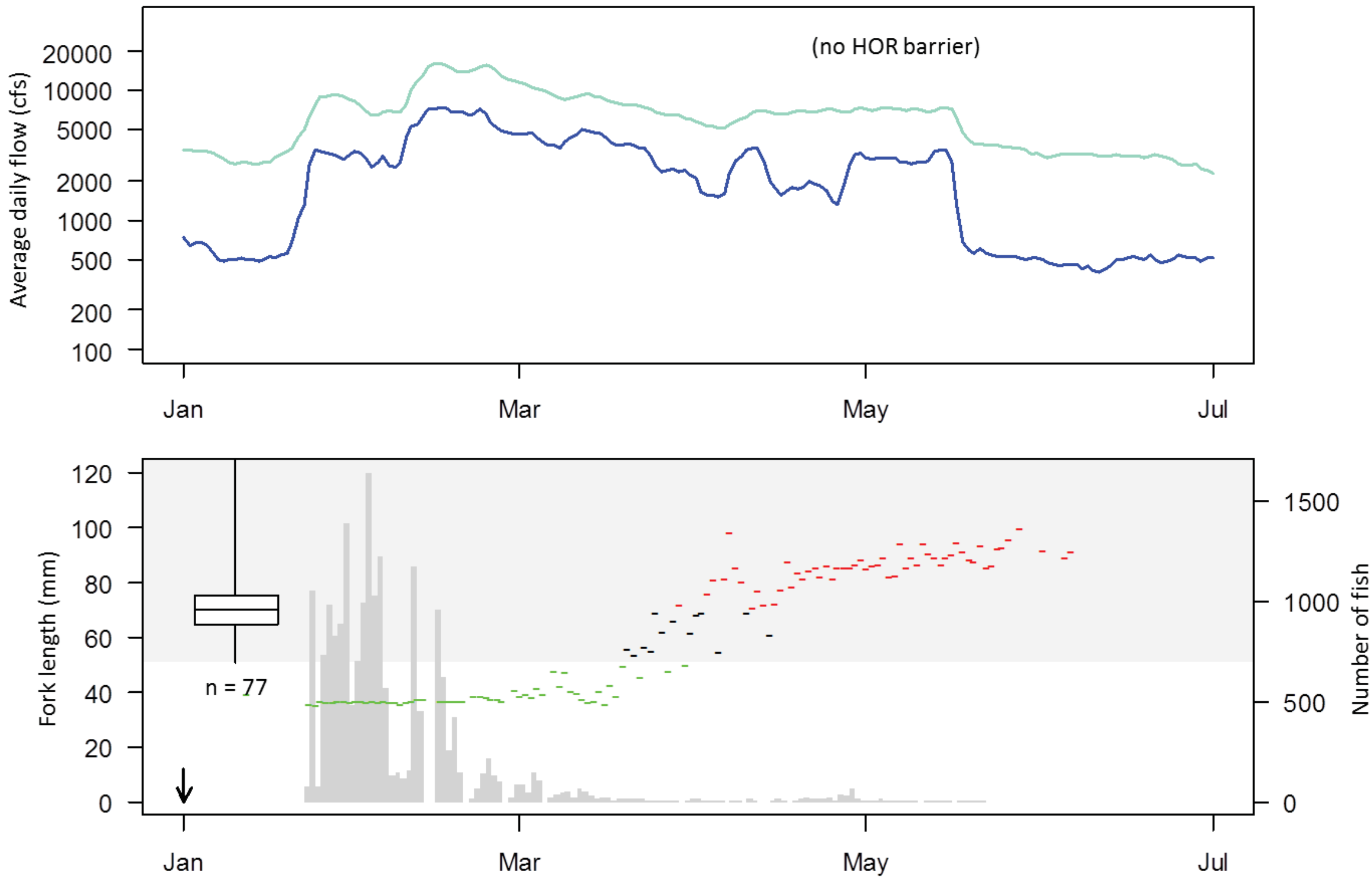

Figure 5.3-6. **1999 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

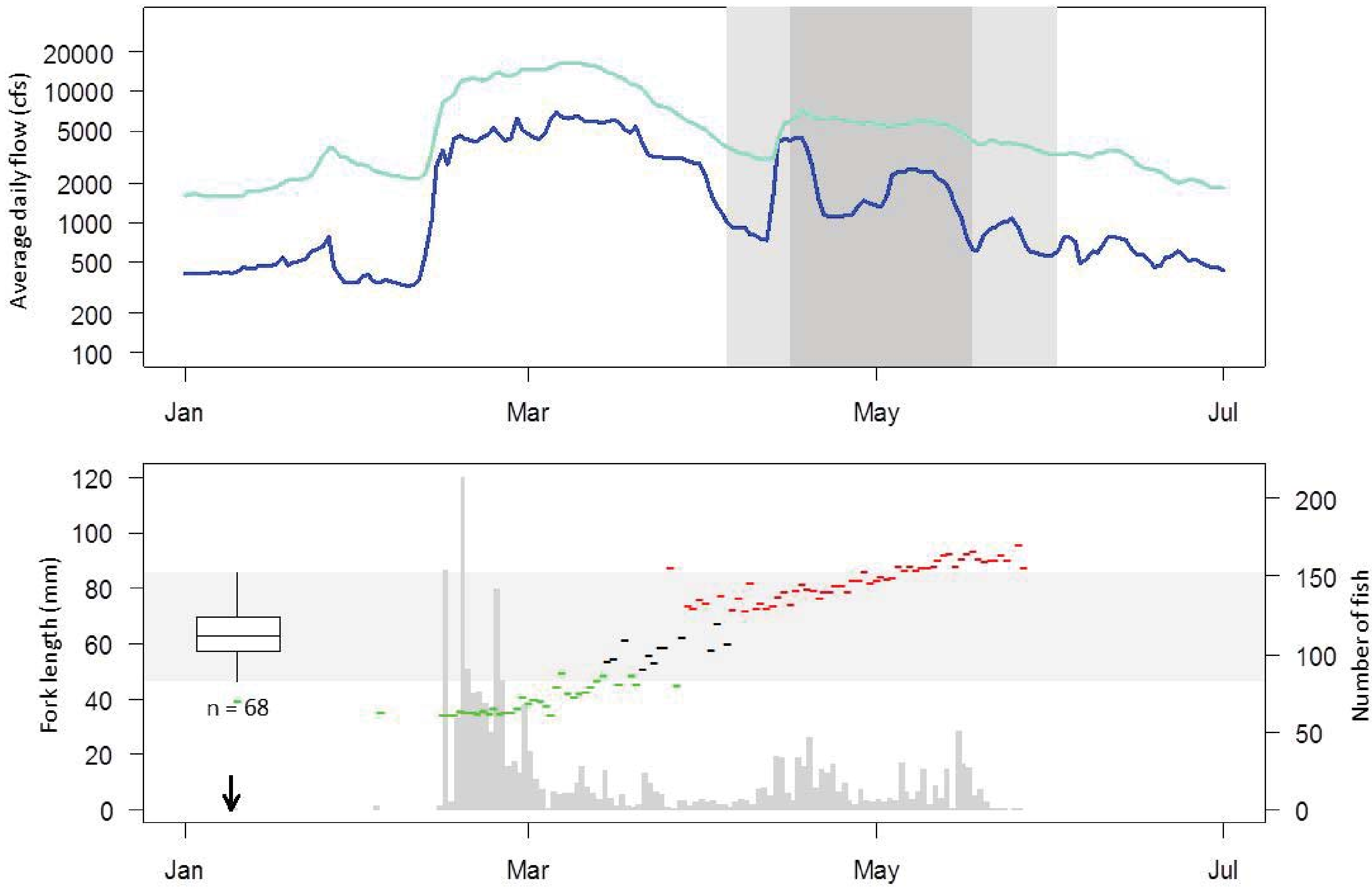

Figure 5.3-7. **2000 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

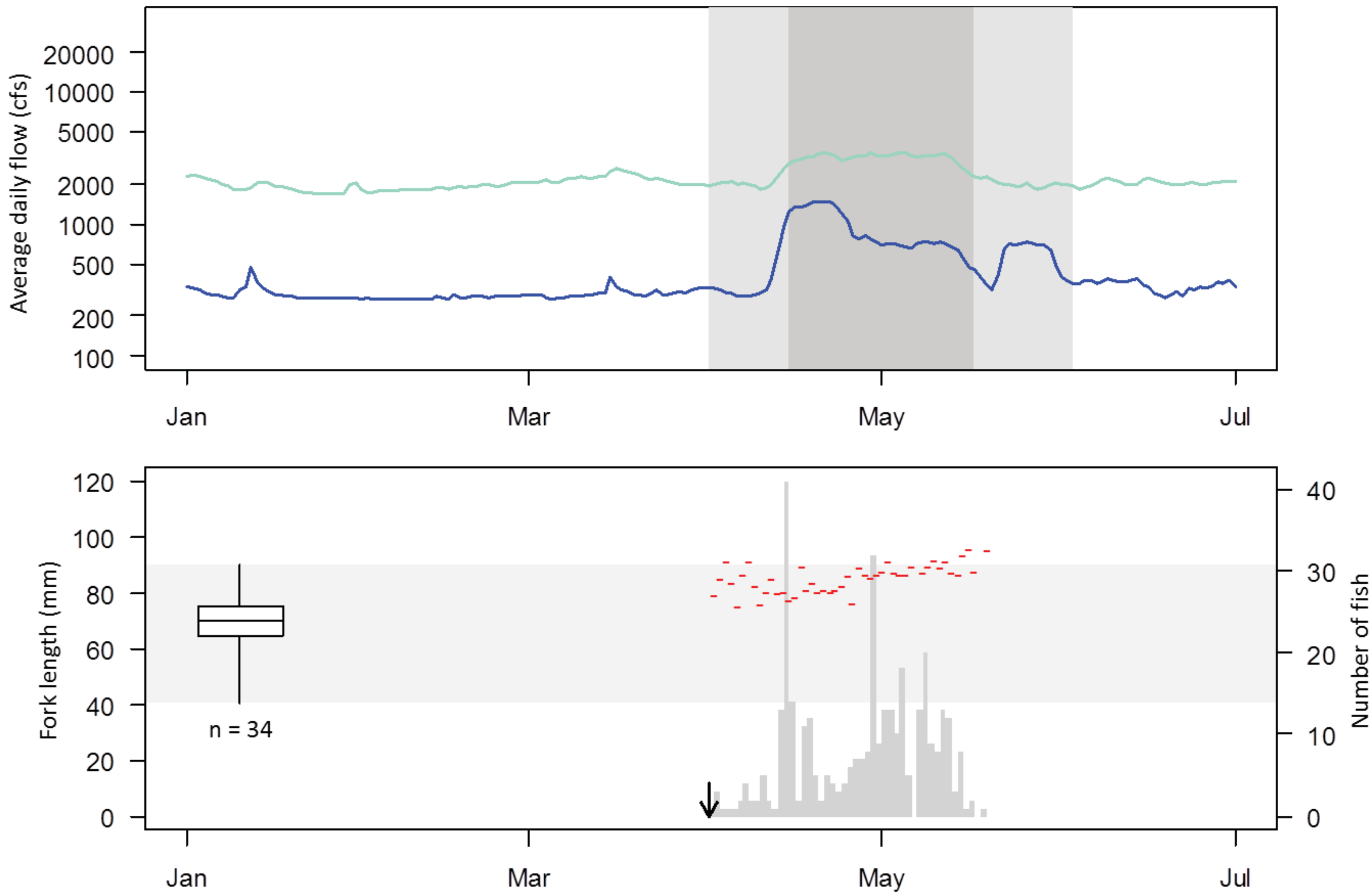

Figure 5.3-8. **2003 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

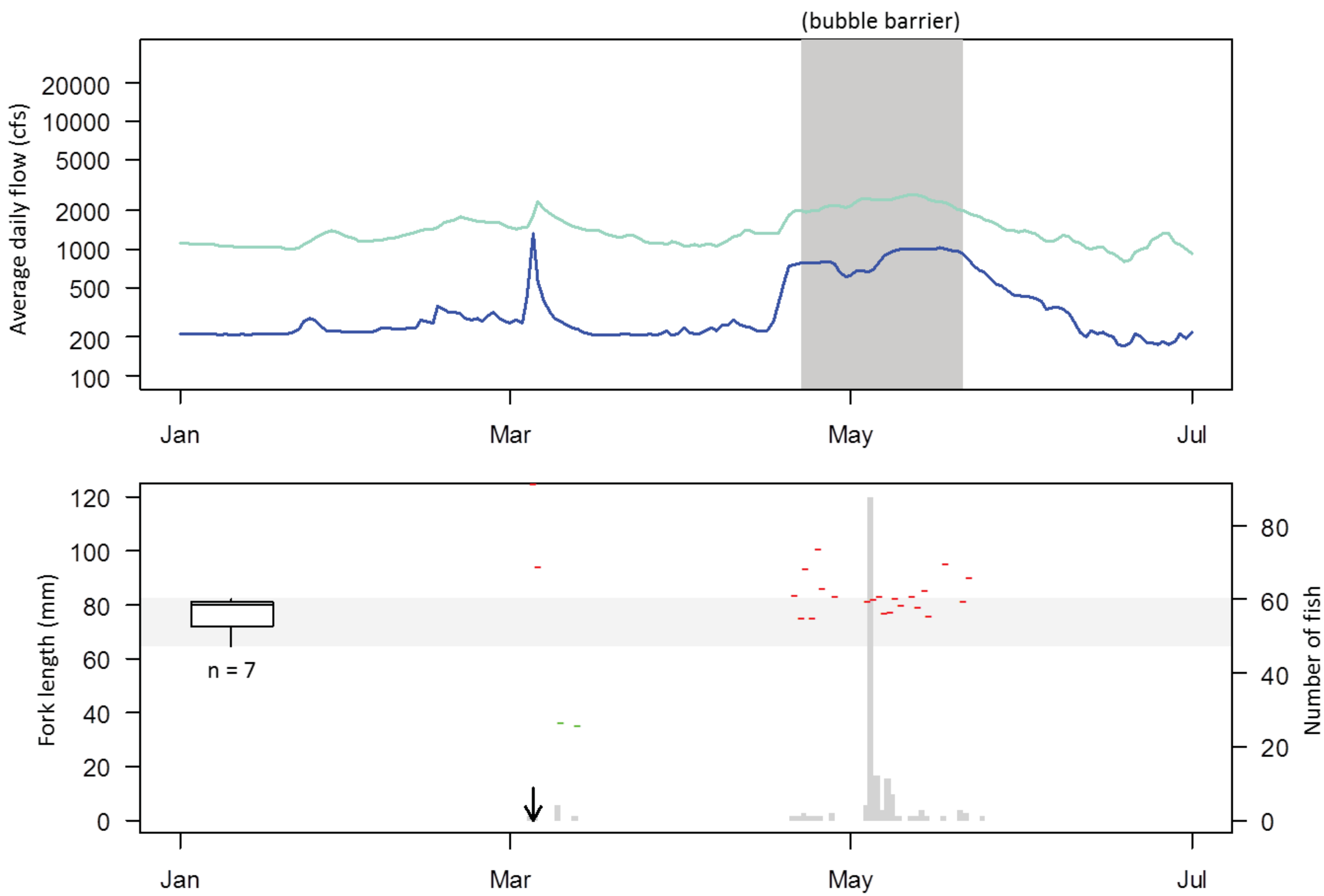

Figure 5.3-9. **2009 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

5.3.3 Relationships between monthly flows and early life-history emigration patterns

Other than associations with HORB status (Section 5.3.2), examination of mean monthly discharge, minimum monthly discharge, and maximum monthly discharge in the Tuolumne River at La Grange and Modesto for January through April did not reveal a discernable relationship with respect to growth rate, size at outmigration, or age at either outmigration or ocean entry for juveniles that originated in and returned to the Tuolumne River during the five years included in this study. Delta hydrologic patterns (at Vernalis) on a monthly timescale also did not exhibit clear relationships with growth rate, fish size, or age at ocean entry. Linear regressions indicated a lack of any compelling relationship ($R^2<0.4$, $p>0.1$) for the 192 combinations of fish size, fish age, monthly average flows for each of four months (January, February, March, April), and each of the 24 DAYFLOW parameters/indices (see Section 4.3).

6.0 DISCUSSION AND FINDINGS

Results of the analyses described above met both of the study objectives of using otolith microstructural growth patterns and/or microchemistry in order to identify:

- whether returning adults originated from hatcheries or riverine environments other than the Tuolumne River; and,
- growth rates and sizes of 'wild' fish at exit from the Tuolumne River and from the freshwater Delta.

These are discussed further below.

6.1 Hatchery origin fish

To provide an estimate of total hatchery contributions to Tuolumne River spawning escapement for the years examined in this study, the existing proportions of adipose fin clipped (i.e., hatchery marked) fish from CDFW annual spawning surveys can be combined with the proportions of unmarked hatchery fish estimated through otolith analysis. For each of the five outmigration years included in this study, a significant number of unmarked fish were classified as hatchery-origin fish through microstructural examination of otolith samples. The proportion of returning unmarked adults that originated in Central Valley hatcheries was greatest for the two below normal WY types (2003, 2009), exceeding the contribution from wild fish by approximately 2–4 times (Figure 5.1-1). The proportion of hatchery fish was relatively lower for above normal/wet WY types (1998, 1999, 2000), with the lowest proportion (33-44%) corresponding to outmigration year 1998 (Table 5.1-1). While these patterns are suggestive of a positive relationship between flow and the successful emigration of wild fish that later return as adults, confirmation of this relationship based on WY type should consider the relatively small sample size for below normal/dry WY types (n=31) vs. above normal/wet WY types (n=238).

Table 6.1-1 shows the proportions of marked (ad-clipped) and unmarked fish identified in the eight CDFW spawner survey years that recovered fish from outmigration years 1998, 1999, 2000, 2003, and 2009. The proportion of marked hatchery fish ranged from a low of 1% in 2006 to a high of 55% in 2011. For the unmarked fish, approximately 43% were identified as hatchery-origin (n=255) using results of the otolith analysis (Section 5.1). Combining the outmigration year unmarked hatchery contribution estimates with the known marked fish from subsequent escapement year surveys, Table 6.1-1 shows the total estimated hatchery contribution ranged from 39 to 100%, with a mean of 67% and generally increasing hatchery contribution in later years. To further refine this estimate and recognizing that some years in the otolith sample inventory over- and under-represent the typical age class structure in the escapement record, the overall proportion using only 3-year old recoveries, which are expected to make up the bulk of the annual escapement, ranges from 36 to 90%, with a mean of 58% (Table 6.1-1). Further consideration of large coded wire tag (CWT) releases to the Tuolumne River up to April 2005 suggests that some of the marked fish returning to the river during this period could be from the CWT release groups and thus would not be considered true hatchery strays. Separating the Tuolumne River CWT release groups from all marked (ad-clipped) fish identified in the annual spawner surveys would reduce the estimated hatchery fractions for these years in Table 6.1-1. At the same time, large hatchery releases into the Tuolumne River may potentially have swamped the existing predator population and increased outmigrant survival of emigrating wild fish. This would have the effect of slightly increasing the number of wild fish successfully emigrating and eventually returning to spawn. Nevertheless, it is apparent that hatchery contributions make up a large proportion of the annual spawning runs and the proportions of hatchery fish have been increasing in recent years.

Table 6.1-1. Estimated total hatchery contribution to annual escapement for spawner years corresponding to the five outmigration years included in the otolith study.

Spawner Year	CDFW spawner surveys			Including unmarked hatchery fish (all otolith samples)			Including unmarked hatchery fish (Age-3 otolith samples only)		
	Escapement[1]	Fraction Marked[2]	Marked Fish[2]	Unmarked Hatchery	Total Hatchery	Fraction Hatchery	Unmarked Hatchery	Total Hatchery	Fraction Hatchery
2000	17,873	6%	1,157	5,742	6,899	39%	5,207	6,364	36%
2001	9,222	16%	1,464	2,466	3,930	43%	2,667	4,131	45%
2002	7,125	31%	2,175	1,824	3,999	56%	1,566	3,742	53%
2005	719	11%	82	396	477	66%	396	477	66%
2006	625	1%	7	481	488	78%	-	-	-
2010	766	32%	245	521	766	100%	-	-	-
2011	2,847	55%	1,566	982	2,548	90%	982	2,548	90%
2012	2,120	29%	615	753	1,367	65%	-	-	-
Mean						67%	Mean		58%

[1] Data source: Stillwater Sciences (2013c).
[2] Data sources: Annual CDFW spawning survey reports (e.g., CDFG 2010) and annual FishBio weir monitoring reports (e.g., Wright et al. 2013).

Overall, results of this study are consistent with observations of increasing hatchery contributions to salmon escapement in the Central Valley as a whole (Barnett-Johnson 2007, Johnson et al. 2011). The high proportions of marked and unmarked hatchery-origin fish represented in spawning runs to the Tuolumne River suggests that the influence of Project related effects upon salmon production as well as the ability to discriminate the effectiveness of potential measures intended to benefit Chinook salmon may be obscured by variations in the production and ocean survival of hatchery fish from the Merced River Fish Facility and other Central Valley hatcheries.

6.2 Growth and residence in the Tuolumne River and the Delta

Based on Sr isotope ratios ($^{87}Sr/^{86}Sr$) and otolith microstructural features, the study results suggest that mean fish size at exit from the Tuolumne River showed no apparent relationship with WY type, with the exception of outmigration year 2000 when mean fish size was significantly different ($p<0.005$) from the other four years of the study. Mean fish size at freshwater exit from the Delta also did not exhibit a relationship with WY type.

Age distributions at exit from the Tuolumne River and at exit from the Delta suggest that overall the total days of development from formation of otolith core to ocean entry for juvenile salmonids was relatively constant at 99±20 days for each of the five outmigration years included in the study. Fewer days spent rearing in the Tuolumne River resulted in relatively more days rearing in the Delta (Figure 5.2-1). The latter suggests extended rearing in the Delta for some parr-sized fish that emigrate early from the Tuolumne River. This is particularly evident in the average number of days spent in the Delta (27.6±12.1 days; Table 5.2-1) for outmigrating juveniles in 2000, which exceeded a more typical migration time of 14–21 days and suggests that some fish spent over 4 weeks in the Delta during the 2000 outmigration.

Size-standardized estimated growth rates from this study were generally greater for fish that reared in the Tuolumne River as compared with fish that reared in the Delta, but the pattern was not consistently statistically distinguishable between the two rearing locations. As discussed in the Salmonid Information Synthesis Study (Stillwater Sciences 2013b), available food resources in the Delta may be limiting growth opportunities for juvenile Chinook salmon in some conditions, with effects upon early ocean survival and long-term population levels. For example, MacFarlane and Norton (2002) found that as compared to upstream (riverine) rearing locations, juvenile Chinook grew more slowly in the Delta and San Francisco Bay estuary.

6.3 Phenotypic contributions to spawning and potential management implications

Based upon the limited number of sampling years and otoliths available for analysis by this study, it is apparent that spawning populations in the Tuolumne River exhibit low representation of early emigrating fry, with zero contributions in three out of five outmigration years analyzed and a maximum contribution of 5% in WY 2000. However, a 5% fry contribution in years when escapement on the order of 5,000–10,000 returning adults is a non-negligible number of fish (250–500 spawners) and may be on par with total spawner numbers in low escapement years. Although observations of phenotypic contributions to spawning in the Stanislaus River indicate relatively higher fry contributions during both WY 2000 (23%) and WY 2003 (10%) (Sturrock et al. 2015), parr and smolt sized emigrants represented the vast majority of returning adults in both rivers, implying a survival advantage for fish emigrating at larger sizes.

The relative spawner contributions of juvenile Chinook salmon emigrating from the Tuolumne River at size classes corresponding to fry (<50 mm FL), parr (≥50 to <70 mm FL), and smolt (≥70 mm FL) did not vary consistently with WY type or discharge in this study. The relatively high parr (70%) and fry (5%) representation in returning adults for outmigration year 2000 is interesting, especially given that year 2000 exhibited lower and later-peaking average daily flows than the other two above normal/wet years included in the study (1998, 1999). Although the timing of juvenile life stage transitions and timing of outmigration are relatively consistent from year-to-year, we conducted additional analyses to explore the potential effects of brood-year spawner timing as well as the effects of flow and barrier operations during juvenile outmigration.

For the above normal/wet WY types represented in the otolith samples, consideration of spawner run timing in 1997, 1998, and 1999, which corresponds to outmigration years 1998, 1999, and 2000, suggests that the peak of spawning occurred 7–9 days earlier in 1997 and 1998 than the 1999 run, where the latter corresponds to the year 2000 outmigration (Figure 6.3-1). By comparison, the peak of spawner run timing for the two below normal/dry WY types (i.e., spawner years 2002 and 2008) differ by only 3-days (Figure 6.3-1). One potential explanation of the lower fry representation of spawners originating from outmigration years 1998 and 1999 is the combination of earlier spawning during 1997 and 1998 and the extended high flows that occurred during 1998 and 1999 (Figure 5.3-5 and Figure 5.3-6). These factors may have resulted in extended in-river rearing and relatively higher numbers of fish emigrating at larger (i.e., smolt) sizes in these years than occurred in 2000. Another potential explanation of differing representation of fry contributions to subsequent spawning is that the two years of extended high flows during spring 1998 and 1999 may have disrupted nesting and other essential reproductive behaviors of predators such as black bass (Loppnow et al. 2013, Cavallo et al. 2012, Kleinschmidt 2008, Montgomery et al. 1980) and led to reduced predator populations and greater numbers of fry emigrating from the Tuolumne River and into the Delta during WY 2000 (Figure 5.3-7).

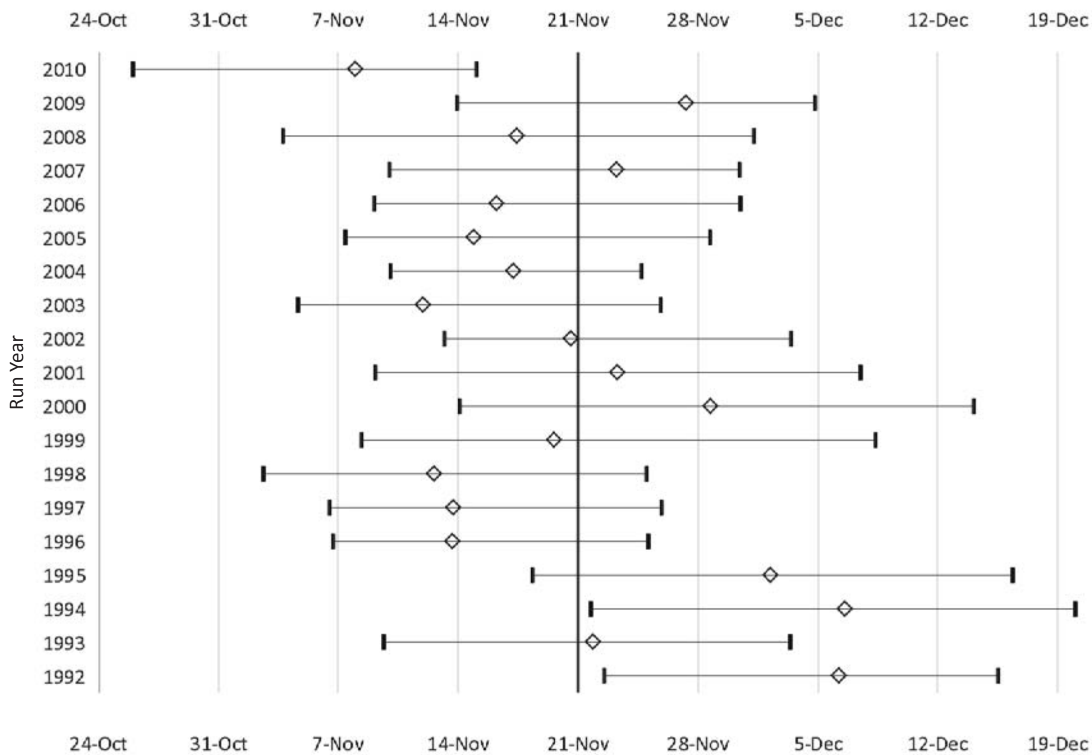

Figure 6.3-1. **Tuolumne River spawner run-timing. Data sources: Annual CDFW spawning survey reports (e.g., CDFG 2010) and annual FishBio weir monitoring reports since 2009 (e.g., Wright et al. 2013).**

The low fry contributions identified in this study for both wet and dry WY types suggest that flow-related increases in the number of juvenile Chinook salmon leaving the Tuolumne River as fry may not necessarily result in corresponding increases in subsequent escapement. In addition to spawner timing and flow related effects upon phenotypic contributions to spawning populations discussed above, we also examined the influence of barrier operations in the south Delta. Among the three above normal/wet WY types represented in the otolith samples, the physical HORB was only installed in WY 2000. This may have increased fry contribution to subsequent spawner returns relative to WY 1998 and 1999 when the HORB was not in place. Based upon the statistically significant improvements in through-Delta survival of juvenile Chinook salmon with the HORB in place (Newman 2008), HORB operation in WY 2003 may have also reduced mortality of later emigrating fry in this year as well, when 4% of returning spawners appear to have emigrated as fry. By WY 2009, the physical HORB was no longer used and it is possible that the low contribution from fry originating in this year may be due to a combination of fry entrainment into Old River as well as increased rates of predation.

As previously stated, the conclusions of this study are based upon a relatively small otolith sample size (n=31) for spawners originating from below normal/dry WY types as compared to samples (n=238) from the above normal/wet WY types. Additional analysis of adult otoliths from individuals emigrating under current Delta flow management for both above normal/wet as well as below normal/dry WY types in the future may help better discern whether variations in spring discharge are associated with greater or lower juvenile size class representation in subsequent spawning populations.

7.0 STUDY VARIANCES AND MODIFICATIONS

The study was conducted in conformance to the FERC-approved *Chinook Salmon Otolith Study Plan* (W&AR-11) approved in FERC's December 22, 2011 Determination. There are no variances.

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Study Report W&AR-11
Chinook Salmon Otolith Study

Appendix A

Tuolumne River Chinook Salmon Otolith Study – Analysis of Archival Otoliths Using Stable Isotope Microchemistry

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TUOLUMNE RIVER CHINOOK SALMON OTOLITH STUDY - ANALYSIS OF ARCHIVAL OTOLITHS USING STABLE ISOTOPE MICROCHEMISTRY

UNIVERSITY OF CALIFORNIA DAVIS

PERIOD 11/13-6/14

Prepared by Drs. Anna Sturrock and Rachel Johnson as part of Don Pedro Project Relicensing (FERC No. 2299)

EXECUTIVE SUMMARY

Processes occurring in freshwater, estuarine, and marine habitats strongly influence the growth, survival and reproductive success of salmonids. One of the fundamental challenges in understanding salmon population dynamics lies in our inability to link and evaluate the relative importance of processes occurring throughout the complex salmon life cycle. For example, a critical unknown is the extent to which environmental conditions and management actions in the freshwater contribute to the expression and survivorship of different juvenile outmigration strategies into adulthood.

Here, we use Sr isotope ratios ($^{87}Sr/^{86}Sr$) and daily growth information recorded in Central Valley fall-run Chinook salmon, *Oncorhynchus tshawytcha,* otoliths ("earbones") to reconstruct the stream or hatchery-of-origin and early life movements of adult salmon collected on the Tuolumne River in the San Joaquin River Basin, California. A total of 598 paired otolith and scale samples were used to reconstruct and compare size-specific outmigration patterns for fish emigrating from the Tuolumne River in the spring of 1998, 1999, 2000, 2003 and 2009, incorporating dry, below normal, above normal and wet water year types. First, we identified adults that originated from the Tuolumne River (i.e. removed strays) using an updated 'strontium isoscape' and otolith growth characteristics exhibited by hatchery and wild salmon in the Central Valley [1, 2]. For each individual, otolith isotopic and microstructural data were linked with otolith radius in order to reconstruct the size and age at which they had exited from their natal river and from freshwater. Back-calculated fork lengths (± 95% CI) were used to classify outmigrants into one of three life history stages: fry (≤55mm), parr (>55mm to ≤75mm) or smolt (>75 mm).

Our study shows that a significant number of adults spawning in the Tuolumne River in fall of 2000-2012 were strays from other rivers and hatcheries in the Central Valley. The earliest three outmigration years examined had relatively low straying rates of unmarked fish, with a greater proportion of spawners having originated in and reared in the Tuolumne River (1998: 57-68% returns, 33-44% strays; 1999: 38-53% returns, 47-62% strays; 2000: 61-64% returns, 36-39% strays). Outmigration year 2003 exhibited an intermediary straying rate (27-35% returns, 65-73% strays) while outmigration year 2009 was subject to particularly high straying rates (9-15% returns, 85-91% strays, primarily from the Coleman National Fish Hatchery on Battle Creek in the Sacramento River watershed, which comprised 57% of the unmarked sample).

All size classes of juvenile outmigrants were represented in the adult spawning populations. Tuolumne-origin adults were largely comprised of individuals that had emigrated from the Tuolumne River as parr and smolts, however, in outmigration year 2000, 20% of the returning adults had outmigrated as fry. Comparable with findings on other rivers in the San Joaquin Basin, parr outmigrants were consistently the most commonly observed phenotype in the returning adults.

INTRODUCTION

Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) exhibit significant variation in the size, timing and age that they emigrate from their natal rivers [14]. Typically, juveniles rear in the freshwater for one to three months before smoltification prompts downstream migration towards the ocean; however, early spring flows are often also coupled with large pulses of emigrating fry [5, 14, 17]. In some years, fry-sized individuals are the most numerous size-class leaving natal rivers and entering the delta [17, 18]. The contribution of these smaller outmigrants to the adult population is often assumed to be negligible, as juvenile survival is generally positively correlated with body size [e.g. 19] and there is little evidence for significant downstream rearing in the San Francisco estuary [20]. Hatcheries tend to release larger smolts to maximize survival rates and their contribution to the ocean fishery, but a recent study indicated that the majority of California Central Valley (CCV) adults captured in the Oregon troll fishery had emigrated as fry and parr [21]. Scale analyses have also inferred greater survival rates of intermediate-sized juveniles [22]. Understanding the relative survivorship of different outmigrant size classes is critical to our understanding of population dynamics and evaluation of freshwater management actions and water operations.

Quantifying the relative contribution of different size classes and/or developmental stages of juvenile salmon to the adult spawning population has largely been limited by the methodological challenges associated with reconstructing early life history movements of the adults. Mark-recapture studies using coded wire tags (CWT) have provided empirical indices of juvenile survival rates through the Sacramento-San Joaquin system [28], but are hindered by low rates of return and often use hatchery fish, which may exhibit different behavior and survival than their wild counterparts [29]. No study to date has tracked habitat use of individual salmon over an entire lifecycle to estimate the relative success or survivorship of juvenile outmigration phenotypes, let alone under different flow conditions or between different rivers in the same year. Most have relied on correlations between environmental conditions (e.g. flow) experienced during juvenile outmigration periods and abundance of returns [16, 30].

Recent advances in techniques using chemical markers recorded in biomineralized tissues provide rare opportunity to retrospectively "geolocate" individual fish in time and space [31]. Otoliths are metabolically inert, calcium carbonate "earbones" found in all bony fishes, that grow incrementally from birth (the otolith "primordia") to death (the outer edge of the otolith). The otolith microstructure features daily and annual growth rings that can be determined visually using light microscopy [32]. In Chinook salmon, as the otoliths grow proportionally to fish length during juvenile stages, daily increment widths can be used to reconstruct individual growth trajectories, providing a means to compare growth rates across life stages, hydrologic regimes and contrasting environments. Otolith microstructure can therefore provide insights into how juvenile salmon growth is affected by biotic and abiotic factors such as food availability and water temperature. When microstructural and microchemical techniques are combined, otoliths can provide a powerful natural tag for reconstructing movement patterns of individual fish [33]. The technique relies on differences in the physicochemical environment producing a distinct and reproducible "chemical fingerprint" in the otolith. In the CCV, strontium isotopes ($^{87}Sr/^{86}Sr$) are ideal markers because the water signature varies with the parent geology, differing among many of the rivers and salmon outmigration paths, and is faithfully recorded in the otoliths of Chinook salmon [1, 34]. Changes in otolith $^{87}Sr/^{86}Sr$ values can be used to reconstruct time- and age-resolved movements as salmon migrate through the freshwater, estuarine, and ocean environments [1, 34]. Furthermore, in salmon, otolith size is significantly related to body size [32, 35, 36], allowing back-calculation of individual fork length (FL) at specific life history events.

Here, we used otolith $^{87}Sr/^{86}Sr$ ratios and microstructure to identify natal origin and reconstruct size/age at emigration of adults that spawned in the Tuolumne River in 1996-2008. These adults represent cohorts that emigrated as juveniles from the freshwater in 1998, 1999, 2000, 2003 or 2009. First we used the otolith data to differentiate between adults that strayed from other rivers from adults that were born and returned to the Tuolumne River. After removing strays from other rivers, we used otolith $^{87}Sr/^{86}Sr$ ratios, growth increments and radii to determine the size and age at which returning (i.e. "successful") adults had originally emigrated from the Tuolumne River and from the freshwater system. We aimed to address the following questions:

1. What was the early fresh-water life history of the adult Chinook salmon? More specifically, at what age (days from exogenous feeding) and estimated size did the returning adult leave the Tuolumne River as a juvenile?
2. What was the origin of the adult Chinook salmon? More specifically, what portion of the adult Chinook salmon escaping to the Tuolumne River originated from the Tuolumne River separate from hatcheries and other riverine environments of the Sacramento and San Joaquin Central Valley drainages?

STUDY AREA

The Tuolumne River is one of the southernmost tributaries of the San Joaquin River (SJR) (Fig. 1). The lower basin typically experiences a Mediterranean climate with wet winters and dry summers, and the tributaries are predominantly fed by snowmelt from the Sierra Nevada Mountains. The Tuolumne watershed encompasses a 1,900 square-mile area of the central Sierra Nevada and northern San Joaquin Valley and includes the northern half of Yosemite National Park. The Tuolumne is the largest tributary to the SJR, producing an average annual unimpaired yield of 1,906,000 acre-feet. The river flows for 150 miles from its headwaters at over 13,000 ft on Mt. Dana and Mt. Lyell to its confluence with the SJR at an elevation of 30 ft . The lower Tuolumne extends from its confluence with the SJR to La Grange Dam at river mile (rm) 52.2, which has been the upstream barrier to anadromous fish movements since at least 1871 [10].

Around 90% of the annual precipitation on the Tuolumne River occurs between November and April, with an annual minimum flow schedule including migration pulse flows in April and May required by the Federal Energy Regulatory Commission (FERC 1996).

METHODS

ADULT SAMPLING AND COHORT RECONSTRUCTION

Otoliths were extracted from age 2, 3 and 4 year old adults in the Tuolumne River during carcass surveys conducted by CDFW in the fall of 2000-2012 (Table 1). The five focus years of the current study (1998, 1999, 2000, 2003 and 2009) encompassed a range of hydrologic conditions (wet, above normal, above normal, below normal and dry, respectively) based on the San Joaquin valley water index (http://cdec.water.ca.gov). Carcass surveys were typically run from October to early-January depending on abundance and hydrologic conditions. Sample selection was temporally stratified to follow the same cohort across different escapement years, as fish return at different ages. This approach was taken to capture the age structure typically observed for salmon in the San Joaquin tributaries. This was deemed important in order to capture a representative sample that accounted for the potential for the outmigration strategy to co-vary with age-at-return. For example, it is unclear the extent to which larger outmigrants may have a higher likelihood of returning as younger (age 2) adults. Our sampling design was not intended to explicitly test whether there was a linkage between outmigration strategies and return age, however. Ages and outmigration cohorts were determined by counting scale winter annuli by experts at CDFW La Grange, as per established and validated techniques [41].

Otolith treatment and $^{87}Sr/^{86}Sr$ analyses

Otoliths were prepared and analyzed for $^{87}Sr/^{86}Sr$ ratios by multi-collector laser ablation inductively coupled plasma mass spectrometry (MC-LA-ICPMS) using the methods described in Barnett-Johnson et al. [2]. In brief, otoliths were rinsed 2-3 times with deionized water and cleaned of adhering tissue. Once dry, otoliths were stored in clean microcentrifuge tubes then mounted in Crystalbond™ resin and polished (600 grit, 1500 grit, 3 μm then 1 μm lapping film) until the primordia were exposed. $^{87}Sr/^{86}Sr$ analyses were carried out on a Nu plasma HR (Nu Instruments Inc.) interfaced with a Nd:YAG 213 nm laser (New Wave Research) at the UC Davis Interdisciplinary Center for Plasma Mass Spectrometry. Contrasting with the line transects used to establish natal signatures of tributaries in the CCV [1, 2] we used spot analyses to prevent cross-contamination of ablated material and to allow coupling of chemical data with discrete microstructural features. A 40μm or 55μm laser beam diameter was used (roughly equivalent to 10-14 days of growth) with pulse rate of 20 or 10 Hz at 70 or 65% power and a dwell time of 25 or 35 seconds. Helium was used as the carrier gas to improve sensitivity and was mixed with argon before reaching the plasma source. Gas blank and background signals were monitored following sample changes and measured for 30 seconds prior to each batch of spot analyses. A modern coral sample was analyzed at the start of each analytical session and the outer (marine) portion of adult salmon otoliths was analyzed between every otolith. The measured $^{87}Sr/^{86}Sr$ ratio was normalized to $^{86}Sr/^{88}Sr = 0.1194$ and to maximize accuracy, batches of unknowns were corrected to the global $^{86}Sr/^{88}Sr$ value (0.70918) by correcting to the mean of three spot analyses on the marine portion of an adult salmon otolith analyzed immediately afterwards.

A standardized 90° transect was used for $^{87}Sr/^{86}Sr$ and otolith radius measurements, starting at the post-rostrum primordia going in the dorsal direction (Fig. 2). Juvenile otoliths of known origin (from previous studies) were used to assign natal origins of adults in the current project. In the juvenile otoliths, the transect was terminated at the otolith edge to ensure analysis of the most recently deposited material in order to characterize capture site (natal) signature. In the adult otoliths of unknown origin, the transect was terminated past the ocean entry check or to a distance of c.800μm (c. 120mm FL) to ensure inclusion of the full freshwater outmigration period. To improve the spatial resolution and accuracy of exit spot identification and back-calculated FL, additional $^{87}Sr/^{86}Sr$ analyses were carried out around the Tuolumne-SJR transition. These additional spots ("respots") meant that generally, subweekly resolution could be achieved.

Strontium isoscape

As part of ongoing work to provide better resolution on the determination of fish origin useful in this study, Sr isotope values of known-origin otolith samples from juveniles and CWT adults were combined with the previously published $^{87}Sr/^{86}Sr$ baseline [1]. Water samples (A. Sturrock, unpublished) were combined with data from Ingram and Weber (1999) and P. Weber (unpublished). The resulting 'strontium isoscape' was comprised of 480 samples from all potential natal sources in the CCV, with many sites sampled across multiple years (1998-2013) and hydrologic regimes (Table 3). Thus, the isoscape can be quantitatively characterized by the mean $^{87}Sr/^{86}Sr$ isotope values and the standard deviations for the different salmon rivers and hatcheries in the CCV.

Otoliths from juveniles collected from their natal tributary or hatchery were analyzed for $^{87}Sr/^{86}Sr$ using the same type of transect as the adults, and the natal signature determined from otolith material deposited immediately after onset of exogenous feeding (~250μm from the core, see [2]). Material deposited prior to this point exhibits an elevated signature due to the influence of maternally-derived strontium from the yolk, which for fall-run salmon, was formed while the mother was in the ocean.

Identification of natal origin

In order to reconstruct juvenile outmigration strategies for the Tuolumne River salmon population, it was critical to remove any fish that had strayed from other tributaries or hatcheries. Given that hatcheries tend to release at larger sizes [21], not detecting and removing hatchery strays in our analyses would likely bias the representation of smolt outmigrants. To identify the origin of our unknown fish, we measured the natal $^{87}Sr/^{86}Sr$ and then statistically determined which river or hatchery in the strontium isoscape (see previous section) had the most similar $^{87}Sr/^{86}Sr$ to the unknown fish. The utility of using a linear discriminant function analysis (DFA) to classify unknown origin fish into their likely rivers/hatcheries of origin, is that it allows one to use additional sources of information. In this case, we can use previous observations of hatchery strays from coded wire tag recoveries in the Constant Fractional Marking Report (probabilities/group weightings) and use that information to help weight our statistical model to more accurately account for hatchery strays (Table 2) [42, 43]. Thus, the DFA approach allowed us to incorporate empirical data of stray-rates from the major hatcheries into our statistical model to account for non-random patterns in salmon straying and improve classification accuracy. As the majority of Chinook salmon return to freshwater at 3 years old [14], the more recent report (escapement year 2011 [42]) was cohort-matched to outmigration year 2009 (escapement year – outmigration year + 1). All adults from previous outmigration cohorts were assigned using priors from the earlier CFM report [43].

The natal signature was determined by averaging the $^{87}Sr/^{86}Sr$ values that corresponded with the otolith material deposited immediately after onset of exogenous feeding (but prior to emigration from the natal river). The DFA assignments for the mean natal value were used to determine the river or hatchery of origin. Juveniles collected in the Tuolumne River exhibit more variable isotopic signatures within and among individuals than in other rivers in the CCV (see Results). Some juveniles that were collected in the Tuolumne River exhibited $^{87}Sr/^{86}Sr$ values that appeared to imply movement into the SJR or Stanislaus River immediately after emergence and then return to the Tuolumne (e.g. Fig. 3C). However, given that the changes in isotopic values tended to occur at early stages, when individuals are unlikely to be strong enough swimmers to move freely up and downstream, we interpreted this pattern to represent geographic variations in the $^{87}Sr/^{86}Sr$ signature within the Tuolumne River, confirmed with additional water sampling carried out as part of other projects (Fig. 1 & 8).

As the Tuolumne River exhibits variable water chemistry from upper to lower reaches (P. Weber, A. Sturrock, unpublished), and otolith $^{87}Sr/^{86}Sr$ values of known-origin fish from the Tuolumne River, Mokelumne River Hatchery and Feather River Hatchery can overlap (see Results), there is a potential of misclassifying Tuolumne-origin fish. Thus, to improve our assignment accuracy, any individuals exhibiting ambiguity in their natal assignment were also analyzed for otolith microstructural features that can discriminate hatchery from wild fish. We used the methods developed for CCV Chinook [44], where individuals are classified as hatchery or wild based on the prominence of the exogenous feeding check (scored blind by 2-3 independent readers) and the mean and variance in increment width around the first 30 daily increments following onset of exogenous feeding.

Reconstructing size and age at outmigration

Emigration from the Tuolumne River ('natal exit') was determined using the distance from the core to the 'last natal spot' rather than the 'first non-natal spot', because to accrete sufficient new otolith material to modify the isotopic composition of the otolith, the fish would have inhabited isotopically distinct (i.e. non-natal) water for several days, after which time it would be a significant distance downstream of the confluence. The method used to identify the 'last natal spot' was to work backwards from the final inflection point indicative of ocean-bound migration (Fig. 3A-C). We assumed that the lowest point of this final inflection represented movement through the SJR, and thus used the spot prior as the last natal spot. The only exceptions were on occasions when the lowest point prior to ocean migration was lower than any value measured in the SJR (e.g. Fig. 3D); on these occasions the lowest point was assumed to have been deposited while the fish was rearing in the lower Tuolumne River, which has been shown to exhibit values as low as 0.7066 (P. Weber, A. Sturrock, unpublished). Emigration from freshwater ('freshwater exit') was defined as the distance at which otolith $^{87}Sr/^{86}Sr$ values last reached 0.7080 (equivalent to 1ppt based on [45]), determined using linear interpolation.

To back-calculate fish size at natal and freshwater exit, the relationship between otolith radius and FL was quantified using fall run Chinook salmon juveniles from the same "Evolutionarily Significant Unit" (ESU), which is of utmost importance for producing relevant and unbiased back calculation models [46]. Otolith radius was measured using a Leica DM1000 microscope and Image Pro Plus 7. Reference samples were collected as part of other projects from the Tuolumne River (2003; n = 6), Stanislaus River (2000 and 2002; n = 95), the Coleman National Fish Hatchery (2002; n=40) and in the San Francisco Bay at Golden Gate Bridge (2005; n = 83) (Fig. 5). The Tuolumne-origin fish tended to sit above the mean regression line (Fig. 5), but there was no significant difference between the back-calculated FL of Tuolumne vs. non-Tuolumne fish (ANCOVA: $p = 0.08$), nor any difference in the slopes (ANCOVA: $p = 0.8$). As such, we assumed that the overall OR-FL relationship was suitable for reconstructing FLs of juveniles from the Tuolumne River, however it would be advisable to increase representation of Tuolumne-origin juveniles in future analyses. The error around the OR-FL calibration line (Fig. 5) was used to estimate 95% confidence intervals (CI) around individual FL reconstructions. Individuals were categorized as fry, parr or smolt outmigrants based on FL: ≤55mm, >55 to <75mm, and >75mm FL, respectively (after [21]).

Daily growth bands were counted and widths between daily increments were measured along the same 90 degree transect as the geochemical analysis, beginning at the post exogenous feeding check until freshwater exit. Some otoliths were difficult to age and given low readability scores (1-2); ages are not provided for these individuals. The ages of fish at Tuolumne River exit, Freshwater exit, and habitat-specific growth rates were obtained for fish with otolith readability scores of 3-5. A subset of otoliths were aged by two independent readers, providing an estimate of error associated with fish aging. The two independent reads of each fish demonstrated high agreement, with an average difference of ± 5 days (range 0-12 days).

RESULTS

ACCURACY OF NATAL ASSIGNMENTS

The DFA assigned 63% of samples back to the correct site of origin (Table 4), with the majority of misclassified sites being among the Mokelumne River Hatchery (MOH), Feather River Hatchery (FEH) and the Tuolumne River (TUO), which overlap in their chemical composition (Fig. 6). The use of otolith microstructure (~10% error rate for hatchery vs. wild assignments) [44] and weighted priors helped to separate TUO-origin fish from MOH and FEH strays, however there remains potential for misclassifications between the two hatchery sites (FEH and MOH), particularly given that (except for outmigration year 2009) the priors used were not cohort-specific. We prepared and processed 13 CWT fish from outmigration years 1999 and 2000 of known hatchery origin. However, the presence of these samples was withheld from the individuals preparing the samples, collecting the $^{87}Sr/^{86}Sr$ data, as well as statistically assigning them to natal origin. Thus, these known samples were treated in the same way as all the unknowns in the study. Once the assignments were made, the true identify of these fish were revealed to the analysts. All fish were correctly classified to the Merced River Hatchery (MEH).

PATTERNS IN $^{87}SR/^{86}SR$ VALUES WITHIN THE TUOLUMNE RIVER

Contrary to the stable $^{87}Sr/^{86}Sr$ profiles observed in other CCV rivers, the Tuolumne River is characterized by variable $^{87}Sr/^{86}Sr$ values from the upper spawning reaches to the confluence with the San Joaquin River (A. Sturrock, unpublished). This variability was first observed in some water analyses (P. Weber, unpublished) and known-origin juveniles (Fig. 3C & D), and subsequently in adult otolith $^{87}Sr/^{86}Sr$ profiles from outmigration years 2000 and 2003 [47]. The lower isotopic values in the lower river were originally hypothesized to result from inputs of Stanislaus River water via Dry Creek (a tributary to the Tuolumne River at river mile [rm] 17). However, subsequent water analyses (carried out as part of other studies) indicated declines in $^{87}Sr/^{86}Sr$ values as far upstream as rm46, with rm 22 to the confluence exhibiting relatively stable signatures around 0.7065 (Fig. 8). The average variability (2SD) of the water analyses based on analyses of multiple standard reference materials was 0.000020, providing high confidence in these data. The geographic trends in Tuolumne River water $^{87}Sr/^{86}Sr$ cannot be explained by inputs from Dry Creek alone (rm 17), implying additional sources of isotopically light water to the upper and mid reaches of the river.

These patterns have clear implications for identifying fish origin, determining rearing location(s) within the Tuolumne River, and the rules used to identify transitions between the Tuolumne and San Joaquin rivers (Fig. 2, 3). Trace elemental analyses of water samples carried out as part of past and ongoing projects (P. Weber, A. Sturrock, unpublished) indicate clear differences in water Sr/Ca and Ba/Ca ratios between the Tuolumne and San Joaquin Rivers (Fig. 9). Thus, future studies attempting to identify fish transition across this confluence might benefit from a multi-elemental approach, combining otolith Sr isotopes with Sr/Ca and Ba/Ca analyses [48].

STRAYING AND RETURN RATES TO THE TUOLUMNE RIVER

Overall, straying rates of unmarked fish have increased over time coincident with increasingly dry environmental conditions. The earliest three outmigration years examined had relative low straying rates of unmarked fish (1998: 57-68% returns, 33-44% strays, 1999: 38-53% returns, 47-62% strays, 2000: 61-64% returns, 36-39% strays). Outmigration year 2003 had intermediary straying rates (27-35% returns, 65-73% strays), while outmigration year 2009 was characterized by particularly high straying rates (9-15% returns, 85-91% strays, primarily from the Coleman National Fish Hatchery on Battle Creek, which comprised 57% of the total sample).

SIZE AND AGE AT OUTMIGRATION

Given the variance around the mean OR-FL regression line (approximately ±10mm FL; Fig. 5), it is not advisable to place too much emphasis on any one particular FL reconstruction; with the upper and lower FL estimates often resulting in fish spanning multiple life stages (Appendix 1A & B). However, given a lack of bias in the OR-FL relationship, and its consistency between Sacramento and San Joaquin basin-origin fish (Fig. 5), the average FLs and overall life stage assignments (Tables 6 and 7) were deemed relatively robust and representative population-level metrics.

All size classes of juvenile outmigrants were represented in the adult spawning population. Tuolumne-origin adults were largely comprised of individuals that had emigrated from the Tuolumne as parr and smolts, however, in outmigration year 2000, 20% of the returning adults had outmigrated as fry (Table 6). Consistent with observations of other populations in the San Joaquin Basin, parr outmigrants were generally the most commonly observed phenotype in the returning adults, implying a potential survival advantage despite being smaller than smolts. There were significant differences in size, age and growth rate between outmigration years ($p<0.05$, Fig. 9, Table 7), but no inter-annual difference in growth rate variability (as tested through comparisons of the coefficient of variation in increment width; $p>0.05$). In general, outmigration year 2000 was characterized by younger, smaller outmigrants; however, the number of days in the freshwater delta was longer (Fig. 9), implying a higher frequency of non-natal rearing during this season.

TABLES

Table 1. Numbers of otolith samples sampled randomly from unclipped salmon carcasses in the Tuolumne River between 2000 and 2012. Ages were obtained from CDFW scale readings and samples matched to outmigration years 1998, 1999, 2000, 2003 and 2009 before Sr isotope analysis.

Cohort		**Adult carcass sampling year**	**Age at return (yr)**	**Number of individuals**	**% of total sample**
Brood year	**Outmigration year (WYT†)**				
1997	1998 (Wet)	2000	3	124	62%
		2001	4	76	38%
1998	1999 (Above normal)	2000	2	9	6%
		2001	3	64	44%
		2002	4	73	50%
1999	2000 (Above normal)	2001	2	31	28%
		2002	3	79	72%
		2003	4	0	0%
2002	2003 (Below normal)	2004	2	0	0%
		2005	3	87	91%
		2006	4	9	9%
2008	2009 (Dry)	2010	2	14	30%
		2011	3	30	65%
		2012	4	2	4%
TOTAL				598	

† San Joaquin Valley Index Water year type during juvenile rearing & outmigration

Table 2. Discriminant Function Analysis (DFA) priors used in the current study to predict natal origin of adults obtained in the Tuolumne River Carcass Survey corresponding to outmigration years 1998, 1999, 2000, 2003 and 2009. The probabilities are based on the CWT-derived proportions of hatchery strays in the Tuolumne in escapement year 2010 and 2011 constant fractional marking (CFM) reports and an assumed natural straying rate of 5% [49], removed from the proportion of "natural" fish reported in the CFM report and divided equally among the remaining salmon rivers in the California Central Valley. Priors from CFM escapement year 2010 were applied to all cohorts pre-2009, while priors from CFM escapement year 2011 were applied to outmigration year 2009, given cohort-matching to the dominant year class. Note that Feather River Hatchery and Thermalito Rearing Annex were not distinguished between in the CFM reports, so the priors for the former were divided equally between the two sites.

Natal origin	**Site code**	**"Wild" or hatchery**	**Prior probability based on CFM 2010 escapement** *(all outmigration years <2009)*	**Prior probability based on CFM 2011 escapement** *(outmigration year 2009 only)*
Tuolumne River (RETURNS)	TUO	W	0.4845	0.2565
Merced River Hatchery	MEH	H	0.1060	0.2081
Feather River Hatchery	FEH	H	0.0624	0.0684
Thermalito Rearing Annex	THE	H	0.0624	0.0684
Nimbus Hatchery	NIM	H	0.0433	0.0116
Coleman National Fish Hatchery	CNH	H	0.1345	0.0848
Mokelumne River Hatchery	MOH	H	0.0569	0.2524
Battle Creek	BAT	W	0.005	0.005
Deer Creek	DEE	W	0.005	0.005
Mill Creek	MIL	W	0.005	0.005
Butte Creek	BUT	W	0.005	0.005
Feather River	FEA	W	0.005	0.005
Stanislaus River	STA	W	0.005	0.005
Mokelumne River	MOK	W	0.005	0.005
Yuba River	YUB	W	0.005	0.005
Merced River	MER	W	0.005	0.005
American River	AME	W	0.005	0.005

Table 3. Details of samples and mean $^{87}Sr/^{86}Sr$ included in the DFA to assign natal origin (n=480), where "matrix" includes juvenile otoliths (J), CWT adult otoliths (CWT) and water samples (W). All analyses were carried out as part of existing or ongoing projects ([1], [34], P. Weber, A. Sturrock, unpublished), and used to predict the origin of adults collected in the current study. Site codes are provided in Table 2.

Site	Matrix	Year	N	Mean 87Sr/86Sr	SD
AME	J	1999	5	0.71025	0.00004
AME	W	1998	4	0.70979	0.00017
BAT	J	1999	9	0.70391	0.00017
BUT	W	1998	5	0.70481	0.00009
CNH	CWT	2000	1	0.70527	
CNH	CWT	2009	7	0.70547	0.00043
CNH	CWT	2010	3	0.70557	0.00013
CNH	J	2000	5	0.70531	0.00020
CNH	J	2002	8	0.70535	0.00038
DEE	J	2002	8	0.70412	0.00004
DEE	W	1998	5	0.70409	0.00003
FEA	J	1999	5	0.70622	0.00012
FEA	J	2000	5	0.70621	0.00020
FEA	J	2002	8	0.70615	0.00003
FEA	W	1998	7	0.70620	0.00011
FEH	CWT	2007	14	0.70728	0.00013
FEH	CWT	2008	19	0.70741	0.00014
FEH	J	1999	5	0.70673	0.00012
FEH	J	2000	5	0.70736	0.00017
FEH	J	2002	17	0.70717	0.00020
FEH	J	2004	5	0.70709	0.00014
MEH	CWT	1998	5	0.70888	0.00009
MEH	CWT	1999	5	0.70886	0.00006
MEH	CWT	2001	6	0.70854	0.00006
MEH	CWT	2003	6	0.70872	0.00006
MEH	CWT	2004	2	0.70862	0.00004
MEH	CWT	2006	5	0.70892	0.00007
MEH	CWT	2009	6	0.70871	0.00002
MEH	CWT	2010	6	0.70865	0.00010
MEH	J	1999	1	0.70885	
MEH	J	2002	9	0.70861	0.00003
MEH	J	2004	5	0.70869	0.00011
MER	J	2003	13	0.70852	0.00010
MER	W	1998	4	0.70846	0.00063
MIL	J	2002	10	0.70412	0.00003
MIL	W	1998	5	0.70396	0.00002
MOH	CWT	1998	2	0.70742	0.00003
MOH	CWT	1999	6	0.70767	0.00011
MOH	CWT	2000	13	0.70757	0.00009
MOH	CWT	2001	7	0.70751	0.00009
MOH	CWT	2002	4	0.70757	0.00012
MOH	CWT	2007	8	0.70736	0.00010
MOH	CWT	2008	5	0.70744	0.00014
MOH	CWT	2009	6	0.70737	0.00009
MOH	CWT	2010	8	0.70723	0.00007
MOH	J	1999	4	0.70768	0.00008
MOH	J	2000	5	0.70760	0.00007
MOH	J	2002	11	0.70755	0.00013
MOK	J	2000	4	0.70709	0.00005
MOK	J	2002	10	0.70690	0.00004
MOK	W	1998	4	0.70696	0.00016
NIH	J	2002	9	0.70974	0.00006
STA	J	1999	7	0.70663	0.00002
STA	J	2000	7	0.70663	0.00004
STA	J	2002	10	0.70656	0.00011
STA	J	2011	3	0.70646	0.00005
STA	J	2012	12	0.70643	0.00007
STA	J	2013	7	0.70641	0.00011
STA	W	2012	5	0.70639	0.00002
THE	J	2004	5	0.70581	0.00011
TUO	J	1999	3	0.70783	0.00042
TUO	J	2003	6	0.70757	0.00022
TUO	J	2007	34	0.70763	0.00019
TUO	J	2010	7	0.70780	0.00014
TUO	J	2011	4	0.70780	0.00003
TUO	W	1998	5	0.70789	0.00025
TUO	W	2013	2	0.70785	0.00006
YUB	J	2002	19	0.70823	0.00021

Table 4. Performance of the unweighted DFA for natal assignments. For the unknown samples in this study, weighted priors were used (Table 2) and hatchery vs. wild assignments based on otolith microstructure improved classification accuracy [44].

Site	BAT	DEE	MIL	BUT	CNH	THE	FEA	STA	MOK	FEH	MOH	TUO	YUB	MER	MEH	NIH	AME	Total	% Correct
BAT	**7**	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	78%
DEE	0	**8**	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	62%
MIL	5	9	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	7%
BUT	0	0	0	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	5	100%
CNH	0	0	0	4	**14**	5	1	0	0	0	0	0	0	0	0	0	0	24	58%
THE	0	0	0	0	0	**5**	0	0	0	0	0	0	0	0	0	0	0	5	100%
FEA	0	0	0	0	0	1	**22**	2	0	0	0	0	0	0	0	0	0	25	88%
STA	0	0	0	0	0	0	4	**47**	0	0	0	0	0	0	0	0	0	51	92%
MOK	0	0	0	0	0	0	0	0	**15**	3	0	0	0	0	0	0	0	18	83%
FEH	0	0	0	0	0	0	0	2	13	**26**	24	0	0	0	0	0	0	65	40%
MOH	0	0	0	0	0	0	0	0	0	19	**35**	25	0	0	0	0	0	79	44%
TUO	0	0	0	0	0	0	0	0	1	2	18	**35**	5	0	0	0	0	61	57%
YUB	0	0	0	0	0	0	0	0	0	0	0	1	**14**	4	0	0	0	19	74%
MER	0	0	0	0	0	0	0	0	0	0	0	1	0	**12**	4	0	0	17	71%
MEH	0	0	0	0	0	0	0	0	0	0	0	0	0	14	**42**	0	0	56	75%
NIH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**9**	0	9	100%
AME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	**6**	9	67%
OVERALL																			63%

Table 5. Natal origin of all unclipped fish analyzed for 5 outmigration years (1998, 1999, 2000, 2003 and 2009). Note that adclipped fish have been removed (1 from OMY1999, 12 from OMY 2000 - all correctly assigned to Merced Hatchery).

			1998		**1999**		**2000**		**2003**		**2009**	
	Site	**Code**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Wild	Tuolumne R.	TUO	117	59%	55	38%	66	61%	26	27%	5	11%
	Tuolumne R.*	TUO*	17	9%	22	15%	2	2%	8	8%	2	4%
	Stanislaus R.	STA	5	3%	8	5%	4	4%	0	0%	0	0%
	Merced R.	MER	1	1%	0	0%	0	0%	0	0%	0	0%
	Mokelumne R.	MOK	2	1%	1	1%	0	0%	0	0%	0	0%
	Feather R.	FEA	0	0%	0	0%	0	0%	0	0%	1	2%
Hatchery	Coleman H.	CNH	0	0%	0	0%	0	0%	1	1%	26	57%
	Feather H.	FEH	1	1%	5	3%	4	4%	6	6%	4	9%
	Mokelumne H.	MOH	8	4%	28	19%	23	21%	39	41%	1	2%
	Merced H.	MEH	34	17%	9	6%	5	5%	4	4%	2	4%
	Nimbus H.	NIH	0	0%	5	3%	1	1%	9	9%	2	4%
	Thermalito (Feather H.)	THE	0	0%	2	1%	0	0%	3	3%	3	7%
	Habitat X ‡	X	15	8%	11	8%	5	5%	0	0%	0	0%
	Total		**200**		**146**		**110**		**96**		**46**	

* Individuals assigned to the Tuolumne with <0.5 posterior probability based on mean natal $^{87}Sr/^{86}Sr$ values.

‡ Individuals assigned as hatchery-origin based on otolith microstructure, but where natal $^{87}Sr/^{86}Sr$ values are outside of the observed range of any hatchery in the CCV.

Table 6. Life stage † at natal exit for fish assigned to the Tuolumne River with high confidence

Outmigration year	N	Fry	Parr	Smolt
1998	117	2%	56%	43%
1999	55	4%	62%	35%
2000	67	20%	73%	8%
2003	26	4%	65%	31%
2009	5	0%	40%	60%

† Life stage defined as fry (≤55mm), parr (>55mm to ≤75mm) or smolt (>75 mm) after [21]

Table 7. Summary of average forklength (FL) at exit, number of increments (days) and increment width (growth rate) in the natal river and freshwater delta by outmigration year for juveniles that originated in and returned to the Tuolumne River (identified as "TUO" in Appendix Table 1). Trends are also visualized in Figure 9 in the form of box plots (i.e. displaying median values as opposed to means), alongside the results of statistical comparisons among years.

		Natal river			Freshwater delta		
Outmigration year	Sample size	FL at exit (mm)	No. increments (days)	Increment width (μm)	FL at exit (mm)	No. increments (days)	Increment width (μm)
1998	117	73.3 ± 8.5	91.0 ± 16.2	3.07 ± 0.28	80.8 ± 9.0	15.8 ± 7.5	3.24 ± 0.54
1999	55	72.6 ± 11.6	82.0 ± 13.6	3.20 ± 0.27	82.3 ± 11.5	16.5 ± 8.7	3.35 ± 0.56
2000	66	63.5 ± 8.6	68.5 ± 18.6	3.10 ± 0.26	77.4 ± 6.9	27.6 ± 12.1	3.52 ± 0.52
2003	26	71.0 ± 10.6	79.7 ± 17.9	3.39 ± 0.43	80.1 ± 10.0	10.5 ± 5.2	3.65 ± 0.62
2009	5	76.0 ± 7.1	88.0 ± 20.3	3.36 0.29	83.4 ± 6.8	16.0 ± 7.5	3.03 ± 0.36

FIGURES

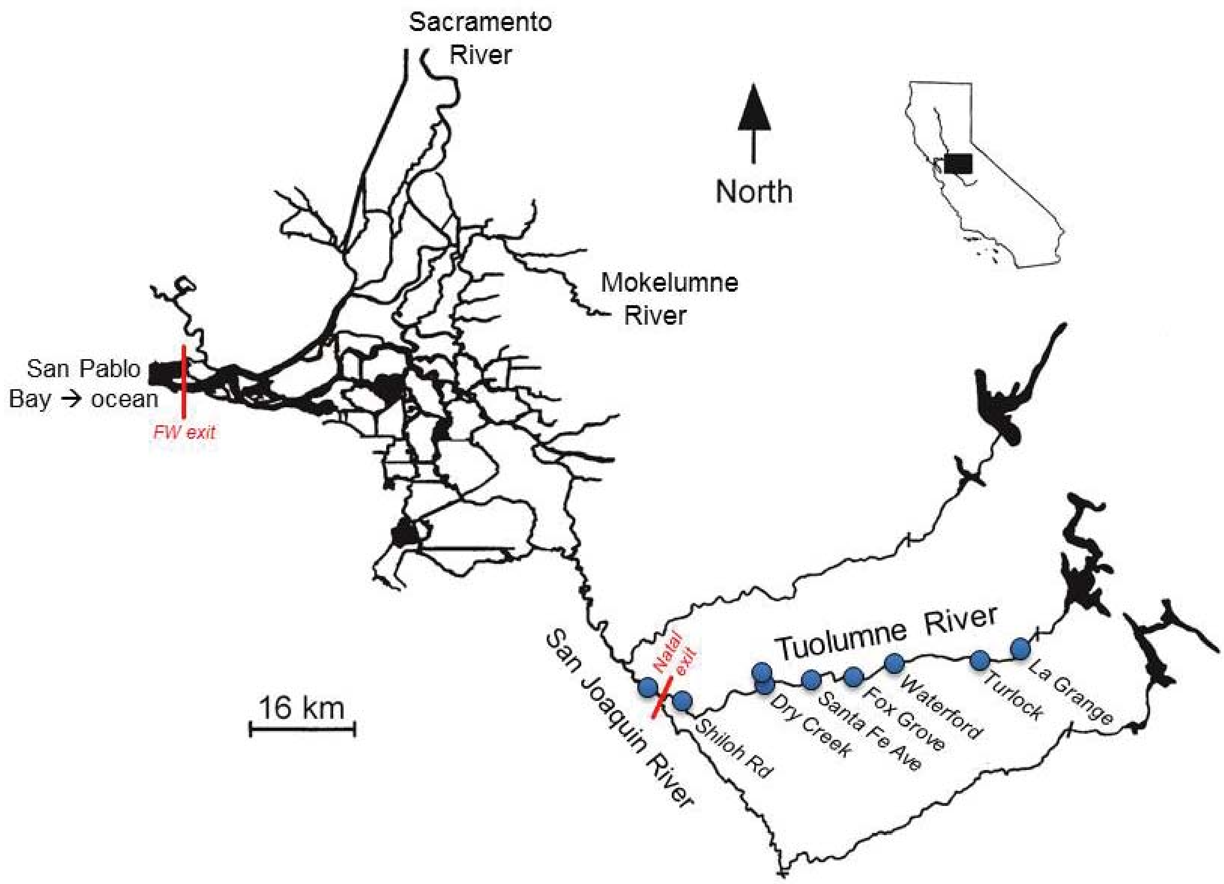


Fig. 1 Map to show location of the Tuolumne and San Joaquin rivers, and the sites sampled for water isotope analyses as part of a different project (blue circles; A. Sturrock, unpublished). The locations defined as natal and freshwater (FW) exit are indicated by red lines.

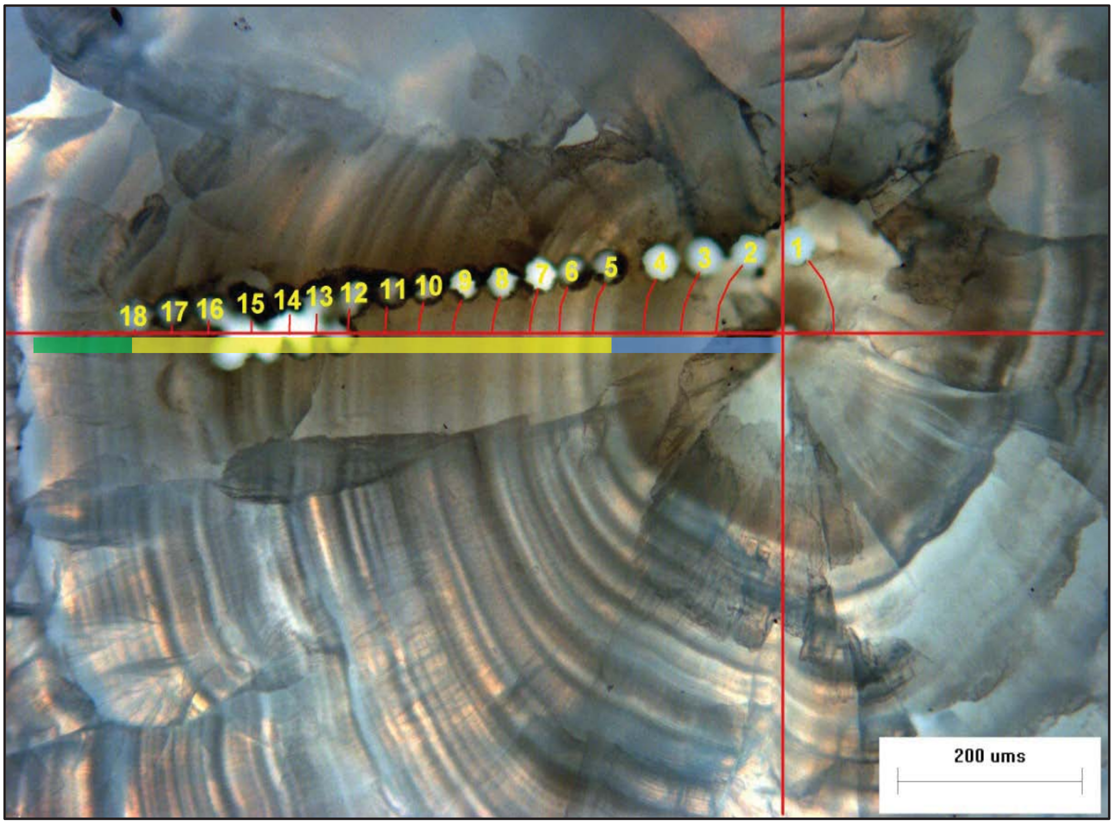


Fig. 2 A typical $^{87}Sr/^{86}Sr$ transect showing spot analyses (numbered) from the core to ocean entry. The life history stages are indicated by letters: maternal (M), juvenile (J) and ocean (O). The distance at which the final 'natal spot' intersected the 90° transect (indicated by curved red lines) was used to back-calculate size at outmigration. Note the 'respots' at positions 12.5 to 15.5 (located under the yellow bar) used to more accurately identify exit point.

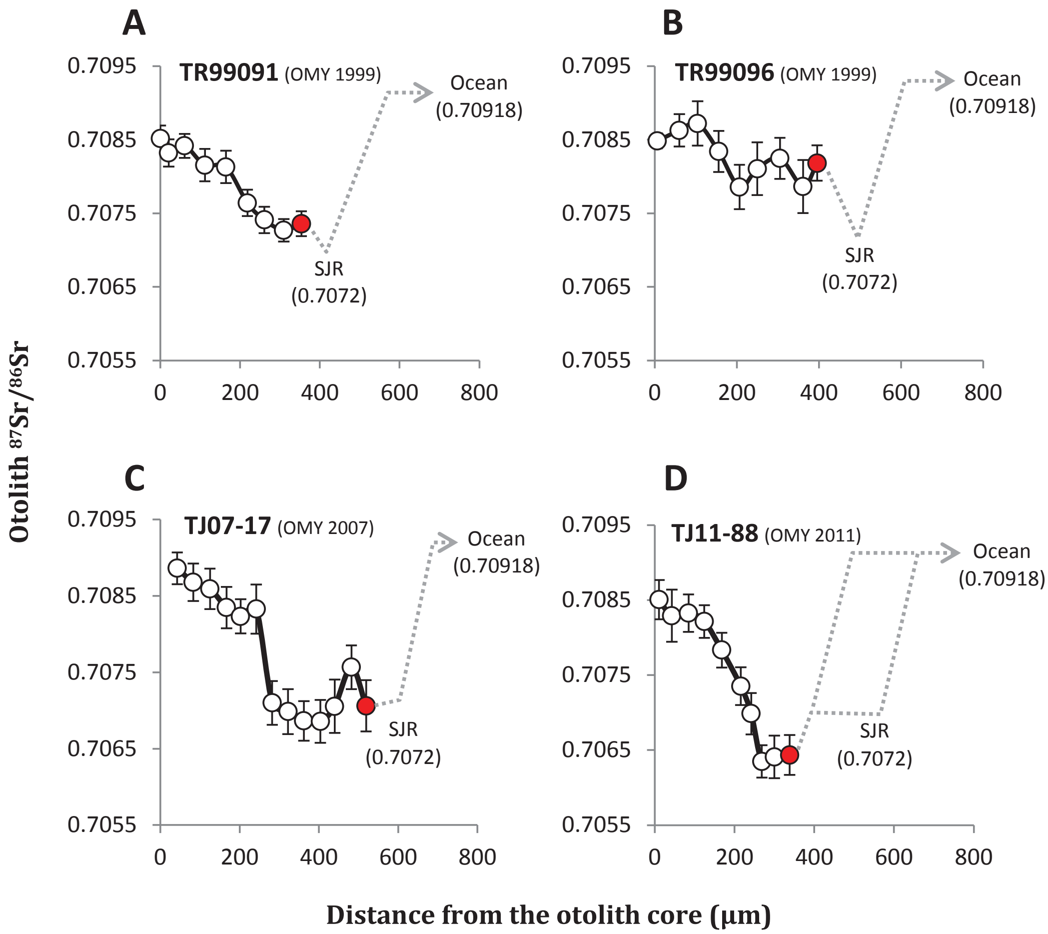


Fig. 3 Otolith $^{87}Sr/^{86}Sr$ profiles from four juvenile salmon captured in the lower Tuolumne River in outmigration years (OMY) 1999, 2007 and 2011. The natal exit spot ("last natal value") is indicated in red, along with the expected profile trajectory (dotted lines) through the San Joaquin River (SJR) to the ocean, had the fish not been captured as a juvenile and was instead being sampled as a returning adult. Note that the juvenile in plot D had moved to the lower river (or Dry Creek) immediately after emergence (~250um from the core) and the dotted lines indicate two possible trajectories, one with extended rearing in the SJR prior to leaving freshwater and the other with direct outmigration to the ocean.

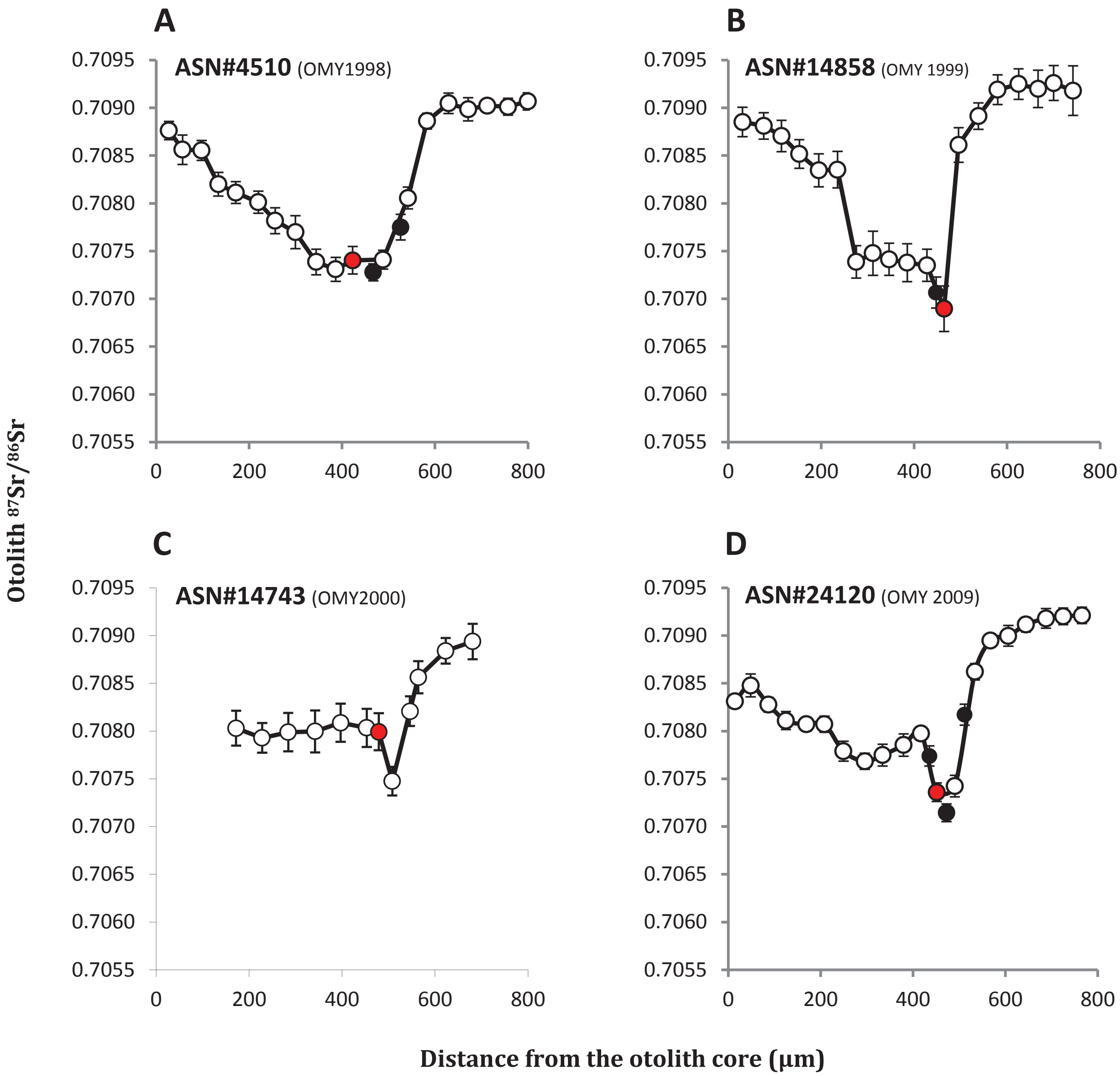


Fig. 4 Examples of otolith $^{87}Sr/^{86}Sr$ profiles from adult salmon carcasses collected in the lower Tuolumne River that were assigned to the Tuolumne River, having outmigrated as juveniles in 1998-2009. The inferred 'last natal spot' prior to outmigration to the SJR and ocean is shown in red. Black symbols indicate respots.

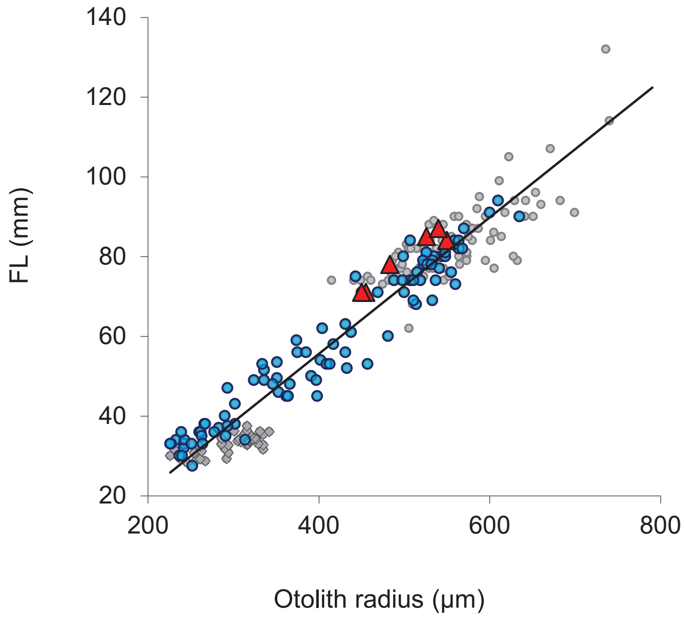


Fig. 5 Relationship between otolith radius and fork length (FL) of juveniles of known origin (Sturrock, unpublished) (n=224, $r^2 = 0.92$) used to reconstruct size at outmigration in returning adults from the current study. The 224 reference samples are all in the same Evolutionary Significant Unit (California Central Valley fall run salmon) and include individuals from the Tuolumne River (n=6; red triangles), the Stanislaus River (n=95; blue circles), Coleman National Fish Hatchery (n=40; grey diamonds) and the San Francisco Bay at Golden Gate Bridge of unknown origin within the CCV (n=83; grey circles).

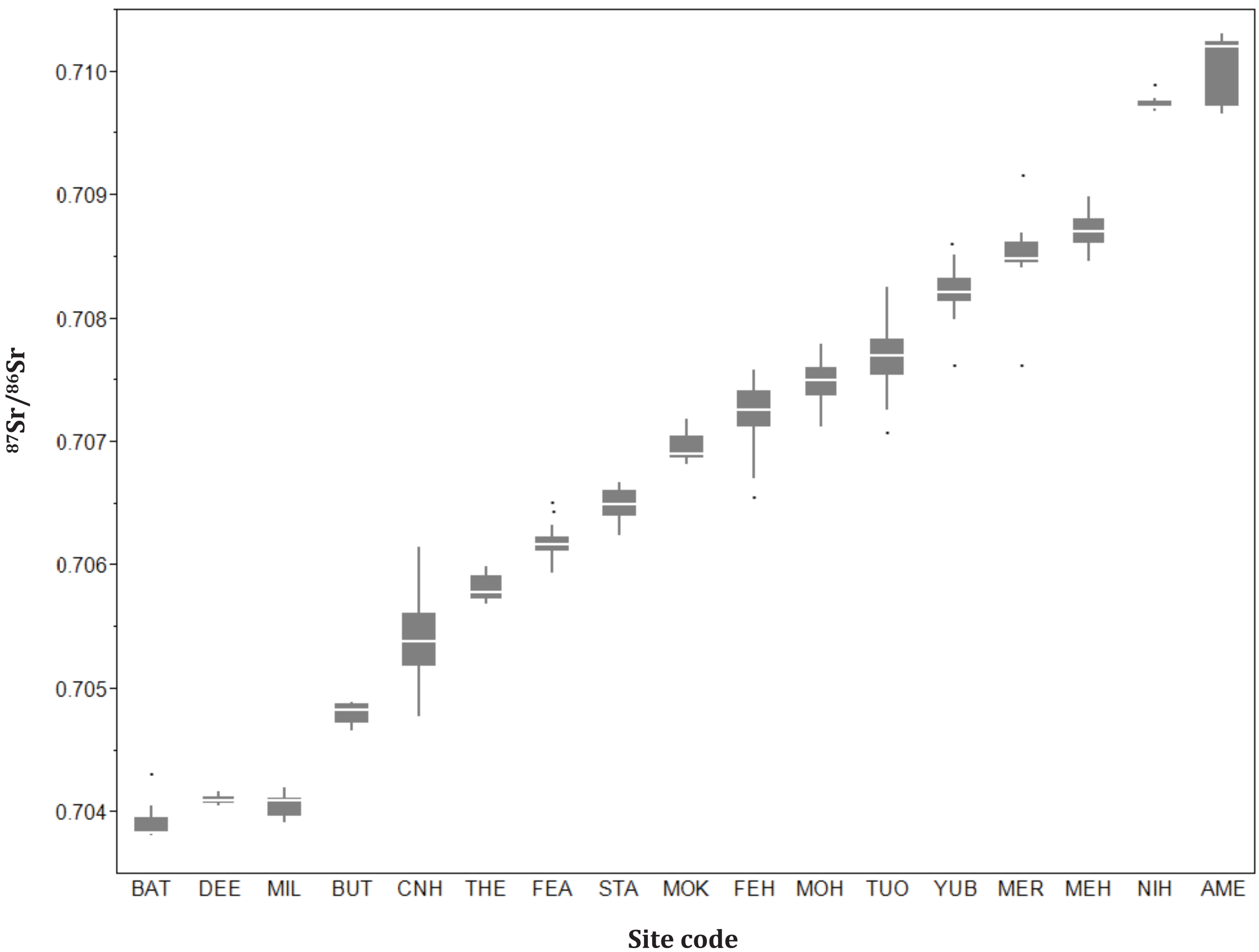


Fig. 6 Differences in $^{87}Sr/^{86}Sr$ values among sites in the CCV, modified from [1] using additional water samples and otoliths from known-origin juveniles and adult CWT fish analyzed as part of existing and ongoing projects ([34], P. Weber & A. Sturrock, unpublished). Site codes identified in Table 2. These data were used to predict the origin of adults collected in the current study. Due to overlap among TUO, MOH and FEH, all fish identified as potentially originated in the Tuolumne River (TUO) using Sr isotopes were also assigned to hatchery/wild using otolith microstructure (Barnett-Johnson et al., 2007).

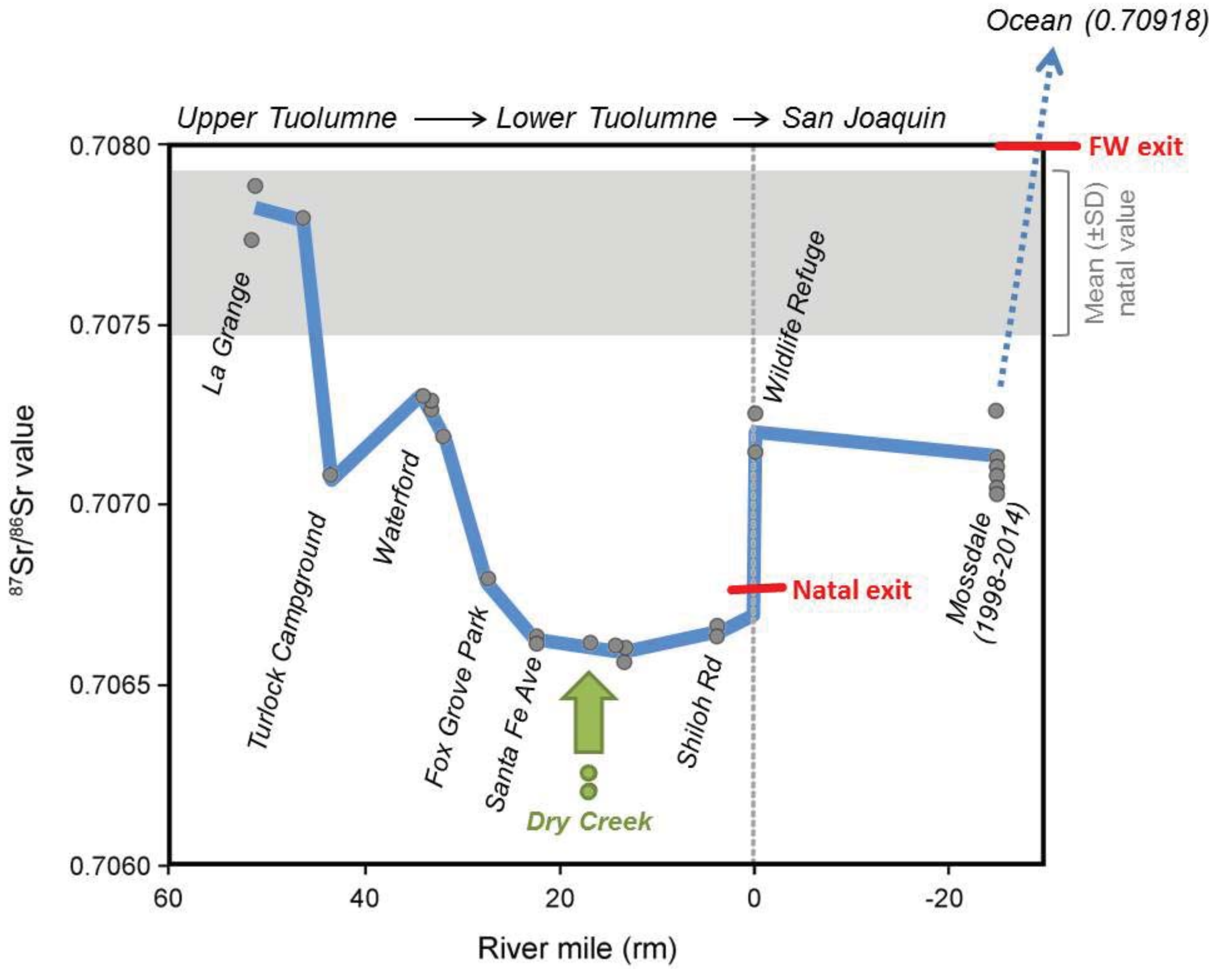


Fig. 7 Trends in water $^{87}Sr/^{86}Sr$ in the mainstem Tuolumne and San Joaquin Rivers (samples collected as part of other studies). The majority of measurements were collected in January and February 2014; however, additional years are included where available. The shaded grey bar indicates the mean natal value allocated to the Tuolumne (±SD), based on otolith analyses of juveniles captured in a rotary screw trap close to Shiloh Road (i.e., prior to outmigration). The blue trend line within the Tuolumne River is driven by sources of isotopically light water entering the river downstream of the spawning reaches (~rm50). At the time of writing, Dry Creek (rm 16.7) is the only known example of such a source.

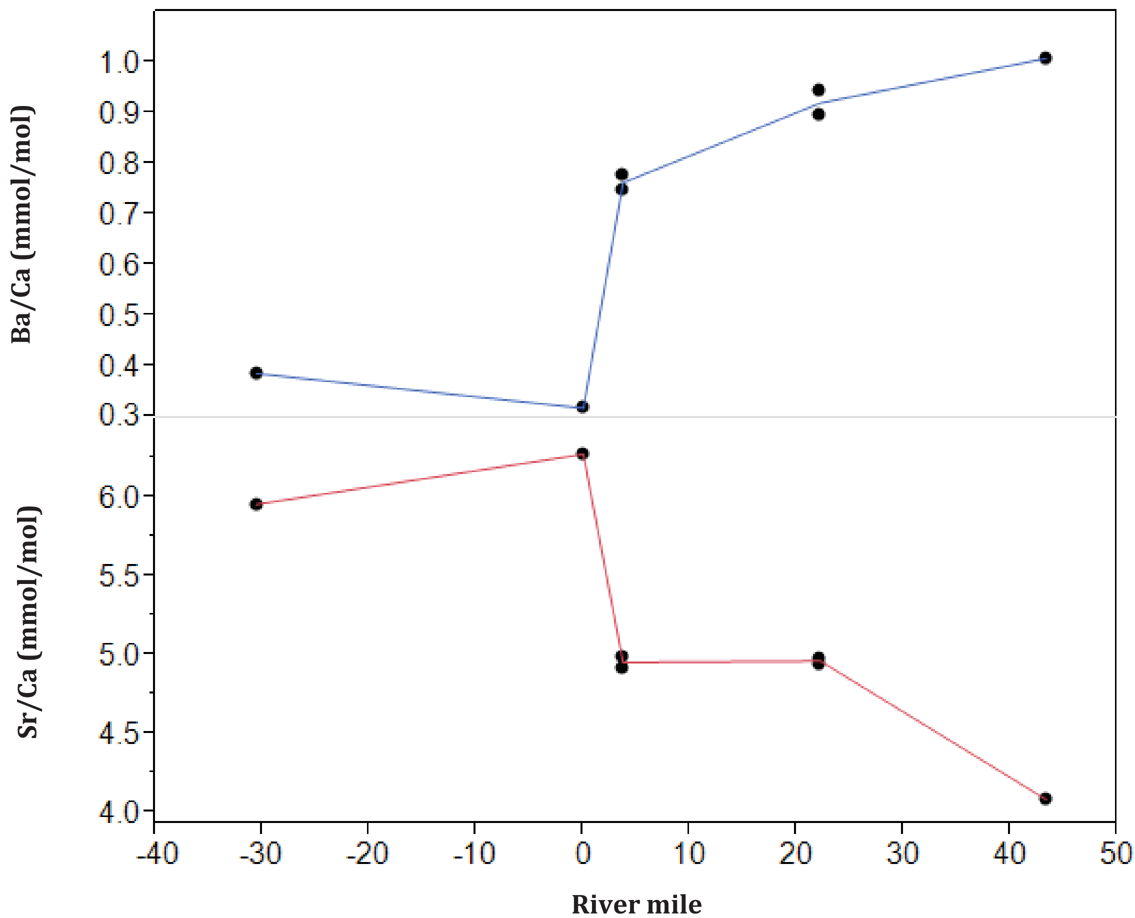
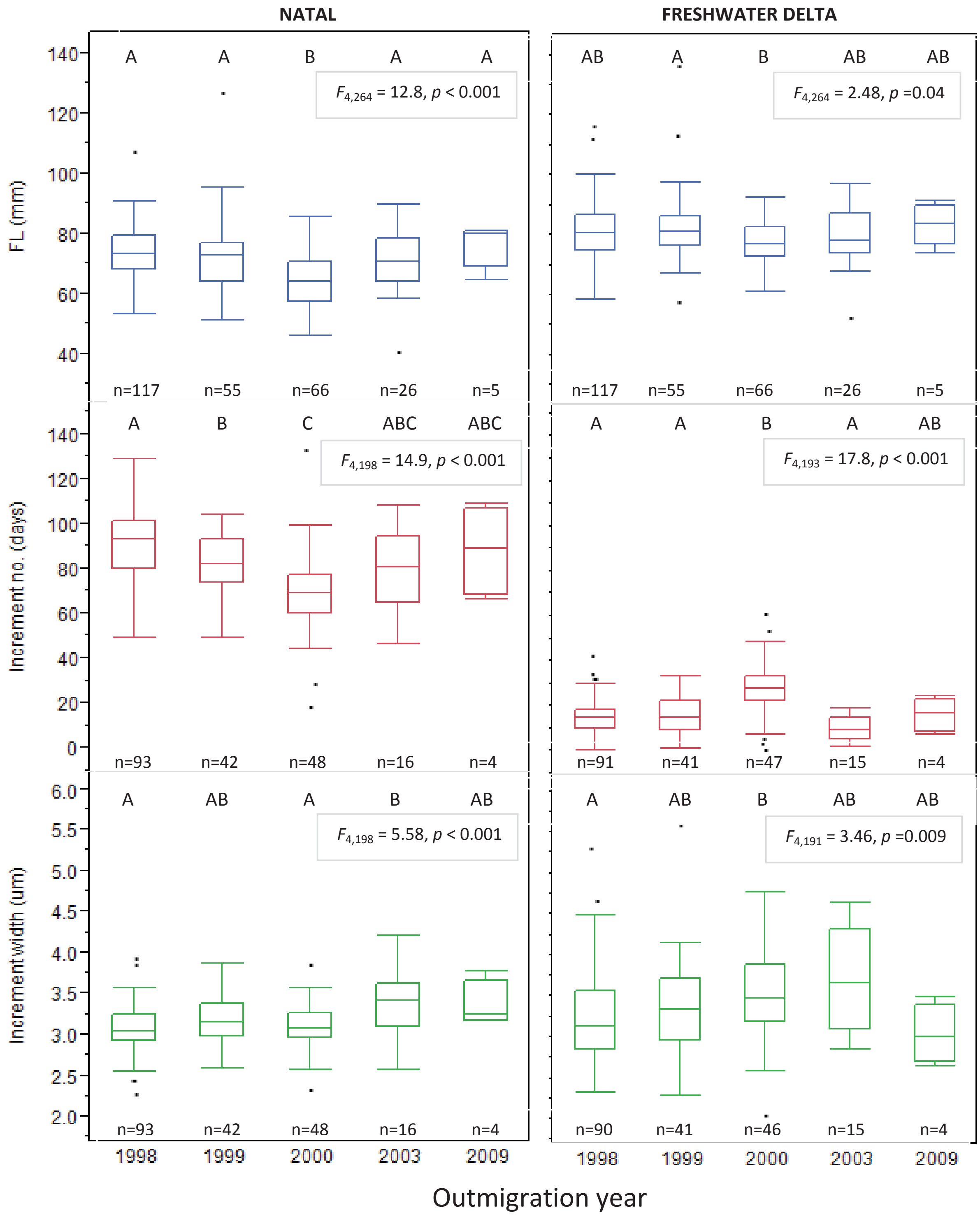


Fig. 8 Trends in water Ba/Ca and Sr/Ca between the Tuolumne and San Joaquin rivers (samples collected as part of other studies). Note the sharp inflection between the lower Tuolumne (~river mile 3) and the San Joaquin (river mile 0) rivers.

Fig. 9 Trends in median fork length at exit (FL), number of otolith increments (age) and increment width (growth rate) in the natal river (left) and freshwater delta (right) of juveniles that originated in and returned to the Tuolumne River. Overall differences among years were tested by ANOVA (results exhibited on each plot). Bars not connected by the same letter are significantly different (p<0.05, Tukey's test).



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Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

						Natal Sr ratio				Natal exit	Predicted FL at natal exit (mm)			Predicted life stage at natal exit [3]				Increment width (um)		
Sample ID	Capture date	Capture FL (cm)	Scale age	Sex	Outmi-gration year	Mean natal value	Prob to TUO [1]	H vs. W [2]	Natal location	Otolith distance (um)	FL	Lower 95% CI	Upper 95% CI	Life stage	Lower 95% CI	Upper 95% CI	Increment no (days)	Mean	CV	Notes
4175	10/10/00	98	3	M	1998	0.70799	0.97	W	TUO	576.6	85.8	77.2	95.9	S	S	S	109	3.26	0.19	
4176	10/10/00	91	3	M	1998	0.70774	0.95	W	TUO	544.4	80.3	71.7	90.4	S	P	S	96	3.53	0.21	
4182	10/17/00	76	3	M	1998	0.70803	0.96	W	TUO	544.1	80.3	71.7	90.3	S	P	S	112	2.96	0.19	
4183	10/17/00	90	3	M	1998	0.70797	0.97	W	TUO	494.3	71.8	63.2	81.8	P	P	S	94	2.74	0.22	
4185	10/17/00	84	3	F	1998	0.70728	0.64	W	TUO	522.7	76.6	68.0	86.7	S	P	S	107	3.17	0.26	
4189	10/24/00	90	3	F	1998	0.70806	0.94	W	TUO	452.6	64.6	56.1	74.7	P	P	P	83	2.90	0.23	
4192	10/24/00	87.5	3	F	1998	0.70807	0.93	W	TUO	487.5	70.6	62.0	80.7	P	P	S	87	3.22	0.23	
4196	10/24/00	67.9	3	F	1998	0.70800	0.97	W	TUO	493.3	71.6	63.0	81.7	P	P	S	98 †	2.62	0.20	† Microstructure ran out 33um before last natal spot (inferred 12 increments)
4197	10/24/00	78.6	3	F	1998	0.70740	0.61	W	TUO	423.2	59.6	51.0	69.7	P	F	P	79	2.74	0.26	
4200	10/24/00	68.6	3	F	1998	0.70760	0.88	W	TUO	569.4	84.6	76.0	94.7	S	S	S	102	3.20	0.27	
4210	10/24/00	88.3	3	M	1998	0.70764	0.91	W	TUO	488.9	70.8	62.2	80.9	P	P	S	93	2.98	0.28	
4211	10/24/00	72	3	F	1998	0.70783	0.97	W	TUO	581.0	86.6	78.0	96.6	S	S	S	.			
4212	10/24/00	78.1	3	M	1998	0.70765	0.91	W	TUO	541.0	79.7	71.2	89.8	S	P	S	93	2.93	0.20	
4215	10/25/00	79	3	F	1998	0.70802	0.96	W	TUO	552.5	81.7	73.1	91.8	S	P	S	111	3.03	0.20	
4226	10/25/00	80	3	F	1998	0.70770	0.93	W	TUO	446.6	63.6	55.0	73.7	P	P	P	70	3.11	0.33	
4232	10/25/00	88.5	3	M	1998	0.70821	0.53	W	TUO	519.3	76.0	67.5	86.1	S	P	S	.			
4233	10/25/00	72	3	F	1998	0.70795	0.98	W	TUO	452.6	64.6	56.1	74.7	P	P	P	74	3.02	0.20	
4234	10/25/00	77	3	F	1998	0.70823	0.45	W	TUO*	579.9	86.4	77.8	96.5	S	S	S	*Inconclusive natal assignment*			
4240	10/26/00	80	3	F	1998	0.70726	0.28	W	TUO*	426.2	60.1	51.5	70.2	P	F	P	*Inconclusive natal assignment*			
4249	10/30/00	80	3	F	1998	0.70737	0.54	W	TUO	485.8	70.3	61.7	80.4	P	P	S	.			
4253	10/30/00	80	3	M	1998	0.70810	0.90	W	TUO	554.2	82.0	73.4	92.1	S	P	S	101	3.05	0.26	
4266	10/30/00	77	3	F	1998	0.70740	0.60	W	TUO	461.1	66.1	57.5	76.2	P	P	S	100	2.43	0.25	
4267	10/30/00	75	3	F	1998	0.70812	0.86	W	TUO	476.3	68.7	60.1	78.8	P	P	S	.			
4269	10/30/00	80	3	F	1998	0.70732	0.43	W	TUO*	581.6	86.7	78.1	96.8	S	S	S	*Inconclusive natal assignment*			
4275	10/31/00	79	3	F	1998	0.70721	0.18	W	TUO*	416.1	58.4	49.8	68.5	P	F	P	*Inconclusive natal assignment*			
4278	10/31/00	83	3	F	1998	0.70802	0.96	W	TUO	480.1	69.3	60.7	79.4	P	P	S	.			
4279	10/31/00	87.5	3	F	1998	0.70798	0.97	W	TUO	568.8	84.5	75.9	94.6	S	S	S	120	3.18	0.22	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

4281	10/31/00	91	3	M	1998	0.70728	0.31	W	TUO*	454.0	64.9	56.3	74.9	P	P	P	*Inconclusive natal assignment*			
4292	10/31/00	74	3	F	1998	0.70733	0.44	W	TUO*	526.1	77.2	68.6	87.3	S	P	S	*Inconclusive natal assignment*			
4294	10/31/00	86	3	F	1998	0.70800	0.97	W	TUO	560.6	83.1	74.5	93.2	S	P	S	.			
4295	10/31/00	72	3	F	1998	0.70816	0.77	W	TUO	495.0	71.9	63.3	81.9	P	P	S	87	3.13	0.23	
4297	11/01/00	74	3	F	1998	0.70805	0.95	W	TUO	576.9	85.9	77.3	96.0	S	S	S	109	2.98	0.18	
4299	11/06/00	81	3	F	1998	0.70801	0.97	W	TUO	527.8	77.5	68.9	87.6	S	P	S	.			
4300	11/06/00	96	3	M	1998	0.70735	0.50	W	TUO*	452.0	64.5	55.9	74.6	P	P	P	*Inconclusive natal assignment*			
4306	11/06/00	85	3	F	1998	0.70801	0.97	W	TUO	520.7	76.3	67.7	86.3	S	P	S	93	3.27	0.17	
4309	11/06/00	84	3	F	1998	0.70807	0.93	W	TUO	453.7	64.8	56.2	74.9	P	P	P	.			
4311	11/06/00	74	3	F	1998	0.70752	0.81	W	TUO	432.7	61.2	52.6	71.3	P	F	P	73	3.03	0.22	
4316	11/06/00	81	3	F	1998	0.70738	0.55	W	TUO	383.9	52.9	44.3	63.0	F	F	P	.			
4317	11/06/00	79	3	F	1998	0.70786	0.97	W	TUO	488.2	70.7	62.1	80.8	P	P	S	94 †	2.82	0.26	† Microstructure ran out 55um before last natal spot (inferred 19 increments)
4321	11/06/00	70	3	F	1998	0.70742	0.65	W	TUO	500.4	72.8	64.2	82.9	P	P	S	73	3.54	0.36	
4331	11/07/00	86	3	M	1998	0.70798	0.97	W	TUO	571.5	85.0	76.4	95.0	S	S	S	127	3.00	0.20	
4334	11/07/00	85	3	F	1998	0.70739	0.59	W	TUO	384.6	53.0	44.4	63.1	F	F	P	54	3.44	0.23	
4337	11/07/00	74	3	F	1998	0.70733	0.45	W	TUO*	535.3	78.8	70.2	88.8	S	P	S	*Inconclusive natal assignment*			
4340	11/07/00	75.5	3	F	1998	0.70783	0.97	W	TUO	490.2	71.1	62.5	81.1	P	P	S	.			
4343	11/07/00	81	3	F	1998	0.70768	0.92	W	TUO	509.5	74.4	65.8	84.4	P	P	S	109	2.96	0.26	
4352	11/07/00	73	3	F	1998	0.70788	0.97	W	TUO	563.0	83.5	74.9	93.6	S	P	S	81	3.09	0.20	
4360	11/08/00	76.5	3	F	1998	0.70818	0.67	W	TUO	578.2	86.1	77.5	96.2	S	S	S	.			
4376	11/09/00	85	3	F	1998	0.70733	0.46	W	TUO*	571.8	85.0	76.4	95.1	S	S	S	*Inconclusive natal assignment*			
4378	11/09/00	88	3	M	1998	0.70728	0.33	W	TUO*	607.4	91.1	82.5	101.2	S	S	S	*Inconclusive natal assignment*			
4381	11/13/00	90	3	M	1998	0.70816	0.75	W	TUO	455.0	65.0	56.5	75.1	P	P	S	75	3.02	0.20	
4383	11/13/00	79	3	M	1998	0.70756	0.85	W	TUO	529.2	77.7	69.1	87.8	S	P	S	.			
4384	11/13/00	80	3	F	1998	0.70786	0.97	W	TUO	506.8	73.9	65.3	84.0	P	P	S	85	3.16	0.23	
4397	11/13/00	67	3	F	1998	0.70819	0.66	W	TUO	474.7	68.4	59.8	78.5	P	P	S	84	2.93	0.26	
4403	11/14/00	77	3	F	1998	0.70808	0.92	W	TUO	501.7	73.0	64.4	83.1	P	P	S	90	2.99	0.23	
4414	11/14/00	81	3	F	1998	0.70749	0.77	W	TUO	467.5	67.2	58.6	77.3	P	P	S	.			
4418	11/14/00	86	3	F	1998	0.70742	0.66	W	TUO	460.1	65.9	57.3	76.0	P	P	S	65	3.84	0.34	
4424	11/14/00	77	3	F	1998	0.70783	0.97	W	TUO	552.9	81.8	73.2	91.8	S	P	S	125	2.95	0.21	
4441	11/20/00	72	3	F	1998	0.70823	0.45	W	TUO*	485.5	70.3	61.7	80.3	P	P	S	*Inconclusive natal assignment*			

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

4442	11/20/00	95	3	M	1998	0.70771	0.94	W	TUO	592.1	88.5	79.9	98.6	S	S	S	114	3.25	0.28
4443	11/20/00	100	3	M	1998	0.70735	0.50	W	TUO*	475.3	68.5	59.9	78.6	P	P	S	*Inconclusive natal assignment*		
4450	11/20/00	82	3	F	1998	0.70817	0.73	W	TUO	447.6	63.8	55.2	73.8	P	P	P	104	2.26	0.24
4451	11/20/00	92	3	M	1998	0.70817	0.72	W	TUO	472.3	68.0	59.4	78.1	P	P	S	108	2.82	0.25
4455	11/20/00	74	3	F	1998	0.70769	0.93	W	TUO	514.6	75.2	66.6	85.3	S	P	S	78	3.29	0.22
4458	11/21/00	80	3	F	1998	0.70792	0.98	W	TUO	543.4	80.2	71.6	90.2	S	P	S	92	3.33	0.26
4476	11/22/00	100	3	M	1998	0.70804	0.95	W	TUO	514.9	75.3	66.7	85.4	S	P	S	111	2.68	0.32
4484	11/27/00	77	3	F	1998	0.70788	0.97	W	TUO	528.8	77.7	69.1	87.7	S	P	S	90	3.06	0.26
4487	11/27/00	84	3	F	1998	0.70800	0.97	W	TUO	493.6	71.6	63.1	81.7	P	P	S	.		
4504	12/04/00	100	3	M	1998	0.70826	0.30	W	TUO*	480.4	69.4	60.8	79.5	P	P	S	*Inconclusive natal assignment*		
4506	12/04/00	80	3	F	1998	0.70756	0.85	W	TUO	406.6	56.8	48.2	66.8	P	F	P	60	3.23	0.24
4508	12/04/00	89	3	F	1998	0.70806	0.94	W	TUO	466.5	67.0	58.4	77.1	P	P	S	85	2.76	0.18
4509	12/04/00	70.5	3	F	1998	0.70812	0.86	W	TUO	489.9	71.0	62.4	81.1	P	P	S	91	3.14	0.22
4510	12/05/00	77	3	F	1998	0.70776	0.95	W	TUO	422.9	59.5	51.0	69.6	P	F	P	49	3.30	0.28
4514	12/05/00	78	3	F	1998	0.70794	0.98	W	TUO	462.1	66.3	57.7	76.3	P	P	S	.		
4515	12/05/00	77	3	F	1998	0.70815	0.80	W	TUO	481.1	69.5	60.9	79.6	P	P	S	80	3.39	0.21
4516	12/05/00	82	3	F	1998	0.70818	0.69	W	TUO	471.3	67.8	59.2	77.9	P	P	S	75	3.31	0.22
4517	12/05/00	88.5	3	F	1998	0.70798	0.97	W	TUO	526.8	77.3	68.7	87.4	S	P	S	95	3.04	0.20
4518	12/05/00	83	3	F	1998	0.70789	0.97	W	TUO	519.3	76.0	67.5	86.1	S	P	S	94	3.30	0.24
4521	12/06/00	78.5	3	F	1998	0.70788	0.97	W	TUO	537.6	79.2	70.6	89.2	S	P	S	83	3.24	0.22
4527	12/11/00	83	3	M	1998	0.70819	0.66	W	TUO	543.4	80.2	71.6	90.2	S	P	S	93	3.40	0.27
4535	12/19/00	78	3	F	1998	0.70814	0.82	W	TUO	503.1	73.3	64.7	83.3	P	P	S	100	3.14	0.22
9536	07/07/00	75	3	F	1998	0.70775	0.95	W	TUO	700.5	107.0	98.4	117.1	S	S	S	.		
11015	11/16/01	86.5	4	F	1998	0.70789	0.97	W	TUO	486.3	70.4	61.8	80.5	P	P	S	80	3.53	0.28
11036	12/11/01	86	4	F	1998	0.70772	0.94	W	TUO	580.3	86.5	77.9	96.5	S	S	S	95	3.56	0.21
11037	12/11/01	110	4	M	1998	0.70792	0.98	W	TUO	538.6	79.3	70.8	89.4	S	P	S	93	3.02	0.27
11038	12/11/01	78	4	F	1998	0.70821	0.53	W	TUO	477.7	68.9	60.3	79.0	P	P	S	.		
11040	12/11/01	98	4	F	1998	0.70812	0.86	W	TUO	549.8	81.3	72.7	91.3	S	P	S	114	3.02	0.30
11056	11/20/01	78	4	F	1998	0.70779	0.96	W	TUO	504.4	73.5	64.9	83.6	P	P	S	115	2.67	0.23
11064	11/20/01	95	4	M	1998	0.70745	0.71	W	TUO	541.0	79.7	71.2	89.8	S	P	S	92	3.92	0.34
11072	11/20/01	112	4	M	1998	0.70816	0.75	W	TUO	468.6	67.4	58.8	77.4	P	P	S	75	3.05	0.19
11085	11/20/01	87	4	F	1998	0.70737	0.55	W	TUO	411.3	57.6	49.0	67.6	P	F	P	.		
11089	11/20/01	104	4	M	1998	0.70816	0.76	W	TUO	479.1	69.2	60.6	79.2	P	P	S	90	2.79	0.19

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11097	11/30/01	82	4	M	1998	0.70743	0.67	W	TUO	518.3	75.9	67.3	85.9	S	P	S	88	3.23	0.39
11098	11/30/01	87	4	F	1998	0.70807	0.93	W	TUO	530.2	77.9	69.3	88.0	S	P	S	93	3.20	0.20
11140	11/26/01	88	4	F	1998	0.70769	0.93	W	TUO	479.4	69.2	60.6	79.3	P	P	S	79	2.90	0.27
11154	11/26/01	87	4	F	1998	0.70794	0.98	W	TUO	518.7	75.9	67.3	86.0	S	P	S	91	3.25	0.27
11176	12/07/01	92.5	4	F	1998	0.70821	0.54	W	TUO	544.7	80.4	71.8	90.5	S	P	S	.		
11177	12/07/01	90	4	F	1998	0.70781	0.96	W	TUO	484.1	70.0	61.4	80.1	P	P	S	.		
11181	12/18/01	87	3	F	1998	0.70819	0.63	W	TUO	604.7	90.6	82.0	100.7	S	S	S	129	3.21	0.22
11182	12/17/01	99	4	M	1998	0.70798	0.97	W	TUO	397.8	55.3	46.7	65.3	P	F	P	51	3.10	0.23
11190	11/23/01	90	3	M	1998	0.70821	0.53	W	TUO	506.8	73.9	65.3	84.0	P	P	S	95	2.99	0.24
11216	11/21/01	94	4	F	1998	0.70821	0.54	W	TUO	517.6	75.8	67.2	85.8	S	P	S	122	2.55	0.27
19680	11/15/01	103	4	M	1998	0.70766	0.92	W	TUO	603.0	90.3	81.8	100.4	S	S	S	.		
19684	11/15/01	92	3.5	M	1998	0.70776	0.95	W	TUO	508.2	74.1	65.5	84.2	P	P	S	.		
19685	11/15/01	87	4	F	1998	0.70811	0.89	W	TUO	513.2	75.0	66.4	85.1	S	P	S	.		
19687	11/15/01	82	3.5	M	1998	0.70806	0.95	W	TUO	515.3	75.4	66.8	85.4	S	P	S	96	2.97	0.21
19691	11/15/01	91	4	M	1998	0.70721	0.19	W	TUO*	421.8	59.4	50.8	69.4	P	F	P	*Inconclusive natal assignment*		
19719	11/19/01	94.5	3.5	F	1998	0.70806	0.94	W	TUO	510.5	74.5	66.0	84.6	P	P	S	89	2.88	0.23
19772	11/28/01	97	4	F	1998	0.70769	0.93	W	TUO	467.9	67.2	58.7	77.3	P	P	S	84	2.81	0.24
19776	11/28/01	90	4	F	1998	0.70821	0.53	W	TUO	522.7	76.6	68.0	86.7	S	P	S	101	3.10	0.19
19777	11/28/01	91	4	F	1998	0.70816	0.76	W	TUO	489.2	70.9	62.3	81.0	P	P	S	96	2.67	0.30
19781	11/28/01	86	4	F	1998	0.70824	0.37	W	TUO*	532.5	78.3	69.7	88.4	S	P	S	*Inconclusive natal assignment*		
19783	11/28/01	89	4	F	1998	0.70793	0.98	W	TUO	432.7	61.2	52.6	71.3	P	F	P	68	3.03	0.26
19785	11/28/01	88	4	F	1998	0.70765	0.91	W	TUO	446.2	63.5	55.0	73.6	P	F	P	67	3.16	0.25
19790	11/28/01	94	4	F	1998	0.70818	0.68	W	TUO	504.1	73.4	64.9	83.5	P	P	S	104	2.44	0.24
19796	12/03/01	81	4	F	1998	0.70811	0.88	W	TUO	509.9	74.4	65.8	84.5	P	P	S	83	3.31	0.24
19798	12/03/01	93	4	M	1998	0.70814	0.83	W	TUO	474.7	68.4	59.8	78.5	P	P	S	101	3.02	0.23
19800	12/03/01	114	4	M	1998	0.70776	0.95	W	TUO	569.8	84.7	76.1	94.7	S	S	S	.		
19802	12/03/01	97	4	F	1998	0.70824	0.40	W	TUO*	539.3	79.5	70.9	89.5	S	P	S	*Inconclusive natal assignment*		
19805	12/03/01	88	4	F	1998	0.70821	0.56	W	TUO	496.7	72.2	63.6	82.2	P	P	S	95	3.15	0.25
19806	12/03/01	89	4	F	1998	0.70769	0.93	W	TUO	542.4	80.0	71.4	90.0	S	P	S	103	3.04	0.28
19810	12/03/01	85	4	F	1998	0.70765	0.91	W	TUO	479.1	69.2	60.6	79.2	P	P	S	74	3.56	0.28
19820	12/03/01	105	4	M	1998	0.70779	0.96	W	TUO	492.6	71.5	62.9	81.5	P	P	S	88	3.37	0.28
19821	12/03/01	94	4	F	1998	0.70812	0.86	W	TUO	494.3	71.8	63.2	81.8	P	P	S	95	2.63	0.30
19838	12/03/01	73	4	F	1998	0.70765	0.91	W	TUO	462.1	66.3	57.7	76.3	P	P	S	77	3.16	0.24

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19840	12/03/01	81	4	F	1998	0.70813	0.84	W	TUO	436.1	61.8	53.2	71.9	P	F	P	84	2.87	0.24	
19857	12/04/01	97	4	M	1998	0.70776	0.95	W	TUO	538.0	79.2	70.6	89.3	S	P	S	93	3.20	0.20	
19864	12/04/01	99	4	M	1998	0.70813	0.84	W	TUO	514.9	75.3	66.7	85.4	S	P	S	109	3.02	0.27	
19867	12/04/01	86	4	F	1998	0.70808	0.93	W	TUO	478.7	69.1	60.5	79.2	P	P	S	95	2.99	0.26	
19872	12/10/01	84	4	F	1998	0.70815	0.78	W	TUO	463.1	66.4	57.8	76.5	P	P	S	77	2.88	0.19	
19875	12/10/01	83	4	F	1998	0.70823	0.42	W	TUO*	478.7	69.1	60.5	79.2	P	P	S	*Inconclusive natal assignment*			
19879	12/10/01	76	4	F	1998	0.70766	0.91	W	TUO	464.2	66.6	58.0	76.7	P	P	S	84	3.01	0.21	
19880	12/10/01	89	4	F	1998	0.70765	0.91	W	TUO	447.6	63.8	55.2	73.8	P	P	P	72	2.95	0.23	
19881	12/10/01	99	4	F	1998	0.70813	0.85	W	TUO	528.5	77.6	69.0	87.7	S	P	S	73	2.85	0.21	
20183	11/28/01	101	4	F	1998	0.70773	0.94	W	TUO	525.4	77.1	68.5	87.2	S	P	S	98	3.30	0.31	
4492	11/28/00	57	2	M	1999	0.70804	0.95	W	TUO	578.6	86.2	77.6	96.2	S	S	S	104 †	3.21	0.25	† Microstructure ran out 18um before last natal spot (inferred 5 increments)
4526	12/11/00	67	2	F	1999	0.70800	0.97	W	TUO	815.6	126.7	118.1	136.8	S	S	S	.			
11009	11/16/01	.	3	F	1999	0.70757	0.86	W	TUO	441.7	62.8	54.2	72.8	P	F	P	.			
11016	11/16/01	79.5	3	F	1999	0.70731	0.40	W	TUO*	369.6	50.4	41.9	60.5	F	F	P	49	2.84	0.25	
11019	11/16/01	60	3	F	1999	0.70743	0.67	INC	TUO*	476.5	68.7	60.1	78.8	P	P	S	.			Unreadable, so cannot assign natal location or do ageing
11021	11/16/01	73	3	F	1999	0.70731	0.39	W	TUO*	478.8	69.1	60.5	79.2	P	P	S	84	2.75	0.21	
11041	12/11/01	77	3	F	1999	0.70805	0.95	W	TUO	509.5	74.4	65.8	84.4	P	P	S	93	2.97	0.24	
11094	11/30/01	80	3	F	1999	0.70756	0.85	W	TUO	444.0	63.2	54.6	73.2	P	F	P	64	2.98	0.29	
11096	11/30/01	77	3	F	1999	0.70764	0.91	W	TUO	503.0	73.3	64.7	83.3	P	P	S	97	2.94	0.23	
11099	11/30/01	73	3	F	1999	0.70733	0.44	W	TUO*	467.2	67.1	58.5	77.2	P	P	S	*Inconclusive natal assignment*			
11100	11/30/01	83	3	F	1999	0.70748	0.75	W	TUO	442.6	62.9	54.3	73.0	P	F	P	.			
11132	11/26/01	76	3	F	1999	0.70734	0.46	W	TUO*	462.1	66.3	57.7	76.3	P	P	S	91	2.91	0.24	
11141	11/26/01	77	3	F	1999	0.70741	0.63	W	TUO	395.6	54.9	46.3	65.0	F	F	P	.			
11146	11/26/01	81	3	F	1999	0.70722	0.20	W	TUO*	434.2	61.5	52.9	71.6	P	F	P	*Inconclusive natal assignment*			
11157	11/26/01	80	3	M	1999	0.70740	0.61	W	TUO	405.4	56.6	48.0	66.6	P	F	P	64	3.00	0.32	
11161	11/26/01	74	3	F	1999	0.70792	0.98	W	TUO	426.3	60.1	51.6	70.2	P	F	P	.			
11162	11/26/01	78	3	F	1999	0.70724	0.25	W	TUO*	469.1	67.5	58.9	77.5	P	P	S	68	3.56	0.26	
11174	12/07/01	80	3	F	1999	0.70754	0.83	W	TUO	404.9	56.5	47.9	66.6	P	F	P	61	3.15	0.21	
11192	11/23/01	74	3	F	1999	0.70772	0.94	W	TUO	478.8	69.1	60.5	79.2	P	P	S	74	3.02	0.28	
11209	11/21/01	97	3	M	1999	0.70771	0.94	W	TUO	551.4	81.5	72.9	91.6	S	P	S	85	3.72	0.31	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

11213	11/21/01	83	3	F	1999	0.70771	0.94	W	TUO	483.5	69.9	61.3	80.0	P	P	S	.			
11217	11/21/01	40.5	3	M	1999	0.70764	0.90	W	TUO	447.2	63.7	55.1	73.8	P	P	P	84	2.59	0.23	
14499	11/04/02	93	4	F	1999	0.70814	0.83	W	TUO	542.7	80.0	71.5	90.1	S	P	S	92	2.99	0.21	
14568	11/05/02	107	4	M	1999	0.70761	0.89	W	TUO	591.8	88.4	79.9	98.5	S	S	S	82	3.39	0.25	
14621	11/12/02	104	4	M	1999	0.70776	0.95	W	TUO	538.8	79.4	70.8	89.4	S	P	S	88	2.84	0.25	
14623	11/12/02	85	4	F	1999	0.70782	0.97	W	TUO	492.8	71.5	62.9	81.6	P	P	S	90	2.96	0.20	
14627	11/12/02	97	4	F	1999	0.70754	0.83	W	TUO	437.0	62.0	53.4	72.0	P	F	P	.			
14635	11/12/02	101	4	M	1999	0.70777	0.96	W	TUO	510.0	74.4	65.9	84.5	P	P	S	74	3.37	0.20	
14647	11/12/02	96	4	F	1999	0.70805	0.95	W	TUO	466.8	67.1	58.5	77.1	P	P	S	.			
14669	11/12/02	104	4	M	1999	0.70761	0.89	W	TUO	475.1	68.5	59.9	78.6	P	P	S	80	3.09	0.22	
14687	11/12/02	91	4	F	1999	0.70738	0.56	W	TUO	510.5	74.5	65.9	84.6	P	P	S	81	3.57	0.27	
14693	11/12/02	99	4	M	1999	0.70751	0.80	W	TUO	521.6	76.4	67.8	86.5	S	P	S	84	3.04	0.19	
14716	11/13/02	97	4	M	1999	0.70757	0.85	W	TUO	522.6	76.6	68.0	86.7	S	P	S	80	3.05	0.25	
14729	11/13/02	96	4	M	1999	0.70726	0.28	W	TUO*	462.6	66.3	57.8	76.4	P	P	S	69	3.08	0.21	
14759	11/14/02	101	4	M	1999	0.70766	0.91	W	TUO	508.1	74.1	65.5	84.2	P	P	S	94	2.95	0.24	
14774	11/14/02	86	4	F	1999	0.70786	0.97	W	TUO	483.1	69.9	61.3	79.9	P	P	S	.			
14804	11/14/02	93	4	F	1999	0.70768	0.93	W	TUO	488.6	70.8	62.2	80.9	P	P	S	78	3.07	0.17	
14824	11/15/02	98	4	M	1999	0.70733	0.44	W	TUO*	517.4	75.7	67.1	85.8	S	P	S	*Inconclusive natal assignment*			
14850	11/18/02	92	4	F	1999	0.70722	0.19	W	TUO*	465.4	66.8	58.2	76.9	P	P	S	*Inconclusive natal assignment*			
14884	11/18/02	89	4	F	1999	0.70749	0.77	W	TUO	499.0	72.6	64.0	82.6	P	P	S	.			
14889	11/18/02	88	4	M	1999	0.70754	0.82	W	TUO	508.5	74.2	65.6	84.3	P	P	S	80	3.11	0.22	
14892	11/18/02	100	4	M	1999	0.70725	0.26	W	TUO*	471.9	67.9	59.4	78.0	P	P	S	*Inconclusive natal assignment*			
14904	11/18/02	100	4	M	1999	0.70745	0.70	W	TUO	480.2	69.4	60.8	79.4	P	P	S	61	3.65	0.25	
14919	11/18/02	88	4	F	1999	0.70729	0.35	W	TUO*	409.7	57.3	48.7	67.4	P	F	P	*Inconclusive natal assignment*			
14953	11/19/02	103	4	M	1999	0.70787	0.97	W	TUO	489.5	71.0	62.4	81.0	P	P	S	92	2.91	0.18	
14955	11/19/02	94	4	F	1999	0.70813	0.84	W	TUO	527.1	77.4	68.8	87.4	S	P	S	96	3.28	0.25	
14976	11/19/02	102	4	M	1999	0.70765	0.91	W	TUO	496.3	72.1	63.5	82.2	P	P	S	94	3.21	0.26	
14999	11/20/02	104	4	M	1999	0.70726	0.27	W	TUO*	489.5	71.0	62.4	81.0	P	P	S	67	3.88	0.22	
15001	11/20/02	101	4	M	1999	0.70787	0.97	W	TUO	431.7	61.1	52.5	71.1	P	F	P	74	2.92	0.25	
15052	11/20/02	105	4	M	1999	0.70776	0.95	W	TUO	557.9	82.6	74.1	92.7	S	P	S	.			
15064	11/20/02	98	4	M	1999	0.70775	0.95	W	TUO	415.1	58.2	49.6	68.3	P	F	P	49	3.21	0.25	
15097	11/21/02	104	4	M	1999	0.70774	0.95	W	TUO	539.3	79.5	70.9	89.5	S	P	S	101	3.22	0.26	

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15146	11/24/02	107	4	M	1999	0.70721	0.19	W	TUO*	451.0	64.4	55.8	74.4	P	P	P	*Inconclusive natal assignment*		
15150	11/24/02	108	4	M	1999	0.70761	0.89	W	TUO	436.4	61.9	53.3	71.9	P	F	P	64	3.34	0.28
15165	11/24/02	100	4	M	1999	0.70726	0.27	W	TUO*	406.9	56.8	48.2	66.9	P	F	P	*Inconclusive natal assignment*		
19679	11/15/01	78	3	F	1999	0.70754	0.83	W	TUO	514.2	75.2	66.6	85.2	S	P	S	98	3.26	0.26
19686	11/15/01	81	3	F	1999	0.70780	0.96	W	TUO	518.4	75.9	67.3	85.9	S	P	S	96	3.40	0.22
19688	11/15/01	72.5	3	F	1999	0.70772	0.94	W	TUO	554.6	82.1	73.5	92.1	S	P	S	.		
19705	11/15/01	76	3	F	1999	0.70729	0.35	W	TUO*	373.8	51.2	42.6	61.2	F	F	P	*Inconclusive natal assignment*		
19722	11/19/01	87	3	F	1999	0.70733	0.44	W	TUO*	553.2	81.8	73.3	91.9	S	P	S	*Inconclusive natal assignment*		
19775	11/28/01	83	3	F	1999	0.70736	0.52	W	TUO	509.5	74.4	65.8	84.4	P	P	S	81	3.44	0.25
19779	11/28/01	70	3	F	1999	0.70760	0.88	W	TUO	477.0	68.8	60.2	78.9	P	P	S	65	3.63	0.22
19782	11/28/01	76	3	M	1999	0.70779	0.96	W	TUO	514.6	75.2	66.7	85.3	S	P	S	89	3.03	0.19
19786	11/28/01	85	3	M	1999	0.70746	0.73	W	TUO	549.0	81.1	72.5	91.2	S	P	S	101	3.30	0.26
19791	11/28/01	79	3	F	1999	0.70735	0.49	W	TUO*	461.2	66.1	57.5	76.2	P	P	S	*Inconclusive natal assignment*		
19792	11/28/01	76	3	F	1999	0.70814	0.83	W	TUO	486.8	70.5	61.9	80.5	P	P	S	82	3.78	0.25
19797	12/03/01	84	3	F	1999	0.70735	0.48	W	TUO*	458.1	65.6	57.0	75.6	P	P	S	*Inconclusive natal assignment*		
19816	12/03/01	81	3	M	1999	0.70770	0.93	W	TUO	632.3	95.4	86.8	105.4	S	S	S	.		
19836	12/03/01	88	3	M	1999	0.70726	0.29	W	TUO*	451.4	64.4	55.8	74.5	P	P	P	*Inconclusive natal assignment*		
19841	12/03/01	74	3	F	1999	0.70724	0.23	W	TUO*	457.9	65.5	57.0	75.6	P	P	S	*Inconclusive natal assignment*		
19845	12/04/01	87	3	M	1999	0.70788	0.97	W	TUO	514.2	75.2	66.6	85.2	S	P	S	93	2.96	0.20
19855	12/04/01	85	3	M	1999	0.70768	0.92	W	TUO	441.7	62.8	54.2	72.8	P	F	P	61	3.15	0.32
19861	12/04/01	74	3	F	1999	0.70775	0.95	W	TUO	494.2	71.7	63.2	81.8	P	P	S	80	3.13	0.22
19866	12/04/01	86	3	M	1999	0.70724	0.23	W	TUO*	467.7	67.2	58.6	77.3	P	P	S	63	3.24	0.27
19868	12/04/01	74	3	F	1999	0.70736	0.51	W	TUO	583.5	87.0	78.4	97.1	S	S	S	97	3.86	0.29
19874	12/10/01	75	3	F	1999	0.70756	0.84	W	TUO	372.4	50.9	42.3	61.0	F	F	P	61	3.21	0.26
19876	12/10/01	71	3	M	1999	0.70765	0.91	W	TUO	507.2	74.0	65.4	84.0	P	P	S	79	3.48	0.20
11055	11/20/01	56	2	M	2000	0.70770	0.93	W	TUO	354.0	47.8	39.2	57.8	F	F	P	.		
11063	11/20/01	58	2	M	2000	0.70763	0.90	W	TUO	524.0	76.8	68.3	86.9	S	P	S	81	3.13	0.22
11076	11/20/01	81	2	F	2000	0.70807	0.93	W	TUO	509.0	74.3	65.7	84.3	P	P	S	98	2.98	0.23
11083	11/20/01	59	2	M	2000	0.70742	0.65	W	TUO	419.0	58.9	50.3	69.0	P	F	P	49	3.28	0.23
11111	11/08/01	54.5	2	F	2000	0.70775	0.95	W	TUO	477.0	68.8	60.2	78.9	P	P	S	81	3.00	0.23
11133	11/26/01	59	2	F	2000	0.70797	0.97	W	TUO	472.0	68.0	59.4	78.0	P	P	S	.		
11167	11/26/01	60	2	F	2000	0.70752	0.81	W	TUO	451.0	64.4	55.8	74.4	P	P	P	61	2.99	0.29
11212	11/21/01	65.5	2	F	2000	0.70760	0.88	W	TUO	465.0	66.8	58.2	76.8	P	P	S	60	3.38	0.26

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11215	11/21/01	60	2	F	2000	0.70795	0.98	W	TUO	508.0	74.1	65.5	84.2	P	P	S	69	3.84	0.26	
11220	10/31/01	62	2	F	2000	0.70789	0.97	W	TUO	548.0	80.9	72.4	91.0	S	P	S	84	3.37	0.30	
11223	10/31/01	54	2	M	2000	0.70784	0.97	W	TUO	494.0	71.7	63.1	81.8	P	P	S	77	3.05	0.21	
11228	10/31/01	60	2	M	2000	0.70778	0.96	W	TUO	407.0	56.8	48.2	66.9	P	F	P	66	3.11	0.19	
14528	11/04/02	95	3	M	2000	0.70813	0.85	W	TUO	513.0	75.0	66.4	85.0	P	P	S	84	2.93	0.24	
14539	11/04/02	72	3	F	2000	0.70789	0.97	W	TUO	451.0	64.4	55.8	74.4	P	P	P	69	2.97	0.19	
14540	11/04/02	69	3	F	2000	0.70777	0.96	INC	TUO*	438.0	62.1	53.6	72.2	P	F	P	.			Unreadable, so cannot assign natal location or do ageing
14544	11/05/02	78	3	F	2000	0.70782	0.96	W	TUO	429.0	60.6	52.0	70.7	P	F	P	48	2.90	0.22	
14545	11/05/02	92	3	M	2000	0.70792	0.98	W	TUO	404.0	56.3	47.7	66.4	P	F	P	.			
14548	11/05/02	72	3	F	2000	0.70801	0.97	W	TUO	574.0	85.4	76.8	95.5	S	S	S	.			
14550	11/05/02	80	3	M	2000	0.70789	0.97	W	TUO	387.0	53.4	44.8	63.5	F	F	P	62	2.75	0.25	
14556	11/05/02	73	3	F	2000	0.70742	0.64	W	TUO	433.0	61.3	52.7	71.4	P	F	P	71	3.15	0.26	
14559	11/05/02	89	3	M	2000	0.70768	0.92	W	TUO	382.0	52.6	44.0	62.6	F	F	P	.			
14560	11/05/02	78	3	F	2000	0.70756	0.85	W	TUO	434.0	61.5	52.9	71.5	P	F	P	69	2.96	0.22	
14566	11/05/02	79	3	F	2000	0.70786	0.97	W	TUO	431.0	60.9	52.4	71.0	P	F	P	.			
14571	11/05/02	97	3	M	2000	0.70763	0.90	W	TUO	502.0	73.1	64.5	83.1	P	P	S	77	2.91	0.24	
14575	11/05/02	73	3	F	2000	0.70795	0.98	W	TUO	438.0	62.1	53.6	72.2	P	F	P	72	3.07	0.22	
14578	11/05/02	73	3	F	2000	0.70745	0.71	W	TUO	411.0	57.5	48.9	67.6	P	F	P	.			
14579	11/05/02	93	3	M	2000	0.70742	0.65	W	TUO	413.0	57.9	49.3	67.9	P	F	P	60	3.41	0.30	
14584	11/05/02	81	.	M	2000	0.70772	0.94	W	TUO	464.0	66.6	58.0	76.7	P	P	S	.			
14587	11/05/02	80	3	F	2000	0.70780	0.96	W	TUO	508.0	74.1	65.5	84.2	P	P	S	.			
14596	11/05/02	80	3	F	2000	0.70800	0.97	W	TUO	516.0	75.5	66.9	85.5	S	P	S	99	2.97	0.22	
14597	11/05/02	91	3	M	2000	0.70756	0.85	W	TUO	409.0	57.2	48.6	67.2	P	F	P	57	3.05	0.29	
14600	11/05/02	75	3	F	2000	0.70774	0.95	W	TUO	383.0	52.7	44.1	62.8	F	F	P	.			
14616	11/12/02	94	3	M	2000	0.70768	0.92	W	TUO	344.0	46.1	37.5	56.1	F	F	P	18	2.56	0.13	
14626	11/12/02	91	3	M	2000	0.70735	0.50	W	TUO	461.0	66.1	57.5	76.1	P	P	S	.			
14629	11/12/02	74	3	F	2000	0.70772	0.94	W	TUO	486.0	70.3	61.8	80.4	P	P	S	.			
14661	11/12/02	94	3	M	2000	0.70761	0.89	W	TUO	412.0	57.7	49.1	67.8	P	F	P	73	2.64	0.31	
14668	11/12/02	90	3	M	2000	0.70785	0.97	W	TUO	466.0	66.9	58.3	77.0	P	P	S	75	2.93	0.21	
14673	11/12/02	90	3	M	2000	0.70770	0.93	W	TUO	447.0	63.7	55.1	73.7	P	P	P	61	3.28	0.22	
14689	11/12/02	93	3	M	2000	0.70803	0.96	W	TUO	465.0	66.8	58.2	76.8	P	P	S	87	3.34	0.23	Microstructure ran out 13um before last natal spot (inferred 4

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																				increments)
14701	11/13/02	93	3	M	2000	0.70803	0.96	W	TUO	456.0	65.2	56.6	75.3	P	P	S	60	2.32	0.25	Strange profile (used same distance for natal and FW exit)
14721	11/13/02	76	3	F	2000	0.70804	0.95	W	TUO	453.0	64.7	56.1	74.8	P	P	P	75	3.05	0.25	
14735	11/13/02	92	3	M	2000	0.70763	0.90	W	TUO	367.0	50.0	41.4	60.1	F	F	P	44	3.19	0.17	
14743	11/13/02	76	3	F	2000	0.70802	0.96	W	TUO	479.0	69.1	60.6	79.2	P	P	S	89	2.89	0.22	
14749	11/14/02	80	3	F	2000	0.70773	0.94	W	TUO	372.0	50.9	42.3	60.9	F	F	P	45	2.86	0.17	
14753	11/14/02	84	3	M	2000	0.70774	0.95	W	TUO	393.0	54.4	45.9	64.5	F	F	P	64	3.10	0.20	
14769	11/14/02	81	3	F	2000	0.70757	0.85	W	TUO	378.0	51.9	43.3	61.9	F	F	P	51	3.19	0.27	
14783	11/14/02	89	3	M	2000	0.70793	0.98	W	TUO	496.0	72.1	63.5	82.1	P	P	S	77	3.43	0.22	
14785	11/14/02	95	3	M	2000	0.70766	0.91	W	TUO	447.0	63.7	55.1	73.7	P	P	P	.			
14786	11/14/02	76	3	F	2000	0.70781	0.96	W	TUO	421.0	59.2	50.6	69.3	P	F	P	51	3.57	0.20	
14813	11/14/02	86	3	M	2000	0.70799	0.97	W	TUO	430.0	60.8	52.2	70.8	P	F	P	65	3.08	0.24	
14815	11/15/02	82	3	F	2000	0.70761	0.89	W	TUO	438.0	62.1	53.6	72.2	P	F	P	.			
14858	11/18/02	104	3	M	2000	0.70740	0.61	W	TUO	464.2	66.6	58.0	76.7	P	P	S	73	3.23	0.29	
14880	11/18/02	80	3	M	2000	0.70727	0.31	W	TUO*	409.0	57.2	48.6	67.2	P	F	P	48	3.57	0.28	
14907	11/18/02	74	3	F	2000	0.70773	0.95	W	TUO	475.0	68.5	59.9	78.5	P	P	S	71	3.08	0.22	
14921	11/18/02	93	3.5	F	2000	0.70780	0.96	W	TUO	377.0	51.7	43.1	61.8	F	F	P	28	3.08	0.21	
14929	11/18/02	91	3	M	2000	0.70764	0.90	W	TUO	454.0	64.9	56.3	74.9	P	P	P	67	3.37	0.27	
14975	11/19/02	102	3	M	2000	0.70743	0.67	W	TUO	392.0	54.3	45.7	64.3	F	F	P	.			
15091	11/21/02	100	3	F	2000	0.70792	0.98	W	TUO	497.0	72.2	63.6	82.3	P	P	S	60	3.52	0.23	
15113	11/21/02	100	3	M	2000	0.70763	0.90	W	TUO	407.0	56.8	48.2	66.9	P	F	P	.			
15133	11/24/02	103	3	M	2000	0.70754	0.83	W	TUO	428.0	60.4	51.8	70.5	P	F	P	67	3.06	0.25	
15193	11/24/02	101	3	M	2000	0.70773	0.94	W	TUO	508.0	74.1	65.5	84.2	P	P	S	79	3.11	0.25	
15243	12/02/02	91	3	M	2000	0.70777	0.95	W	TUO	414.0	58.0	49.4	68.1	P	F	P	71	3.02	0.27	
19681	11/15/01	65	2	M	2000	0.70759	0.87	W	TUO	383.0	52.7	44.1	62.8	F	F	P	.			
19695	11/19/01	59.5	2	M	2000	0.70759	0.88	W	TUO	488.0	70.7	62.1	80.8	P	P	S	74	3.09	0.26	
19813	12/03/01	48	2	M	2000	0.70789	0.97	W	TUO	503.0	73.3	64.7	83.3	P	P	S	133	3.11	0.26	
19831	12/03/01	57	2	F	2000	0.70779	0.96	W	TUO	386.0	53.2	44.7	63.3	F	F	P	48	3.29	0.24	
19853	12/04/01	60	2	F	2000	0.70781	0.96	W	TUO	517.0	75.6	67.1	85.7	S	P	S	90	3.14	0.29	
19858	12/04/01	58	2	F	2000	0.70761	0.89	W	TUO	437.0	62.0	53.4	72.0	P	F	P	.			
17628	11/14/05	91	3	M	2003	0.70730	0.37	W	TUO*	459.8	65.9	57.3	75.9	P	P	S	70	3.67	0.26	
17631	11/14/05	84	3	F	2003	0.70751	0.80	W	TUO	554.2	82.0	73.4	92.1	S	P	S	94	3.80	0.25	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

17634	11/14/05	81	3	F	2003	0.70772	0.94	W	TUO	475.1	68.5	59.9	78.6	P	P	S	94	2.57	0.22	
17637	11/16/05	92	3	M	2003	0.70726	0.27	W	TUO*	381.2	52.4	43.8	62.5	F	F	P	*Inconclusive natal assignment*			
17638	11/16/05	76	3	F	2003	0.70731	0.41	W	TUO*	536.5	79.0	70.4	89.0	S	P	S	81	3.60	0.24	
17645	11/21/05	75	3	F	2003	0.70747	0.74	W	TUO	557.4	82.6	74.0	92.6	S	P	S	.			
17651	11/21/05	88	3	M	2003	0.70745	0.71	W	TUO	538.8	79.4	70.8	89.4	S	P	S	76	3.98	0.22	
17654	11/21/05	73	3	F	2003	0.70757	0.86	W	TUO	309.6	40.2	31.6	50.3	F	F	F	57	2.79	0.26	
17666	11/28/05	73	3	F	2003	0.70753	0.82	W	TUO	485.8	70.3	61.7	80.4	P	P	S	88	3.09	0.20	
17667	11/28/05	75	3	F	2003	0.70744	0.69	W	TUO	493.7	71.7	63.1	81.7	P	P	S	97	3.34	0.27	
17669	11/28/05	72	3	F	2003	0.70743	0.66	W	TUO	504.9	73.6	65.0	83.6	P	P	S	.			
17672	11/28/05	79	3	F	2003	0.70756	0.85	INC	TUO*	n/a (vaterite)	n/a	n/a	n/a	n/a	n/a	n/a	.			Otolith was vateritic during natal rearing (so no HvW assignment or exit age/distance)
17673	11/28/05	71	3	F	2003	0.70745	0.70	W	TUO	450.5	64.3	55.7	74.3	P	P	P	.			
17679	11/28/05	85	3	M	2003	0.70729	0.34	W	TUO*	452.8	64.7	56.1	74.7	P	P	P	53	3.86	0.22	
17680	11/28/05	75	3	F	2003	0.70777	0.96	W	TUO	507.7	74.1	65.5	84.1	P	P	S	85	2.92	0.26	Microstructure ran out 54um before last natal spot (inferred 18 increments)
17681	11/28/05	72	3	F	2003	0.70763	0.90	W	TUO	441.7	62.8	54.2	72.8	P	F	P	.			
17685	11/28/05	61	3	M	2003	0.70727	0.30	W	TUO*	419.8	59.0	50.4	69.1	P	F	P	*Inconclusive natal assignment*			
17690	11/28/05	83	3	M	2003	0.70754	0.83	W	TUO	565.8	84.0	75.4	94.1	S	S	S	102	3.61	0.28	
17692	11/29/05	85	3	F	2003	0.70759	0.87	W	TUO	432.4	61.2	52.6	71.2	P	F	P	46	4.20	0.19	
17703	12/06/05	75	3	F	2003	0.70751	0.79	W	TUO	599.2	89.7	81.1	99.8	S	S	S	108	3.33	0.19	
17712	12/06/05	90	3	M	2003	0.70734	0.46	W	TUO*	456.5	65.3	56.7	75.4	P	P	S	*Inconclusive natal assignment*			
17713	12/06/05	76	3	F	2003	0.70755	0.84	W	TUO	446.3	63.6	55.0	73.6	P	F	P	66	3.63	0.20	
17716	12/06/05	82	3	F	2003	0.70744	0.69	W	TUO	514.6	75.2	66.7	85.3	S	P	S	.			
17718	12/07/05	79	3	F	2003	0.70751	0.79	W	TUO	530.9	78.0	69.4	88.1	S	P	S	.			
17729	12/12/05	92	3	M	2003	0.70754	0.82	W	TUO	481.6	69.6	61.0	79.7	P	P	S	.			
17740	12/12/05	79	3	F	2003	0.70738	0.56	W	TUO	453.7	64.8	56.2	74.9	P	P	P	.			
17742	12/12/05	75	3	F	2003	0.70743	0.66	W	TUO	416.6	58.5	49.9	68.5	P	F	P	65	3.09	0.21	
17746	12/12/05	72	3	F	2003	0.70762	0.89	W	TUO	599.7	89.8	81.2	99.9	S	S	S	.			
17751	12/12/05	85	3	F	2003	0.70755	0.84	W	TUO	504.9	73.6	65.0	83.6	P	P	S	93	3.49	0.21	
17753	12/12/05	81	3	M	2003	0.70750	0.79	W	TUO	478.8	69.1	60.5	79.2	P	P	S	65	3.50	0.26	
17758	12/12/05	84	3	F	2003	0.70718	0.14	W	TUO*	501.2	72.9	64.4	83.0	P	P	S	76	3.59	0.21	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

17759	12/12/05	70	3	F	2003	0.70765	0.91	W	TUO	487.2	70.6	62.0	80.6	P	P	S	.			
17763	12/12/05	79	3	F	2003	0.70744	0.70	W	TUO	461.6	66.2	57.6	76.2	P	P	S	74	3.59	0.19	
18144	12/05/06	86	4	F	2003	0.70726	0.29	W	TUO*	502.1	73.1	64.5	83.2	P	P	S	78	3.37	0.22	
18150	12/11/06	84	4	F	2003	0.70741	0.62	W	TUO	444.9	63.3	54.7	73.4	P	F	P	65	3.30	0.17	
24120	11/07/11	76	3	F	2009	0.70777	0.73	W	TUO	451.3	64.4	55.8	74.5	P	P	P	66	3.29	0.23	
24176	11/14/11	81	3	F	2009	0.70781	0.77	W	TUO	542.0	79.9	71.3	90.0	S	P	S	76	3.78	0.24	
24178	11/14/11	67	3	M	2009	0.70778	0.74	W	TUO	559.0	81.0	72.4	91.0	S	P	S	109	3.19	0.23	
24238	11/21/11	70	3	F	2009	0.70773	0.69	W	TUO	508.2	74.1	65.5	84.2	P	P	S	.			
24283	11/23/11	83	3	M	2009	0.70734	0.16	W	TUO*	479.7	69.3	60.7	79.3	P	P	S	*Inconclusive natal assignment*			
24292	11/28/11	95	3	M	2009	0.70730	0.12	W	TUO*	555.9	82.3	73.7	92.4	S	P	S	*Inconclusive natal assignment*			
26012	11/13/12	84	4	F	2009	0.70780	0.76	W	TUO	546.1	80.6	72.0	90.7	S	P	S	101	3.16	0.23	

[1] Assignments using isotope-based discriminant function analysis and reference samples from existing or ongoing projects ([1], [2], P. Weber, A. Sturrock, unpub)
[2] Hatchery vs. wild assignment using microstructure-based discriminant function analysis and existing reference samples, after [3].
[3] Size-defined life stage designations (fry: <55mm, parr: >55mm to <75mm, smolt: >75mm), after [4].

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

						Natal Sr ratio				FW EXIT	Predicted FL at natal exit (mm)			Predicted life stage at natal exit [3]				Increment width (um)		
Sample ID	Capture date	Capture FL (cm)	Scale age	Sex	Outmi-gration year	Mean natal value	Prob to TUO [1]	H vs. W [2]	Natal location	Otolith distance (um)	FL	Lower 95% CI	Upper 95% CI	Life stage	Lower 95% CI	Upper 95% CI	Increment number (days)	Mean	CV	Notes
4175	10/10/00	98	3	M	1998	0.70799	0.97	W	TUO	603.6	90.4	81.9	100.5	S	S	S	4	3.1	0.2	
4176	10/10/00	91	3	M	1998	0.70774	0.95	W	TUO	604.3	90.6	82.0	100.6	S	S	S	22	3.1	0.2	
4182	10/17/00	76	3	M	1998	0.70803	0.96	W	TUO	578.3	86.1	77.5	96.2	S	S	S	11	2.8	0.3	
4183	10/17/00	90	3	M	1998	0.70797	0.97	W	TUO	514.7	75.3	66.7	85.3	S	P	S	16	3.7	0.2	
4185	10/17/00	84	3	F	1998	0.70728	0.64	W	TUO	585.4	87.3	78.7	97.4	S	S	S	30	2.6	0.2	
4189	10/24/00	90	3	F	1998	0.70806	0.94	W	TUO	496.4	72.1	63.5	82.2	P	P	S	11	2.9	0.3	
4192	10/24/00	87.5	3	F	1998	0.70807	0.93	W	TUO	517.3	75.7	67.1	85.8	S	P	S	5	5.3	0.3	
4196	10/24/00	67.9	3	F	1998	0.70800	0.97	W	TUO	524.7	77.0	68.4	87.0	S	P	S	n/a	n/a	n/a	
4197	10/24/00	78.6	3	F	1998	0.70740	0.61	W	TUO	531.8	78.2	69.6	88.2	S	P	S	23	3.8	0.2	
4200	10/24/00	68.6	3	F	1998	0.70760	0.88	W	TUO	611.4	91.8	83.2	101.9	S	S	S	9	3.4	0.2	
4210	10/24/00	88.3	3	M	1998	0.70764	0.91	W	TUO	511.3	74.7	66.1	84.7	P	P	S	8	3.9	0.2	
4211	10/24/00	72	3	F	1998	0.70783	0.97	W	TUO	625.4	94.2	85.6	104.2	S	S	S	.			
4212	10/24/00	78.1	3	M	1998	0.70765	0.91	W	TUO	568.9	84.5	75.9	94.6	S	S	S	13	2.8	0.3	
4215	10/25/00	79	3	F	1998	0.70802	0.96	W	TUO	620.1	93.3	84.7	103.3	S	S	S	18	3.5	0.2	
4226	10/25/00	80	3	F	1998	0.70770	0.93	W	TUO	479.9	69.3	60.7	79.4	P	P	S	6	4.1	0.2	
4232	10/25/00	88.5	3	M	1998	0.70821	0.53	W	TUO	540.3	79.6	71.0	89.7	S	P	S	.			
4233	10/25/00	72	3	F	1998	0.70795	0.98	W	TUO	504.7	73.5	64.9	83.6	P	P	S	18	2.5	0.2	
4234	10/25/00	77	3	F	1998	0.70823	0.45	W	TUO*	607.6	91.1	82.6	101.2	S	S	S	*Inconclusive natal assignment*			
4240	10/26/00	80	3	F	1998	0.70726	0.28	W	TUO*	484.4	70.1	61.5	80.1	P	P	S	*Inconclusive natal assignment*			
4249	10/30/00	80	3	F	1998	0.70737	0.54	W	TUO	520.5	76.2	67.6	86.3	S	P	S	.			
4253	10/30/00	80	3	M	1998	0.70810	0.90	W	TUO	595.9	89.1	80.6	99.2	S	S	S	16	2.8	0.3	
4266	10/30/00	77	3	F	1998	0.70740	0.60	W	TUO	508.6	74.2	65.6	84.3	P	P	S	19	2.7	0.2	
4267	10/30/00	75	3	F	1998	0.70812	0.86	W	TUO	534.2	78.6	70.0	88.7	S	P	S	.			
4269	10/30/00	80	3	F	1998	0.70732	0.43	W	TUO*	662.8	100.6	92.0	110.6	S	S	S	*Inconclusive natal assignment*			
4275	10/31/00	79	3	F	1998	0.70721	0.18	W	TUO*	444.6	63.3	54.7	73.3	P	F	P	*Inconclusive natal assignment*			
4278	10/31/00	83	3	F	1998	0.70802	0.96	W	TUO	515.7	75.4	66.8	85.5	S	P	S	.			
4279	10/31/00	87.5	3	F	1998	0.70798	0.97	W	TUO	596.6	89.3	80.7	99.3	S	S	S	7	3.0	0.2	
4281	10/31/00	91	3	M	1998	0.70728	0.31	W	TUO*	523.6	76.8	68.2	86.8	S	P	S	*Inconclusive natal assignment*			
4292	10/31/00	74	3	F	1998	0.70733	0.44	W	TUO*	608.5	91.3	82.7	101.4	S	S	S	*Inconclusive natal assignment*			
4294	10/31/00	86	3	F	1998	0.70800	0.97	W	TUO	586.2	87.5	78.9	97.6	S	S	S	.			

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

4295	10/31/00	72	3	F	1998	0.70816	0.77	W	TUO	518.5	75.9	67.3	86.0	S	P	S	10	2.8	0.2	
4297	11/01/00	74	3	F	1998	0.70805	0.95	W	TUO	644.1	97.4	88.8	107.4	S	S	S	13	3.3	0.2	
4299	11/06/00	81	3	F	1998	0.70801	0.97	W	TUO	555.3	82.2	73.6	92.3	S	P	S	.			
4300	11/06/00	96	3	M	1998	0.70735	0.50	W	TUO*	520.0	76.2	67.6	86.2	S	P	S	*Inconclusive natal assignment*			
4306	11/06/00	85	3	F	1998	0.70801	0.97	W	TUO	576.1	85.7	77.2	95.8	S	S	S	18	3.1	0.2	
4309	11/06/00	84	3	F	1998	0.70807	0.93	W	TUO	453.7	64.8	56.2	74.9	P	P	P	.			
4311	11/06/00	74	3	F	1998	0.70752	0.81	W	TUO	503.0	73.3	64.7	83.3	P	P	S	18	3.2	0.2	
4316	11/06/00	81	3	F	1998	0.70738	0.55	W	TUO	428.0	60.4	51.8	70.5	P	F	P	.			
4317	11/06/00	79	3	F	1998	0.70786	0.97	W	TUO	520.8	76.3	67.7	86.4	S	P	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
4321	11/06/00	70	3	F	1998	0.70742	0.65	W	TUO	592.5	88.6	80.0	98.6	S	S	S	29	3.9	0.3	
4331	11/07/00	86	3	M	1998	0.70798	0.97	W	TUO	604.8	90.7	82.1	100.7	S	S	S	10	2.3	0.2	
4334	11/07/00	85	3	F	1998	0.70739	0.59	W	TUO	439.7	62.4	53.8	72.5	P	F	P	11	3.4	0.1	
4337	11/07/00	74	3	F	1998	0.70733	0.45	W	TUO*	601.7	90.1	81.5	100.2	S	S	S	*Inconclusive natal assignment*			
4340	11/07/00	75.5	3	F	1998	0.70783	0.97	W	TUO	531.7	78.2	69.6	88.2	S	P	S	.			
4343	11/07/00	81	3	F	1998	0.70768	0.92	W	TUO	545.2	80.5	71.9	90.5	S	P	S	11	3.5	0.2	
4352	11/07/00	73	3	F	1998	0.70788	0.97	W	TUO	588.8	87.9	79.3	98.0	S	S	S	26	2.5	0.3	
4360	11/08/00	76.5	3	F	1998	0.70818	0.67	W	TUO	596.3	89.2	80.6	99.3	S	S	S	.			
4376	11/09/00	85	3	F	1998	0.70733	0.46	W	TUO*	621.8	93.6	85.0	103.6	S	S	S	*Inconclusive natal assignment*			
4378	11/09/00	88	3	M	1998	0.70728	0.33	W	TUO*	647.5	98.0	89.4	108.0	S	S	S	*Inconclusive natal assignment*			
4381	11/13/00	90	3	M	1998	0.70816	0.75	W	TUO	483.0	69.8	61.2	79.9	P	P	S	10	3.1	0.2	
4383	11/13/00	79	3	M	1998	0.70756	0.85	W	TUO	567.9	84.3	75.8	94.4	S	S	S	.			
4384	11/13/00	80	3	F	1998	0.70786	0.97	W	TUO	563.9	83.7	75.1	93.7	S	S	S	20	3.5	0.3	
4397	11/13/00	67	3	F	1998	0.70819	0.66	W	TUO	515.4	75.4	66.8	85.4	S	P	S	14	2.9	0.3	
4403	11/14/00	77	3	F	1998	0.70808	0.92	W	TUO	538.8	79.4	70.8	89.4	S	P	S	10	3.3	0.2	
4414	11/14/00	81	3	F	1998	0.70749	0.77	W	TUO	507.4	74.0	65.4	84.1	P	P	S	.			
4418	11/14/00	86	3	F	1998	0.70742	0.66	W	TUO	520.4	76.2	67.6	86.3	S	P	S	17	4.7	0.2	
4424	11/14/00	77	3	F	1998	0.70783	0.97	W	TUO	591.3	88.3	79.8	98.4	S	S	S	10	3.2	0.2	
4441	11/20/00	72	3	F	1998	0.70823	0.45	W	TUO*	531.0	78.0	69.5	88.1	S	P	S	*Inconclusive natal assignment*			
4442	11/20/00	95	3	M	1998	0.70771	0.94	W	TUO	631.7	95.3	86.7	105.3	S	S	S	26	3.1	0.4	
4443	11/20/00	100	3	M	1998	0.70735	0.50	W	TUO*	541.5	79.8	71.3	89.9	S	P	S	*Inconclusive natal assignment*			
4450	11/20/00	82	3	F	1998	0.70817	0.73	W	TUO	447.6	63.8	55.2	73.8	P	P	P	0	n/a	n/a	Strange profile (used same distance for natal and FW exit)

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

4451	11/20/00	92	3	M	1998	0.70817	0.72	W	TUO	507.3	74.0	65.4	84.1	P	P	S	25	2.7	0.2	
4455	11/20/00	74	3	F	1998	0.70769	0.93	W	TUO	533.3	78.4	69.9	88.5	S	P	S	12	3.6	0.3	
4458	11/21/00	80	3	F	1998	0.70792	0.98	W	TUO	591.4	88.4	79.8	98.4	S	S	S	16	3.7	0.2	
4476	11/22/00	100	3	M	1998	0.70804	0.95	W	TUO	556.0	82.3	73.7	92.4	S	P	S	15	3.1	0.3	
4484	11/27/00	77	3	F	1998	0.70788	0.97	W	TUO	557.1	82.5	73.9	92.6	S	P	S	12	3.5	0.1	
4487	11/27/00	84	3	F	1998	0.70800	0.97	W	TUO	533.6	78.5	69.9	88.6	S	P	S	.			
4504	12/04/00	100	3	M	1998	0.70826	0.30	W	TUO*	517.5	75.7	67.1	85.8	S	P	S	*Inconclusive natal assignment*			
4506	12/04/00	80	3	F	1998	0.70756	0.85	W	TUO	458.0	65.6	57.0	75.6	P	P	S	15	3.7	0.2	
4508	12/04/00	89	3	F	1998	0.70806	0.94	W	TUO	500.1	72.8	64.2	82.8	P	P	S	25	2.7	0.2	
4509	12/04/00	70.5	3	F	1998	0.70812	0.86	W	TUO	520.7	76.3	67.7	86.4	S	P	S	14	4.0	0.2	
4510	12/05/00	77	3	F	1998	0.70776	0.95	W	TUO	538.9	79.4	70.8	89.5	S	P	S	27	4.3	0.2	
4514	12/05/00	78	3	F	1998	0.70794	0.98	W	TUO	488.2	70.7	62.1	80.8	P	P	S	.			
4515	12/05/00	77	3	F	1998	0.70815	0.80	W	TUO	545.4	80.5	71.9	90.6	S	P	S	9	3.1	0.1	
4516	12/05/00	82	3	F	1998	0.70818	0.69	W	TUO	497.1	72.2	63.7	82.3	P	P	S	9	3.7	0.2	
4517	12/05/00	88.5	3	F	1998	0.70798	0.97	W	TUO	555.9	82.3	73.7	92.4	S	P	S	16	3.0	0.2	
4518	12/05/00	83	3	F	1998	0.70789	0.97	W	TUO	563.3	83.6	75.0	93.6	S	P	S	15	3.0	0.2	
4521	12/06/00	78.5	3	F	1998	0.70788	0.97	W	TUO	563.3	83.6	75.0	93.6	S	P	S	14	3.2	0.2	
4527	12/11/00	83	3	M	1998	0.70819	0.66	W	TUO	604.6	90.6	82.0	100.7	S	S	S	30	2.9	0.2	
4535	12/19/00	78	3	F	1998	0.70814	0.82	W	TUO	541.6	79.9	71.3	89.9	S	P	S	11	3.5	0.1	
9536	07/07/00	75	3	F	1998	0.70775	0.95	W	TUO	752.4	115.9	107.3	126.0	S	S	S	.			
11015	11/16/01	86.5	4	F	1998	0.70789	0.97	W	TUO	548.6	81.0	72.5	91.1	S	P	S	10	4.3	0.2	
11036	12/11/01	86	4	F	1998	0.70772	0.94	W	TUO	617.6	92.8	84.3	102.9	S	S	S	17	2.6	0.2	
11037	12/11/01	110	4	M	1998	0.70792	0.98	W	TUO	592.2	88.5	79.9	98.6	S	S	S	18	3.6	0.2	
11038	12/11/01	78	4	F	1998	0.70821	0.53	W	TUO	504.6	73.5	64.9	83.6	P	P	S	.			
11040	12/11/01	98	4	F	1998	0.70812	0.86	W	TUO	595.5	89.1	80.5	99.1	S	S	S	18	3.0	0.2	
11056	11/20/01	78	4	F	1998	0.70779	0.96	W	TUO	571.4	85.0	76.4	95.0	S	S	S	19	2.9	0.3	
11064	11/20/01	95	4	M	1998	0.70745	0.71	W	TUO	586.3	87.5	78.9	97.6	S	S	S	10	4.0	0.4	
11072	11/20/01	112	4	M	1998	0.70816	0.75	W	TUO	500.3	72.8	64.2	82.9	P	P	S	9	3.5	0.1	
11085	11/20/01	87	4	F	1998	0.70737	0.55	W	TUO	448.5	63.9	55.4	74.0	P	P	P	.			
11089	11/20/01	104	4	M	1998	0.70816	0.76	W	TUO	509.0	74.3	65.7	84.3	P	P	S	17	2.5	0.3	
11097	11/30/01	82	4	M	1998	0.70743	0.67	W	TUO	573.9	85.4	76.8	95.4	S	S	S	29	2.8	0.3	
11098	11/30/01	87	4	F	1998	0.70807	0.93	W	TUO	553.7	81.9	73.3	92.0	S	P	S	10	3.4	0.1	
11140	11/26/01	88	4	F	1998	0.70769	0.93	W	TUO	526.7	77.3	68.7	87.4	S	P	S	18	3.1	0.2	
11154	11/26/01	87	4	F	1998	0.70794	0.98	W	TUO	568.6	84.5	75.9	94.5	S	S	S	18	2.8	0.1	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

11176	12/07/01	92.5	4	F	1998	0.70821	0.54	W	TUO	605.9	90.8	82.3	100.9	S	S	S	.			
11177	12/07/01	90	4	F	1998	0.70781	0.96	W	TUO	546.6	80.7	72.1	90.8	S	P	S	.			
11181	12/18/01	87	3	F	1998	0.70819	0.63	W	TUO	730.2	112.1	103.5	122.2	S	S	S	42	2.5	0.2	
11182	12/17/01	99	4	M	1998	0.70798	0.97	W	TUO	417.2	58.6	50.0	68.7	P	F	P	3	3.56	0.24	
11190	11/23/01	90	3	M	1998	0.70821	0.53	W	TUO	540.6	79.7	71.1	89.8	S	P	S	18	2.6	0.2	
11216	11/21/01	94	4	F	1998	0.70821	0.54	W	TUO	552.9	81.8	73.2	91.9	S	P	S	14	2.6	0.2	
19680	11/15/01	103	4	M	1998	0.70766	0.92	W	TUO	661.5	100.4	91.8	110.4	S	S	S	.			
19684	11/15/01	92	3.5	M	1998	0.70776	0.95	W	TUO	578.3	86.1	77.5	96.2	S	S	S	.			
19685	11/15/01	87	4	F	1998	0.70811	0.89	W	TUO	545.7	80.6	72.0	90.6	S	P	S	.			
19687	11/15/01	82	3.5	M	1998	0.70806	0.95	W	TUO	557.0	82.5	73.9	92.5	S	P	S	16	3.5	0.3	
19691	11/15/01	91	4	M	1998	0.70721	0.19	W	TUO*	488.7	70.8	62.2	80.9	P	P	S	*Inconclusive natal assignment*			
19719	11/19/01	94.5	3.5	F	1998	0.70806	0.94	W	TUO	547.9	80.9	72.3	91.0	S	P	S	18	3.0	0.2	
19772	11/28/01	97	4	F	1998	0.70769	0.93	W	TUO	506.5	73.8	65.3	83.9	P	P	S	13	2.9	0.2	
19776	11/28/01	90	4	F	1998	0.70821	0.53	W	TUO	542.0	79.9	71.3	90.0	S	P	S	9	2.5	0.4	
19777	11/28/01	91	4	F	1998	0.70816	0.76	W	TUO	519.7	76.1	67.5	86.2	S	P	S	8	3.7	0.1	
19781	11/28/01	86	4	F	1998	0.70824	0.37	W	TUO*	532.5	78.3	69.7	88.4	S	P	S	*Inconclusive natal assignment*			
19783	11/28/01	89	4	F	1998	0.70793	0.98	W	TUO	480.4	69.4	60.8	79.5	P	P	S	16	3.0	0.2	
19785	11/28/01	88	4	F	1998	0.70765	0.91	W	TUO	540.6	79.7	71.1	89.8	S	P	S	34	3.2	0.3	
19790	11/28/01	94	4	F	1998	0.70818	0.68	W	TUO	583.5	87.0	78.4	97.1	S	S	S	32	2.9	0.2	
19796	12/03/01	81	4	F	1998	0.70811	0.88	W	TUO	566.3	84.1	75.5	94.1	S	S	S	17	3.8	0.1	
19798	12/03/01	93	4	M	1998	0.70814	0.83	W	TUO	525.6	77.1	68.5	87.2	S	P	S	17	4.0	0.2	
19800	12/03/01	114	4	M	1998	0.70776	0.95	W	TUO	595.1	89.0	80.4	99.1	S	S	S	.			
19802	12/03/01	97	4	F	1998	0.70824	0.40	W	TUO*	556.7	82.4	73.8	92.5	S	P	S	*Inconclusive natal assignment*			
19805	12/03/01	88	4	F	1998	0.70821	0.56	W	TUO	524.7	77.0	68.4	87.0	S	P	S	10	3.1	0.2	
19806	12/03/01	89	4	F	1998	0.70769	0.93	W	TUO	573.4	85.3	76.7	95.4	S	S	S	6	3.6	0.2	
19810	12/03/01	85	4	F	1998	0.70765	0.91	W	TUO	516.6	75.6	67.0	85.6	S	P	S	15	3.5	0.1	
19820	12/03/01	105	4	M	1998	0.70779	0.96	W	TUO	536.5	79.0	70.4	89.0	S	P	S	23	3.0	0.2	
19821	12/03/01	94	4	F	1998	0.70812	0.86	W	TUO	549.4	81.2	72.6	91.2	S	P	S	14	3.1	0.2	
19838	12/03/01	73	4	F	1998	0.70765	0.91	W	TUO	501.6	73.0	64.4	83.1	P	P	S	19	3.4	0.2	
19840	12/03/01	81	4	F	1998	0.70813	0.84	W	TUO	484.3	70.1	61.5	80.1	P	P	S	14	3.8	0.2	
19857	12/04/01	97	4	M	1998	0.70776	0.95	W	TUO	574.8	85.5	76.9	95.6	S	S	S	10	3.1	0.3	
19864	12/04/01	99	4	M	1998	0.70813	0.84	W	TUO	564.5	83.8	75.2	93.8	S	S	S	17	2.5	0.3	
19867	12/04/01	86	4	F	1998	0.70808	0.93	W	TUO	502.5	73.2	64.6	83.2	P	P	S	6	3.1	0.2	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

19872	12/10/01	84	4	F	1998	0.70815	0.78	W	TUO	508.7	74.2	65.6	84.3	P	P	S	16	3.1	0.2	
19875	12/10/01	83	4	F	1998	0.70823	0.42	W	TUO*	526.6	77.3	68.7	87.4	S	P	S	*Inconclusive natal assignment*			
19879	12/10/01	76	4	F	1998	0.70766	0.91	W	TUO	530.5	78.0	69.4	88.0	S	P	S	15	2.5	0.1	
19880	12/10/01	89	4	F	1998	0.70765	0.91	W	TUO	506.0	73.8	65.2	83.8	P	P	S	32	3.3	0.3	
19881	12/10/01	99	4	F	1998	0.70813	0.85	W	TUO	586.0	87.4	78.9	97.5	S	S	S	23	2.8	0.4	
20183	11/28/01	101	4	F	1998	0.70773	0.94	W	TUO	577.9	86.1	77.5	96.1	S	S	S	11	4.5	0.2	
4492	11/28/00	57	2	M	1999	0.70804	0.95	W	TUO	603.8	90.5	81.9	100.6	S	S	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
4526	12/11/00	67	2	F	1999	0.70800	0.97	W	TUO	871.9	136.3	127.7	146.4	S	S	S	.			
11009	11/16/01	.	3	F	1999	0.70757	0.86	W	TUO	517.8	75.8	67.2	85.8	S	P	S	.			
11016	11/16/01	79.5	3	F	1999	0.70731	0.40	W	TUO*	465.7	66.9	58.3	76.9	P	P	S	24	3.1	0.2	
11019	11/16/01	60	3	F	1999	0.70743	0.67	INC	TUO*	548.1	81.0	72.4	91.0	S	P	S		.		Unreadable, so cannot assign natal location or do ageing
11021	11/16/01	73	3	F	1999	0.70731	0.39	W	TUO*	525.1	77.0	68.4	87.1	S	P	S	17	2.8	0.3	
11041	12/11/01	77	3	F	1999	0.70805	0.95	W	TUO	556.9	82.5	73.9	92.5	S	P	S	13	3.0	0.2	
11094	11/30/01	80	3	F	1999	0.70756	0.85	W	TUO	516.3	75.5	66.9	85.6	S	P	S	15	3.8	0.3	
11096	11/30/01	77	3	F	1999	0.70764	0.91	W	TUO	568.8	84.5	75.9	94.6	S	S	S	12	3.5	0.2	
11099	11/30/01	73	3	F	1999	0.70733	0.44	W	TUO*	491.3	71.3	62.7	81.3	P	P	S	*Inconclusive natal assignment*			
11100	11/30/01	83	3	F	1999	0.70748	0.75	W	TUO	572.6	85.2	76.6	95.2	S	S	S	.			
11132	11/26/01	76	3	F	1999	0.70734	0.46	W	TUO*	521.5	76.4	67.8	86.5	S	P	S	15	3.0	0.3	
11141	11/26/01	77	3	F	1999	0.70741	0.63	W	TUO	485.0	70.2	61.6	80.2	P	P	S	.			
11146	11/26/01	81	3	F	1999	0.70722	0.20	W	TUO*	487.0	70.5	61.9	80.6	P	P	S	*Inconclusive natal assignment*			
11157	11/26/01	80	3	M	1999	0.70740	0.61	W	TUO	467.5	67.2	58.6	77.3	P	P	S	8	5.6	0.1	
11161	11/26/01	74	3	F	1999	0.70792	0.98	W	TUO	519.2	76.0	67.4	86.1	S	P	S	.			
11162	11/26/01	78	3	F	1999	0.70724	0.25	W	TUO*	534.0	78.6	70.0	88.6	S	P	S	7	4.7	0.3	
11174	12/07/01	80	3	F	1999	0.70754	0.83	W	TUO	488.2	70.7	62.1	80.8	P	P	S	1	2.7	n/a	
11192	11/23/01	74	3	F	1999	0.70772	0.94	W	TUO	550.0	81.3	72.7	91.4	S	P	S	29	3.1	0.3	
11209	11/21/01	97	3	M	1999	0.70771	0.94	W	TUO	602.1	90.2	81.6	100.3	S	S	S	15	3.8	0.2	
11213	11/21/01	83	3	F	1999	0.70771	0.94	W	TUO	521.3	76.4	67.8	86.4	S	P	S	.			
11217	11/21/01	40.5	3	M	1999	0.70764	0.90	W	TUO	474.1	68.3	59.7	78.4	P	P	S	10	2.8	0.2	
14499	11/04/02	93	4	F	1999	0.70814	0.83	W	TUO	610.2	91.6	83.0	101.6	S	S	S	33	2.8	0.3	
14568	11/05/02	107	4	M	1999	0.70761	0.89	W	TUO	631.3	95.2	86.6	105.3	S	S	S	30	2.69	0.3 6	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

14621	11/12/02	104	4	M	1999	0.70776	0.95	W	TUO	642.0	97.0	88.4	107.1	S	S	S	31	3.1	0.2	
14623	11/12/02	85	4	F	1999	0.70782	0.97	W	TUO	531.8	78.2	69.6	88.2	S	P	S	12	3.0	0.2	
14627	11/12/02	97	4	F	1999	0.70754	0.83	W	TUO	522.3	76.6	68.0	86.6	S	P	S	.			
14635	11/12/02	101	4	M	1999	0.70777	0.96	W	TUO	548.5	81.0	72.4	91.1	S	P	S	17	2.9	0.3	
14647	11/12/02	96	4	F	1999	0.70805	0.95	W	TUO	503.9	73.4	64.8	83.5	P	P	S	.			
14669	11/12/02	104	4	M	1999	0.70761	0.89	W	TUO	541.0	79.7	71.2	89.8	S	P	S	15	3.8	0.2	
14687	11/12/02	91	4	F	1999	0.70738	0.56	W	TUO	580.1	86.4	77.8	96.5	S	S	S	20	3.7	0.2	
14693	11/12/02	99	4	M	1999	0.70751	0.80	W	TUO	570.7	84.8	76.2	94.9	S	S	S	27	3.2	0.2	
14716	11/13/02	97	4	M	1999	0.70757	0.85	W	TUO	597.6	89.4	80.8	99.5	S	S	S	28	3.2	0.3	
14729	11/13/02	96	4	M	1999	0.70726	0.28	W	TUO*	533.1	78.4	69.8	88.5	S	P	S	20	3.7	0.3	
14759	11/14/02	101	4	M	1999	0.70766	0.91	W	TUO	563.5	83.6	75.0	93.7	S	S	S	22	2.3	0.2	
14774	11/14/02	86	4	F	1999	0.70786	0.97	W	TUO	528.7	77.6	69.1	87.7	S	P	S	.			
14804	11/14/02	93	4	F	1999	0.70768	0.93	W	TUO	543.8	80.2	71.6	90.3	S	P	S	18	3.9	0.2	
14824	11/15/02	98	4	M	1999	0.70733	0.44	W	TUO*	551.6	81.6	73.0	91.6	S	P	S	*Inconclusive natal assignment*			
14850	11/18/02	92	4	F	1999	0.70722	0.19	W	TUO*	513.4	75.0	66.4	85.1	S	P	S	*Inconclusive natal assignment*			
14884	11/18/02	89	4	F	1999	0.70749	0.77	W	TUO	545.5	80.5	71.9	90.6	S	P	S	.			
14889	11/18/02	88	4	M	1999	0.70754	0.82	W	TUO	576.1	85.8	77.2	95.8	S	S	S	22	3.7	0.2	
14892	11/18/02	100	4	M	1999	0.70725	0.26	W	TUO*	534.3	78.6	70.0	88.7	S	P	S	*Inconclusive natal assignment*			
14904	11/18/02	100	4	M	1999	0.70745	0.70	W	TUO	553.8	81.9	73.3	92.0	S	P	S	28	3.4	0.2	
14919	11/18/02	88	4	F	1999	0.70729	0.35	W	TUO*	458.5	65.6	57.1	75.7	P	P	S	*Inconclusive natal assignment*			
14953	11/19/02	103	4	M	1999	0.70787	0.97	W	TUO	534.2	78.6	70.0	88.6	S	P	S	16	2.7	0.3	
14955	11/19/02	94	4	F	1999	0.70813	0.84	W	TUO	562.1	83.4	74.8	93.4	S	P	S	8	3.4	0.3	
14976	11/19/02	102	4	M	1999	0.70765	0.91	W	TUO	524.7	77.0	68.4	87.0	S	P	S	5	3.9	0.1	
14999	11/20/02	104	4	M	1999	0.70726	0.27	W	TUO*	523.4	76.7	68.1	86.8	S	P	S	1	4.9		
15001	11/20/02	101	4	M	1999	0.70787	0.97	W	TUO	487.7	70.6	62.0	80.7	P	P	S	13	3.7	0.3	
15052	11/20/02	105	4	M	1999	0.70776	0.95	W	TUO	590.3	88.2	79.6	98.2	S	S	S	.			
15064	11/20/02	98	4	M	1999	0.70775	0.95	W	TUO	475.5	68.5	60.0	78.6	P	P	S	11	3.2	0.4	
15097	11/21/02	104	4	M	1999	0.70774	0.95	W	TUO	563.5	83.6	75.0	93.7	S	S	S	11	3.3	0.1	
15146	11/24/02	107	4	M	1999	0.70721	0.19	W	TUO*	513.8	75.1	66.5	85.2	S	P	S	*Inconclusive natal assignment*			
15150	11/24/02	108	4	M	1999	0.70761	0.89	W	TUO	505.1	73.6	65.0	83.7	P	P	S	22	3.6	0.3	
15165	11/24/02	100	4	M	1999	0.70726	0.27	W	TUO*	447.6	63.8	55.2	73.9	P	P	P	*Inconclusive natal assignment*			
19679	11/15/01	78	3	F	1999	0.70754	0.83	W	TUO	559.9	83.0	74.4	93.1	S	P	S	11	3.0	0.1	
19686	11/15/01	81	3	F	1999	0.70780	0.96	W	TUO	567.8	84.3	75.7	94.4	S	S	S	6	4.2	0.3	
19688	11/15/01	72.5	3	F	1999	0.70772	0.94	W	TUO	578.5	86.2	77.6	96.2	S	S	S	.			

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19705	11/15/01	76	3	F	1999	0.70729	0.35	W	TUO*	440.8	62.6	54.0	72.7	P	F	P	*Inconclusive natal assignment*			
19722	11/19/01	87	3	F	1999	0.70733	0.44	W	TUO*	582.6	86.9	78.3	96.9	S	S	S	*Inconclusive natal assignment*			
19775	11/28/01	83	3	F	1999	0.70736	0.52	W	TUO	592.7	88.6	80.0	98.7	S	S	S	31	3.7	0.2	
19779	11/28/01	70	3	F	1999	0.70760	0.88	W	TUO	522.2	76.5	67.9	86.6	S	P	S	10	3.5	0.2	
19782	11/28/01	76	3	M	1999	0.70779	0.96	W	TUO	555.0	82.1	73.6	92.2	S	P	S	18	3.1	0.2	
19786	11/28/01	85	3	M	1999	0.70746	0.73	W	TUO	580.0	86.4	77.8	96.5	S	S	S	9	3.5	0.3	
19791	11/28/01	79	3	F	1999	0.70735	0.49	W	TUO*	508.6	74.2	65.6	84.3	P	P	S	*Inconclusive natal assignment*			
19792	11/28/01	76	3	F	1999	0.70814	0.83	W	TUO	520.8	76.3	67.7	86.4	S	P	S	5	4.1	0.1	
19797	12/03/01	84	3	F	1999	0.70735	0.48	W	TUO*	523.0	76.7	68.1	86.7	S	P	S	*Inconclusive natal assignment*			
19816	12/03/01	81	3	M	1999	0.70770	0.93	W	TUO	736.1	113.1	104.5	123.2	S	S	S	.			
19836	12/03/01	88	3	M	1999	0.70726	0.29	W	TUO*	486.4	70.4	61.8	80.5	P	P	S	*Inconclusive natal assignment*			
19841	12/03/01	74	3	F	1999	0.70724	0.23	W	TUO*	491.7	71.3	62.7	81.4	P	P	S	*Inconclusive natal assignment*			
19845	12/04/01	87	3	M	1999	0.70788	0.97	W	TUO	549.3	81.2	72.6	91.2	S	P	S	20	3.2	0.2	
19855	12/04/01	85	3	M	1999	0.70768	0.92	W	TUO	523.0	76.7	68.1	86.7	S	P	S	33	2.8	0.2	
19861	12/04/01	74	3	F	1999	0.70775	0.95	W	TUO	544.2	80.3	71.7	90.4	S	P	S	8	3.4	0.2	
19866	12/04/01	86	3	M	1999	0.70724	0.23	W	TUO*	487.4	70.6	62.0	80.6	P	P	S	9	3.1	0.2	
19868	12/04/01	74	3	F	1999	0.70736	0.51	W	TUO	645.4	97.6	89.0	107.7	S	S	S	9	3.7	0.2	
19874	12/10/01	75	3	F	1999	0.70756	0.84	W	TUO	409.6	57.3	48.7	67.4	P	F	P	8	2.73	0.14	
19876	12/10/01	71	3	M	1999	0.70765	0.91	W	TUO	538.8	79.4	70.8	89.4	S	P	S	16	3.2	0.2	
11055	11/20/01	56	2	M	2000	0.70770	0.93	W	TUO	433.6	61.4	52.8	71.5	P	F	P	.			
11063	11/20/01	58	2	M	2000	0.70763	0.90	W	TUO	614.4	92.3	83.7	102.4	S	S	S	53	2.8	0.2	
11076	11/20/01	81	2	F	2000	0.70807	0.93	W	TUO	557.2	82.5	73.9	92.6	S	P	S	5	3.1	0.1	
11083	11/20/01	59	2	M	2000	0.70742	0.65	W	TUO	529.8	77.8	69.2	87.9	S	P	S	35	3.2	0.2	
11111	11/08/01	54.5	2	F	2000	0.70775	0.95	W	TUO	563.7	83.6	75.0	93.7	S	S	S	24	4.0	0.3	
11133	11/26/01	59	2	F	2000	0.70797	0.97	W	TUO	472.4	68.0	59.4	78.1	P	P	S	.			
11167	11/26/01	60	2	F	2000	0.70752	0.81	W	TUO	512.3	74.8	66.3	84.9	P	P	S	33	3.4	0.3	
11212	11/21/01	65.5	2	F	2000	0.70760	0.88	W	TUO	559.7	82.9	74.4	93.0	S	P	S	32	3.8	0.2	
11215	11/21/01	60	2	F	2000	0.70795	0.98	W	TUO	577.4	86.0	77.4	96.0	S	S	S	20	4.3	0.3	
11220	10/31/01	62	2	F	2000	0.70789	0.97	W	TUO	601.9	90.2	81.6	100.2	S	S	S	30	2.7	0.3	
11223	10/31/01	54	2	M	2000	0.70784	0.97	W	TUO	571.0	84.9	76.3	94.9	S	S	S	33	3.4	0.3	
11228	10/31/01	60	2	M	2000	0.70778	0.96	W	TUO	519.3	76.0	67.4	86.1	S	P	S	30	3.7	0.3	
14528	11/04/02	95	3	M	2000	0.70813	0.85	W	TUO	558.3	82.7	74.1	92.8	S	P	S	24	3.3	0.2	
14539	11/04/02	72	3	F	2000	0.70789	0.97	W	TUO	519.7	76.1	67.5	86.2	S	P	S	28	3.2	0.1	

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14540	11/04/02	69	3	F	2000	0.70777	0.96	INC	TUO*	466.3	67.0	58.4	77.0	P	P	S	.			Unreadable, so cannot assign natal location or do ageing
14544	11/05/02	78	3	F	2000	0.70782	0.96	W	TUO	523.5	76.8	68.2	86.8	S	P	S	39	3.0	0.2	
14545	11/05/02	92	3	M	2000	0.70792	0.98	W	TUO	482.3	69.7	61.1	79.8	P	P	S	.			
14548	11/05/02	72	3	F	2000	0.70801	0.97	W	TUO	615.8	92.5	84.0	102.6	S	S	S	.			
14550	11/05/02	80	3	M	2000	0.70789	0.97	W	TUO	487.8	70.7	62.1	80.7	P	P	S	29	3.1	0.3	
14556	11/05/02	73	3	F	2000	0.70742	0.64	W	TUO	552.0	81.6	73.0	91.7	S	P	S	29	4.0	0.3	
14559	11/05/02	89	3	M	2000	0.70768	0.92	W	TUO	430.9	60.9	52.3	71.0	P	F	P	.			
14560	11/05/02	78	3	F	2000	0.70756	0.85	W	TUO	537.9	79.2	70.6	89.3	S	P	S	28	3.8	0.2	
14566	11/05/02	79	3	F	2000	0.70786	0.97	W	TUO	504.0	73.4	64.8	83.5	P	P	S	.			
14571	11/05/02	97	3	M	2000	0.70763	0.90	W	TUO	590.4	88.2	79.6	98.3	S	S	S	38	3.4	0.3	
14575	11/05/02	73	3	F	2000	0.70795	0.98	W	TUO	500.4	72.8	64.2	82.9	P	P	S	21	3.1	0.3	
14578	11/05/02	73	3	F	2000	0.70745	0.71	W	TUO	511.4	74.7	66.1	84.8	P	P	S	.			
14579	11/05/02	93	3	M	2000	0.70742	0.65	W	TUO	521.3	76.4	67.8	86.4	S	P	S	31	3.8	0.2	
14584	11/05/02	81	.	M	2000	0.70772	0.94	W	TUO	520.2	76.2	67.6	86.3	S	P	S	.			
14587	11/05/02	80	3	F	2000	0.70780	0.96	W	TUO	584.3	87.2	78.6	97.2	S	S	S	.			
14596	11/05/02	80	3	F	2000	0.70800	0.97	W	TUO	568.9	84.5	75.9	94.6	S	S	S	19	2.9	0.3	
14597	11/05/02	91	3	M	2000	0.70756	0.85	W	TUO	528.1	77.5	69.0	87.6	S	P	S	35	3.4	0.3	
14600	11/05/02	75	3	F	2000	0.70774	0.95	W	TUO	460.7	66.0	57.4	76.1	P	P	S	.			
14616	11/12/02	94	3	M	2000	0.70768	0.92	W	TUO	494.1	71.7	63.1	81.8	P	P	S	61	3.5	0.2	
14626	11/12/02	91	3	M	2000	0.70735	0.50	W	TUO	545.9	80.6	72.0	90.7	S	P	S	.			
14629	11/12/02	74	3	F	2000	0.70772	0.94	W	TUO	555.0	82.1	73.6	92.2	S	P	S	.			
14661	11/12/02	94	3	M	2000	0.70761	0.89	W	TUO	556.0	82.3	73.7	92.4	S	P	S	42	3.8	0.3	
14668	11/12/02	90	3	M	2000	0.70785	0.97	W	TUO	530.4	77.9	69.3	88.0	S	P	S	23	3.3	0.2	
14673	11/12/02	90	3	M	2000	0.70770	0.93	W	TUO	532.9	78.4	69.8	88.4	S	P	S	26	3.8	0.2	
14689	11/12/02	93	3	M	2000	0.70803	0.96	W	TUO	521.2	76.4	67.8	86.4	S	P	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
14701	11/13/02	93	3	M	2000	0.70803	0.96	W	TUO	456.0	65.2	56.6	75.3	P	P	S	0	n/a	n/a	Strange profile (used same distance for natal and FW exit)
14721	11/13/02	76	3	F	2000	0.70804	0.95	W	TUO	512.1	74.8	66.2	84.9	P	P	S	18	3.7	0.2	
14735	11/13/02	92	3	M	2000	0.70763	0.90	W	TUO	514.7	75.2	66.7	85.3	S	P	S	38	3.9	0.3	
14743	11/13/02	76	3	F	2000	0.70802	0.96	W	TUO	535.2	78.8	70.2	88.8	S	P	S	12	4.2	0.2	

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14749	11/14/02	80	3	F	2000	0.70773	0.94	W	TUO	473.3	68.2	59.6	78.2	P	P	S	34	2.6	0.2	
14753	11/14/02	84	3	M	2000	0.70774	0.95	W	TUO	525.1	77.0	68.4	87.1	S	P	S	31	4.1	0.3	
14769	11/14/02	81	3	F	2000	0.70757	0.85	W	TUO	503.2	73.3	64.7	83.4	P	P	S	31	3.7	0.3	
14783	11/14/02	89	3	M	2000	0.70793	0.98	W	TUO	564.4	83.8	75.2	93.8	S	S	S	12	4.6	0.2	
14785	11/14/02	95	3	M	2000	0.70766	0.91	W	TUO	535.2	78.8	70.2	88.8	S	P	S	.			
14786	11/14/02	76	3	F	2000	0.70781	0.96	W	TUO	505.4	73.7	65.1	83.7	P	P	S	23	4.1	0.3	
14813	11/14/02	86	3	M	2000	0.70799	0.97	W	TUO	500.7	72.9	64.3	82.9	P	P	S	25	3.4	0.3	
14815	11/15/02	82	3	F	2000	0.70761	0.89	W	TUO	501.9	73.1	64.5	83.1	P	P	S	.			
14858	11/18/02	104	3	M	2000	0.70740	0.61	W	TUO	484.4	70.1	61.5	80.1	P	P	S	3	2.0	0.0	
14880	11/18/02	80	3	M	2000	0.70727	0.31	W	TUO*	480.4	69.4	60.8	79.5	P	P	S	12	5.1	0.2	
14907	11/18/02	74	3	F	2000	0.70773	0.95	W	TUO	497.3	72.3	63.7	82.3	P	P	S	14	3.9	0.2	
14921	11/18/02	93	3.5	F	2000	0.70780	0.96	W	TUO	547.1	80.8	72.2	90.9	S	P	S	47	3.3	0.2	
14929	11/18/02	91	3	M	2000	0.70764	0.90	W	TUO	529.8	77.8	69.3	87.9	S	P	S	30	3.2	0.3	
14975	11/19/02	102	3	M	2000	0.70743	0.67	W	TUO	565.7	84.0	75.4	94.0	S	S	S	.			
15091	11/21/02	100	3	F	2000	0.70792	0.98	W	TUO	557.5	82.6	74.0	92.6	S	P	S	26 †	3.90	0.15	† Microstructure ran out 52um before FW exit (inferred 13 increments at end)
15113	11/21/02	100	3	M	2000	0.70763	0.90	W	TUO	495.1	71.9	63.3	82.0	P	P	S	.			
15133	11/24/02	103	3	M	2000	0.70754	0.83	W	TUO	513.7	75.1	66.5	85.1	S	P	S	23	3.8	0.2	
15193	11/24/02	101	3	M	2000	0.70773	0.94	W	TUO	611.3	91.8	83.2	101.8	S	S	S	31	3.1	0.3	
15243	12/02/02	91	3	M	2000	0.70777	0.95	W	TUO	524.0	76.8	68.3	86.9	S	P	S	22	3.5	0.2	
19681	11/15/01	65	2	M	2000	0.70759	0.87	W	TUO	478.4	69.1	60.5	79.1	P	P	S	.			
19695	11/19/01	59.5	2	M	2000	0.70759	0.88	W	TUO	540.6	79.7	71.1	89.7	S	P	S	25	3.2	0.3	
19813	12/03/01	48	2	M	2000	0.70789	0.97	W	TUO	561.0	83.2	74.6	93.2	S	P	S	48	3.4	0.3	
19831	12/03/01	57	2	F	2000	0.70779	0.96	W	TUO	498.5	72.5	63.9	82.5	P	P	S	28	4.8	0.3	
19853	12/04/01	60	2	F	2000	0.70781	0.96	W	TUO	544.3	80.3	71.7	90.4	S	P	S	7	4.0	0.2	
19858	12/04/01	58	2	F	2000	0.70761	0.89	W	TUO	487.6	70.6	62.0	80.7	P	P	S	.			
17628	11/14/05	91	3	M	2003	0.70730	0.37	W	TUO*	551.7	81.6	73.0	91.6	S	P	S	19	3.2	0.3	
17631	11/14/05	84	3	F	2003	0.70751	0.80	W	TUO	594.7	88.9	80.4	99.0	S	S	S	12	4.6	0.2	
17634	11/14/05	81	3	F	2003	0.70772	0.94	W	TUO	511.9	74.8	66.2	84.8	P	P	S	9	2.9	0.1	
17637	11/16/05	92	3	M	2003	0.70726	0.27	W	TUO*	457.4	65.5	56.9	75.5	P	P	S	*Inconclusive natal assignment*			
17638	11/16/05	76	3	F	2003	0.70731	0.41	W	TUO*	558.9	82.8	74.2	92.9	S	P	S	11	3.1	0.2	
17645	11/21/05	75	3	F	2003	0.70747	0.74	W	TUO	628.3	94.7	86.1	104.7	S	S	S	.			

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

17651	11/21/05	88	3	M	2003	0.70745	0.71	W	TUO	582.0	86.8	78.2	96.8	S	S	S	8	4.4	0.2	
17654	11/21/05	73	3	F	2003	0.70757	0.86	W	TUO	380.8	52.4	43.8	62.4	F	F	P	16	3.6	0.1	
17666	11/28/05	73	3	F	2003	0.70753	0.82	W	TUO	529.0	77.7	69.1	87.8	S	P	S	5	2.9	0.3	
17667	11/28/05	75	3	F	2003	0.70744	0.69	W	TUO	531.9	78.2	69.6	88.3	S	P	S	18	2.9	0.3	
17669	11/28/05	72	3	F	2003	0.70743	0.66	W	TUO	597.8	89.5	80.9	99.5	S	S	S	.			
17672	11/28/05	79	3	F	2003	0.70756	0.85	INC	TUO*		n/a (vaterite)							.		Otolith vateritic during natal rearing (so no HvW assignment or exit age/dist)
17673	11/28/05	71	3	F	2003	0.70745	0.70	W	TUO		73.8	65.2	83.8	P	P	S	.			
17679	11/28/05	85	3	M	2003	0.70729	0.34	W	TUO*		82.3	73.7	92.4	S	P	S	21	4.6	0.3	
17680	11/28/05	75	3	F	2003	0.70777	0.96	W	TUO		86.6	78.0	96.6	S	S	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
17681	11/28/05	72	3	F	2003	0.70763	0.90	W	TUO		67.5	58.9	77.6	P	P	S	.			
17685	11/28/05	61	3	M	2003	0.70727	0.30	W	TUO*		74.7	66.1	84.8	P	P	S	*Inconclusive natal assignment*			
17690	11/28/05	83	3	M	2003	0.70754	0.83	W	TUO		91.5	82.9	101.5	S	S	S	8	3.1	0.3	
17692	11/29/05	85	3	F	2003	0.70759	0.87	W	TUO		73.9	65.4	84.0	P	P	S	2	4.3	0.1	
17703	12/06/05	75	3	F	2003	0.70751	0.79	W	TUO		96.9	88.3	106.9	S	S	S	14	3.1	0.2	
17712	12/06/05	90	3	M	2003	0.70734	0.46	W	TUO*		79.8	71.2	89.8	S	P	S	*Inconclusive natal assignment*			
17713	12/06/05	76	3	F	2003	0.70755	0.84	W	TUO		70.3	61.7	80.3	P	P	S	5	4.4	0.2	
17716	12/06/05	82	3	F	2003	0.70744	0.69	W	TUO		85.0	76.4	95.1	S	S	S	.			
17718	12/07/05	79	3	F	2003	0.70751	0.79	W	TUO		86.7	78.1	96.8	S	S	S	.			
17729	12/12/05	92	3	M	2003	0.70754	0.82	W	TUO		81.7	73.1	91.8	S	P	S	.			
17740	12/12/05	79	3	F	2003	0.70738	0.56	W	TUO		73.6	65.0	83.6	P	P	S	.			
17742	12/12/05	75	3	F	2003	0.70743	0.66	W	TUO		74.6	66.0	84.6	P	P	S	19	3.8	0.2	
17746	12/12/05	72	3	F	2003	0.70762	0.89	W	TUO		94.7	86.1	104.8	S	S	S	.			
17751	12/12/05	85	3	F	2003	0.70755	0.84	W	TUO		83.2	74.6	93.3	S	P	S	9	3.7	0.1	
17753	12/12/05	81	3	M	2003	0.70750	0.79	W	TUO		73.2	64.7	83.3	P	P	S	5	4.1	0.1	
17758	12/12/05	84	3	F	2003	0.70718	0.14	W	TUO*		78.1	69.5	88.2	S	P	S	8	3.6	0.3	
17759	12/12/05	70	3	F	2003	0.70765	0.91	W	TUO		78.3	69.8	88.4	S	P	S	.			
17763	12/12/05	79	3	F	2003	0.70744	0.70	W	TUO		75.9	67.3	86.0	S	P	S	13	3.9	0.2	
18144	12/05/06	86	4	F	2003	0.70726	0.29	W	TUO*		80.7	72.1	90.8	S	P	S	16	3.1	0.1	
18150	12/11/06	84	4	F	2003	0.70741	0.62	W	TUO		72.3	63.7	82.4	P	P	S	15	3.2	0.2	
24120	11/07/11	76	3	F	2009	0.70777	0.73	W	TUO		73.9	65.4	84.0	P	P	S	24	3.1	0.3	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

24176	11/14/11	81	3	F	2009	0.70781	0.77	W	TUO		91.3	82.7	101.4	S	S	S	20	2.9	0.4	
24178	11/14/11	67	3	M	2009	0.70778	0.74	W	TUO		88.0	79.4	98.1	S	S	S	13	3.5	0.3	
24238	11/21/11	70	3	F	2009	0.70773	0.69	W	TUO		80.1	71.5	90.2	S	P	S	.			
24283	11/23/11	83	3	M	2009	0.70734	0.16	W	TUO*		80.1	71.5	90.2	S	P	S	*Inconclusive natal assignment*			
24292	11/28/11	95	3	M	2009	0.70730	0.12	W	TUO*		91.4	82.8	101.4	S	S	S	*Inconclusive natal assignment*			
26012	11/13/12	84	4	F	2009	0.70780	0.76	W	TUO		83.7	75.1	93.8	S	S	S	7	2.6	0.1	

[1] Assignments using isotope-based discriminant function analysis and reference samples from existing or ongoing projects ([1], [2], P. Weber, A. Sturrock, unpub)
[2] Hatchery vs. wild assignment using microstructure-based discriminant function analysis and existing reference samples, after [3].
[3] Size-defined life stage designations (fry: <55mm, parr: >55mm to <75mm, smolt: >75mm), after [4].

1. Barnett-Johnson, R., et al., *Tracking natal origins of salmon using isotopes, otoliths, and landscape geology.* Limnology and Oceanography, 2008. **53**(4): p. 1633-1642.
2. Ingram, L.B. and P.K. Weber, *Salmon origin in California's Sacramento–San Joaquin river system as determined by otolith strontium isotopic composition.* Geology, 1999. **27**(9): p. 851-854.
3. Barnett-Johnson, R., et al., *Identifying the contribution of wild and hatchery Chinook salmon (Oncorhynchus tshawytscha) to the ocean fishery using otolith microstructure as natural tags.* Canadian Journal of Fisheries and Aquatic Sciences, 2007. **64**(12): p. 1683-1692.
4. Miller, J.A., A. Gray, and J. Merz, *Quantifying the contribution of juvenile migratory phenotypes in a population of Chinook salmon Oncorhynchus tshawytscha.* Marine Ecology Progress Series, 2010. **408**: p. 227-240.

Appendix 2 Capture details and natal assignments of strays to the Tuolumne River from outmigration years 1998, 1999, 2000, 2003 and 2009. The natal assignments were primarily based on otolith Sr isotopes, however where there was ambiguity in the assignment, otolith microstructure analyses were used to separate hatchery from wild fish (HvW). Site codes are provided in Table 2 of the main report.

ASN	Outmigration year	Date	Age	Length	Sex	Natal location	HvW
4184	1998	10/17/2000	3	84	F	X	H
4188	1998	10/19/2000	3	79.5	F	MOH	H
4190	1998	10/24/2000	3	91	M	MOH	H
4224	1998	10/25/2000	3	91	M	X	H
4227	1998	10/25/2000	3	87	M	X	H
4235	1998	10/25/2000	3	91	M	FEH	H
4236	1998	10/25/2000	3	72	F	MEH	n/a
4250	1998	10/30/2000	3	80	F	MOH	H
4260	1998	10/30/2000	3	78.5	M	X	H
4268	1998	10/30/2000	3	77	F	MOH	H
4273	1998	10/31/2000	3	78	F	MOK	W
4282	1998	10/31/2000	3	87	M	MEH	n/a
4285	1998	10/31/2000	3	77.5	F	MEH	n/a
4286	1998	10/31/2000	3	80	F	MEH	n/a
4289	1998	10/31/2000	3	83	F	MEH	n/a
4302	1998	11/6/2000	3	81.5	F	X	H
4313	1998	11/6/2000	3	92	F	MEH	H
4314	1998	11/6/2000	3	76	F	MEH	n/a
4324	1998	11/6/2000	3	77	F	MEH	H
4336	1998	11/7/2000	3	87	M	MEH	n/a
4338	1998	11/7/2000	3	84	F	MEH	n/a
4344	1998	11/7/2000	3	68	M	MEH	n/a
4349	1998	11/7/2000	3	75	F	MEH	n/a
4382	1998	11/13/2000	3	87	F	MEH	n/a
4396	1998	11/13/2000	3	92.5	M	MEH	n/a
4402	1998	11/14/2000	3	75	F	X	H
4406	1998	11/15/2000	3	88	M	MEH	n/a
4416	1998	11/15/2000	3	75	F	MEH	n/a
4422	1998	11/14/2000	3	80	F	MEH	n/a
4453	1998	11/20/2000	3	97	F	STA	W
4457	1998	11/20/2000	3	75	F	MEH	n/a
4467	1998	11/21/2000	3	92	F	STA	n/a
4479	1998	11/27/2000	3	63.5	F	MEH	n/a
4491	1998	11/28/2000	3	54	F	MEH	H
4495	1998	11/28/2000	3	86	F	X	H
4498	1998	11/29/2000	3	82	F	X	H
4503	1998	12/4/2000	3	83	F	X	H
4529	1998	12/12/2000	3	67	F	X	H
4530	1998	12/12/2000	3	61	F	X	H
9534	1998	7/7/2000	3	68	F	MOH	H
9551	1998	8/11/2000	3	74	F	MOH	H
11067	1998	11/20/2001	4	88	F	MEH	n/a
11095	1998	11/29/2001	4	86	F	MEH	n/a
11145	1998	11/26/2001	4	95	F	MEH	n/a
11147	1998	11/26/2001	4	93	F	MEH	n/a
11149	1998	11/26/2001	4	118	M	MEH	H
11150	1998	11/26/2001	4	84	M	MEH	n/a
11153	1998	11/26/2001	4	110	M	MEH	H
11156	1998	11/26/2001	4	92	F	MEH	n/a
11165	1998	11/26/2001	4	87	F	X	H
11170	1998	11/26/2001	4	95	F	MOH	H
11171	1998	11/26/2001	4	84	F	X	H
11172	1998	11/26/2001	4	83	F	MEH	H
11175	1998	12/7/2001	4	96	M	X	H
11178	1998	12/7/2001	4	88	F	MEH	H

Appendix 2 Capture details and natal assignments of strays to the Tuolumne River from outmigration years 1998, 1999, 2000, 2003 and 2009. The natal assignments were primarily based on otolith Sr isotopes, however where there was ambiguity in the assignment, otolith microstructure analyses were used to separate hatchery from wild fish (HvW). Site codes are provided in Table 2 of the main report.

11180	1998	12/19/2001	4	90	F	MER	W
11208	1998	11/21/2001	4	84	F	MOH	H
19676	1998	11/15/2001	4	103	M	STA	W
19766	1998	11/27/2001	3.5	84	F	MEH	n/a
19804	1998	12/3/2001	4	98	M	MEH	n/a
19814	1998	12/3/2001	4	91	F	MOK	W
19825	1998	12/3/2001	4	96	M	MEH	n/a
19839	1998	12/3/2001	4	82	F	MEH	n/a
19843	1998	12/3/2001	4	87	F	X	H
19848	1998	12/4/2001	3.5	85	F	STA	W
19856	1998	12/4/2001	4	103	M	STA	W
4375	1999	11/8/2000	2	57.5	F	THE	n/a
4404	1999	11/15/2000	2	56	M	MEH	n/a
4405	1999	11/15/2000	2	57	M	MEH	n/a
4468	1999	11/21/2000	2	37	F	MOH	H
4536	1999	12/20/2000	2	52	M	NIH	n/a
9548	1999	7/28/2000	2	81	F	MOH	H
9549	1999	8/4/2000	2	78	F	MOH	H
11011	1999	11/16/2001	3	77	F	FEH	H
11075	1999	11/20/2001	3	92.5	M	MOH	H
11077	1999	11/20/2001	3	91	F	MEH	H
11091	1999	11/20/2001	3	81	F	MOH	H
11148	1999	11/26/2001	3	72	F	MOH	H
11159	1999	11/26/2001	3	77	F	MOH	H
11168	1999	11/26/2001	3	71	F	THE	n/a
11169	1999	11/26/2001	3	75	F	MOH	H
11179	1999	12/7/2001	3	93	M	NIH	n/a
11183	1999	12/17/2001	3	80	M	NIH	n/a
14525	1999	11/4/2002	4	99	M	MOH	H
14546	1999	11/5/2002	4	95	M	MOH	H
14639	1999	11/12/2002	4	99	M	FEH	H
14640	1999	11/12/2002	4	88	F	STA	n/a
14641	1999	11/12/2002	4	96	F	FEH	H
14644	1999	11/12/2002	4	103	M	MOH	H
14645	1999	11/12/2002	4	101	M	MEH	n/a
14651	1999	11/12/2002	4	101	M	STA	n/a
14692	1999	11/12/2002	4	90	F	MOH	H
14711	1999	11/13/2002	4	94	M	MOH	H
14736	1999	11/13/2002	4	95	M	X	H
14737	1999	11/13/2002	4	110	M	X	H
14800	1999	11/14/2002	4	104	M	MOH	H
14827	1999	11/16/2002	4	98	F	STA	n/a
14828	1999	11/16/2002	4	99	M	X	H
14839	1999	11/18/2002	4	103	M	X	H
14877	1999	11/18/2002	4	90	M	STA	n/a
14883	1999	11/18/2002	4	90	M	STA	n/a
14906	1999	11/18/2002	4	100	M	MOH	H
14908	1999	11/18/2002	4	101	M	MOH	H
14912	1999	11/18/2002	4	102	M	MOH	H
14931	1999	11/18/2002	4	92	F	X	H
14944	1999	11/19/2002	4	101	M	MOH	H
14997	1999	11/20/2002	4	103	M	STA	n/a
15015	1999	11/20/2002	4	103	M	MOH	H
15098	1999	11/21/2002	4	96	M	MOH	H
15112	1999	11/21/2002	4	95	F	NIH	n/a
15114	1999	11/21/2002	4	100	M	MOH	H

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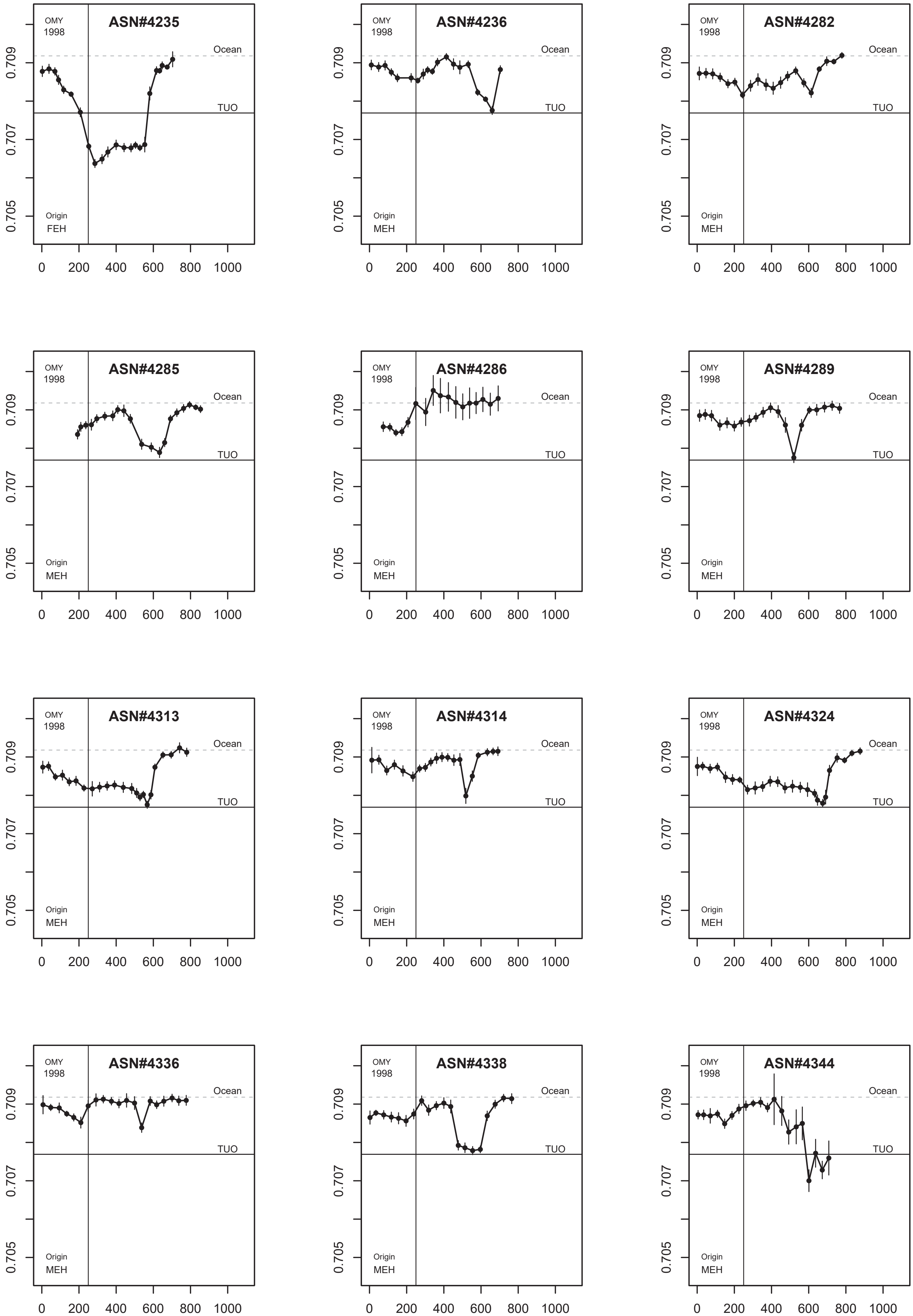
15124	1999	11/22/2002	4	95	F	STA	n/a
15127	1999	11/22/2002	4	102	M	STA	n/a
15131	1999	11/24/2002	4	100	M	MOK	n/a
15172	1999	11/24/2002	4	101	M	FEH	H
15178	1999	11/24/2002	4	104	F	MEH	H
15191	1999	11/24/2002	4	100	M	MOH	H
15216	1999	11/25/2002	4	98	M	FEH	H
15231	1999	11/26/2002	3.5	86	F	MOH	H
15236	1999	11/27/2002	4	100	M	NIH	n/a
15262	1999	12/3/2002	4	108	M	X	H
15269	1999	12/4/2002	4	102	M	X	H
15273	1999	12/5/2002	4	72	F	MOH	H
19678	1999	11/15/2001	3	82	F	MOH	H
19682	1999	11/15/2001	3	80	F	MEH	n/a
19689	1999	11/15/2001	3	88	F	X	H
19700	1999	11/15/2001	3	78	F	MEH	n/a
19778	1999	11/28/2001	3	77	F	MOH	H
19784	1999	11/28/2001	3	70	F	X	H
19787	1999	11/28/2001	3	89	F	X	H
19807	1999	12/3/2001	3	.		MEH	H
19832	1999	12/3/2001	3	69	F	MOH	H
19865	1999	12/4/2001	3	70	F	MOH	H
19870	1999	12/4/2001	3	75	M	X	H
19873	1999	12/10/2001	3	80	F	MEH	H
11012	2000	11/16/2001	2	58	F	X	H
11025	2000	11/9/2001	2	66	M	X	H
11062	2000	11/20/2001	2	86	M	FEH	H
11078	2000	11/20/2001	2	59	M	MEH	n/a
11079	2000	11/20/2001	2	55	M	MEH	n/a
11080	2000	11/20/2001	2	63	F	MOH	H
11103	2000	11/8/2001	2	57	M	MEH	n/a
11144	2000	11/26/2001	2	61	F	MEH	n/a
11184	2000	12/18/2001	2	54	M	NIH	n/a
11198	2000	11/21/2001	2	55.5	F	MOH	H
14486	2000	11/4/2002	3	110	M	MOH	H
14522	2000	11/4/2002	3	83	F	MOH	H
14524	2000	11/4/2002	3	77	F	MOH	H
14529	2000	11/4/2002	3	75	F	MOH	H
14547	2000	11/5/2002	3	79	M	MOH	H
14551	2000	11/5/2002	3	77	F	MOH	H
14569	2000	11/5/2002	3	81	M	MOH	H
14572	2000	11/5/2002	3	94	M	MOH	H
14577	2000	11/5/2002	3	99	M	FEH	H
14607	2000	11/6/2002	3	92	M	MOH	H
14612	2000	11/7/2002	3	98	M	MOH	H
14646	2000	11/12/2002	3	92	M	MOH	H
14657	2000	11/12/2002	3	76	F	MOH	H
14660	2000	11/12/2002	3	104	M	STA	W
14672	2000	11/12/2002	3	93	M	X	H
14744	2000	11/14/2002	3	84	M	X	H
14746	2000	11/14/2002	3	75	F	STA	W
14758	2000	11/14/2002	3	85	M	FEH	H
14763	2000	11/14/2002	3	79	F	X	H
14766	2000	11/14/2002	3	85	M	MOH	H
14890	2000	11/18/2002	3	87	M	MOH	H
14893	2000	11/18/2002	3	72	F	MOH	H

Appendix 2 Capture details and natal assignments of strays to the Tuolumne River from outmigration years 1998, 1999, 2000, 2003 and 2009. The natal assignments were primarily based on otolith Sr isotopes, however where there was ambiguity in the assignment, otolith microstructure analyses were used to separate hatchery from wild fish (HvW). Site codes are provided in Table 2 of the main report.

14895	2000	11/18/2002	3	75	F	MOH	H
14900	2000	11/18/2002	3	76	F	MOH	H
15025	2000	11/20/2002	3	100	M	STA	W
15067	2000	11/20/2002	3	99	M	MOH	H
15105	2000	11/21/2002	3	100	M	MOH	H
15128	2000	11/24/2002	3	107	M	STA	n/a
15159	2000	11/24/2002	3	105	M	FEH	H
19768	2000	11/27/2001	2	60	F	MOH	H
19789	2000	11/28/2001	2	64	F	MOH	H
19882	2000	12/10/2001	2	58	F	MEH	n/a
17621	2003	11/14/2005	3	75	F	MEH	n/a
17623	2003	11/14/2005	3	73	F	THE	n/a
17630	2003	11/14/2005	3	67	F	MOH	H
17632	2003	11/14/2005	3	65	F	THE	n/a
17641	2003	11/21/2005	3	70	F	MEH	n/a
17644	2003	11/21/2005	3	84	M	MOH	H
17647	2003	11/21/2005	3	85	F	MOH	H
17653	2003	11/21/2005	3	75	F	MOH	H
17658	2003	11/21/2005	3	74	F	MOH	H
17659	2003	11/21/2005	3	73	F	MOH	H
17661	2003	11/21/2005	3	75	F	MOH	H
17663	2003	11/21/2005	3	90	M	MEH	n/a
17674	2003	11/28/2005	3	74	F	NIH	n/a
17675	2003	11/28/2005	3	65	F	MOH	H
17676	2003	11/28/2005	3	79	F	MOH	H
17677	2003	11/28/2005	3	75	F	MOH	H
17686	2003	11/28/2005	3	70	M	NIH	n/a
17687	2003	11/28/2005	3	65	F	MOH	H
17688	2003	11/28/2005	3	76	F	MOH	H
17689	2003	11/28/2005	3	76	F	MEH	n/a
17694	2003	12/6/2005	3	77	F	MOH	H
17696	2003	12/6/2005	3	78	M	MOH	H
17697	2003	12/6/2005	3	81	F	NIH	n/a
17698	2003	12/6/2005	3	80	F	NIH	n/a
17704	2003	12/6/2005	3	81	F	MOH	H
17705	2003	12/6/2005	3	85	M	NIH	n/a
17707	2003	12/6/2005	3	84	M	MOH	H
17708	2003	12/6/2005	3	69	F	MOH	H
17709	2003	12/6/2005	3	79	F	NIH	n/a
17710	2003	12/6/2005	3	78	F	MOH	H
17719	2003	12/7/2005	3	80	M	MOH	H
17720	2003	12/7/2005	3	90	M	MOH	H
17721	2003	12/7/2005	3	79	F	NIH	n/a
17724	2003	12/12/2005	3	74	F	FEH	H
17726	2003	12/12/2005	3	80	F	NIH	n/a
17727	2003	12/12/2005	3	76	F	MOH	H
17730	2003	12/12/2005	3	79	M	MOH	H
17731	2003	12/12/2005	3	78	F	MOH	H
17732	2003	12/12/2005	3	69	F	MOH	H
17737	2003	12/12/2005	3	82	F	MOH	H
17739	2003	12/12/2005	3	77	F	THE	n/a
17741	2003	12/12/2005	3	77	F	FEH	H
17743	2003	12/12/2005	3	92	M	MOH	H
17744	2003	12/12/2005	3	75	F	FEH	H
17745	2003	12/12/2005	3	70	F	FEH	H
17747	2003	12/12/2005	3	78	F	MOH	H

Appendix 2 Capture details and natal assignments of strays to the Tuolumne River from outmigration years 1998, 1999, 2000, 2003 and 2009. The natal assignments were primarily based on otolith Sr isotopes, however where there was ambiguity in the assignment, otolith microstructure analyses were used to separate hatchery from wild fish (HvW). Site codes are provided in Table 2 of the main report.

17748	2003	12/12/2005	3	71	F	MOH	H
17749	2003	12/12/2005	3	78	F	MOH	H
17752	2003	12/12/2005	3	82	M	MOH	H
17754	2003	12/12/2005	3	73	F	FEH	H
17755	2003	12/12/2005	3	79	F	NIH	H
17760	2003	12/12/2005	3	74	F	MOH	H
17761	2003	12/12/2005	3	73	F	MOH	H
17762	2003	12/12/2005	3	83	F	MOH	H
18082	2003	11/14/2006	4	92	F	MOH	H
18095	2003	11/20/2006	4	78	F	MOH	H
18096	2003	11/20/2006	4	76	F	CNH	n/a
18101	2003	11/20/2006	4	88	F	MOH	H
18121	2003	11/21/2006	4	95	M	FEH	H
18129	2003	11/27/2006	4	88	F	MOH	H
18142	2003	12/4/2006	4	86	F	MOH	H
20197	2009	11/1/2010	2	63	M	CNH	n/a
20199	2009	11/1/2010	2	74	M	THE	H
20203	2009	11/1/2010	2	67	M	CNH	n/a
20204	2009	11/1/2010	2	63	M	CNH	n/a
20207	2009	11/8/2010	2	50	M	CNH	n/a
20218	2009	11/15/2010	2	59	M	MEH	n/a
20231	2009	11/15/2010	2	61	M	CNH	n/a
20239	2009	11/15/2010	2	60	M	CNH	n/a
20241	2009	11/15/2010	2	60	M	CNH	n/a
20242	2009	11/15/2010	2	62	M	CNH	n/a
20248	2009	11/17/2010	2	65	M	CNH	n/a
20249	2009	11/17/2010	2	68	M	CNH	n/a
20256	2009	11/22/2010	2	68	M	CNH	n/a
20264	2009	11/23/2010	2	63	M	MEH	n/a
24015	2009	10/3/2011	3	78	F	THE	n/a
24035	2009	10/10/2011	3	81	M	FEH	H
24038	2009	10/17/2011	3	77	F	FEA	W
24043	2009	10/17/2011	3	83	M	FEH	H
24052	2009	10/24/2011	3	81	F	FEH	H
24054	2009	10/24/2011	3	83	F	CNH	n/a
24056	2009	10/24/2011	3	82	F	CNH	n/a
24059	2009	10/24/2011	3	86	M	CNH	n/a
24065	2009	10/24/2011	3	82	F	CNH	n/a
24066	2009	10/24/2011	3	92	M	CNH	n/a
24112	2009	11/7/2011	3	77	M	FEH	H
24114	2009	11/7/2011	3	78	F	CNH	n/a
24117	2009	11/7/2011	3	86	M	CNH	n/a
24131	2009	11/7/2011	3	75	F	CNH	n/a
24141	2009	11/7/2011	3	77	F	CNH	n/a
24164	2009	11/9/2011	3	82	F	CNH	n/a
24168	2009	11/9/2011	3	87	M	CNH	n/a
24174	2009	11/14/2011	3	72	F	CNH	H
24177	2009	11/14/2011	3	78	F	CNH	n/a
24193	2009	11/14/2011	3	88	M	CNH	n/a
24214	2009	11/14/2011	3	85	F	CNH	n/a
24239	2009	11/21/2011	3	81	F	MOH	H
24290	2009	11/28/2011	3	75	F	NIH	n/a
24410	2009	12/12/2011	3	73	F	NIH	n/a
25886	2009	11/6/2012	4	81	F	THE	n/a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Origin MEH
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Origin MEH
ASN#4289
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Origin MEH
ASN#4313
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Origin MEH
ASN#4324
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Origin MEH
ASN#4338
OMY 1998
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Origin MEH
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TUO
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0.709
0
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400
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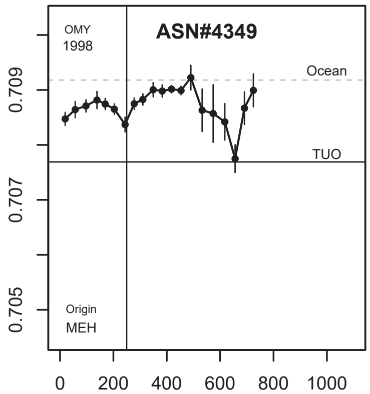
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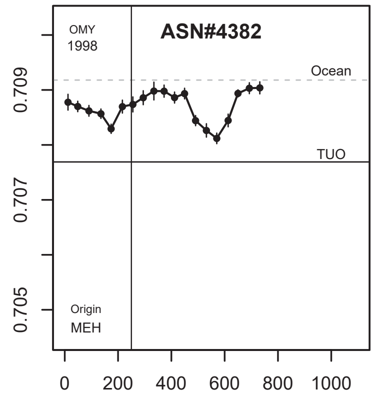
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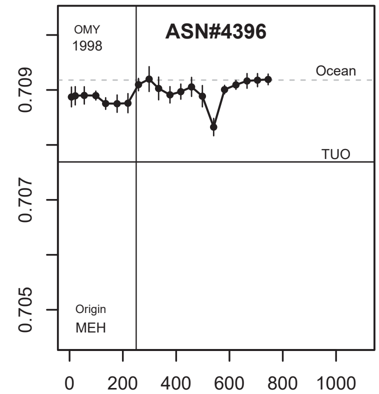
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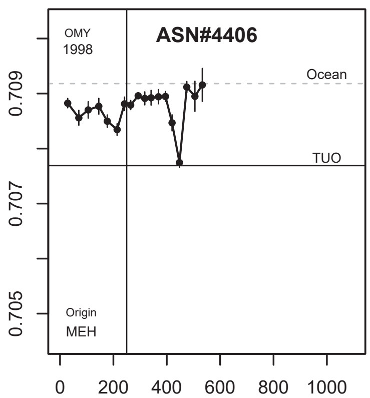
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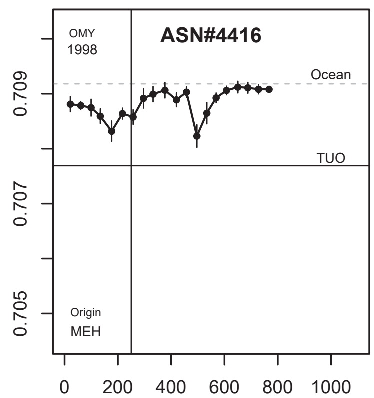
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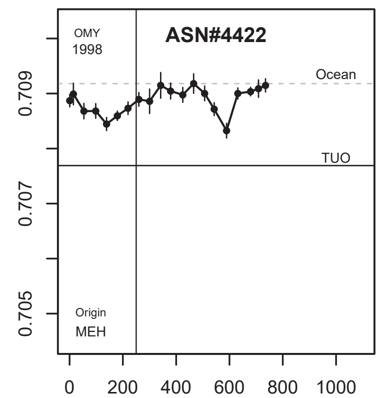
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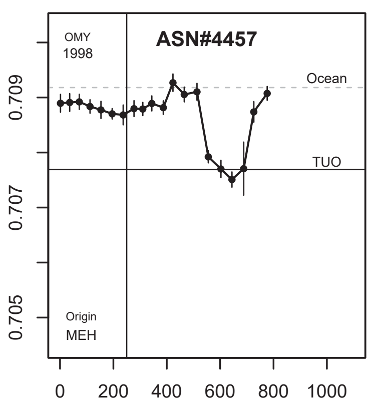
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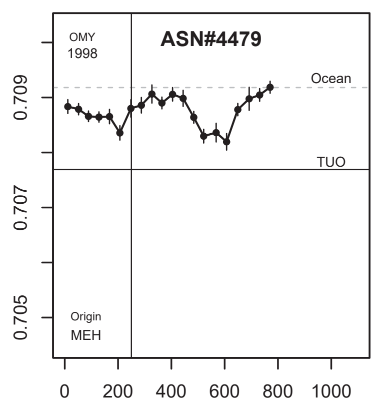
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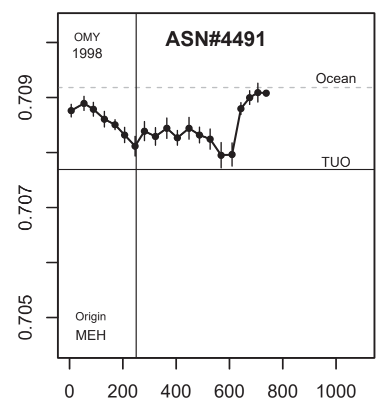
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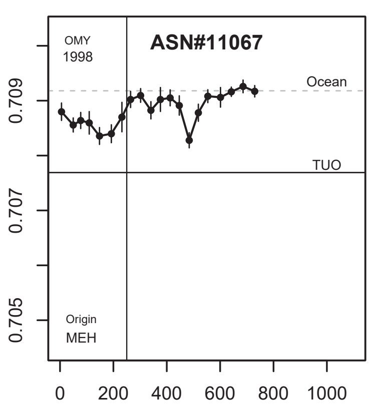
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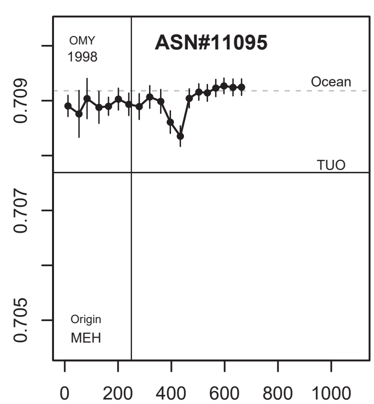
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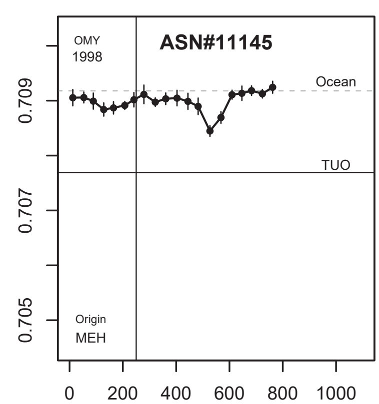
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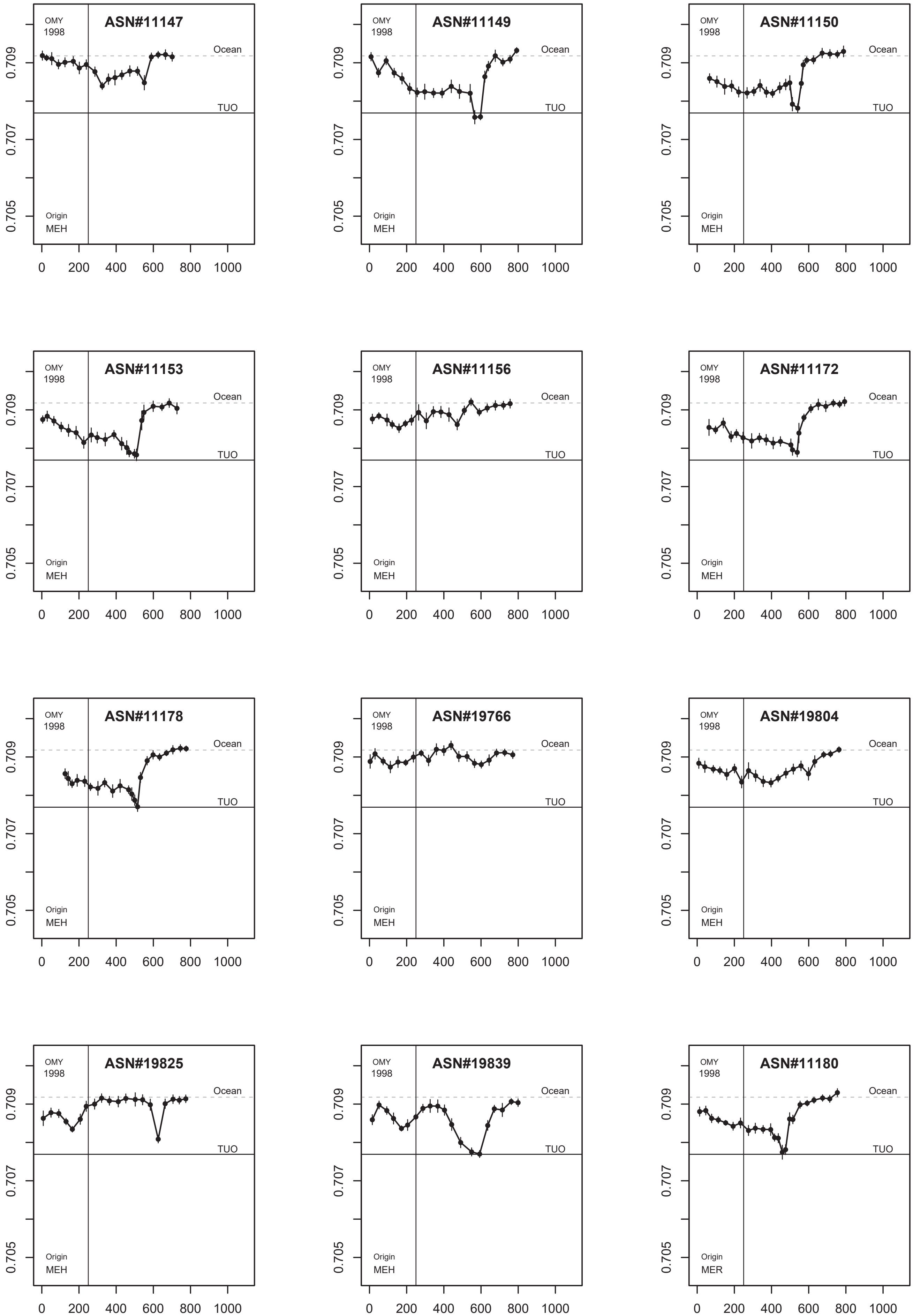
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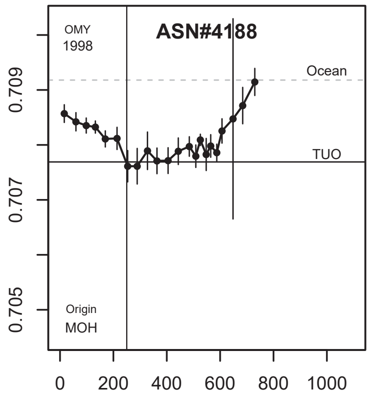
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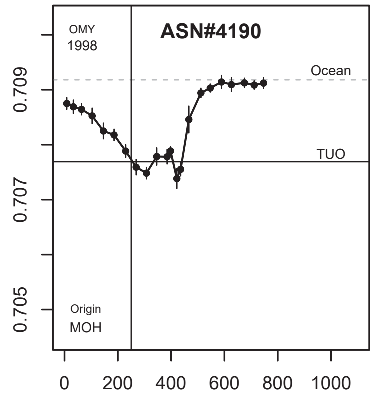
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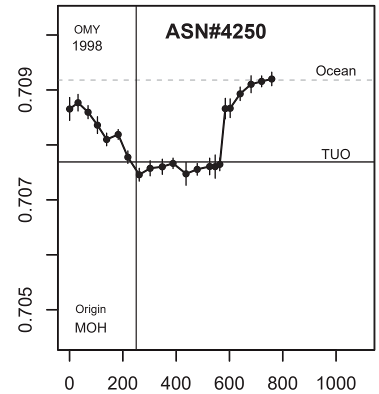
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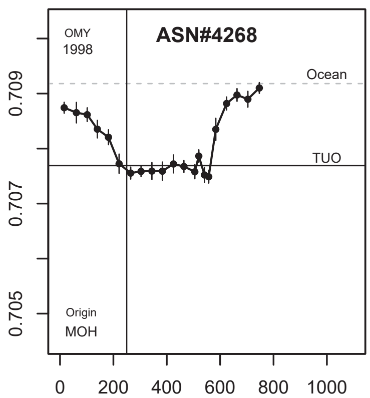
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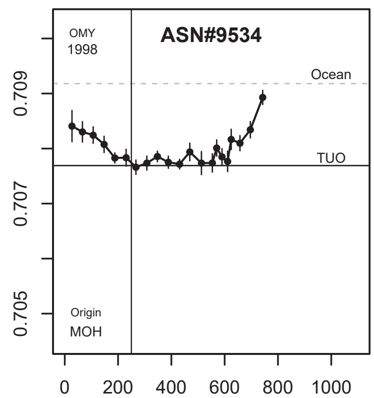
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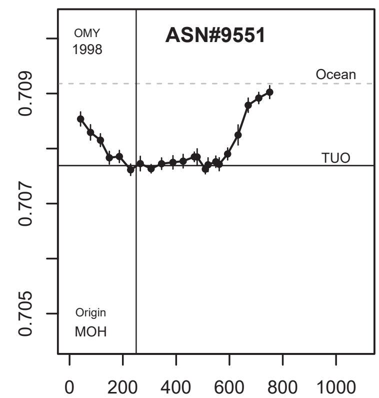
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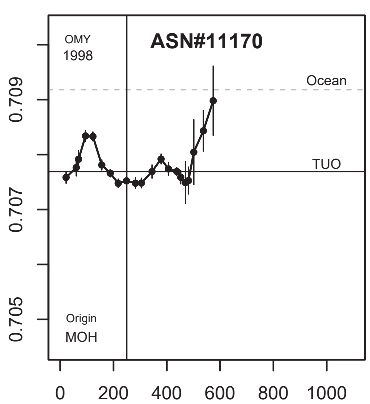
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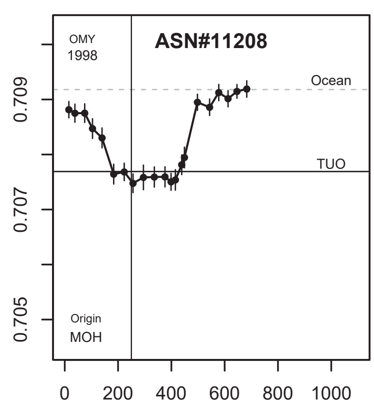
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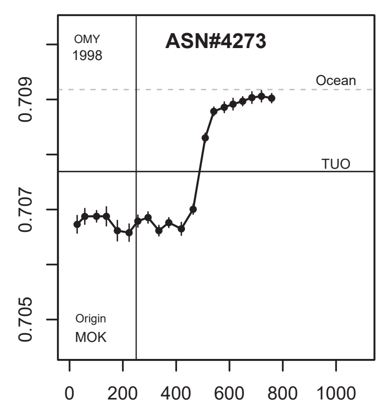
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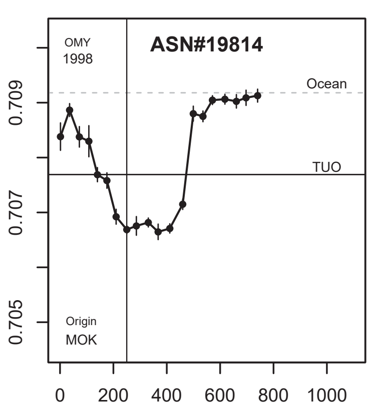
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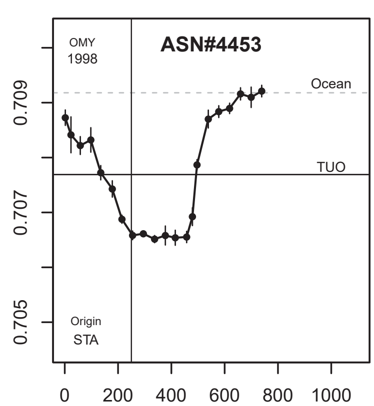
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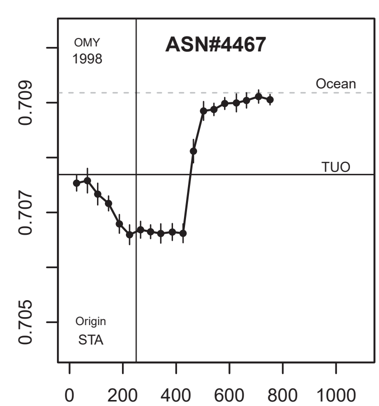
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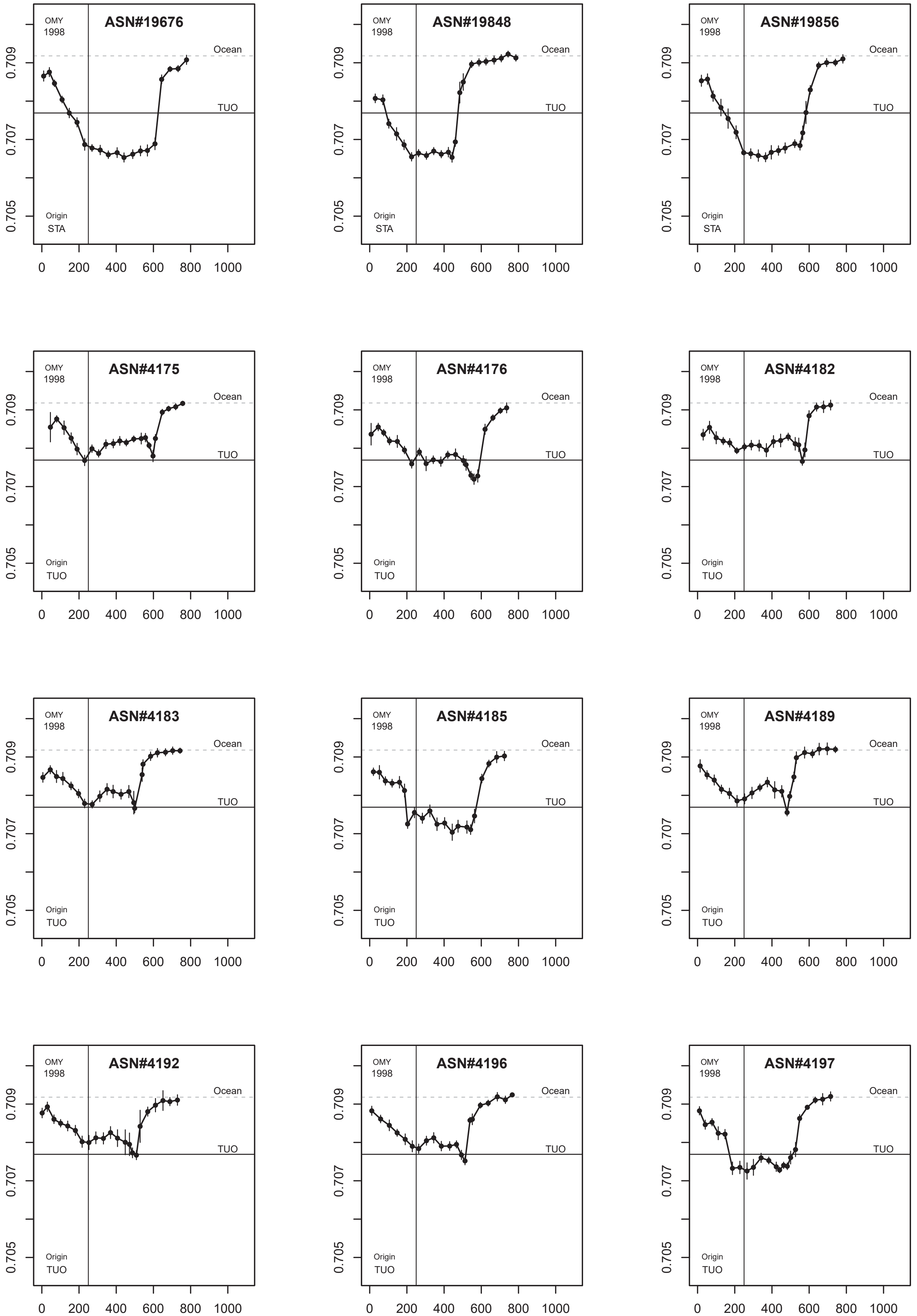
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TUO
Origin
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1998
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TUO
Origin
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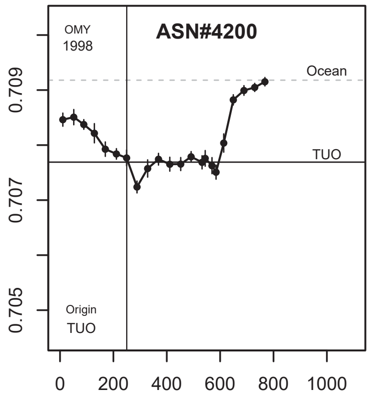
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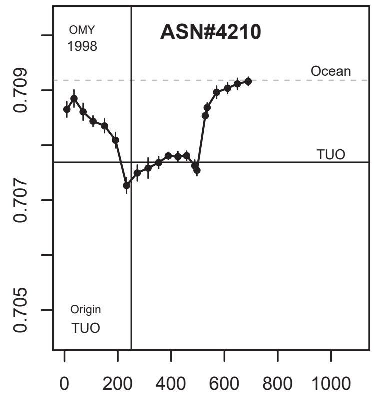
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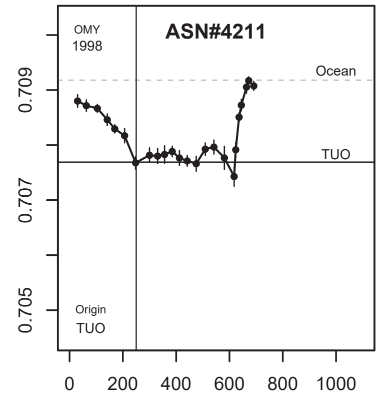
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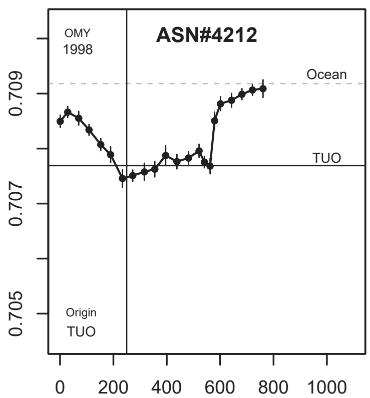
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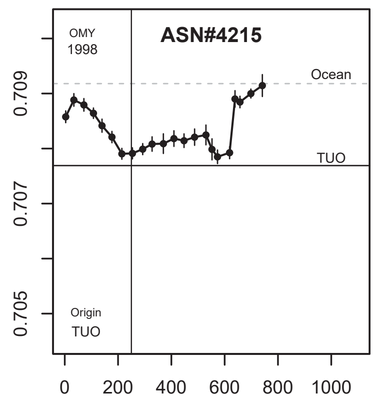
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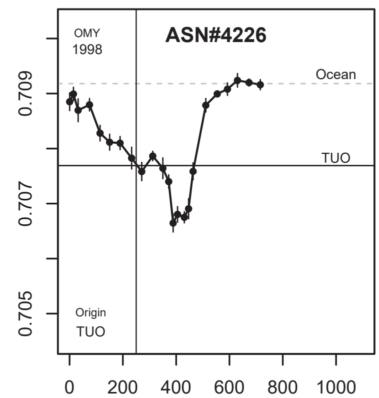
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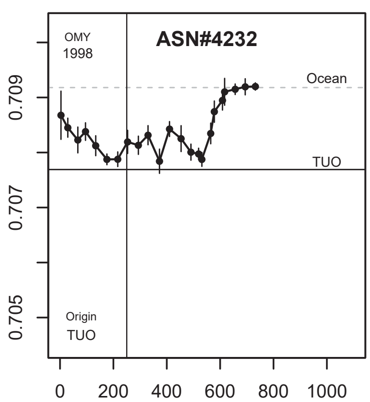
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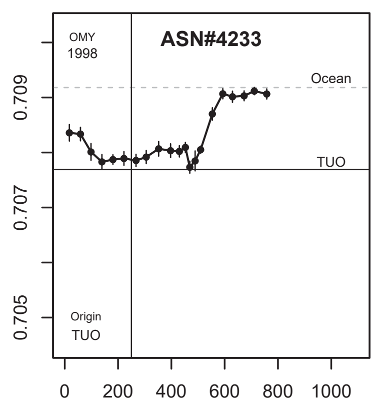
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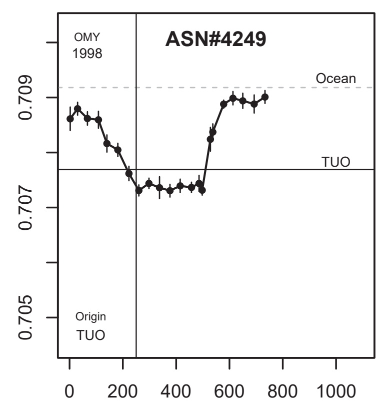
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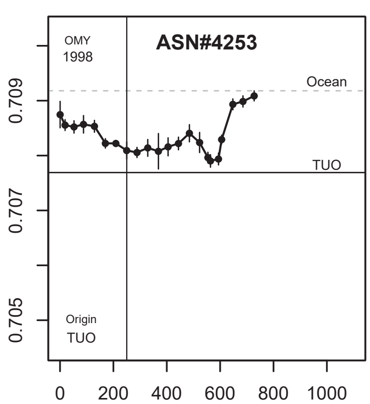
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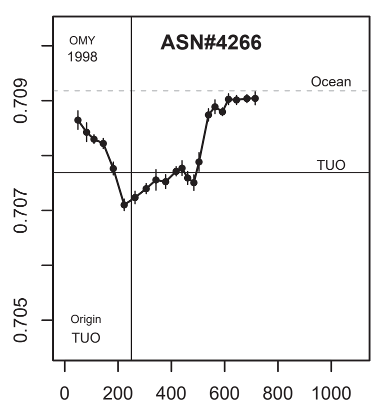
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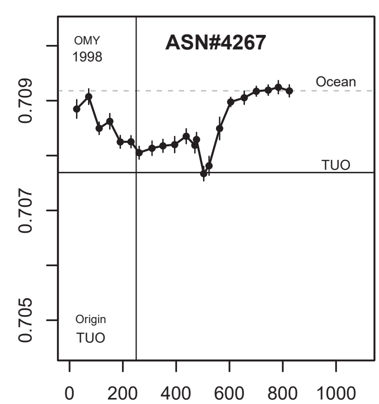
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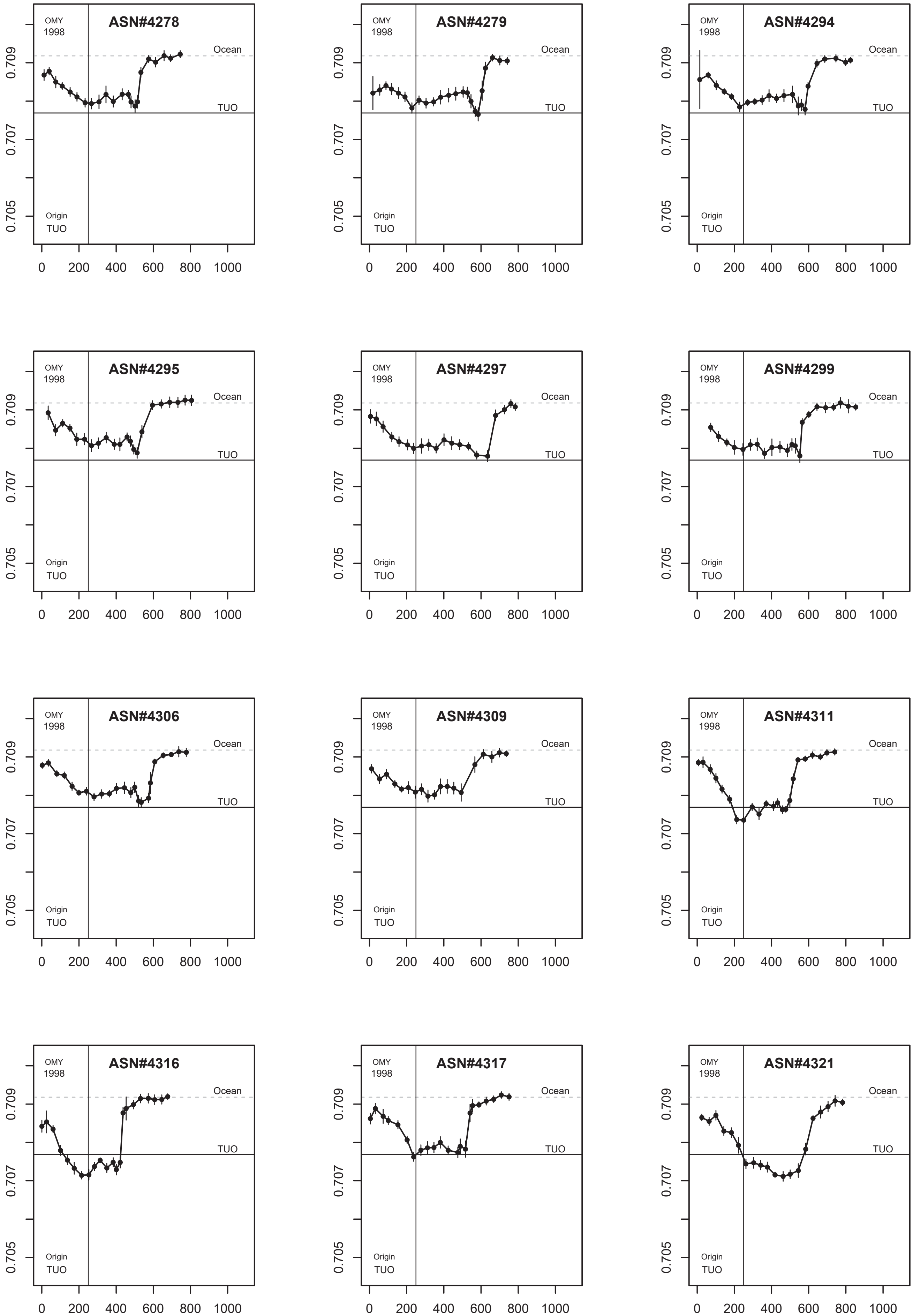
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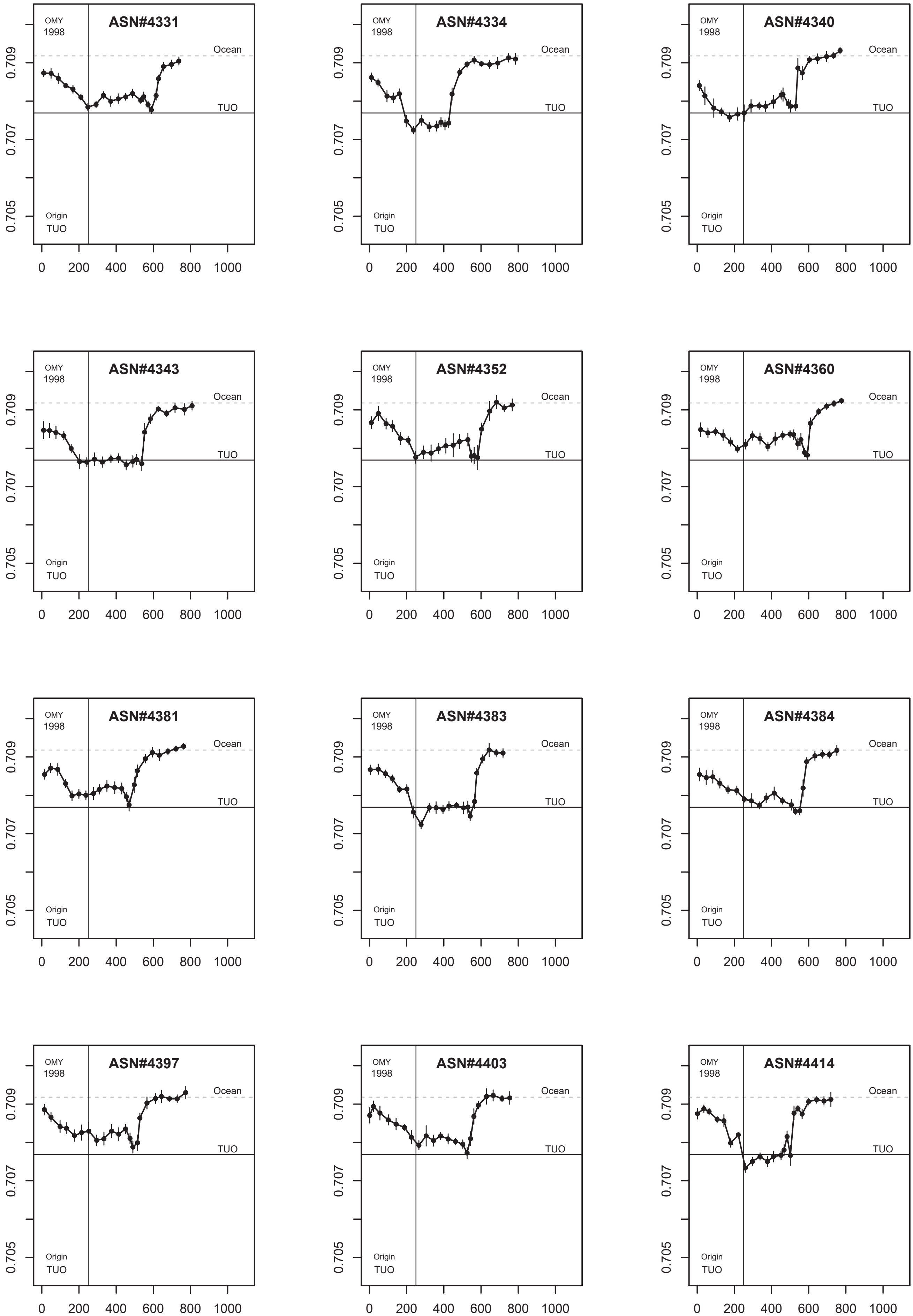
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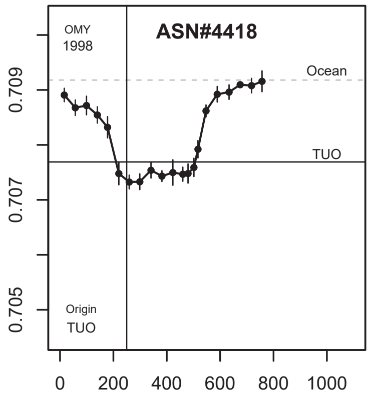
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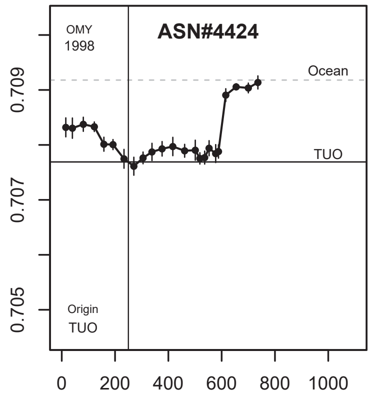
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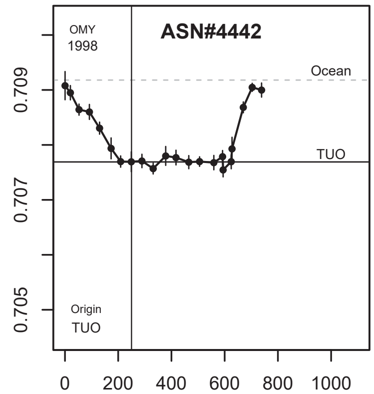
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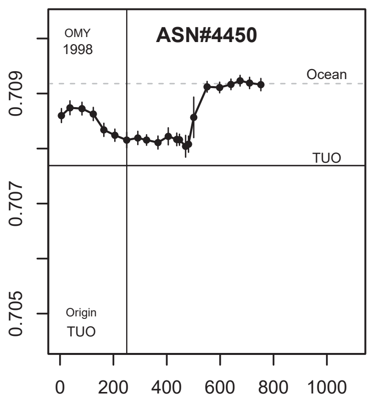
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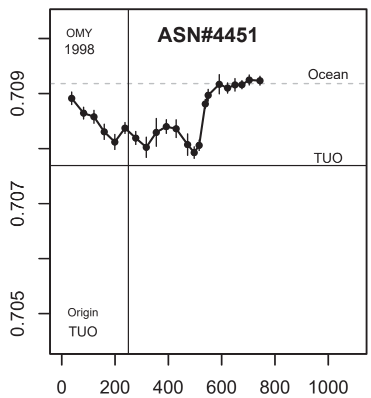
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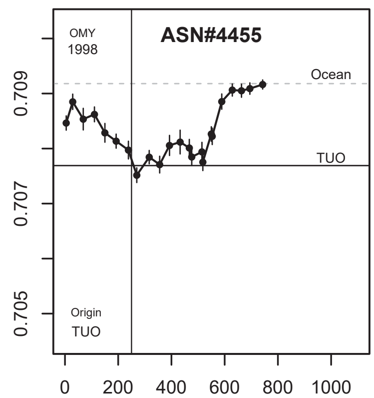
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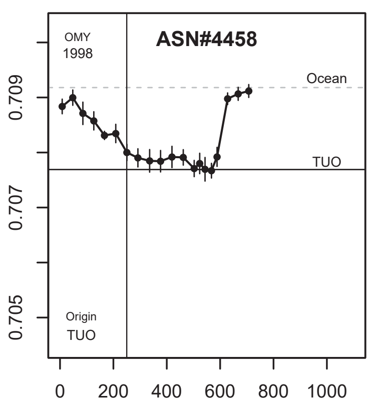
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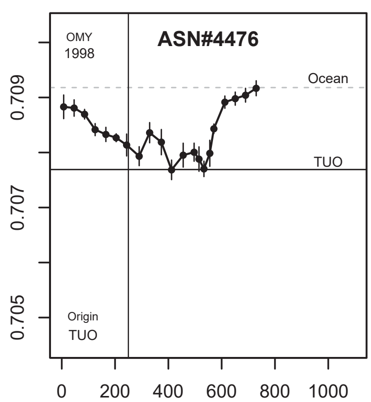
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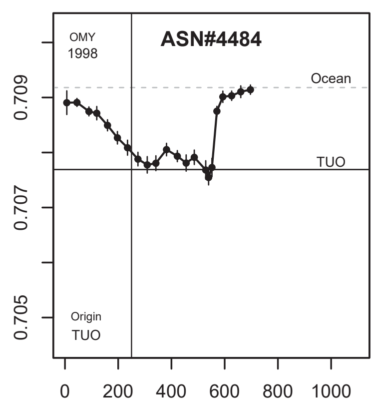
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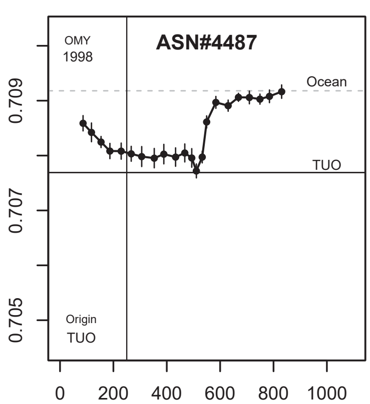
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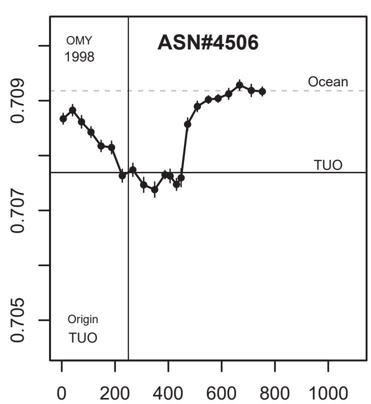
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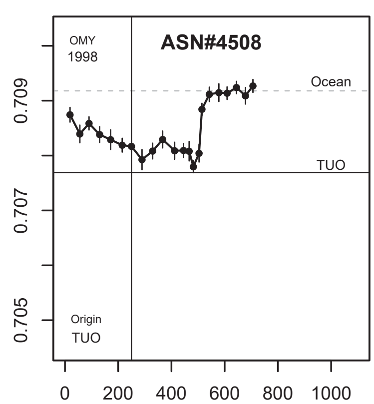
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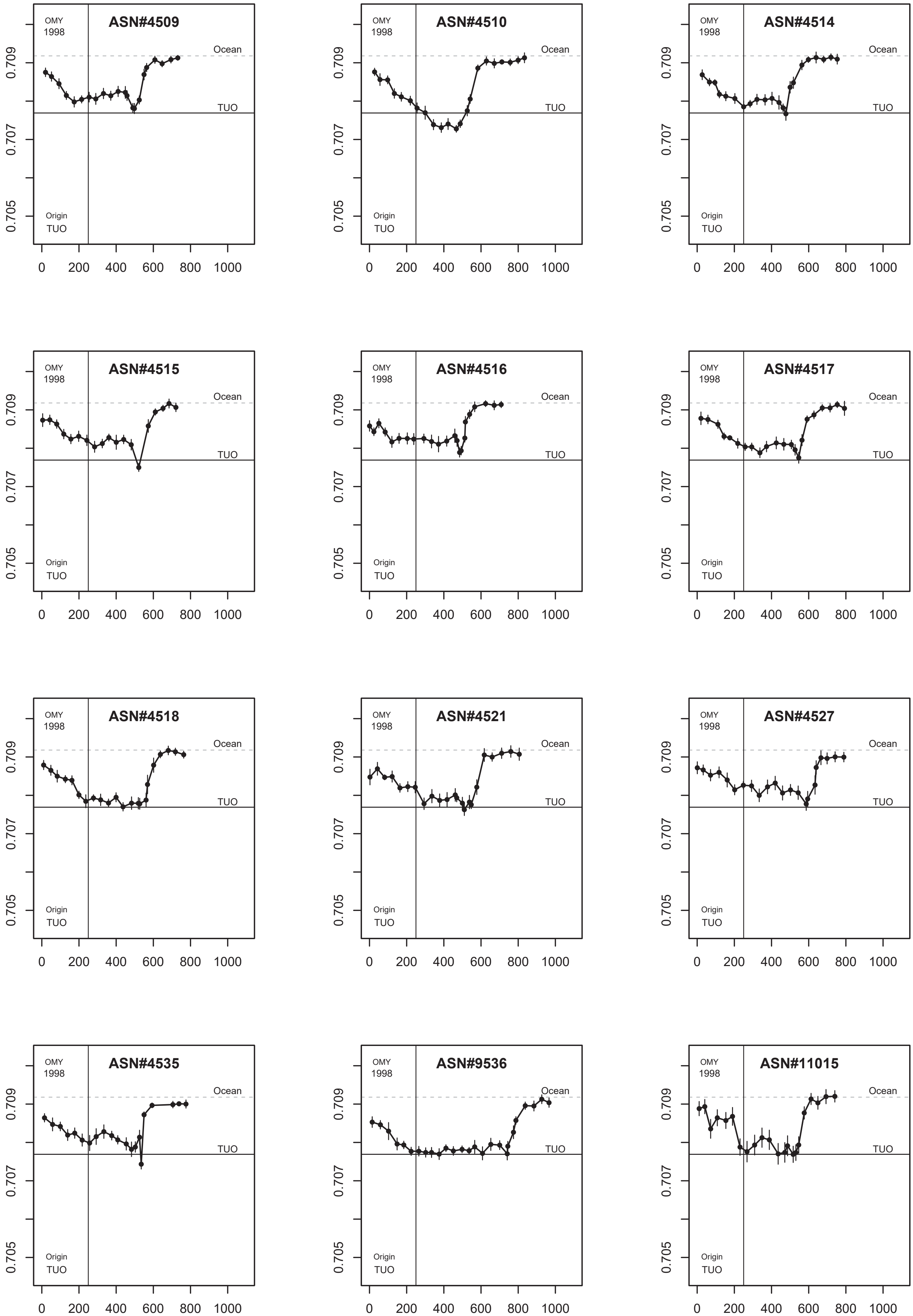

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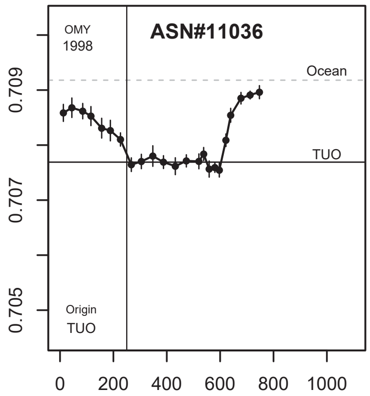
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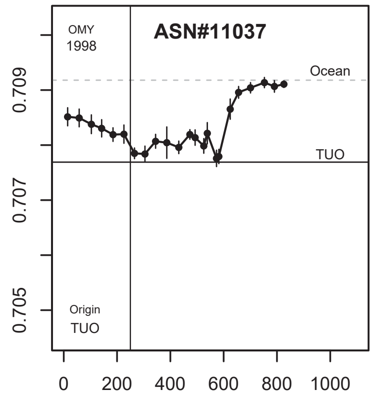
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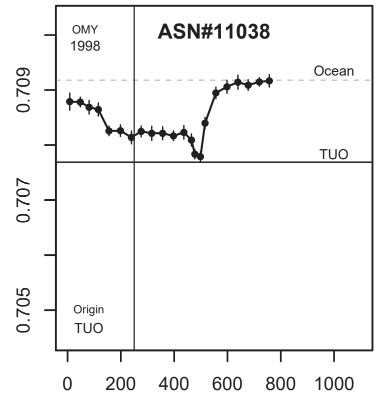
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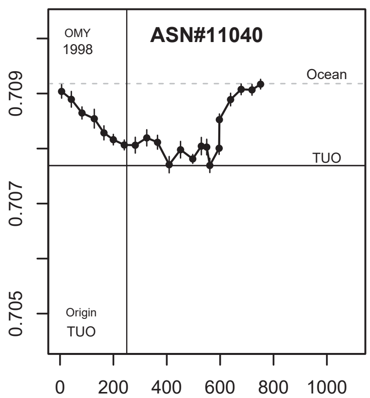
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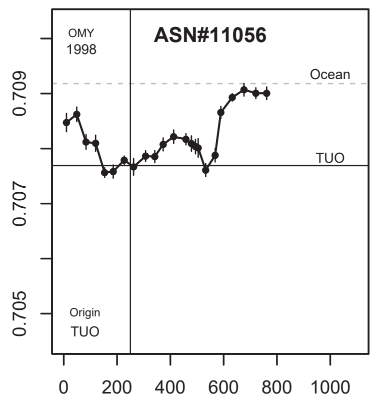
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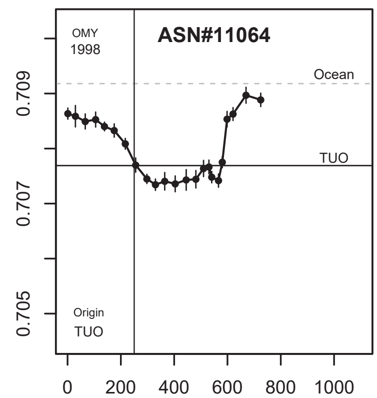
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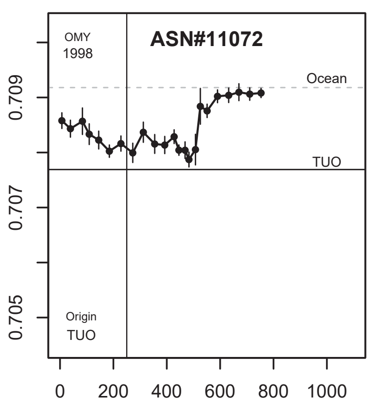
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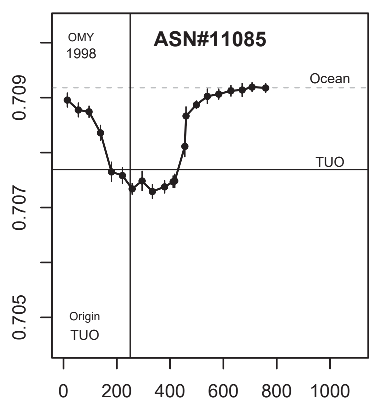
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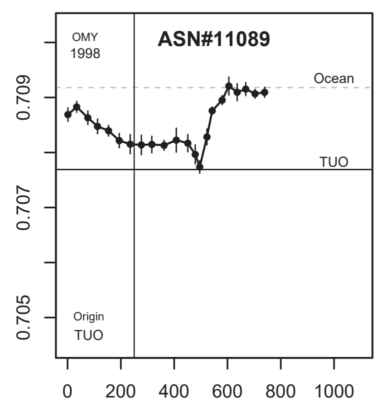
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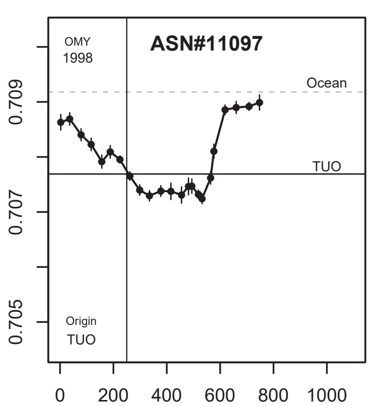
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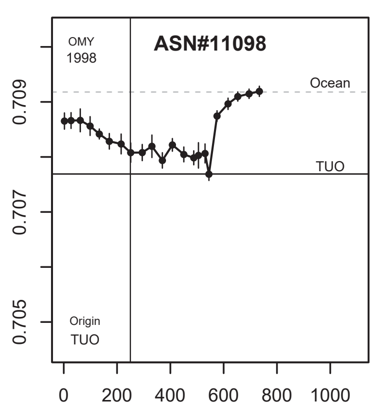
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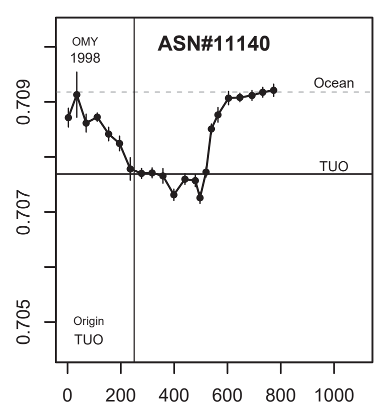
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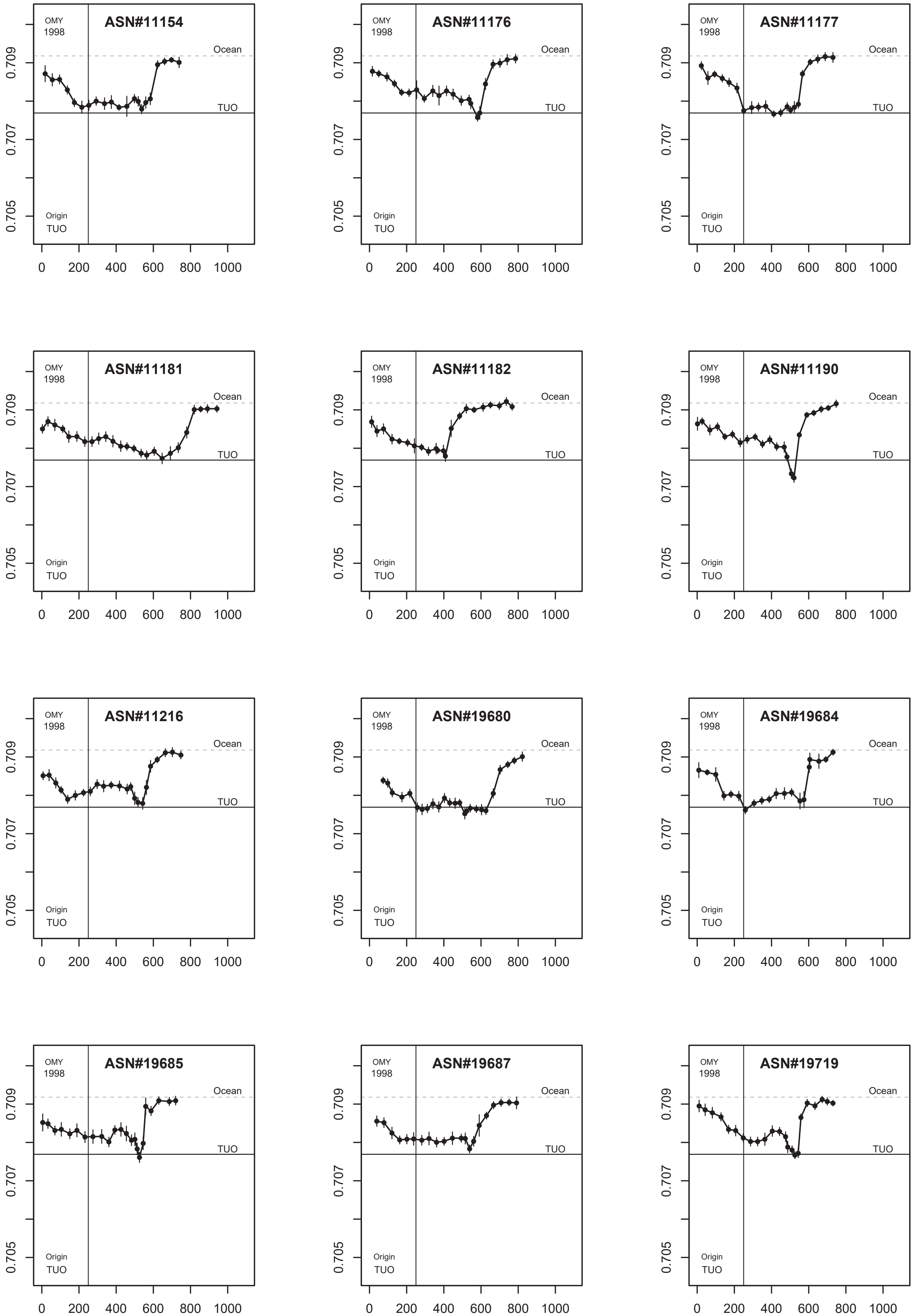
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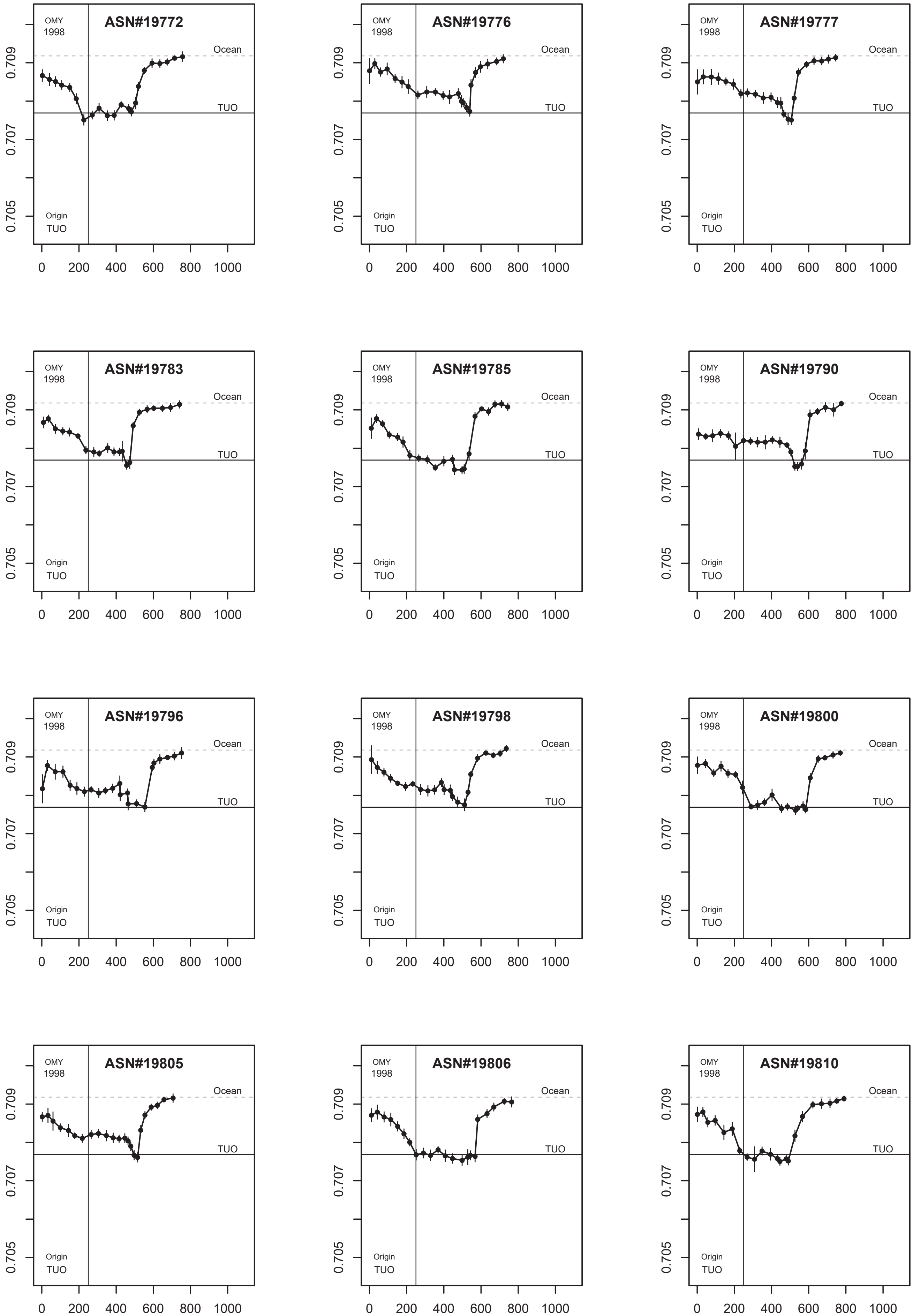
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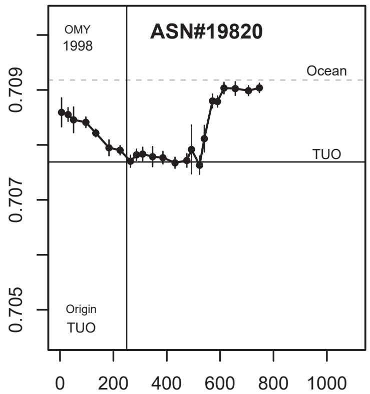
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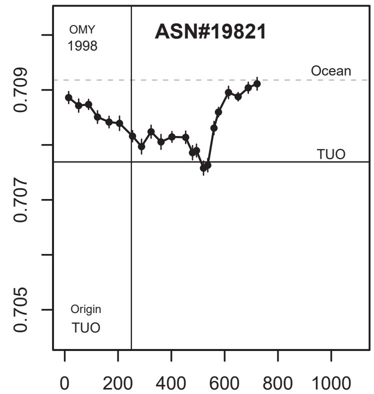
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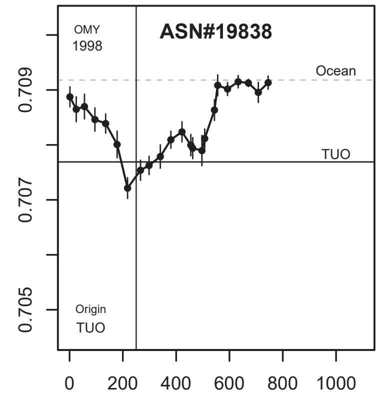
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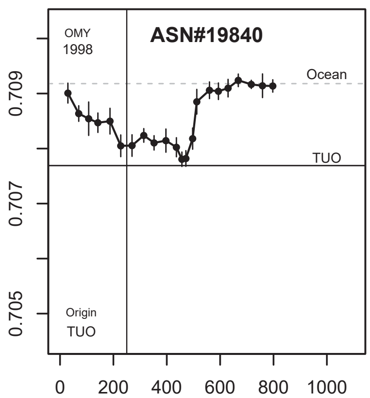
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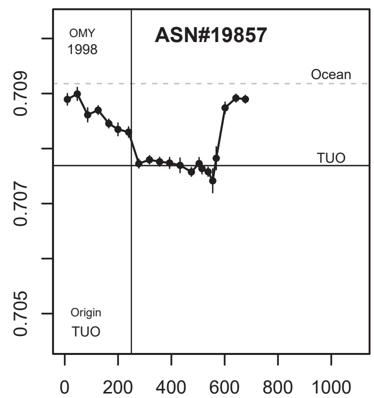
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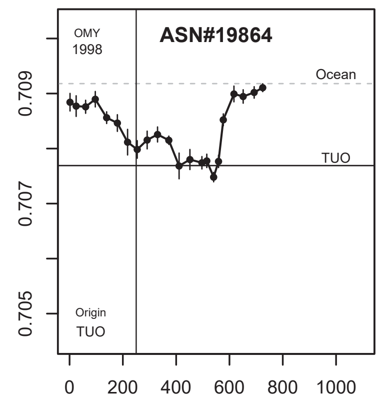
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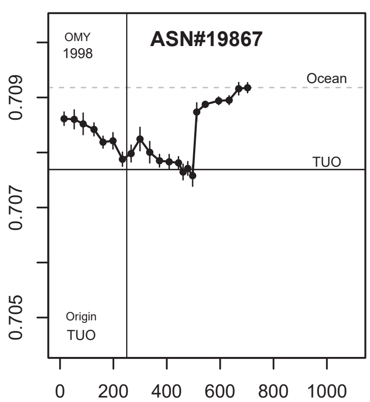
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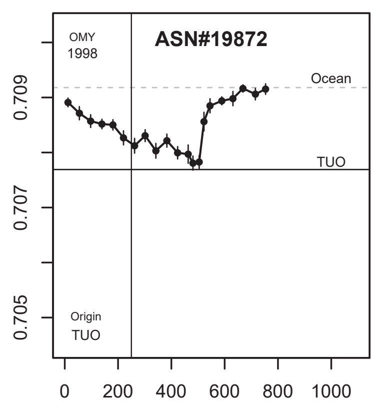
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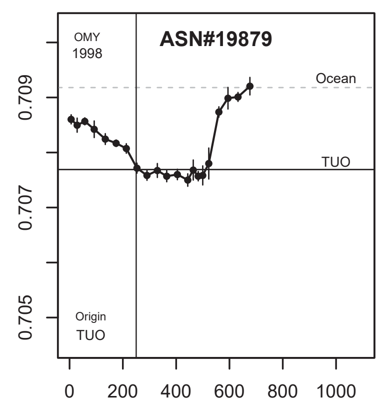
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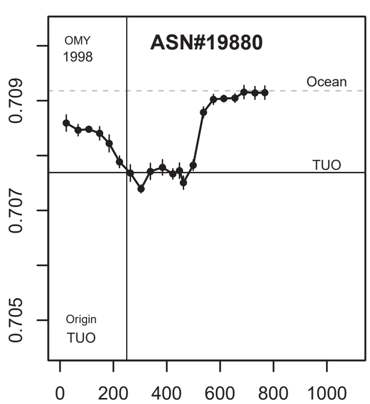
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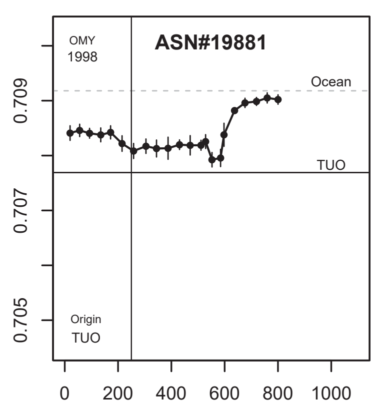
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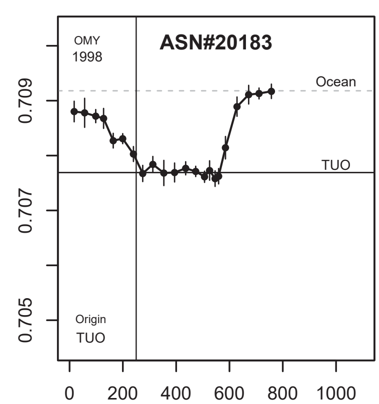
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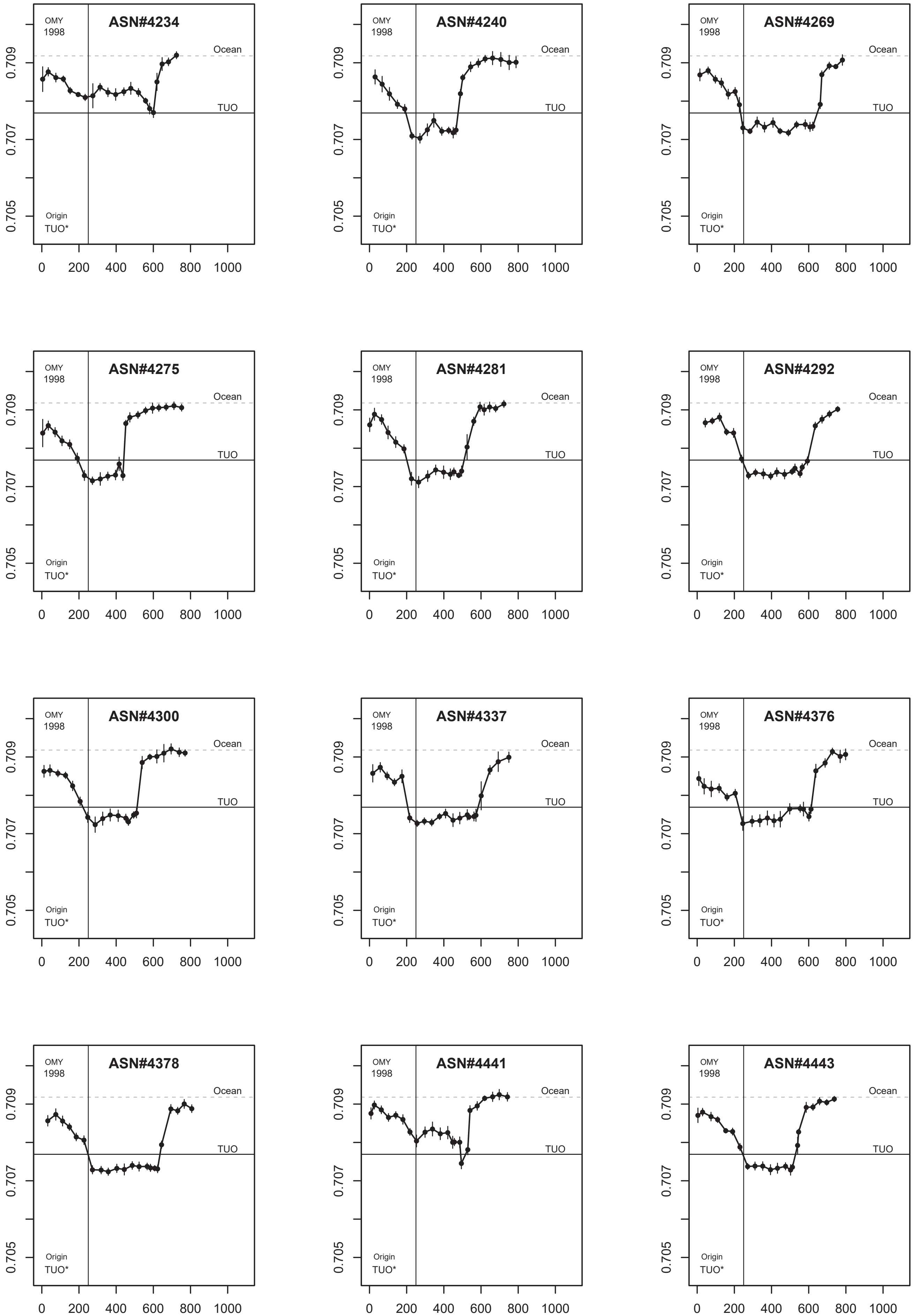
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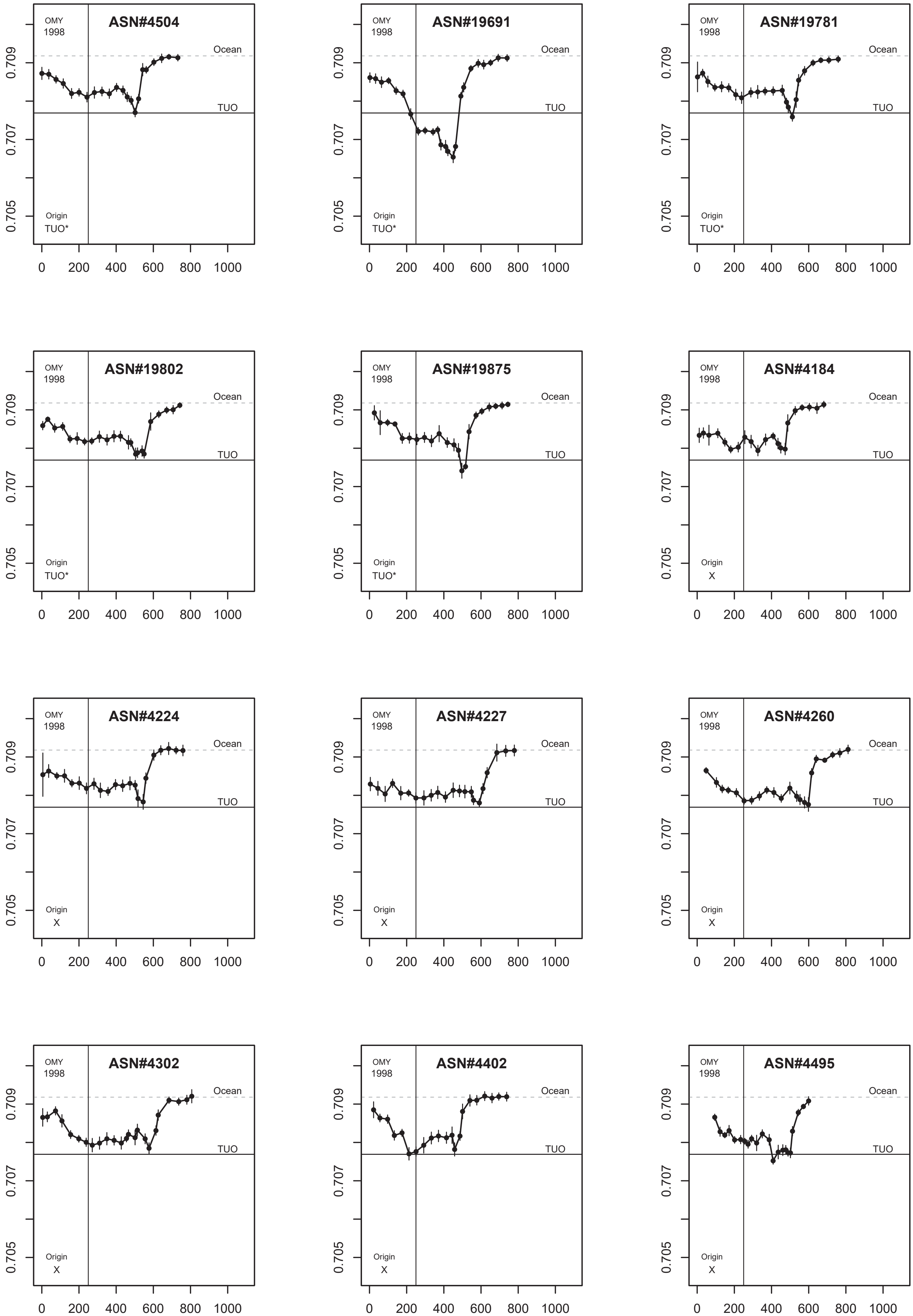
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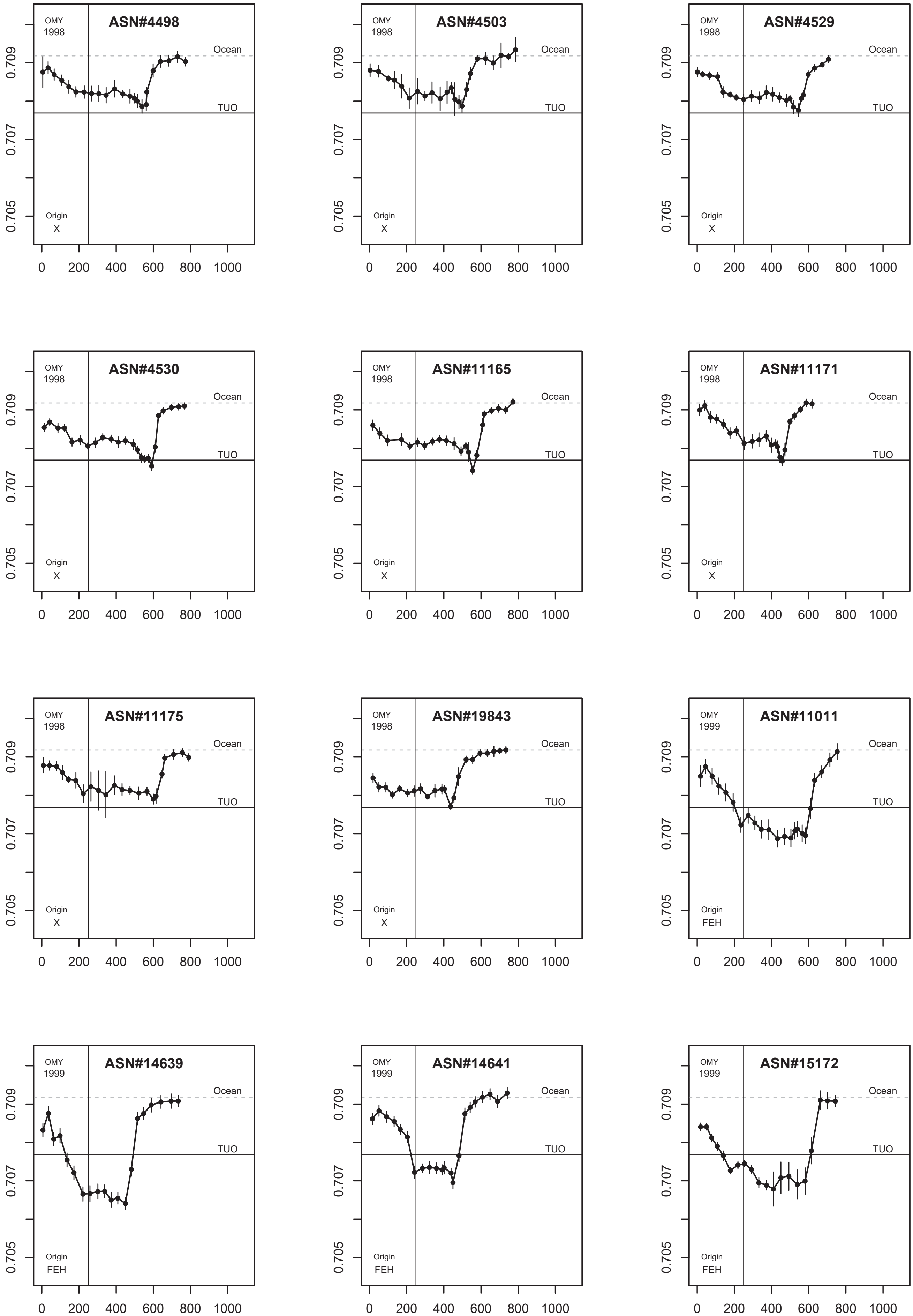
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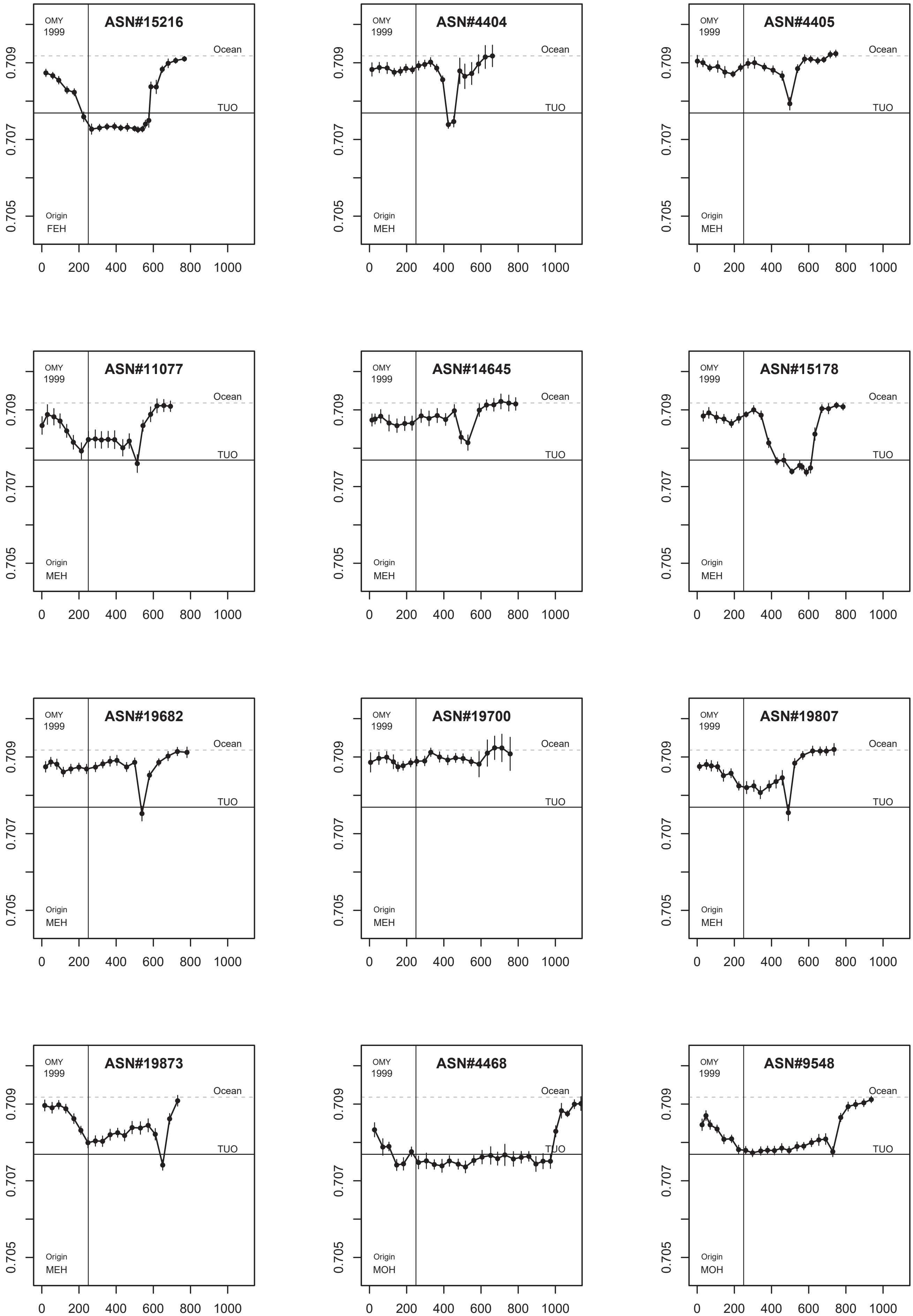
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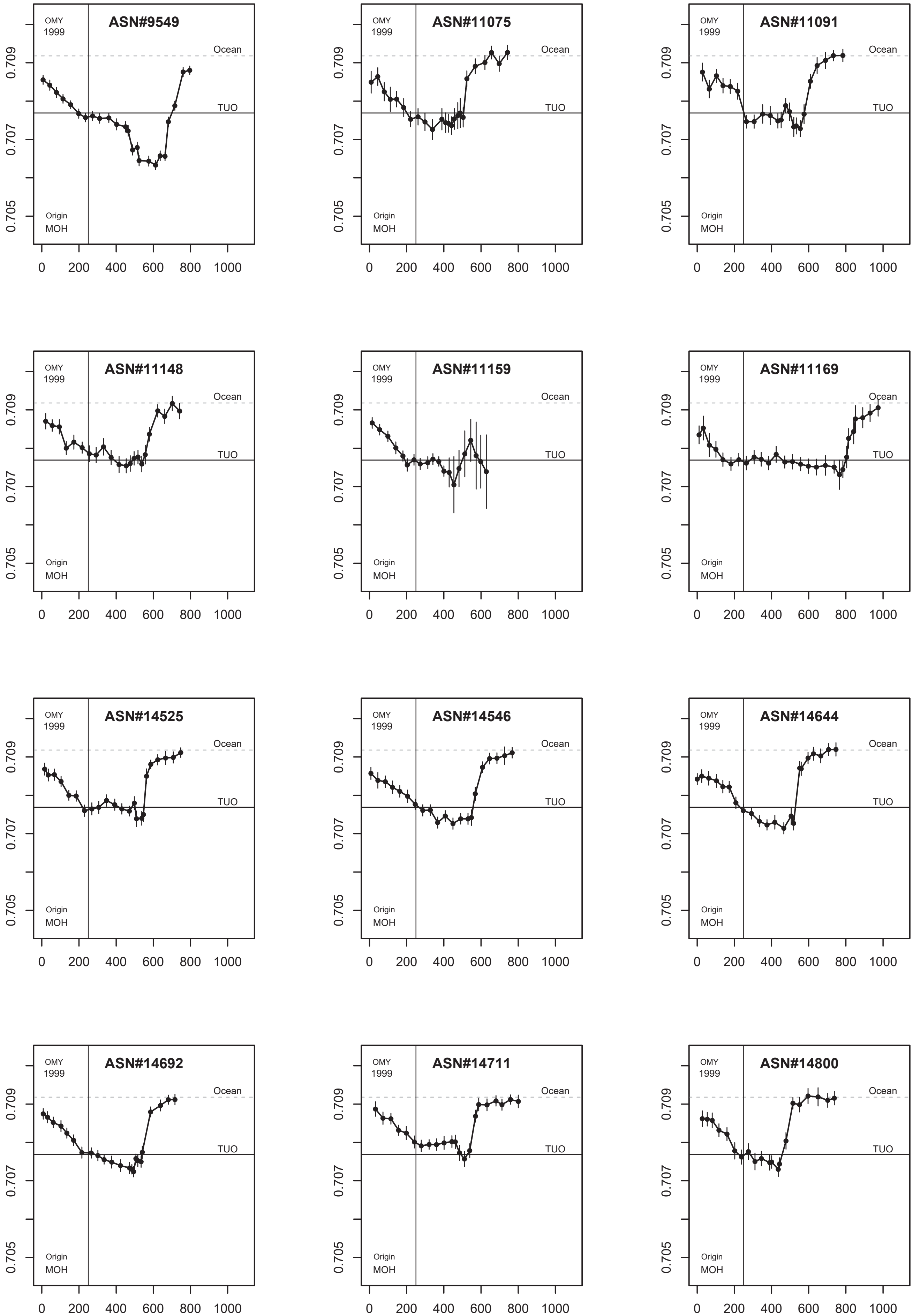
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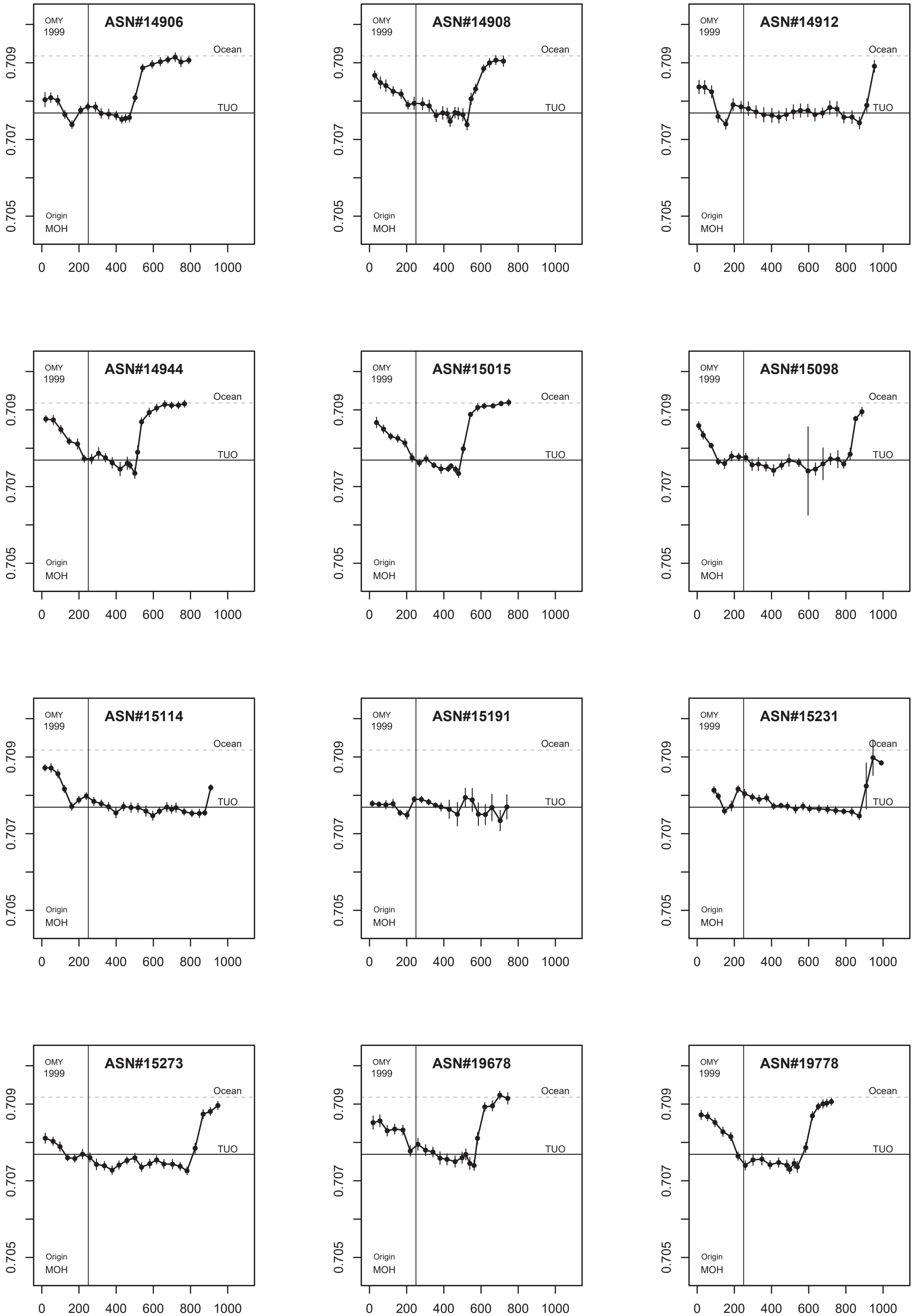
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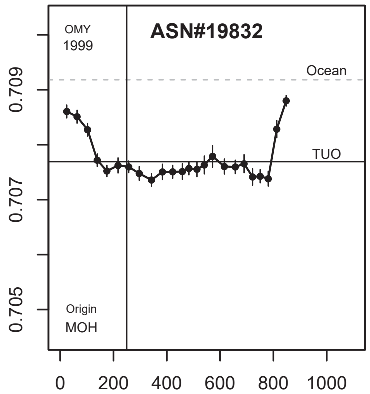
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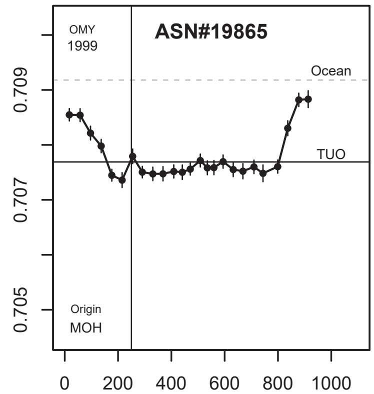
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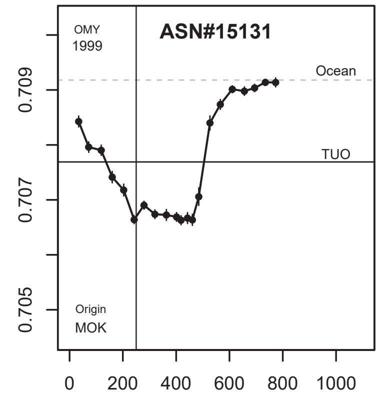
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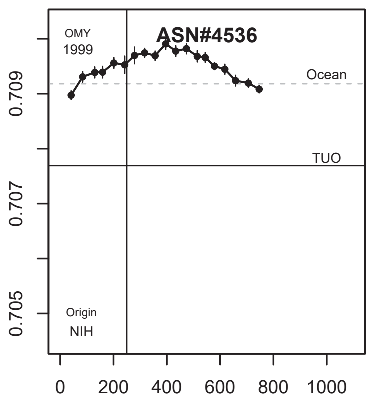
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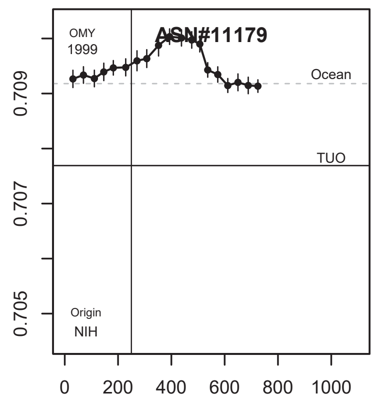
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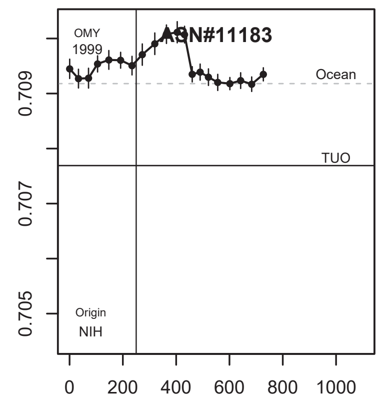
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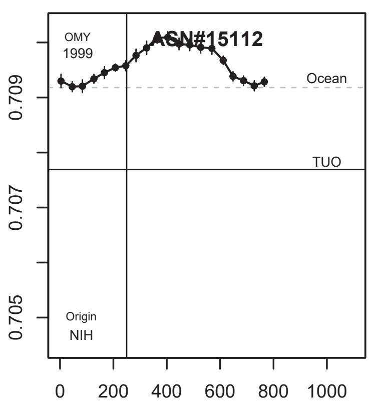
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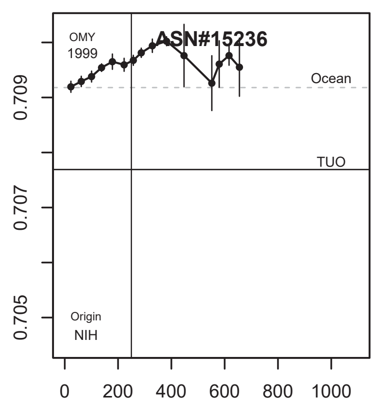
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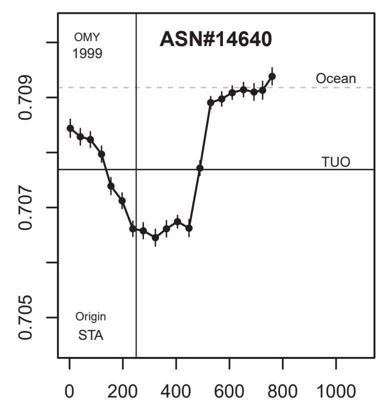
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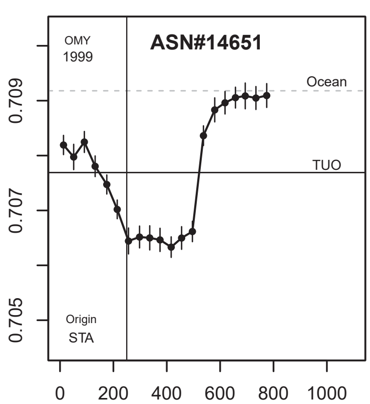
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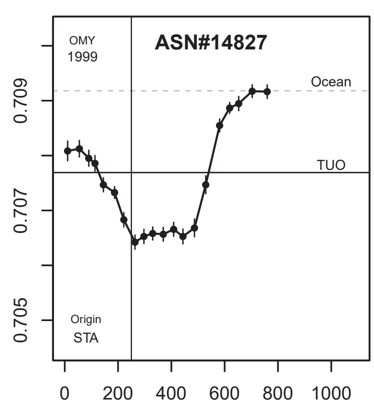
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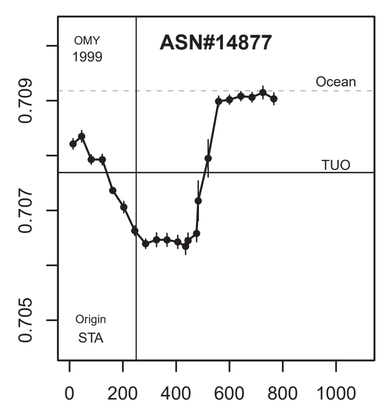
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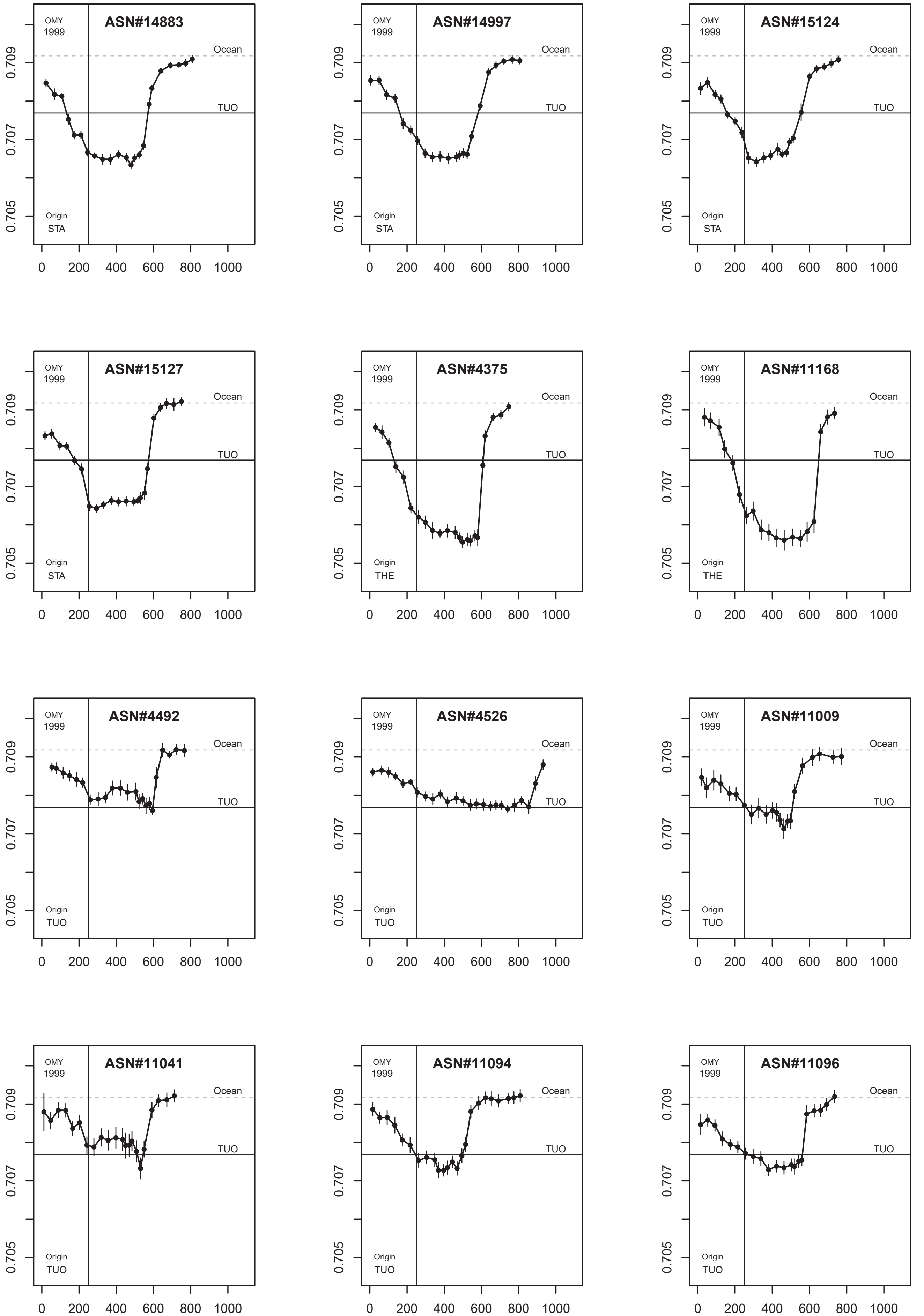

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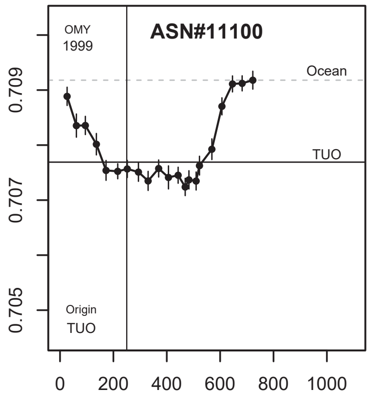
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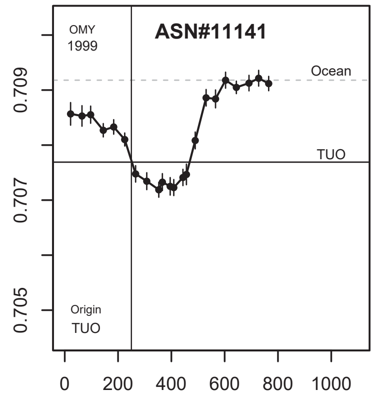
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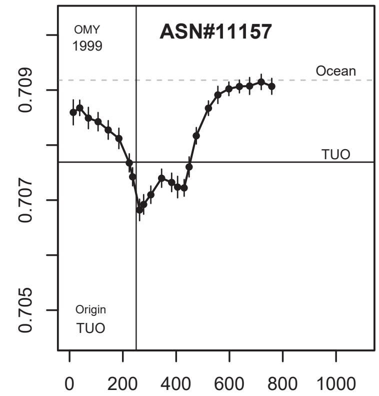
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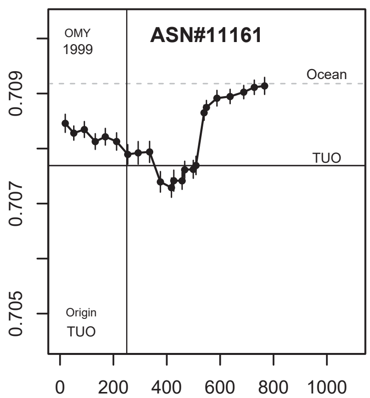
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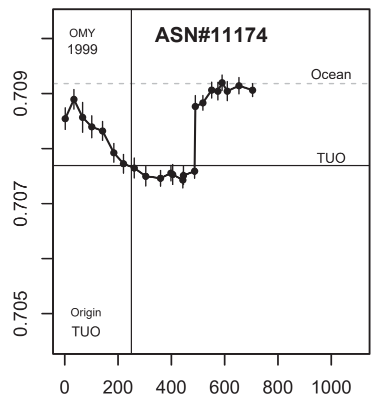
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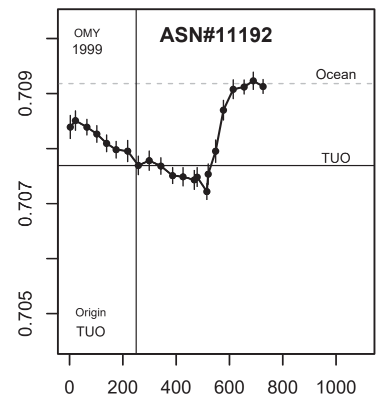
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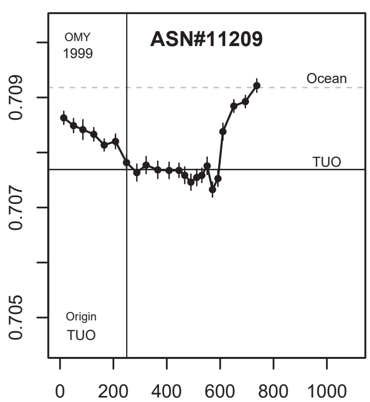
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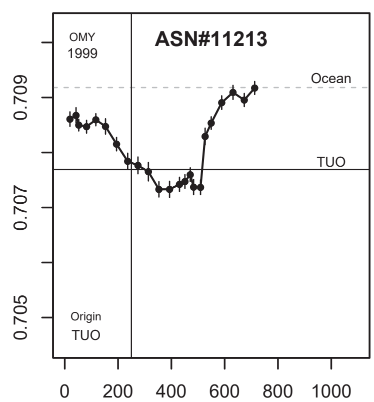
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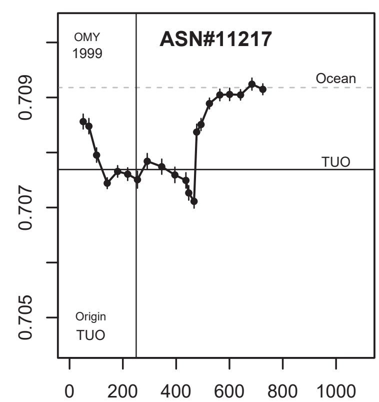
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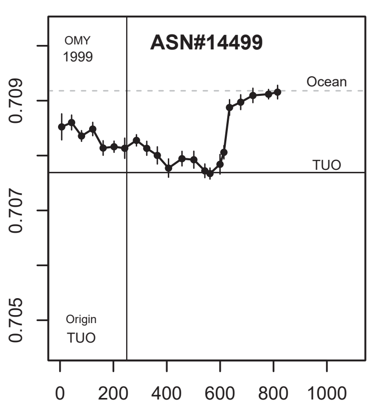
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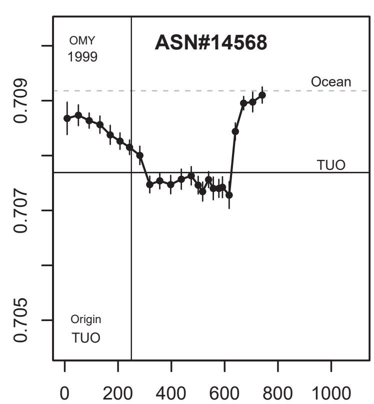
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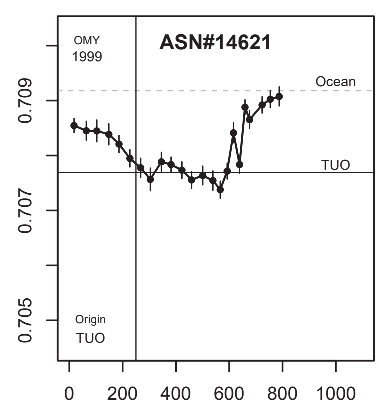
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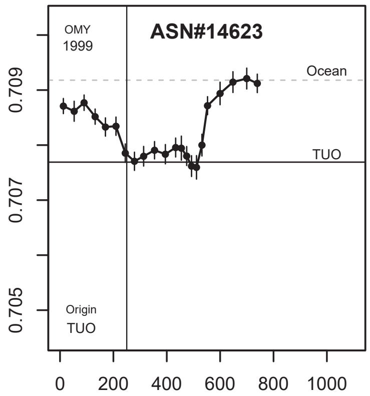
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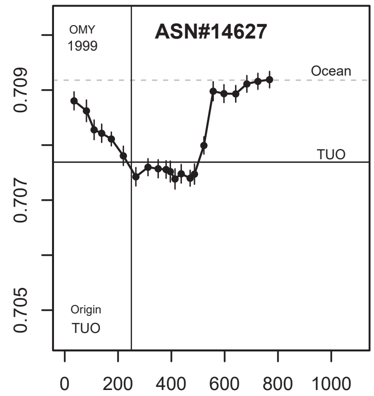
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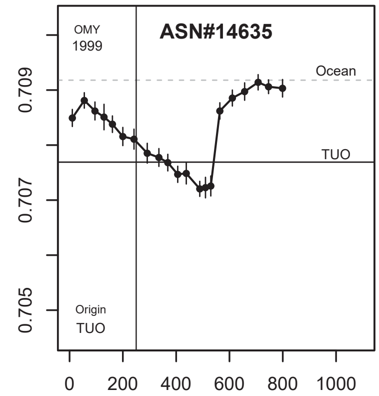
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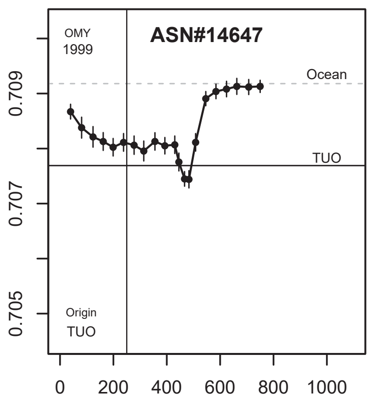
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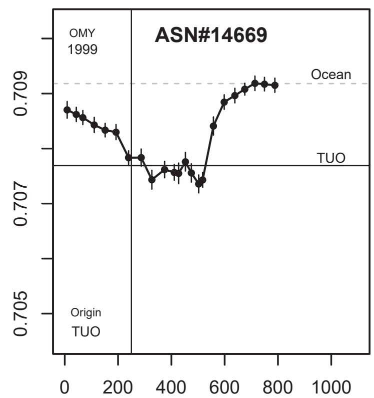
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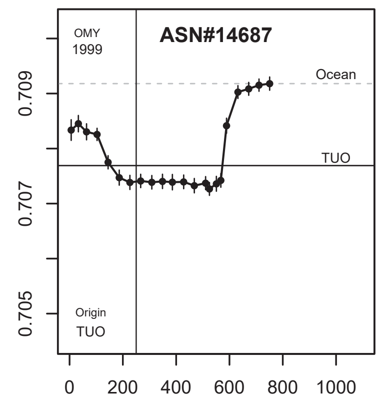
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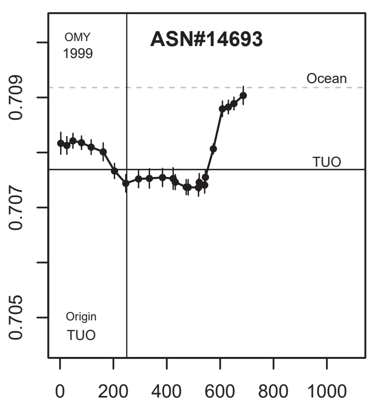
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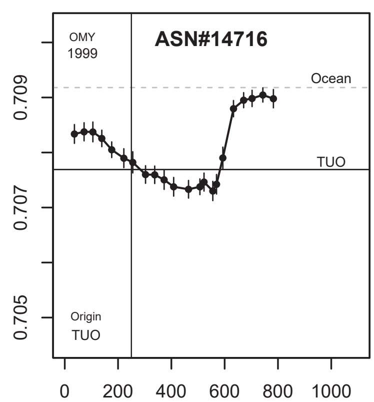
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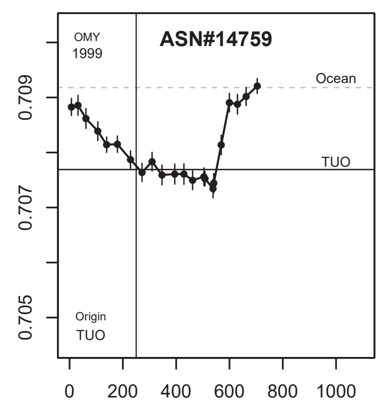
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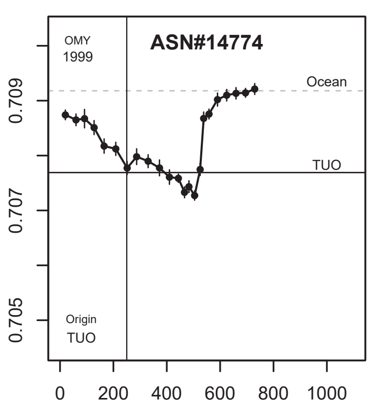
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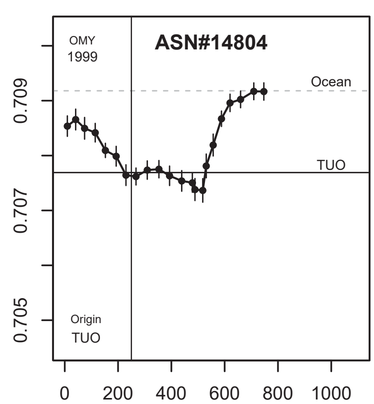
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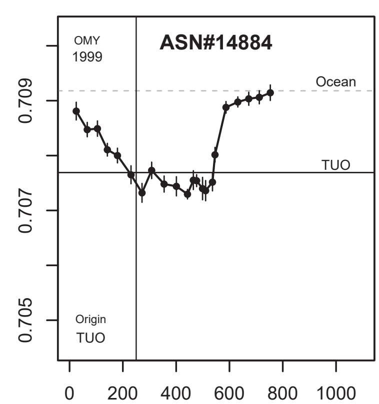
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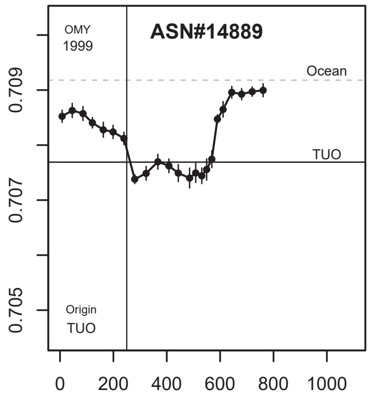
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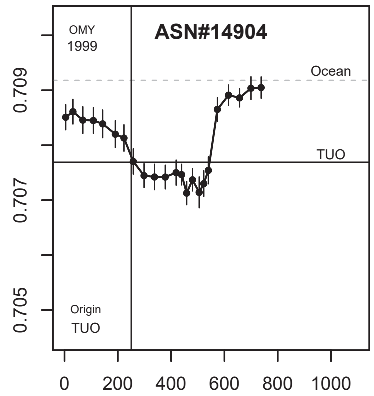
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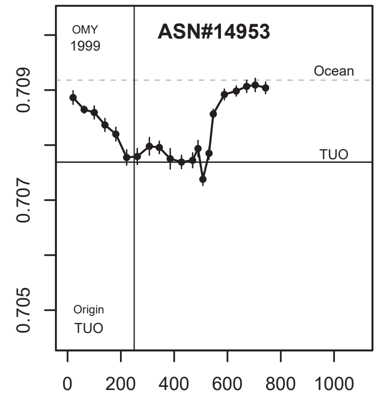
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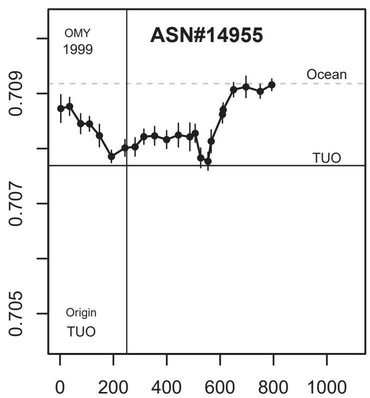
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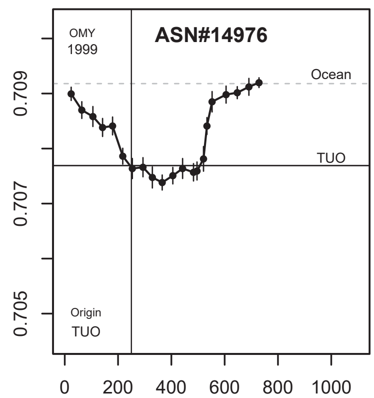
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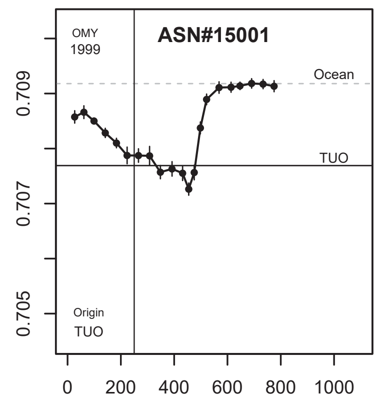
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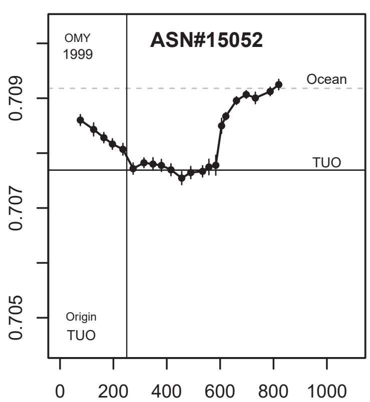
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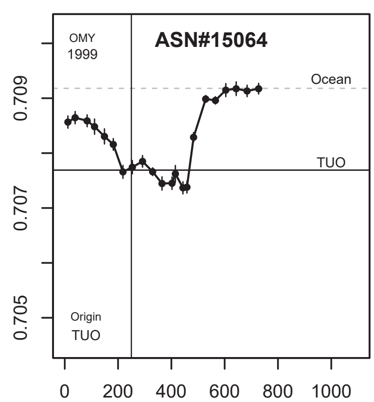
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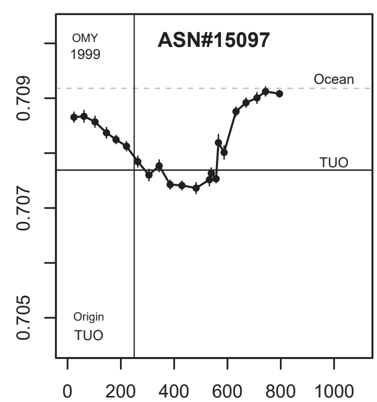
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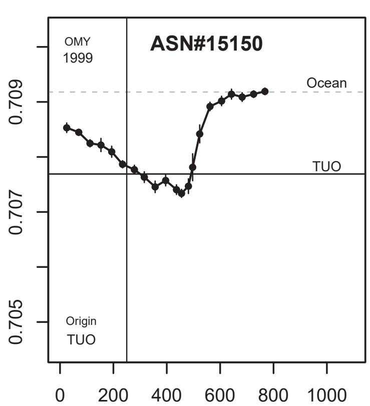
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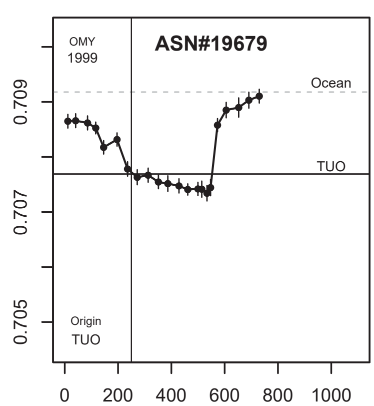
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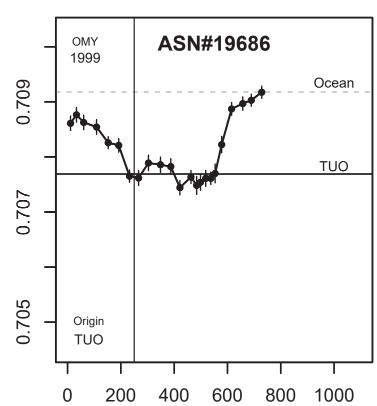
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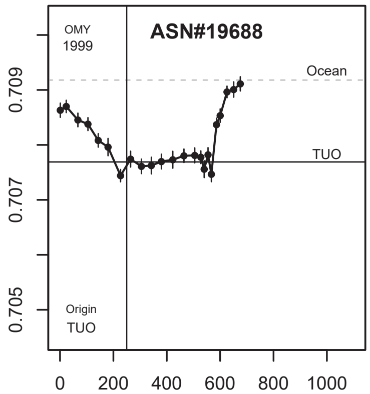
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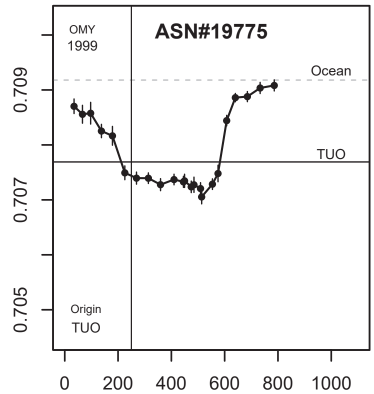
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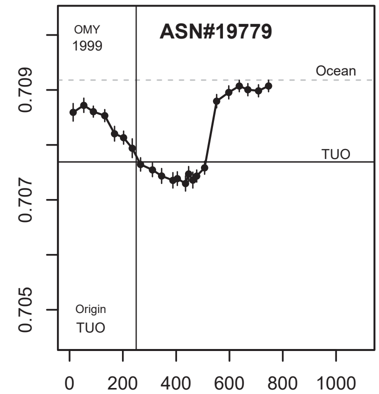
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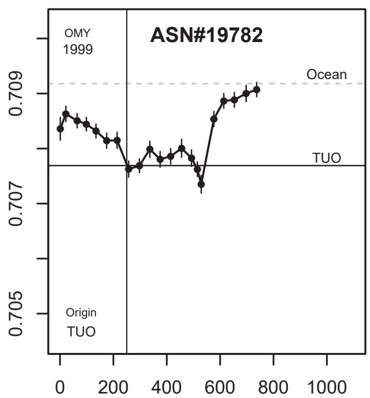
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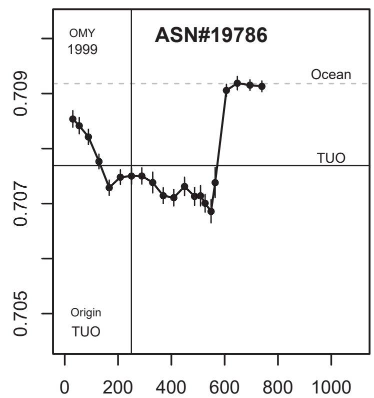
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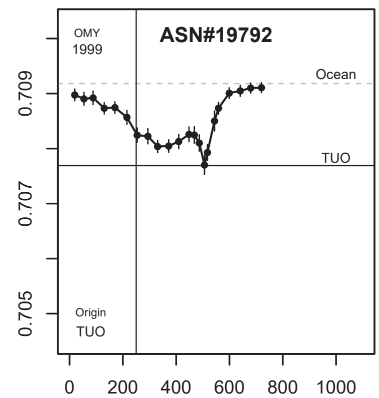
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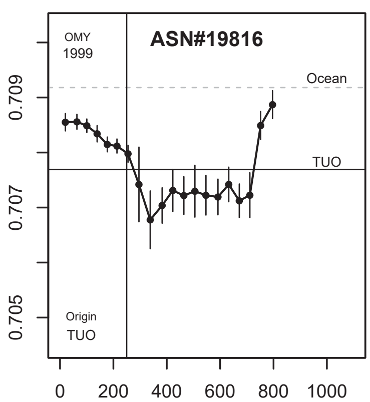
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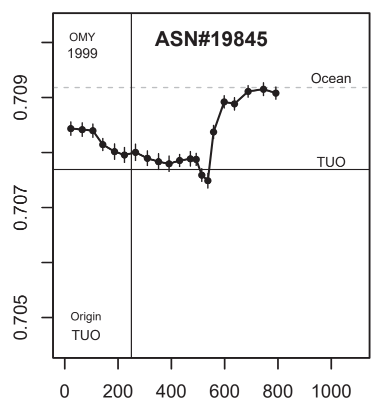
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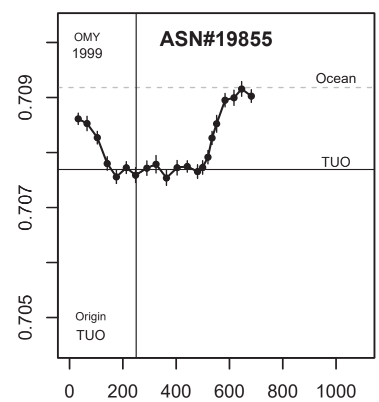
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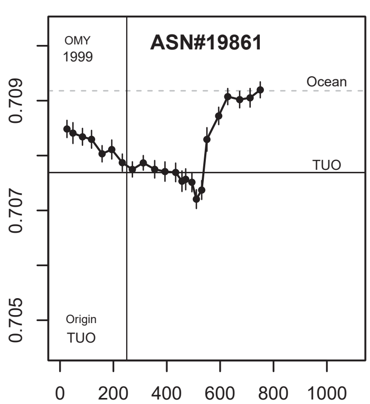
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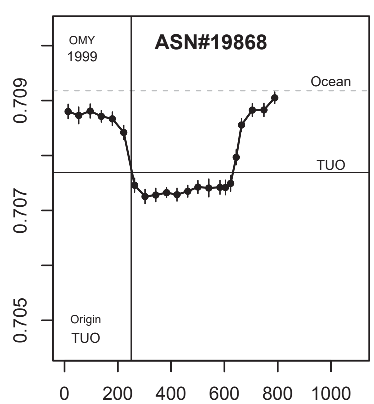
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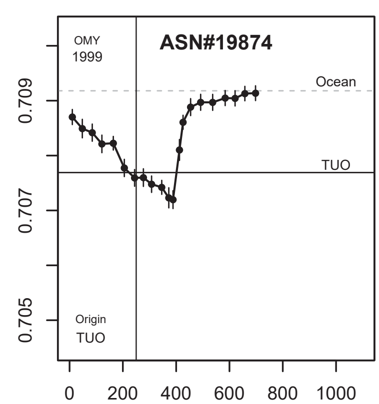
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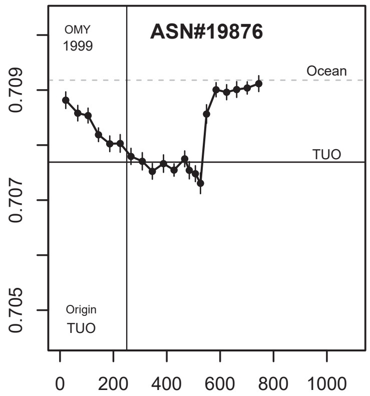
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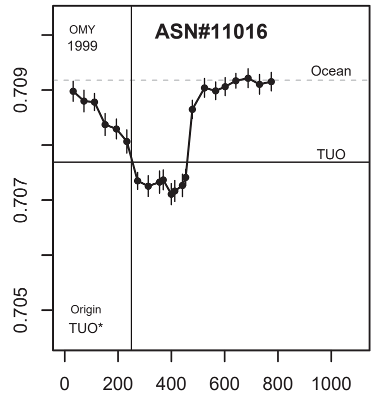
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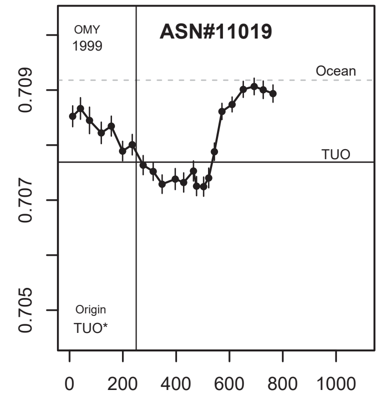
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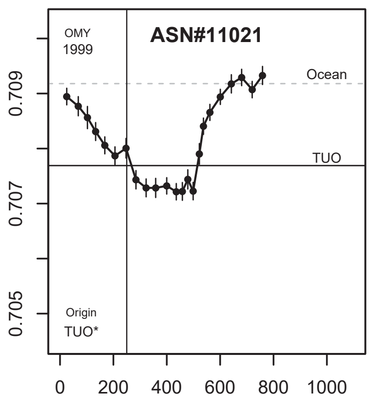
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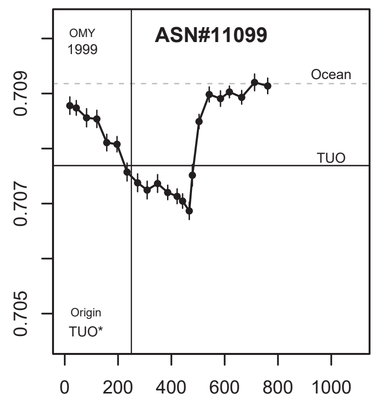
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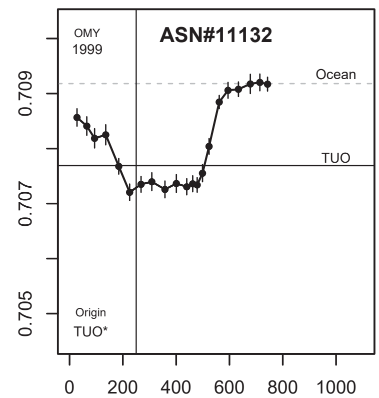
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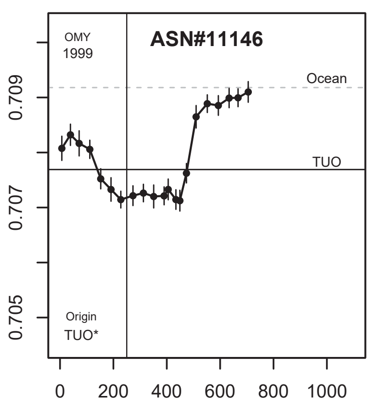
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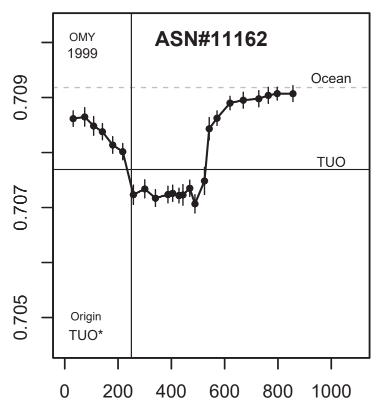
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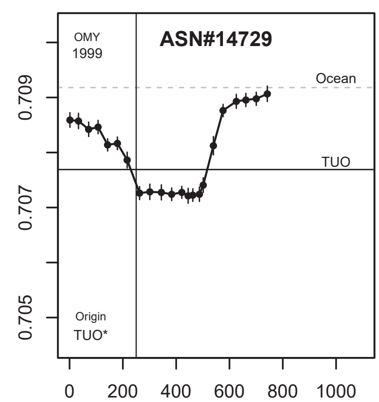
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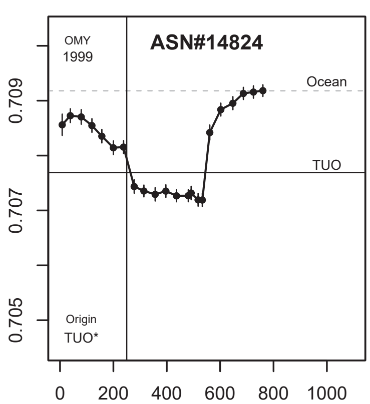
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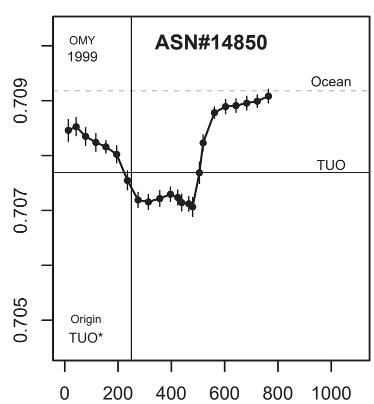
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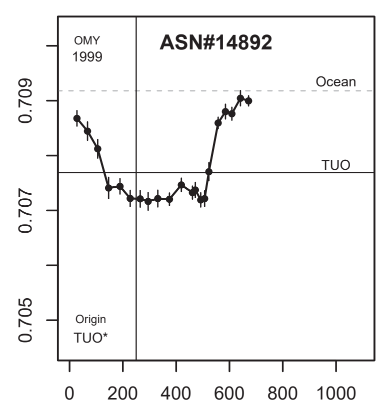
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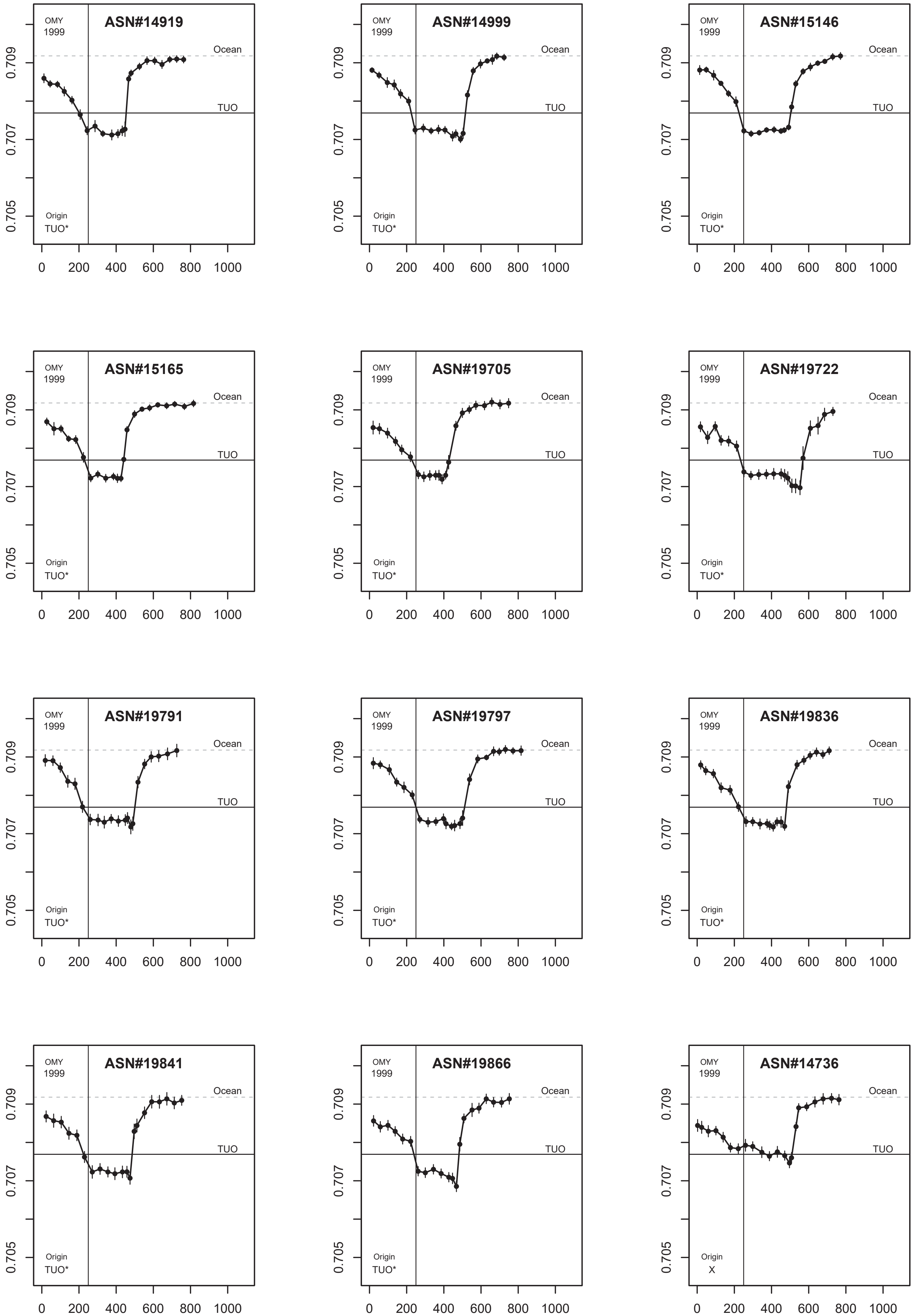

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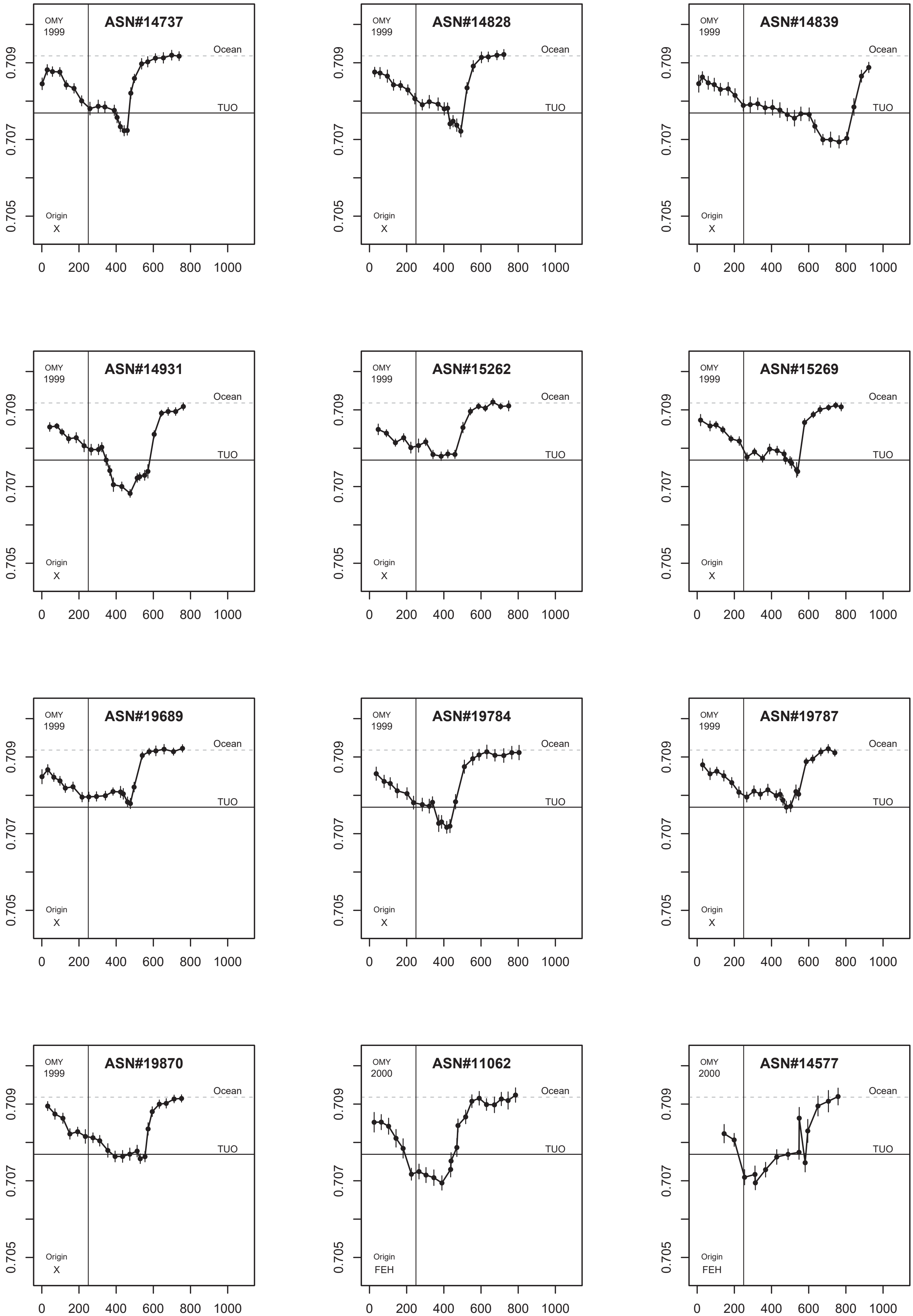
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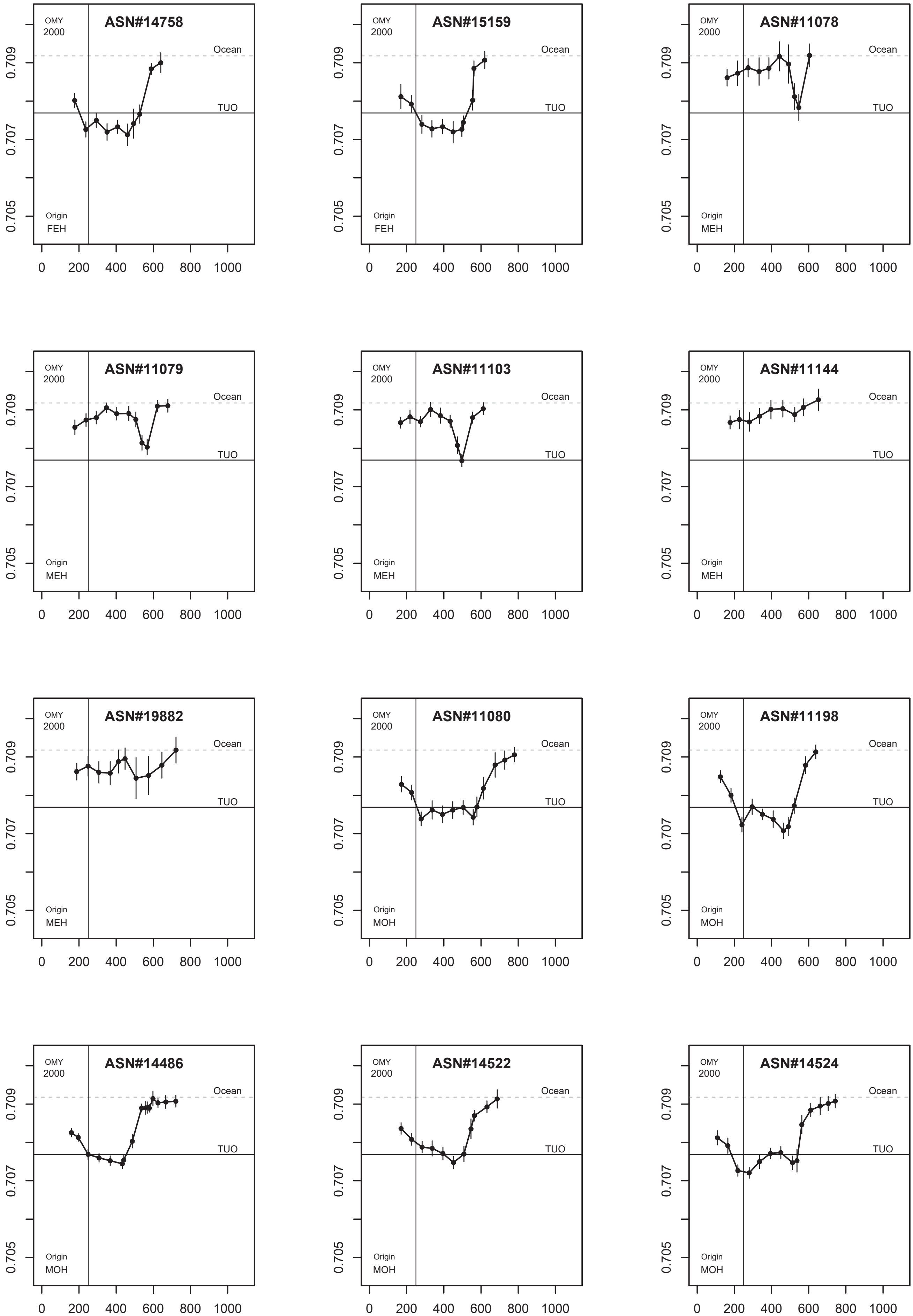
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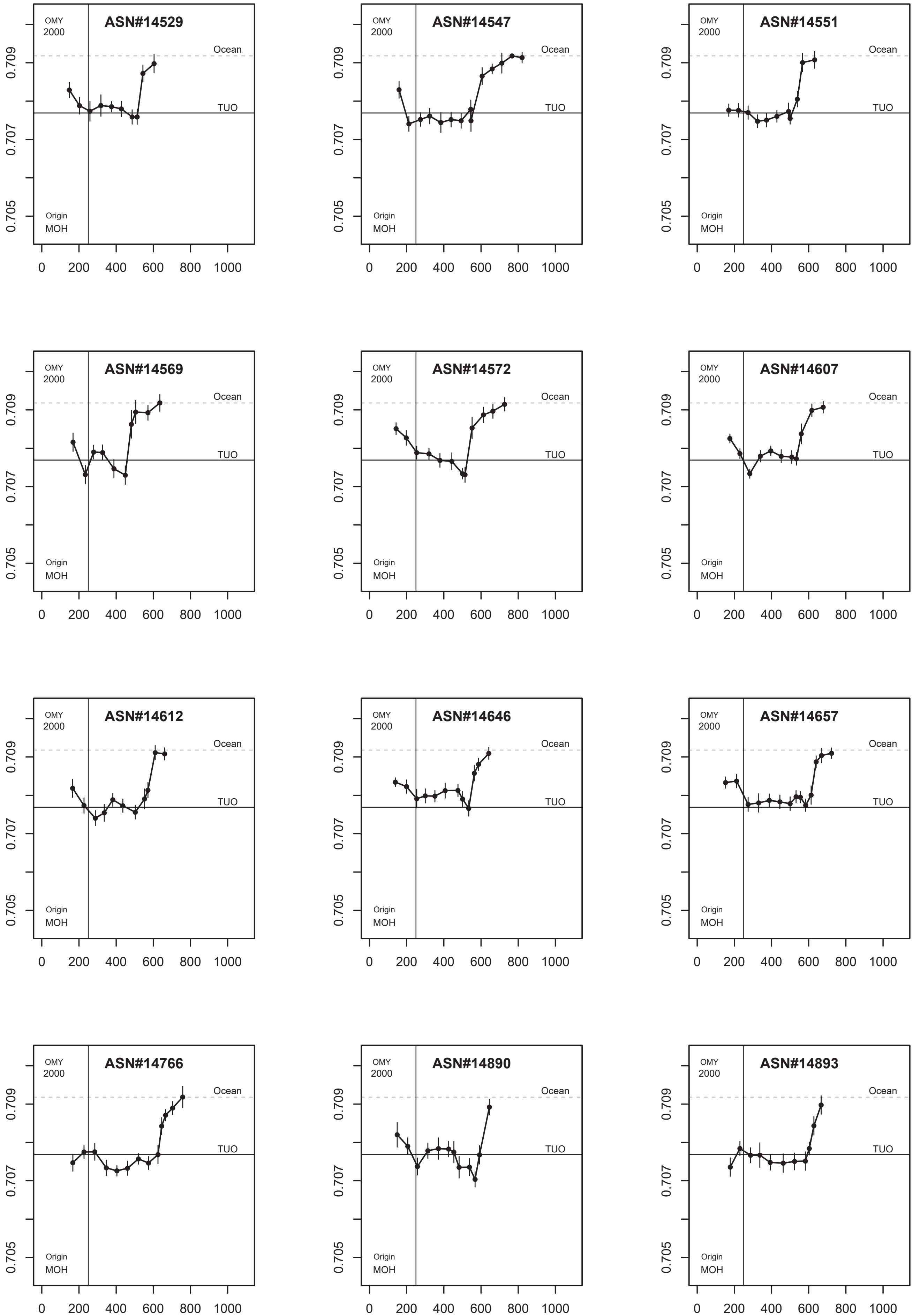
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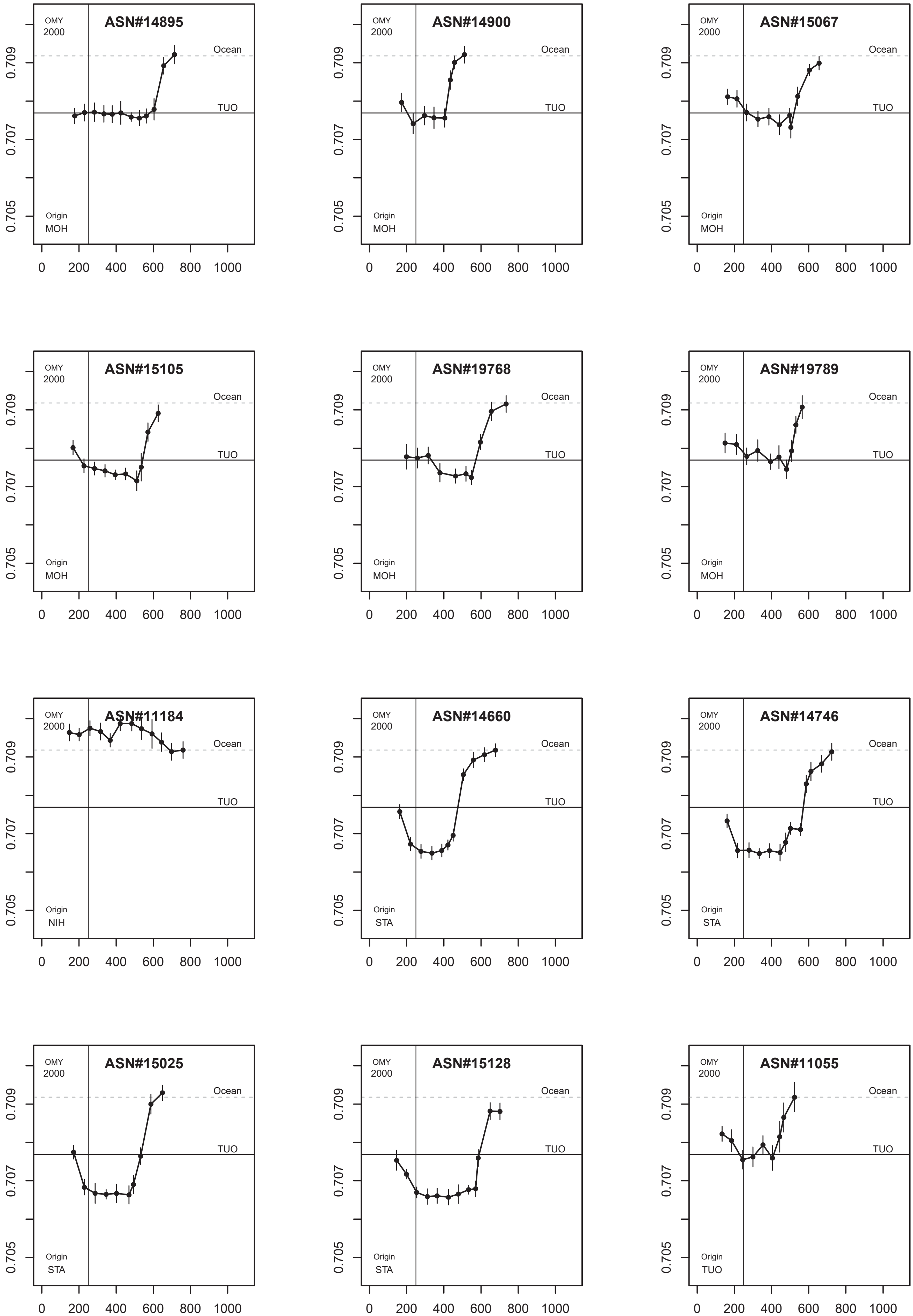
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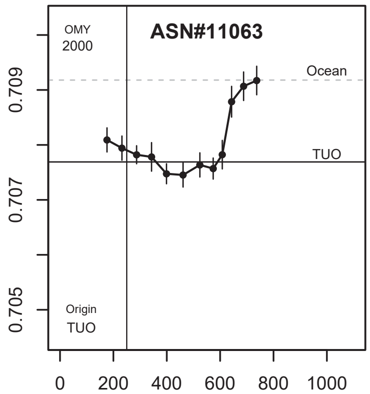
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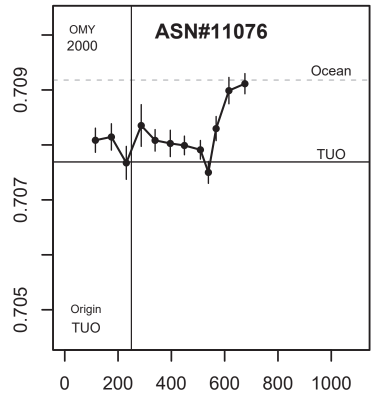
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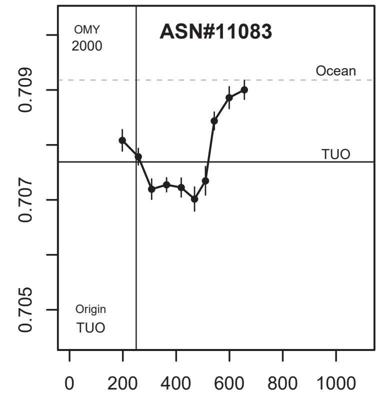
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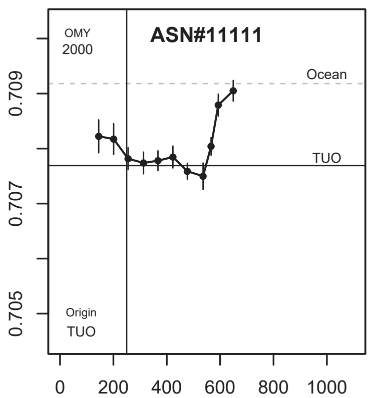
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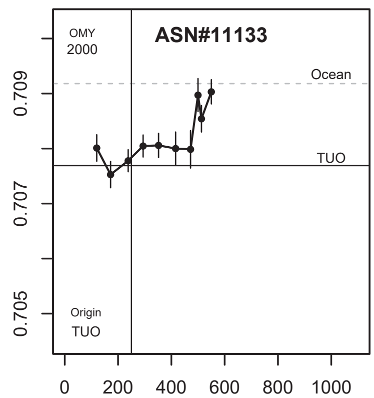
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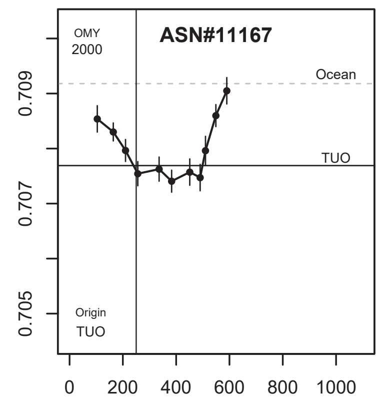
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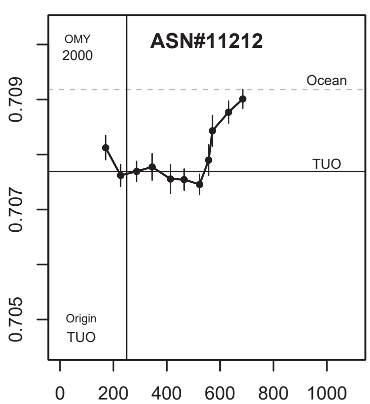
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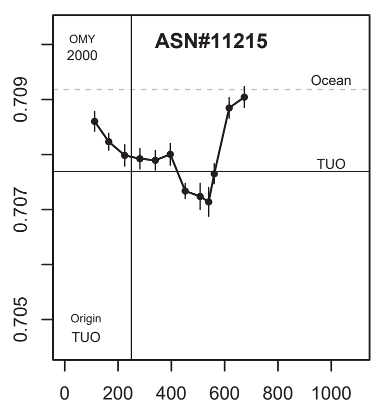
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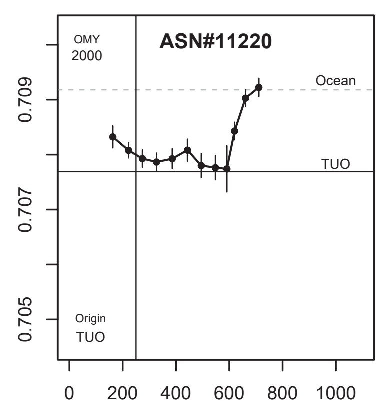
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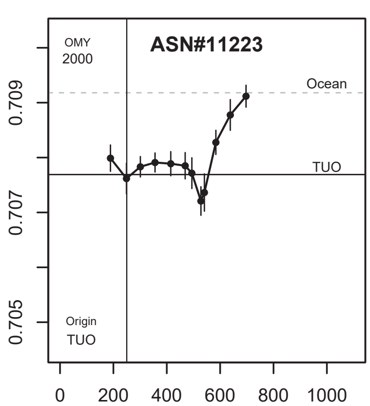
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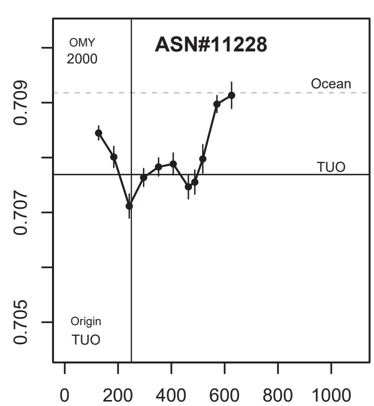
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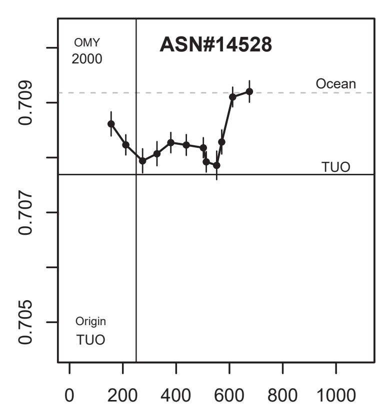
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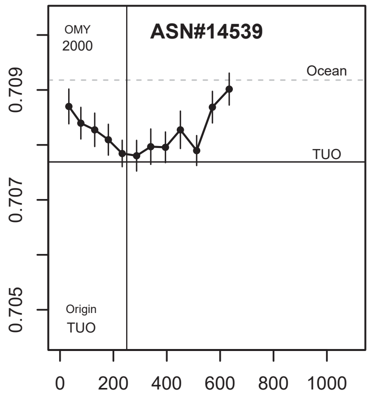
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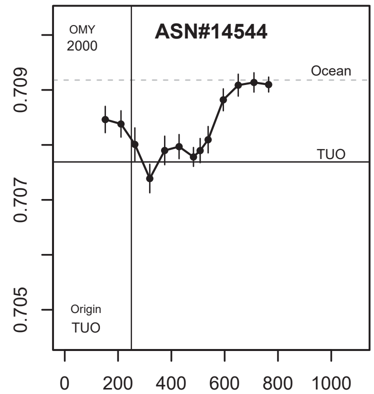
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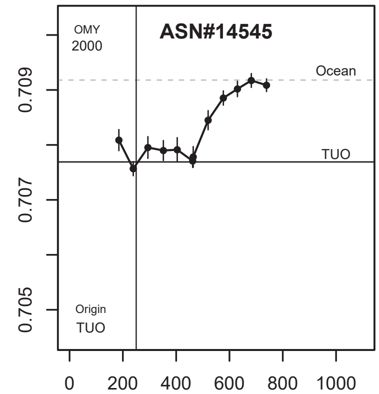
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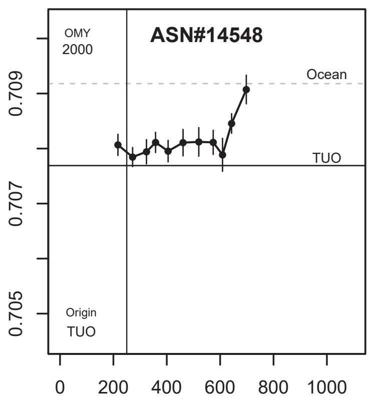
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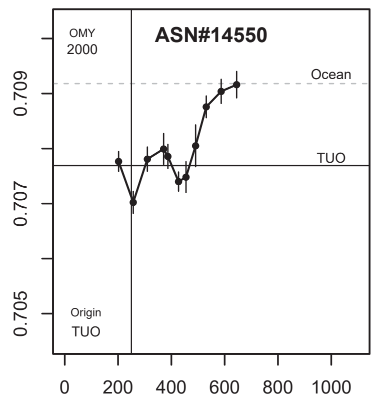
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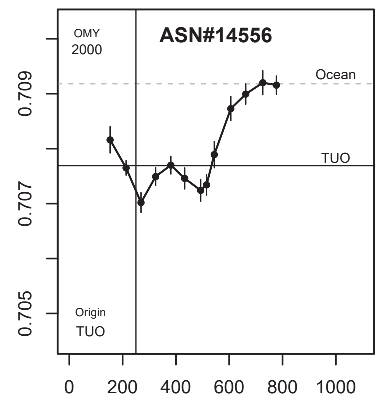
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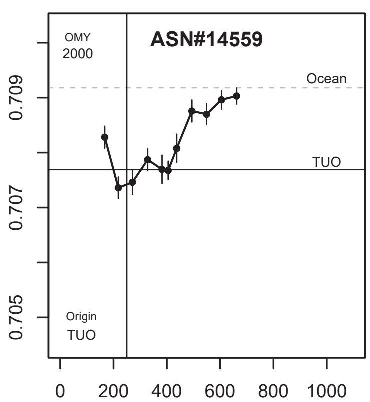
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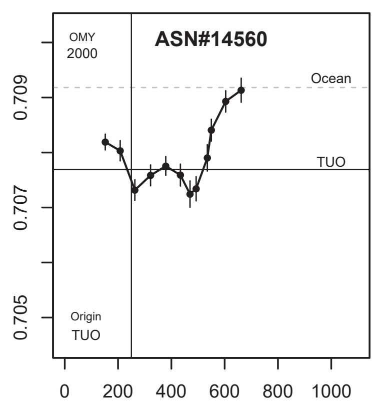
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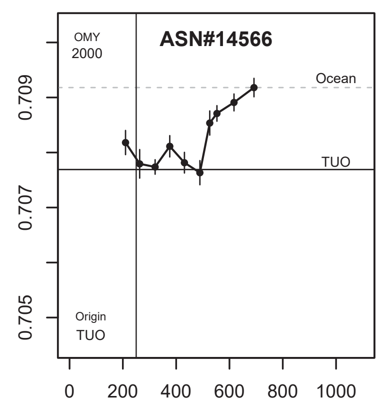
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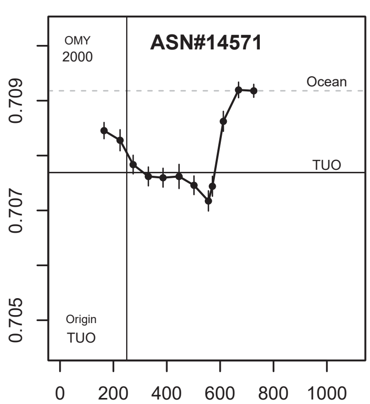
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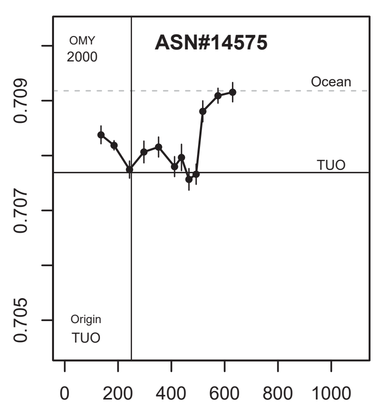
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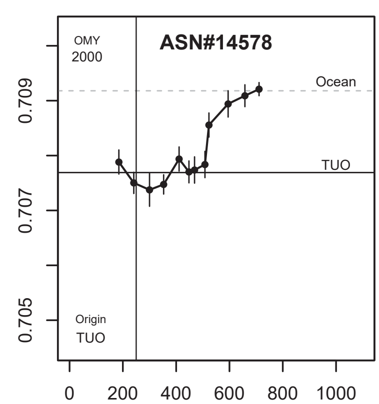
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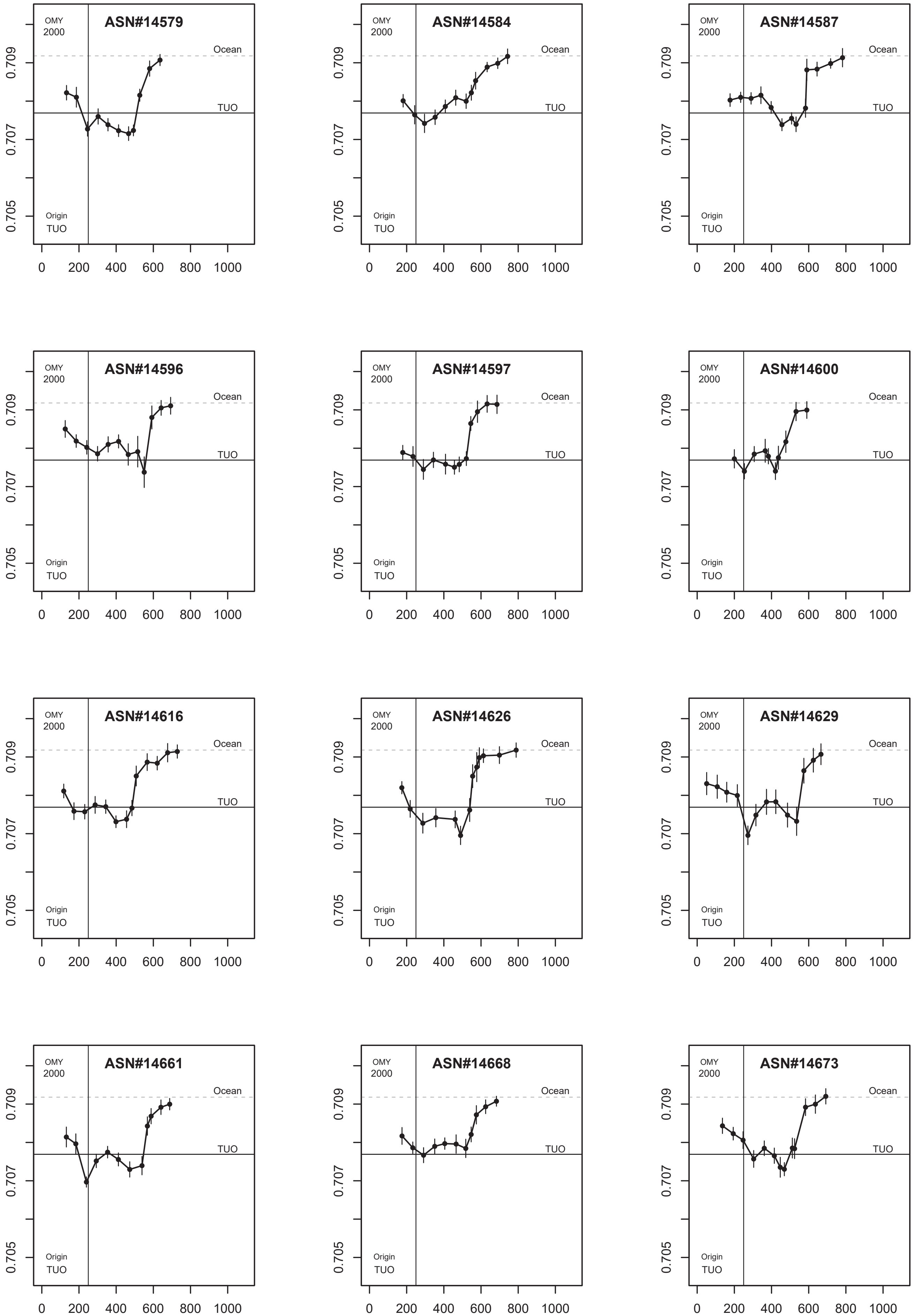
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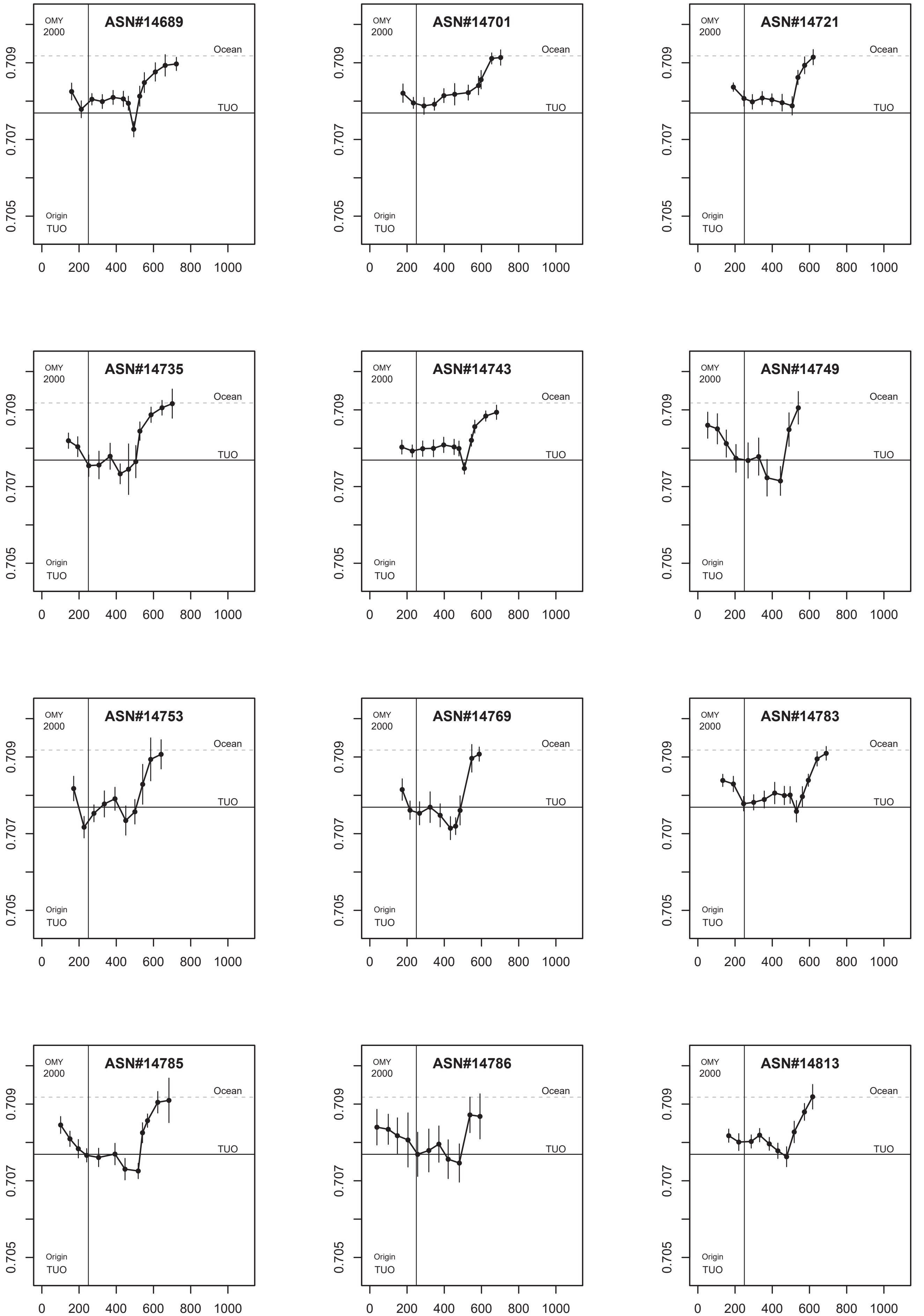

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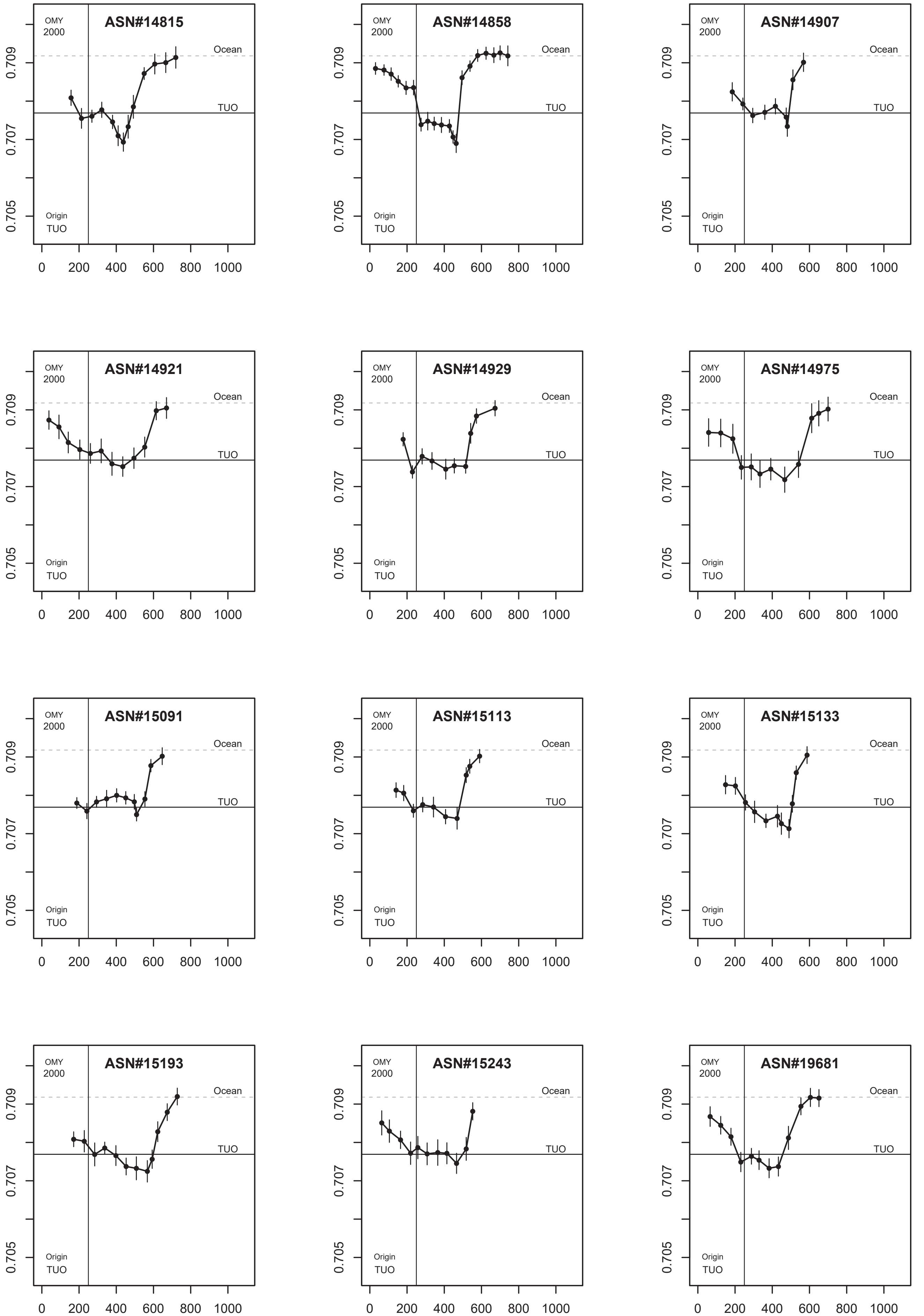
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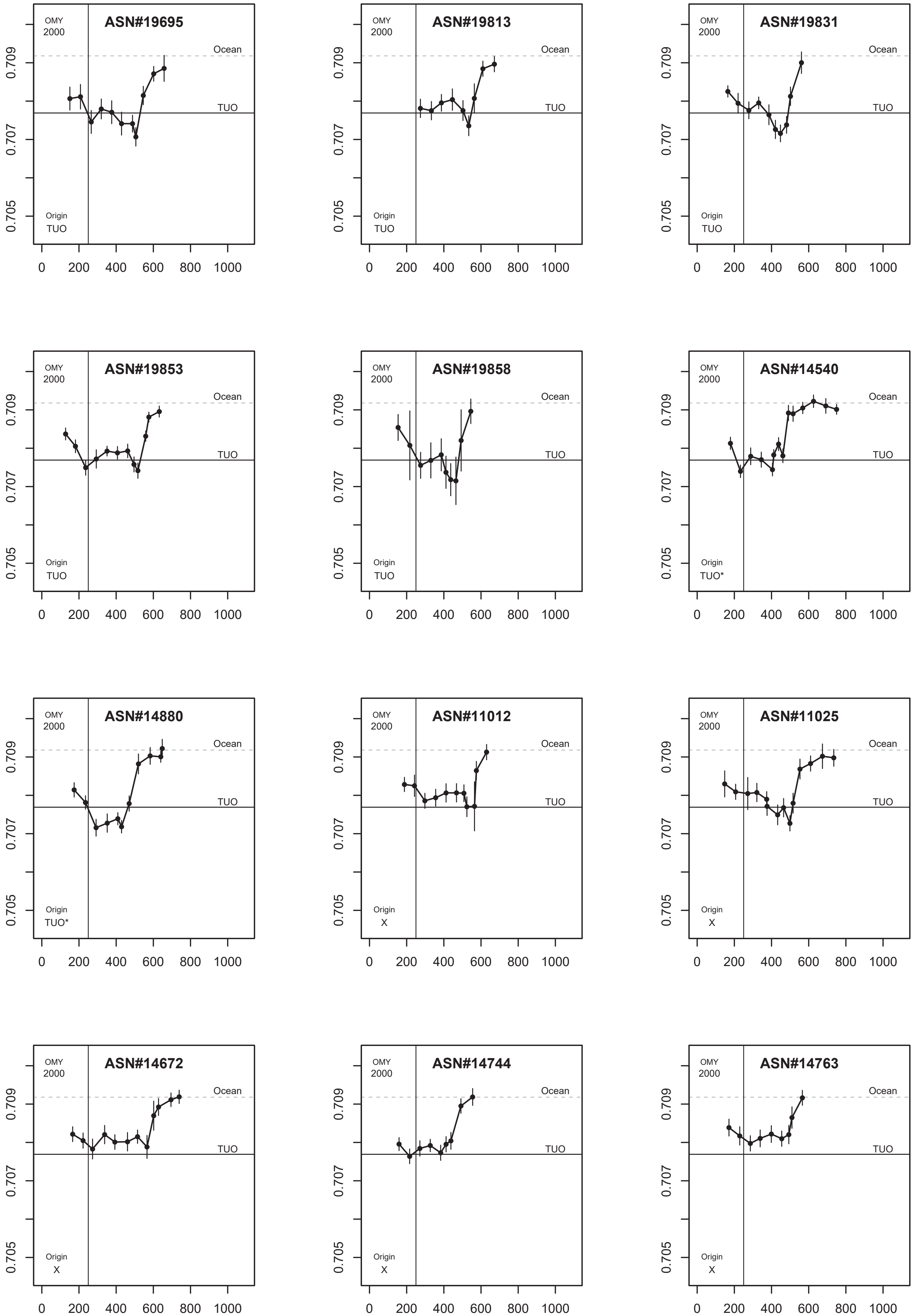
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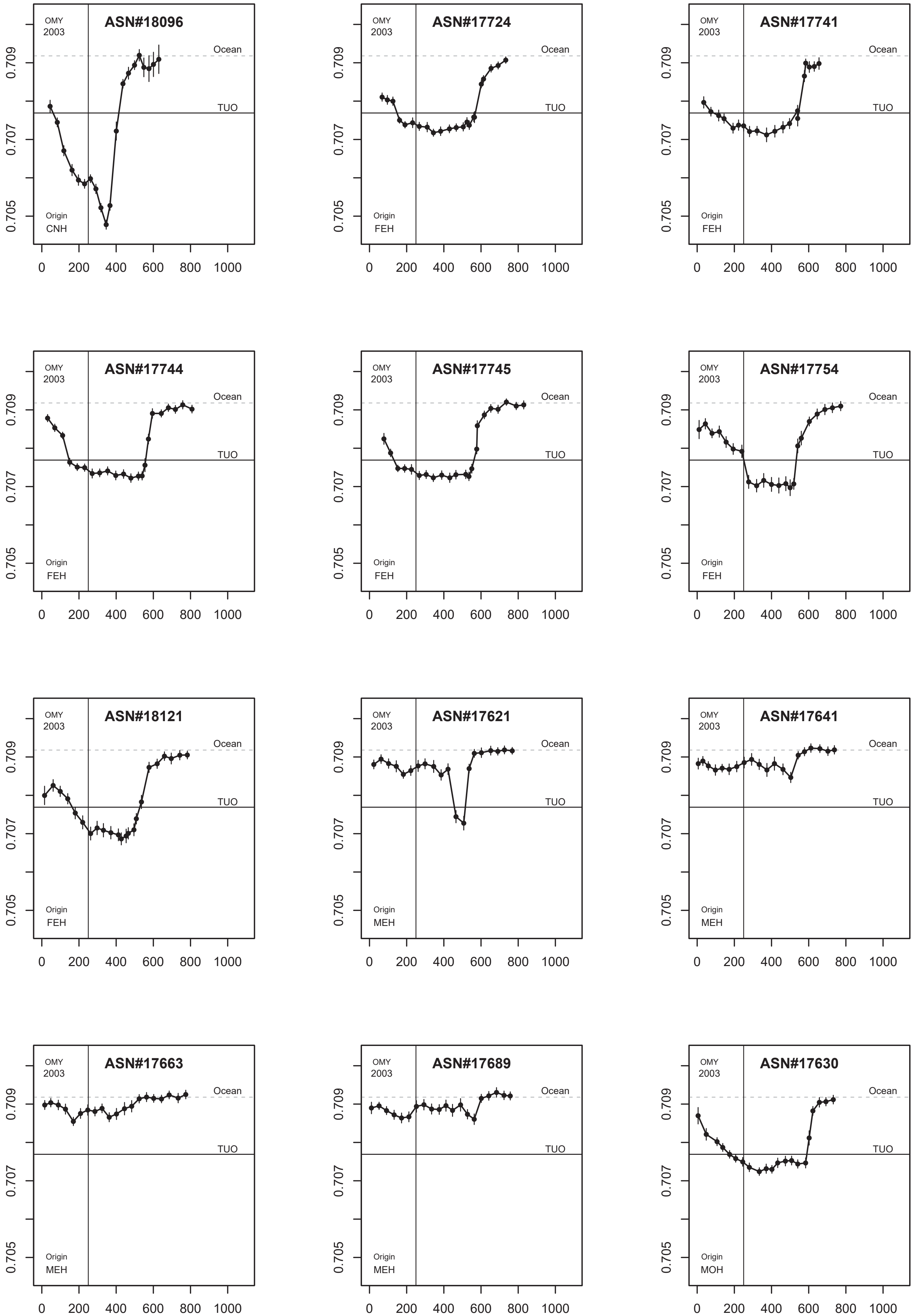
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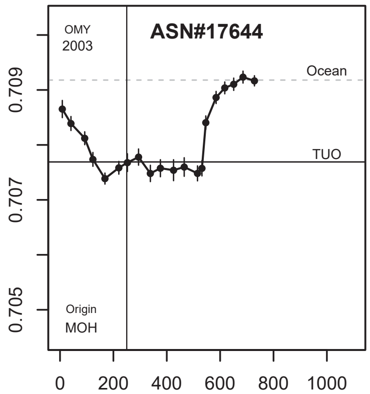
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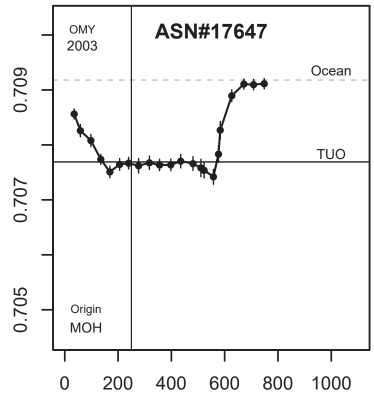
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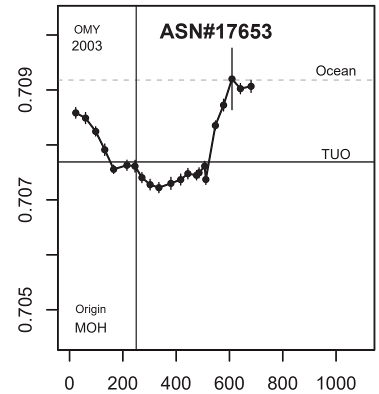
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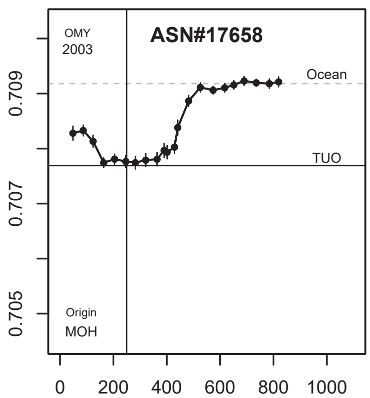
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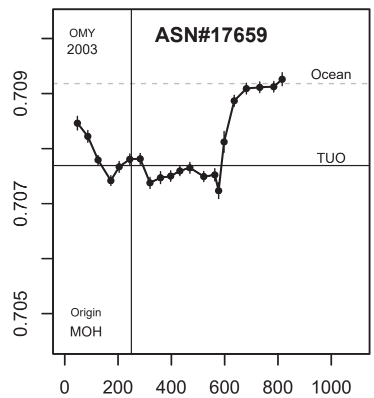
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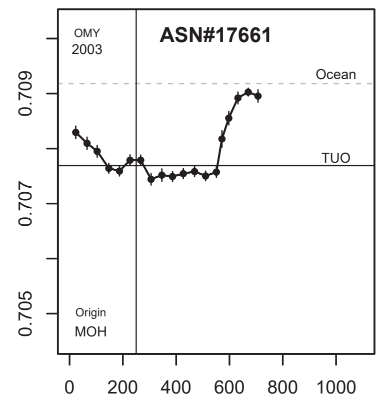
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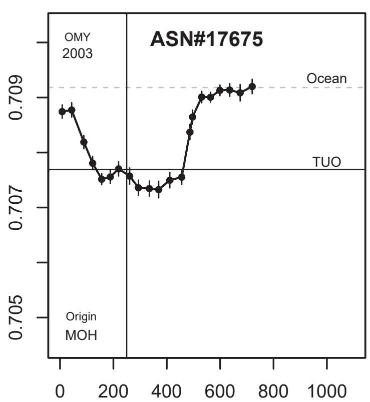
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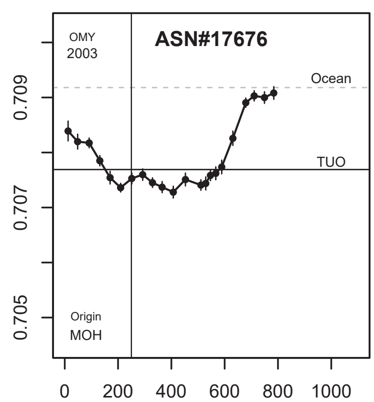
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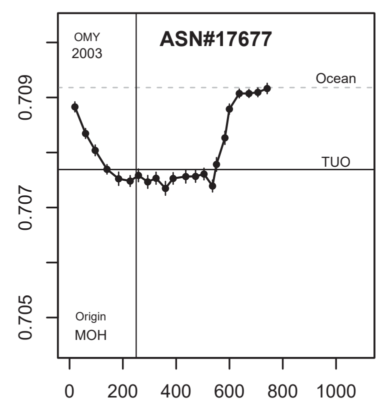
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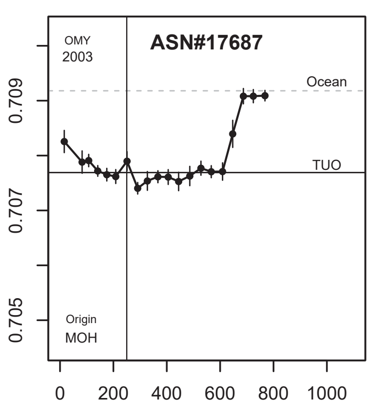
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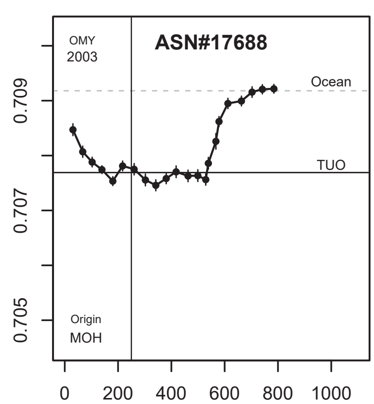
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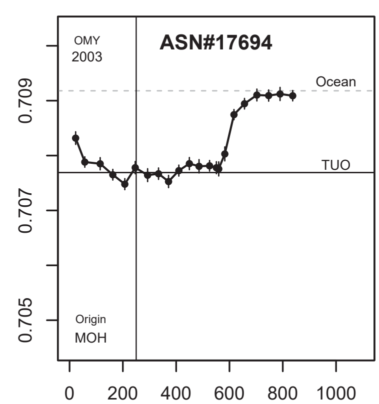
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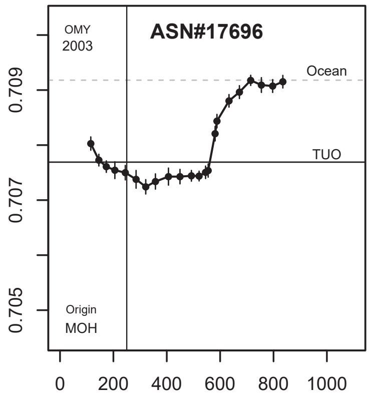
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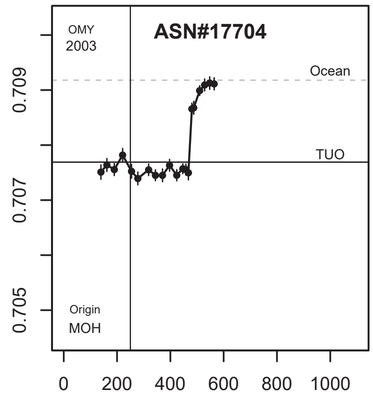
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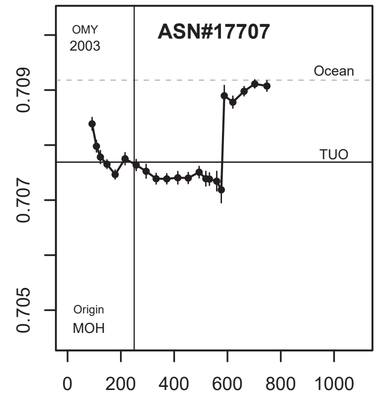
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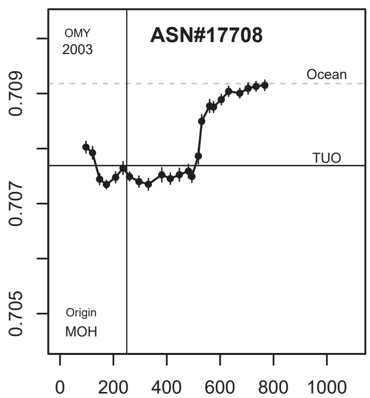
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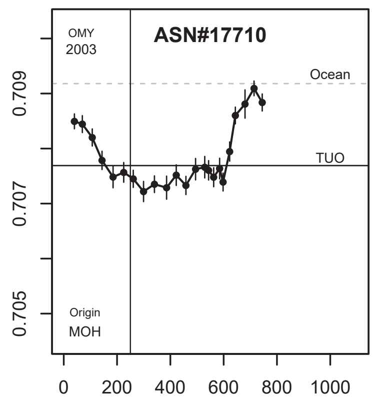
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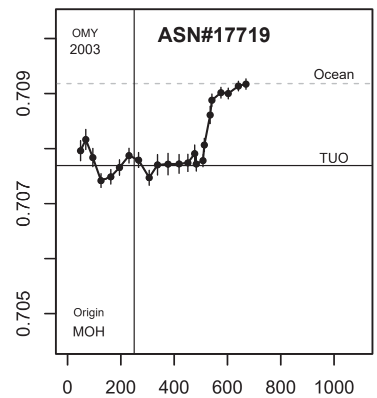
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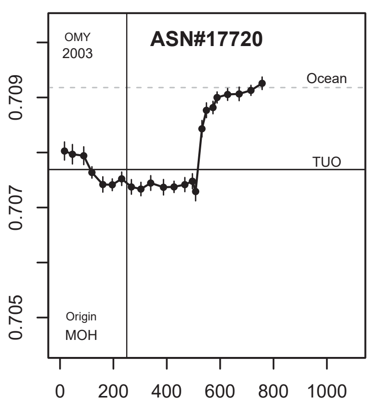
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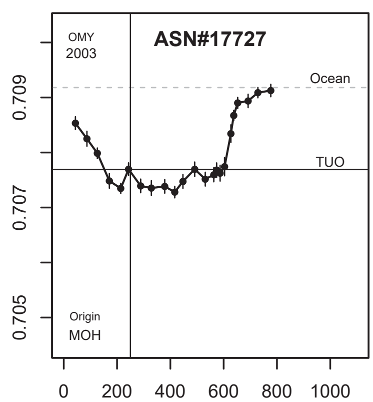
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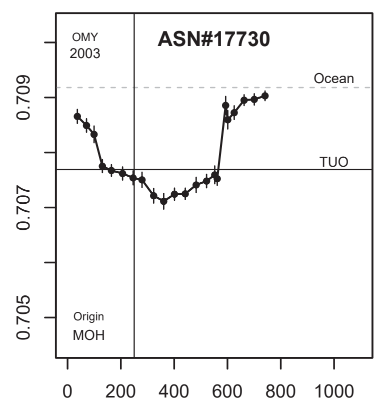
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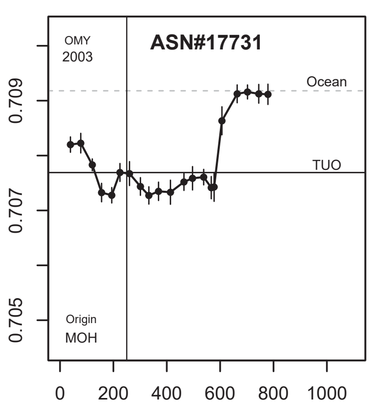
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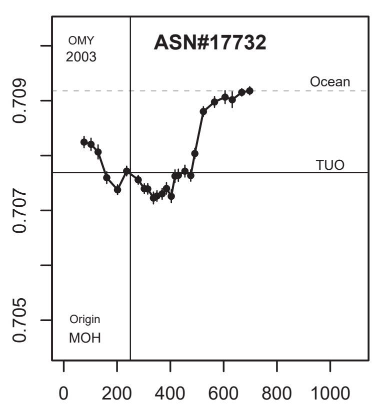
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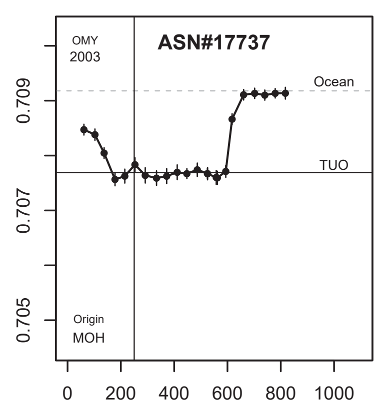
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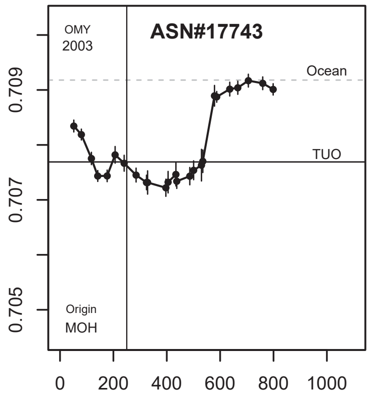
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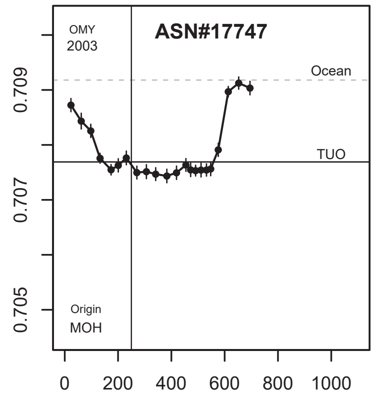
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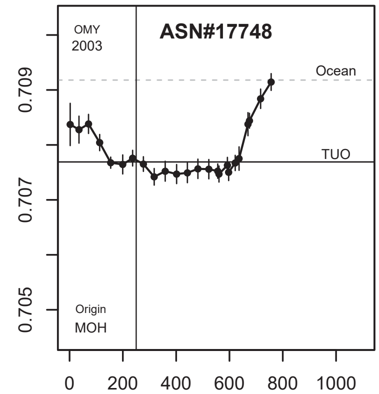
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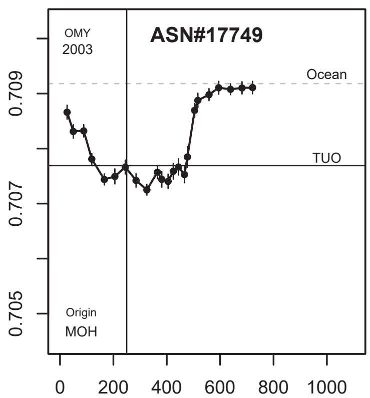
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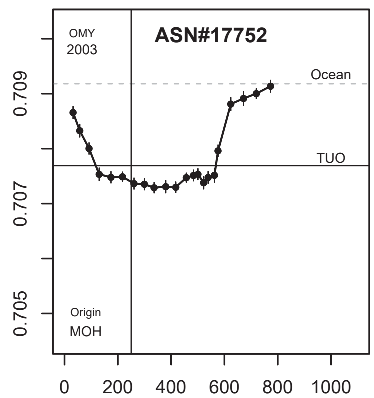
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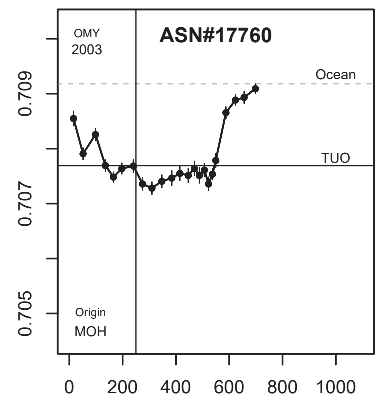
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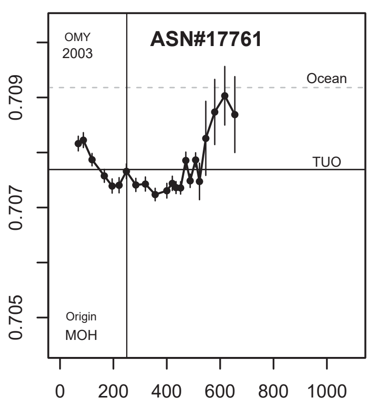
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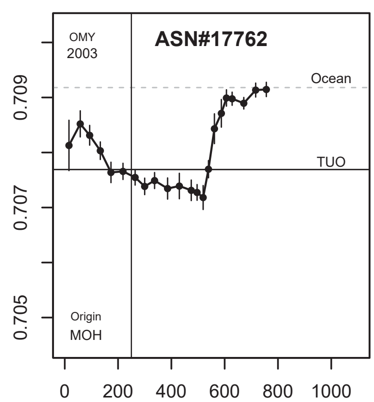
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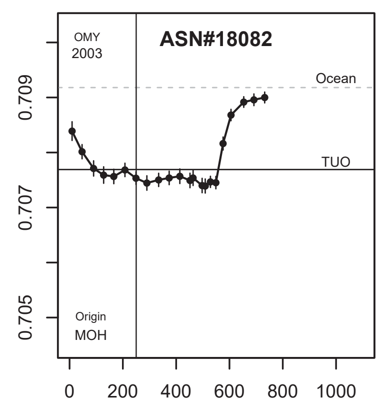
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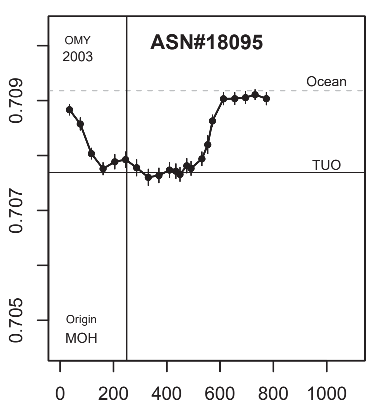
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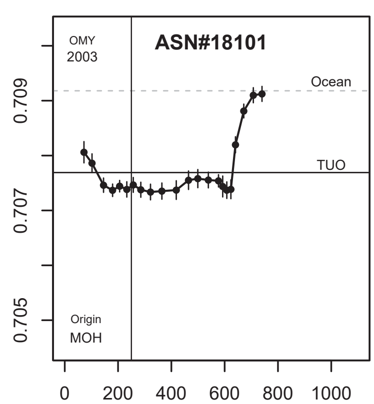
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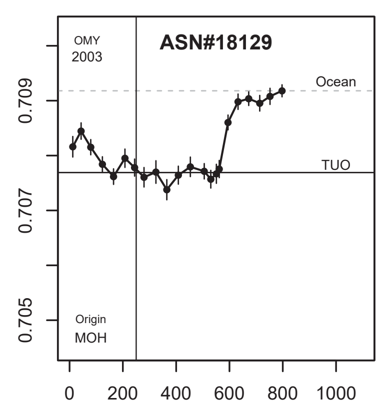
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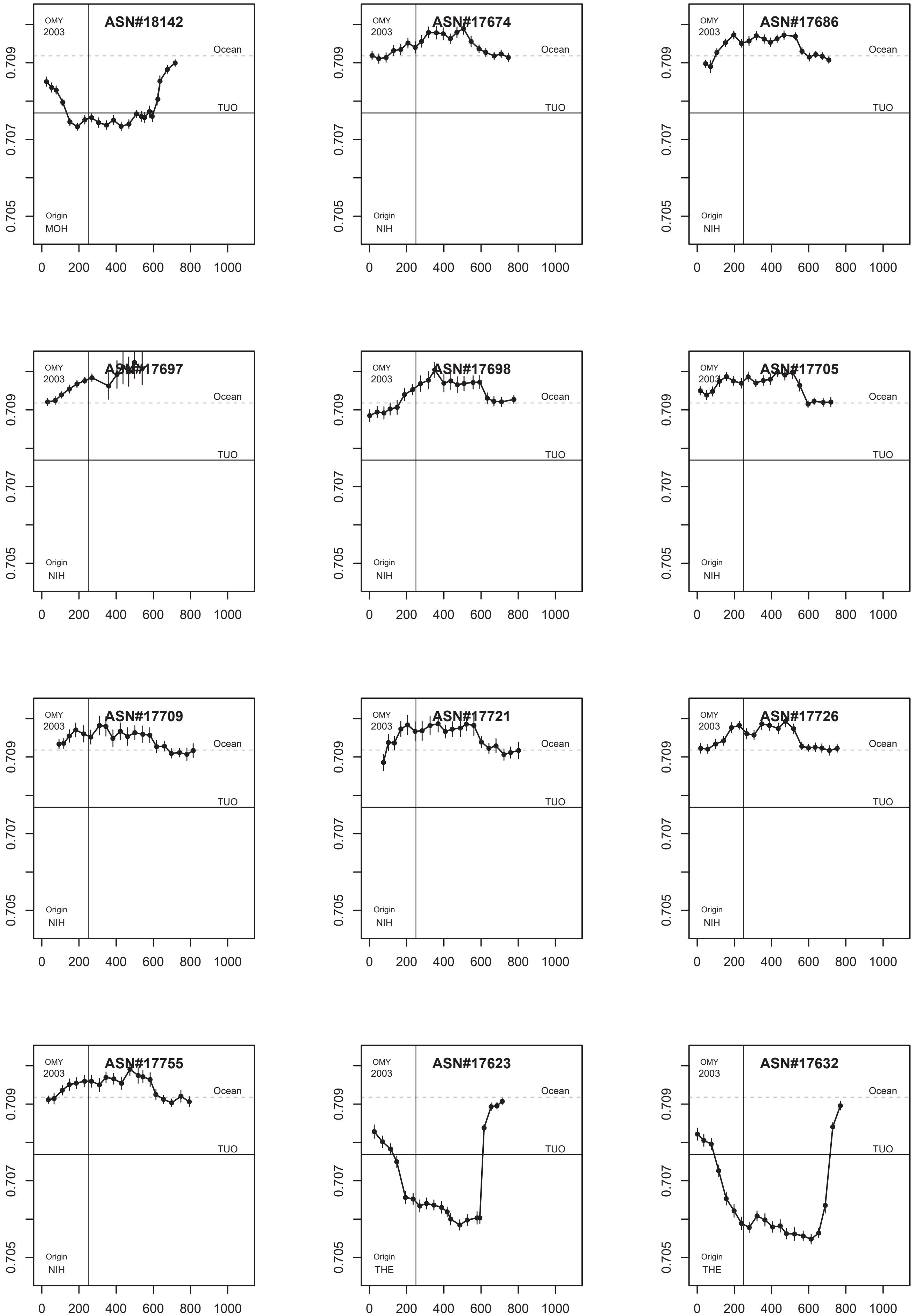
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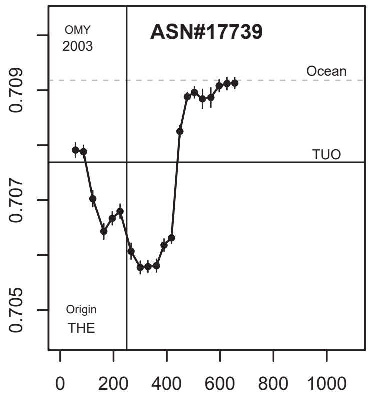
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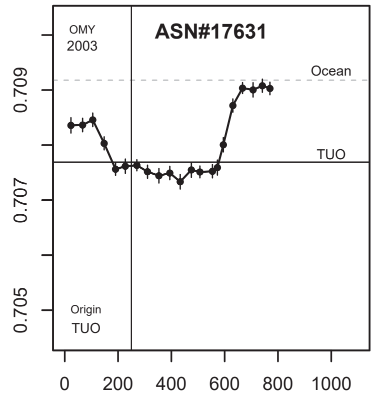
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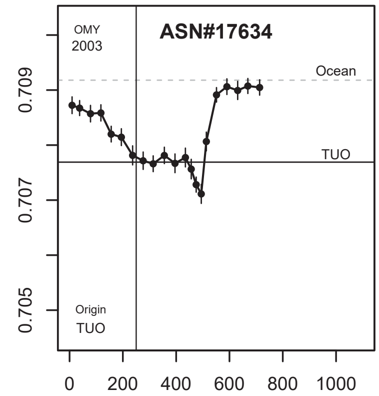
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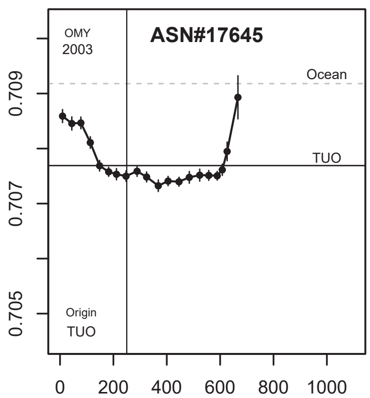
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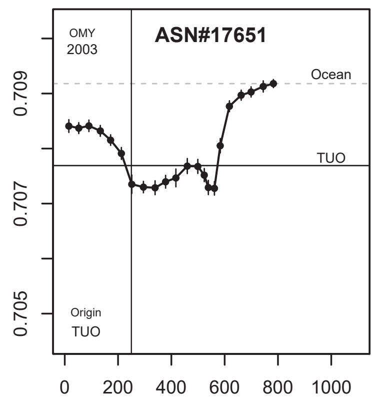
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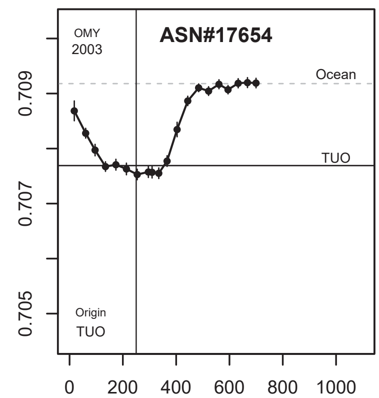
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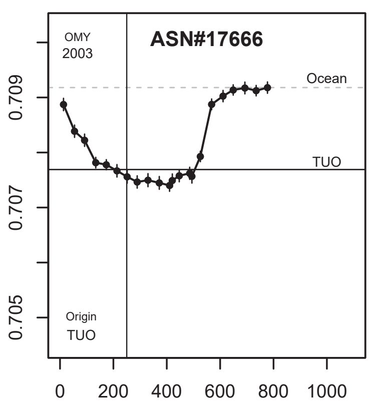
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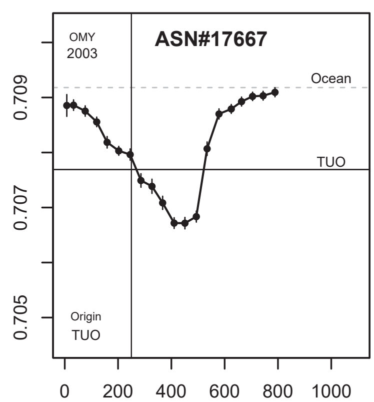
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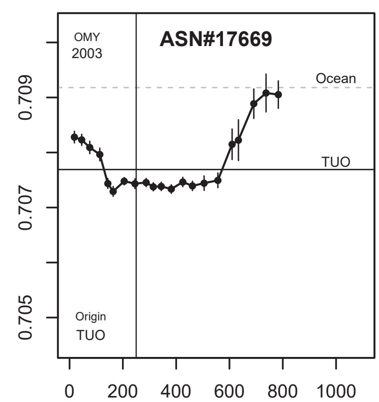
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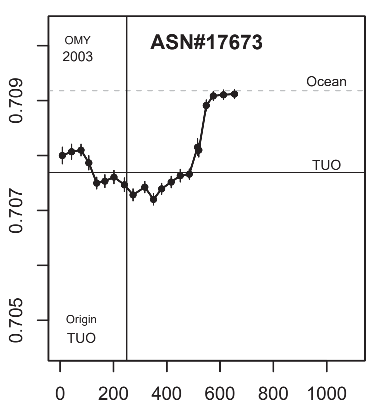
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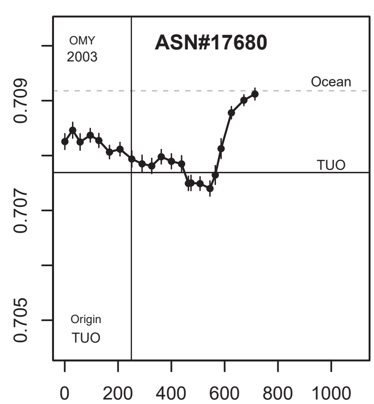
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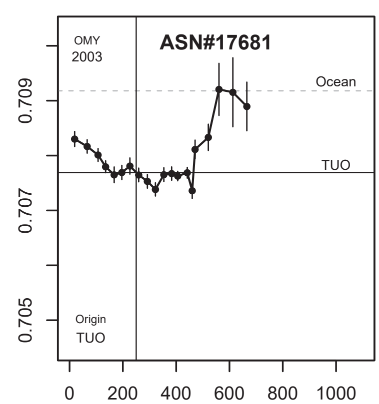
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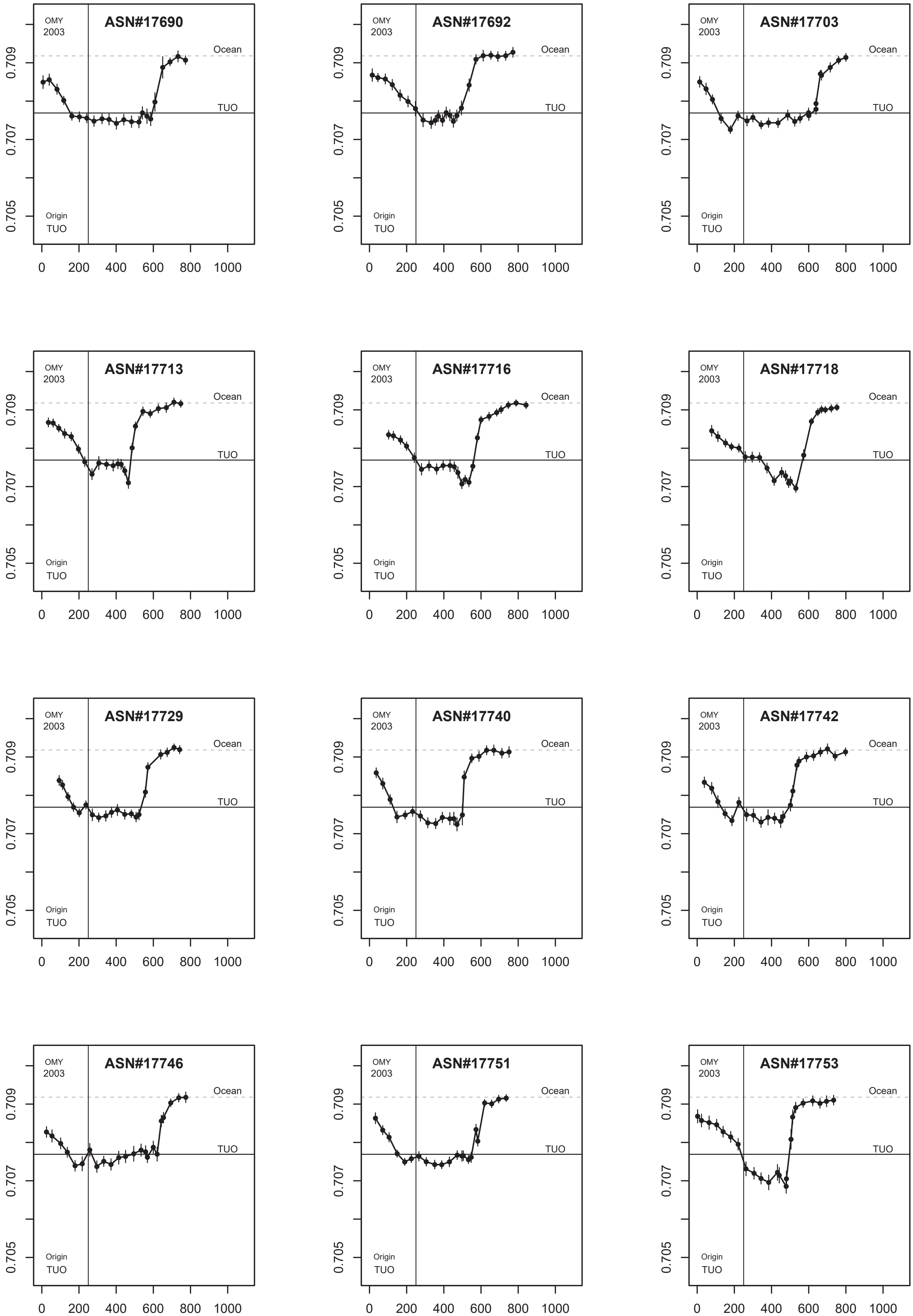
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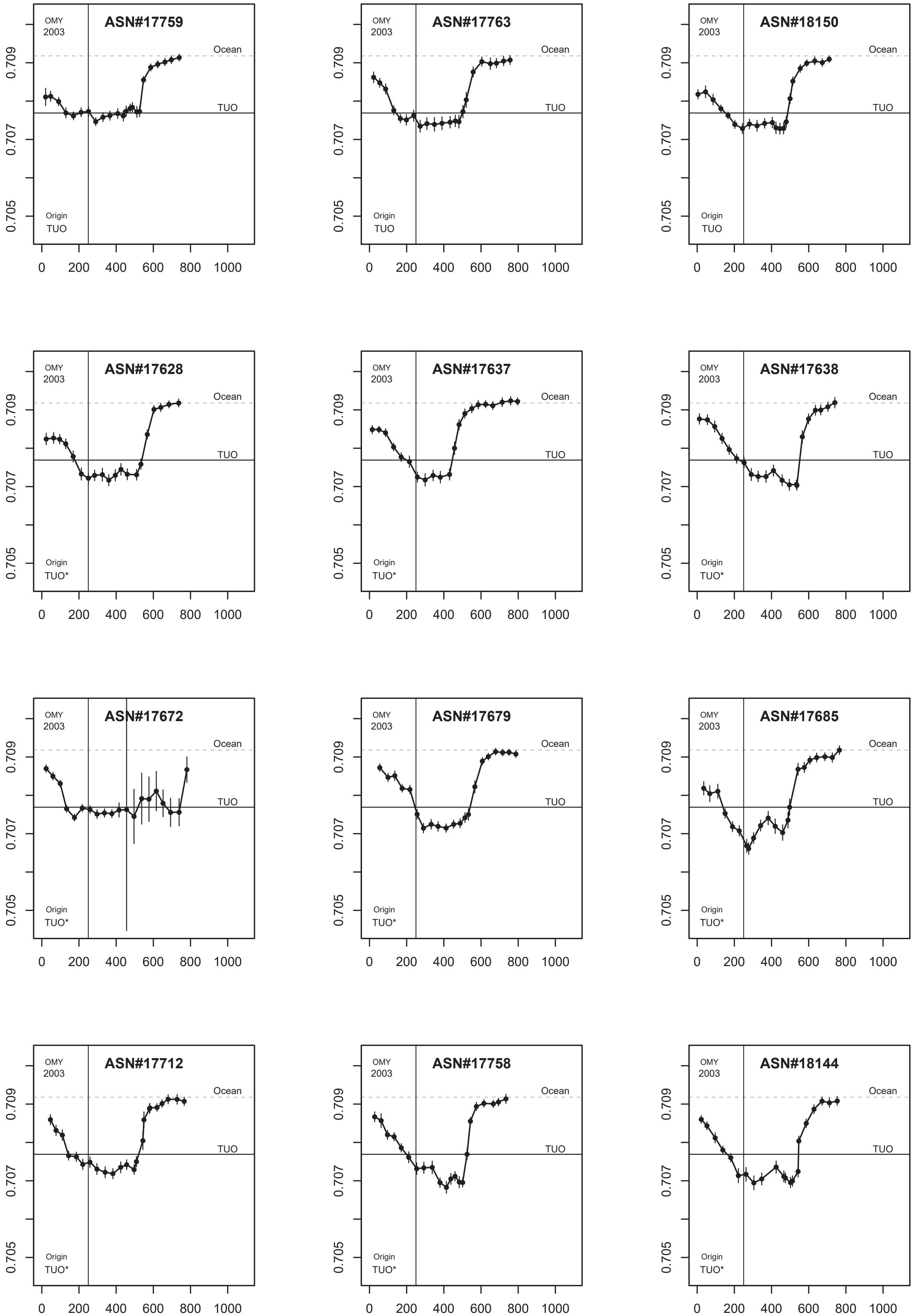
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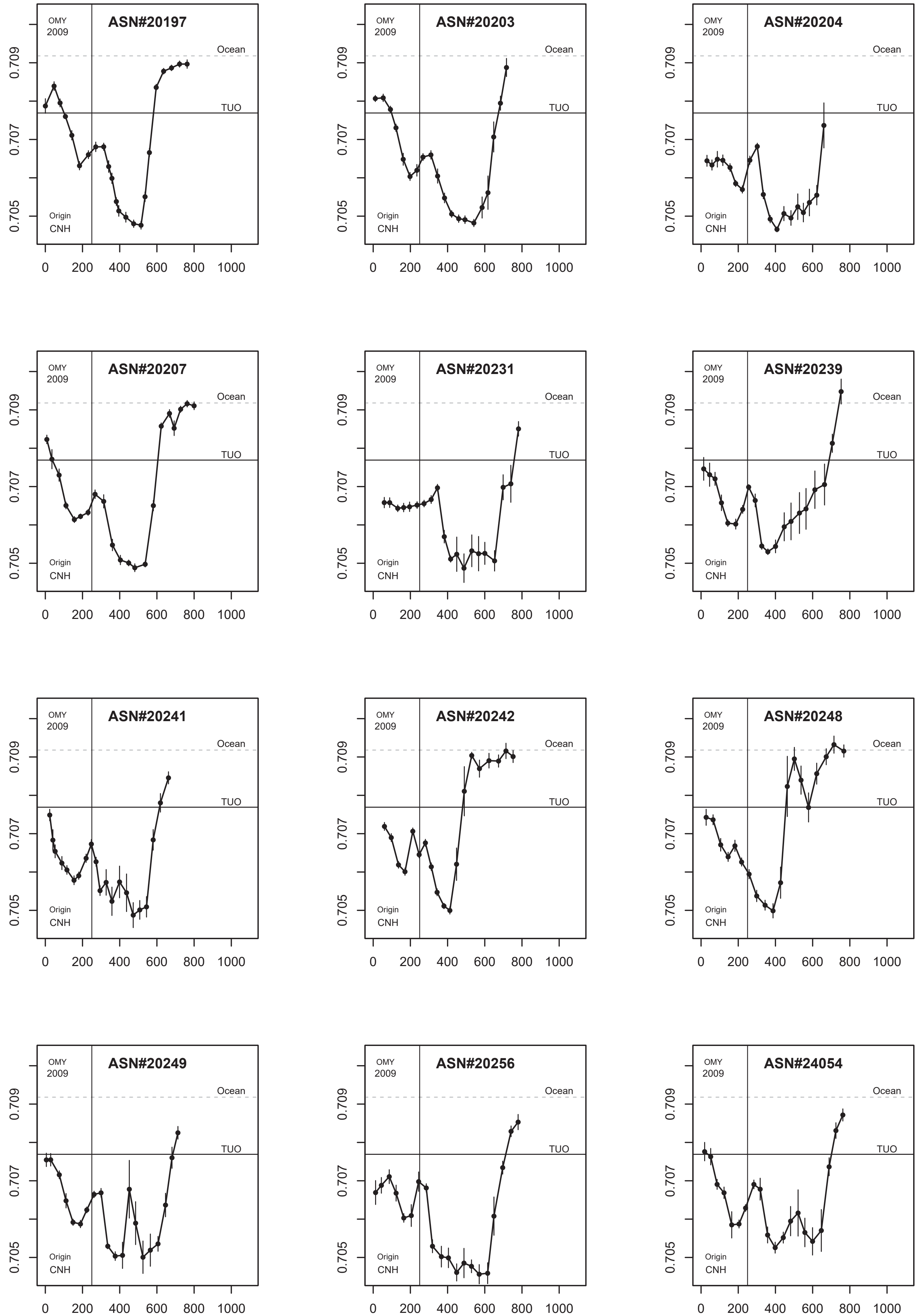
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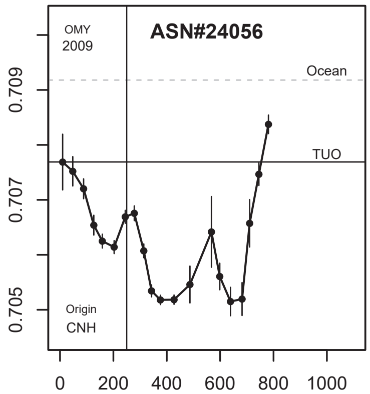
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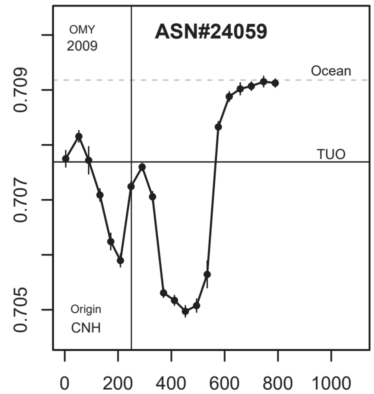
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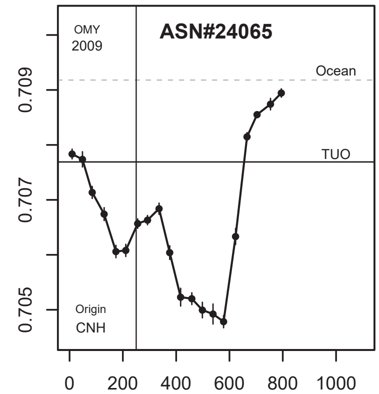
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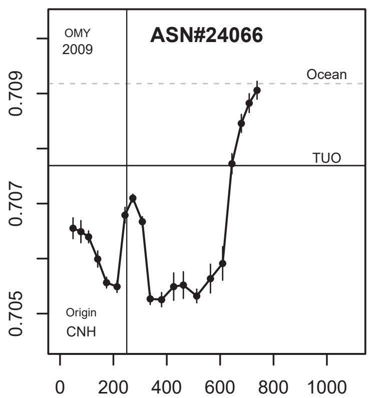
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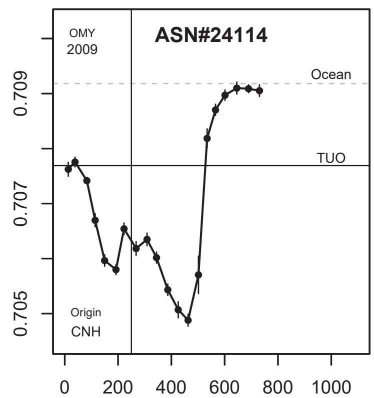
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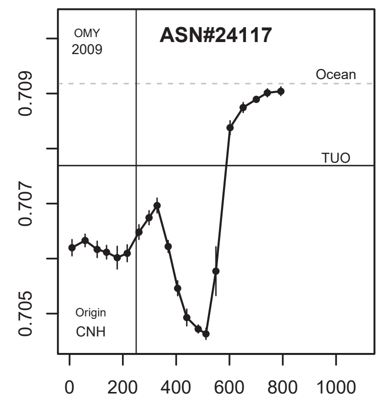
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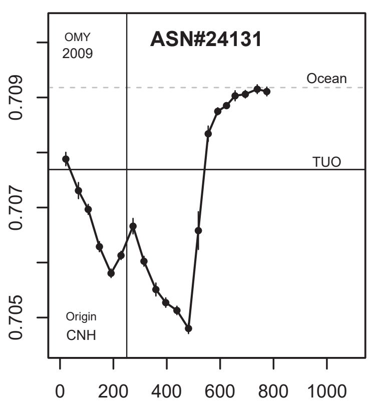
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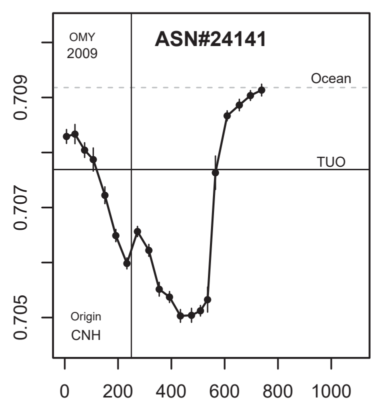
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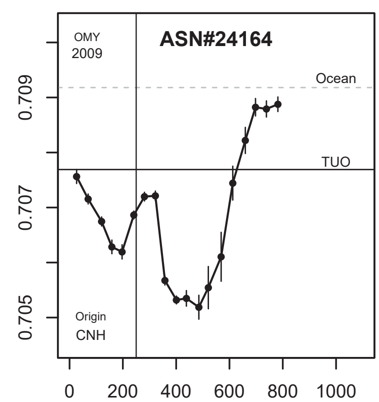
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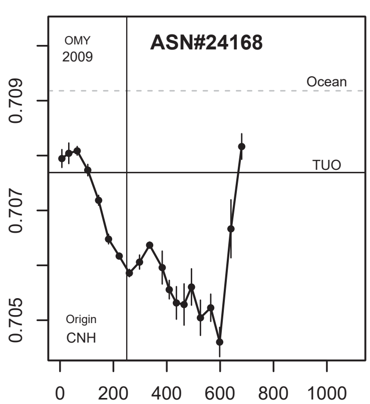
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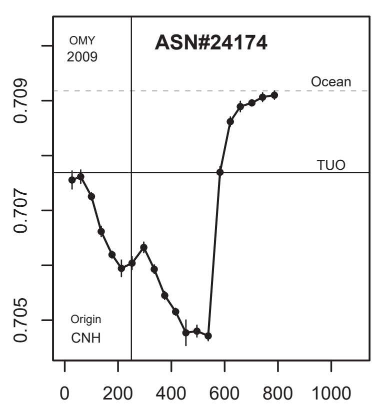
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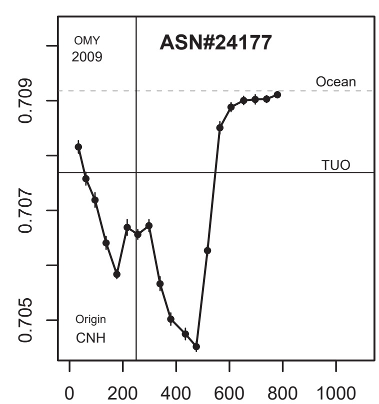
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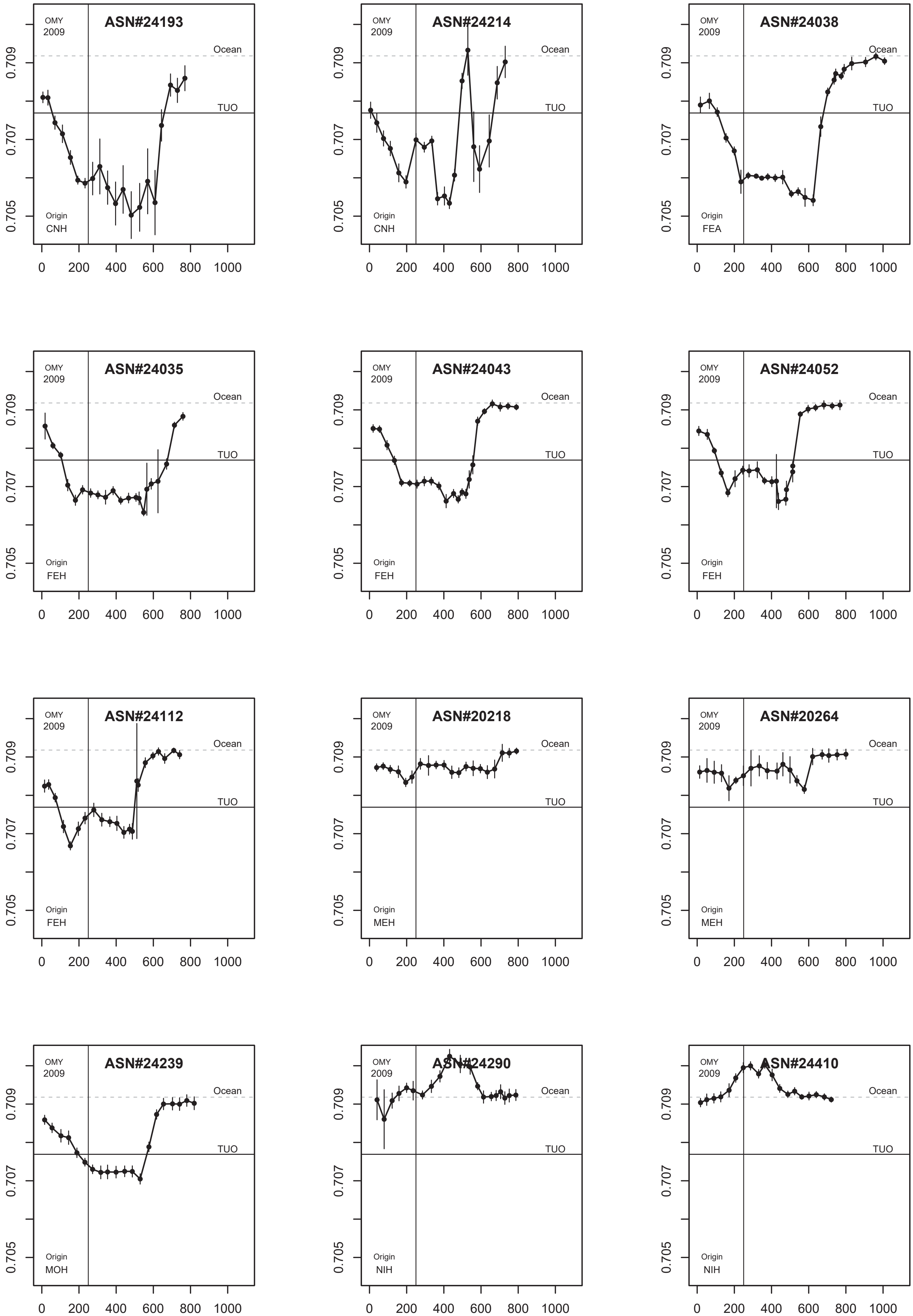
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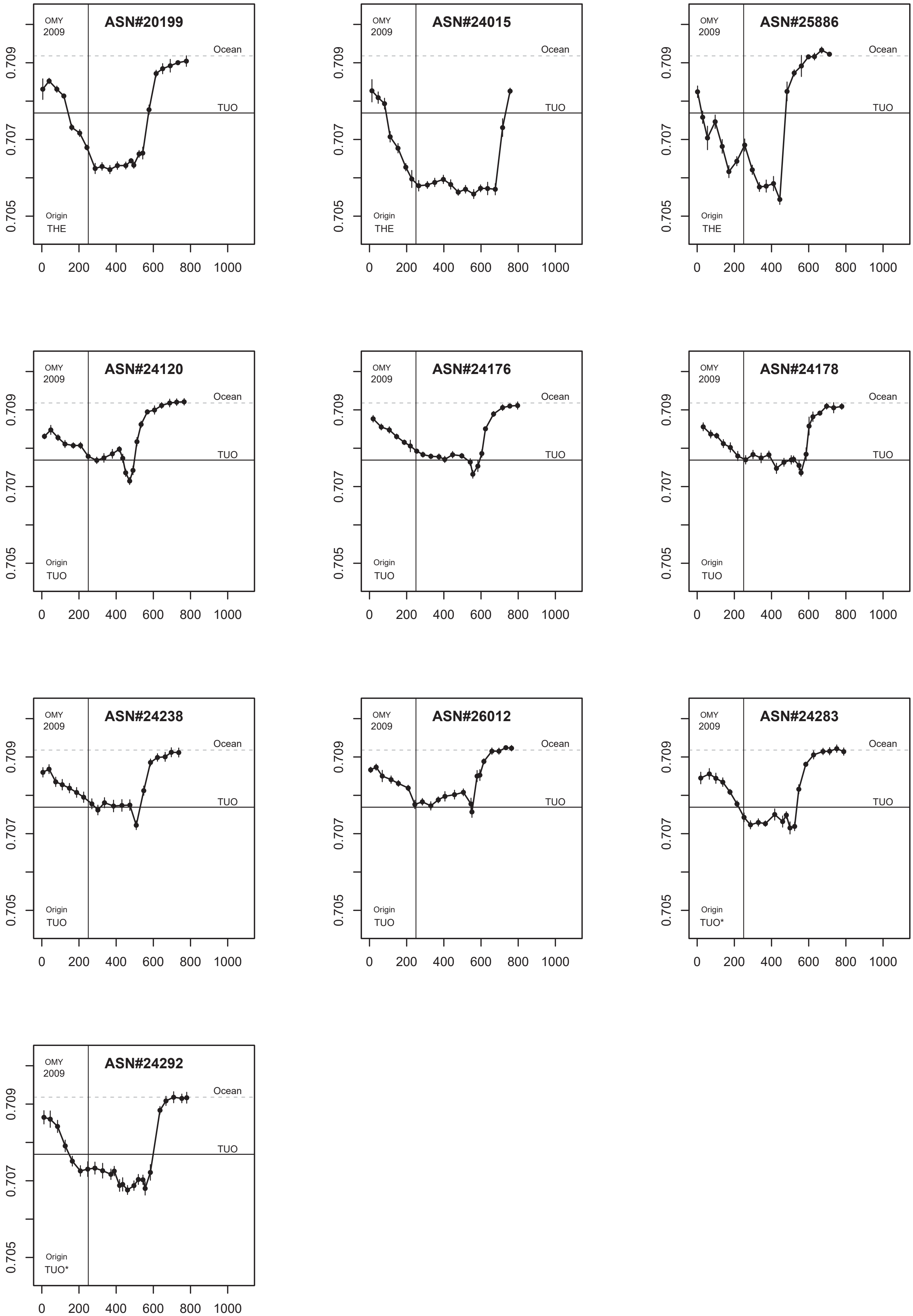
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0.705
0.707
0.709
0 200 400 600 800 1000

Study Report W&AR-11
Chinook Salmon Otolith Study

Appendix B

Response to Draft Study Report Comments by U.S. Fish and Wildlife Service

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RESPONSES TO DRAFT STUDY REPORT COMMENTS BY U.S. FISH AND WILDLIFE SERVICE

As part of the ongoing studies under the Integrated Licensing Process (ILP) for the Don Pedro Hydroelectric Project (Project), the Turlock Irrigation District and the Modesto Irrigation District, co-licensees of the Project (collectively, the Districts) conducted a study to identify the geographic origin and early life history rearing and emigration patterns of Tuolumne River fall-run Chinook salmon during above- and below-normal water year (WY) types. The draft report for W&AR-11 was provided to relicensing participants on March 16, 2015, for 30-day review. Comments on the draft report were provided on April 23, 2015 by the U.S. Fish and Wildlife Service (USFWS). This appendix repeats the USFWS comments and provides the Districts' response to each.

Page 4-5, Figure 4.2-2: How did the study address the overlap of the Tuolumne River with the Yuba River?

Although there is some geographic overlap of Sr isotope signature in various locations along the west slope of the Sierra Nevada, we are confident in the Tuolumne and Yuba River natal assignments made for this study. As stated in Appendix A, *Identification of Natal Origin*, the natal signature was determined by averaging the 87Sr/86Sr values that correspond with the otolith material deposited immediately after onset of exogenous feeding (but prior to emigration from the natal river). Linear discriminant function analysis (DFA) assignments for mean natal value were used to determine the river or hatchery of origin, with a mean 87Sr/86Sr value of 0.70823assigned to the Yuba River based upon 19 juvenile otolith samples collected in 2002, and mean 87Sr/86Sr values ranging from 0.70757 to 0.70783 assigned to the Tuolumne River based upon 54 juvenile otolith samples collected 1999–2011, as well as seven water samples collected in 1998 and 2013 (Table 3, Appendix A). However, fish that were assigned to the Yuba River by the DFA consistently had a low (<0.5) posterior probability of assignment to the Tuolumne River. As shown in Table 4 (Appendix A), the DFA assignments misclassified one of the 19 known Yuba River juvenile samples as originating from the Tuolumne River (5% error) and 5 of 61 known Tuolumne River juvenile samples as originating from the Yuba River (8% error). Since it is unlikely that a large number of wild Yuba River fish stray into the San Joaquin basin tributaries, individuals assigned to the Yuba River by the DFA were instead identified as of likely Tuolumne-origin (or "TUO*" in Appendix A) and excluded from further analysis because of the uncertainty.

Page 4-7: The report should perform a multivariate analysis to examine effects of flow regime, temperature and spawner density, similar to the analysis done by Zeug et al. (2014). In particular, the acre-days of floodplain inundation below (values based on U.S. Fish and Wildlife Service 2008) should be examined as a potential independent variable.

The comment invites an analysis of juvenile abundance in relation to potential explanatory factors analyzed by Zeug et al (2014) (i.e., spawner density, flow, temperature) as well as the influence of the duration of floodplain inundation during rearing. While the present study was not designed to examine interannual variations in juvenile production or subsequent escapement, the fact that no consistent differences in estimated growth rates were found for the outmigration years sampled (see also response to comment on Page 5-11) indicates that such a factorial data exploration would not be expected to provide additional insights into factors affecting juvenile growth trajectories or early ocean survival.

Page 5-11: Are there any density-dependent effects that might partially explain the observed year to year variation on growth rates? The statistical significant difference in growth rates given in Figure 9 of Appendix A should be given here. There is a limited ability to draw conclusions based on the small sample size (26 fish in 2003 and 5 fish in 2009).

As stated in several locations in the report, the evaluation of patterns in size and age at exit and growth rates for the below normal WY types represented in this study should consider the relatively small sample size (n=31 from outmigration years 2003 and 2009) vs. above normal/wet WY types (n=238 from outmigration years 1998–2000). However, the comment also appears to suggest that density-dependent competition for food resources within riverine, floodplain, and estuarine environments may be reflected in inter-annual variations in growth rates of juvenile fall-run Chinook salmon originating from the Tuolumne River. Although the present study was not designed to compare rearing densities by year or location, we undertook an additional analysis of individual growth trajectories accounting for ontogeny (i.e., variation in growth rates with size/age of fish) in order to further explore whether the mean increment widths (mean ±1SD) reported in Table 5.2-1 (and shown in Figure 9 of Appendix A) indicate variation in growth rate by WY and/or rearing location. Results indicate that no consistent differences in juvenile growth rates were observed by location, outmigration year or WY type in this study (see new Figures 5.2-2 and 5.2-3 in the report).

Page 6-1: "While these patterns are suggestive of a positive relationship between flow and the successful emigration of wild fish that later return as adults, confirmation of this relationship based on (Water Year) WY type should consider the relatively small sample size for below normal/dry WY types (n=31) vs. above normal/wet WY types (n=238)." While it *is* true that care must be taken when making inferences from small sample sizes, *it* is also true that the small sample sizes are the result of poor conditions. That is, that the sample size would likely have been larger had conditions during WY s 2003 and 2009 been adequate to ensure sufficient juvenile survival. Lateral, off-channel habitats (e.g. floodplain and side-channel habitats) are more likely to inundate during wetter year types, and have been shown to increase growth and survival in rearing juvenile Chinook salmon (Jeffres et al. 2008; Sommer et al. 2001; Junk et al 1989).

The Districts are well aware of the existing literature comparing fish sizes reared in floodplain and riverine environments by Sommer et al (2001) as well as studies showing increased growth in warmer side channel habitats (e.g., Jeffres et al. 2008, Limm and Marchetti 2009). While the commenter appears to suggest that inter-annual growth variations may be evident on the Tuolumne River, there is no support for this assertion in the current study because no consistent growth rate patterns were observed between WY type or rearing location (Tuolumne River vs Delta) in the present study (see also response to comment on Page 5-11).

Periods of high and low escapement of Chinook salmon originating from the Central Valley tributaries have been associated with climate driven changes in ocean conditions (MacFarlane et al 2005; Lindley et al 2009) and have been correlated with runoff patterns resulting in flood control releases and extended San Joaquin River basin outflows during spring (Speed 1993; TID/MID 1997, Report 96-5). For this reason, the low sample sizes of fish originating from below normal WY types may be attributable to a combination of factors potentially ranging from high predation rates in the Tuolumne River and Delta, to potentially poor growth conditions in riverine and estuarine habitats leading to reduced size at ocean entry, or to poor growth conditions in the Pacific Ocean. The present study was not designed to examine interannual variations in juvenile production or subsequent escapement, only the contributions of various size classes at emigration to subsequent spawner returns.

Page 6-2 states: "Based on Sr isotope ratios (87Sr/86Sr) and otolith microstructural features, the study results suggest that mean fish size at exit from the Tuolumne River showed no apparent relationship with WY type, with the exception of outmigration year 2000 when mean fish size was significantly different ($p<0.005$) from the other four years of the study. Mean fish size at freshwater exit from the Delta also did not exhibit a relationship with WY type." Is it reasonable to draw conclusions on whether or not there exists a relationship between WY type and mean fish size, given the small sample size representing below normal WY type? The sample size for dry WY types was significantly lower (2003 and 2.009 sample size = 31 fish; 15.5 fish on average per year) than wet year types (1998, 1999, & 2000 sample size = 238 fish; 79.3 fish on average per year).

As indicated in literature referenced in other comments, because studies of floodplain habitat rearing have indicated differences in fish sizes for fish reared within in-channel vs. floodplain and off channel habitats (e.g., Sommer et al 2001, Jeffres et al 2008) there is some basis to compare the results of the present study by WY type. That is, if floodplain habitats consistently provided growth benefits for rearing salmon, the high flows occurring during the above normal/wet WY types (i.e., 1998–2000) would be expected to provide evidence of enhanced growth conditions in comparison to the below normal/dry WY types represented (i.e., 2003, 2009).

Although the present study was not designed to examine interannual variations in juvenile production or subsequent escapement (see also response to comment on Page 5-11), additional analysis to standardize estimated growth rates to fish size (age), and thereby correctly account for ontogeny, indicates a high degree of growth rate variability within and between WYs and across otolith size (age) (see new Figure 5.2-3 in the report). While WY 2003 (dry) exhibits the highest estimated growth rates, variability during this year was also relatively high, and within the uncertainty of the data, it is not possible to state whether specific growth rates were in fact greater in WY 2003 than other years included in the study. The final report text has been modified accordingly.

Page 6-3: Under this discussion (Section 6.2) on growth and residence, the Districts should consider adding language discussing the potential that density-dependent factors may play a significant role in the variation in growth rate observed across years for Tuolumne River. For 2003 & 2009, a relationship could potentially exist between the low sample sizes and

the higher growth rates estimated for these years (if the low sample size is indeed indicative of low numbers of rearing fish) (see Table 5.2-1). Assuming a relationship between adult escapement numbers and juvenile rearing fish numbers: CDFW escapement values for 2003 and 2009 were 2,693 and 124 respectively; and escapement for 1998, 1999, and 2000 were 8,910, 8,232, and 17,873 respectively (representing the 3 highest escapement years over the past 28 years) (Azat 2014). This implies that significantly fewer numbers of rearing fish were present in 2003 and 2009 as compared to 1998-2000. Fewer rearing fish potentially means less competition and more resources (food & suitable rearing habitat) available, which could help to explain the higher growth rates.

While the commenter appears to suggest that inter-annual growth variations may be evident on the Tuolumne River, no consistent growth rate patterns were observed between WY type or rearing location (Tuolumne River vs Delta) in the present study (see also response to comments on Page 5-11). As stated in response to comment on page 6-1, the present study was not designed to examine interannual variations in juvenile production or subsequent escapement, only the contributions of various size classes at emigration to subsequent spawner returns.

Appendix A, Page 7, last paragraph: the text should say Fig. 9, Table 7, instead of Fig. 7, Table 9. There is no Table 9 in Appendix A.

Appendix A text has been corrected.

REFERENCES CITED IN THE RESPONSE TO COMMENTS

Jeffres, C., J. Opperman, and P. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83:449-458.

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Turlock Irrigation District and Modesto Irrigation District (TID/MID). 1997. 1996 Report of Turlock Irrigation District and Modesto Irrigation District Pursuant to Article 58 of the License for the Don Pedro Project, No. 2299. 6 Volumes. March.

APPENDIX H

Final Report

Chinook Salmon Otolith Study

E-Filed with FERC February 2016

WATER & POWER
Serving Central California since 1887

Modesto Irrigation District
The Power to Grow

February 8, 2016

Filed via Electronic Submittal (E-File)

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, DC 20426

Subject: Don Pedro Hydroelectric Project, FERC Project No. 2299
Submittal of Final Chinook Salmon Otolith Study Report (W&AR-11)

Dear Secretary Bose:

On March 16, 2015, Turlock Irrigation District and Modesto Irrigation District (collectively, the "Districts"), co-licensees of the Don Pedro Hydroelectric Project on the Tuolumne River, provided the draft Chinook Salmon Otolith Study Report (W&AR-11) to relicensing participants for a 30-day review and comment period. On April 14, 2015, comments were received from Dr. Rachel Johnson, who oversaw the Chinook Salmon Otolith Study laboratory analysis. On April 23, 2015, the U.S. Fish and Wildlife Service provided comments. The Districts have reviewed all comments. Responses to comments from Dr. Johnson and the U.S. Fish and Wildlife Service are provided in an errata sheet and Attachment B, respectively. In addition, revisions to the study report were made based on the comments.

The Districts herewith file with FERC the final Chinook Salmon Otolith Study Report. If you have any questions about this filing, please contact the undersigned at the addresses and telephone numbers listed below.

Sincerely,

Steve Boyd
Turlock Irrigation District
P.O. Box 949
Turlock, CA 95381
(209) 883-8364
seboyd@tid.org

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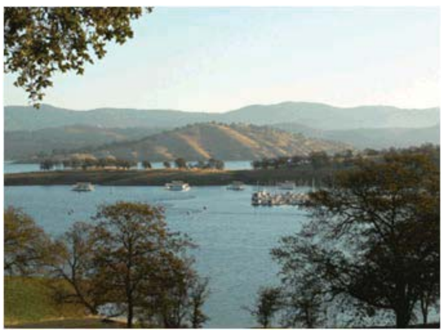
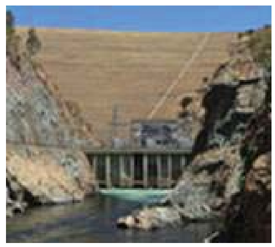
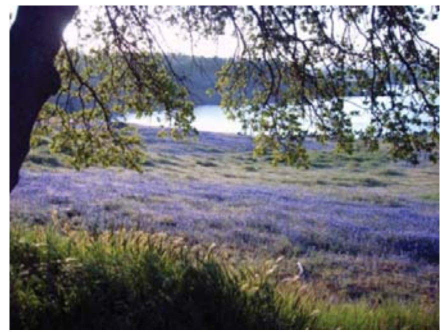
cc: Relicensing Participants E-Mail List

Attachment: Chinook Salmon Otolith Study Report (W&AR-11)

CHINOOK SALMON OTOLITH STUDY
STUDY REPORT
DON PEDRO PROJECT
FERC NO. 2299

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
Stillwater Sciences

February 2016

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This study has involved the cooperation and participation of the
California Department of Fish and Wildlife
and Dr. Rachel Johnson and Dr. Anna Sturrock
at the University of California Davis,
Department of Animal Science.

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Errata Sheet

The following changes were made to the draft study report in response to comments provided by Dr. Rachel Johnson (University of California, Davis), who oversaw the laboratory analysis conducted for W&AR-11.

Section 5.2, pages 5-11 to 5-12, various. Language to clarify that otolith data have been used to *estimate* juvenile outmigrant age, size, and growth rates, such that the reader does not misinterpret study results as actual juvenile outmigration size data rather than a reconstruction of the early life history of surviving adults.

Section 5.3.2, pages 5-20 to 5-33, including new figures 5.3-4 to 5.3-9. Inclusion of juvenile outmigrant monitoring data corresponding to water years (WYs) represented in the study, in order to better support statements about emigration patterns and variations in phenotypic contributions estimated from otolith data.

Section 6.3, page 6-3. Clarification of study findings regarding the low representation of early emigrating fry contributions to subsequent escapement.

Section 6.3, page 6-3. Reference to recent study results from the Stanislaus River, California, regarding phenotypic contributions to escapement during wet and dry water year types, as further context for the Tuolumne River results reported in this study.

Chinook Salmon Otolith Study
Study Report

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List of Acronyms

ac ....acres
ACEC ....Area of Critical Environmental Concern
AF ....acre-feet
ACOE.........................U.S. Army Corps of Engineers
AFY............................acre-feet per year
ADA ....Americans with Disabilities Act
ALJ.............................Administrative Law Judge
APE ....Area of Potential Effect
ARMR........................Archaeological Resource Management Report
BA ....Biological Assessment
BAWSCA ....Bay Area Water Supply Conservation Agency
BDCP ....Bay-Delta Conservation Plan
BEA............................Bureau of Economic Analysis
BLM ...........................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI ....Benthic macroinvertebrates
BMP ....Best Management Practices
BO ....Biological Opinion
CAISO........................California Independent System Operators
CalEPPC ....California Exotic Pest Plant Council
CalSPA.......................California Sports Fisherman Association
CALVIN ....California Value Integrated Network
CAS............................California Academy of Sciences
CASFMRA ....California Chapter of the American Society of Farm Managers and Rural Appraisers
CCC............................Criterion Continuous Concentrations
CCIC ....Central California Information Center
CCSF..........................City and County of San Francisco
CCVHJV ....California Central Valley Habitat Joint Venture
CD ....Compact Disc
CDBW........................California Department of Boating and Waterways

CDEC.........................California Data Exchange Center

CDFA.........................California Department of Food and Agriculture

CDFG.........................California Department of Fish and Game (as of January 2013, Department of Fish and Wildlife)

CDMG........................California Division of Mines and Geology

CDOF.........................California Department of Finance

CDP............................Census Designated Place

CDPH.........................California Department of Public Health

CDPR.........................California Department of Parks and Recreation

CDSOD......................California Division of Safety of Dams

CDWR........................California Department of Water Resources

CE ....California Endangered Species

CEII............................Critical Energy Infrastructure Information

CEQA.........................California Environmental Quality Act

CESA ....California Endangered Species Act

CFR............................Code of Federal Regulations

cfs...............................cubic feet per second

CGS............................California Geological Survey

CMAP ....California Monitoring and Assessment Program

CMC...........................Criterion Maximum Concentrations

CNDDB......................California Natural Diversity Database

CNPS..........................California Native Plant Society

CORP.........................California Outdoor Recreation Plan

CPI ....Consumer Price Index

CPUE ....Catch Per Unit Effort

CRAM........................California Rapid Assessment Method

CRLF..........................California Red-Legged Frog

CRRF ....California Rivers Restoration Fund

CSAS..........................Central Sierra Audubon Society

CSBP..........................California Stream Bioassessment Procedure

CT ....Census Tract

CT ....California Threatened Species

CTR............................California Toxics Rule

CTS ....California Tiger Salamander
CUWA ....California Urban Water Agency
CV ....Contingent Valuation
CVP............................Central Valley Project
CVPIA........................Central Valley Project Improvement Act
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWD ....Chowchilla Water District
CWHR........................California Wildlife Habitat Relationship
CWT...........................hundredweight
Districts ....Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA ....Don Pedro Recreation Agency
DO..............................Dissolved Oxygen
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity
EDD ....Employment Development Department
EFH ....Essential Fish Habitat
EIR ....Environmental Impact Report
EIS..............................Environmental Impact Statement
ENSO ....El Nino – Southern Oscillation
EO ....Executive Order
EPA ............................U.S. Environmental Protection Agency
ERS ....Economic Research Service (USDA)
ESA ....Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU ....Evolutionary Significant Unit
ET...............................Evapotranspiration
EVC............................Existing Visual Condition
EWUA........................Effective Weighted Useable Area
FEMA ....Federal Emergency Management Agency
FERC..........................Federal Energy Regulatory Commission

FFS............................Foothills Fault System
FL..............................Fork length
FMU..........................Fire Management Unit
FMV..........................Fair Market Value
FOT...........................Friends of the Tuolumne
FPC ....Federal Power Commission
FPPA.........................Federal Plant Protection Act
FPC ....Federal Power Commission
ft................................feet
ft/mi...........................feet per mile
FWCA.......................Fish and Wildlife Coordination Act
FYLF.........................Foothill Yellow-Legged Frog
g.................................grams
GAMS.......................General Algebraic Modeling System
GIS............................Geographic Information System
GLO ....General Land Office
GPM..........................Gallons per Minute
GPS ....Global Positioning System
HCP...........................Habitat Conservation Plan
HHWP.......................Hetch Hetchy Water and Power
HORB ....Head of Old River Barrier
HPMP........................Historic Properties Management Plan
ILP.............................Integrated Licensing Process
IMPLAN ....Impact analysis for planning
I-O.............................Input-Output
ISR ....Initial Study Report
ITA............................Indian Trust Assets
kV..............................kilovolt
LTAM ....Long-Term Acoustic Monitoring
LTR...........................Lower Tuolumne River
m ....meters
M&I...........................Municipal and Industrial
MCL..........................Maximum Contaminant Level

mg/kg ....milligrams/kilogram
mg/L...........................milligrams per liter
mgd ....million gallons per day
mi ....miles
mi^2 ....square miles
MID............................Modesto Irrigation District
MOU ....Memorandum of Understanding
MRP ....Monitoring and Reporting Program
MRWTP.....................Modesto Regional Water Treatment Plant
MSCS.........................Multi-Species Conservation Strategy
msl..............................mean sea level
MVA ....Megavolt Ampere
MW ....megawatt
MWh ....megawatt hour
mya.............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAICS........................North America Industrial Classification System
NAS............................National Academy of Sciences
NASS ....National Agricultural Statistics Service (USDA)
NAVD 88...................North American Vertical Datum of 1988
NAWQA ....National Water Quality Assessment
NCCP ....Natural Community Conservation Plan
NEPA ....National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NMP...........................Nutrient Management Plan
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent

NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP ....National Register of Historic Places
NRI.............................Nationwide Rivers Inventory
NTU ....Nephelometric Turbidity Unit
NWI............................National Wetland Inventory
NWIS ....National Water Information System
NWR ....National Wildlife Refuge
NGVD 29 ....National Geodetic Vertical Datum of 1929
O&M ....operation and maintenance
OEHHA......................Office of Environmental Health Hazard Assessment
OID ....Oakdale Irrigation District
ORV ....Outstanding Remarkable Value
PAD............................Pre-Application Document
PDO............................Pacific Decadal Oscillation
PEIR ....Program Environmental Impact Report
PGA............................Peak Ground Acceleration
PHG............................Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF............................Probable Maximum Flood
PMP............................Positive Mathematical Programming
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb.............................parts per billion
ppm ....parts per million
PSP ....Proposed Study Plan
QA..............................Quality Assurance
QC ....Quality Control
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ...............U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RMP ....Resource Management Plan
RP...............................Relicensing Participant

RR ....Recreation Resources
RSP ....Revised Study Plan
RST ....Rotary Screw Trap
RWF...........................Resource-Specific Work Groups
RWG ....Resource Work Group
RWQCB....................Regional Water Quality Control Board
SC..............................State candidate for listing under CESA
SCD...........................State candidate for delisting under CESA
SCE ....State candidate for listing as endangered under CESA
SCT ....State candidate for listing as threatened under CESA
SD1 ....Scoping Document 1
SD2 ....Scoping Document 2
SE..............................State Endangered Species under the CESA
SFP ....State Fully Protected Species under CESA
SFPUC ....San Francisco Public Utilities Commission
SHPO ....State Historic Preservation Office
SIC ....Standard Industry Classification
SJR ....San Joaquin River
SJRA ....San Joaquin River Agreement
SJRGA ....San Joaquin River Group Authority
SJTA ....San Joaquin River Tributaries Authority
SPD ....Study Plan Determination
SRA...........................State Recreation Area
SRMA ....Special Recreation Management Area or Sierra Resource Management Area (as per use)
SRMP........................Sierra Resource Management Plan
SRP ....Special Run Pools
SSC ....State species of special concern
ST..............................California Threatened Species under the CESA
STORET ....Storage and Retrieval
SWAMP....................Surface Water Ambient Monitoring Program
SWAP ....Statewide Agricultural Model
SWE ....Snow-Water Equivalent

SWP ....State Water Project
SWRCB......................State Water Resources Control Board
TAC............................Technical Advisory Committee
TAF ....thousand acre-feet
TC ....Travel Cost
TCP ....Traditional Cultural Properties
TDS ....Total Dissolved Solids
TID ....Turlock Irrigation District
TIN .... Triangular Irregular Network
TMDL ....Total Maximum Daily Load
TOC............................Total Organic Carbon
TPH ....Total Petroleum hydrocarbon
TRT ....Tuolumne River Trust
TRTAC ....Tuolumne River Technical Advisory Committee
UC ....University of California
UCCE.........................University of California Cooperative Extension
USDA.........................U.S. Department of Agriculture
USDOC......................U.S. Department of Commerce
USDOI .......................U.S. Department of the Interior
USFS..........................U.S. Department of Agriculture, Forest Service
USFWS ......................U.S. Department of the Interior, Fish and Wildlife Service
USGS .........................U.S. Department of the Interior, Geological Survey
USR............................Updated Study Report
UTM...........................Universal Transverse Mercator
VAMP ....Vernalis Adaptive Management Plan
VELB ....Valley Elderberry Longhorn Beetle
VES ....Visual Encounter Surveys
VRM ....Visual Resource Management
W&AR ....Water & Aquatic Resources
WMP ....Waste Management Plan
WPT ....Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP ....Water System Improvement Program

WTP ....Willingness to Pay

WWTP ....Wastewater Treatment Plant

WY.............................water year

μS/cm ....microSiemens per centimeter

1.0 INTRODUCTION

1.1 Background

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir has a normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2). The Project is designated by the Federal Energy Regulatory Commission (FERC) as project no. 2299.

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Don Pedro Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with agreements between the Districts and City and County of San Francisco (CCSF), the Don Pedro Reservoir also includes a "water bank" of up to 570,000 AF of storage which CCSF uses to efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. The "water bank" within Don Pedro Reservoir provides significant benefits for CCSF's 2.6 million customers in the San Francisco Bay Area.

The Don Pedro Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Don Pedro Project are recreation, protection of aquatic resources in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from RM 53.2, which is one mile below the Don Pedro powerhouse, upstream to RM 80.8 at a water surface elevation of 845 ft (31 FPC ¶ 510 [1964]). The Project Boundary encompasses approximately 18,370 ac with 74 percent of the lands owned jointly by the Districts and the remaining 26 percent (approximately 4,802 ac) owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Don Pedro Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Don Pedro Project and its primary facilities is shown in Figure 1.1-1.

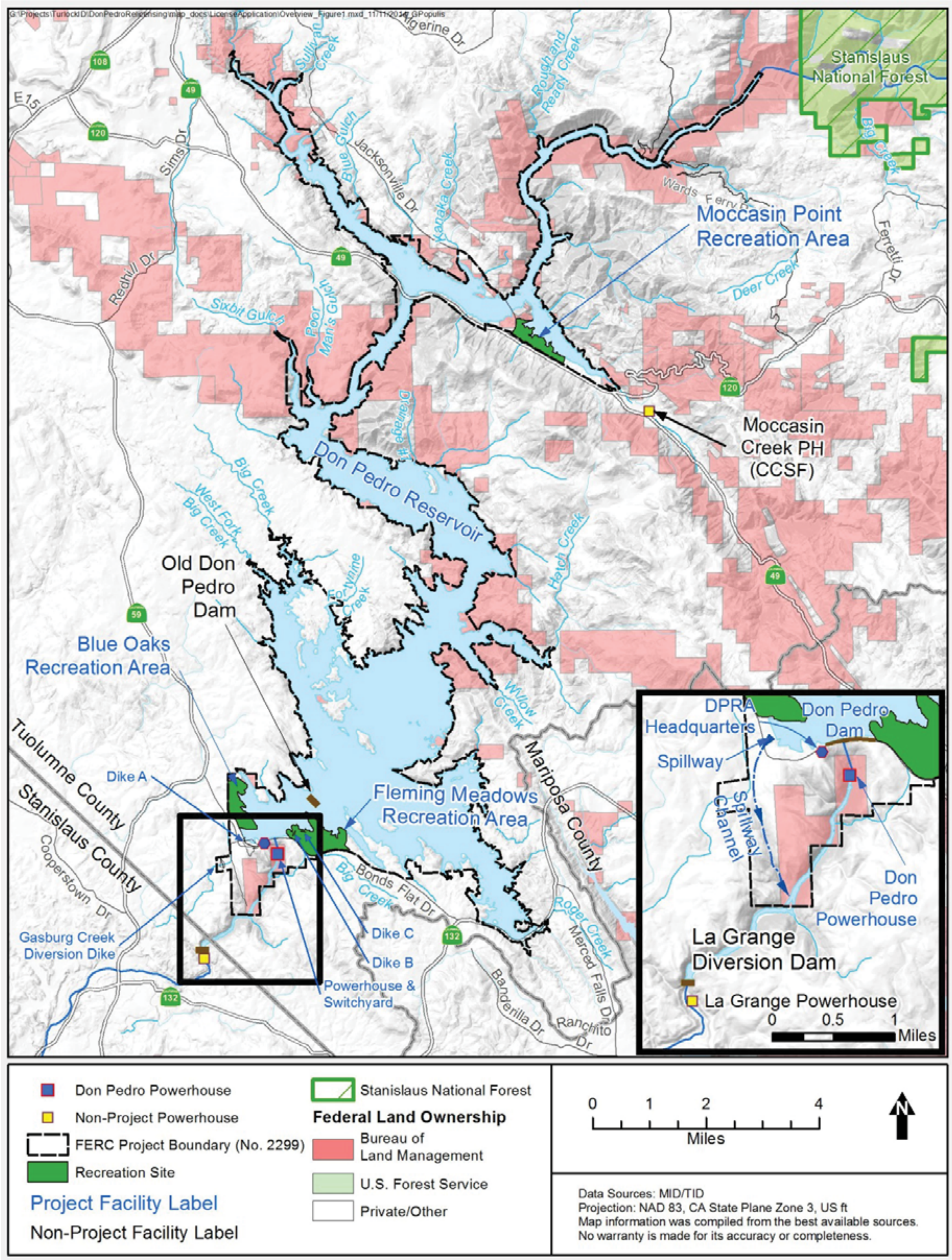

Figure 1.1-1. Don Pedro Project site location map.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts applied for a new license on April 30, 2014. At that time, and consistent with study schedules approved by FERC through the Integrated Licensing Process (ILP) study plan determinations, five important studies involving the resources of the lower Tuolumne River were still in-progress. These studies are scheduled to be completed by April 2016. Once these studies are completed, the Districts will evaluate all data, reports, and models then available for the purpose of identifying appropriate protection, mitigation, and enhancement (PM&E) measures to address the direct, indirect, and cumulative effects of Project operations and maintenance. Upon completion of this evaluation, the Districts will prepare any needed amendments to the license application.

The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, in accordance with the regulations governing the ILP. The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012. The *Chinook Salmon Otolith Study* (W&AR-11) was not a subject of the dispute resolution process.

On January 17, 2013, the Districts issued the Initial Study Report (ISR) and held an ISR meeting on January 30 and 31, 2013. The Districts filed a summary of the ISR meeting with FERC on February 8, 2013. Comments on the meeting summary and requests for new studies and study modifications were filed by relicensing participants on or before March 11, 2013, and the Districts filed reply comments on April 9, 2013. FERC issued the Determination on Requests for

Study Modifications and New Studies on May 21, 2013. The determination did not involve the study plan for the *Chinook Salmon Otolith Study* (W&AR-11).

The Districts filed the Updated Study Report (USR) on January 6, 2014; held a USR meeting on January 16, 2014; and filed a summary of the meeting on January 27, 2014. Relicensing participant comments on the meeting summary and requests for new studies and study modifications were due by February 26, 2014. The Districts filed reply comments on March 28, 2014. FERC issued the Determination on Requests for Study Modifications on April 29, 2014.

This study report describes the objectives, methods, and results of the *Chinook Salmon Otolith Study* (W&AR-11) as implemented by the Districts in accordance with FERC's December 22, 2011 Order. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at http://www.donpedro-relicensing.com/.

1.3 Study Report

Results of laboratory analyses conducted for W&AR-11 are provided in Appendix A of this study report. The draft study report (including Appendix A) was provided to relicensing participants on March 16, 2015, for 30-day review. Comments on the draft report were provided on April 23, 2015 by the U.S. Fish and Wildlife Service (USFWS). Responses to draft study report comments are presented in Appendix B. Additional comments on the draft report were provided by Dr. Rachel Johnson (University of California, Davis), who oversaw the laboratory analysis, on April 14, 2015. Changes made to the draft report based on Dr. Johnson's comments are presented in the errata sheet included above.

2.0 CHINOOK SALMON OTOLITH STUDY GOALS AND OBJECTIVES

Otoliths (commonly referred to as "earstones") are calcium carbonate structures in the inner ear of fish that grow in proportion to the overall growth of the individual, such that daily or weekly growth increments can be measured to allow the age and fish size at various habitat transitions to be identified. Through analysis of otoliths, the goal of this study was to identify the geographic origin and early life history rearing and emigration patterns of Tuolumne River Chinook salmon during above- and below-normal water year (WY) types. Examination of otolith microstructure has been used to identify differing rearing environments of juvenile salmon (e.g., Neilson et al. 1985) as well as differences in rearing temperatures (Zhang et al. 1995; Volk et al. 1996). Additionally, using one of several methods of microchemical analysis, the concentrations of elements (e.g., strontium, barium, calcium) and proportions of stable strontium (Sr) isotopes in otoliths may be compared to those in the water in which the fish inhabits in order to provide a tracer of the location where the fish has been (e.g., freshwater, saltwater, natal stream) (Campana and Neilson 1985). Otolith microchemistry has been used to examine early life history rearing environments of salmonids to address questions of streams of natal origin (Ingram and Weber 1999; Campana and Thorrold 2001) as well as the timing of entry into estuarine and saline environments (Zimmerman 2005).

This study applies microstructural and microchemical analysis of otoliths to address questions regarding the success of various early life-history emigration patterns of fall-run Chinook salmon originating from the Tuolumne River. Early life history events in juvenile salmonid development, including incubation, emergence, and habitat transitioning, can be linked to otolith microstructural patterns due to the thermal, physical, and chemical regime under which these fish were reared. Identification of the natal streams of adults that spawn in the Tuolumne River may allow additional quantification of straying rates from other rivers and, hence, more accurate assessments of the population size of indigenous Tuolumne River salmon. The relative contribution of emigrant fry, parr and smolts to subsequent escapement may have implications for the magnitude and timing of flow in the Tuolumne River, as well as the timing of operations of barriers and export facilities in the southern Sacramento and San Joaquin River delta (Delta[1]).

In brief, the study objectives were to use otolith microstructural growth patterns and/or microchemistry in order to identify:

- whether returning adults originated from hatcheries or riverine environments other than the Tuolumne River; and,
- growth rates and sizes of 'wild' fish at exit from the Tuolumne River and from the freshwater Delta.

[1] The Delta received its first official boundary in 1959 with the passage of the Delta Protection Act (Section 12220 of the California Water Code), with the southern boundary in the San Joaquin River located at Vernalis (RM 69.3) and a western boundary at the confluence of the Sacramento and San Joaquin Rivers (RM 0) near Chipps Island.

3.0 STUDY AREA

The study area consists of locations of Chinook salmon carcass recoveries collected by California Department of Fish and Wildlife (CDFW) from the lower Tuolumne River, typically extending from approximately 0.5 miles downstream of the lower end of the La Grange powerhouse tailrace (RM 51.6) to the end of routine spawning surveys at approximately RM 21.2. The lower San Joaquin River from the Tuolumne River confluence (RM 84) to Vernalis (RM 69.3), Delta, San Francisco Bay Estuary[2], and the Pacific Ocean are also addressed in terms of their use by rearing and emigrant juvenile life stages of Chinook salmon.

[2] The greater San Francisco Bay estuary extends from the Golden Gate Bridge in San Francisco Bay eastwards across salt and brackish water habitats included in San Leandro, Richardson, San Rafael, and San Pablo bays, as well as the Carquinez Strait, Honker, and Suisun bays further to the east near the western edge of the Delta.

4.0 METHODOLOGY

4.1 Existing Data Compilation

This study relied upon the existing inventory of fall-run Chinook salmon otoliths sampled from unmarked carcasses collected by CDFW during annual spawner escapement surveys in the lower Tuolumne River, which are typically conducted from October to early-January. Otoliths were provided cooperatively by CDFW under a memorandum of understanding (MOU) with the Districts and the Department of Animal Science, University of California, Davis (UC Davis). In order to examine potential variations in early life-history emigration patterns, otoliths were selected to represent returning adults that had emigrated during five focus years (1998, 1999, 2000, 2003, and 2009), representing "above normal" or "wet" and "below normal" or "dry" WY types[3]. With a sampling goal of obtaining 100–200 otoliths from each outmigration year for laboratory analysis, these five years were also selected because they represented years with the greatest number of available samples from the existing CDFW inventory. The sampling goal was met for the above normal/wet WY types 1998, 1999, and 2000, but was not met for the below normal/dry WY types 2003 and 2009, which had comparatively fewer samples available (Table 4.2-1). As the otoliths were collected from unmarked fish, the samples did not include known hatchery-origin fish[4].

4.2 Laboratory Otolith Analysis

A summary of the otolith analytical methods is provided below, with additional details provided in Sturrock and Johnson (2014), which is appended to this study report as Appendix A.

4.2.1 Adult sampling and cohort reconstruction

Adult salmon from a given outmigration year typically return between 2 and 5 years later with the greatest proportion returning after 3 and 4 years respectively in historical Tuolumne River spawner surveys (TID/MID 2014a). Thus, for each outmigration year that was examined in this study, otolith samples were recovered from carcasses collected over several escapement years (Table 4.2-1). Experts at CDFW determined the ages of the adult samples by counting scale winter annuli from unmarked adult salmon carcasses in accordance with established and validated techniques (Guignard 2008). Information regarding the date of collection, location, fish length, sex, and estimated age-at-return were provided by CDFW for each otolith sample.

[3] CDWR Bulletin 120 estimates unimpaired runoff as TAF for the San Joaquin River and tributaries. The San Joaquin Basin 60-20-20 Index classifies water years (October 1 through September 30) into five basic types (C=Critical, D=Dry, BN=Below Normal, AN=Above Normal, W=Wet) which are further refined under Article 37 of the FERC (1996) license. For the purposes of this report, the broader CDWR Water Year types are used as a basis of discussion.

[4] Although the Merced River Fish Facility (MRFF) does not participate in the Constant Fractional Marking Program implemented since 2007, the MRFF historically only marked a proportion of hatchery fish, and that proportion has varied over time.

Table 4.2-1. Otolith sampling inventory by juvenile cohort and outmigration WY type collected from unmarked adult salmon carcasses in the Tuolumne River between 1999 and 2012. Source: Sturrock and Johnson (2014).

Juveniles Represented			Adults Sampled			
Spawning year[1]	**Outmigration year[2]**	**WY type during rearing & outmigration[3]**	**Escapement year[4]**	**Estimated age at return (yr)[5]**	**Number of individuals sampled**	**% of total sample**
1997	1998	Wet	1999	2	0	0%
			2000	3	124	62%
			2001	4	76	38%
			Sum		**200**	**100%**
1998	1999	Above normal	2000	2	9	6%
			2001	3	64	44%
			2002	4	73	50%
			Sum		**146**	**100%**
1999	2000	Above normal	2001	2	31	28%
			2002	3	79	72%
			2003	4	0	0%
			Sum		**110**	**100%**
2002	2003	Below normal	2004	2	0	0%
			2005	3	87	91%
			2006	4	9	9%
			Sum		**96**	**100%**
2008	2009	Below normal	2010	2	14	30%
			2011	3	30	65%
			2012	4	2	4%
			Sum		**46**	**100%**
TOTAL					**598**	

1 Although CDFW uses the term "brood-year" to designate the year in which fry first emerge (typically December), here we simply indicate the year in which the majority of spawning occurred.
2 Outmigration-year designation is based on the timing of the first juveniles' departure from the natal river.
3 CDWR Bulletin 120 estimates unimpaired runoff as TAF for the San Joaquin River and tributaries. The San Joaquin Basin 60-20-20 Index classifies WYs (October 1 through September 30) into five basic types (C=Critical, D=Dry, BN=Below Normal, AN=Above Normal, W=Wet), which are further refined under Article 37 of the FERC (1996) license. For the purposes of this report, the broader CDWR WY types are used as a basis of discussion.
4 Sampled during CDFW annual spawner escapement surveys.
5 Estimated from CDFW scale readings.

4.2.2 Strontium isotope analysis

Adult otoliths were prepared and analyzed for strontium isotopic ($^{87}Sr/^{86}Sr$) ratios using standard techniques described in Sturrock and Johnson (2014). In brief, the technique relies on detecting daily deposition of chemical elements from the surrounding environment in otolith growth rings, producing a distinct and reproducible "chemical fingerprint". In the California Central Valley, strontium isotopes ($^{87}Sr/^{86}Sr$) are ideal markers because the water signature varies with watershed geology, therefore differing among many of the rivers and salmon outmigration paths (Ingram and Weber 1999; Barnett-Johnson et al. 2008).

Otoliths were rinsed and cleaned of adhering tissue, then mounted in resin and polished until each primordial core (i.e., center) was exposed. Each otolith was sampled at multiple spots along a 90° radial transect starting at the primordial core and ending just past the point of ocean entry (also called the "freshwater exit"), in order to ensure inclusion of the full freshwater outmigration period in the analysis (Figure 4.2-1). At each sample spot, $^{87}Sr/^{86}Sr$ ratios were determined by multi-collector laser ablation inductively coupled plasma mass spectrometry (MC-LA-ICPMS) (Barnett-Johnson et al. 2005). To improve the spatial resolution and accuracy of the ocean entry spot identification and outmigration fork length (see also Section 4.2.4), additional $^{87}Sr/^{86}Sr$ sample spots were re-sampled at the region representing an isotope ratio shift (e.g., the Tuolumne-San Joaquin River transition).

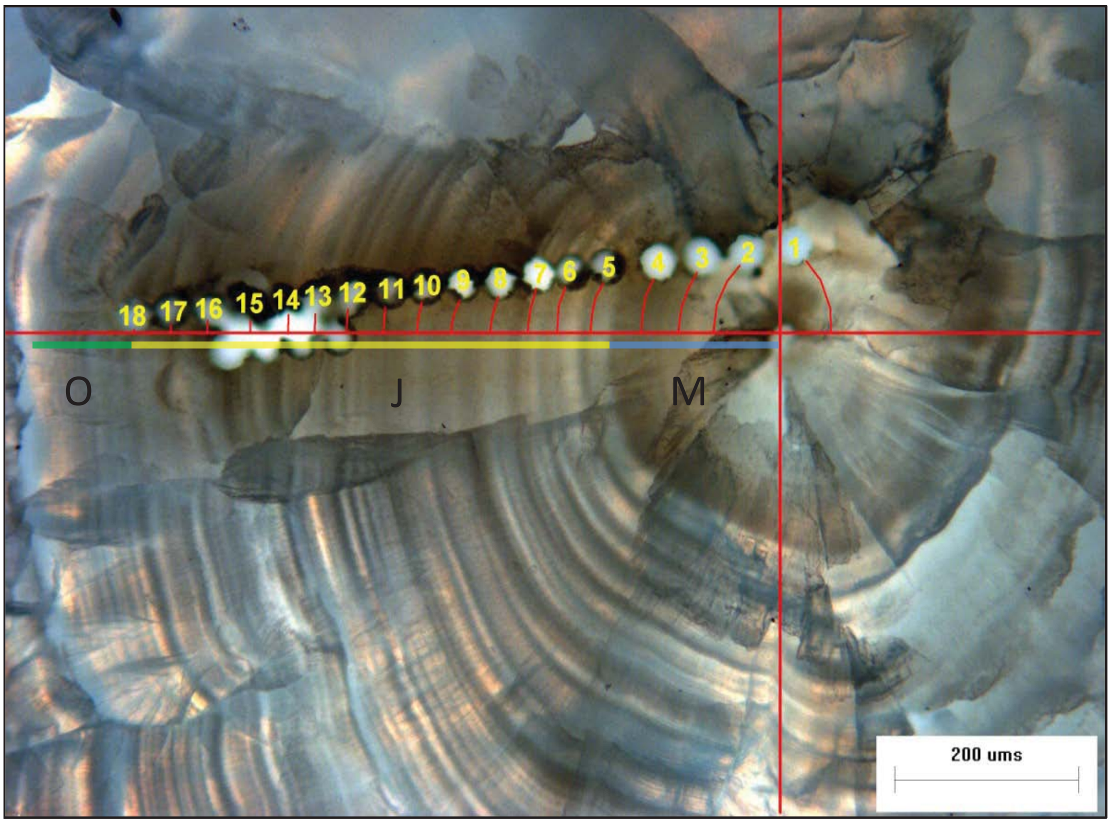

Figure 4.2-1. **A typical 87Sr/86Sr transect showing spot analyses (numbered) from the core to ocean entry. The life history stages are indicated by letters: maternal (M), juvenile (J) and ocean (O). The distance at which the final 'natal spot' intersected the 90° transect (indicated by curved red lines) was used to back-calculate size at outmigration. 'Respots' occurred at positions 12.5 to 15.5 used to more accurately identify exit point. Source: Sturrock and Johnson (2014).**

4.2.3 Identification of natal origin

To identify the natal origin of the otolith samples, measured $^{87}Sr/^{86}Sr$ ratios were statistically compared to a "strontium isoscape" comprised of the previously published $^{87}Sr/^{86}Sr$ baseline for California Central Valley rivers and hatcheries, additional Sr isotope values of otolith samples from juveniles and coded wire tag (CWT) adults known to originate from the Tuolumne River, and Sr isotope values from Tuolumne River and San Joaquin River water samples collected in 2014 (Ingram and Weber 1999; Sturrock and Johnson 2014). The resulting strontium isoscape included a total of 480 tissue and water samples from all potential natal sources in the California Central Valley, with many sites sampled across multiple years (1998–2013) and hydrologic regimes (Sturrock and Johnson 2014, Table 3).

Given the variability in Sr isotope values in water samples from upper to lower reaches of the lower Tuolumne River (Ingram and Weber 1999; Sturrock and Johnson 2014), juveniles collected in the Tuolumne River tend to exhibit more variable isotopic signatures within and among individuals than in other rivers in the Central Valley (Figure 4.2-2). Additionally, otolith $^{87}Sr/^{86}Sr$ values of known-origin Tuolumne River fish, Mokelumne River Hatchery and Feather River Hatchery can overlap (Figure 4.2-2), increasing the potential of misclassifying Tuolumne-origin fish. To improve assignment accuracy, any otolith samples exhibiting ambiguity in their natal assignment were also analyzed for otolith microstructural features that can discriminate hatchery from wild fish. Following methods developed for California Central Valley Chinook (Barnett-Johnson et al. 2007), individuals were classified as hatchery or wild based on the prominence of the exogenous feeding check (scored blind by 2–3 independent readers) and the mean and variance in increment width around the first 30 daily increments following onset of exogenous feeding after fry emergence from the spawning gravels.

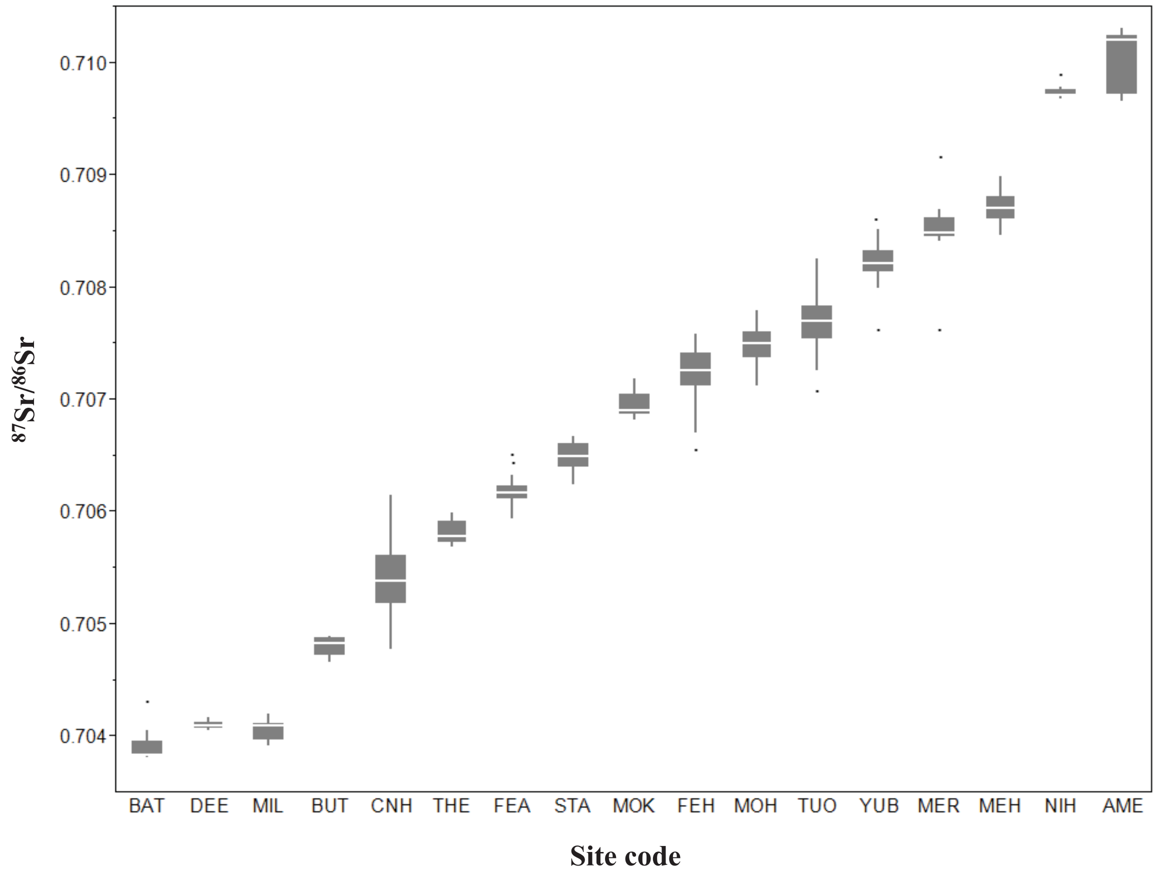

Figure 4.2-2. Differences in 87Sr/86Sr values among sites in the California Central Valley. Source: Sturrock and Johnson (2014). Due to overlap among the Tuolumne River (TUO), Mokelumne River Hatchery (MOH), and Feather River Hatchery (FEH), all fish identified as potentially originating from the Tuolumne River using Sr isotopes were also assigned to hatchery/wild using otolith microstructure. Other side codes: Battle Creek (BAT), Deer Creek (DEE), Mill Creek (MIL), Butte Creek (BUT), Coleman National Fish Hatchery (CNH), Thermalito Rearing Annex (THE), Feather River (FEA), Stanislaus River (STA), Mokelumne River (MOK), Yuba River (YUB), Merced River (MER), Merced River Hatchery (MEH), Nimbus Hatchery (NIH), American River (AME).

4.2.4 Reconstructing size and age at outmigration

Variations in the $^{87}Sr/^{86}Sr$ ratio along the sampling transect were used to indicate the location and thus life history timing of emigration from the Tuolumne River ('natal exit') using the distance from the otolith primordial core to the 'last natal spot'. The 'last natal spot' rather than the 'first non-natal spot' was used because to accrete sufficient new otolith material to modify the isotopic composition of the otolith, the fish would have inhabited isotopically distinct (i.e., non-natal) water for several days, after which time it would be a significant distance downstream of the Tuolumne-San Joaquin River confluence. The 'last natal spot' was identified by working backwards from the final inflection point indicative of ocean-bound migration, and using the spot just prior to the lowest point of inflection, where the latter represented likely movement through the San Joaquin River (Sturrock and Johnson 2014, Figure 3, Plots A, B, and C). The only exceptions were on occasions when the lowest point prior to ocean migration was lower than any value measured in the San Joaquin River (Sturrock and Johnson 2014, Figure 3, Plot D); on these occasions the lowest point was assumed to have been deposited while the fish was rearing in the lower Tuolumne River, which has been shown to exhibit $^{87}Sr/^{86}Sr$ values as low as 0.7066 (Sturrock and Johnson 2014).

The point of emigration from freshwater ('freshwater exit') was defined as the distance at which otolith $^{87}Sr/^{86}Sr$ values last reached 0.7080 (equivalent to a salinity of 1ppt based on Hobbs et al. 2010), determined using linear interpolation.

In order to estimate fish size at the natal and freshwater exit points, radial otolith distances to these points were measured for use with an existing relationship between otolith radius and fork length (FL) from the California Central Valley fall run Chinook salmon Evolutionarily Significant Unit (ESU) (Zabel et al. 2010). Juvenile reference samples for the Zabel et al. (2010) relationship were collected at various locations including samples from the Tuolumne River (2003; n = 6), Stanislaus River (2000 and 2002; n = 95), the Coleman National Fish Hatchery (2002; n=40) and in the San Francisco Bay at Golden Gate Bridge (2005; n = 83) (Figure 4.2-3). While the small number of Tuolumne-origin fish included in the relationship tended to sit above the mean regression line (Figure 4.2-3), there was no significant difference between the back-calculated fork length of Tuolumne vs. non-Tuolumne fish, nor any difference in the slopes (Sturrock and Johnson 2014). The uncertainty in the otolith radius-fork length regression was used to estimate 95% confidence intervals (CI) for the estimated juvenile fork lengths associated with individual adult otolith samples.

For each length estimate at natal exit from the Tuolumne River, fish were classified as fry (<50 mm FL), parr (≥50 to <70 mm FL), and smolt (≥70 mm FL) in this report. Although these size cutoffs are 5 mm larger than those from the Mokelumne River (Miller et al. 2010) used in Sturrock and Johnson (2014), the Tuolumne River size cutoffs were re-assigned here based upon operational definitions used in juvenile outmigration studies (TID/MID 2014b). For example, the smallest sized juveniles reported as smolts in historical sampling range as low as 65 mm FL in some years (Stillwater Sciences 2013a).

Fish age at outmigration was determined by counting daily growth bands and measuring widths between daily increments along the same 90° radial transect as the $^{87}Sr/^{86}Sr$ analysis, beginning at the point when the maternal yolk sac is depleted and exogenous feeding begins ("post exogenous feeding check") until freshwater exit from the Delta to the San Francisco Bay and Pacific Ocean. Some otoliths were difficult to age and given low readability scores (1-2); ages were not provided for these individuals. The ages of fish at natal exit from the lower Tuolumne River, freshwater exit from the Delta, and habitat-specific growth rates were obtained for fish with otolith readability scores of 3–5. A subset of otoliths was aged by two independent readers, providing an estimate of error associated with fish aging. The two independent reads of each fish demonstrated high agreement, with an average difference of ± 5 days (range 0–12 days).

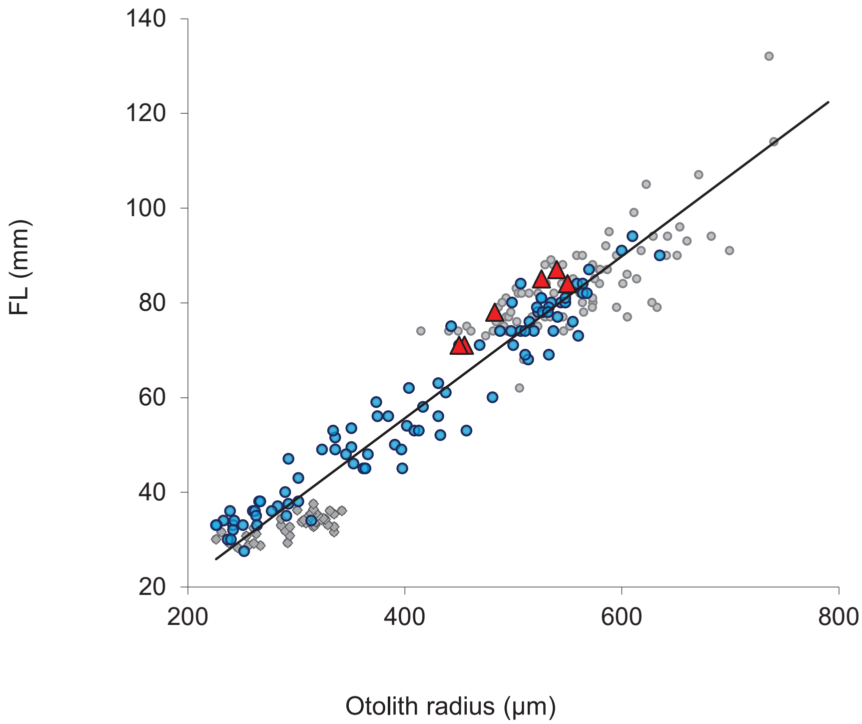

Figure 4.2-3. **Relationship between otolith radius and fork length (FL) of juveniles of known origin from the California Central Valley fall run Chinook salmon Evolutionarily Significant Unit (ESU). (n=224, r2 = 0.92) Red triangles = Tuolumne River (n = 6); blue circles = Stanislaus River (n = 95); grey diamonds = Coleman National Fish Hatchery (n=40); grey circles = San Francisco Bay at Golden Gate Bridge unknown origin (n = 83). Source: Sturrock and Johnson (2014).**

4.3 Analysis of Potential Flow Relationships

Tuolumne River hydrologic patterns were explored for each of the five outmigration years using available flow data for gages at La Grange (USGS #11289650), Modesto (USGS #11290000), and Vernalis (USGS #11303500). Daily flow data were pooled to develop flow metrics at 2-week and monthly intervals from January through June, including minimum, maximum, and mean Tuolumne River discharge. Each of the Tuolumne River flow metrics were used in linear regressions against fish size at natal exit and fish age at natal exit (determined by the otolith analyses) for each of the five outmigration years included in the study (1998, 1999, 2000, 2003, and 2009).

Average daily flow magnitude and timing were also examined in combination with mean fish size and age at exit from the Tuolumne River and the Delta to determine any potential relationships between flow and fish age/size at exit. This exploratory analysis was undertaken to determine whether flow may explain various early life-history emigration patterns of juvenile salmon from differing WY types.

Delta hydrologic patterns were investigated using California Department of Water Resources (CDWR) DAYFLOW data, including 24 flow parameters and indices characterizing the following (CDWR 2015):

- daily river inflows (e.g., Sacramento, Yolo, Cosumnes, Mokelumne, San Joaquin, Calaveras plus other miscellaneous creek flows);
- interior Delta flows (e.g., Delta Cross Channel and Georgiana Slough, Jersey Point, Rio Vista);
- water exports and diversions/transfers (e.g., Central Valley Project at Tracy, Contra Costa Water District Diversions at Middle River, Rock Slough, Old River, North Bay Aqueduct, State Water Project);
- estimates of Delta agriculture depletions; and,
- fish-related flows (i.e., percent water diverted, effective Western/Central Delta inflow, effective percent Western/Central Delta water diverted).

Daily average flow data for each of the DAYFLOW 24 parameters/indices were pooled into aggregated monthly averages from January through June. Each of these averages were used in exploratory linear regressions against fish size at freshwater exit and fish age at freshwater exit for each of the five outmigration years included in the study (1998, 1999, 2000, 2003, and 2009).

5.0 RESULTS

5.1 Natal Origin

Analysis of Sr isotope ratios ($^{87}Sr/^{86}Sr$) and microstructural features (see Section 4.2.3) in otoliths collected from unmarked Chinook salmon carcasses indicated both wild- and hatchery-origin fish in Tuolumne River spawning adults corresponding to outmigration years 1998, 1999, 2000, 2003, and 2009 (Figure 5.1-1). The earliest three years exhibited the highest numbers of Tuolumne River returning wild fish, with smaller numbers of wild fish exhibiting Sr isotope ratios indicating straying from the Stanislaus, Merced, and Mokelumne rivers. The hatchery component in these outmigration years was primarily from the Merced and Mokelumne river hatcheries, with smaller contributions from the Feather River and Nimbus hatcheries. Overall, returning wild fish made up 38–68% of the sample of unmarked fish for outmigration years 1998–2000 (Table 5.1-1). For outmigration years 2003 and 2009, relatively low numbers of returning wild fish were present in the sample, with larger hatchery components primarily from the Mokelumne River Hatchery (2003) and the Coleman National Fish Hatchery (2009) (Table 5.1-1). Overall, returning wild fish made up 9–25% of the sample for outmigration years 2003 and 2009 (Table 5.1-1). Considering all five outmigration years combined (n=598), 54% of the unmarked fish samples were identified as wild and of Tuolumne River origin (n=321), 43% were identified as hatchery-origin (n=255), and 4% were identified as wild strays from other rivers (n=22).

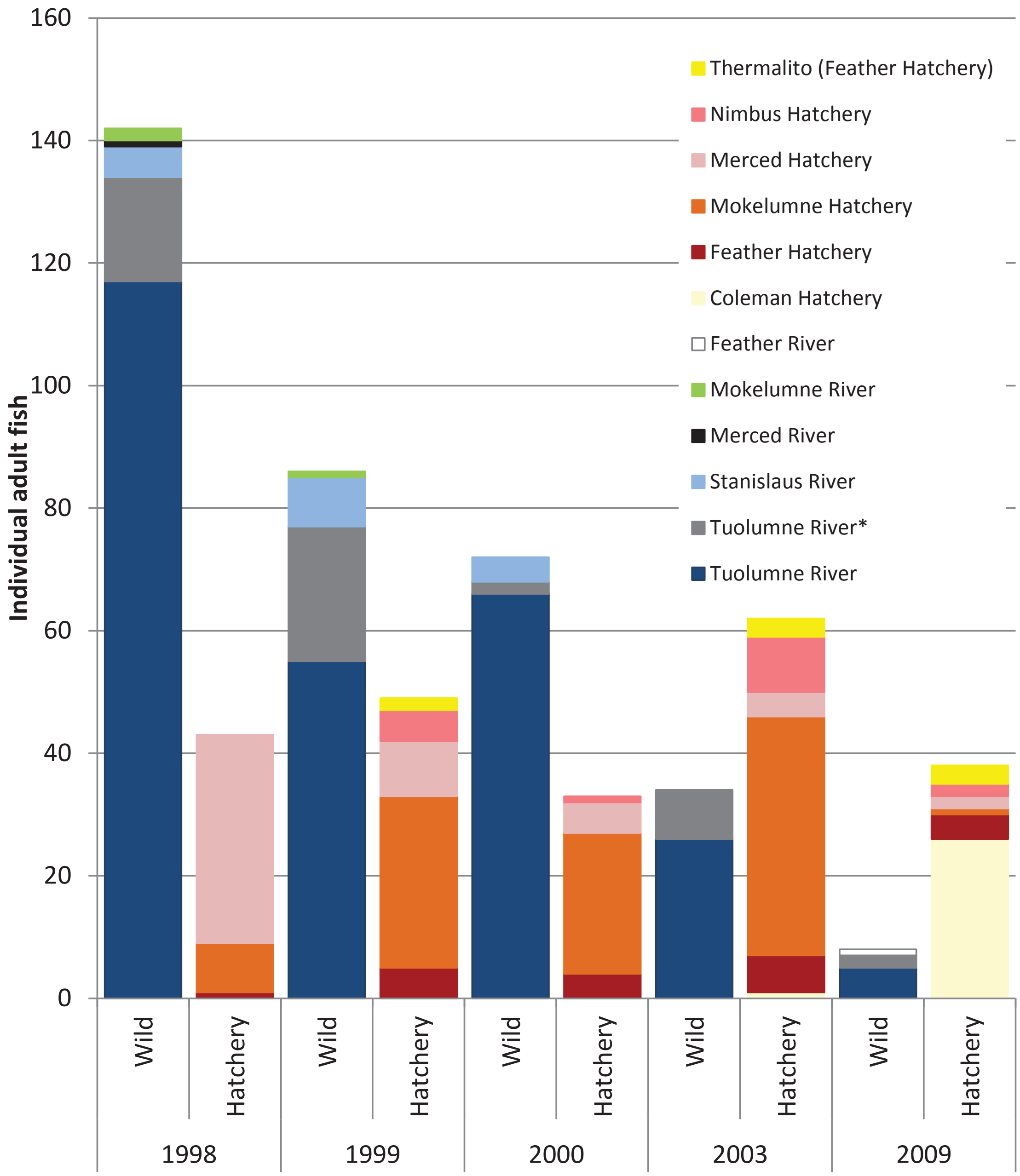

Figure 5.1-1. **Natal origin of all unmarked fish (n=598) analyzed for outmigration years 1998, 1999, 2000, 2003 and 2009. [*] indicates individuals assigned to the Tuolumne River with <0.5 posterior probability based on mean natal 87Sr/86Sr values or individuals assigned to the Tuolumne River, but with inconclusive hatchery/wild assignment based on otolith microstructure. Data from Sturrock and Johnson (2014).**

Table 5.1-1. Summary of straying and return rates to the Tuolumne River for unmarked fish (n=598). Data from Sturrock and Johnson (2014).

Outmigration year	San Joaquin River Index Water Year Type[1]	Sample size	Returns (Wild)[2]	Strays (Wild and Hatchery)[2]	Primary origin of strays
1998	Wet	200	57–68%	33–44%	Merced Hatchery
1999	Above normal	146	38–53%	47–62%	Mokelumne Hatchery
2000	Above normal	110	61–64%	36–39%	Mokelumne Hatchery
2003	Below normal	96	27–35%	65–73%	Mokelumne Hatchery
2009	Below normal	46	9–15%	85–91%	Coleman Hatchery

1 San Joaquin Basin 60-20-20 Index from CDWR Bulletin 120.
2 Range in natal assignment is based on probabilities associated with the isotope-based discriminant function analysis and reference samples from existing or ongoing projects.

5.2 Growth and Residency of Juveniles

Estimated mean fish size at exit from the Tuolumne River based on otolith analyses ranged 63.5–76.0 mm, with the lowest mean size exhibited in outmigration year 2000. The year 2000 mean size was significantly different ($p<0.005$) from that estimated for the other four years of the study. Similarly, estimated age at exit from the Tuolumne River was lower in outmigration year 2000 (68.5 days) as compared with that of other years, although there was generally higher variability in age at exit such that no single year was statistically lowest (Table 5.2-1).

Estimated mean fish size at freshwater exit from the Delta based on otolith analyses ranged 77.4–83.4 mm, with slightly greater variability within years than that of the Tuolumne River (Table 5.2-1). Examination of the distributions of age at exit from the Tuolumne River and the Delta suggests that overall the total days from the end of exogenous feeding (i.e., emergence from gravels) to ocean entry was relatively constant at 99±20 days for each of the five outmigration years, such that fewer days spent rearing in the Tuolumne River resulted in relatively more days rearing in the Delta (Figure 5.2-1).

Table 5.2-1. Summary of estimated fish size, age, and increment widths (mean ±1SD) at natal exit and freshwater exit by outmigration year for juveniles that originated in and returned to the Tuolumne River. Source: Sturrock and Johnson (2014).

Out-migration year (WY Type[2])	Sample Size	Tuolumne River			Delta		
		FL at exit (mm)	No. increments (days)	Increment width[1] (um)	FL at exit (mm)	No. increments (days)	Increment width[1] (um)
1998 (W)	117	73.3 ± 8.5	91.0 ± 16.2	3.07 ± 0.28	80.8 ± 9.0	15.8 ± 7.5	3.24 ± 0.54
1999 (AN)	55	72.6 ± 11.6	82.0 ± 13.6	3.20 ± 0.27	82.3 ± 11.5	16.5 ± 8.7	3.35 ± 0.56
2000 (AN)	66	63.5 ± 8.6	68.5 ± 18.6	3.10 ± 0.26	77.4 ± 6.9	27.6 ± 12.1	3.52 ± 0.52
2003 (BN)	26	71.0 ± 10.6	79.7 ± 17.9	3.39 ± 0.43	80.1 ± 10.0	10.5 ± 5.2	3.65 ± 0.62
2009 (BN)	5	76.0 ± 7.1	88.0 ± 20.3	3.36 ± 0.29	83.4 ± 6.8	16.0 ± 7.5	3.03 ± 0.36

1 Width between daily increments is a measure of growth rate.
2 San Joaquin Basin 60-20-20 Index from CDWR Bulletin 120.

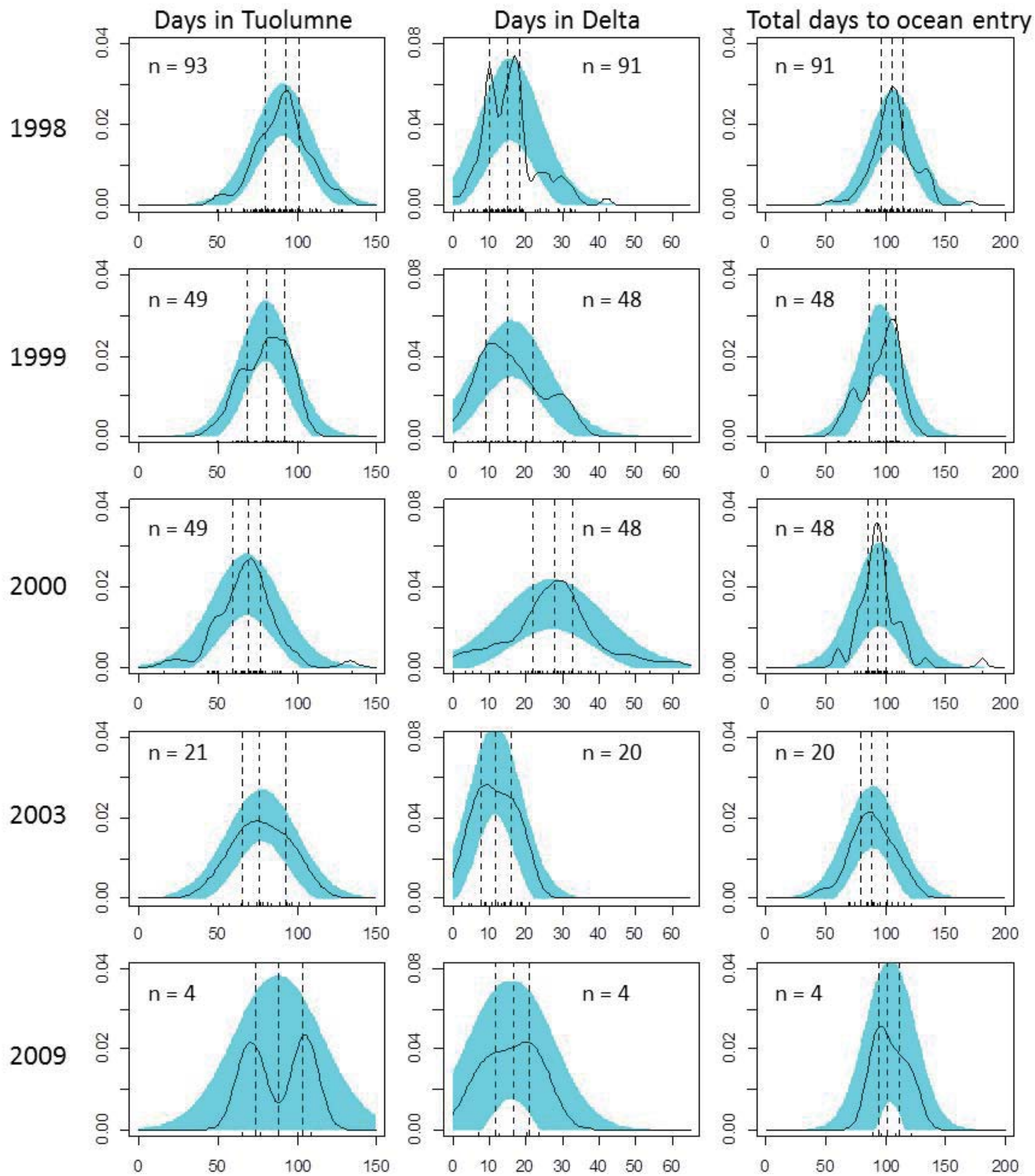

Figure 5.2-1. **Estimated days of development from formation of otolith core to ocean entry. The rug plots show values for individual otoliths from unmarked adult samples. The curves are non-parametric density estimates obtained by kernel smoothing, deliberately under-smoothed. The cyan bands encode a test for normality. The vertical dashed lines mark the data quartiles.**

Table 5.2-1 (and Figure 9 of Sturrock and Johnson 2014) presents the central tendency and general range of increment widths as an indication of growth rates in the Tuolumne River and the Delta for each WY included in this study. It should be noted, however, that Chinook growth rates vary with fish size among other factors (Titus et al 2004). Since juvenile outmigrants will generally have attained a larger size by the time they have reached Delta habitats, average growth rates in the Delta will generally be lower than for samples including a larger proportion of fish that completed the fry/parr transition within the natal river. To remove this potential effect from the analysis, a growth trajectory was created for each otolith sample by plotting increment number against distance along the otolith radial transect (um), with the transition point between Tuolumne River and Delta rearing based upon results of the Sr isotope analysis. The individual growth trajectories exhibit little discernable difference in slope between natal stream and Delta rearing locations for individual fish (Figure 5.2-2).

Additionally, specific otolith growth rates (um/d) were plotted as a function of fish size to allow direct growth rate comparisons between the Tuolumne River and the Delta for each WY included in this study. Figure 5.2-3 shows a high degree of growth rate variability for fish of the same estimated fork length in both riverine and Delta habitats, although some patterns are apparent. In two of the three wet WY types (1998, 1999), estimated growth rates in the Tuolumne River were greater than those of the Delta (95% confidence interval [CI]) for larger parr-sized individuals, corresponding to otolith distances of approximately 475 um (68 mm FL estimate) and greater. However, estimated growth rates of smaller juveniles, corresponding to otolith sizes of 425 um (60 mm FL estimate) and smaller fish, were not different between the river and the Delta during 1998 and 1999. Conversely, for the other above normal/wet WY type represented (2000), estimated growth rates in the Delta were greater than those of the Tuolumne River (95% CI) for parr-sized individuals, corresponding to otolith distances of approximately 425–475 um (60–68 mm FL estimate) and larger fish. The remaining comparisons for other otolith distances during WY 2000 fell within the 95% CI and are not statistically distinguishable. Lastly, in the dry WY types (2003, 2009), estimated growth rates for a given fish size were not different between the Tuolumne River and the Delta (95% CI), save for otolith distances 475−525 um (68−77 mm FL estimate parr and smolts) which exhibited higher estimated growth rates in the Tuolumne River.

Overall, with the exception of parr-sized individuals collected from carcasses originating from outmigration year 2000, size-standardized estimated growth rates for juveniles were generally greater in the Tuolumne River than similar-sized juveniles that reared in Delta habitats, or were not statistically distinguishable between the two rearing locations.

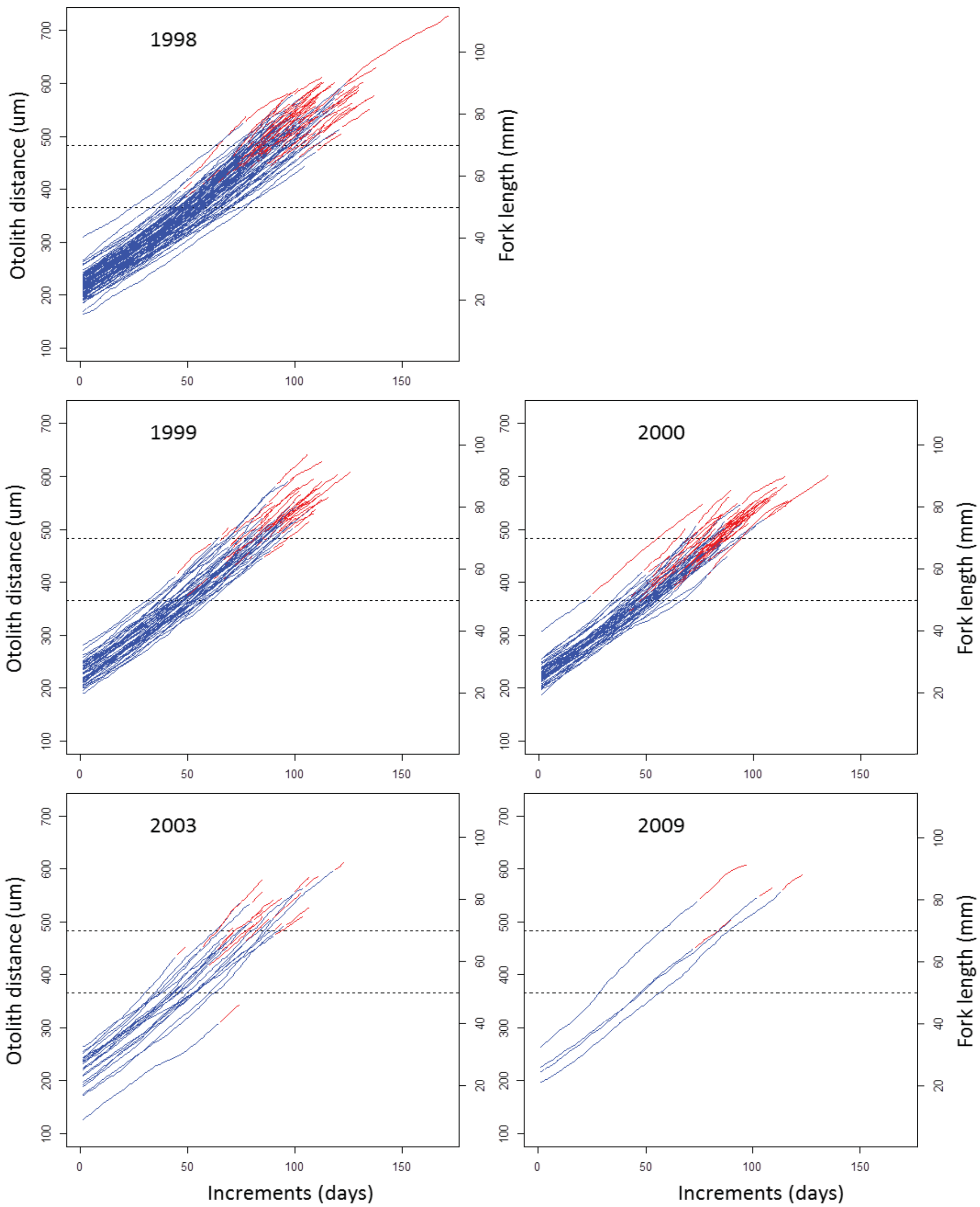

Figure 5.2-2. **Tuolumne River individual otolith growth trajectories. Each line shows data for an individual otolith. The blue portion shows growth in the Tuolumne River, the red portion shows growth after leaving the river but before entering salt water. Horizontal dashed lines indicate approximate otolith distances corresponding to the fry/parr (50 mm FL) and parr/smolt (70 mm FL) life stage transitions. Data source: Sturrock and Johnson (2014).**

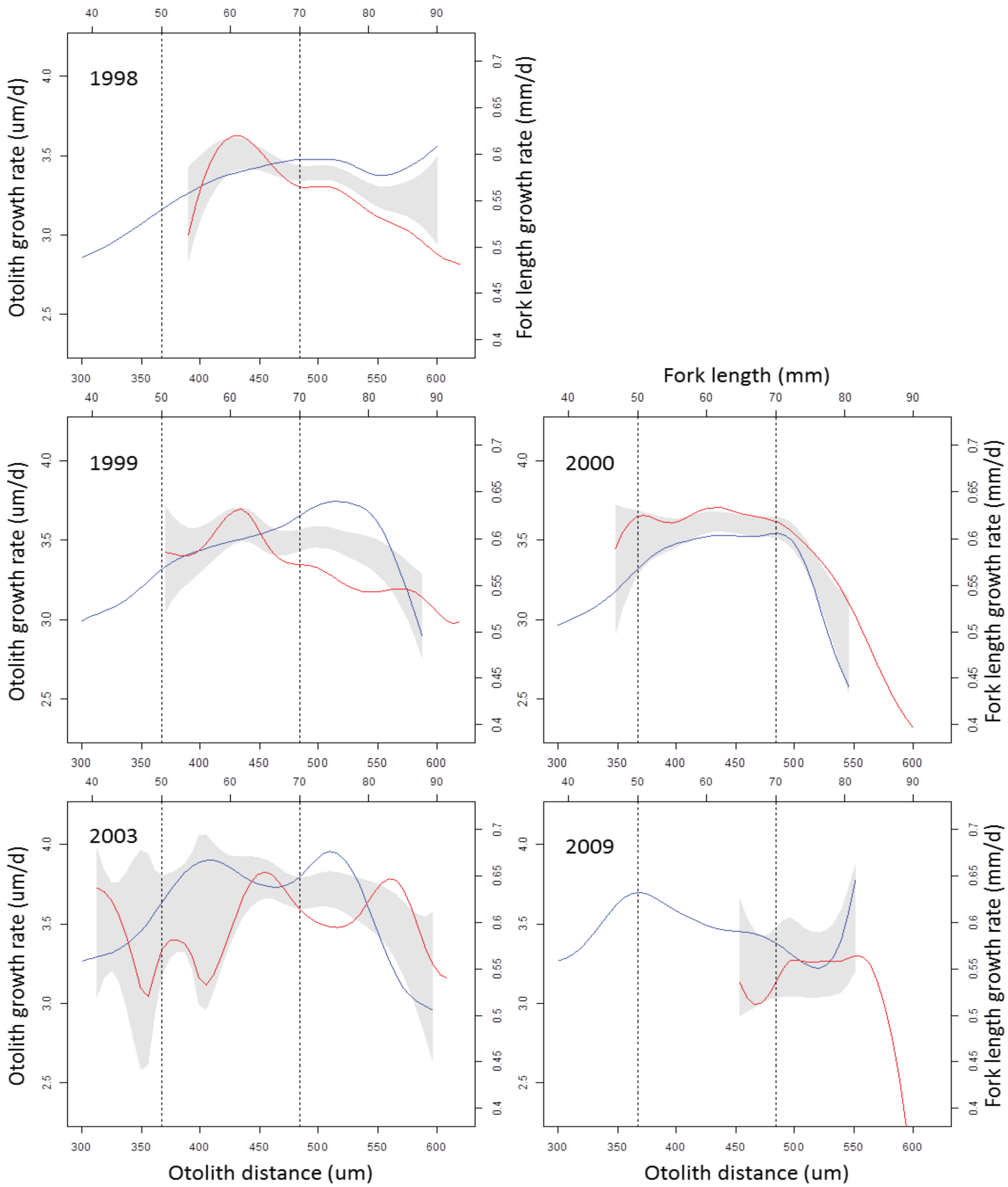

Figure 5.2-3. Tuolumne River otolith growth rates as a function of fish size. Plots present smoothed (n=20) values of daily growth increments across all samples from a given outmigration year. The grey band encodes an approximate 95% confidence band for equality between samples from the Tuolumne River (blue line) and Delta (red line) habitats. Vertical dashed lines indicate approximate otolith distances corresponding to the fry/parr (50 mm FL) and parr/smolt (70 mm FL) life stage transitions. The fitted lines are clipped to a range in which there is some overlap between the otolith sizes. Data source: Sturrock and Johnson (2014).

Using size cutoffs for juvenile life stage transitions in the Tuolumne River (fry <50 mm FL, parr ≥50 to <70 mm FL, and smolt ≥70 mm FL), emigrants from all juvenile life stages were represented in the returning adult spawning population. However, Tuolumne-origin adults were overwhelmingly comprised of individuals that had emigrated from the Tuolumne as parr and smolts, with only small contributions from fry-sized emigrants evident in 2000 and 2003 (Table 5.2-2). In 2000, a relatively high percentage of the returning adults had emigrated as parr (70%). In 2009, although the sample size was very low (n=5), an apparently high percentage of the returning adults had emigrated as smolts (80%) (Table 5.2-2).

Table 5.2-2. Water year type and juvenile outmigrant size classes at natal exit for unmarked fish. Life stage size cutoffs revised from fork length data presented in Sturrock and Johnson (2014).

Outmigration year	San Joaquin River Index Water Year Type	N	Fry (< 50 mm)	Parr (50–69 mm)	Smolt (≥ 70 mm)
1998	Wet	117	0%	34%	66%
1999	Above normal	55	0%	38%	62%
2000	Above normal	66[1]	5%	70%	26%
2003	Below normal	26	4%	42%	54%
2009	Below normal	5	0%	20%	80%

[1] Sample size for outmigration year 2000 incorrectly reported as 67 in Sturrock and Johnson (2014).

5.3 Hydrology

5.3.1 Daily flows

Tuolumne River hydrographs for WYs 1998, 1999, 2000, 2003, and 2009 are presented in Figure 5.3-1 and Figure 5.3-2. At the La Grange and Modesto gages, during the three above normal/wet WY types (1998, 1999, 2000), winter flows increased during December through February, typically remaining at or above 2,000 cfs until at least early/mid-summer. In WY 1998, average daily flows increased beginning in mid-January and remained high, exceeding 5,000 cfs multiple times from February through July. In WY 1999, flows increased to 2,000–3,000 cfs in December, and again in mid-January, remaining generally at or near this range through mid-May. WY 2000 experienced a relatively later increase in winter flows than either WY 1998 or 1999, with flow increases occurring in mid-February (Figure 5.3-1 and Figure 5.3-2).

Average daily flows at La Grange during the two below normal/dry WY types (2003, 2009) remained at or below approximately 200 cfs through March, with pulse flow releases peaking in mid-April at 1,500 cfs in WY 2003, and peaking in mid-May at 950 cfs in WY 2009 (Figure 5.3-1). In general, average daily flows were slightly greater further downstream at Modesto, with the exception of a short but relatively large increase in average daily flow (> 1,000 cfs) that occurred during early March in WY 2009 (Figure 5.3-2).

In the San Joaquin River at Vernalis, peak flows during the above normal/wet WY types 1998 and 1999 occurred in mid-February, although their relative magnitudes were opposite those of the Tuolumne River, with 1999 flows exceeding 1998 flows at this location (Figure 5.3-3). WY 2000 flows peaked approximately a month later in mid-March, consistent with hydrology exhibited in the Tuolumne River (Figure 5.3-1 and Figure 5.3-2). Average daily flows at Vernalis for the below normal/dry WY types exhibited the pulse flow releases in mid-April, similar to the Tuolumne River (Figure 5.3-3).

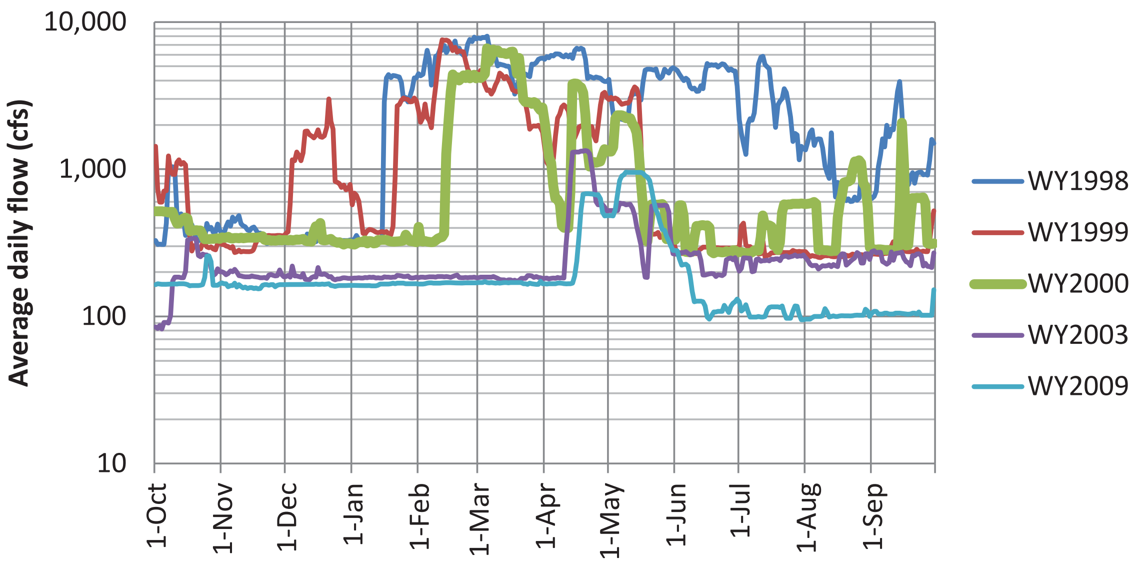

Figure 5.3-1. Tuolumne River average daily flow (cfs). Data from Tuolumne River Below La Grange Dam (USGS gage #11289650).

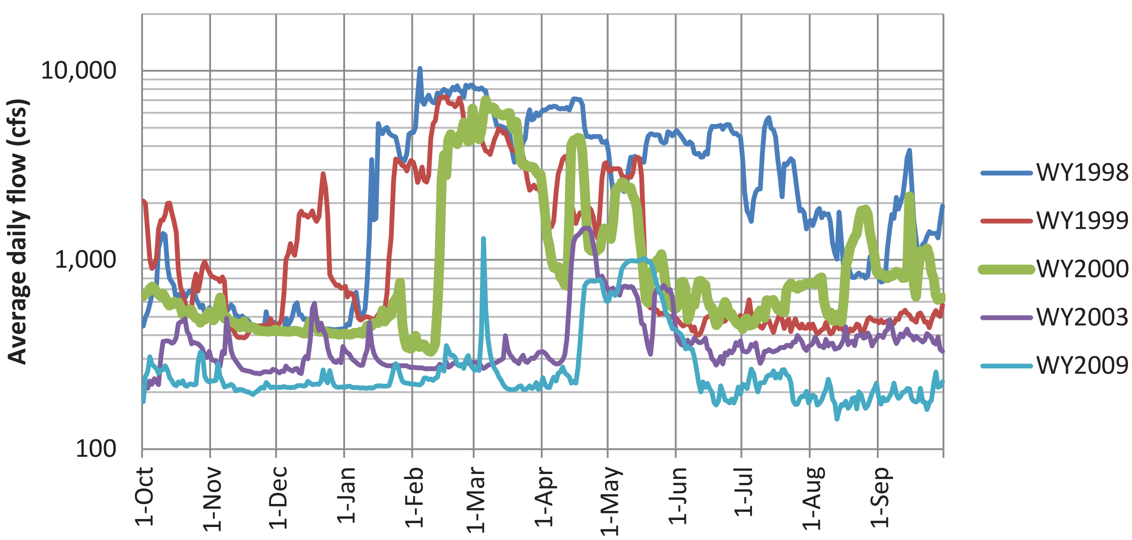

Figure 5.3-2. Tuolumne River average daily flow (cfs). Data from Tuolumne River at Modesto (USGS gage #11290000).

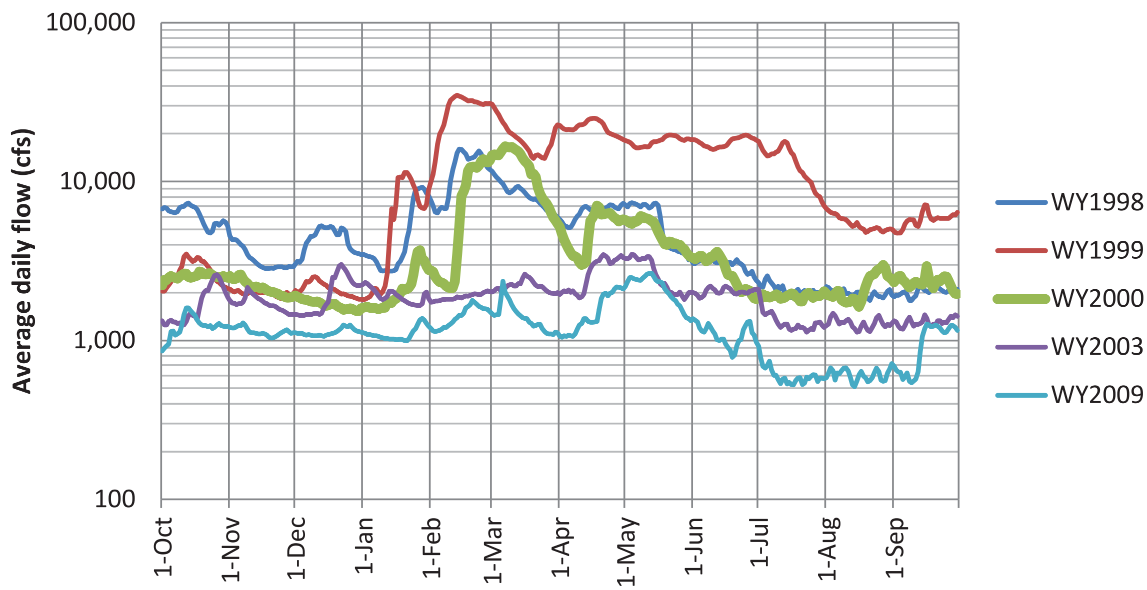

Figure 5.3-3. San Joaquin River average daily flow (cfs). Data from San Joaquin River at Vernalis (USGS gage #11303500).

5.3.2 Relationship between average daily flows and juvenile growth and residency

Average daily flow magnitude and timing was examined in relation to estimated mean fish size and age at exit for both the Tuolumne River (at La Grange and Modesto) and the Delta (at Vernalis) across above normal/wet WY types (1998, 1999, 2000) and dry WY types (2003, 2009). In 1998 and 1999, when average daily flows were sustained at relatively high levels during winter through spring months (extending into summer months in 1999), otolith data indicate that mean fish size and age at exit from the Tuolumne River for fish that returned to spawn were also relatively high, at approximately 73 mm FL (both years) corresponding to smolts, 91 days (1998), and 82 days (1999) (Table 5.2-1). Conversely, rotary screw trap data for 1998 and 1999 indicate that the majority of outmigrants were fry (< 50 mm FL) moving downstream during periods of increasing flow, with particularly high numbers (>500 per day) in WY 1999 (Figure 5.3-5 and Figure 5.3-6).

Although the pattern for 1998 and 1999 is consistent with prior observations of relatively larger sizes at emigration for above normal and wet WY types (Stillwater Sciences 2013b), mean fish size and age at natal exit (for fish that returned to spawn) were relatively lower at 64 mm and 69 days (Table 5.2-1) for outmigration year 2000, with the majority of individuals (70%) classified as parr (Figure 5.3-7). In contrast to other above normal and wet WY types examined, daily flows in the Tuolumne River did not increase until later in the winter (mid-February) in 2000, and were generally sustained through mid-May. Again, rotary screw trap data for WY 2000 indicate that the majority of outmigrants during WY 2000 were fry (< 50 mm FL), leaving in late February/early March (Figure 5.3-7).

Similar fish size associations were evident in the Delta as found at exit from the Tuolumne River, with larger mean fish size at ocean entry exhibited in outmigration years 1998–1999 than in 2000. However, the mean number of days spent rearing in the Delta was roughly twice as high in 2000 as in 1998 and 1999. As noted previously (Section 5.2), overall the total days from the end of exogenous feeding (i.e., emergence from gravels) to ocean entry was relatively constant at 99±20 days across all outmigration years included in the study, such that fewer days spent rearing in the Tuolumne River resulted in relatively more days rearing in the Delta (Figure 5.2-1).

Within the below normal WY types (2003, 2009), when average daily flows followed the FERC (1996) minimum flow schedule, including pulse flow releases from La Grange Diversion Dam, estimated mean fish size and age at exit were generally similar to those of the above normal/wet WY types 1998 and 1999. Rotary screw trap (RST) data indicate that very few or no fry were represented in the Shiloh Road RST (RM 3.4) data for the below normal/dry WY types (2003, 2009), in contrast to large number of fry that were observed outmigrating during the three wet WY types included in the study (1998, 1999, 2000) (Figure 5.3-8 and Figure 5.3-9). However, it should be noted that the traps were not installed until April 1 in WY 2003 and early March in WY 2009, so earlier fry emigration during these years would have been missed. Further, confirmation of any relationship between mean fish size and age at exit and below normal/dry WY hydrology should consider the relatively small sample size (n=31) for these WY types and for outmigration year 2009 in particular (n=5).

Lastly, additional exploratory analyses were conducted to determine whether barrier operations in the lower San Joaquin River and south Delta may have influenced the relative survival of early emigrating fry vs. later emigrating smolts. For example, the physical Head of Old River barrier (HORB) was in place in WY 2000 (Figure 5.3-7), corresponding to one of only two years in which there was a fry contribution to escapement (5%). Conversely, this physical (rock) barrier was not in place in WY's 1998 and 1999 when flows were too high to allow installation (Figure 5.3-5 and Figure 5.3-6); the estimated fry contribution to escapement for these years was zero. The physical HORB was in place for smolt outmigration in 2003 (Figure 5.3-8), the second of only two years when there was an estimated fry contribution to escapement (4%). An experimental behavioral barrier ("bubble barrier") was operated intermittently during smolt outmigration in 2009 when the estimated fry contribution was zero (Figure 5.3-9). These data suggest poor through-Delta juvenile survival in the absence of a physical HORB, consistent with prior studies evaluating survival of juvenile emigrants through the south Delta (Newman 2008, NMFS 2012).

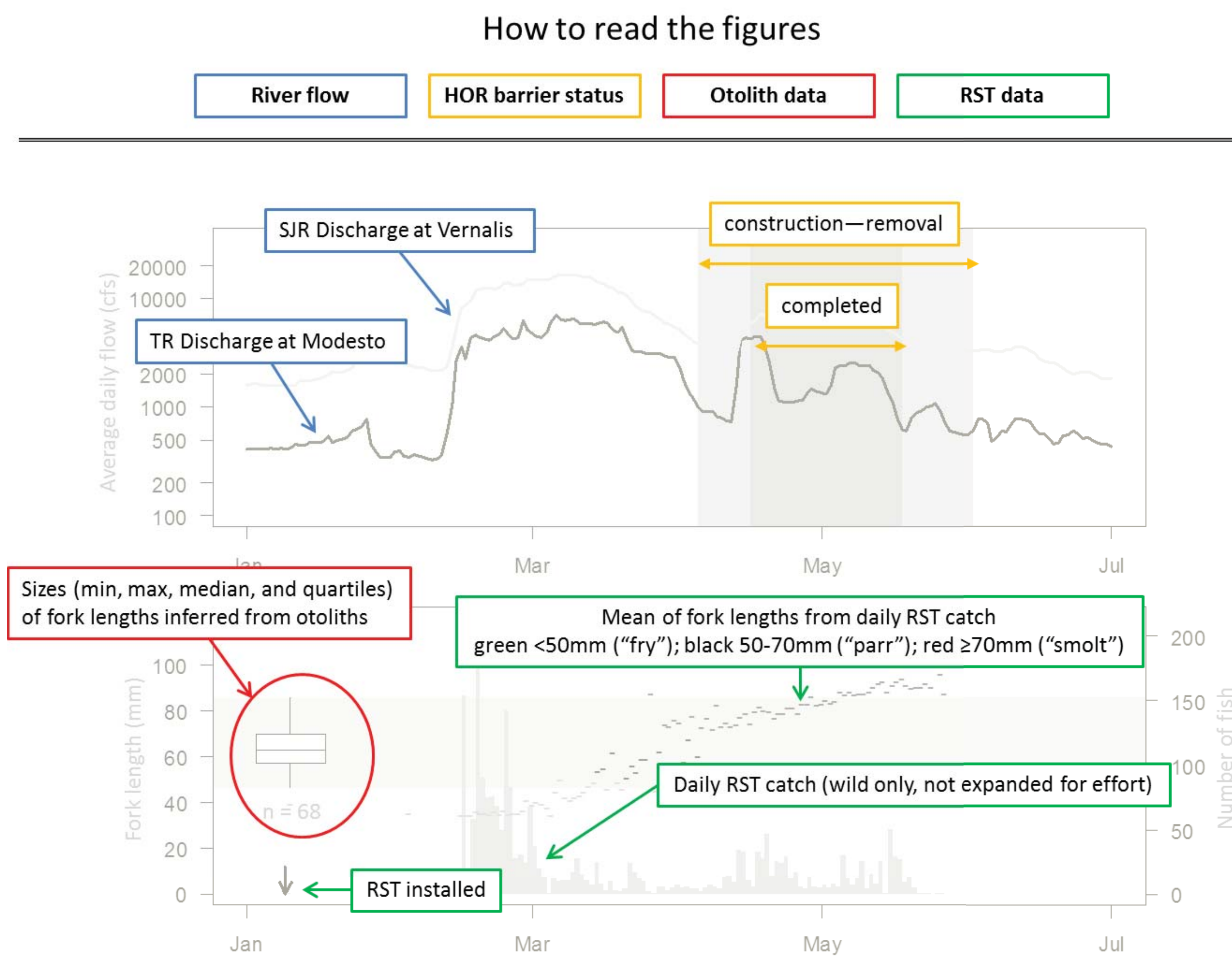

Figure 5.3-4. **Key for hydrology, rotary screw trap (RST) data, and of size-at-exit of returning fish (from otolith analysis).**

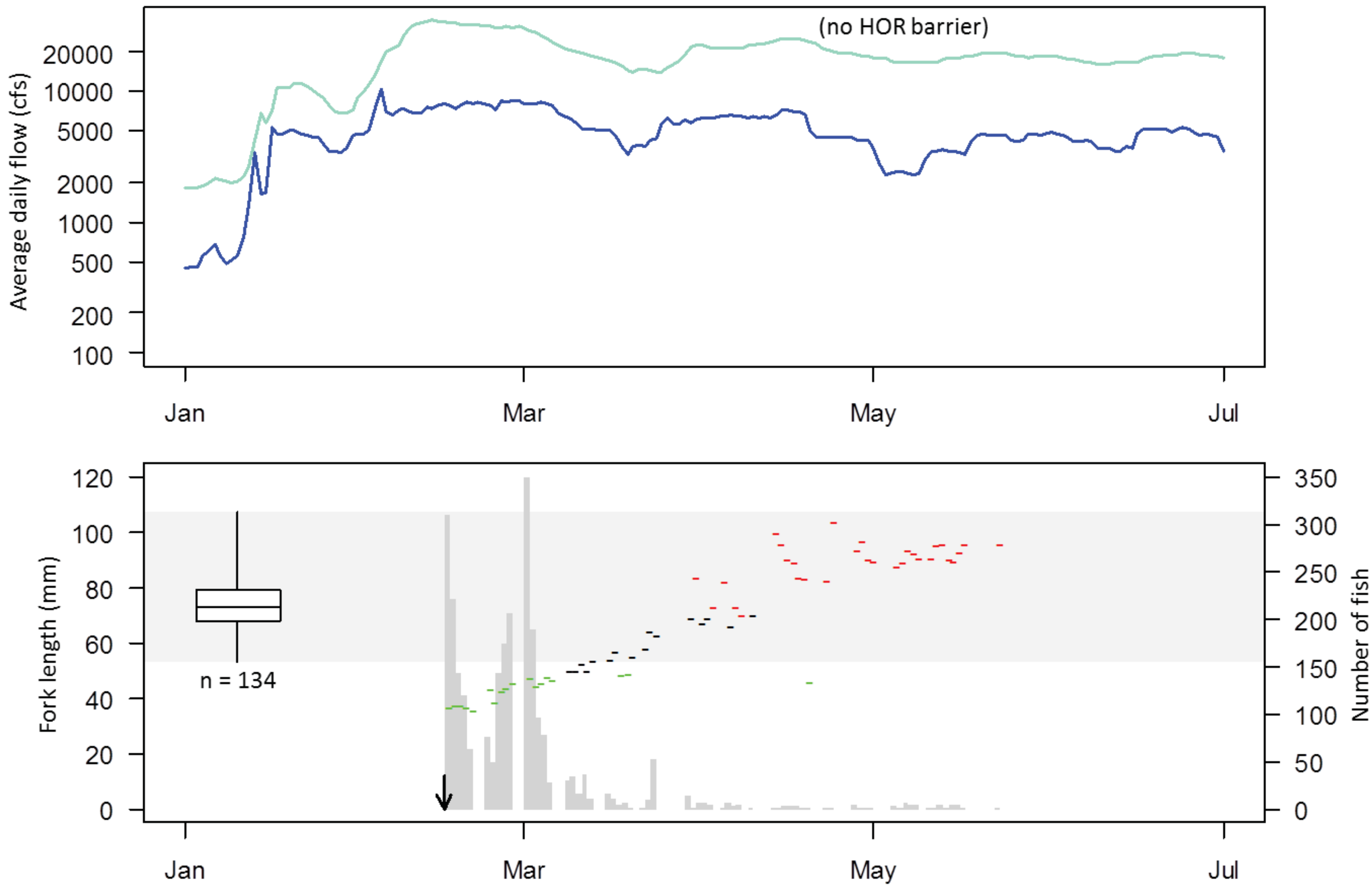

Figure 5.3-5. **1998 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

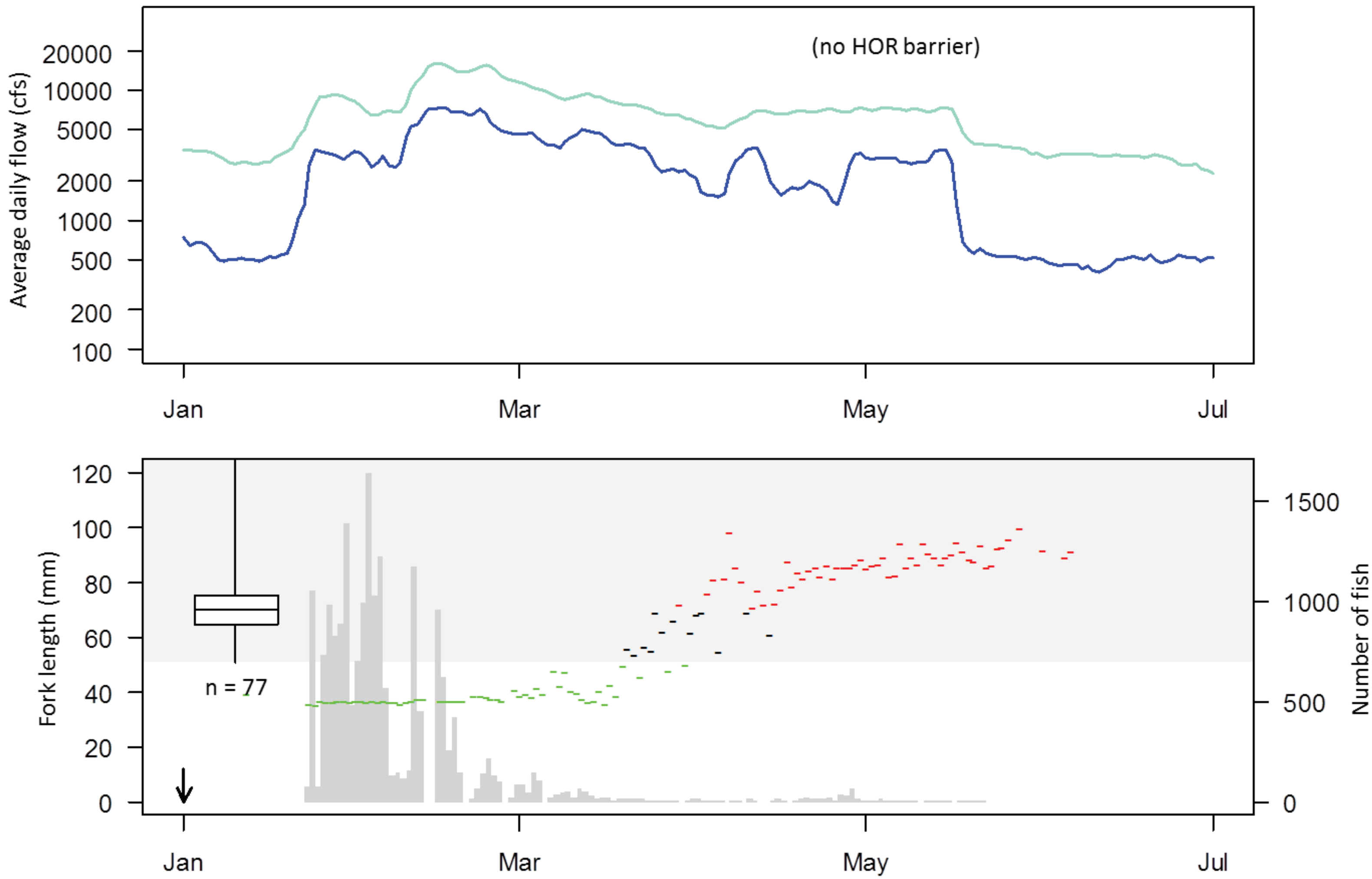

Figure 5.3-6. **1999 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

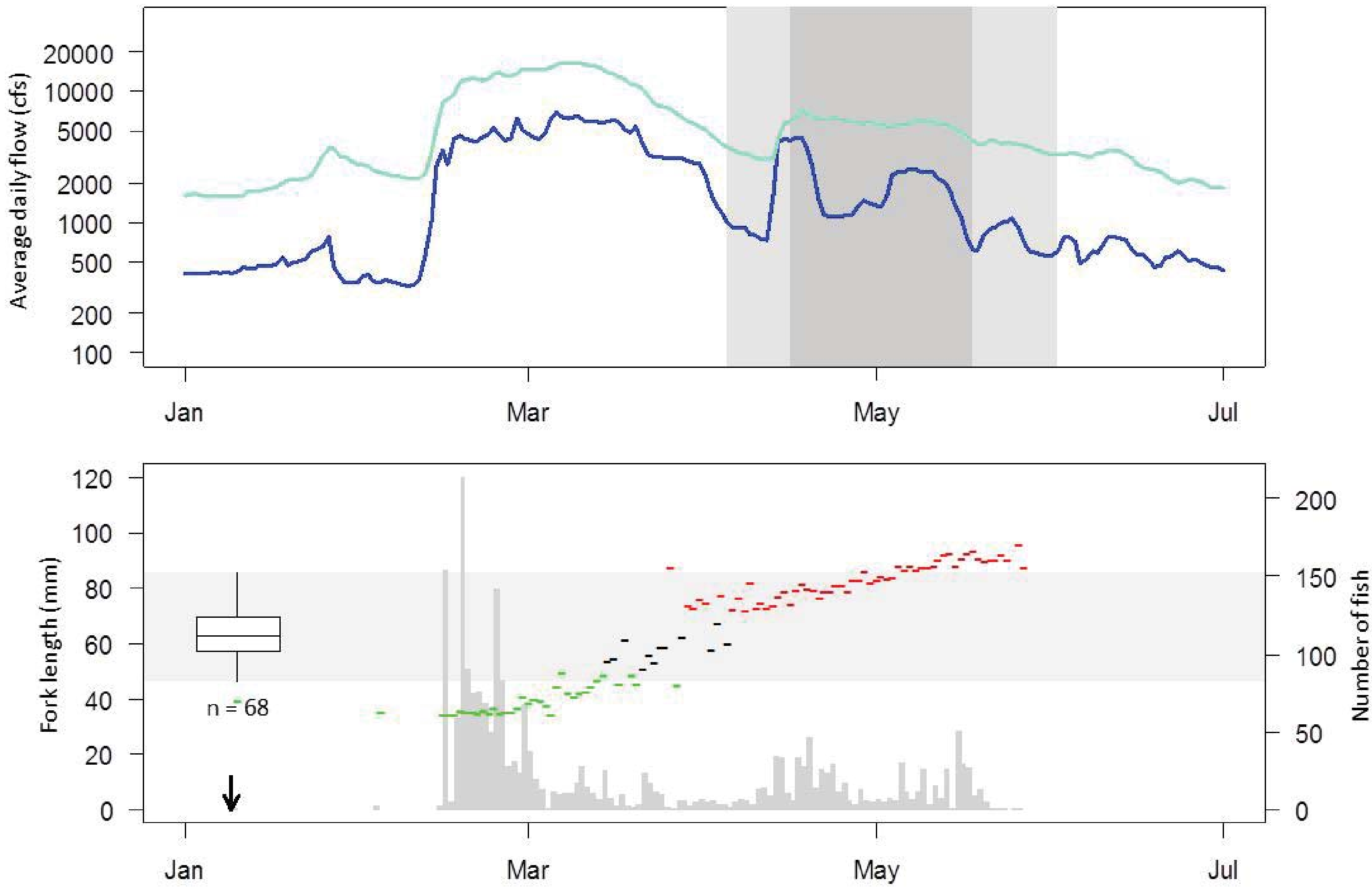

Figure 5.3-7. **2000 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

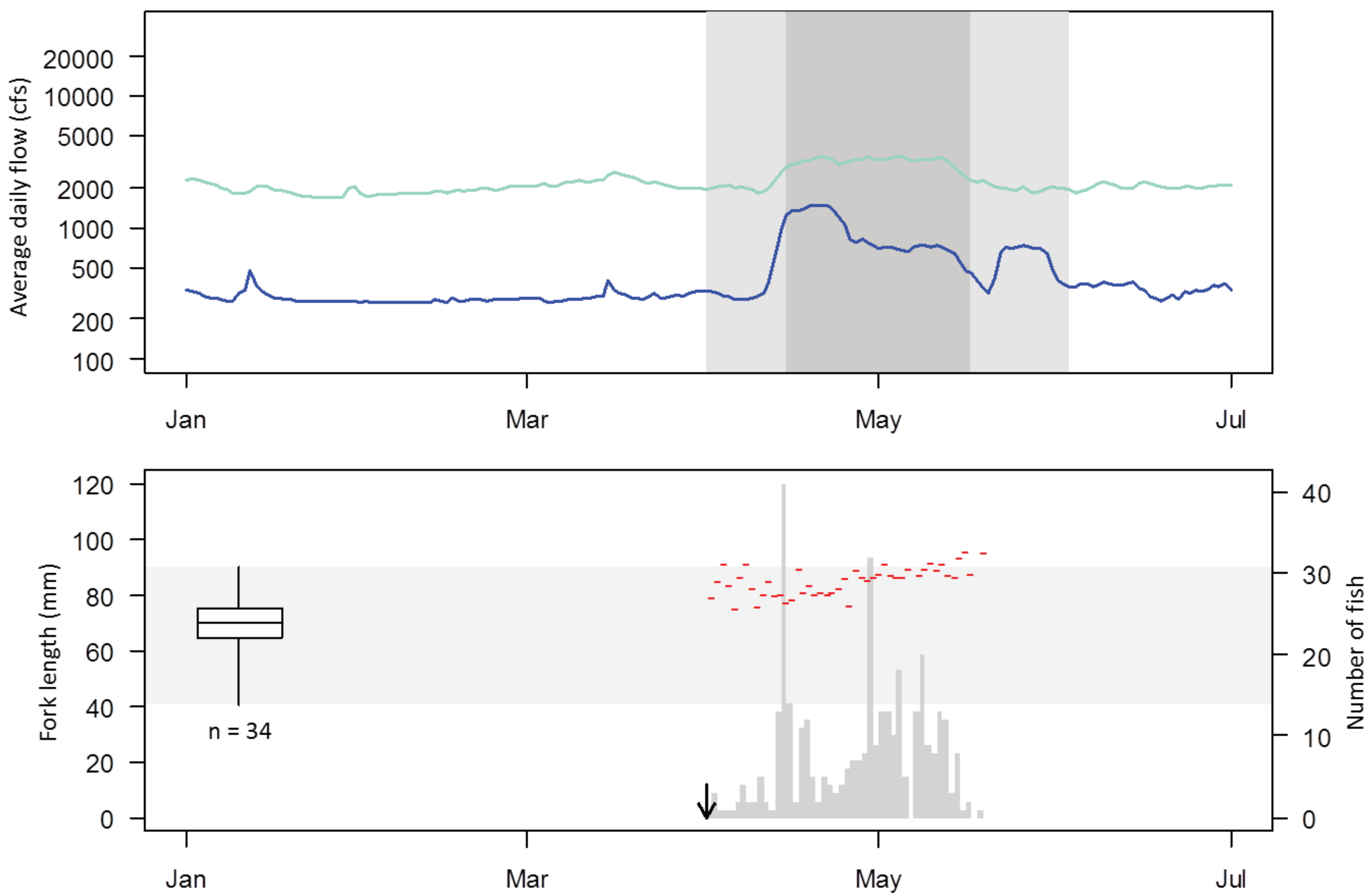

Figure 5.3-8. **2003 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

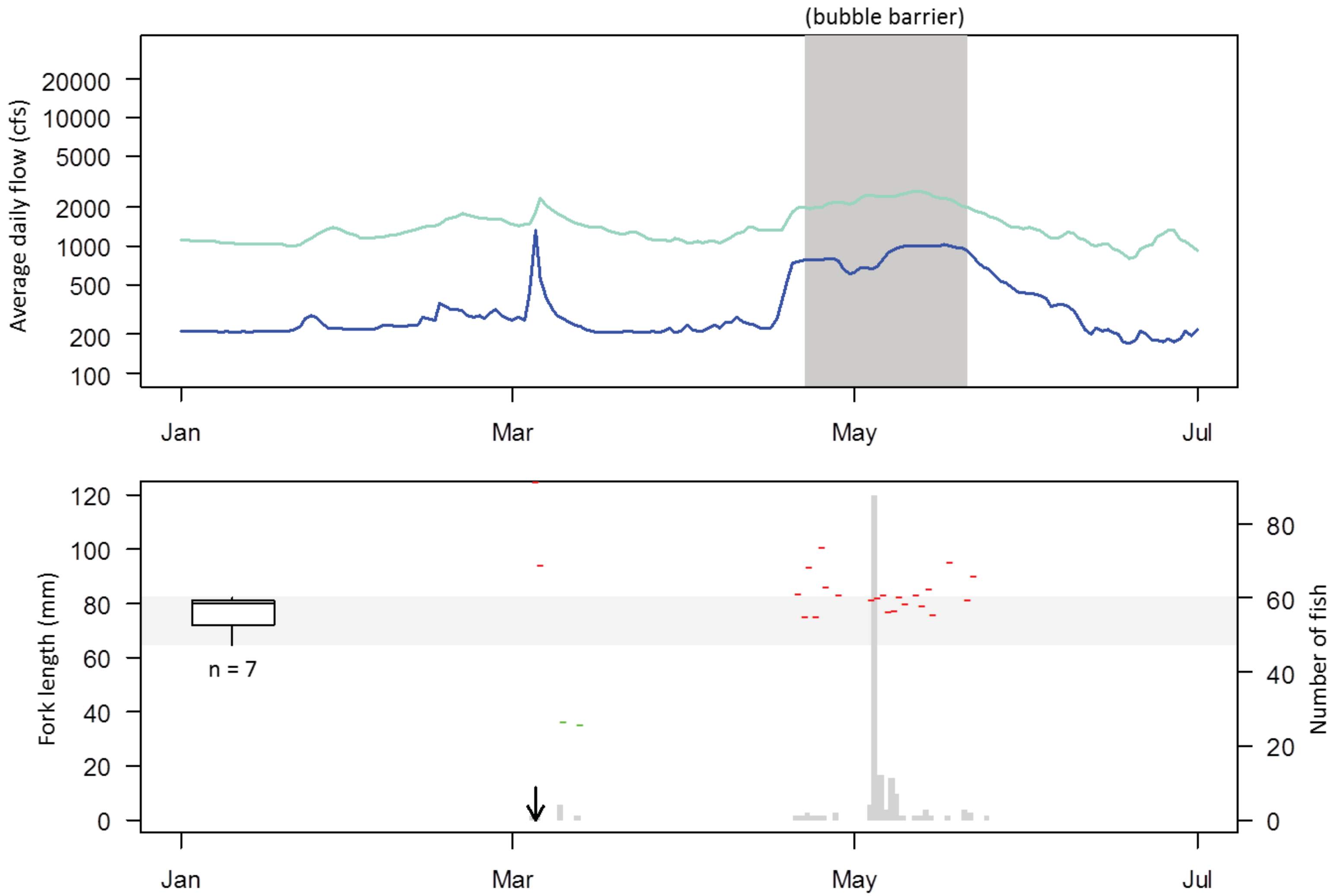

Figure 5.3-9. **2009 hydrology (Tuolumne River at Modesto [blue line] and the Delta at Vernalis [light blue line]), together with sizes and counts from the rotary screw trap (RST) near Shiloh and summary of size-at-exit of returning fish, estimated from otolith analysis (see also key in Figure 5.3-4).**

5.3.3 Relationships between monthly flows and early life-history emigration patterns

Other than associations with HORB status (Section 5.3.2), examination of mean monthly discharge, minimum monthly discharge, and maximum monthly discharge in the Tuolumne River at La Grange and Modesto for January through April did not reveal a discernable relationship with respect to growth rate, size at outmigration, or age at either outmigration or ocean entry for juveniles that originated in and returned to the Tuolumne River during the five years included in this study. Delta hydrologic patterns (at Vernalis) on a monthly timescale also did not exhibit clear relationships with growth rate, fish size, or age at ocean entry. Linear regressions indicated a lack of any compelling relationship (R^2<0.4, p>0.1) for the 192 combinations of fish size, fish age, monthly average flows for each of four months (January, February, March, April), and each of the 24 DAYFLOW parameters/indices (see Section 4.3).

6.0 DISCUSSION AND FINDINGS

Results of the analyses described above met both of the study objectives of using otolith microstructural growth patterns and/or microchemistry in order to identify:

- whether returning adults originated from hatcheries or riverine environments other than the Tuolumne River; and,
- growth rates and sizes of 'wild' fish at exit from the Tuolumne River and from the freshwater Delta.

These are discussed further below.

6.1 Hatchery origin fish

To provide an estimate of total hatchery contributions to Tuolumne River spawning escapement for the years examined in this study, the existing proportions of adipose fin clipped (i.e., hatchery marked) fish from CDFW annual spawning surveys can be combined with the proportions of unmarked hatchery fish estimated through otolith analysis. For each of the five outmigration years included in this study, a significant number of unmarked fish were classified as hatchery-origin fish through microstructural examination of otolith samples. The proportion of returning unmarked adults that originated in Central Valley hatcheries was greatest for the two below normal WY types (2003, 2009), exceeding the contribution from wild fish by approximately 2–4 times (Figure 5.1-1). The proportion of hatchery fish was relatively lower for above normal/wet WY types (1998, 1999, 2000), with the lowest proportion (33-44%) corresponding to outmigration year 1998 (Table 5.1-1). While these patterns are suggestive of a positive relationship between flow and the successful emigration of wild fish that later return as adults, confirmation of this relationship based on WY type should consider the relatively small sample size for below normal/dry WY types (n=31) vs. above normal/wet WY types (n=238).

Table 6.1-1 shows the proportions of marked (ad-clipped) and unmarked fish identified in the eight CDFW spawner survey years that recovered fish from outmigration years 1998, 1999, 2000, 2003, and 2009. The proportion of marked hatchery fish ranged from a low of 1% in 2006 to a high of 55% in 2011. For the unmarked fish, approximately 43% were identified as hatchery-origin (n=255) using results of the otolith analysis (Section 5.1). Combining the outmigration year unmarked hatchery contribution estimates with the known marked fish from subsequent escapement year surveys, Table 6.1-1 shows the total estimated hatchery contribution ranged from 39 to 100%, with a mean of 67% and generally increasing hatchery contribution in later years. To further refine this estimate and recognizing that some years in the otolith sample inventory over- and under-represent the typical age class structure in the escapement record, the overall proportion using only 3-year old recoveries, which are expected to make up the bulk of the annual escapement, ranges from 36 to 90%, with a mean of 58% (Table 6.1-1). Further consideration of large coded wire tag (CWT) releases to the Tuolumne River up to April 2005 suggests that some of the marked fish returning to the river during this period could be from the CWT release groups and thus would not be considered true hatchery strays. Separating the Tuolumne River CWT release groups from all marked (ad-clipped) fish identified in the annual spawner surveys would reduce the estimated hatchery fractions for these years in Table 6.1-1. At the same time, large hatchery releases into the Tuolumne River may potentially have swamped the existing predator population and increased outmigrant survival of emigrating wild fish. This would have the effect of slightly increasing the number of wild fish successfully emigrating and eventually returning to spawn. Nevertheless, it is apparent that hatchery contributions make up a large proportion of the annual spawning runs and the proportions of hatchery fish have been increasing in recent years.

Table 6.1-1. Estimated total hatchery contribution to annual escapement for spawner years corresponding to the five outmigration years included in the otolith study.

Spawner Year	CDFW spawner surveys			Including unmarked hatchery fish (all otolith samples)			Including unmarked hatchery fish (Age-3 otolith samples only)		
	Escapement[1]	Fraction Marked[2]	Marked Fish[2]	Unmarked Hatchery	Total Hatchery	Fraction Hatchery	Unmarked Hatchery	Total Hatchery	Fraction Hatchery
2000	17,873	6%	1,157	5,742	6,899	39%	5,207	6,364	36%
2001	9,222	16%	1,464	2,466	3,930	43%	2,667	4,131	45%
2002	7,125	31%	2,175	1,824	3,999	56%	1,566	3,742	53%
2005	719	11%	82	396	477	66%	396	477	66%
2006	625	1%	7	481	488	78%	-	-	-
2010	766	32%	245	521	766	100%	-	-	-
2011	2,847	55%	1,566	982	2,548	90%	982	2,548	90%
2012	2,120	29%	615	753	1,367	65%	-	-	-
Mean						67%	Mean		58%

[1] Data source: Stillwater Sciences (2013c).
[2] Data sources: Annual CDFW spawning survey reports (e.g., CDFG 2010) and annual FishBio weir monitoring reports (e.g., Wright et al. 2013).

Overall, results of this study are consistent with observations of increasing hatchery contributions to salmon escapement in the Central Valley as a whole (Barnett-Johnson 2007, Johnson et al. 2011). The high proportions of marked and unmarked hatchery-origin fish represented in spawning runs to the Tuolumne River suggests that the influence of Project related effects upon salmon production as well as the ability to discriminate the effectiveness of potential measures intended to benefit Chinook salmon may be obscured by variations in the production and ocean survival of hatchery fish from the Merced River Fish Facility and other Central Valley hatcheries.

6.2 Growth and residence in the Tuolumne River and the Delta

Based on Sr isotope ratios ($^{87}Sr/^{86}Sr$) and otolith microstructural features, the study results suggest that mean fish size at exit from the Tuolumne River showed no apparent relationship with WY type, with the exception of outmigration year 2000 when mean fish size was significantly different ($p<0.005$) from the other four years of the study. Mean fish size at freshwater exit from the Delta also did not exhibit a relationship with WY type.

Age distributions at exit from the Tuolumne River and at exit from the Delta suggest that overall the total days of development from formation of otolith core to ocean entry for juvenile salmonids was relatively constant at 99±20 days for each of the five outmigration years included in the study. Fewer days spent rearing in the Tuolumne River resulted in relatively more days rearing in the Delta (Figure 5.2-1). The latter suggests extended rearing in the Delta for some parr-sized fish that emigrate early from the Tuolumne River. This is particularly evident in the average number of days spent in the Delta (27.6±12.1 days; Table 5.2-1) for outmigrating juveniles in 2000, which exceeded a more typical migration time of 14–21 days and suggests that some fish spent over 4 weeks in the Delta during the 2000 outmigration.

Size-standardized estimated growth rates from this study were generally greater for fish that reared in the Tuolumne River as compared with fish that reared in the Delta, but the pattern was not consistently statistically distinguishable between the two rearing locations. As discussed in the Salmonid Information Synthesis Study (Stillwater Sciences 2013b), available food resources in the Delta may be limiting growth opportunities for juvenile Chinook salmon in some conditions, with effects upon early ocean survival and long-term population levels. For example, MacFarlane and Norton (2002) found that as compared to upstream (riverine) rearing locations, juvenile Chinook grew more slowly in the Delta and San Francisco Bay estuary.

6.3 Phenotypic contributions to spawning and potential management implications

Based upon the limited number of sampling years and otoliths available for analysis by this study, it is apparent that spawning populations in the Tuolumne River exhibit low representation of early emigrating fry, with zero contributions in three out of five outmigration years analyzed and a maximum contribution of 5% in WY 2000. However, a 5% fry contribution in years when escapement on the order of 5,000–10,000 returning adults is a non-negligible number of fish (250–500 spawners) and may be on par with total spawner numbers in low escapement years. Although observations of phenotypic contributions to spawning in the Stanislaus River indicate relatively higher fry contributions during both WY 2000 (23%) and WY 2003 (10%) (Sturrock et al. 2015), parr and smolt sized emigrants represented the vast majority of returning adults in both rivers, implying a survival advantage for fish emigrating at larger sizes.

The relative spawner contributions of juvenile Chinook salmon emigrating from the Tuolumne River at size classes corresponding to fry (<50 mm FL), parr (≥50 to <70 mm FL), and smolt (≥70 mm FL) did not vary consistently with WY type or discharge in this study. The relatively high parr (70%) and fry (5%) representation in returning adults for outmigration year 2000 is interesting, especially given that year 2000 exhibited lower and later-peaking average daily flows than the other two above normal/wet years included in the study (1998, 1999). Although the timing of juvenile life stage transitions and timing of outmigration are relatively consistent from year-to-year, we conducted additional analyses to explore the potential effects of brood-year spawner timing as well as the effects of flow and barrier operations during juvenile outmigration.

For the above normal/wet WY types represented in the otolith samples, consideration of spawner run timing in 1997, 1998, and 1999, which corresponds to outmigration years 1998, 1999, and 2000, suggests that the peak of spawning occurred 7–9 days earlier in 1997 and 1998 than the 1999 run, where the latter corresponds to the year 2000 outmigration (Figure 6.3-1). By comparison, the peak of spawner run timing for the two below normal/dry WY types (i.e., spawner years 2002 and 2008) differ by only 3-days (Figure 6.3-1). One potential explanation of the lower fry representation of spawners originating from outmigration years 1998 and 1999 is the combination of earlier spawning during 1997 and 1998 and the extended high flows that occurred during 1998 and 1999 (Figure 5.3-5 and Figure 5.3-6). These factors may have resulted in extended in-river rearing and relatively higher numbers of fish emigrating at larger (i.e., smolt) sizes in these years than occurred in 2000. Another potential explanation of differing representation of fry contributions to subsequent spawning is that the two years of extended high flows during spring 1998 and 1999 may have disrupted nesting and other essential reproductive behaviors of predators such as black bass (Loppnow et al. 2013, Cavallo et al. 2012, Kleinschmidt 2008, Montgomery et al. 1980) and led to reduced predator populations and greater numbers of fry emigrating from the Tuolumne River and into the Delta during WY 2000 (Figure 5.3-7).

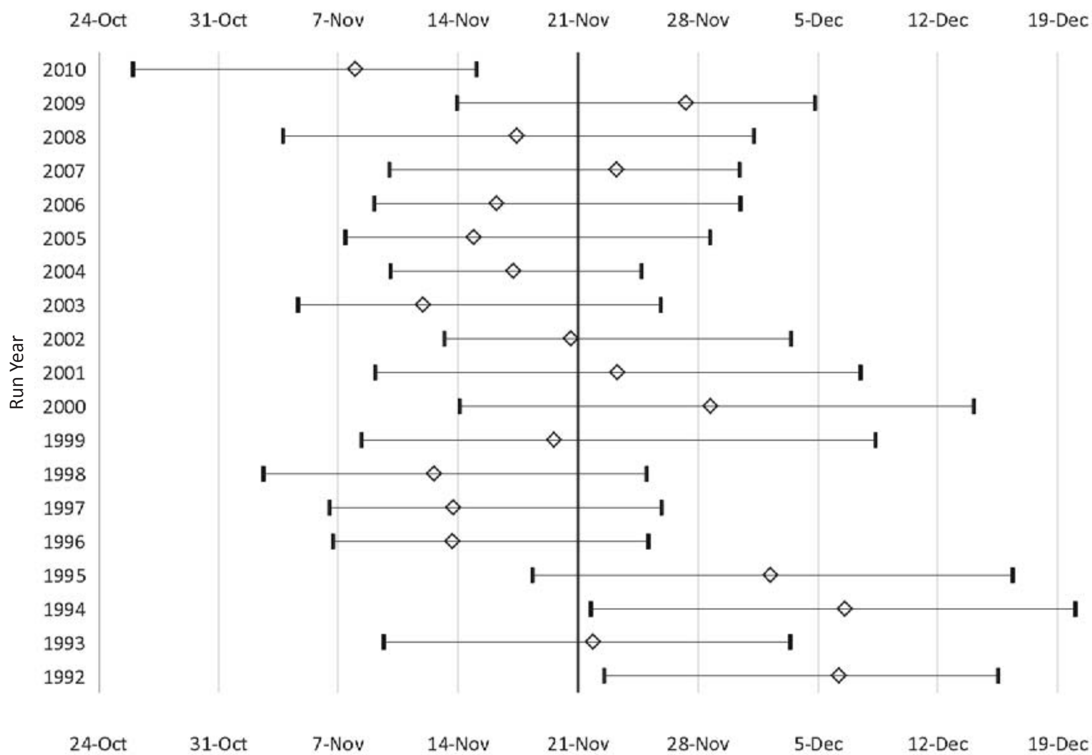

Figure 6.3-1. Tuolumne River spawner run-timing. Data sources: Annual CDFW spawning survey reports (e.g., CDFG 2010) and annual FishBio weir monitoring reports since 2009 (e.g., Wright et al. 2013).

The low fry contributions identified in this study for both wet and dry WY types suggest that flow-related increases in the number of juvenile Chinook salmon leaving the Tuolumne River as fry may not necessarily result in corresponding increases in subsequent escapement. In addition to spawner timing and flow related effects upon phenotypic contributions to spawning populations discussed above, we also examined the influence of barrier operations in the south Delta. Among the three above normal/wet WY types represented in the otolith samples, the physical HORB was only installed in WY 2000. This may have increased fry contribution to subsequent spawner returns relative to WY 1998 and 1999 when the HORB was not in place. Based upon the statistically significant improvements in through-Delta survival of juvenile Chinook salmon with the HORB in place (Newman 2008), HORB operation in WY 2003 may have also reduced mortality of later emigrating fry in this year as well, when 4% of returning spawners appear to have emigrated as fry. By WY 2009, the physical HORB was no longer used and it is possible that the low contribution from fry originating in this year may be due to a combination of fry entrainment into Old River as well as increased rates of predation.

As previously stated, the conclusions of this study are based upon a relatively small otolith sample size (n=31) for spawners originating from below normal/dry WY types as compared to samples (n=238) from the above normal/wet WY types. Additional analysis of adult otoliths from individuals emigrating under current Delta flow management for both above normal/wet as well as below normal/dry WY types in the future may help better discern whether variations in spring discharge are associated with greater or lower juvenile size class representation in subsequent spawning populations.

7.0 STUDY VARIANCES AND MODIFICATIONS

The study was conducted in conformance to the FERC-approved *Chinook Salmon Otolith Study Plan* (W&AR-11) approved in FERC's December 22, 2011 Determination. There are no variances.

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Appendix A

Tuolumne River Chinook Salmon Otolith Study – Analysis of Archival Otoliths Using Stable Isotope Microchemistry

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TUOLUMNE RIVER CHINOOK SALMON OTOLITH STUDY - ANALYSIS OF ARCHIVAL OTOLITHS USING STABLE ISOTOPE MICROCHEMISTRY

UNIVERSITY OF CALIFORNIA DAVIS

PERIOD 11/13-6/14

Prepared by Drs. Anna Sturrock and Rachel Johnson as part of Don Pedro Project Relicensing (FERC No. 2299)

EXECUTIVE SUMMARY

Processes occurring in freshwater, estuarine, and marine habitats strongly influence the growth, survival and reproductive success of salmonids. One of the fundamental challenges in understanding salmon population dynamics lies in our inability to link and evaluate the relative importance of processes occurring throughout the complex salmon life cycle. For example, a critical unknown is the extent to which environmental conditions and management actions in the freshwater contribute to the expression and survivorship of different juvenile outmigration strategies into adulthood.

Here, we use Sr isotope ratios ($^{87}Sr/^{86}Sr$) and daily growth information recorded in Central Valley fall-run Chinook salmon, *Oncorhynchus tshawytcha,* otoliths ("earbones") to reconstruct the stream or hatchery-of-origin and early life movements of adult salmon collected on the Tuolumne River in the San Joaquin River Basin, California. A total of 598 paired otolith and scale samples were used to reconstruct and compare size-specific outmigration patterns for fish emigrating from the Tuolumne River in the spring of 1998, 1999, 2000, 2003 and 2009, incorporating dry, below normal, above normal and wet water year types. First, we identified adults that originated from the Tuolumne River (i.e. removed strays) using an updated 'strontium isoscape' and otolith growth characteristics exhibited by hatchery and wild salmon in the Central Valley [1, 2]. For each individual, otolith isotopic and microstructural data were linked with otolith radius in order to reconstruct the size and age at which they had exited from their natal river and from freshwater. Back-calculated fork lengths (± 95% CI) were used to classify outmigrants into one of three life history stages: fry (≤55mm), parr (>55mm to ≤75mm) or smolt (>75 mm).

Our study shows that a significant number of adults spawning in the Tuolumne River in fall of 2000-2012 were strays from other rivers and hatcheries in the Central Valley. The earliest three outmigration years examined had relatively low straying rates of unmarked fish, with a greater proportion of spawners having originated in and reared in the Tuolumne River (1998: 57-68% returns, 33-44% strays; 1999: 38-53% returns, 47-62% strays; 2000: 61-64% returns, 36-39% strays). Outmigration year 2003 exhibited an intermediary straying rate (27-35% returns, 65-73% strays) while outmigration year 2009 was subject to particularly high straying rates (9-15% returns, 85-91% strays, primarily from the Coleman National Fish Hatchery on Battle Creek in the Sacramento River watershed, which comprised 57% of the unmarked sample).

All size classes of juvenile outmigrants were represented in the adult spawning populations. Tuolumne-origin adults were largely comprised of individuals that had emigrated from the Tuolumne River as parr and smolts, however, in outmigration year 2000, 20% of the returning adults had outmigrated as fry. Comparable with findings on other rivers in the San Joaquin Basin, parr outmigrants were consistently the most commonly observed phenotype in the returning adults.

INTRODUCTION

Juvenile Chinook salmon (*Oncorhynchus tshawytscha*) exhibit significant variation in the size, timing and age that they emigrate from their natal rivers [14]. Typically, juveniles rear in the freshwater for one to three months before smoltification prompts downstream migration towards the ocean; however, early spring flows are often also coupled with large pulses of emigrating fry [5, 14, 17]. In some years, fry-sized individuals are the most numerous size-class leaving natal rivers and entering the delta [17, 18]. The contribution of these smaller outmigrants to the adult population is often assumed to be negligible, as juvenile survival is generally positively correlated with body size [e.g. 19] and there is little evidence for significant downstream rearing in the San Francisco estuary [20]. Hatcheries tend to release larger smolts to maximize survival rates and their contribution to the ocean fishery, but a recent study indicated that the majority of California Central Valley (CCV) adults captured in the Oregon troll fishery had emigrated as fry and parr [21]. Scale analyses have also inferred greater survival rates of intermediate-sized juveniles [22]. Understanding the relative survivorship of different outmigrant size classes is critical to our understanding of population dynamics and evaluation of freshwater management actions and water operations.

Quantifying the relative contribution of different size classes and/or developmental stages of juvenile salmon to the adult spawning population has largely been limited by the methodological challenges associated with reconstructing early life history movements of the adults. Mark-recapture studies using coded wire tags (CWT) have provided empirical indices of juvenile survival rates through the Sacramento-San Joaquin system [28], but are hindered by low rates of return and often use hatchery fish, which may exhibit different behavior and survival than their wild counterparts [29]. No study to date has tracked habitat use of individual salmon over an entire lifecycle to estimate the relative success or survivorship of juvenile outmigration phenotypes, let alone under different flow conditions or between different rivers in the same year. Most have relied on correlations between environmental conditions (e.g. flow) experienced during juvenile outmigration periods and abundance of returns [16, 30].

Recent advances in techniques using chemical markers recorded in biomineralized tissues provide rare opportunity to retrospectively "geolocate" individual fish in time and space [31]. Otoliths are metabolically inert, calcium carbonate "earbones" found in all bony fishes, that grow incrementally from birth (the otolith "primordia") to death (the outer edge of the otolith). The otolith microstructure features daily and annual growth rings that can be determined visually using light microscopy [32]. In Chinook salmon, as the otoliths grow proportionally to fish length during juvenile stages, daily increment widths can be used to reconstruct individual growth trajectories, providing a means to compare growth rates across life stages, hydrologic regimes and contrasting environments. Otolith microstructure can therefore provide insights into how juvenile salmon growth is affected by biotic and abiotic factors such as food availability and water temperature. When microstructural and microchemical techniques are combined, otoliths can provide a powerful natural tag for reconstructing movement patterns of individual fish [33]. The technique relies on differences in the physicochemical environment producing a distinct and reproducible "chemical fingerprint" in the otolith. In the CCV, strontium isotopes ($^{87}Sr/^{86}Sr$) are ideal markers because the water signature varies with the parent geology, differing among many of the rivers and salmon outmigration paths, and is faithfully recorded in the otoliths of Chinook salmon [1, 34]. Changes in otolith $^{87}Sr/^{86}Sr$ values can be used to reconstruct time- and age-resolved movements as salmon migrate through the freshwater, estuarine, and ocean environments [1, 34]. Furthermore, in salmon, otolith size is significantly related to body size [32, 35, 36], allowing back-calculation of individual fork length (FL) at specific life history events.

Here, we used otolith $^{87}Sr/^{86}Sr$ ratios and microstructure to identify natal origin and reconstruct size/age at emigration of adults that spawned in the Tuolumne River in 1996-2008. These adults represent cohorts that emigrated as juveniles from the freshwater in 1998, 1999, 2000, 2003 or 2009. First we used the otolith data to differentiate between adults that strayed from other rivers from adults that were born and returned to the Tuolumne River. After removing strays from other rivers, we used otolith $^{87}Sr/^{86}Sr$ ratios, growth increments and radii to determine the size and age at which returning (i.e. "successful") adults had originally emigrated from the Tuolumne River and from the freshwater system. We aimed to address the following questions:

1. What was the early fresh-water life history of the adult Chinook salmon? More specifically, at what age (days from exogenous feeding) and estimated size did the returning adult leave the Tuolumne River as a juvenile?
2. What was the origin of the adult Chinook salmon? More specifically, what portion of the adult Chinook salmon escaping to the Tuolumne River originated from the Tuolumne River separate from hatcheries and other riverine environments of the Sacramento and San Joaquin Central Valley drainages?

Study area

The Tuolumne River is one of the southernmost tributaries of the San Joaquin River (SJR) (Fig. 1). The lower basin typically experiences a Mediterranean climate with wet winters and dry summers, and the tributaries are predominantly fed by snowmelt from the Sierra Nevada Mountains. The Tuolumne watershed encompasses a 1,900 square-mile area of the central Sierra Nevada and northern San Joaquin Valley and includes the northern half of Yosemite National Park. The Tuolumne is the largest tributary to the SJR, producing an average annual unimpaired yield of 1,906,000 acre-feet. The river flows for 150 miles from its headwaters at over 13,000 ft on Mt. Dana and Mt. Lyell to its confluence with the SJR at an elevation of 30 ft . The lower Tuolumne extends from its confluence with the SJR to La Grange Dam at river mile (rm) 52.2, which has been the upstream barrier to anadromous fish movements since at least 1871 [10].

Around 90% of the annual precipitation on the Tuolumne River occurs between November and April, with an annual minimum flow schedule including migration pulse flows in April and May required by the Federal Energy Regulatory Commission (FERC 1996).

Methods

Adult sampling and cohort reconstruction

Otoliths were extracted from age 2, 3 and 4 year old adults in the Tuolumne River during carcass surveys conducted by CDFW in the fall of 2000-2012 (Table 1). The five focus years of the current study (1998, 1999, 2000, 2003 and 2009) encompassed a range of hydrologic conditions (wet, above normal, above normal, below normal and dry, respectively) based on the San Joaquin valley water index (http://cdec.water.ca.gov). Carcass surveys were typically run from October to early-January depending on abundance and hydrologic conditions. Sample selection was temporally stratified to follow the same cohort across different escapement years, as fish return at different ages. This approach was taken to capture the age structure typically observed for salmon in the San Joaquin tributaries. This was deemed important in order to capture a representative sample that accounted for the potential for the outmigration strategy to co-vary with age-at-return. For example, it is unclear the extent to which larger outmigrants may have a higher likelihood of returning as younger (age 2) adults. Our sampling design was not intended to explicitly test whether there was a linkage between outmigration strategies and return age, however. Ages and outmigration cohorts were determined by counting scale winter annuli by experts at CDFW La Grange, as per established and validated techniques [41].

Otolith treatment and $^{87}Sr/^{86}Sr$ analyses

Otoliths were prepared and analyzed for $^{87}Sr/^{86}Sr$ ratios by multi-collector laser ablation inductively coupled plasma mass spectrometry (MC-LA-ICPMS) using the methods described in Barnett-Johnson et al. [2]. In brief, otoliths were rinsed 2-3 times with deionized water and cleaned of adhering tissue. Once dry, otoliths were stored in clean microcentrifuge tubes then mounted in Crystalbond™ resin and polished (600 grit, 1500 grit, 3 μm then 1 μm lapping film) until the primordia were exposed. $^{87}Sr/^{86}Sr$ analyses were carried out on a Nu plasma HR (Nu Instruments Inc.) interfaced with a Nd:YAG 213 nm laser (New Wave Research) at the UC Davis Interdisciplinary Center for Plasma Mass Spectrometry. Contrasting with the line transects used to establish natal signatures of tributaries in the CCV [1, 2] we used spot analyses to prevent cross-contamination of ablated material and to allow coupling of chemical data with discrete microstructural features. A 40μm or 55μm laser beam diameter was used (roughly equivalent to 10-14 days of growth) with pulse rate of 20 or 10 Hz at 70 or 65% power and a dwell time of 25 or 35 seconds. Helium was used as the carrier gas to improve sensitivity and was mixed with argon before reaching the plasma source. Gas blank and background signals were monitored following sample changes and measured for 30 seconds prior to each batch of spot analyses. A modern coral sample was analyzed at the start of each analytical session and the outer (marine) portion of adult salmon otoliths was analyzed between every otolith. The measured $^{87}Sr/^{86}Sr$ ratio was normalized to $^{86}Sr/^{88}Sr = 0.1194$ and to maximize accuracy, batches of unknowns were corrected to the global $^{86}Sr/^{88}Sr$ value (0.70918) by correcting to the mean of three spot analyses on the marine portion of an adult salmon otolith analyzed immediately afterwards.

A standardized 90° transect was used for $^{87}Sr/^{86}Sr$ and otolith radius measurements, starting at the post-rostrum primordia going in the dorsal direction (Fig. 2). Juvenile otoliths of known origin (from previous studies) were used to assign natal origins of adults in the current project. In the juvenile otoliths, the transect was terminated at the otolith edge to ensure analysis of the most recently deposited material in order to characterize capture site (natal) signature. In the adult otoliths of unknown origin, the transect was terminated past the ocean entry check or to a distance of c.800μm (c. 120mm FL) to ensure inclusion of the full freshwater outmigration period. To improve the spatial resolution and accuracy of exit spot identification and back-calculated FL, additional $^{87}Sr/^{86}Sr$ analyses were carried out around the Tuolumne-SJR transition. These additional spots ("respots") meant that generally, subweekly resolution could be achieved.

Strontium isoscape

As part of ongoing work to provide better resolution on the determination of fish origin useful in this study, Sr isotope values of known-origin otolith samples from juveniles and CWT adults were combined with the previously published $^{87}Sr/^{86}Sr$ baseline [1]. Water samples (A. Sturrock, unpublished) were combined with data from Ingram and Weber (1999) and P. Weber (unpublished). The resulting 'strontium isoscape' was comprised of 480 samples from all potential natal sources in the CCV, with many sites sampled across multiple years (1998-2013) and hydrologic regimes (Table 3). Thus, the isoscape can be quantitatively characterized by the mean $^{87}Sr/^{86}Sr$ isotope values and the standard deviations for the different salmon rivers and hatcheries in the CCV.

Otoliths from juveniles collected from their natal tributary or hatchery were analyzed for $^{87}Sr/^{86}Sr$ using the same type of transect as the adults, and the natal signature determined from otolith material deposited immediately after onset of exogenous feeding (~250µm from the core, see [2]). Material deposited prior to this point exhibits an elevated signature due to the influence of maternally-derived strontium from the yolk, which for fall-run salmon, was formed while the mother was in the ocean.

Identification of natal origin

In order to reconstruct juvenile outmigration strategies for the Tuolumne River salmon population, it was critical to remove any fish that had strayed from other tributaries or hatcheries. Given that hatcheries tend to release at larger sizes [21], not detecting and removing hatchery strays in our analyses would likely bias the representation of smolt outmigrants. To identify the origin of our unknown fish, we measured the natal $^{87}Sr/^{86}Sr$ and then statistically determined which river or hatchery in the strontium isoscape (see previous section) had the most similar $^{87}Sr/^{86}Sr$ to the unknown fish. The utility of using a linear discriminant function analysis (DFA) to classify unknown origin fish into their likely rivers/hatcheries of origin, is that it allows one to use additional sources of information. In this case, we can use previous observations of hatchery strays from coded wire tag recoveries in the Constant Fractional Marking Report (probabilities/group weightings) and use that information to help weight our statistical model to more accurately account for hatchery strays (Table 2) [42, 43]. Thus, the DFA approach allowed us to incorporate empirical data of stray-rates from the major hatcheries into our statistical model to account for non-random patterns in salmon straying and improve classification accuracy. As the majority of Chinook salmon return to freshwater at 3 years old [14], the more recent report (escapement year 2011 [42]) was cohort-matched to outmigration year 2009 (escapement year – outmigration year + 1). All adults from previous outmigration cohorts were assigned using priors from the earlier CFM report [43].

The natal signature was determined by averaging the $^{87}Sr/^{86}Sr$ values that corresponded with the otolith material deposited immediately after onset of exogenous feeding (but prior to emigration from the natal river). The DFA assignments for the mean natal value were used to determine the river or hatchery of origin. Juveniles collected in the Tuolumne River exhibit more variable isotopic signatures within and among individuals than in other rivers in the CCV (see Results). Some juveniles that were collected in the Tuolumne River exhibited $^{87}Sr/^{86}Sr$ values that appeared to imply movement into the SJR or Stanislaus River immediately after emergence and then return to the Tuolumne (e.g. Fig. 3C). However, given that the changes in isotopic values tended to occur at early stages, when individuals are unlikely to be strong enough swimmers to move freely up and downstream, we interpreted this pattern to represent geographic variations in the $^{87}Sr/^{86}Sr$ signature within the Tuolumne River, confirmed with additional water sampling carried out as part of other projects (Fig. 1 & 8).

As the Tuolumne River exhibits variable water chemistry from upper to lower reaches (P. Weber, A. Sturrock, unpublished), and otolith $^{87}Sr/^{86}Sr$ values of known-origin fish from the Tuolumne River, Mokelumne River Hatchery and Feather River Hatchery can overlap (see Results), there is a potential of misclassifying Tuolumne-origin fish. Thus, to improve our assignment accuracy, any individuals exhibiting ambiguity in their natal assignment were also analyzed for otolith microstructural features that can discriminate hatchery from wild fish. We used the methods developed for CCV Chinook [44], where individuals are classified as hatchery or wild based on the prominence of the exogenous feeding check (scored blind by 2-3 independent readers) and the mean and variance in increment width around the first 30 daily increments following onset of exogenous feeding.

RECONSTRUCTING SIZE AND AGE AT OUTMIGRATION

Emigration from the Tuolumne River ('natal exit') was determined using the distance from the core to the 'last natal spot' rather than the 'first non-natal spot', because to accrete sufficient new otolith material to modify the isotopic composition of the otolith, the fish would have inhabited isotopically distinct (i.e. non-natal) water for several days, after which time it would be a significant distance downstream of the confluence. The method used to identify the 'last natal spot' was to work backwards from the final inflection point indicative of ocean-bound migration (Fig. 3A-C). We assumed that the lowest point of this final inflection represented movement through the SJR, and thus used the spot prior as the last natal spot. The only exceptions were on occasions when the lowest point prior to ocean migration was lower than any value measured in the SJR (e.g. Fig. 3D); on these occasions the lowest point was assumed to have been deposited while the fish was rearing in the lower Tuolumne River, which has been shown to exhibit values as low as 0.7066 (P. Weber, A. Sturrock, unpublished). Emigration from freshwater ('freshwater exit') was defined as the distance at which otolith $^{87}Sr/^{86}Sr$ values last reached 0.7080 (equivalent to 1ppt based on [45]), determined using linear interpolation.

To back-calculate fish size at natal and freshwater exit, the relationship between otolith radius and FL was quantified using fall run Chinook salmon juveniles from the same "Evolutionarily Significant Unit" (ESU), which is of utmost importance for producing relevant and unbiased back calculation models [46]. Otolith radius was measured using a Leica DM1000 microscope and Image Pro Plus 7. Reference samples were collected as part of other projects from the Tuolumne River (2003; n = 6), Stanislaus River (2000 and 2002; n = 95), the Coleman National Fish Hatchery (2002; n=40) and in the San Francisco Bay at Golden Gate Bridge (2005; n = 83) (Fig. 5). The Tuolumne-origin fish tended to sit above the mean regression line (Fig. 5), but there was no significant difference between the back-calculated FL of Tuolumne vs. non-Tuolumne fish (ANCOVA: $p = 0.08$), nor any difference in the slopes (ANCOVA: $p = 0.8$). As such, we assumed that the overall OR-FL relationship was suitable for reconstructing FLs of juveniles from the Tuolumne River, however it would be advisable to increase representation of Tuolumne-origin juveniles in future analyses. The error around the OR-FL calibration line (Fig. 5) was used to estimate 95% confidence intervals (CI) around individual FL reconstructions. Individuals were categorized as fry, parr or smolt outmigrants based on FL: ≤55mm, >55 to <75mm, and >75mm FL, respectively (after [21]).

Daily growth bands were counted and widths between daily increments were measured along the same 90 degree transect as the geochemical analysis, beginning at the post exogenous feeding check until freshwater exit. Some otoliths were difficult to age and given low readability scores (1-2); ages are not provided for these individuals. The ages of fish at Tuolumne River exit, Freshwater exit, and habitat-specific growth rates were obtained for fish with otolith readability scores of 3-5. A subset of otoliths were aged by two independent readers, providing an estimate of error associated with fish aging. The two independent reads of each fish demonstrated high agreement, with an average difference of ± 5 days (range 0-12 days).

RESULTS

ACCURACY OF NATAL ASSIGNMENTS

The DFA assigned 63% of samples back to the correct site of origin (Table 4), with the majority of misclassified sites being among the Mokelumne River Hatchery (MOH), Feather River Hatchery (FEH) and the Tuolumne River (TUO), which overlap in their chemical composition (Fig. 6). The use of otolith microstructure (~10% error rate for hatchery vs. wild assignments) [44] and weighted priors helped to separate TUO-origin fish from MOH and FEH strays, however there remains potential for misclassifications between the two hatchery sites (FEH and MOH), particularly given that (except for outmigration year 2009) the priors used were not cohort-specific. We prepared and processed 13 CWT fish from outmigration years 1999 and 2000 of known hatchery origin. However, the presence of these samples was withheld from the individuals preparing the samples, collecting the $^{87}Sr/^{86}Sr$ data, as well as statistically assigning them to natal origin. Thus, these known samples were treated in the same way as all the unknowns in the study. Once the assignments were made, the true identify of these fish were revealed to the analysts. All fish were correctly classified to the Merced River Hatchery (MEH).

PATTERNS IN $^{87}SR/^{86}SR$ VALUES WITHIN THE TUOLUMNE RIVER

Contrary to the stable $^{87}Sr/^{86}Sr$ profiles observed in other CCV rivers, the Tuolumne River is characterized by variable $^{87}Sr/^{86}Sr$ values from the upper spawning reaches to the confluence with the San Joaquin River (A. Sturrock, unpublished). This variability was first observed in some water analyses (P. Weber, unpublished) and known-origin juveniles (Fig. 3C & D), and subsequently in adult otolith $^{87}Sr/^{86}Sr$ profiles from outmigration years 2000 and 2003 [47]. The lower isotopic values in the lower river were originally hypothesized to result from inputs of Stanislaus River water via Dry Creek (a tributary to the Tuolumne River at river mile [rm] 17). However, subsequent water analyses (carried out as part of other studies) indicated declines in $^{87}Sr/^{86}Sr$ values as far upstream as rm46, with rm 22 to the confluence exhibiting relatively stable signatures around 0.7065 (Fig. 8). The average variability (2SD) of the water analyses based on analyses of multiple standard reference materials was 0.000020, providing high confidence in these data. The geographic trends in Tuolumne River water $^{87}Sr/^{86}Sr$ cannot be explained by inputs from Dry Creek alone (rm 17), implying additional sources of isotopically light water to the upper and mid reaches of the river.

These patterns have clear implications for identifying fish origin, determining rearing location(s) within the Tuolumne River, and the rules used to identify transitions between the Tuolumne and San Joaquin rivers (Fig. 2, 3). Trace elemental analyses of water samples carried out as part of past and ongoing projects (P. Weber, A. Sturrock, unpublished) indicate clear differences in water Sr/Ca and Ba/Ca ratios between the Tuolumne and San Joaquin Rivers (Fig. 9). Thus, future studies attempting to identify fish transition across this confluence might benefit from a multi-elemental approach, combining otolith Sr isotopes with Sr/Ca and Ba/Ca analyses [48].

STRAYING AND RETURN RATES TO THE TUOLUMNE RIVER

Overall, straying rates of unmarked fish have increased over time coincident with increasingly dry environmental conditions. The earliest three outmigration years examined had relative low straying rates of unmarked fish (1998: 57-68% returns, 33-44% strays, 1999: 38-53% returns, 47-62% strays, 2000: 61-64% returns, 36-39% strays). Outmigration year 2003 had intermediary straying rates (27-35% returns, 65-73% strays), while outmigration year 2009 was characterized by particularly high straying rates (9-15% returns, 85-91% strays, primarily from the Coleman National Fish Hatchery on Battle Creek, which comprised 57% of the total sample).

SIZE AND AGE AT OUTMIGRATION

Given the variance around the mean OR-FL regression line (approximately ±10mm FL; Fig. 5), it is not advisable to place too much emphasis on any one particular FL reconstruction; with the upper and lower FL estimates often resulting in fish spanning multiple life stages (Appendix 1A & B). However, given a lack of bias in the OR-FL relationship, and its consistency between Sacramento and San Joaquin basin-origin fish (Fig. 5), the average FLs and overall life stage assignments (Tables 6 and 7) were deemed relatively robust and representative population-level metrics.

All size classes of juvenile outmigrants were represented in the adult spawning population. Tuolumne-origin adults were largely comprised of individuals that had emigrated from the Tuolumne as parr and smolts, however, in outmigration year 2000, 20% of the returning adults had outmigrated as fry (Table 6). Consistent with observations of other populations in the San Joaquin Basin, parr outmigrants were generally the most commonly observed phenotype in the returning adults, implying a potential survival advantage despite being smaller than smolts. There were significant differences in size, age and growth rate between outmigration years ($p<0.05$, Fig. 9, Table 7), but no inter-annual difference in growth rate variability (as tested through comparisons of the coefficient of variation in increment width; $p>0.05$). In general, outmigration year 2000 was characterized by younger, smaller outmigrants; however, the number of days in the freshwater delta was longer (Fig. 9), implying a higher frequency of non-natal rearing during this season.

TABLES

Table 1. Numbers of otolith samples sampled randomly from unclipped salmon carcasses in the Tuolumne River between 2000 and 2012. Ages were obtained from CDFW scale readings and samples matched to outmigration years 1998, 1999, 2000, 2003 and 2009 before Sr isotope analysis.

Cohort		Adult carcass sampling year	Age at return (yr)	Number of individuals	% of total sample
Brood year	Outmigration year (WYT†)				
1997	1998 (Wet)	2000	3	124	62%
		2001	4	76	38%
1998	1999 (Above normal)	2000	2	9	6%
		2001	3	64	44%
		2002	4	73	50%
1999	2000 (Above normal)	2001	2	31	28%
		2002	3	79	72%
		2003	4	0	0%
2002	2003 (Below normal)	2004	2	0	0%
		2005	3	87	91%
		2006	4	9	9%
2008	2009 (Dry)	2010	2	14	30%
		2011	3	30	65%
		2012	4	2	4%
TOTAL				598	

† San Joaquin Valley Index Water year type during juvenile rearing & outmigration

Table 2. Discriminant Function Analysis (DFA) priors used in the current study to predict natal origin of adults obtained in the Tuolumne River Carcass Survey corresponding to outmigration years 1998, 1999, 2000, 2003 and 2009. The probabilities are based on the CWT-derived proportions of hatchery strays in the Tuolumne in escapement year 2010 and 2011 constant fractional marking (CFM) reports and an assumed natural straying rate of 5% [49], removed from the proportion of "natural" fish reported in the CFM report and divided equally among the remaining salmon rivers in the California Central Valley. Priors from CFM escapement year 2010 were applied to all cohorts pre-2009, while priors from CFM escapement year 2011 were applied to outmigration year 2009, given cohort-matching to the dominant year class. Note that Feather River Hatchery and Thermalito Rearing Annex were not distinguished between in the CFM reports, so the priors for the former were divided equally between the two sites.

Natal origin	**Site code**	**"Wild" or hatchery**	**Prior probability based on CFM 2010 escapement** *(all outmigration years <2009)*	**Prior probability based on CFM 2011 escapement** *(outmigration year 2009 only)*
Tuolumne River (RETURNS)	TUO	W	0.4845	0.2565
Merced River Hatchery	MEH	H	0.1060	0.2081
Feather River Hatchery	FEH	H	0.0624	0.0684
Thermalito Rearing Annex	THE	H	0.0624	0.0684
Nimbus Hatchery	NIM	H	0.0433	0.0116
Coleman National Fish Hatchery	CNH	H	0.1345	0.0848
Mokelumne River Hatchery	MOH	H	0.0569	0.2524
Battle Creek	BAT	W	0.005	0.005
Deer Creek	DEE	W	0.005	0.005
Mill Creek	MIL	W	0.005	0.005
Butte Creek	BUT	W	0.005	0.005
Feather River	FEA	W	0.005	0.005
Stanislaus River	STA	W	0.005	0.005
Mokelumne River	MOK	W	0.005	0.005
Yuba River	YUB	W	0.005	0.005
Merced River	MER	W	0.005	0.005
American River	AME	W	0.005	0.005

Table 3. Details of samples and mean $^{87}Sr/^{86}Sr$ included in the DFA to assign natal origin (n=480), where "matrix" includes juvenile otoliths (J), CWT adult otoliths (CWT) and water samples (W). All analyses were carried out as part of existing or ongoing projects ([1], [34], P. Weber, A. Sturrock, unpublished), and used to predict the origin of adults collected in the current study. Site codes are provided in Table 2.

Site	Matrix	Year	N	Mean 87Sr/86Sr	SD
AME	J	1999	5	0.71025	0.00004
AME	W	1998	4	0.70979	0.00017
BAT	J	1999	9	0.70391	0.00017
BUT	W	1998	5	0.70481	0.00009
CNH	CWT	2000	1	0.70527	
CNH	CWT	2009	7	0.70547	0.00043
CNH	CWT	2010	3	0.70557	0.00013
CNH	J	2000	5	0.70531	0.00020
CNH	J	2002	8	0.70535	0.00038
DEE	J	2002	8	0.70412	0.00004
DEE	W	1998	5	0.70409	0.00003
FEA	J	1999	5	0.70622	0.00012
FEA	J	2000	5	0.70621	0.00020
FEA	J	2002	8	0.70615	0.00003
FEA	W	1998	7	0.70620	0.00011
FEH	CWT	2007	14	0.70728	0.00013
FEH	CWT	2008	19	0.70741	0.00014
FEH	J	1999	5	0.70673	0.00012
FEH	J	2000	5	0.70736	0.00017
FEH	J	2002	17	0.70717	0.00020
FEH	J	2004	5	0.70709	0.00014
MEH	CWT	1998	5	0.70888	0.00009
MEH	CWT	1999	5	0.70886	0.00006
MEH	CWT	2001	6	0.70854	0.00006
MEH	CWT	2003	6	0.70872	0.00006
MEH	CWT	2004	2	0.70862	0.00004
MEH	CWT	2006	5	0.70892	0.00007
MEH	CWT	2009	6	0.70871	0.00002
MEH	CWT	2010	6	0.70865	0.00010
MEH	J	1999	1	0.70885	
MEH	J	2002	9	0.70861	0.00003
MEH	J	2004	5	0.70869	0.00011
MER	J	2003	13	0.70852	0.00010
MER	W	1998	4	0.70846	0.00063
MIL	J	2002	10	0.70412	0.00003
MIL	W	1998	5	0.70396	0.00002
MOH	CWT	1998	2	0.70742	0.00003
MOH	CWT	1999	6	0.70767	0.00011
MOH	CWT	2000	13	0.70757	0.00009
MOH	CWT	2001	7	0.70751	0.00009
MOH	CWT	2002	4	0.70757	0.00012
MOH	CWT	2007	8	0.70736	0.00010
MOH	CWT	2008	5	0.70744	0.00014
MOH	CWT	2009	6	0.70737	0.00009
MOH	CWT	2010	8	0.70723	0.00007
MOH	J	1999	4	0.70768	0.00008
MOH	J	2000	5	0.70760	0.00007
MOH	J	2002	11	0.70755	0.00013
MOK	J	2000	4	0.70709	0.00005
MOK	J	2002	10	0.70690	0.00004
MOK	W	1998	4	0.70696	0.00016
NIH	J	2002	9	0.70974	0.00006
STA	J	1999	7	0.70663	0.00002
STA	J	2000	7	0.70663	0.00004
STA	J	2002	10	0.70656	0.00011
STA	J	2011	3	0.70646	0.00005
STA	J	2012	12	0.70643	0.00007
STA	J	2013	7	0.70641	0.00011
STA	W	2012	5	0.70639	0.00002
THE	J	2004	5	0.70581	0.00011
TUO	J	1999	3	0.70783	0.00042
TUO	J	2003	6	0.70757	0.00022
TUO	J	2007	34	0.70763	0.00019
TUO	J	2010	7	0.70780	0.00014
TUO	J	2011	4	0.70780	0.00003
TUO	W	1998	5	0.70789	0.00025
TUO	W	2013	2	0.70785	0.00006
YUB	J	2002	19	0.70823	0.00021

Table 4. Performance of the unweighted DFA for natal assignments. For the unknown samples in this study, weighted priors were used (Table 2) and hatchery vs. wild assignments based on otolith microstructure improved classification accuracy [44].

Site	BAT	DEE	MIL	BUT	CNH	THE	FEA	STA	MOK	FEH	MOH	TUO	YUB	MER	MEH	NIH	AME	Total	% Correct
BAT	**7**	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	78%
DEE	0	**8**	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	62%
MIL	5	9	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	7%
BUT	0	0	0	**5**	0	0	0	0	0	0	0	0	0	0	0	0	0	5	100%
CNH	0	0	0	4	**14**	5	1	0	0	0	0	0	0	0	0	0	0	24	58%
THE	0	0	0	0	0	**5**	0	0	0	0	0	0	0	0	0	0	0	5	100%
FEA	0	0	0	0	0	1	**22**	2	0	0	0	0	0	0	0	0	0	25	88%
STA	0	0	0	0	0	0	4	**47**	0	0	0	0	0	0	0	0	0	51	92%
MOK	0	0	0	0	0	0	0	0	**15**	3	0	0	0	0	0	0	0	18	83%
FEH	0	0	0	0	0	0	0	2	13	**26**	24	0	0	0	0	0	0	65	40%
MOH	0	0	0	0	0	0	0	0	0	19	**35**	25	0	0	0	0	0	79	44%
TUO	0	0	0	0	0	0	0	0	1	2	18	**35**	5	0	0	0	0	61	57%
YUB	0	0	0	0	0	0	0	0	0	0	0	1	**14**	4	0	0	0	19	74%
MER	0	0	0	0	0	0	0	0	0	0	0	1	0	**12**	4	0	0	17	71%
MEH	0	0	0	0	0	0	0	0	0	0	0	0	0	14	**42**	0	0	56	75%
NIH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**9**	0	9	100%
AME	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	**6**	9	67%
OVERALL																			63%

Table 5. Natal origin of all unclipped fish analyzed for 5 outmigration years (1998, 1999, 2000, 2003 and 2009). Note that adclipped fish have been removed (1 from OMY1999, 12 from OMY 2000 - all correctly assigned to Merced Hatchery).

			1998		**1999**		**2000**		**2003**		**2009**	
	Site	**Code**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Wild	Tuolumne R.	TUO	117	59%	55	38%	66	61%	26	27%	5	11%
	Tuolumne R.*	TUO*	17	9%	22	15%	2	2%	8	8%	2	4%
	Stanislaus R.	STA	5	3%	8	5%	4	4%	0	0%	0	0%
	Merced R.	MER	1	1%	0	0%	0	0%	0	0%	0	0%
	Mokelumne R.	MOK	2	1%	1	1%	0	0%	0	0%	0	0%
	Feather R.	FEA	0	0%	0	0%	0	0%	0	0%	1	2%
Hatchery	Coleman H.	CNH	0	0%	0	0%	0	0%	1	1%	26	57%
	Feather H.	FEH	1	1%	5	3%	4	4%	6	6%	4	9%
	Mokelumne H.	MOH	8	4%	28	19%	23	21%	39	41%	1	2%
	Merced H.	MEH	34	17%	9	6%	5	5%	4	4%	2	4%
	Nimbus H.	NIH	0	0%	5	3%	1	1%	9	9%	2	4%
	Thermalito (Feather H.)	THE	0	0%	2	1%	0	0%	3	3%	3	7%
	Habitat X ‡	X	15	8%	11	8%	5	5%	0	0%	0	0%
	Total		**200**		**146**		**110**		**96**		**46**	

* Individuals assigned to the Tuolumne with <0.5 posterior probability based on mean natal $^{87}Sr/^{86}Sr$ values.

‡ Individuals assigned as hatchery-origin based on otolith microstructure, but where natal $^{87}Sr/^{86}Sr$ values are outside of the observed range of any hatchery in the CCV.

Table 6. Life stage † at natal exit for fish assigned to the Tuolumne River with high confidence

Outmigration year	N	Fry	Parr	Smolt
1998	117	2%	56%	43%
1999	55	4%	62%	35%
2000	67	20%	73%	8%
2003	26	4%	65%	31%
2009	5	0%	40%	60%

† Life stage defined as fry (≤55mm), parr (>55mm to ≤75mm) or smolt (>75 mm) after [21]

Table 7. Summary of average forklength (FL) at exit, number of increments (days) and increment width (growth rate) in the natal river and freshwater delta by outmigration year for juveniles that originated in and returned to the Tuolumne River (identified as "TUO" in Appendix Table 1). Trends are also visualized in Figure 9 in the form of box plots (i.e. displaying median values as opposed to means), alongside the results of statistical comparisons among years.

		Natal river			Freshwater delta		
Outmigration year	Sample size	FL at exit (mm)	No. increments (days)	Increment width (µm)	FL at exit (mm)	No. increments (days)	Increment width (µm)
1998	117	73.3 ± 8.5	91.0 ± 16.2	3.07 ± 0.28	80.8 ± 9.0	15.8 ± 7.5	3.24 ± 0.54
1999	55	72.6 ± 11.6	82.0 ± 13.6	3.20 ± 0.27	82.3 ± 11.5	16.5 ± 8.7	3.35 ± 0.56
2000	66	63.5 ± 8.6	68.5 ± 18.6	3.10 ± 0.26	77.4 ± 6.9	27.6 ± 12.1	3.52 ± 0.52
2003	26	71.0 ± 10.6	79.7 ± 17.9	3.39 ± 0.43	80.1 ± 10.0	10.5 ± 5.2	3.65 ± 0.62
2009	5	76.0 ± 7.1	88.0 ± 20.3	3.36 0.29	83.4 ± 6.8	16.0 ± 7.5	3.03 ± 0.36

FIGURES

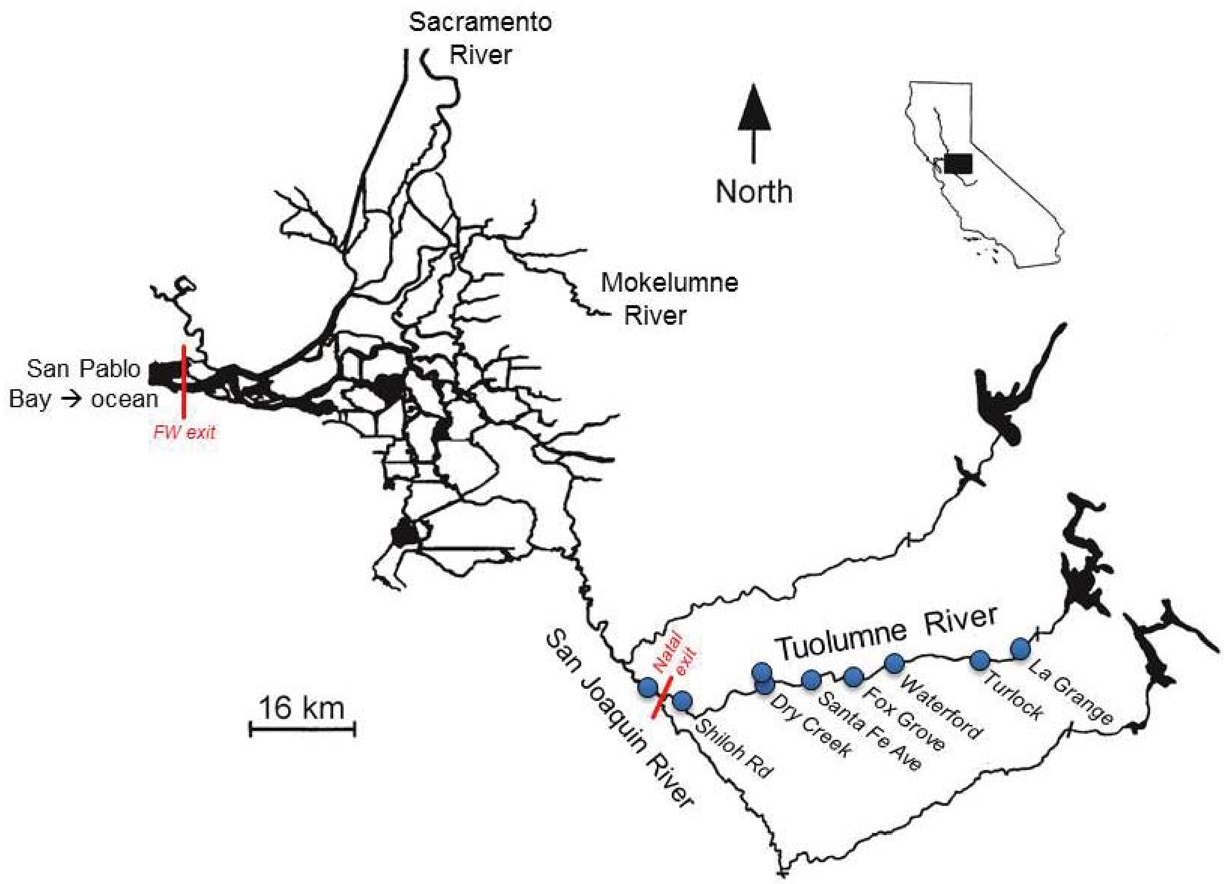


Fig. 1 Map to show location of the Tuolumne and San Joaquin rivers, and the sites sampled for water isotope analyses as part of a different project (blue circles; A. Sturrock, unpublished). The locations defined as natal and freshwater (FW) exit are indicated by red lines.

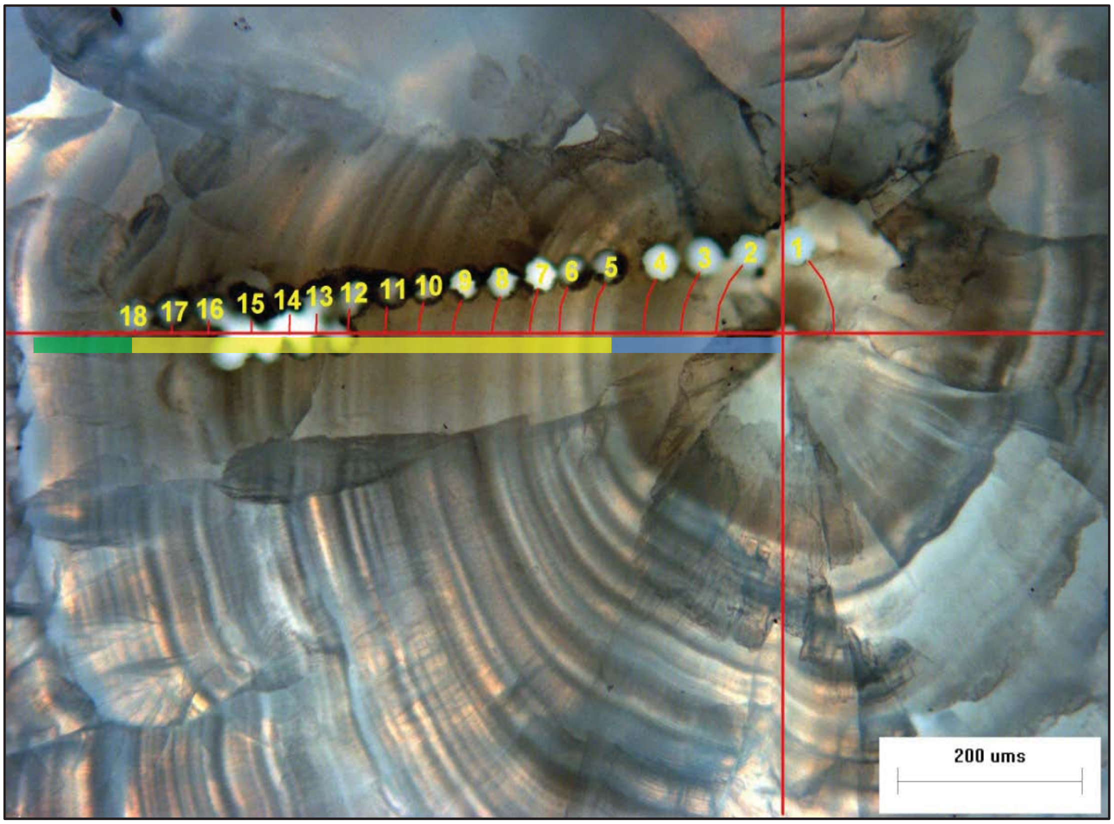


Fig. 2 A typical $^{87}Sr/^{86}Sr$ transect showing spot analyses (numbered) from the core to ocean entry. The life history stages are indicated by letters: maternal (M), juvenile (J) and ocean (O). The distance at which the final 'natal spot' intersected the 90° transect (indicated by curved red lines) was used to back-calculate size at outmigration. Note the 'respots' at positions 12.5 to 15.5 (located under the yellow bar) used to more accurately identify exit point.

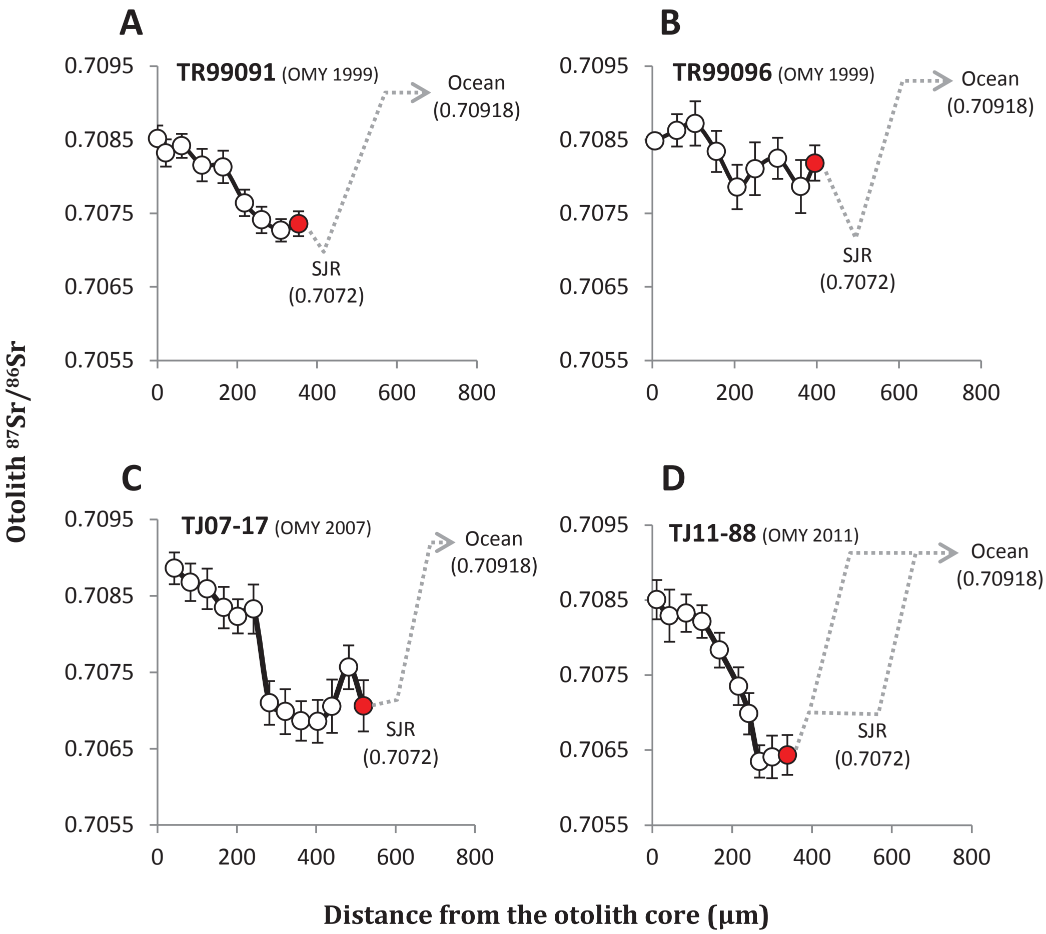


Fig. 3 Otolith $^{87}Sr/^{86}Sr$ profiles from four juvenile salmon captured in the lower Tuolumne River in outmigration years (OMY) 1999, 2007 and 2011. The natal exit spot ("last natal value") is indicated in red, along with the expected profile trajectory (dotted lines) through the San Joaquin River (SJR) to the ocean, had the fish not been captured as a juvenile and was instead being sampled as a returning adult. Note that the juvenile in plot D had moved to the lower river (or Dry Creek) immediately after emergence (~250um from the core) and the dotted lines indicate two possible trajectories, one with extended rearing in the SJR prior to leaving freshwater and the other with direct outmigration to the ocean.

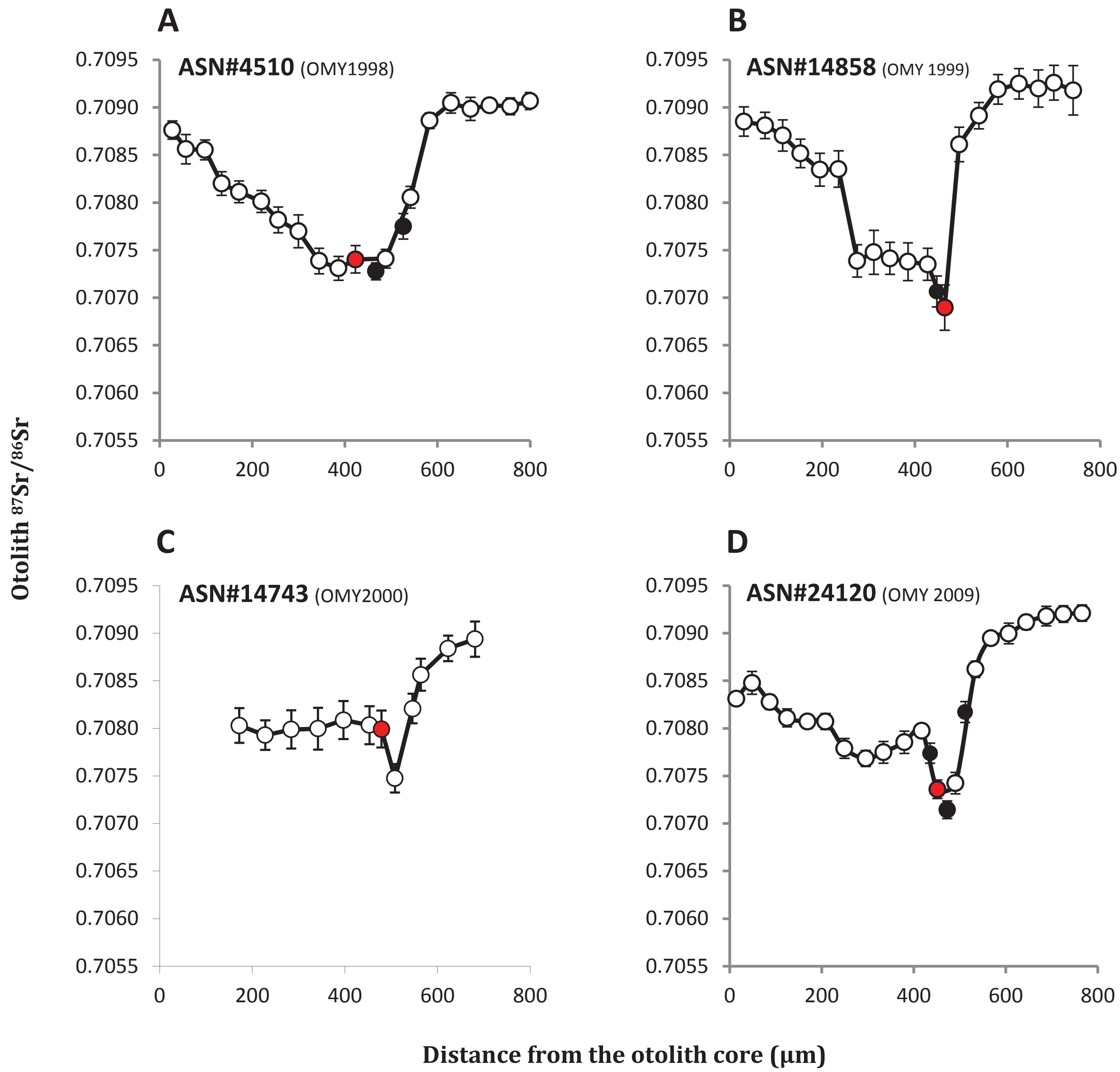


Fig. 4 Examples of otolith $^{87}Sr/^{86}Sr$ profiles from adult salmon carcasses collected in the lower Tuolumne River that were assigned to the Tuolumne River, having outmigrated as juveniles in 1998-2009. The inferred 'last natal spot' prior to outmigration to the SJR and ocean is shown in red. Black symbols indicate respots.

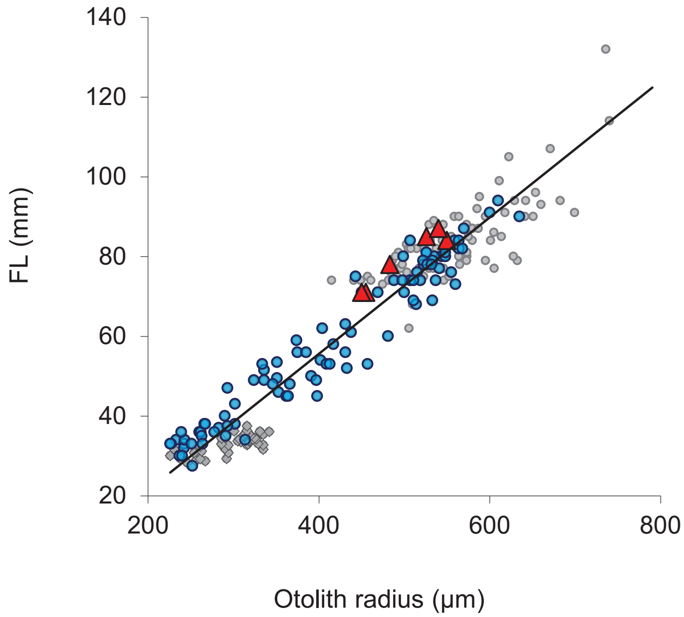


Fig. 5 Relationship between otolith radius and fork length (FL) of juveniles of known origin (Sturrock, unpublished) ($n=224$, $r^2 = 0.92$) used to reconstruct size at outmigration in returning adults from the current study. The 224 reference samples are all in the same Evolutionary Significant Unit (California Central Valley fall run salmon) and include individuals from the Tuolumne River (n=6; red triangles), the Stanislaus River (n=95; blue circles), Coleman National Fish Hatchery (n=40; grey diamonds) and the San Francisco Bay at Golden Gate Bridge of unknown origin within the CCV (n=83; grey circles).

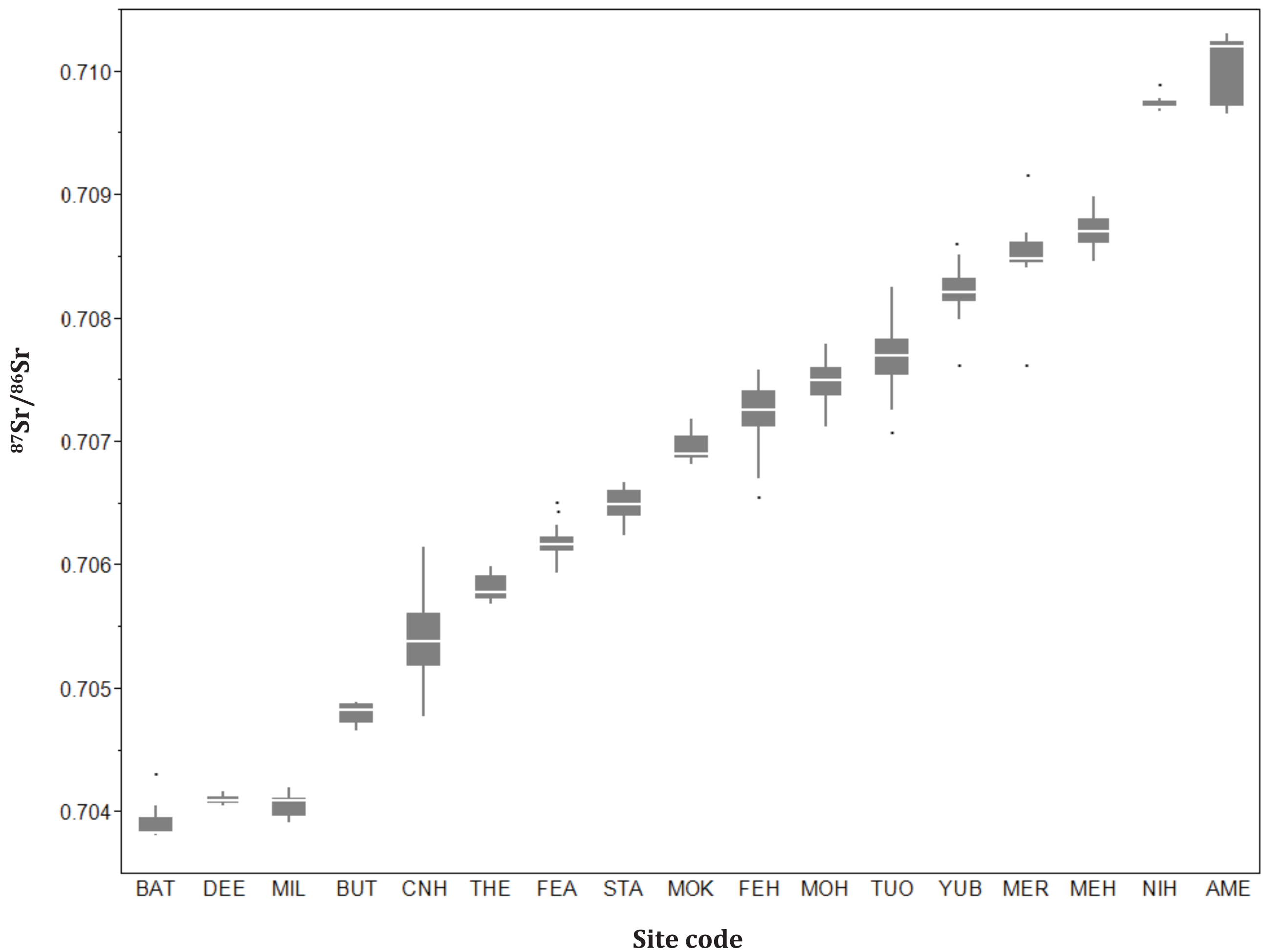


Fig. 6 Differences in $^{87}Sr/^{86}Sr$ values among sites in the CCV, modified from [1] using additional water samples and otoliths from known-origin juveniles and adult CWT fish analyzed as part of existing and ongoing projects ([34], P. Weber & A. Sturrock, unpublished). Site codes identified in Table 2. These data were used to predict the origin of adults collected in the current study. Due to overlap among TUO, MOH and FEH, all fish identified as potentially originated in the Tuolumne River (TUO) using Sr isotopes were also assigned to hatchery/wild using otolith microstructure (Barnett-Johnson et al., 2007).

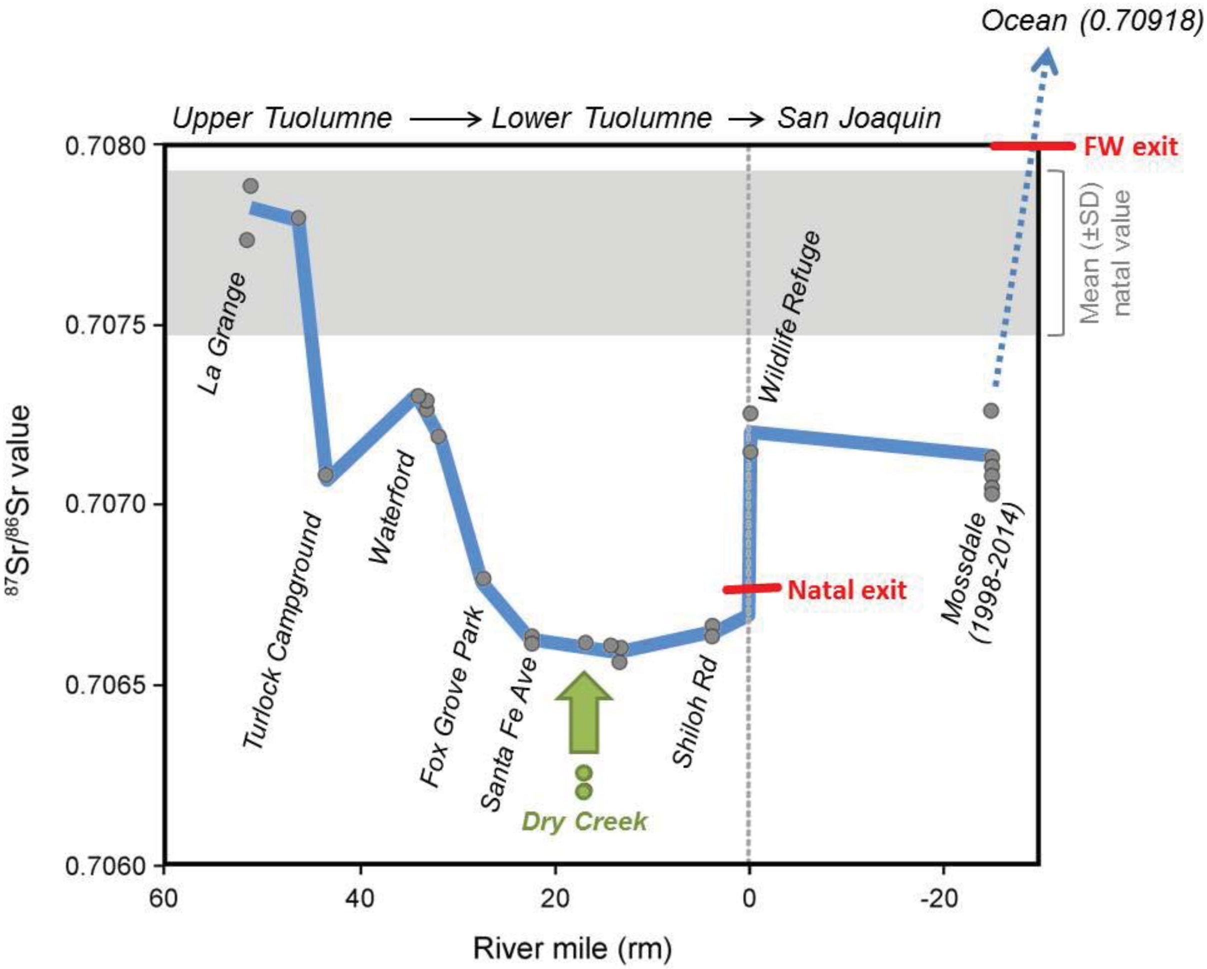


Fig. 7 Trends in water $^{87}Sr/^{86}Sr$ in the mainstem Tuolumne and San Joaquin Rivers (samples collected as part of other studies). The majority of measurements were collected in January and February 2014; however, additional years are included where available. The shaded grey bar indicates the mean natal value allocated to the Tuolumne (±SD), based on otolith analyses of juveniles captured in a rotary screw trap close to Shiloh Road (i.e., prior to outmigration). The blue trend line within the Tuolumne River is driven by sources of isotopically light water entering the river downstream of the spawning reaches (~rm50). At the time of writing, Dry Creek (rm 16.7) is the only known example of such a source.

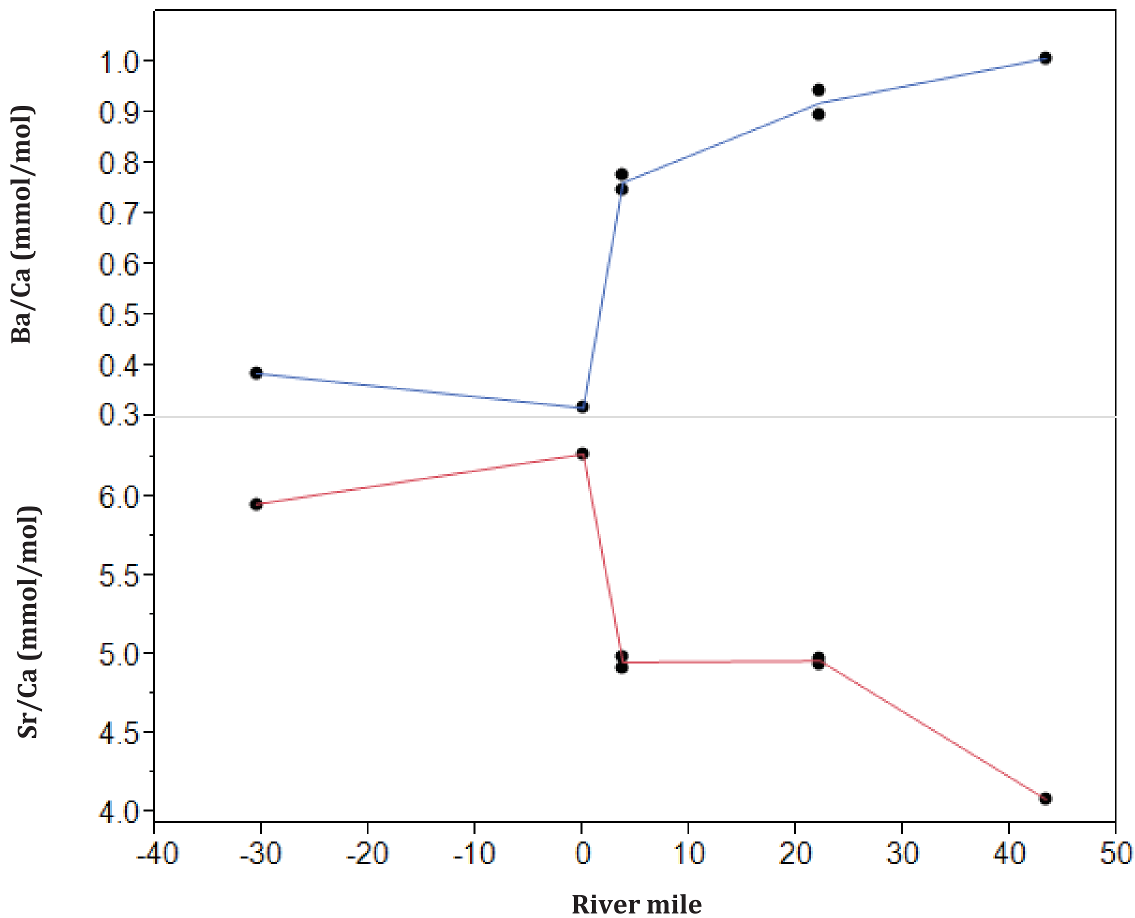
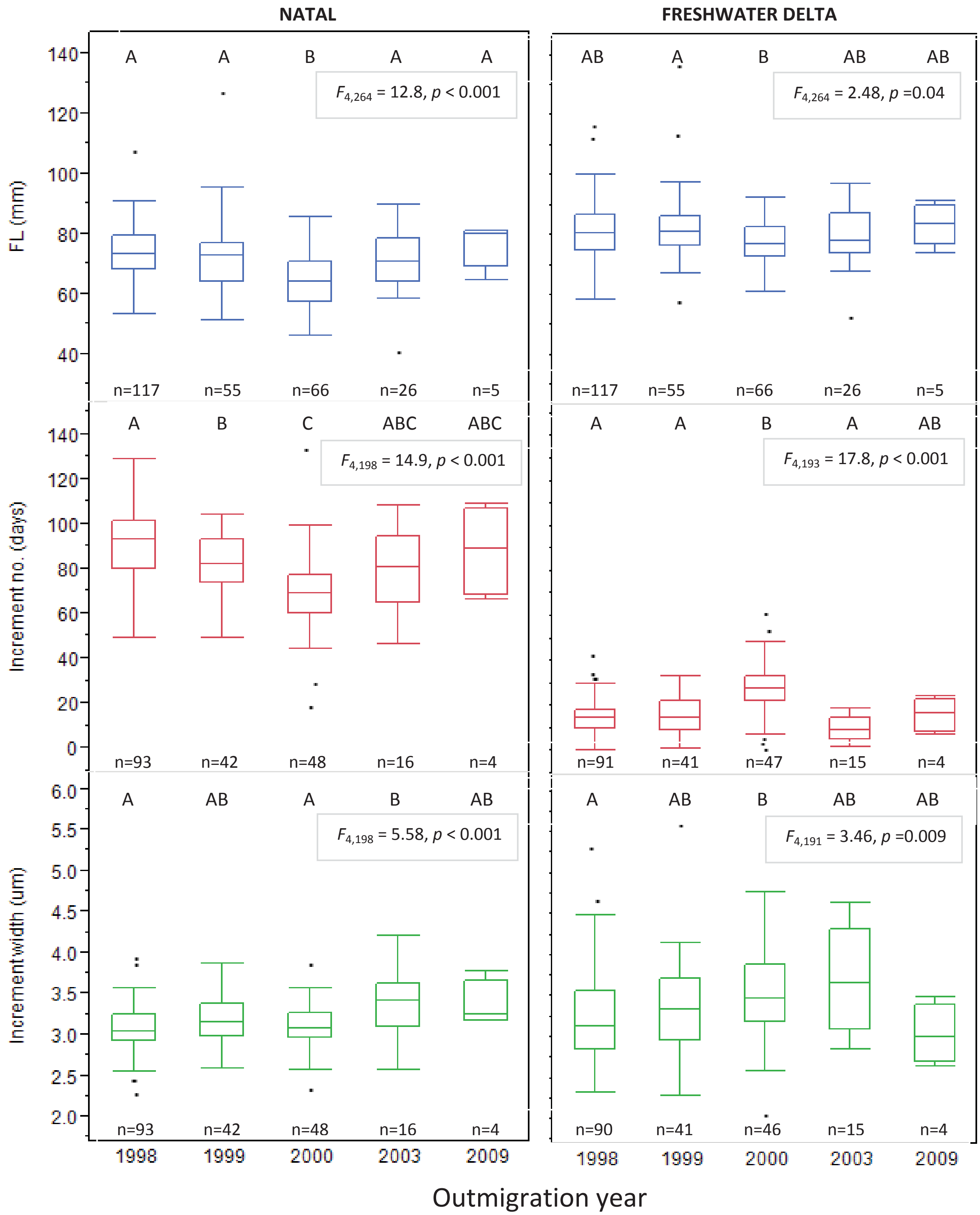


Fig. 8 Trends in water Ba/Ca and Sr/Ca between the Tuolumne and San Joaquin rivers (samples collected as part of other studies). Note the sharp inflection between the lower Tuolumne (~river mile 3) and the San Joaquin (river mile 0) rivers.

Fig. 9 Trends in median fork length at exit (FL), number of otolith increments (age) and increment width (growth rate) in the natal river (left) and freshwater delta (right) of juveniles that originated in and returned to the Tuolumne River. Overall differences among years were tested by ANOVA (results exhibited on each plot). Bars not connected by the same letter are significantly different (p<0.05, Tukey's test).



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Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

						Natal Sr ratio				Natal exit	Predicted FL at natal exit (mm)			Predicted life stage at natal exit [3]				Increment width (um)		
Sample ID	Capture date	Capture FL (cm)	Scale age	Sex	Outmi-gration year	Mean natal value	Prob to TUO [1]	H vs. W [2]	Natal location	Otolith distance (um)	FL	Lower 95% CI	Upper 95% CI	Life stage	Lower 95% CI	Upper 95% CI	Increment no (days)	Mean	CV	Notes
4175	10/10/00	98	3	M	1998	0.70799	0.97	W	TUO	576.6	85.8	77.2	95.9	S	S	S	109	3.26	0.19	
4176	10/10/00	91	3	M	1998	0.70774	0.95	W	TUO	544.4	80.3	71.7	90.4	S	P	S	96	3.53	0.21	
4182	10/17/00	76	3	M	1998	0.70803	0.96	W	TUO	544.1	80.3	71.7	90.3	S	P	S	112	2.96	0.19	
4183	10/17/00	90	3	M	1998	0.70797	0.97	W	TUO	494.3	71.8	63.2	81.8	P	P	S	94	2.74	0.22	
4185	10/17/00	84	3	F	1998	0.70728	0.64	W	TUO	522.7	76.6	68.0	86.7	S	P	S	107	3.17	0.26	
4189	10/24/00	90	3	F	1998	0.70806	0.94	W	TUO	452.6	64.6	56.1	74.7	P	P	P	83	2.90	0.23	
4192	10/24/00	87.5	3	F	1998	0.70807	0.93	W	TUO	487.5	70.6	62.0	80.7	P	P	S	87	3.22	0.23	
4196	10/24/00	67.9	3	F	1998	0.70800	0.97	W	TUO	493.3	71.6	63.0	81.7	P	P	S	98 †	2.62	0.20	† Microstructure ran out 33um before last natal spot (inferred 12 increments)
4197	10/24/00	78.6	3	F	1998	0.70740	0.61	W	TUO	423.2	59.6	51.0	69.7	P	F	P	79	2.74	0.26	
4200	10/24/00	68.6	3	F	1998	0.70760	0.88	W	TUO	569.4	84.6	76.0	94.7	S	S	S	102	3.20	0.27	
4210	10/24/00	88.3	3	M	1998	0.70764	0.91	W	TUO	488.9	70.8	62.2	80.9	P	P	S	93	2.98	0.28	
4211	10/24/00	72	3	F	1998	0.70783	0.97	W	TUO	581.0	86.6	78.0	96.6	S	S	S	.			
4212	10/24/00	78.1	3	M	1998	0.70765	0.91	W	TUO	541.0	79.7	71.2	89.8	S	P	S	93	2.93	0.20	
4215	10/25/00	79	3	F	1998	0.70802	0.96	W	TUO	552.5	81.7	73.1	91.8	S	P	S	111	3.03	0.20	
4226	10/25/00	80	3	F	1998	0.70770	0.93	W	TUO	446.6	63.6	55.0	73.7	P	P	P	70	3.11	0.33	
4232	10/25/00	88.5	3	M	1998	0.70821	0.53	W	TUO	519.3	76.0	67.5	86.1	S	P	S	.			
4233	10/25/00	72	3	F	1998	0.70795	0.98	W	TUO	452.6	64.6	56.1	74.7	P	P	P	74	3.02	0.20	
4234	10/25/00	77	3	F	1998	0.70823	0.45	W	TUO*	579.9	86.4	77.8	96.5	S	S	S	*Inconclusive natal assignment*			
4240	10/26/00	80	3	F	1998	0.70726	0.28	W	TUO*	426.2	60.1	51.5	70.2	P	F	P	*Inconclusive natal assignment*			
4249	10/30/00	80	3	F	1998	0.70737	0.54	W	TUO	485.8	70.3	61.7	80.4	P	P	S	.			
4253	10/30/00	80	3	M	1998	0.70810	0.90	W	TUO	554.2	82.0	73.4	92.1	S	P	S	101	3.05	0.26	
4266	10/30/00	77	3	F	1998	0.70740	0.60	W	TUO	461.1	66.1	57.5	76.2	P	P	S	100	2.43	0.25	
4267	10/30/00	75	3	F	1998	0.70812	0.86	W	TUO	476.3	68.7	60.1	78.8	P	P	S	.			
4269	10/30/00	80	3	F	1998	0.70732	0.43	W	TUO*	581.6	86.7	78.1	96.8	S	S	S	*Inconclusive natal assignment*			
4275	10/31/00	79	3	F	1998	0.70721	0.18	W	TUO*	416.1	58.4	49.8	68.5	P	F	P	*Inconclusive natal assignment*			
4278	10/31/00	83	3	F	1998	0.70802	0.96	W	TUO	480.1	69.3	60.7	79.4	P	P	S	.			
4279	10/31/00	87.5	3	F	1998	0.70798	0.97	W	TUO	568.8	84.5	75.9	94.6	S	S	S	120	3.18	0.22	

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4281	10/31/00	91	3	M	1998	0.70728	0.31	W	TUO*	454.0	64.9	56.3	74.9	P	P	P	*Inconclusive natal assignment*			
4292	10/31/00	74	3	F	1998	0.70733	0.44	W	TUO*	526.1	77.2	68.6	87.3	S	P	S	*Inconclusive natal assignment*			
4294	10/31/00	86	3	F	1998	0.70800	0.97	W	TUO	560.6	83.1	74.5	93.2	S	P	S	.			
4295	10/31/00	72	3	F	1998	0.70816	0.77	W	TUO	495.0	71.9	63.3	81.9	P	P	S	87	3.13	0.23	
4297	11/01/00	74	3	F	1998	0.70805	0.95	W	TUO	576.9	85.9	77.3	96.0	S	S	S	109	2.98	0.18	
4299	11/06/00	81	3	F	1998	0.70801	0.97	W	TUO	527.8	77.5	68.9	87.6	S	P	S	.			
4300	11/06/00	96	3	M	1998	0.70735	0.50	W	TUO*	452.0	64.5	55.9	74.6	P	P	P	*Inconclusive natal assignment*			
4306	11/06/00	85	3	F	1998	0.70801	0.97	W	TUO	520.7	76.3	67.7	86.3	S	P	S	93	3.27	0.17	
4309	11/06/00	84	3	F	1998	0.70807	0.93	W	TUO	453.7	64.8	56.2	74.9	P	P	P	.			
4311	11/06/00	74	3	F	1998	0.70752	0.81	W	TUO	432.7	61.2	52.6	71.3	P	F	P	73	3.03	0.22	
4316	11/06/00	81	3	F	1998	0.70738	0.55	W	TUO	383.9	52.9	44.3	63.0	F	F	P	.			
4317	11/06/00	79	3	F	1998	0.70786	0.97	W	TUO	488.2	70.7	62.1	80.8	P	P	S	94 †	2.82	0.26	† Microstructure ran out 55um before last natal spot (inferred 19 increments)
4321	11/06/00	70	3	F	1998	0.70742	0.65	W	TUO	500.4	72.8	64.2	82.9	P	P	S	73	3.54	0.36	
4331	11/07/00	86	3	M	1998	0.70798	0.97	W	TUO	571.5	85.0	76.4	95.0	S	S	S	127	3.00	0.20	
4334	11/07/00	85	3	F	1998	0.70739	0.59	W	TUO	384.6	53.0	44.4	63.1	F	F	P	54	3.44	0.23	
4337	11/07/00	74	3	F	1998	0.70733	0.45	W	TUO*	535.3	78.8	70.2	88.8	S	P	S	*Inconclusive natal assignment*			
4340	11/07/00	75.5	3	F	1998	0.70783	0.97	W	TUO	490.2	71.1	62.5	81.1	P	P	S	.			
4343	11/07/00	81	3	F	1998	0.70768	0.92	W	TUO	509.5	74.4	65.8	84.4	P	P	S	109	2.96	0.26	
4352	11/07/00	73	3	F	1998	0.70788	0.97	W	TUO	563.0	83.5	74.9	93.6	S	P	S	81	3.09	0.20	
4360	11/08/00	76.5	3	F	1998	0.70818	0.67	W	TUO	578.2	86.1	77.5	96.2	S	S	S	.			
4376	11/09/00	85	3	F	1998	0.70733	0.46	W	TUO*	571.8	85.0	76.4	95.1	S	S	S	*Inconclusive natal assignment*			
4378	11/09/00	88	3	M	1998	0.70728	0.33	W	TUO*	607.4	91.1	82.5	101.2	S	S	S	*Inconclusive natal assignment*			
4381	11/13/00	90	3	M	1998	0.70816	0.75	W	TUO	455.0	65.0	56.5	75.1	P	P	S	75	3.02	0.20	
4383	11/13/00	79	3	M	1998	0.70756	0.85	W	TUO	529.2	77.7	69.1	87.8	S	P	S	.			
4384	11/13/00	80	3	F	1998	0.70786	0.97	W	TUO	506.8	73.9	65.3	84.0	P	P	S	85	3.16	0.23	
4397	11/13/00	67	3	F	1998	0.70819	0.66	W	TUO	474.7	68.4	59.8	78.5	P	P	S	84	2.93	0.26	
4403	11/14/00	77	3	F	1998	0.70808	0.92	W	TUO	501.7	73.0	64.4	83.1	P	P	S	90	2.99	0.23	
4414	11/14/00	81	3	F	1998	0.70749	0.77	W	TUO	467.5	67.2	58.6	77.3	P	P	S	.			
4418	11/14/00	86	3	F	1998	0.70742	0.66	W	TUO	460.1	65.9	57.3	76.0	P	P	S	65	3.84	0.34	
4424	11/14/00	77	3	F	1998	0.70783	0.97	W	TUO	552.9	81.8	73.2	91.8	S	P	S	125	2.95	0.21	
4441	11/20/00	72	3	F	1998	0.70823	0.45	W	TUO*	485.5	70.3	61.7	80.3	P	P	S	*Inconclusive natal assignment*			

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4442	11/20/00	95	3	M	1998	0.70771	0.94	W	TUO	592.1	88.5	79.9	98.6	S	S	S	114	3.25	0.28	
4443	11/20/00	100	3	M	1998	0.70735	0.50	W	TUO*	475.3	68.5	59.9	78.6	P	P	S	*Inconclusive natal assignment*			
4450	11/20/00	82	3	F	1998	0.70817	0.73	W	TUO	447.6	63.8	55.2	73.8	P	P	P	104	2.26	0.24	
4451	11/20/00	92	3	M	1998	0.70817	0.72	W	TUO	472.3	68.0	59.4	78.1	P	P	S	108	2.82	0.25	
4455	11/20/00	74	3	F	1998	0.70769	0.93	W	TUO	514.6	75.2	66.6	85.3	S	P	S	78	3.29	0.22	
4458	11/21/00	80	3	F	1998	0.70792	0.98	W	TUO	543.4	80.2	71.6	90.2	S	P	S	92	3.33	0.26	
4476	11/22/00	100	3	M	1998	0.70804	0.95	W	TUO	514.9	75.3	66.7	85.4	S	P	S	111	2.68	0.32	
4484	11/27/00	77	3	F	1998	0.70788	0.97	W	TUO	528.8	77.7	69.1	87.7	S	P	S	90	3.06	0.26	
4487	11/27/00	84	3	F	1998	0.70800	0.97	W	TUO	493.6	71.6	63.1	81.7	P	P	S	.			
4504	12/04/00	100	3	M	1998	0.70826	0.30	W	TUO*	480.4	69.4	60.8	79.5	P	P	S	*Inconclusive natal assignment*			
4506	12/04/00	80	3	F	1998	0.70756	0.85	W	TUO	406.6	56.8	48.2	66.8	P	F	P	60	3.23	0.24	
4508	12/04/00	89	3	F	1998	0.70806	0.94	W	TUO	466.5	67.0	58.4	77.1	P	P	S	85	2.76	0.18	
4509	12/04/00	70.5	3	F	1998	0.70812	0.86	W	TUO	489.9	71.0	62.4	81.1	P	P	S	91	3.14	0.22	
4510	12/05/00	77	3	F	1998	0.70776	0.95	W	TUO	422.9	59.5	51.0	69.6	P	F	P	49	3.30	0.28	
4514	12/05/00	78	3	F	1998	0.70794	0.98	W	TUO	462.1	66.3	57.7	76.3	P	P	S	.			
4515	12/05/00	77	3	F	1998	0.70815	0.80	W	TUO	481.1	69.5	60.9	79.6	P	P	S	80	3.39	0.21	
4516	12/05/00	82	3	F	1998	0.70818	0.69	W	TUO	471.3	67.8	59.2	77.9	P	P	S	75	3.31	0.22	
4517	12/05/00	88.5	3	F	1998	0.70798	0.97	W	TUO	526.8	77.3	68.7	87.4	S	P	S	95	3.04	0.20	
4518	12/05/00	83	3	F	1998	0.70789	0.97	W	TUO	519.3	76.0	67.5	86.1	S	P	S	94	3.30	0.24	
4521	12/06/00	78.5	3	F	1998	0.70788	0.97	W	TUO	537.6	79.2	70.6	89.2	S	P	S	83	3.24	0.22	
4527	12/11/00	83	3	M	1998	0.70819	0.66	W	TUO	543.4	80.2	71.6	90.2	S	P	S	93	3.40	0.27	
4535	12/19/00	78	3	F	1998	0.70814	0.82	W	TUO	503.1	73.3	64.7	83.3	P	P	S	100	3.14	0.22	
9536	07/07/00	75	3	F	1998	0.70775	0.95	W	TUO	700.5	107.0	98.4	117.1	S	S	S	.			
11015	11/16/01	86.5	4	F	1998	0.70789	0.97	W	TUO	486.3	70.4	61.8	80.5	P	P	S	80	3.53	0.28	
11036	12/11/01	86	4	F	1998	0.70772	0.94	W	TUO	580.3	86.5	77.9	96.5	S	S	S	95	3.56	0.21	
11037	12/11/01	110	4	M	1998	0.70792	0.98	W	TUO	538.6	79.3	70.8	89.4	S	P	S	93	3.02	0.27	
11038	12/11/01	78	4	F	1998	0.70821	0.53	W	TUO	477.7	68.9	60.3	79.0	P	P	S	.			
11040	12/11/01	98	4	F	1998	0.70812	0.86	W	TUO	549.8	81.3	72.7	91.3	S	P	S	114	3.02	0.30	
11056	11/20/01	78	4	F	1998	0.70779	0.96	W	TUO	504.4	73.5	64.9	83.6	P	P	S	115	2.67	0.23	
11064	11/20/01	95	4	M	1998	0.70745	0.71	W	TUO	541.0	79.7	71.2	89.8	S	P	S	92	3.92	0.34	
11072	11/20/01	112	4	M	1998	0.70816	0.75	W	TUO	468.6	67.4	58.8	77.4	P	P	S	75	3.05	0.19	
11085	11/20/01	87	4	F	1998	0.70737	0.55	W	TUO	411.3	57.6	49.0	67.6	P	F	P	.			
11089	11/20/01	104	4	M	1998	0.70816	0.76	W	TUO	479.1	69.2	60.6	79.2	P	P	S	90	2.79	0.19	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

11097	11/30/01	82	4	M	1998	0.70743	0.67	W	TUO	518.3	75.9	67.3	85.9	S	P	S	88	3.23	0.39
11098	11/30/01	87	4	F	1998	0.70807	0.93	W	TUO	530.2	77.9	69.3	88.0	S	P	S	93	3.20	0.20
11140	11/26/01	88	4	F	1998	0.70769	0.93	W	TUO	479.4	69.2	60.6	79.3	P	P	S	79	2.90	0.27
11154	11/26/01	87	4	F	1998	0.70794	0.98	W	TUO	518.7	75.9	67.3	86.0	S	P	S	91	3.25	0.27
11176	12/07/01	92.5	4	F	1998	0.70821	0.54	W	TUO	544.7	80.4	71.8	90.5	S	P	S	.		
11177	12/07/01	90	4	F	1998	0.70781	0.96	W	TUO	484.1	70.0	61.4	80.1	P	P	S	.		
11181	12/18/01	87	3	F	1998	0.70819	0.63	W	TUO	604.7	90.6	82.0	100.7	S	S	S	129	3.21	0.22
11182	12/17/01	99	4	M	1998	0.70798	0.97	W	TUO	397.8	55.3	46.7	65.3	P	F	P	51	3.10	0.23
11190	11/23/01	90	3	M	1998	0.70821	0.53	W	TUO	506.8	73.9	65.3	84.0	P	P	S	95	2.99	0.24
11216	11/21/01	94	4	F	1998	0.70821	0.54	W	TUO	517.6	75.8	67.2	85.8	S	P	S	122	2.55	0.27
19680	11/15/01	103	4	M	1998	0.70766	0.92	W	TUO	603.0	90.3	81.8	100.4	S	S	S	.		
19684	11/15/01	92	3.5	M	1998	0.70776	0.95	W	TUO	508.2	74.1	65.5	84.2	P	P	S	.		
19685	11/15/01	87	4	F	1998	0.70811	0.89	W	TUO	513.2	75.0	66.4	85.1	S	P	S	.		
19687	11/15/01	82	3.5	M	1998	0.70806	0.95	W	TUO	515.3	75.4	66.8	85.4	S	P	S	96	2.97	0.21
19691	11/15/01	91	4	M	1998	0.70721	0.19	W	TUO*	421.8	59.4	50.8	69.4	P	F	P	*Inconclusive natal assignment*		
19719	11/19/01	94.5	3.5	F	1998	0.70806	0.94	W	TUO	510.5	74.5	66.0	84.6	P	P	S	89	2.88	0.23
19772	11/28/01	97	4	F	1998	0.70769	0.93	W	TUO	467.9	67.2	58.7	77.3	P	P	S	84	2.81	0.24
19776	11/28/01	90	4	F	1998	0.70821	0.53	W	TUO	522.7	76.6	68.0	86.7	S	P	S	101	3.10	0.19
19777	11/28/01	91	4	F	1998	0.70816	0.76	W	TUO	489.2	70.9	62.3	81.0	P	P	S	96	2.67	0.30
19781	11/28/01	86	4	F	1998	0.70824	0.37	W	TUO*	532.5	78.3	69.7	88.4	S	P	S	*Inconclusive natal assignment*		
19783	11/28/01	89	4	F	1998	0.70793	0.98	W	TUO	432.7	61.2	52.6	71.3	P	F	P	68	3.03	0.26
19785	11/28/01	88	4	F	1998	0.70765	0.91	W	TUO	446.2	63.5	55.0	73.6	P	F	P	67	3.16	0.25
19790	11/28/01	94	4	F	1998	0.70818	0.68	W	TUO	504.1	73.4	64.9	83.5	P	P	S	104	2.44	0.24
19796	12/03/01	81	4	F	1998	0.70811	0.88	W	TUO	509.9	74.4	65.8	84.5	P	P	S	83	3.31	0.24
19798	12/03/01	93	4	M	1998	0.70814	0.83	W	TUO	474.7	68.4	59.8	78.5	P	P	S	101	3.02	0.23
19800	12/03/01	114	4	M	1998	0.70776	0.95	W	TUO	569.8	84.7	76.1	94.7	S	S	S	.		
19802	12/03/01	97	4	F	1998	0.70824	0.40	W	TUO*	539.3	79.5	70.9	89.5	S	P	S	*Inconclusive natal assignment*		
19805	12/03/01	88	4	F	1998	0.70821	0.56	W	TUO	496.7	72.2	63.6	82.2	P	P	S	95	3.15	0.25
19806	12/03/01	89	4	F	1998	0.70769	0.93	W	TUO	542.4	80.0	71.4	90.0	S	P	S	103	3.04	0.28
19810	12/03/01	85	4	F	1998	0.70765	0.91	W	TUO	479.1	69.2	60.6	79.2	P	P	S	74	3.56	0.28
19820	12/03/01	105	4	M	1998	0.70779	0.96	W	TUO	492.6	71.5	62.9	81.5	P	P	S	88	3.37	0.28
19821	12/03/01	94	4	F	1998	0.70812	0.86	W	TUO	494.3	71.8	63.2	81.8	P	P	S	95	2.63	0.30
19838	12/03/01	73	4	F	1998	0.70765	0.91	W	TUO	462.1	66.3	57.7	76.3	P	P	S	77	3.16	0.24

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

19840	12/03/01	81	4	F	1998	0.70813	0.84	W	TUO	436.1	61.8	53.2	71.9	P	F	P	84	2.87	0.24	
19857	12/04/01	97	4	M	1998	0.70776	0.95	W	TUO	538.0	79.2	70.6	89.3	S	P	S	93	3.20	0.20	
19864	12/04/01	99	4	M	1998	0.70813	0.84	W	TUO	514.9	75.3	66.7	85.4	S	P	S	109	3.02	0.27	
19867	12/04/01	86	4	F	1998	0.70808	0.93	W	TUO	478.7	69.1	60.5	79.2	P	P	S	95	2.99	0.26	
19872	12/10/01	84	4	F	1998	0.70815	0.78	W	TUO	463.1	66.4	57.8	76.5	P	P	S	77	2.88	0.19	
19875	12/10/01	83	4	F	1998	0.70823	0.42	W	TUO*	478.7	69.1	60.5	79.2	P	P	S	*Inconclusive natal assignment*			
19879	12/10/01	76	4	F	1998	0.70766	0.91	W	TUO	464.2	66.6	58.0	76.7	P	P	S	84	3.01	0.21	
19880	12/10/01	89	4	F	1998	0.70765	0.91	W	TUO	447.6	63.8	55.2	73.8	P	P	P	72	2.95	0.23	
19881	12/10/01	99	4	F	1998	0.70813	0.85	W	TUO	528.5	77.6	69.0	87.7	S	P	S	73	2.85	0.21	
20183	11/28/01	101	4	F	1998	0.70773	0.94	W	TUO	525.4	77.1	68.5	87.2	S	P	S	98	3.30	0.31	
4492	11/28/00	57	2	M	1999	0.70804	0.95	W	TUO	578.6	86.2	77.6	96.2	S	S	S	104 †	3.21	0.25	† Microstructure ran out 18um before last natal spot (inferred 5 increments)
4526	12/11/00	67	2	F	1999	0.70800	0.97	W	TUO	815.6	126.7	118.1	136.8	S	S	S	.			
11009	11/16/01	.	3	F	1999	0.70757	0.86	W	TUO	441.7	62.8	54.2	72.8	P	F	P	.			
11016	11/16/01	79.5	3	F	1999	0.70731	0.40	W	TUO*	369.6	50.4	41.9	60.5	F	F	P	49	2.84	0.25	
11019	11/16/01	60	3	F	1999	0.70743	0.67	INC	TUO*	476.5	68.7	60.1	78.8	P	P	S	.			Unreadable, so cannot assign natal location or do ageing
11021	11/16/01	73	3	F	1999	0.70731	0.39	W	TUO*	478.8	69.1	60.5	79.2	P	P	S	84	2.75	0.21	
11041	12/11/01	77	3	F	1999	0.70805	0.95	W	TUO	509.5	74.4	65.8	84.4	P	P	S	93	2.97	0.24	
11094	11/30/01	80	3	F	1999	0.70756	0.85	W	TUO	444.0	63.2	54.6	73.2	P	F	P	64	2.98	0.29	
11096	11/30/01	77	3	F	1999	0.70764	0.91	W	TUO	503.0	73.3	64.7	83.3	P	P	S	97	2.94	0.23	
11099	11/30/01	73	3	F	1999	0.70733	0.44	W	TUO*	467.2	67.1	58.5	77.2	P	P	S	*Inconclusive natal assignment*			
11100	11/30/01	83	3	F	1999	0.70748	0.75	W	TUO	442.6	62.9	54.3	73.0	P	F	P	.			
11132	11/26/01	76	3	F	1999	0.70734	0.46	W	TUO*	462.1	66.3	57.7	76.3	P	P	S	91	2.91	0.24	
11141	11/26/01	77	3	F	1999	0.70741	0.63	W	TUO	395.6	54.9	46.3	65.0	F	F	P	.			
11146	11/26/01	81	3	F	1999	0.70722	0.20	W	TUO*	434.2	61.5	52.9	71.6	P	F	P	*Inconclusive natal assignment*			
11157	11/26/01	80	3	M	1999	0.70740	0.61	W	TUO	405.4	56.6	48.0	66.6	P	F	P	64	3.00	0.32	
11161	11/26/01	74	3	F	1999	0.70792	0.98	W	TUO	426.3	60.1	51.6	70.2	P	F	P	.			
11162	11/26/01	78	3	F	1999	0.70724	0.25	W	TUO*	469.1	67.5	58.9	77.5	P	P	S	68	3.56	0.26	
11174	12/07/01	80	3	F	1999	0.70754	0.83	W	TUO	404.9	56.5	47.9	66.6	P	F	P	61	3.15	0.21	
11192	11/23/01	74	3	F	1999	0.70772	0.94	W	TUO	478.8	69.1	60.5	79.2	P	P	S	74	3.02	0.28	
11209	11/21/01	97	3	M	1999	0.70771	0.94	W	TUO	551.4	81.5	72.9	91.6	S	P	S	85	3.72	0.31	

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11213	11/21/01	83	3	F	1999	0.70771	0.94	W	TUO	483.5	69.9	61.3	80.0	P	P	S	.			
11217	11/21/01	40.5	3	M	1999	0.70764	0.90	W	TUO	447.2	63.7	55.1	73.8	P	P	P	84	2.59	0.23	
14499	11/04/02	93	4	F	1999	0.70814	0.83	W	TUO	542.7	80.0	71.5	90.1	S	P	S	92	2.99	0.21	
14568	11/05/02	107	4	M	1999	0.70761	0.89	W	TUO	591.8	88.4	79.9	98.5	S	S	S	82	3.39	0.25	
14621	11/12/02	104	4	M	1999	0.70776	0.95	W	TUO	538.8	79.4	70.8	89.4	S	P	S	88	2.84	0.25	
14623	11/12/02	85	4	F	1999	0.70782	0.97	W	TUO	492.8	71.5	62.9	81.6	P	P	S	90	2.96	0.20	
14627	11/12/02	97	4	F	1999	0.70754	0.83	W	TUO	437.0	62.0	53.4	72.0	P	F	P	.			
14635	11/12/02	101	4	M	1999	0.70777	0.96	W	TUO	510.0	74.4	65.9	84.5	P	P	S	74	3.37	0.20	
14647	11/12/02	96	4	F	1999	0.70805	0.95	W	TUO	466.8	67.1	58.5	77.1	P	P	S	.			
14669	11/12/02	104	4	M	1999	0.70761	0.89	W	TUO	475.1	68.5	59.9	78.6	P	P	S	80	3.09	0.22	
14687	11/12/02	91	4	F	1999	0.70738	0.56	W	TUO	510.5	74.5	65.9	84.6	P	P	S	81	3.57	0.27	
14693	11/12/02	99	4	M	1999	0.70751	0.80	W	TUO	521.6	76.4	67.8	86.5	S	P	S	84	3.04	0.19	
14716	11/13/02	97	4	M	1999	0.70757	0.85	W	TUO	522.6	76.6	68.0	86.7	S	P	S	80	3.05	0.25	
14729	11/13/02	96	4	M	1999	0.70726	0.28	W	TUO*	462.6	66.3	57.8	76.4	P	P	S	69	3.08	0.21	
14759	11/14/02	101	4	M	1999	0.70766	0.91	W	TUO	508.1	74.1	65.5	84.2	P	P	S	94	2.95	0.24	
14774	11/14/02	86	4	F	1999	0.70786	0.97	W	TUO	483.1	69.9	61.3	79.9	P	P	S	.			
14804	11/14/02	93	4	F	1999	0.70768	0.93	W	TUO	488.6	70.8	62.2	80.9	P	P	S	78	3.07	0.17	
14824	11/15/02	98	4	M	1999	0.70733	0.44	W	TUO*	517.4	75.7	67.1	85.8	S	P	S	*Inconclusive natal assignment*			
14850	11/18/02	92	4	F	1999	0.70722	0.19	W	TUO*	465.4	66.8	58.2	76.9	P	P	S	*Inconclusive natal assignment*			
14884	11/18/02	89	4	F	1999	0.70749	0.77	W	TUO	499.0	72.6	64.0	82.6	P	P	S	.			
14889	11/18/02	88	4	M	1999	0.70754	0.82	W	TUO	508.5	74.2	65.6	84.3	P	P	S	80	3.11	0.22	
14892	11/18/02	100	4	M	1999	0.70725	0.26	W	TUO*	471.9	67.9	59.4	78.0	P	P	S	*Inconclusive natal assignment*			
14904	11/18/02	100	4	M	1999	0.70745	0.70	W	TUO	480.2	69.4	60.8	79.4	P	P	S	61	3.65	0.25	
14919	11/18/02	88	4	F	1999	0.70729	0.35	W	TUO*	409.7	57.3	48.7	67.4	P	F	P	*Inconclusive natal assignment*			
14953	11/19/02	103	4	M	1999	0.70787	0.97	W	TUO	489.5	71.0	62.4	81.0	P	P	S	92	2.91	0.18	
14955	11/19/02	94	4	F	1999	0.70813	0.84	W	TUO	527.1	77.4	68.8	87.4	S	P	S	96	3.28	0.25	
14976	11/19/02	102	4	M	1999	0.70765	0.91	W	TUO	496.3	72.1	63.5	82.2	P	P	S	94	3.21	0.26	
14999	11/20/02	104	4	M	1999	0.70726	0.27	W	TUO*	489.5	71.0	62.4	81.0	P	P	S	67	3.88	0.22	
15001	11/20/02	101	4	M	1999	0.70787	0.97	W	TUO	431.7	61.1	52.5	71.1	P	F	P	74	2.92	0.25	
15052	11/20/02	105	4	M	1999	0.70776	0.95	W	TUO	557.9	82.6	74.1	92.7	S	P	S	.			
15064	11/20/02	98	4	M	1999	0.70775	0.95	W	TUO	415.1	58.2	49.6	68.3	P	F	P	49	3.21	0.25	
15097	11/21/02	104	4	M	1999	0.70774	0.95	W	TUO	539.3	79.5	70.9	89.5	S	P	S	101	3.22	0.26	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

15146	11/24/02	107	4	M	1999	0.70721	0.19	W	TUO*	451.0	64.4	55.8	74.4	P	P	P	*Inconclusive natal assignment*		
15150	11/24/02	108	4	M	1999	0.70761	0.89	W	TUO	436.4	61.9	53.3	71.9	P	F	P	64	3.34	0.28
15165	11/24/02	100	4	M	1999	0.70726	0.27	W	TUO*	406.9	56.8	48.2	66.9	P	F	P	*Inconclusive natal assignment*		
19679	11/15/01	78	3	F	1999	0.70754	0.83	W	TUO	514.2	75.2	66.6	85.2	S	P	S	98	3.26	0.26
19686	11/15/01	81	3	F	1999	0.70780	0.96	W	TUO	518.4	75.9	67.3	85.9	S	P	S	96	3.40	0.22
19688	11/15/01	72.5	3	F	1999	0.70772	0.94	W	TUO	554.6	82.1	73.5	92.1	S	P	S	.		
19705	11/15/01	76	3	F	1999	0.70729	0.35	W	TUO*	373.8	51.2	42.6	61.2	F	F	P	*Inconclusive natal assignment*		
19722	11/19/01	87	3	F	1999	0.70733	0.44	W	TUO*	553.2	81.8	73.3	91.9	S	P	S	*Inconclusive natal assignment*		
19775	11/28/01	83	3	F	1999	0.70736	0.52	W	TUO	509.5	74.4	65.8	84.4	P	P	S	81	3.44	0.25
19779	11/28/01	70	3	F	1999	0.70760	0.88	W	TUO	477.0	68.8	60.2	78.9	P	P	S	65	3.63	0.22
19782	11/28/01	76	3	M	1999	0.70779	0.96	W	TUO	514.6	75.2	66.7	85.3	S	P	S	89	3.03	0.19
19786	11/28/01	85	3	M	1999	0.70746	0.73	W	TUO	549.0	81.1	72.5	91.2	S	P	S	101	3.30	0.26
19791	11/28/01	79	3	F	1999	0.70735	0.49	W	TUO*	461.2	66.1	57.5	76.2	P	P	S	*Inconclusive natal assignment*		
19792	11/28/01	76	3	F	1999	0.70814	0.83	W	TUO	486.8	70.5	61.9	80.5	P	P	S	82	3.78	0.25
19797	12/03/01	84	3	F	1999	0.70735	0.48	W	TUO*	458.1	65.6	57.0	75.6	P	P	S	*Inconclusive natal assignment*		
19816	12/03/01	81	3	M	1999	0.70770	0.93	W	TUO	632.3	95.4	86.8	105.4	S	S	S	.		
19836	12/03/01	88	3	M	1999	0.70726	0.29	W	TUO*	451.4	64.4	55.8	74.5	P	P	P	*Inconclusive natal assignment*		
19841	12/03/01	74	3	F	1999	0.70724	0.23	W	TUO*	457.9	65.5	57.0	75.6	P	P	S	*Inconclusive natal assignment*		
19845	12/04/01	87	3	M	1999	0.70788	0.97	W	TUO	514.2	75.2	66.6	85.2	S	P	S	93	2.96	0.20
19855	12/04/01	85	3	M	1999	0.70768	0.92	W	TUO	441.7	62.8	54.2	72.8	P	F	P	61	3.15	0.32
19861	12/04/01	74	3	F	1999	0.70775	0.95	W	TUO	494.2	71.7	63.2	81.8	P	P	S	80	3.13	0.22
19866	12/04/01	86	3	M	1999	0.70724	0.23	W	TUO*	467.7	67.2	58.6	77.3	P	P	S	63	3.24	0.27
19868	12/04/01	74	3	F	1999	0.70736	0.51	W	TUO	583.5	87.0	78.4	97.1	S	S	S	97	3.86	0.29
19874	12/10/01	75	3	F	1999	0.70756	0.84	W	TUO	372.4	50.9	42.3	61.0	F	F	P	61	3.21	0.26
19876	12/10/01	71	3	M	1999	0.70765	0.91	W	TUO	507.2	74.0	65.4	84.0	P	P	S	79	3.48	0.20
11055	11/20/01	56	2	M	2000	0.70770	0.93	W	TUO	354.0	47.8	39.2	57.8	F	F	P	.		
11063	11/20/01	58	2	M	2000	0.70763	0.90	W	TUO	524.0	76.8	68.3	86.9	S	P	S	81	3.13	0.22
11076	11/20/01	81	2	F	2000	0.70807	0.93	W	TUO	509.0	74.3	65.7	84.3	P	P	S	98	2.98	0.23
11083	11/20/01	59	2	M	2000	0.70742	0.65	W	TUO	419.0	58.9	50.3	69.0	P	F	P	49	3.28	0.23
11111	11/08/01	54.5	2	F	2000	0.70775	0.95	W	TUO	477.0	68.8	60.2	78.9	P	P	S	81	3.00	0.23
11133	11/26/01	59	2	F	2000	0.70797	0.97	W	TUO	472.0	68.0	59.4	78.0	P	P	S	.		
11167	11/26/01	60	2	F	2000	0.70752	0.81	W	TUO	451.0	64.4	55.8	74.4	P	P	P	61	2.99	0.29
11212	11/21/01	65.5	2	F	2000	0.70760	0.88	W	TUO	465.0	66.8	58.2	76.8	P	P	S	60	3.38	0.26

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11215	11/21/01	60	2	F	2000	0.70795	0.98	W	TUO	508.0	74.1	65.5	84.2	P	P	S	69	3.84	0.26	
11220	10/31/01	62	2	F	2000	0.70789	0.97	W	TUO	548.0	80.9	72.4	91.0	S	P	S	84	3.37	0.30	
11223	10/31/01	54	2	M	2000	0.70784	0.97	W	TUO	494.0	71.7	63.1	81.8	P	P	S	77	3.05	0.21	
11228	10/31/01	60	2	M	2000	0.70778	0.96	W	TUO	407.0	56.8	48.2	66.9	P	F	P	66	3.11	0.19	
14528	11/04/02	95	3	M	2000	0.70813	0.85	W	TUO	513.0	75.0	66.4	85.0	P	P	S	84	2.93	0.24	
14539	11/04/02	72	3	F	2000	0.70789	0.97	W	TUO	451.0	64.4	55.8	74.4	P	P	P	69	2.97	0.19	
14540	11/04/02	69	3	F	2000	0.70777	0.96	INC	TUO*	438.0	62.1	53.6	72.2	P	F	P	.			Unreadable, so cannot assign natal location or do ageing
14544	11/05/02	78	3	F	2000	0.70782	0.96	W	TUO	429.0	60.6	52.0	70.7	P	F	P	48	2.90	0.22	
14545	11/05/02	92	3	M	2000	0.70792	0.98	W	TUO	404.0	56.3	47.7	66.4	P	F	P	.			
14548	11/05/02	72	3	F	2000	0.70801	0.97	W	TUO	574.0	85.4	76.8	95.5	S	S	S	.			
14550	11/05/02	80	3	M	2000	0.70789	0.97	W	TUO	387.0	53.4	44.8	63.5	F	F	P	62	2.75	0.25	
14556	11/05/02	73	3	F	2000	0.70742	0.64	W	TUO	433.0	61.3	52.7	71.4	P	F	P	71	3.15	0.26	
14559	11/05/02	89	3	M	2000	0.70768	0.92	W	TUO	382.0	52.6	44.0	62.6	F	F	P	.			
14560	11/05/02	78	3	F	2000	0.70756	0.85	W	TUO	434.0	61.5	52.9	71.5	P	F	P	69	2.96	0.22	
14566	11/05/02	79	3	F	2000	0.70786	0.97	W	TUO	431.0	60.9	52.4	71.0	P	F	P	.			
14571	11/05/02	97	3	M	2000	0.70763	0.90	W	TUO	502.0	73.1	64.5	83.1	P	P	S	77	2.91	0.24	
14575	11/05/02	73	3	F	2000	0.70795	0.98	W	TUO	438.0	62.1	53.6	72.2	P	F	P	72	3.07	0.22	
14578	11/05/02	73	3	F	2000	0.70745	0.71	W	TUO	411.0	57.5	48.9	67.6	P	F	P	.			
14579	11/05/02	93	3	M	2000	0.70742	0.65	W	TUO	413.0	57.9	49.3	67.9	P	F	P	60	3.41	0.30	
14584	11/05/02	81	.	M	2000	0.70772	0.94	W	TUO	464.0	66.6	58.0	76.7	P	P	S	.			
14587	11/05/02	80	3	F	2000	0.70780	0.96	W	TUO	508.0	74.1	65.5	84.2	P	P	S	.			
14596	11/05/02	80	3	F	2000	0.70800	0.97	W	TUO	516.0	75.5	66.9	85.5	S	P	S	99	2.97	0.22	
14597	11/05/02	91	3	M	2000	0.70756	0.85	W	TUO	409.0	57.2	48.6	67.2	P	F	P	57	3.05	0.29	
14600	11/05/02	75	3	F	2000	0.70774	0.95	W	TUO	383.0	52.7	44.1	62.8	F	F	P	.			
14616	11/12/02	94	3	M	2000	0.70768	0.92	W	TUO	344.0	46.1	37.5	56.1	F	F	P	18	2.56	0.13	
14626	11/12/02	91	3	M	2000	0.70735	0.50	W	TUO	461.0	66.1	57.5	76.1	P	P	S	.			
14629	11/12/02	74	3	F	2000	0.70772	0.94	W	TUO	486.0	70.3	61.8	80.4	P	P	S	.			
14661	11/12/02	94	3	M	2000	0.70761	0.89	W	TUO	412.0	57.7	49.1	67.8	P	F	P	73	2.64	0.31	
14668	11/12/02	90	3	M	2000	0.70785	0.97	W	TUO	466.0	66.9	58.3	77.0	P	P	S	75	2.93	0.21	
14673	11/12/02	90	3	M	2000	0.70770	0.93	W	TUO	447.0	63.7	55.1	73.7	P	P	P	61	3.28	0.22	
14689	11/12/02	93	3	M	2000	0.70803	0.96	W	TUO	465.0	66.8	58.2	76.8	P	P	S	87	3.34	0.23	Microstructure ran out 13um before last natal spot (inferred 4

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

																			increments)
14701	11/13/02	93	3	M	2000	0.70803	0.96	W	TUO	456.0	65.2	56.6	75.3	P	P	S	60	2.32	0.25	Strange profile (used same distance for natal and FW exit)
14721	11/13/02	76	3	F	2000	0.70804	0.95	W	TUO	453.0	64.7	56.1	74.8	P	P	P	75	3.05	0.25	
14735	11/13/02	92	3	M	2000	0.70763	0.90	W	TUO	367.0	50.0	41.4	60.1	F	F	P	44	3.19	0.17	
14743	11/13/02	76	3	F	2000	0.70802	0.96	W	TUO	479.0	69.1	60.6	79.2	P	P	S	89	2.89	0.22	
14749	11/14/02	80	3	F	2000	0.70773	0.94	W	TUO	372.0	50.9	42.3	60.9	F	F	P	45	2.86	0.17	
14753	11/14/02	84	3	M	2000	0.70774	0.95	W	TUO	393.0	54.4	45.9	64.5	F	F	P	64	3.10	0.20	
14769	11/14/02	81	3	F	2000	0.70757	0.85	W	TUO	378.0	51.9	43.3	61.9	F	F	P	51	3.19	0.27	
14783	11/14/02	89	3	M	2000	0.70793	0.98	W	TUO	496.0	72.1	63.5	82.1	P	P	S	77	3.43	0.22	
14785	11/14/02	95	3	M	2000	0.70766	0.91	W	TUO	447.0	63.7	55.1	73.7	P	P	P	.			
14786	11/14/02	76	3	F	2000	0.70781	0.96	W	TUO	421.0	59.2	50.6	69.3	P	F	P	51	3.57	0.20	
14813	11/14/02	86	3	M	2000	0.70799	0.97	W	TUO	430.0	60.8	52.2	70.8	P	F	P	65	3.08	0.24	
14815	11/15/02	82	3	F	2000	0.70761	0.89	W	TUO	438.0	62.1	53.6	72.2	P	F	P	.			
14858	11/18/02	104	3	M	2000	0.70740	0.61	W	TUO	464.2	66.6	58.0	76.7	P	P	S	73	3.23	0.29	
14880	11/18/02	80	3	M	2000	0.70727	0.31	W	TUO*	409.0	57.2	48.6	67.2	P	F	P	48	3.57	0.28	
14907	11/18/02	74	3	F	2000	0.70773	0.95	W	TUO	475.0	68.5	59.9	78.5	P	P	S	71	3.08	0.22	
14921	11/18/02	93	3.5	F	2000	0.70780	0.96	W	TUO	377.0	51.7	43.1	61.8	F	F	P	28	3.08	0.21	
14929	11/18/02	91	3	M	2000	0.70764	0.90	W	TUO	454.0	64.9	56.3	74.9	P	P	P	67	3.37	0.27	
14975	11/19/02	102	3	M	2000	0.70743	0.67	W	TUO	392.0	54.3	45.7	64.3	F	F	P	.			
15091	11/21/02	100	3	F	2000	0.70792	0.98	W	TUO	497.0	72.2	63.6	82.3	P	P	S	60	3.52	0.23	
15113	11/21/02	100	3	M	2000	0.70763	0.90	W	TUO	407.0	56.8	48.2	66.9	P	F	P	.			
15133	11/24/02	103	3	M	2000	0.70754	0.83	W	TUO	428.0	60.4	51.8	70.5	P	F	P	67	3.06	0.25	
15193	11/24/02	101	3	M	2000	0.70773	0.94	W	TUO	508.0	74.1	65.5	84.2	P	P	S	79	3.11	0.25	
15243	12/02/02	91	3	M	2000	0.70777	0.95	W	TUO	414.0	58.0	49.4	68.1	P	F	P	71	3.02	0.27	
19681	11/15/01	65	2	M	2000	0.70759	0.87	W	TUO	383.0	52.7	44.1	62.8	F	F	P	.			
19695	11/19/01	59.5	2	M	2000	0.70759	0.88	W	TUO	488.0	70.7	62.1	80.8	P	P	S	74	3.09	0.26	
19813	12/03/01	48	2	M	2000	0.70789	0.97	W	TUO	503.0	73.3	64.7	83.3	P	P	S	133	3.11	0.26	
19831	12/03/01	57	2	F	2000	0.70779	0.96	W	TUO	386.0	53.2	44.7	63.3	F	F	P	48	3.29	0.24	
19853	12/04/01	60	2	F	2000	0.70781	0.96	W	TUO	517.0	75.6	67.1	85.7	S	P	S	90	3.14	0.29	
19858	12/04/01	58	2	F	2000	0.70761	0.89	W	TUO	437.0	62.0	53.4	72.0	P	F	P	.			
17628	11/14/05	91	3	M	2003	0.70730	0.37	W	TUO*	459.8	65.9	57.3	75.9	P	P	S	70	3.67	0.26	
17631	11/14/05	84	3	F	2003	0.70751	0.80	W	TUO	554.2	82.0	73.4	92.1	S	P	S	94	3.80	0.25	

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17634	11/14/05	81	3	F	2003	0.70772	0.94	W	TUO	475.1	68.5	59.9	78.6	P	P	S	94	2.57	0.22	
17637	11/16/05	92	3	M	2003	0.70726	0.27	W	TUO*	381.2	52.4	43.8	62.5	F	F	P	*Inconclusive natal assignment*			
17638	11/16/05	76	3	F	2003	0.70731	0.41	W	TUO*	536.5	79.0	70.4	89.0	S	P	S	81	3.60	0.24	
17645	11/21/05	75	3	F	2003	0.70747	0.74	W	TUO	557.4	82.6	74.0	92.6	S	P	S	.			
17651	11/21/05	88	3	M	2003	0.70745	0.71	W	TUO	538.8	79.4	70.8	89.4	S	P	S	76	3.98	0.22	
17654	11/21/05	73	3	F	2003	0.70757	0.86	W	TUO	309.6	40.2	31.6	50.3	F	F	F	57	2.79	0.26	
17666	11/28/05	73	3	F	2003	0.70753	0.82	W	TUO	485.8	70.3	61.7	80.4	P	P	S	88	3.09	0.20	
17667	11/28/05	75	3	F	2003	0.70744	0.69	W	TUO	493.7	71.7	63.1	81.7	P	P	S	97	3.34	0.27	
17669	11/28/05	72	3	F	2003	0.70743	0.66	W	TUO	504.9	73.6	65.0	83.6	P	P	S	.			
17672	11/28/05	79	3	F	2003	0.70756	0.85	INC	TUO*	n/a (vaterite)	n/a	n/a	n/a	n/a	n/a	n/a	.			Otolith was vateritic during natal rearing (so no HvW assignment or exit age/distance)
17673	11/28/05	71	3	F	2003	0.70745	0.70	W	TUO	450.5	64.3	55.7	74.3	P	P	P	.			
17679	11/28/05	85	3	M	2003	0.70729	0.34	W	TUO*	452.8	64.7	56.1	74.7	P	P	P	53	3.86	0.22	
17680	11/28/05	75	3	F	2003	0.70777	0.96	W	TUO	507.7	74.1	65.5	84.1	P	P	S	85	2.92	0.26	Microstructure ran out 54um before last natal spot (inferred 18 increments)
17681	11/28/05	72	3	F	2003	0.70763	0.90	W	TUO	441.7	62.8	54.2	72.8	P	F	P	.			
17685	11/28/05	61	3	M	2003	0.70727	0.30	W	TUO*	419.8	59.0	50.4	69.1	P	F	P	*Inconclusive natal assignment*			
17690	11/28/05	83	3	M	2003	0.70754	0.83	W	TUO	565.8	84.0	75.4	94.1	S	S	S	102	3.61	0.28	
17692	11/29/05	85	3	F	2003	0.70759	0.87	W	TUO	432.4	61.2	52.6	71.2	P	F	P	46	4.20	0.19	
17703	12/06/05	75	3	F	2003	0.70751	0.79	W	TUO	599.2	89.7	81.1	99.8	S	S	S	108	3.33	0.19	
17712	12/06/05	90	3	M	2003	0.70734	0.46	W	TUO*	456.5	65.3	56.7	75.4	P	P	S	*Inconclusive natal assignment*			
17713	12/06/05	76	3	F	2003	0.70755	0.84	W	TUO	446.3	63.6	55.0	73.6	P	F	P	66	3.63	0.20	
17716	12/06/05	82	3	F	2003	0.70744	0.69	W	TUO	514.6	75.2	66.7	85.3	S	P	S	.			
17718	12/07/05	79	3	F	2003	0.70751	0.79	W	TUO	530.9	78.0	69.4	88.1	S	P	S	.			
17729	12/12/05	92	3	M	2003	0.70754	0.82	W	TUO	481.6	69.6	61.0	79.7	P	P	S	.			
17740	12/12/05	79	3	F	2003	0.70738	0.56	W	TUO	453.7	64.8	56.2	74.9	P	P	P	.			
17742	12/12/05	75	3	F	2003	0.70743	0.66	W	TUO	416.6	58.5	49.9	68.5	P	F	P	65	3.09	0.21	
17746	12/12/05	72	3	F	2003	0.70762	0.89	W	TUO	599.7	89.8	81.2	99.9	S	S	S	.			
17751	12/12/05	85	3	F	2003	0.70755	0.84	W	TUO	504.9	73.6	65.0	83.6	P	P	S	93	3.49	0.21	
17753	12/12/05	81	3	M	2003	0.70750	0.79	W	TUO	478.8	69.1	60.5	79.2	P	P	S	65	3.50	0.26	
17758	12/12/05	84	3	F	2003	0.70718	0.14	W	TUO*	501.2	72.9	64.4	83.0	P	P	S	76	3.59	0.21	

Appendix 1A Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the Tuolumne River (natal exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable. The life stage at natal river exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

17759	12/12/05	70	3	F	2003	0.70765	0.91	W	TUO	487.2	70.6	62.0	80.6	P	P	S	.			
17763	12/12/05	79	3	F	2003	0.70744	0.70	W	TUO	461.6	66.2	57.6	76.2	P	P	S	74	3.59	0.19	
18144	12/05/06	86	4	F	2003	0.70726	0.29	W	TUO*	502.1	73.1	64.5	83.2	P	P	S	78	3.37	0.22	
18150	12/11/06	84	4	F	2003	0.70741	0.62	W	TUO	444.9	63.3	54.7	73.4	P	F	P	65	3.30	0.17	
24120	11/07/11	76	3	F	2009	0.70777	0.73	W	TUO	451.3	64.4	55.8	74.5	P	P	P	66	3.29	0.23	
24176	11/14/11	81	3	F	2009	0.70781	0.77	W	TUO	542.0	79.9	71.3	90.0	S	P	S	76	3.78	0.24	
24178	11/14/11	67	3	M	2009	0.70778	0.74	W	TUO	559.0	81.0	72.4	91.0	S	P	S	109	3.19	0.23	
24238	11/21/11	70	3	F	2009	0.70773	0.69	W	TUO	508.2	74.1	65.5	84.2	P	P	S	.			
24283	11/23/11	83	3	M	2009	0.70734	0.16	W	TUO*	479.7	69.3	60.7	79.3	P	P	S	*Inconclusive natal assignment*			
24292	11/28/11	95	3	M	2009	0.70730	0.12	W	TUO*	555.9	82.3	73.7	92.4	S	P	S	*Inconclusive natal assignment*			
26012	11/13/12	84	4	F	2009	0.70780	0.76	W	TUO	546.1	80.6	72.0	90.7	S	P	S	101	3.16	0.23	

[1] Assignments using isotope-based discriminant function analysis and reference samples from existing or ongoing projects ([1], [2], P. Weber, A. Sturrock, unpub)
[2] Hatchery vs. wild assignment using microstructure-based discriminant function analysis and existing reference samples, after [3].
[3] Size-defined life stage designations (fry: <55mm, parr: >55mm to <75mm, smolt: >75mm), after [4].

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

						Natal Sr ratio				FW EXIT	Predicted FL at natal exit (mm)			Predicted life stage at natal exit [3]				Increment width (um)		
Sample ID	Capture date	Capture FL (cm)	Scale age	Sex	Outmi-gration year	Mean natal value	Prob to TUO [1]	H vs. W [2]	Natal location	Otolith distance (um)	FL	Lower 95% CI	Upper 95% CI	Life stage	Lower 95% CI	Upper 95% CI	Increment number (days)	Mean	CV	Notes
4175	10/10/00	98	3	M	1998	0.70799	0.97	W	TUO	603.6	90.4	81.9	100.5	S	S	S	4	3.1	0.2	
4176	10/10/00	91	3	M	1998	0.70774	0.95	W	TUO	604.3	90.6	82.0	100.6	S	S	S	22	3.1	0.2	
4182	10/17/00	76	3	M	1998	0.70803	0.96	W	TUO	578.3	86.1	77.5	96.2	S	S	S	11	2.8	0.3	
4183	10/17/00	90	3	M	1998	0.70797	0.97	W	TUO	514.7	75.3	66.7	85.3	S	P	S	16	3.7	0.2	
4185	10/17/00	84	3	F	1998	0.70728	0.64	W	TUO	585.4	87.3	78.7	97.4	S	S	S	30	2.6	0.2	
4189	10/24/00	90	3	F	1998	0.70806	0.94	W	TUO	496.4	72.1	63.5	82.2	P	P	S	11	2.9	0.3	
4192	10/24/00	87.5	3	F	1998	0.70807	0.93	W	TUO	517.3	75.7	67.1	85.8	S	P	S	5	5.3	0.3	
4196	10/24/00	67.9	3	F	1998	0.70800	0.97	W	TUO	524.7	77.0	68.4	87.0	S	P	S	n/a	n/a	n/a	
4197	10/24/00	78.6	3	F	1998	0.70740	0.61	W	TUO	531.8	78.2	69.6	88.2	S	P	S	23	3.8	0.2	
4200	10/24/00	68.6	3	F	1998	0.70760	0.88	W	TUO	611.4	91.8	83.2	101.9	S	S	S	9	3.4	0.2	
4210	10/24/00	88.3	3	M	1998	0.70764	0.91	W	TUO	511.3	74.7	66.1	84.7	P	P	S	8	3.9	0.2	
4211	10/24/00	72	3	F	1998	0.70783	0.97	W	TUO	625.4	94.2	85.6	104.2	S	S	S	.			
4212	10/24/00	78.1	3	M	1998	0.70765	0.91	W	TUO	568.9	84.5	75.9	94.6	S	S	S	13	2.8	0.3	
4215	10/25/00	79	3	F	1998	0.70802	0.96	W	TUO	620.1	93.3	84.7	103.3	S	S	S	18	3.5	0.2	
4226	10/25/00	80	3	F	1998	0.70770	0.93	W	TUO	479.9	69.3	60.7	79.4	P	P	S	6	4.1	0.2	
4232	10/25/00	88.5	3	M	1998	0.70821	0.53	W	TUO	540.3	79.6	71.0	89.7	S	P	S	.			
4233	10/25/00	72	3	F	1998	0.70795	0.98	W	TUO	504.7	73.5	64.9	83.6	P	P	S	18	2.5	0.2	
4234	10/25/00	77	3	F	1998	0.70823	0.45	W	TUO*	607.6	91.1	82.6	101.2	S	S	S	*Inconclusive natal assignment*			
4240	10/26/00	80	3	F	1998	0.70726	0.28	W	TUO*	484.4	70.1	61.5	80.1	P	P	S	*Inconclusive natal assignment*			
4249	10/30/00	80	3	F	1998	0.70737	0.54	W	TUO	520.5	76.2	67.6	86.3	S	P	S	.			
4253	10/30/00	80	3	M	1998	0.70810	0.90	W	TUO	595.9	89.1	80.6	99.2	S	S	S	16	2.8	0.3	
4266	10/30/00	77	3	F	1998	0.70740	0.60	W	TUO	508.6	74.2	65.6	84.3	P	P	S	19	2.7	0.2	
4267	10/30/00	75	3	F	1998	0.70812	0.86	W	TUO	534.2	78.6	70.0	88.7	S	P	S	.			
4269	10/30/00	80	3	F	1998	0.70732	0.43	W	TUO*	662.8	100.6	92.0	110.6	S	S	S	*Inconclusive natal assignment*			
4275	10/31/00	79	3	F	1998	0.70721	0.18	W	TUO*	444.6	63.3	54.7	73.3	P	F	P	*Inconclusive natal assignment*			
4278	10/31/00	83	3	F	1998	0.70802	0.96	W	TUO	515.7	75.4	66.8	85.5	S	P	S	.			
4279	10/31/00	87.5	3	F	1998	0.70798	0.97	W	TUO	596.6	89.3	80.7	99.3	S	S	S	7	3.0	0.2	
4281	10/31/00	91	3	M	1998	0.70728	0.31	W	TUO*	523.6	76.8	68.2	86.8	S	P	S	*Inconclusive natal assignment*			
4292	10/31/00	74	3	F	1998	0.70733	0.44	W	TUO*	608.5	91.3	82.7	101.4	S	S	S	*Inconclusive natal assignment*			
4294	10/31/00	86	3	F	1998	0.70800	0.97	W	TUO	586.2	87.5	78.9	97.6	S	S	S	.			

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

4295	10/31/00	72	3	F	1998	0.70816	0.77	W	TUO	518.5	75.9	67.3	86.0	S	P	S	10	2.8	0.2	
4297	11/01/00	74	3	F	1998	0.70805	0.95	W	TUO	644.1	97.4	88.8	107.4	S	S	S	13	3.3	0.2	
4299	11/06/00	81	3	F	1998	0.70801	0.97	W	TUO	555.3	82.2	73.6	92.3	S	P	S	.			
4300	11/06/00	96	3	M	1998	0.70735	0.50	W	TUO*	520.0	76.2	67.6	86.2	S	P	S	*Inconclusive natal assignment*			
4306	11/06/00	85	3	F	1998	0.70801	0.97	W	TUO	576.1	85.7	77.2	95.8	S	S	S	18	3.1	0.2	
4309	11/06/00	84	3	F	1998	0.70807	0.93	W	TUO	453.7	64.8	56.2	74.9	P	P	P	.			
4311	11/06/00	74	3	F	1998	0.70752	0.81	W	TUO	503.0	73.3	64.7	83.3	P	P	S	18	3.2	0.2	
4316	11/06/00	81	3	F	1998	0.70738	0.55	W	TUO	428.0	60.4	51.8	70.5	P	F	P	.			
4317	11/06/00	79	3	F	1998	0.70786	0.97	W	TUO	520.8	76.3	67.7	86.4	S	P	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
4321	11/06/00	70	3	F	1998	0.70742	0.65	W	TUO	592.5	88.6	80.0	98.6	S	S	S	29	3.9	0.3	
4331	11/07/00	86	3	M	1998	0.70798	0.97	W	TUO	604.8	90.7	82.1	100.7	S	S	S	10	2.3	0.2	
4334	11/07/00	85	3	F	1998	0.70739	0.59	W	TUO	439.7	62.4	53.8	72.5	P	F	P	11	3.4	0.1	
4337	11/07/00	74	3	F	1998	0.70733	0.45	W	TUO*	601.7	90.1	81.5	100.2	S	S	S	*Inconclusive natal assignment*			
4340	11/07/00	75.5	3	F	1998	0.70783	0.97	W	TUO	531.7	78.2	69.6	88.2	S	P	S	.			
4343	11/07/00	81	3	F	1998	0.70768	0.92	W	TUO	545.2	80.5	71.9	90.5	S	P	S	11	3.5	0.2	
4352	11/07/00	73	3	F	1998	0.70788	0.97	W	TUO	588.8	87.9	79.3	98.0	S	S	S	26	2.5	0.3	
4360	11/08/00	76.5	3	F	1998	0.70818	0.67	W	TUO	596.3	89.2	80.6	99.3	S	S	S	.			
4376	11/09/00	85	3	F	1998	0.70733	0.46	W	TUO*	621.8	93.6	85.0	103.6	S	S	S	*Inconclusive natal assignment*			
4378	11/09/00	88	3	M	1998	0.70728	0.33	W	TUO*	647.5	98.0	89.4	108.0	S	S	S	*Inconclusive natal assignment*			
4381	11/13/00	90	3	M	1998	0.70816	0.75	W	TUO	483.0	69.8	61.2	79.9	P	P	S	10	3.1	0.2	
4383	11/13/00	79	3	M	1998	0.70756	0.85	W	TUO	567.9	84.3	75.8	94.4	S	S	S	.			
4384	11/13/00	80	3	F	1998	0.70786	0.97	W	TUO	563.9	83.7	75.1	93.7	S	S	S	20	3.5	0.3	
4397	11/13/00	67	3	F	1998	0.70819	0.66	W	TUO	515.4	75.4	66.8	85.4	S	P	S	14	2.9	0.3	
4403	11/14/00	77	3	F	1998	0.70808	0.92	W	TUO	538.8	79.4	70.8	89.4	S	P	S	10	3.3	0.2	
4414	11/14/00	81	3	F	1998	0.70749	0.77	W	TUO	507.4	74.0	65.4	84.1	P	P	S	.			
4418	11/14/00	86	3	F	1998	0.70742	0.66	W	TUO	520.4	76.2	67.6	86.3	S	P	S	17	4.7	0.2	
4424	11/14/00	77	3	F	1998	0.70783	0.97	W	TUO	591.3	88.3	79.8	98.4	S	S	S	10	3.2	0.2	
4441	11/20/00	72	3	F	1998	0.70823	0.45	W	TUO*	531.0	78.0	69.5	88.1	S	P	S	*Inconclusive natal assignment*			
4442	11/20/00	95	3	M	1998	0.70771	0.94	W	TUO	631.7	95.3	86.7	105.3	S	S	S	26	3.1	0.4	
4443	11/20/00	100	3	M	1998	0.70735	0.50	W	TUO*	541.5	79.8	71.3	89.9	S	P	S	*Inconclusive natal assignment*			
4450	11/20/00	82	3	F	1998	0.70817	0.73	W	TUO	447.6	63.8	55.2	73.8	P	P	P	0	n/a	n/a	Strange profile (used same distance for natal and FW exit)

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive (“INC”), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

4451	11/20/00	92	3	M	1998	0.70817	0.72	W	TUO	507.3	74.0	65.4	84.1	P	P	S	25	2.7	0.2	
4455	11/20/00	74	3	F	1998	0.70769	0.93	W	TUO	533.3	78.4	69.9	88.5	S	P	S	12	3.6	0.3	
4458	11/21/00	80	3	F	1998	0.70792	0.98	W	TUO	591.4	88.4	79.8	98.4	S	S	S	16	3.7	0.2	
4476	11/22/00	100	3	M	1998	0.70804	0.95	W	TUO	556.0	82.3	73.7	92.4	S	P	S	15	3.1	0.3	
4484	11/27/00	77	3	F	1998	0.70788	0.97	W	TUO	557.1	82.5	73.9	92.6	S	P	S	12	3.5	0.1	
4487	11/27/00	84	3	F	1998	0.70800	0.97	W	TUO	533.6	78.5	69.9	88.6	S	P	S	.			
4504	12/04/00	100	3	M	1998	0.70826	0.30	W	TUO*	517.5	75.7	67.1	85.8	S	P	S	*Inconclusive natal assignment*			
4506	12/04/00	80	3	F	1998	0.70756	0.85	W	TUO	458.0	65.6	57.0	75.6	P	P	S	15	3.7	0.2	
4508	12/04/00	89	3	F	1998	0.70806	0.94	W	TUO	500.1	72.8	64.2	82.8	P	P	S	25	2.7	0.2	
4509	12/04/00	70.5	3	F	1998	0.70812	0.86	W	TUO	520.7	76.3	67.7	86.4	S	P	S	14	4.0	0.2	
4510	12/05/00	77	3	F	1998	0.70776	0.95	W	TUO	538.9	79.4	70.8	89.5	S	P	S	27	4.3	0.2	
4514	12/05/00	78	3	F	1998	0.70794	0.98	W	TUO	488.2	70.7	62.1	80.8	P	P	S	.			
4515	12/05/00	77	3	F	1998	0.70815	0.80	W	TUO	545.4	80.5	71.9	90.6	S	P	S	9	3.1	0.1	
4516	12/05/00	82	3	F	1998	0.70818	0.69	W	TUO	497.1	72.2	63.7	82.3	P	P	S	9	3.7	0.2	
4517	12/05/00	88.5	3	F	1998	0.70798	0.97	W	TUO	555.9	82.3	73.7	92.4	S	P	S	16	3.0	0.2	
4518	12/05/00	83	3	F	1998	0.70789	0.97	W	TUO	563.3	83.6	75.0	93.6	S	P	S	15	3.0	0.2	
4521	12/06/00	78.5	3	F	1998	0.70788	0.97	W	TUO	563.3	83.6	75.0	93.6	S	P	S	14	3.2	0.2	
4527	12/11/00	83	3	M	1998	0.70819	0.66	W	TUO	604.6	90.6	82.0	100.7	S	S	S	30	2.9	0.2	
4535	12/19/00	78	3	F	1998	0.70814	0.82	W	TUO	541.6	79.9	71.3	89.9	S	P	S	11	3.5	0.1	
9536	07/07/00	75	3	F	1998	0.70775	0.95	W	TUO	752.4	115.9	107.3	126.0	S	S	S	.			
11015	11/16/01	86.5	4	F	1998	0.70789	0.97	W	TUO	548.6	81.0	72.5	91.1	S	P	S	10	4.3	0.2	
11036	12/11/01	86	4	F	1998	0.70772	0.94	W	TUO	617.6	92.8	84.3	102.9	S	S	S	17	2.6	0.2	
11037	12/11/01	110	4	M	1998	0.70792	0.98	W	TUO	592.2	88.5	79.9	98.6	S	S	S	18	3.6	0.2	
11038	12/11/01	78	4	F	1998	0.70821	0.53	W	TUO	504.6	73.5	64.9	83.6	P	P	S	.			
11040	12/11/01	98	4	F	1998	0.70812	0.86	W	TUO	595.5	89.1	80.5	99.1	S	S	S	18	3.0	0.2	
11056	11/20/01	78	4	F	1998	0.70779	0.96	W	TUO	571.4	85.0	76.4	95.0	S	S	S	19	2.9	0.3	
11064	11/20/01	95	4	M	1998	0.70745	0.71	W	TUO	586.3	87.5	78.9	97.6	S	S	S	10	4.0	0.4	
11072	11/20/01	112	4	M	1998	0.70816	0.75	W	TUO	500.3	72.8	64.2	82.9	P	P	S	9	3.5	0.1	
11085	11/20/01	87	4	F	1998	0.70737	0.55	W	TUO	448.5	63.9	55.4	74.0	P	P	P	.			
11089	11/20/01	104	4	M	1998	0.70816	0.76	W	TUO	509.0	74.3	65.7	84.3	P	P	S	17	2.5	0.3	
11097	11/30/01	82	4	M	1998	0.70743	0.67	W	TUO	573.9	85.4	76.8	95.4	S	S	S	29	2.8	0.3	
11098	11/30/01	87	4	F	1998	0.70807	0.93	W	TUO	553.7	81.9	73.3	92.0	S	P	S	10	3.4	0.1	
11140	11/26/01	88	4	F	1998	0.70769	0.93	W	TUO	526.7	77.3	68.7	87.4	S	P	S	18	3.1	0.2	
11154	11/26/01	87	4	F	1998	0.70794	0.98	W	TUO	568.6	84.5	75.9	94.5	S	S	S	18	2.8	0.1	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

11176	12/07/01	92.5	4	F	1998	0.70821	0.54	W	TUO	605.9	90.8	82.3	100.9	S	S	S	.			
11177	12/07/01	90	4	F	1998	0.70781	0.96	W	TUO	546.6	80.7	72.1	90.8	S	P	S	.			
11181	12/18/01	87	3	F	1998	0.70819	0.63	W	TUO	730.2	112.1	103.5	122.2	S	S	S	42	2.5	0.2	
11182	12/17/01	99	4	M	1998	0.70798	0.97	W	TUO	417.2	58.6	50.0	68.7	P	F	P	3	3.56	0.24	
11190	11/23/01	90	3	M	1998	0.70821	0.53	W	TUO	540.6	79.7	71.1	89.8	S	P	S	18	2.6	0.2	
11216	11/21/01	94	4	F	1998	0.70821	0.54	W	TUO	552.9	81.8	73.2	91.9	S	P	S	14	2.6	0.2	
19680	11/15/01	103	4	M	1998	0.70766	0.92	W	TUO	661.5	100.4	91.8	110.4	S	S	S	.			
19684	11/15/01	92	3.5	M	1998	0.70776	0.95	W	TUO	578.3	86.1	77.5	96.2	S	S	S	.			
19685	11/15/01	87	4	F	1998	0.70811	0.89	W	TUO	545.7	80.6	72.0	90.6	S	P	S	.			
19687	11/15/01	82	3.5	M	1998	0.70806	0.95	W	TUO	557.0	82.5	73.9	92.5	S	P	S	16	3.5	0.3	
19691	11/15/01	91	4	M	1998	0.70721	0.19	W	TUO*	488.7	70.8	62.2	80.9	P	P	S	*Inconclusive natal assignment*			
19719	11/19/01	94.5	3.5	F	1998	0.70806	0.94	W	TUO	547.9	80.9	72.3	91.0	S	P	S	18	3.0	0.2	
19772	11/28/01	97	4	F	1998	0.70769	0.93	W	TUO	506.5	73.8	65.3	83.9	P	P	S	13	2.9	0.2	
19776	11/28/01	90	4	F	1998	0.70821	0.53	W	TUO	542.0	79.9	71.3	90.0	S	P	S	9	2.5	0.4	
19777	11/28/01	91	4	F	1998	0.70816	0.76	W	TUO	519.7	76.1	67.5	86.2	S	P	S	8	3.7	0.1	
19781	11/28/01	86	4	F	1998	0.70824	0.37	W	TUO*	532.5	78.3	69.7	88.4	S	P	S	*Inconclusive natal assignment*			
19783	11/28/01	89	4	F	1998	0.70793	0.98	W	TUO	480.4	69.4	60.8	79.5	P	P	S	16	3.0	0.2	
19785	11/28/01	88	4	F	1998	0.70765	0.91	W	TUO	540.6	79.7	71.1	89.8	S	P	S	34	3.2	0.3	
19790	11/28/01	94	4	F	1998	0.70818	0.68	W	TUO	583.5	87.0	78.4	97.1	S	S	S	32	2.9	0.2	
19796	12/03/01	81	4	F	1998	0.70811	0.88	W	TUO	566.3	84.1	75.5	94.1	S	S	S	17	3.8	0.1	
19798	12/03/01	93	4	M	1998	0.70814	0.83	W	TUO	525.6	77.1	68.5	87.2	S	P	S	17	4.0	0.2	
19800	12/03/01	114	4	M	1998	0.70776	0.95	W	TUO	595.1	89.0	80.4	99.1	S	S	S	.			
19802	12/03/01	97	4	F	1998	0.70824	0.40	W	TUO*	556.7	82.4	73.8	92.5	S	P	S	*Inconclusive natal assignment*			
19805	12/03/01	88	4	F	1998	0.70821	0.56	W	TUO	524.7	77.0	68.4	87.0	S	P	S	10	3.1	0.2	
19806	12/03/01	89	4	F	1998	0.70769	0.93	W	TUO	573.4	85.3	76.7	95.4	S	S	S	6	3.6	0.2	
19810	12/03/01	85	4	F	1998	0.70765	0.91	W	TUO	516.6	75.6	67.0	85.6	S	P	S	15	3.5	0.1	
19820	12/03/01	105	4	M	1998	0.70779	0.96	W	TUO	536.5	79.0	70.4	89.0	S	P	S	23	3.0	0.2	
19821	12/03/01	94	4	F	1998	0.70812	0.86	W	TUO	549.4	81.2	72.6	91.2	S	P	S	14	3.1	0.2	
19838	12/03/01	73	4	F	1998	0.70765	0.91	W	TUO	501.6	73.0	64.4	83.1	P	P	S	19	3.4	0.2	
19840	12/03/01	81	4	F	1998	0.70813	0.84	W	TUO	484.3	70.1	61.5	80.1	P	P	S	14	3.8	0.2	
19857	12/04/01	97	4	M	1998	0.70776	0.95	W	TUO	574.8	85.5	76.9	95.6	S	S	S	10	3.1	0.3	
19864	12/04/01	99	4	M	1998	0.70813	0.84	W	TUO	564.5	83.8	75.2	93.8	S	S	S	17	2.5	0.3	
19867	12/04/01	86	4	F	1998	0.70808	0.93	W	TUO	502.5	73.2	64.6	83.2	P	P	S	6	3.1	0.2	

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19872	12/10/01	84	4	F	1998	0.70815	0.78	W	TUO	508.7	74.2	65.6	84.3	P	P	S	16	3.1	0.2	
19875	12/10/01	83	4	F	1998	0.70823	0.42	W	TUO*	526.6	77.3	68.7	87.4	S	P	S	*Inconclusive natal assignment*			
19879	12/10/01	76	4	F	1998	0.70766	0.91	W	TUO	530.5	78.0	69.4	88.0	S	P	S	15	2.5	0.1	
19880	12/10/01	89	4	F	1998	0.70765	0.91	W	TUO	506.0	73.8	65.2	83.8	P	P	S	32	3.3	0.3	
19881	12/10/01	99	4	F	1998	0.70813	0.85	W	TUO	586.0	87.4	78.9	97.5	S	S	S	23	2.8	0.4	
20183	11/28/01	101	4	F	1998	0.70773	0.94	W	TUO	577.9	86.1	77.5	96.1	S	S	S	11	4.5	0.2	
4492	11/28/00	57	2	M	1999	0.70804	0.95	W	TUO	603.8	90.5	81.9	100.6	S	S	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
4526	12/11/00	67	2	F	1999	0.70800	0.97	W	TUO	871.9	136.3	127.7	146.4	S	S	S	.			
11009	11/16/01	.	3	F	1999	0.70757	0.86	W	TUO	517.8	75.8	67.2	85.8	S	P	S	.			
11016	11/16/01	79.5	3	F	1999	0.70731	0.40	W	TUO*	465.7	66.9	58.3	76.9	P	P	S	24	3.1	0.2	
11019	11/16/01	60	3	F	1999	0.70743	0.67	INC	TUO*	548.1	81.0	72.4	91.0	S	P	S	.			Unreadable, so cannot assign natal location or do ageing
11021	11/16/01	73	3	F	1999	0.70731	0.39	W	TUO*	525.1	77.0	68.4	87.1	S	P	S	17	2.8	0.3	
11041	12/11/01	77	3	F	1999	0.70805	0.95	W	TUO	556.9	82.5	73.9	92.5	S	P	S	13	3.0	0.2	
11094	11/30/01	80	3	F	1999	0.70756	0.85	W	TUO	516.3	75.5	66.9	85.6	S	P	S	15	3.8	0.3	
11096	11/30/01	77	3	F	1999	0.70764	0.91	W	TUO	568.8	84.5	75.9	94.6	S	S	S	12	3.5	0.2	
11099	11/30/01	73	3	F	1999	0.70733	0.44	W	TUO*	491.3	71.3	62.7	81.3	P	P	S	*Inconclusive natal assignment*			
11100	11/30/01	83	3	F	1999	0.70748	0.75	W	TUO	572.6	85.2	76.6	95.2	S	S	S	.			
11132	11/26/01	76	3	F	1999	0.70734	0.46	W	TUO*	521.5	76.4	67.8	86.5	S	P	S	15	3.0	0.3	
11141	11/26/01	77	3	F	1999	0.70741	0.63	W	TUO	485.0	70.2	61.6	80.2	P	P	S	.			
11146	11/26/01	81	3	F	1999	0.70722	0.20	W	TUO*	487.0	70.5	61.9	80.6	P	P	S	*Inconclusive natal assignment*			
11157	11/26/01	80	3	M	1999	0.70740	0.61	W	TUO	467.5	67.2	58.6	77.3	P	P	S	8	5.6	0.1	
11161	11/26/01	74	3	F	1999	0.70792	0.98	W	TUO	519.2	76.0	67.4	86.1	S	P	S	.			
11162	11/26/01	78	3	F	1999	0.70724	0.25	W	TUO*	534.0	78.6	70.0	88.6	S	P	S	7	4.7	0.3	
11174	12/07/01	80	3	F	1999	0.70754	0.83	W	TUO	488.2	70.7	62.1	80.8	P	P	S	1	2.7	n/a	
11192	11/23/01	74	3	F	1999	0.70772	0.94	W	TUO	550.0	81.3	72.7	91.4	S	P	S	29	3.1	0.3	
11209	11/21/01	97	3	M	1999	0.70771	0.94	W	TUO	602.1	90.2	81.6	100.3	S	S	S	15	3.8	0.2	
11213	11/21/01	83	3	F	1999	0.70771	0.94	W	TUO	521.3	76.4	67.8	86.4	S	P	S	.			
11217	11/21/01	40.5	3	M	1999	0.70764	0.90	W	TUO	474.1	68.3	59.7	78.4	P	P	S	10	2.8	0.2	
14499	11/04/02	93	4	F	1999	0.70814	0.83	W	TUO	610.2	91.6	83.0	101.6	S	S	S	33	2.8	0.3	
14568	11/05/02	107	4	M	1999	0.70761	0.89	W	TUO	631.3	95.2	86.6	105.3	S	S	S	30	2.69	0.36	

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14621	11/12/02	104	4	M	1999	0.70776	0.95	W	TUO	642.0	97.0	88.4	107.1	S	S	S	31	3.1	0.2	
14623	11/12/02	85	4	F	1999	0.70782	0.97	W	TUO	531.8	78.2	69.6	88.2	S	P	S	12	3.0	0.2	
14627	11/12/02	97	4	F	1999	0.70754	0.83	W	TUO	522.3	76.6	68.0	86.6	S	P	S	.			
14635	11/12/02	101	4	M	1999	0.70777	0.96	W	TUO	548.5	81.0	72.4	91.1	S	P	S	17	2.9	0.3	
14647	11/12/02	96	4	F	1999	0.70805	0.95	W	TUO	503.9	73.4	64.8	83.5	P	P	S	.			
14669	11/12/02	104	4	M	1999	0.70761	0.89	W	TUO	541.0	79.7	71.2	89.8	S	P	S	15	3.8	0.2	
14687	11/12/02	91	4	F	1999	0.70738	0.56	W	TUO	580.1	86.4	77.8	96.5	S	S	S	20	3.7	0.2	
14693	11/12/02	99	4	M	1999	0.70751	0.80	W	TUO	570.7	84.8	76.2	94.9	S	S	S	27	3.2	0.2	
14716	11/13/02	97	4	M	1999	0.70757	0.85	W	TUO	597.6	89.4	80.8	99.5	S	S	S	28	3.2	0.3	
14729	11/13/02	96	4	M	1999	0.70726	0.28	W	TUO*	533.1	78.4	69.8	88.5	S	P	S	20	3.7	0.3	
14759	11/14/02	101	4	M	1999	0.70766	0.91	W	TUO	563.5	83.6	75.0	93.7	S	S	S	22	2.3	0.2	
14774	11/14/02	86	4	F	1999	0.70786	0.97	W	TUO	528.7	77.6	69.1	87.7	S	P	S	.			
14804	11/14/02	93	4	F	1999	0.70768	0.93	W	TUO	543.8	80.2	71.6	90.3	S	P	S	18	3.9	0.2	
14824	11/15/02	98	4	M	1999	0.70733	0.44	W	TUO*	551.6	81.6	73.0	91.6	S	P	S	*Inconclusive natal assignment*			
14850	11/18/02	92	4	F	1999	0.70722	0.19	W	TUO*	513.4	75.0	66.4	85.1	S	P	S	*Inconclusive natal assignment*			
14884	11/18/02	89	4	F	1999	0.70749	0.77	W	TUO	545.5	80.5	71.9	90.6	S	P	S	.			
14889	11/18/02	88	4	M	1999	0.70754	0.82	W	TUO	576.1	85.8	77.2	95.8	S	S	S	22	3.7	0.2	
14892	11/18/02	100	4	M	1999	0.70725	0.26	W	TUO*	534.3	78.6	70.0	88.7	S	P	S	*Inconclusive natal assignment*			
14904	11/18/02	100	4	M	1999	0.70745	0.70	W	TUO	553.8	81.9	73.3	92.0	S	P	S	28	3.4	0.2	
14919	11/18/02	88	4	F	1999	0.70729	0.35	W	TUO*	458.5	65.6	57.1	75.7	P	P	S	*Inconclusive natal assignment*			
14953	11/19/02	103	4	M	1999	0.70787	0.97	W	TUO	534.2	78.6	70.0	88.6	S	P	S	16	2.7	0.3	
14955	11/19/02	94	4	F	1999	0.70813	0.84	W	TUO	562.1	83.4	74.8	93.4	S	P	S	8	3.4	0.3	
14976	11/19/02	102	4	M	1999	0.70765	0.91	W	TUO	524.7	77.0	68.4	87.0	S	P	S	5	3.9	0.1	
14999	11/20/02	104	4	M	1999	0.70726	0.27	W	TUO*	523.4	76.7	68.1	86.8	S	P	S	1	4.9		
15001	11/20/02	101	4	M	1999	0.70787	0.97	W	TUO	487.7	70.6	62.0	80.7	P	P	S	13	3.7	0.3	
15052	11/20/02	105	4	M	1999	0.70776	0.95	W	TUO	590.3	88.2	79.6	98.2	S	S	S	.			
15064	11/20/02	98	4	M	1999	0.70775	0.95	W	TUO	475.5	68.5	60.0	78.6	P	P	S	11	3.2	0.4	
15097	11/21/02	104	4	M	1999	0.70774	0.95	W	TUO	563.5	83.6	75.0	93.7	S	S	S	11	3.3	0.1	
15146	11/24/02	107	4	M	1999	0.70721	0.19	W	TUO*	513.8	75.1	66.5	85.2	S	P	S	*Inconclusive natal assignment*			
15150	11/24/02	108	4	M	1999	0.70761	0.89	W	TUO	505.1	73.6	65.0	83.7	P	P	S	22	3.6	0.3	
15165	11/24/02	100	4	M	1999	0.70726	0.27	W	TUO*	447.6	63.8	55.2	73.9	P	P	P	*Inconclusive natal assignment*			
19679	11/15/01	78	3	F	1999	0.70754	0.83	W	TUO	559.9	83.0	74.4	93.1	S	P	S	11	3.0	0.1	
19686	11/15/01	81	3	F	1999	0.70780	0.96	W	TUO	567.8	84.3	75.7	94.4	S	S	S	6	4.2	0.3	
19688	11/15/01	72.5	3	F	1999	0.70772	0.94	W	TUO	578.5	86.2	77.6	96.2	S	S	S	.			

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19705	11/15/01	76	3	F	1999	0.70729	0.35	W	TUO*	440.8	62.6	54.0	72.7	P	F	P	*Inconclusive natal assignment*			
19722	11/19/01	87	3	F	1999	0.70733	0.44	W	TUO*	582.6	86.9	78.3	96.9	S	S	S	*Inconclusive natal assignment*			
19775	11/28/01	83	3	F	1999	0.70736	0.52	W	TUO	592.7	88.6	80.0	98.7	S	S	S	31	3.7	0.2	
19779	11/28/01	70	3	F	1999	0.70760	0.88	W	TUO	522.2	76.5	67.9	86.6	S	P	S	10	3.5	0.2	
19782	11/28/01	76	3	M	1999	0.70779	0.96	W	TUO	555.0	82.1	73.6	92.2	S	P	S	18	3.1	0.2	
19786	11/28/01	85	3	M	1999	0.70746	0.73	W	TUO	580.0	86.4	77.8	96.5	S	S	S	9	3.5	0.3	
19791	11/28/01	79	3	F	1999	0.70735	0.49	W	TUO*	508.6	74.2	65.6	84.3	P	P	S	*Inconclusive natal assignment*			
19792	11/28/01	76	3	F	1999	0.70814	0.83	W	TUO	520.8	76.3	67.7	86.4	S	P	S	5	4.1	0.1	
19797	12/03/01	84	3	F	1999	0.70735	0.48	W	TUO*	523.0	76.7	68.1	86.7	S	P	S	*Inconclusive natal assignment*			
19816	12/03/01	81	3	M	1999	0.70770	0.93	W	TUO	736.1	113.1	104.5	123.2	S	S	S	.			
19836	12/03/01	88	3	M	1999	0.70726	0.29	W	TUO*	486.4	70.4	61.8	80.5	P	P	S	*Inconclusive natal assignment*			
19841	12/03/01	74	3	F	1999	0.70724	0.23	W	TUO*	491.7	71.3	62.7	81.4	P	P	S	*Inconclusive natal assignment*			
19845	12/04/01	87	3	M	1999	0.70788	0.97	W	TUO	549.3	81.2	72.6	91.2	S	P	S	20	3.2	0.2	
19855	12/04/01	85	3	M	1999	0.70768	0.92	W	TUO	523.0	76.7	68.1	86.7	S	P	S	33	2.8	0.2	
19861	12/04/01	74	3	F	1999	0.70775	0.95	W	TUO	544.2	80.3	71.7	90.4	S	P	S	8	3.4	0.2	
19866	12/04/01	86	3	M	1999	0.70724	0.23	W	TUO*	487.4	70.6	62.0	80.6	P	P	S	9	3.1	0.2	
19868	12/04/01	74	3	F	1999	0.70736	0.51	W	TUO	645.4	97.6	89.0	107.7	S	S	S	9	3.7	0.2	
19874	12/10/01	75	3	F	1999	0.70756	0.84	W	TUO	409.6	57.3	48.7	67.4	P	F	P	8	2.73	0.1 4	
19876	12/10/01	71	3	M	1999	0.70765	0.91	W	TUO	538.8	79.4	70.8	89.4	S	P	S	16	3.2	0.2	
11055	11/20/01	56	2	M	2000	0.70770	0.93	W	TUO	433.6	61.4	52.8	71.5	P	F	P	.			
11063	11/20/01	58	2	M	2000	0.70763	0.90	W	TUO	614.4	92.3	83.7	102.4	S	S	S	53	2.8	0.2	
11076	11/20/01	81	2	F	2000	0.70807	0.93	W	TUO	557.2	82.5	73.9	92.6	S	P	S	5	3.1	0.1	
11083	11/20/01	59	2	M	2000	0.70742	0.65	W	TUO	529.8	77.8	69.2	87.9	S	P	S	35	3.2	0.2	
11111	11/08/01	54.5	2	F	2000	0.70775	0.95	W	TUO	563.7	83.6	75.0	93.7	S	S	S	24	4.0	0.3	
11133	11/26/01	59	2	F	2000	0.70797	0.97	W	TUO	472.4	68.0	59.4	78.1	P	P	S	.			
11167	11/26/01	60	2	F	2000	0.70752	0.81	W	TUO	512.3	74.8	66.3	84.9	P	P	S	33	3.4	0.3	
11212	11/21/01	65.5	2	F	2000	0.70760	0.88	W	TUO	559.7	82.9	74.4	93.0	S	P	S	32	3.8	0.2	
11215	11/21/01	60	2	F	2000	0.70795	0.98	W	TUO	577.4	86.0	77.4	96.0	S	S	S	20	4.3	0.3	
11220	10/31/01	62	2	F	2000	0.70789	0.97	W	TUO	601.9	90.2	81.6	100.2	S	S	S	30	2.7	0.3	
11223	10/31/01	54	2	M	2000	0.70784	0.97	W	TUO	571.0	84.9	76.3	94.9	S	S	S	33	3.4	0.3	
11228	10/31/01	60	2	M	2000	0.70778	0.96	W	TUO	519.3	76.0	67.4	86.1	S	P	S	30	3.7	0.3	
14528	11/04/02	95	3	M	2000	0.70813	0.85	W	TUO	558.3	82.7	74.1	92.8	S	P	S	24	3.3	0.2	
14539	11/04/02	72	3	F	2000	0.70789	0.97	W	TUO	519.7	76.1	67.5	86.2	S	P	S	28	3.2	0.1	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

14540	11/04/02	69	3	F	2000	0.70777	0.96	INC	TUO*	466.3	67.0	58.4	77.0	P	P	S	.			Unreadable, so cannot assign natal location or do ageing
14544	11/05/02	78	3	F	2000	0.70782	0.96	W	TUO	523.5	76.8	68.2	86.8	S	P	S	39	3.0	0.2	
14545	11/05/02	92	3	M	2000	0.70792	0.98	W	TUO	482.3	69.7	61.1	79.8	P	P	S	.			
14548	11/05/02	72	3	F	2000	0.70801	0.97	W	TUO	615.8	92.5	84.0	102.6	S	S	S	.			
14550	11/05/02	80	3	M	2000	0.70789	0.97	W	TUO	487.8	70.7	62.1	80.7	P	P	S	29	3.1	0.3	
14556	11/05/02	73	3	F	2000	0.70742	0.64	W	TUO	552.0	81.6	73.0	91.7	S	P	S	29	4.0	0.3	
14559	11/05/02	89	3	M	2000	0.70768	0.92	W	TUO	430.9	60.9	52.3	71.0	P	F	P	.			
14560	11/05/02	78	3	F	2000	0.70756	0.85	W	TUO	537.9	79.2	70.6	89.3	S	P	S	28	3.8	0.2	
14566	11/05/02	79	3	F	2000	0.70786	0.97	W	TUO	504.0	73.4	64.8	83.5	P	P	S	.			
14571	11/05/02	97	3	M	2000	0.70763	0.90	W	TUO	590.4	88.2	79.6	98.3	S	S	S	38	3.4	0.3	
14575	11/05/02	73	3	F	2000	0.70795	0.98	W	TUO	500.4	72.8	64.2	82.9	P	P	S	21	3.1	0.3	
14578	11/05/02	73	3	F	2000	0.70745	0.71	W	TUO	511.4	74.7	66.1	84.8	P	P	S	.			
14579	11/05/02	93	3	M	2000	0.70742	0.65	W	TUO	521.3	76.4	67.8	86.4	S	P	S	31	3.8	0.2	
14584	11/05/02	81	.	M	2000	0.70772	0.94	W	TUO	520.2	76.2	67.6	86.3	S	P	S	.			
14587	11/05/02	80	3	F	2000	0.70780	0.96	W	TUO	584.3	87.2	78.6	97.2	S	S	S	.			
14596	11/05/02	80	3	F	2000	0.70800	0.97	W	TUO	568.9	84.5	75.9	94.6	S	S	S	19	2.9	0.3	
14597	11/05/02	91	3	M	2000	0.70756	0.85	W	TUO	528.1	77.5	69.0	87.6	S	P	S	35	3.4	0.3	
14600	11/05/02	75	3	F	2000	0.70774	0.95	W	TUO	460.7	66.0	57.4	76.1	P	P	S	.			
14616	11/12/02	94	3	M	2000	0.70768	0.92	W	TUO	494.1	71.7	63.1	81.8	P	P	S	61	3.5	0.2	
14626	11/12/02	91	3	M	2000	0.70735	0.50	W	TUO	545.9	80.6	72.0	90.7	S	P	S	.			
14629	11/12/02	74	3	F	2000	0.70772	0.94	W	TUO	555.0	82.1	73.6	92.2	S	P	S	.			
14661	11/12/02	94	3	M	2000	0.70761	0.89	W	TUO	556.0	82.3	73.7	92.4	S	P	S	42	3.8	0.3	
14668	11/12/02	90	3	M	2000	0.70785	0.97	W	TUO	530.4	77.9	69.3	88.0	S	P	S	23	3.3	0.2	
14673	11/12/02	90	3	M	2000	0.70770	0.93	W	TUO	532.9	78.4	69.8	88.4	S	P	S	26	3.8	0.2	
14689	11/12/02	93	3	M	2000	0.70803	0.96	W	TUO	521.2	76.4	67.8	86.4	S	P	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
14701	11/13/02	93	3	M	2000	0.70803	0.96	W	TUO	456.0	65.2	56.6	75.3	P	P	S	0	n/a	n/a	Strange profile (used same distance for natal and FW exit)
14721	11/13/02	76	3	F	2000	0.70804	0.95	W	TUO	512.1	74.8	66.2	84.9	P	P	S	18	3.7	0.2	
14735	11/13/02	92	3	M	2000	0.70763	0.90	W	TUO	514.7	75.2	66.7	85.3	S	P	S	38	3.9	0.3	
14743	11/13/02	76	3	F	2000	0.70802	0.96	W	TUO	535.2	78.8	70.2	88.8	S	P	S	12	4.2	0.2	

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14749	11/14/02	80	3	F	2000	0.70773	0.94	W	TUO	473.3	68.2	59.6	78.2	P	P	S	34	2.6	0.2	
14753	11/14/02	84	3	M	2000	0.70774	0.95	W	TUO	525.1	77.0	68.4	87.1	S	P	S	31	4.1	0.3	
14769	11/14/02	81	3	F	2000	0.70757	0.85	W	TUO	503.2	73.3	64.7	83.4	P	P	S	31	3.7	0.3	
14783	11/14/02	89	3	M	2000	0.70793	0.98	W	TUO	564.4	83.8	75.2	93.8	S	S	S	12	4.6	0.2	
14785	11/14/02	95	3	M	2000	0.70766	0.91	W	TUO	535.2	78.8	70.2	88.8	S	P	S	.			
14786	11/14/02	76	3	F	2000	0.70781	0.96	W	TUO	505.4	73.7	65.1	83.7	P	P	S	23	4.1	0.3	
14813	11/14/02	86	3	M	2000	0.70799	0.97	W	TUO	500.7	72.9	64.3	82.9	P	P	S	25	3.4	0.3	
14815	11/15/02	82	3	F	2000	0.70761	0.89	W	TUO	501.9	73.1	64.5	83.1	P	P	S	.			
14858	11/18/02	104	3	M	2000	0.70740	0.61	W	TUO	484.4	70.1	61.5	80.1	P	P	S	3	2.0	0.0	
14880	11/18/02	80	3	M	2000	0.70727	0.31	W	TUO*	480.4	69.4	60.8	79.5	P	P	S	12	5.1	0.2	
14907	11/18/02	74	3	F	2000	0.70773	0.95	W	TUO	497.3	72.3	63.7	82.3	P	P	S	14	3.9	0.2	
14921	11/18/02	93	3.5	F	2000	0.70780	0.96	W	TUO	547.1	80.8	72.2	90.9	S	P	S	47	3.3	0.2	
14929	11/18/02	91	3	M	2000	0.70764	0.90	W	TUO	529.8	77.8	69.3	87.9	S	P	S	30	3.2	0.3	
14975	11/19/02	102	3	M	2000	0.70743	0.67	W	TUO	565.7	84.0	75.4	94.0	S	S	S	.			
15091	11/21/02	100	3	F	2000	0.70792	0.98	W	TUO	557.5	82.6	74.0	92.6	S	P	S	26 †	3.90	0.1 5	† Microstructure ran out 52um before FW exit (inferred 13 increments at end)
15113	11/21/02	100	3	M	2000	0.70763	0.90	W	TUO	495.1	71.9	63.3	82.0	P	P	S	.			
15133	11/24/02	103	3	M	2000	0.70754	0.83	W	TUO	513.7	75.1	66.5	85.1	S	P	S	23	3.8	0.2	
15193	11/24/02	101	3	M	2000	0.70773	0.94	W	TUO	611.3	91.8	83.2	101.8	S	S	S	31	3.1	0.3	
15243	12/02/02	91	3	M	2000	0.70777	0.95	W	TUO	524.0	76.8	68.3	86.9	S	P	S	22	3.5	0.2	
19681	11/15/01	65	2	M	2000	0.70759	0.87	W	TUO	478.4	69.1	60.5	79.1	P	P	S	.			
19695	11/19/01	59.5	2	M	2000	0.70759	0.88	W	TUO	540.6	79.7	71.1	89.7	S	P	S	25	3.2	0.3	
19813	12/03/01	48	2	M	2000	0.70789	0.97	W	TUO	561.0	83.2	74.6	93.2	S	P	S	48	3.4	0.3	
19831	12/03/01	57	2	F	2000	0.70779	0.96	W	TUO	498.5	72.5	63.9	82.5	P	P	S	28	4.8	0.3	
19853	12/04/01	60	2	F	2000	0.70781	0.96	W	TUO	544.3	80.3	71.7	90.4	S	P	S	7	4.0	0.2	
19858	12/04/01	58	2	F	2000	0.70761	0.89	W	TUO	487.6	70.6	62.0	80.7	P	P	S	.			
17628	11/14/05	91	3	M	2003	0.70730	0.37	W	TUO*	551.7	81.6	73.0	91.6	S	P	S	19	3.2	0.3	
17631	11/14/05	84	3	F	2003	0.70751	0.80	W	TUO	594.7	88.9	80.4	99.0	S	S	S	12	4.6	0.2	
17634	11/14/05	81	3	F	2003	0.70772	0.94	W	TUO	511.9	74.8	66.2	84.8	P	P	S	9	2.9	0.1	
17637	11/16/05	92	3	M	2003	0.70726	0.27	W	TUO*	457.4	65.5	56.9	75.5	P	P	S	*Inconclusive natal assignment*			
17638	11/16/05	76	3	F	2003	0.70731	0.41	W	TUO*	558.9	82.8	74.2	92.9	S	P	S	11	3.1	0.2	
17645	11/21/05	75	3	F	2003	0.70747	0.74	W	TUO	628.3	94.7	86.1	104.7	S	S	S	.			

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17651	11/21/05	88	3	M	2003	0.70745	0.71	W	TUO	582.0	86.8	78.2	96.8	S	S	S	8	4.4	0.2	
17654	11/21/05	73	3	F	2003	0.70757	0.86	W	TUO	380.8	52.4	43.8	62.4	F	F	P	16	3.6	0.1	
17666	11/28/05	73	3	F	2003	0.70753	0.82	W	TUO	529.0	77.7	69.1	87.8	S	P	S	5	2.9	0.3	
17667	11/28/05	75	3	F	2003	0.70744	0.69	W	TUO	531.9	78.2	69.6	88.3	S	P	S	18	2.9	0.3	
17669	11/28/05	72	3	F	2003	0.70743	0.66	W	TUO	597.8	89.5	80.9	99.5	S	S	S	.			
17672	11/28/05	79	3	F	2003	0.70756	0.85	INC	TUO*		n/a (vaterite)						.			Otolith vateritic during natal rearing (so no HvW assignment or exit age/dist)
17673	11/28/05	71	3	F	2003	0.70745	0.70	W	TUO		73.8	65.2	83.8	P	P	S	.			
17679	11/28/05	85	3	M	2003	0.70729	0.34	W	TUO*		82.3	73.7	92.4	S	P	S	21	4.6	0.3	
17680	11/28/05	75	3	F	2003	0.70777	0.96	W	TUO		86.6	78.0	96.6	S	S	S	n/a	n/a	n/a	Microstructure ran out before fish left natal river
17681	11/28/05	72	3	F	2003	0.70763	0.90	W	TUO		67.5	58.9	77.6	P	P	S	.			
17685	11/28/05	61	3	M	2003	0.70727	0.30	W	TUO*		74.7	66.1	84.8	P	P	S	*Inconclusive natal assignment*			
17690	11/28/05	83	3	M	2003	0.70754	0.83	W	TUO		91.5	82.9	101.5	S	S	S	8	3.1	0.3	
17692	11/29/05	85	3	F	2003	0.70759	0.87	W	TUO		73.9	65.4	84.0	P	P	S	2	4.3	0.1	
17703	12/06/05	75	3	F	2003	0.70751	0.79	W	TUO		96.9	88.3	106.9	S	S	S	14	3.1	0.2	
17712	12/06/05	90	3	M	2003	0.70734	0.46	W	TUO*		79.8	71.2	89.8	S	P	S	*Inconclusive natal assignment*			
17713	12/06/05	76	3	F	2003	0.70755	0.84	W	TUO		70.3	61.7	80.3	P	P	S	5	4.4	0.2	
17716	12/06/05	82	3	F	2003	0.70744	0.69	W	TUO		85.0	76.4	95.1	S	S	S	.			
17718	12/07/05	79	3	F	2003	0.70751	0.79	W	TUO		86.7	78.1	96.8	S	S	S	.			
17729	12/12/05	92	3	M	2003	0.70754	0.82	W	TUO		81.7	73.1	91.8	S	P	S	.			
17740	12/12/05	79	3	F	2003	0.70738	0.56	W	TUO		73.6	65.0	83.6	P	P	S	.			
17742	12/12/05	75	3	F	2003	0.70743	0.66	W	TUO		74.6	66.0	84.6	P	P	S	19	3.8	0.2	
17746	12/12/05	72	3	F	2003	0.70762	0.89	W	TUO		94.7	86.1	104.8	S	S	S	.			
17751	12/12/05	85	3	F	2003	0.70755	0.84	W	TUO		83.2	74.6	93.3	S	P	S	9	3.7	0.1	
17753	12/12/05	81	3	M	2003	0.70750	0.79	W	TUO		73.2	64.7	83.3	P	P	S	5	4.1	0.1	
17758	12/12/05	84	3	F	2003	0.70718	0.14	W	TUO*		78.1	69.5	88.2	S	P	S	8	3.6	0.3	
17759	12/12/05	70	3	F	2003	0.70765	0.91	W	TUO		78.3	69.8	88.4	S	P	S	.			
17763	12/12/05	79	3	F	2003	0.70744	0.70	W	TUO		75.9	67.3	86.0	S	P	S	13	3.9	0.2	
18144	12/05/06	86	4	F	2003	0.70726	0.29	W	TUO*		80.7	72.1	90.8	S	P	S	16	3.1	0.1	
18150	12/11/06	84	4	F	2003	0.70741	0.62	W	TUO		72.3	63.7	82.4	P	P	S	15	3.2	0.2	
24120	11/07/11	76	3	F	2009	0.70777	0.73	W	TUO		73.9	65.4	84.0	P	P	S	24	3.1	0.3	

Appendix 1B Table showing capture details of adult samples, their natal assignment and reconstructed fork length (FL) and age at exit from the freshwater delta (FW exit). The probability of the assignment to the Tuolumne (TUO) based on Sr isotopes is indicated, as well as the results of the otolith microstructure analyses to separate hatchery from wild fish (H vs. W). Where otoliths were unreadable, and microstructure analyses inconclusive ("INC"), or when the probability of assignment to TUO was <0.5 based on mean Sr isotopic values, the natal location is marked by an asterisk. Increment information is marked with (.) if otolith was unreadable.The life stage at FW exit was categorized as fry (F: FL<55mm), parr (P: FL >55mm to <75mm) or smolt (S: FL >75mm).

24176	11/14/11	81	3	F	2009	0.70781	0.77	W	TUO		91.3	82.7	101.4	S	S	S	20	2.9	0.4	
24178	11/14/11	67	3	M	2009	0.70778	0.74	W	TUO		88.0	79.4	98.1	S	S	S	13	3.5	0.3	
24238	11/21/11	70	3	F	2009	0.70773	0.69	W	TUO		80.1	71.5	90.2	S	P	S	.			
24283	11/23/11	83	3	M	2009	0.70734	0.16	W	TUO*		80.1	71.5	90.2	S	P	S	*Inconclusive natal assignment*			
24292	11/28/11	95	3	M	2009	0.70730	0.12	W	TUO*		91.4	82.8	101.4	S	S	S	*Inconclusive natal assignment*			
26012	11/13/12	84	4	F	2009	0.70780	0.76	W	TUO		83.7	75.1	93.8	S	S	S	7	2.6	0.1	

[1] Assignments using isotope-based discriminant function analysis and reference samples from existing or ongoing projects ([1], [2], P. Weber, A. Sturrock, unpub)
[2] Hatchery vs. wild assignment using microstructure-based discriminant function analysis and existing reference samples, after [3].
[3] Size-defined life stage designations (fry: <55mm, parr: >55mm to <75mm, smolt: >75mm), after [4].

1. Barnett-Johnson, R., et al., *Tracking natal origins of salmon using isotopes, otoliths, and landscape geology.* Limnology and Oceanography, 2008. **53**(4): p. 1633-1642.
2. Ingram, L.B. and P.K. Weber, *Salmon origin in California's Sacramento–San Joaquin river system as determined by otolith strontium isotopic composition.* Geology, 1999. **27**(9): p. 851-854.
3. Barnett-Johnson, R., et al., *Identifying the contribution of wild and hatchery Chinook salmon (Oncorhynchus tshawytscha) to the ocean fishery using otolith microstructure as natural tags.* Canadian Journal of Fisheries and Aquatic Sciences, 2007. **64**(12): p. 1683-1692.
4. Miller, J.A., A. Gray, and J. Merz, *Quantifying the contribution of juvenile migratory phenotypes in a population of Chinook salmon Oncorhynchus tshawytscha.* Marine Ecology Progress Series, 2010. **408**: p. 227-240.

Appendix 2 Capture details and natal assignments of strays to the Tuolumne River from outmigration years 1998, 1999, 2000, 2003 and 2009. The natal assignments were primarily based on otolith Sr isotopes, however where there was ambiguity in the assignment, otolith microstructure analyses were used to separate hatchery from wild fish (HvW). Site codes are provided in Table 2 of the main report.

ASN	Outmigration year	Date	Age	Length	Sex	Natal location	HvW
4184	1998	10/17/2000	3	84	F	X	H
4188	1998	10/19/2000	3	79.5	F	MOH	H
4190	1998	10/24/2000	3	91	M	MOH	H
4224	1998	10/25/2000	3	91	M	X	H
4227	1998	10/25/2000	3	87	M	X	H
4235	1998	10/25/2000	3	91	M	FEH	H
4236	1998	10/25/2000	3	72	F	MEH	n/a
4250	1998	10/30/2000	3	80	F	MOH	H
4260	1998	10/30/2000	3	78.5	M	X	H
4268	1998	10/30/2000	3	77	F	MOH	H
4273	1998	10/31/2000	3	78	F	MOK	W
4282	1998	10/31/2000	3	87	M	MEH	n/a
4285	1998	10/31/2000	3	77.5	F	MEH	n/a
4286	1998	10/31/2000	3	80	F	MEH	n/a
4289	1998	10/31/2000	3	83	F	MEH	n/a
4302	1998	11/6/2000	3	81.5	F	X	H
4313	1998	11/6/2000	3	92	F	MEH	H
4314	1998	11/6/2000	3	76	F	MEH	n/a
4324	1998	11/6/2000	3	77	F	MEH	H
4336	1998	11/7/2000	3	87	M	MEH	n/a
4338	1998	11/7/2000	3	84	F	MEH	n/a
4344	1998	11/7/2000	3	68	M	MEH	n/a
4349	1998	11/7/2000	3	75	F	MEH	n/a
4382	1998	11/13/2000	3	87	F	MEH	n/a
4396	1998	11/13/2000	3	92.5	M	MEH	n/a
4402	1998	11/14/2000	3	75	F	X	H
4406	1998	11/15/2000	3	88	M	MEH	n/a
4416	1998	11/15/2000	3	75	F	MEH	n/a
4422	1998	11/14/2000	3	80	F	MEH	n/a
4453	1998	11/20/2000	3	97	F	STA	W
4457	1998	11/20/2000	3	75	F	MEH	n/a
4467	1998	11/21/2000	3	92	F	STA	n/a
4479	1998	11/27/2000	3	63.5	F	MEH	n/a
4491	1998	11/28/2000	3	54	F	MEH	H
4495	1998	11/28/2000	3	86	F	X	H
4498	1998	11/29/2000	3	82	F	X	H
4503	1998	12/4/2000	3	83	F	X	H
4529	1998	12/12/2000	3	67	F	X	H
4530	1998	12/12/2000	3	61	F	X	H
9534	1998	7/7/2000	3	68	F	MOH	H
9551	1998	8/11/2000	3	74	F	MOH	H
11067	1998	11/20/2001	4	88	F	MEH	n/a
11095	1998	11/29/2001	4	86	F	MEH	n/a
11145	1998	11/26/2001	4	95	F	MEH	n/a
11147	1998	11/26/2001	4	93	F	MEH	n/a
11149	1998	11/26/2001	4	118	M	MEH	H
11150	1998	11/26/2001	4	84	M	MEH	n/a
11153	1998	11/26/2001	4	110	M	MEH	H
11156	1998	11/26/2001	4	92	F	MEH	n/a
11165	1998	11/26/2001	4	87	F	X	H
11170	1998	11/26/2001	4	95	F	MOH	H
11171	1998	11/26/2001	4	84	F	X	H
11172	1998	11/26/2001	4	83	F	MEH	H
11175	1998	12/7/2001	4	96	M	X	H
11178	1998	12/7/2001	4	88	F	MEH	H

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11180	1998	12/19/2001	4	90	F	MER	W
11208	1998	11/21/2001	4	84	F	MOH	H
19676	1998	11/15/2001	4	103	M	STA	W
19766	1998	11/27/2001	3.5	84	F	MEH	n/a
19804	1998	12/3/2001	4	98	M	MEH	n/a
19814	1998	12/3/2001	4	91	F	MOK	W
19825	1998	12/3/2001	4	96	M	MEH	n/a
19839	1998	12/3/2001	4	82	F	MEH	n/a
19843	1998	12/3/2001	4	87	F	X	H
19848	1998	12/4/2001	3.5	85	F	STA	W
19856	1998	12/4/2001	4	103	M	STA	W
4375	1999	11/8/2000	2	57.5	F	THE	n/a
4404	1999	11/15/2000	2	56	M	MEH	n/a
4405	1999	11/15/2000	2	57	M	MEH	n/a
4468	1999	11/21/2000	2	37	F	MOH	H
4536	1999	12/20/2000	2	52	M	NIH	n/a
9548	1999	7/28/2000	2	81	F	MOH	H
9549	1999	8/4/2000	2	78	F	MOH	H
11011	1999	11/16/2001	3	77	F	FEH	H
11075	1999	11/20/2001	3	92.5	M	MOH	H
11077	1999	11/20/2001	3	91	F	MEH	H
11091	1999	11/20/2001	3	81	F	MOH	H
11148	1999	11/26/2001	3	72	F	MOH	H
11159	1999	11/26/2001	3	77	F	MOH	H
11168	1999	11/26/2001	3	71	F	THE	n/a
11169	1999	11/26/2001	3	75	F	MOH	H
11179	1999	12/7/2001	3	93	M	NIH	n/a
11183	1999	12/17/2001	3	80	M	NIH	n/a
14525	1999	11/4/2002	4	99	M	MOH	H
14546	1999	11/5/2002	4	95	M	MOH	H
14639	1999	11/12/2002	4	99	M	FEH	H
14640	1999	11/12/2002	4	88	F	STA	n/a
14641	1999	11/12/2002	4	96	F	FEH	H
14644	1999	11/12/2002	4	103	M	MOH	H
14645	1999	11/12/2002	4	101	M	MEH	n/a
14651	1999	11/12/2002	4	101	M	STA	n/a
14692	1999	11/12/2002	4	90	F	MOH	H
14711	1999	11/13/2002	4	94	M	MOH	H
14736	1999	11/13/2002	4	95	M	X	H
14737	1999	11/13/2002	4	110	M	X	H
14800	1999	11/14/2002	4	104	M	MOH	H
14827	1999	11/16/2002	4	98	F	STA	n/a
14828	1999	11/16/2002	4	99	M	X	H
14839	1999	11/18/2002	4	103	M	X	H
14877	1999	11/18/2002	4	90	M	STA	n/a
14883	1999	11/18/2002	4	90	M	STA	n/a
14906	1999	11/18/2002	4	100	M	MOH	H
14908	1999	11/18/2002	4	101	M	MOH	H
14912	1999	11/18/2002	4	102	M	MOH	H
14931	1999	11/18/2002	4	92	F	X	H
14944	1999	11/19/2002	4	101	M	MOH	H
14997	1999	11/20/2002	4	103	M	STA	n/a
15015	1999	11/20/2002	4	103	M	MOH	H
15098	1999	11/21/2002	4	96	M	MOH	H
15112	1999	11/21/2002	4	95	F	NIH	n/a
15114	1999	11/21/2002	4	100	M	MOH	H

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15124	1999	11/22/2002	4	95	F	STA	n/a
15127	1999	11/22/2002	4	102	M	STA	n/a
15131	1999	11/24/2002	4	100	M	MOK	n/a
15172	1999	11/24/2002	4	101	M	FEH	H
15178	1999	11/24/2002	4	104	F	MEH	H
15191	1999	11/24/2002	4	100	M	MOH	H
15216	1999	11/25/2002	4	98	M	FEH	H
15231	1999	11/26/2002	3.5	86	F	MOH	H
15236	1999	11/27/2002	4	100	M	NIH	n/a
15262	1999	12/3/2002	4	108	M	X	H
15269	1999	12/4/2002	4	102	M	X	H
15273	1999	12/5/2002	4	72	F	MOH	H
19678	1999	11/15/2001	3	82	F	MOH	H
19682	1999	11/15/2001	3	80	F	MEH	n/a
19689	1999	11/15/2001	3	88	F	X	H
19700	1999	11/15/2001	3	78	F	MEH	n/a
19778	1999	11/28/2001	3	77	F	MOH	H
19784	1999	11/28/2001	3	70	F	X	H
19787	1999	11/28/2001	3	89	F	X	H
19807	1999	12/3/2001	3	.		MEH	H
19832	1999	12/3/2001	3	69	F	MOH	H
19865	1999	12/4/2001	3	70	F	MOH	H
19870	1999	12/4/2001	3	75	M	X	H
19873	1999	12/10/2001	3	80	F	MEH	H
11012	2000	11/16/2001	2	58	F	X	H
11025	2000	11/9/2001	2	66	M	X	H
11062	2000	11/20/2001	2	86	M	FEH	H
11078	2000	11/20/2001	2	59	M	MEH	n/a
11079	2000	11/20/2001	2	55	M	MEH	n/a
11080	2000	11/20/2001	2	63	F	MOH	H
11103	2000	11/8/2001	2	57	M	MEH	n/a
11144	2000	11/26/2001	2	61	F	MEH	n/a
11184	2000	12/18/2001	2	54	M	NIH	n/a
11198	2000	11/21/2001	2	55.5	F	MOH	H
14486	2000	11/4/2002	3	110	M	MOH	H
14522	2000	11/4/2002	3	83	F	MOH	H
14524	2000	11/4/2002	3	77	F	MOH	H
14529	2000	11/4/2002	3	75	F	MOH	H
14547	2000	11/5/2002	3	79	M	MOH	H
14551	2000	11/5/2002	3	77	F	MOH	H
14569	2000	11/5/2002	3	81	M	MOH	H
14572	2000	11/5/2002	3	94	M	MOH	H
14577	2000	11/5/2002	3	99	M	FEH	H
14607	2000	11/6/2002	3	92	M	MOH	H
14612	2000	11/7/2002	3	98	M	MOH	H
14646	2000	11/12/2002	3	92	M	MOH	H
14657	2000	11/12/2002	3	76	F	MOH	H
14660	2000	11/12/2002	3	104	M	STA	W
14672	2000	11/12/2002	3	93	M	X	H
14744	2000	11/14/2002	3	84	M	X	H
14746	2000	11/14/2002	3	75	F	STA	W
14758	2000	11/14/2002	3	85	M	FEH	H
14763	2000	11/14/2002	3	79	F	X	H
14766	2000	11/14/2002	3	85	M	MOH	H
14890	2000	11/18/2002	3	87	M	MOH	H
14893	2000	11/18/2002	3	72	F	MOH	H

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14895	2000	11/18/2002	3	75	F	MOH	H
14900	2000	11/18/2002	3	76	F	MOH	H
15025	2000	11/20/2002	3	100	M	STA	W
15067	2000	11/20/2002	3	99	M	MOH	H
15105	2000	11/21/2002	3	100	M	MOH	H
15128	2000	11/24/2002	3	107	M	STA	n/a
15159	2000	11/24/2002	3	105	M	FEH	H
19768	2000	11/27/2001	2	60	F	MOH	H
19789	2000	11/28/2001	2	64	F	MOH	H
19882	2000	12/10/2001	2	58	F	MEH	n/a
17621	2003	11/14/2005	3	75	F	MEH	n/a
17623	2003	11/14/2005	3	73	F	THE	n/a
17630	2003	11/14/2005	3	67	F	MOH	H
17632	2003	11/14/2005	3	65	F	THE	n/a
17641	2003	11/21/2005	3	70	F	MEH	n/a
17644	2003	11/21/2005	3	84	M	MOH	H
17647	2003	11/21/2005	3	85	F	MOH	H
17653	2003	11/21/2005	3	75	F	MOH	H
17658	2003	11/21/2005	3	74	F	MOH	H
17659	2003	11/21/2005	3	73	F	MOH	H
17661	2003	11/21/2005	3	75	F	MOH	H
17663	2003	11/21/2005	3	90	M	MEH	n/a
17674	2003	11/28/2005	3	74	F	NIH	n/a
17675	2003	11/28/2005	3	65	F	MOH	H
17676	2003	11/28/2005	3	79	F	MOH	H
17677	2003	11/28/2005	3	75	F	MOH	H
17686	2003	11/28/2005	3	70	M	NIH	n/a
17687	2003	11/28/2005	3	65	F	MOH	H
17688	2003	11/28/2005	3	76	F	MOH	H
17689	2003	11/28/2005	3	76	F	MEH	n/a
17694	2003	12/6/2005	3	77	F	MOH	H
17696	2003	12/6/2005	3	78	M	MOH	H
17697	2003	12/6/2005	3	81	F	NIH	n/a
17698	2003	12/6/2005	3	80	F	NIH	n/a
17704	2003	12/6/2005	3	81	F	MOH	H
17705	2003	12/6/2005	3	85	M	NIH	n/a
17707	2003	12/6/2005	3	84	M	MOH	H
17708	2003	12/6/2005	3	69	F	MOH	H
17709	2003	12/6/2005	3	79	F	NIH	n/a
17710	2003	12/6/2005	3	78	F	MOH	H
17719	2003	12/7/2005	3	80	M	MOH	H
17720	2003	12/7/2005	3	90	M	MOH	H
17721	2003	12/7/2005	3	79	F	NIH	n/a
17724	2003	12/12/2005	3	74	F	FEH	H
17726	2003	12/12/2005	3	80	F	NIH	n/a
17727	2003	12/12/2005	3	76	F	MOH	H
17730	2003	12/12/2005	3	79	M	MOH	H
17731	2003	12/12/2005	3	78	F	MOH	H
17732	2003	12/12/2005	3	69	F	MOH	H
17737	2003	12/12/2005	3	82	F	MOH	H
17739	2003	12/12/2005	3	77	F	THE	n/a
17741	2003	12/12/2005	3	77	F	FEH	H
17743	2003	12/12/2005	3	92	M	MOH	H
17744	2003	12/12/2005	3	75	F	FEH	H
17745	2003	12/12/2005	3	70	F	FEH	H
17747	2003	12/12/2005	3	78	F	MOH	H

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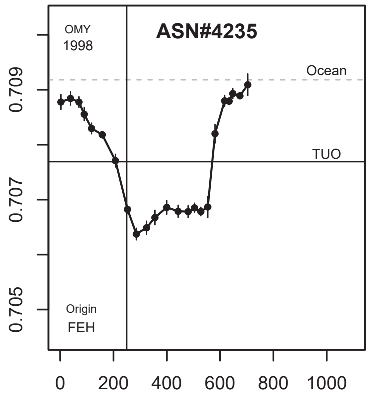
17748	2003	12/12/2005	3	71	F	MOH	H
17749	2003	12/12/2005	3	78	F	MOH	H
17752	2003	12/12/2005	3	82	M	MOH	H
17754	2003	12/12/2005	3	73	F	FEH	H
17755	2003	12/12/2005	3	79	F	NIH	H
17760	2003	12/12/2005	3	74	F	MOH	H
17761	2003	12/12/2005	3	73	F	MOH	H
17762	2003	12/12/2005	3	83	F	MOH	H
18082	2003	11/14/2006	4	92	F	MOH	H
18095	2003	11/20/2006	4	78	F	MOH	H
18096	2003	11/20/2006	4	76	F	CNH	n/a
18101	2003	11/20/2006	4	88	F	MOH	H
18121	2003	11/21/2006	4	95	M	FEH	H
18129	2003	11/27/2006	4	88	F	MOH	H
18142	2003	12/4/2006	4	86	F	MOH	H
20197	2009	11/1/2010	2	63	M	CNH	n/a
20199	2009	11/1/2010	2	74	M	THE	H
20203	2009	11/1/2010	2	67	M	CNH	n/a
20204	2009	11/1/2010	2	63	M	CNH	n/a
20207	2009	11/8/2010	2	50	M	CNH	n/a
20218	2009	11/15/2010	2	59	M	MEH	n/a
20231	2009	11/15/2010	2	61	M	CNH	n/a
20239	2009	11/15/2010	2	60	M	CNH	n/a
20241	2009	11/15/2010	2	60	M	CNH	n/a
20242	2009	11/15/2010	2	62	M	CNH	n/a
20248	2009	11/17/2010	2	65	M	CNH	n/a
20249	2009	11/17/2010	2	68	M	CNH	n/a
20256	2009	11/22/2010	2	68	M	CNH	n/a
20264	2009	11/23/2010	2	63	M	MEH	n/a
24015	2009	10/3/2011	3	78	F	THE	n/a
24035	2009	10/10/2011	3	81	M	FEH	H
24038	2009	10/17/2011	3	77	F	FEA	W
24043	2009	10/17/2011	3	83	M	FEH	H
24052	2009	10/24/2011	3	81	F	FEH	H
24054	2009	10/24/2011	3	83	F	CNH	n/a
24056	2009	10/24/2011	3	82	F	CNH	n/a
24059	2009	10/24/2011	3	86	M	CNH	n/a
24065	2009	10/24/2011	3	82	F	CNH	n/a
24066	2009	10/24/2011	3	92	M	CNH	n/a
24112	2009	11/7/2011	3	77	M	FEH	H
24114	2009	11/7/2011	3	78	F	CNH	n/a
24117	2009	11/7/2011	3	86	M	CNH	n/a
24131	2009	11/7/2011	3	75	F	CNH	n/a
24141	2009	11/7/2011	3	77	F	CNH	n/a
24164	2009	11/9/2011	3	82	F	CNH	n/a
24168	2009	11/9/2011	3	87	M	CNH	n/a
24174	2009	11/14/2011	3	72	F	CNH	H
24177	2009	11/14/2011	3	78	F	CNH	n/a
24193	2009	11/14/2011	3	88	M	CNH	n/a
24214	2009	11/14/2011	3	85	F	CNH	n/a
24239	2009	11/21/2011	3	81	F	MOH	H
24290	2009	11/28/2011	3	75	F	NIH	n/a
24410	2009	12/12/2011	3	73	F	NIH	n/a
25886	2009	11/6/2012	4	81	F	THE	n/a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ASN#4235
Ocean
TUO
Origin
FEH
0.705
0.707
0.709
0
200
400
600
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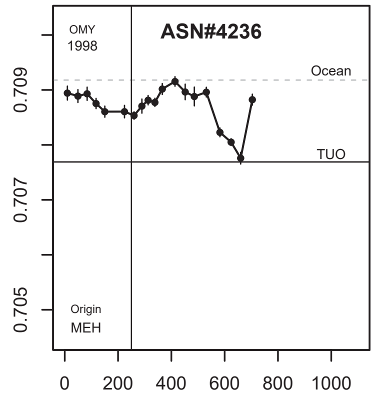
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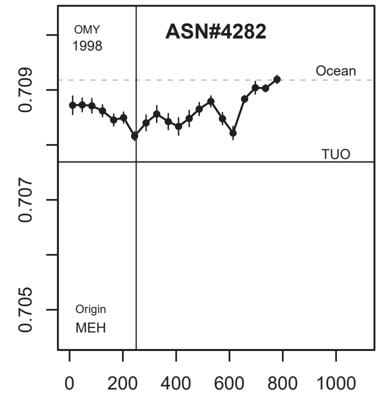
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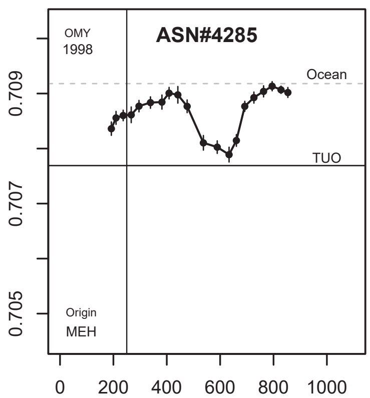
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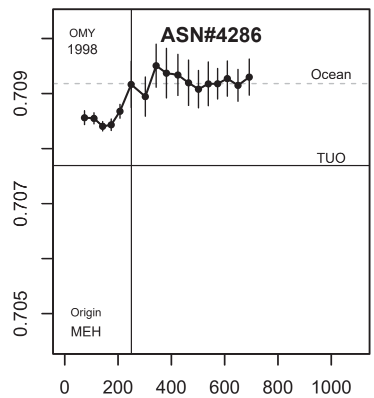
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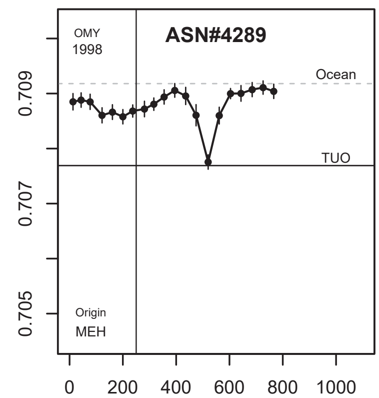
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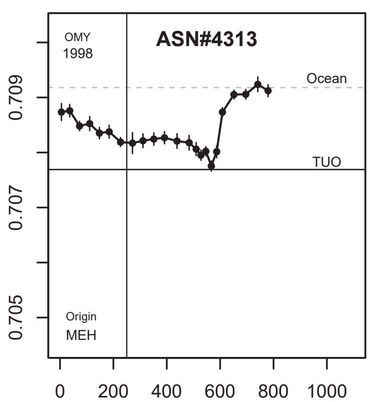
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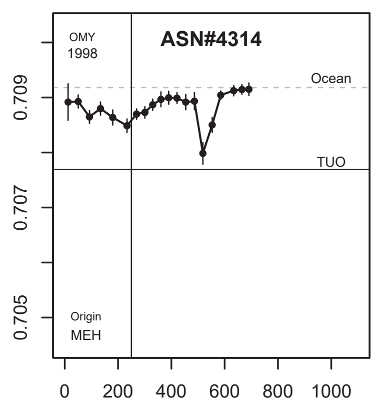
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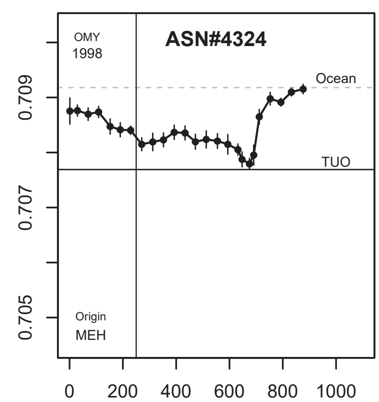
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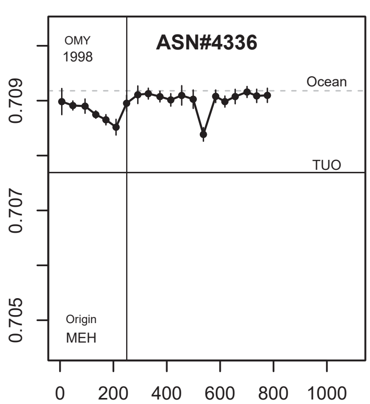
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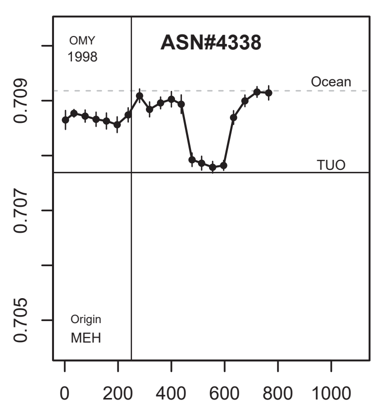
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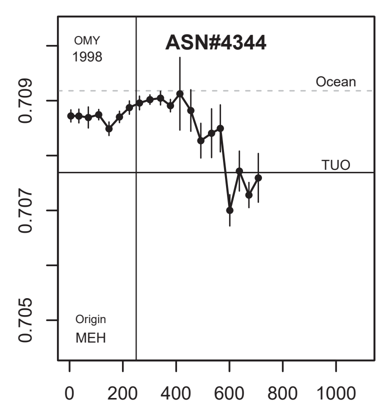
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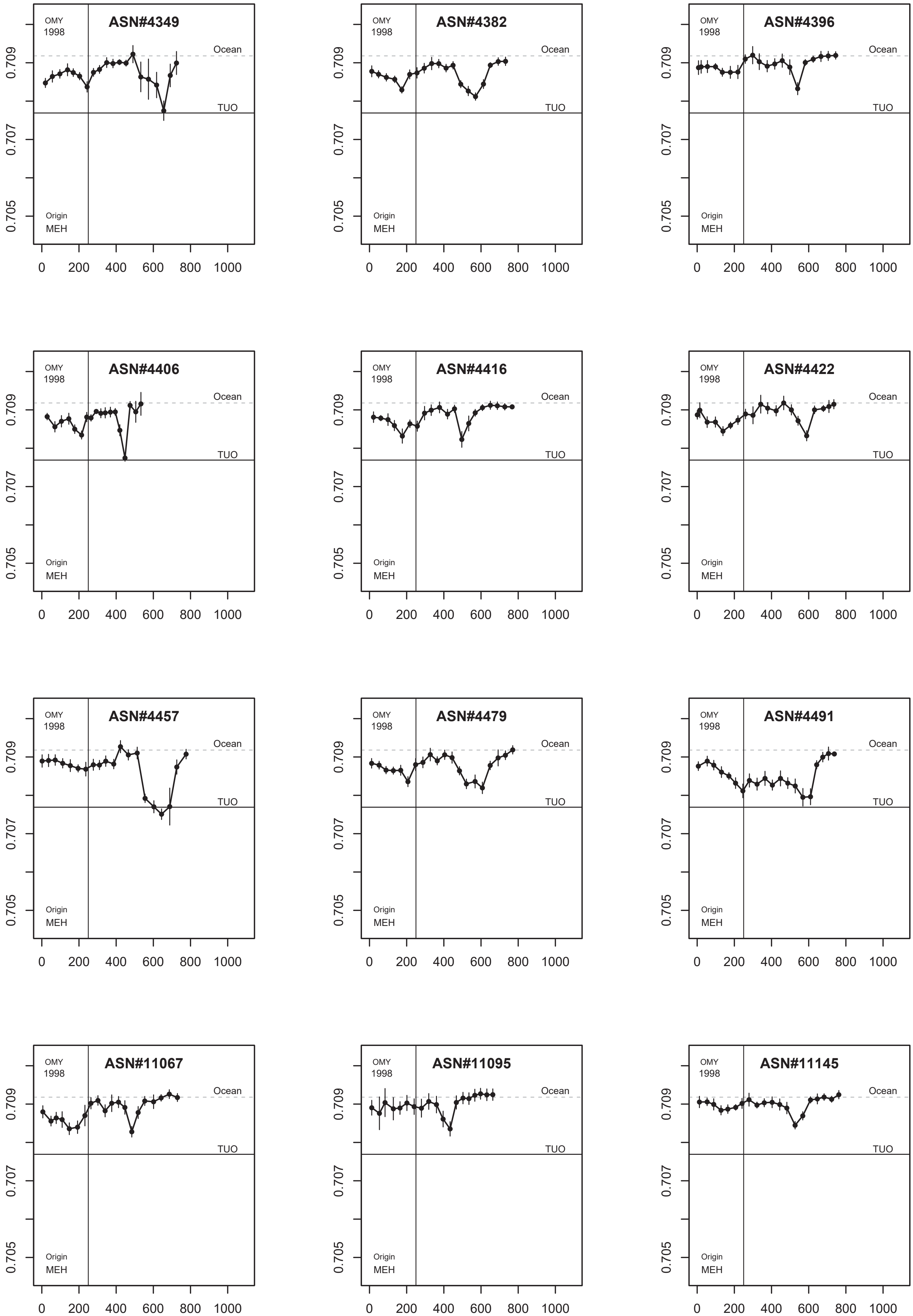
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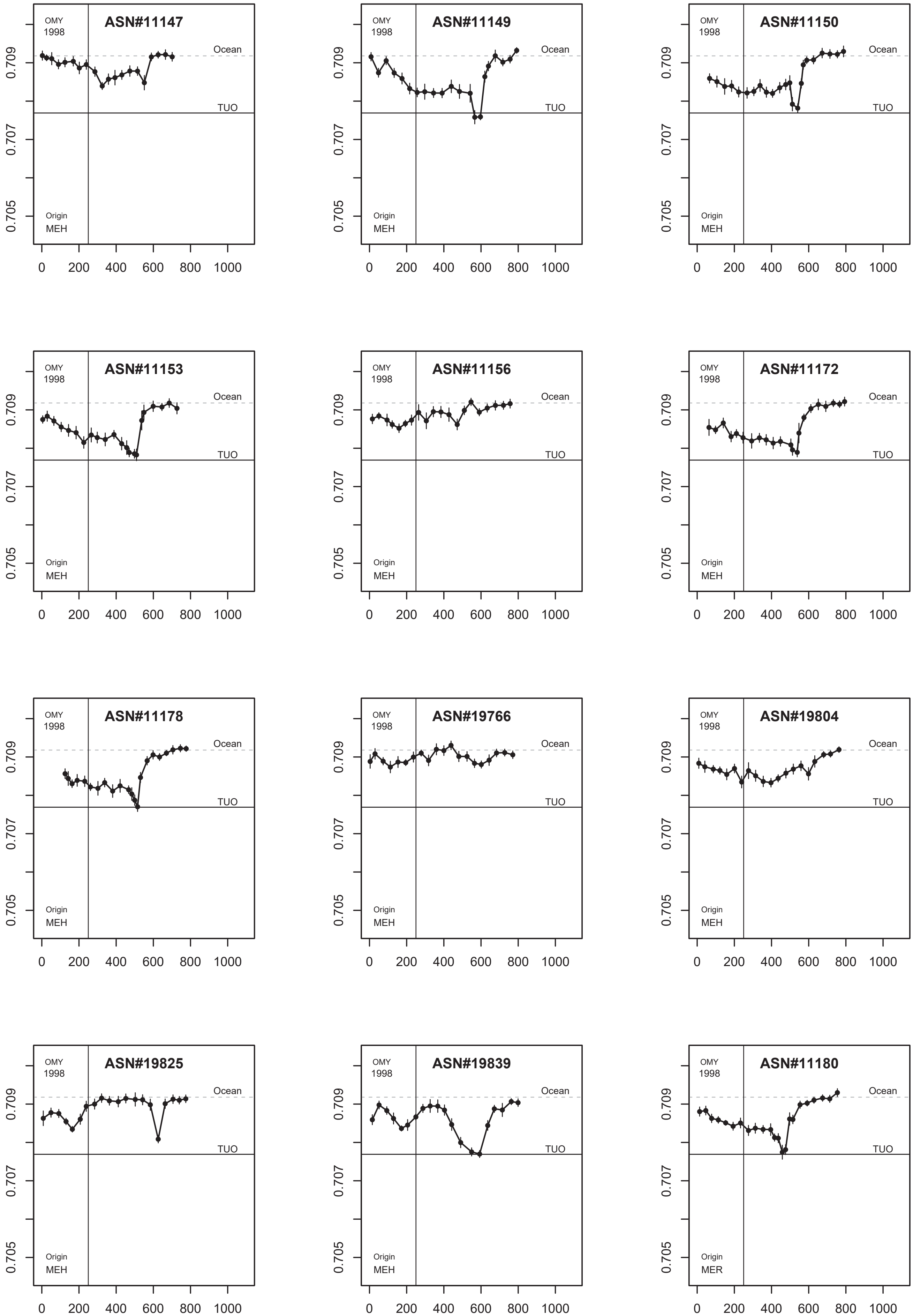
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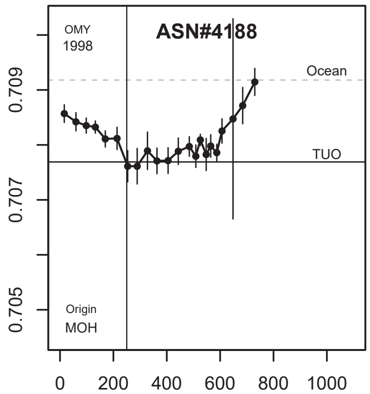
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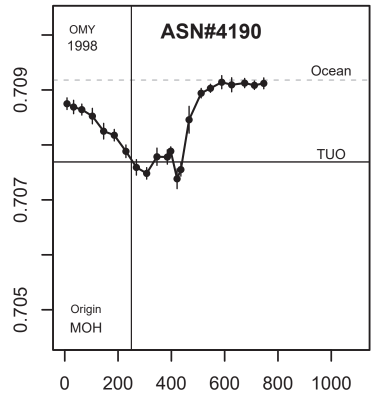
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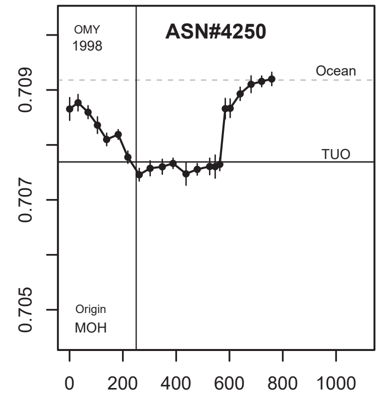
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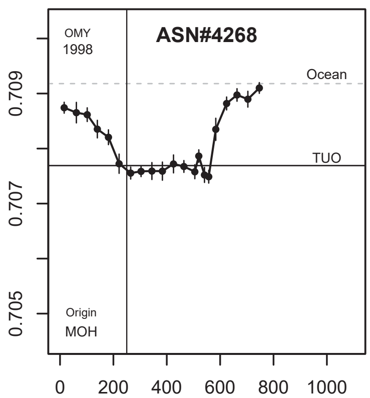
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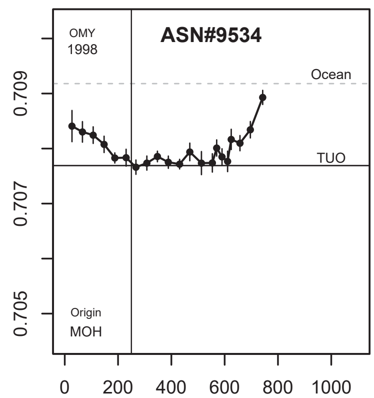
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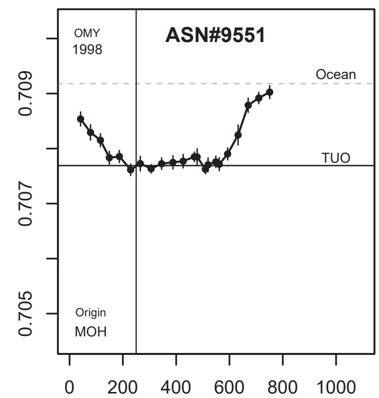
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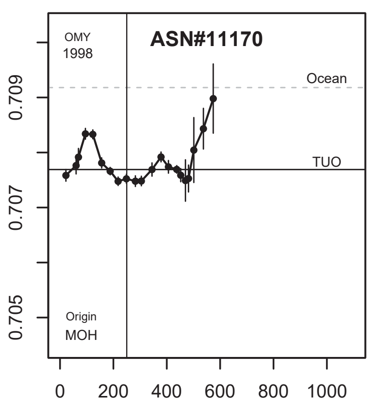
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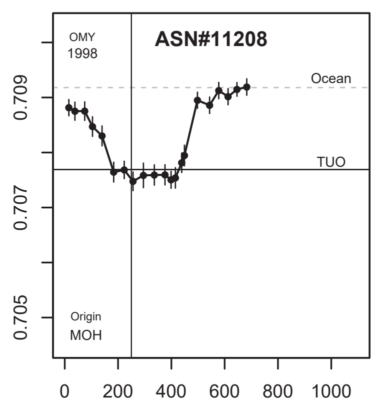
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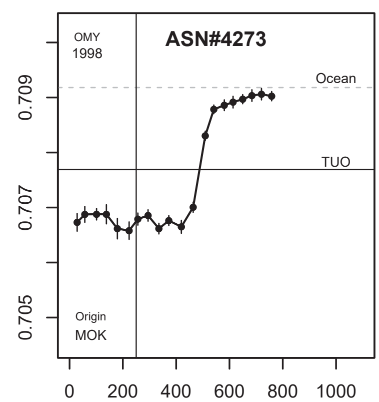
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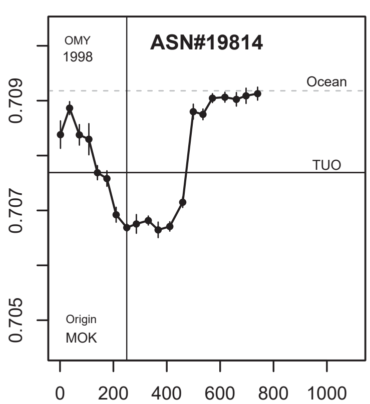
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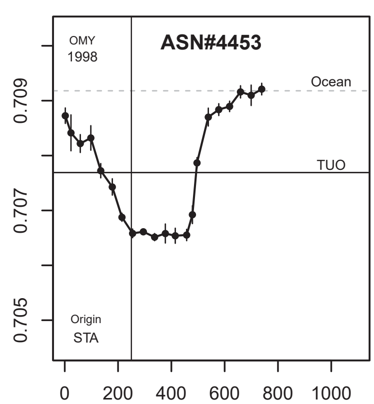
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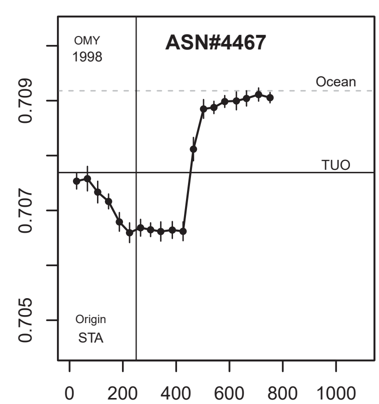
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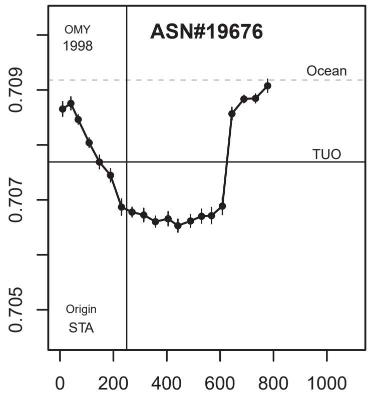
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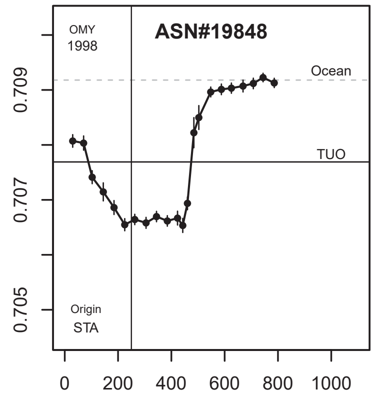
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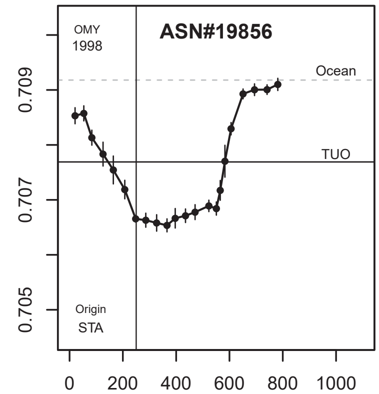
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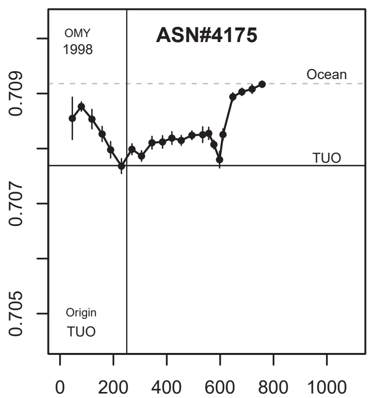
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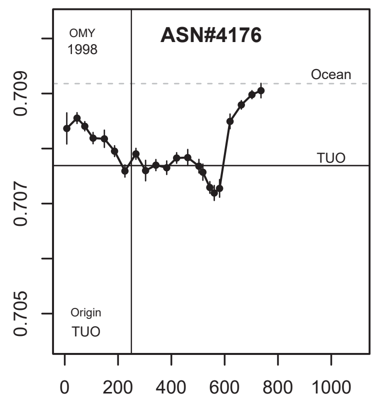
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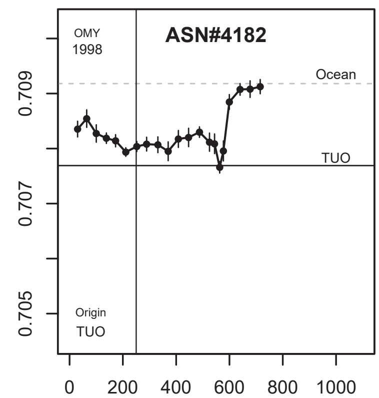
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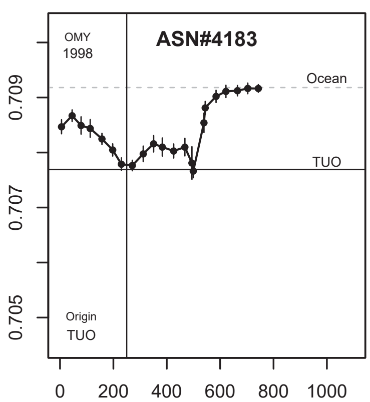
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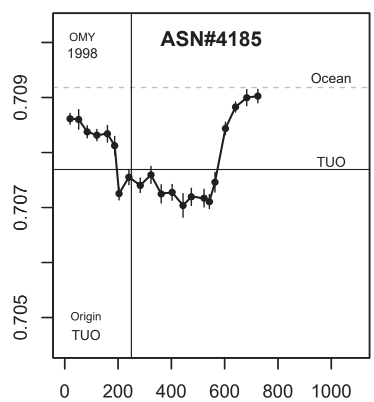
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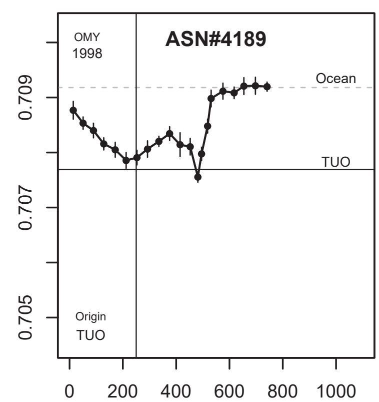
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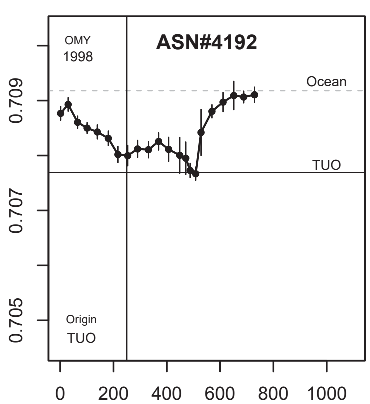
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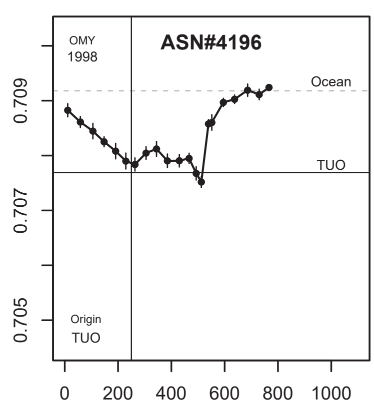
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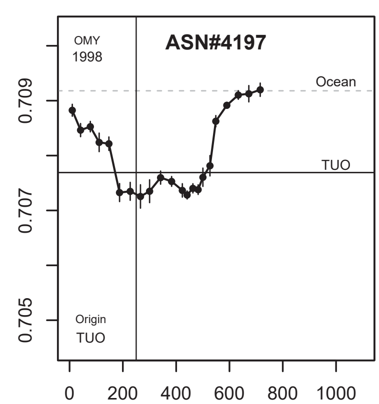
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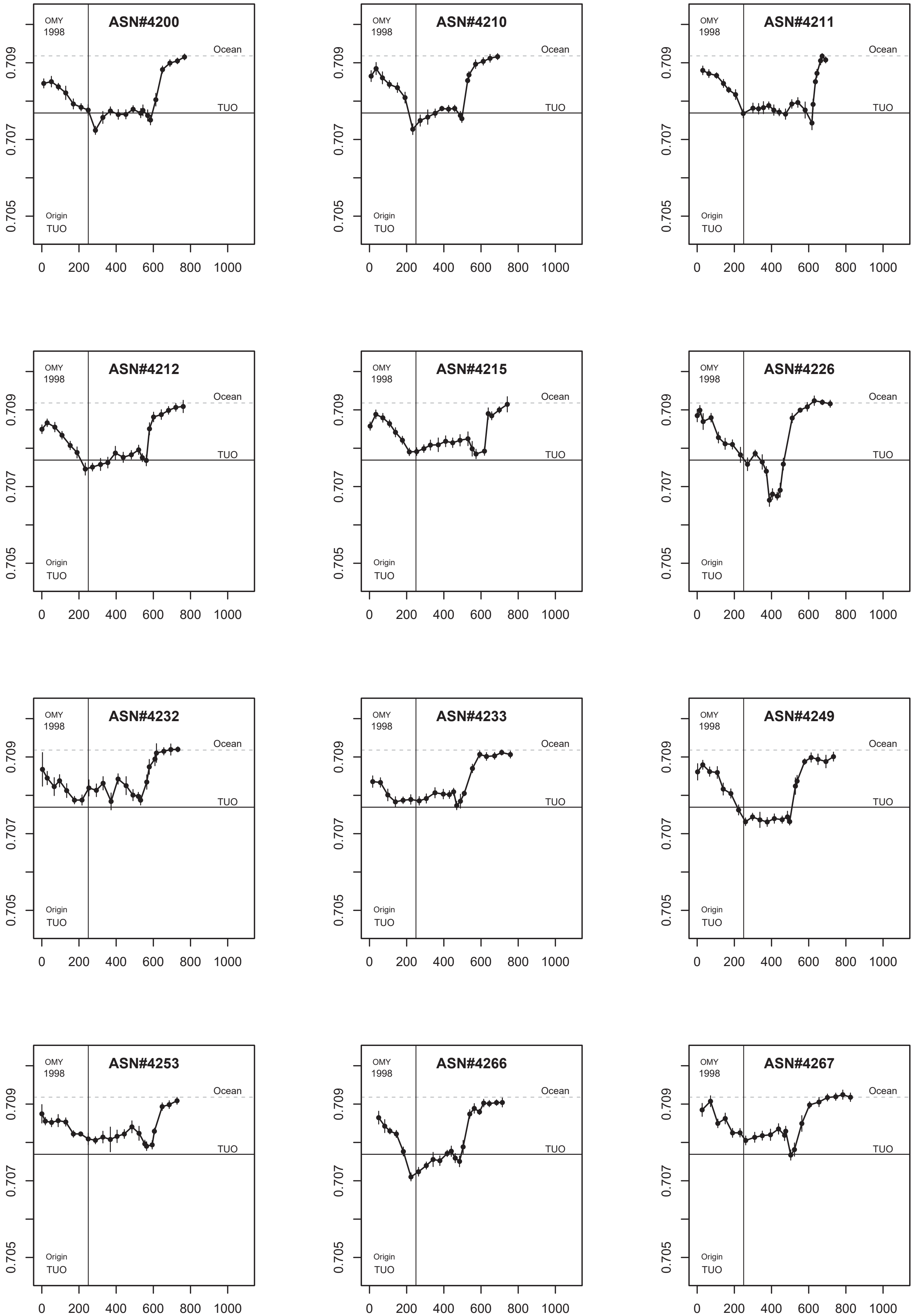

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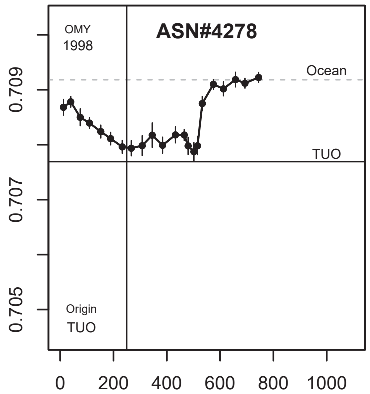
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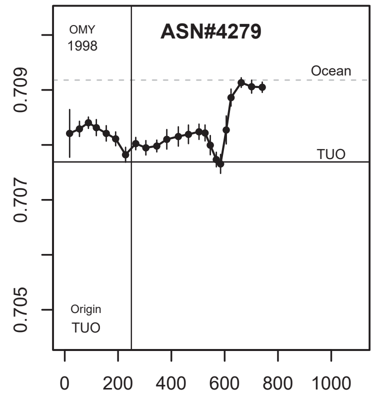
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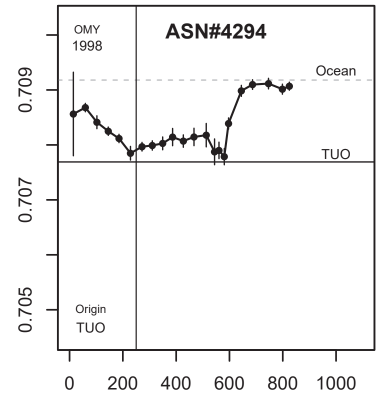
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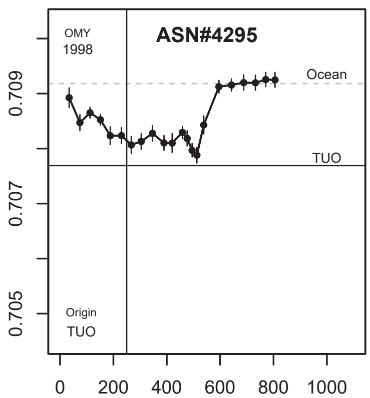
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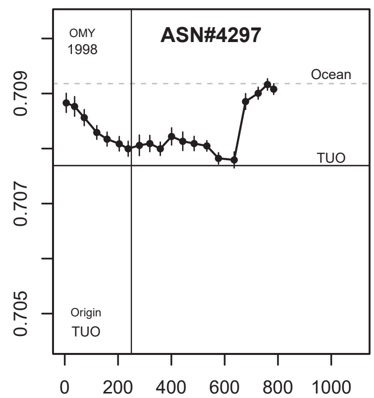
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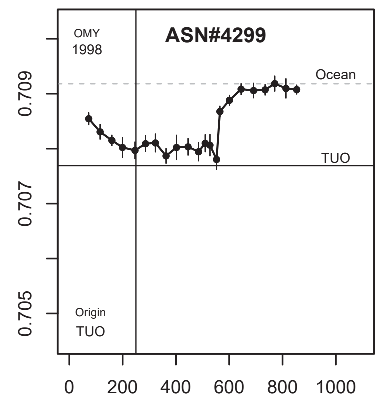
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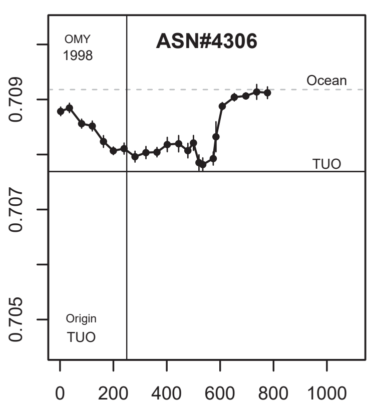
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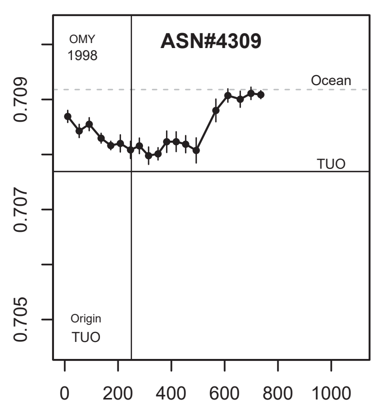
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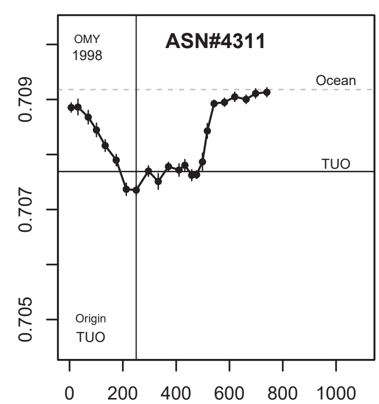
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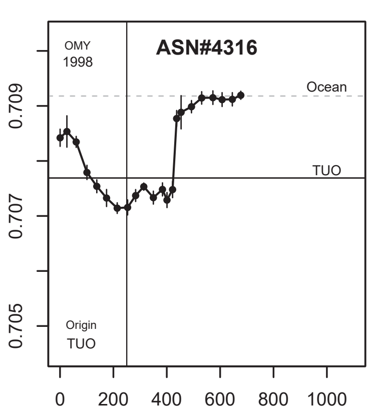
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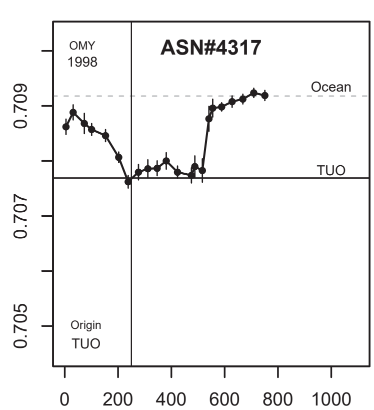
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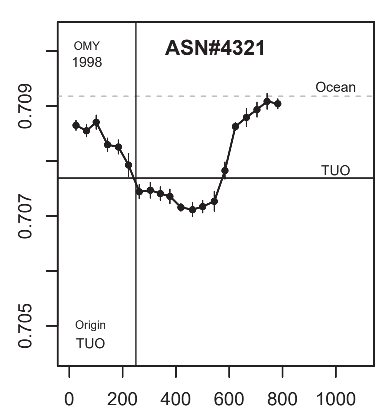
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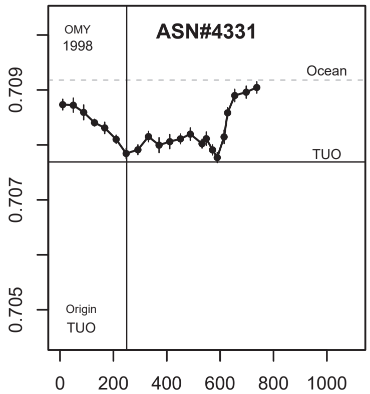
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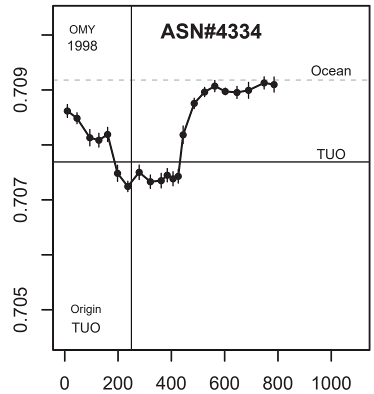
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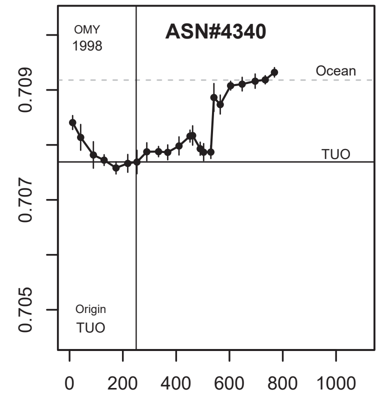
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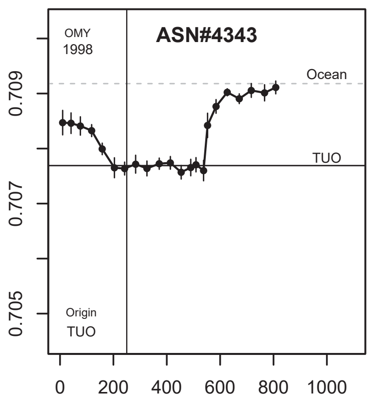
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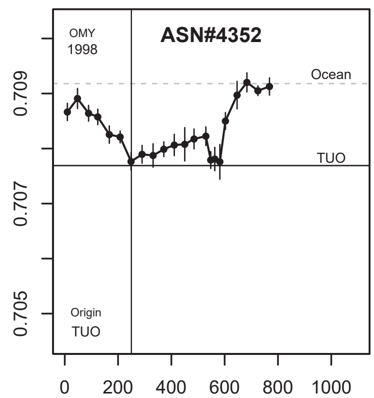
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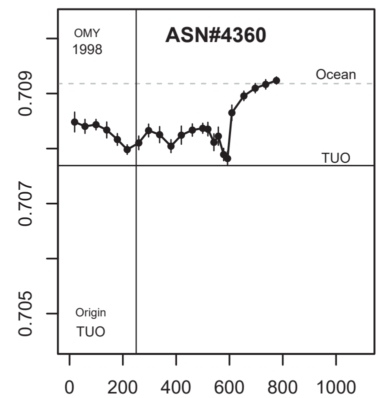
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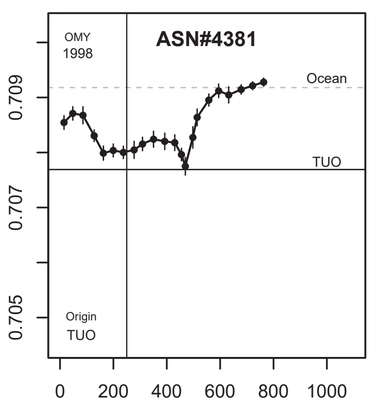
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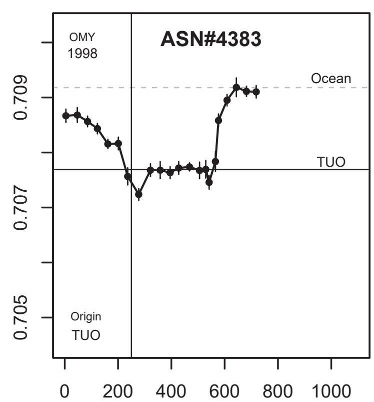
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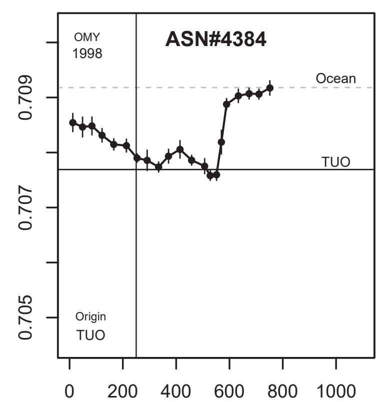
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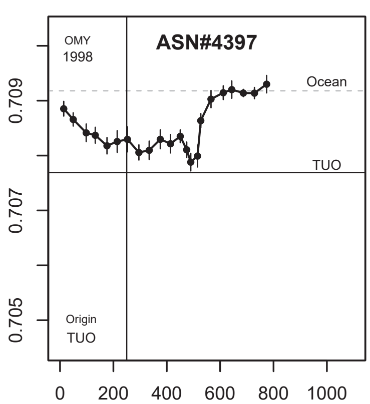
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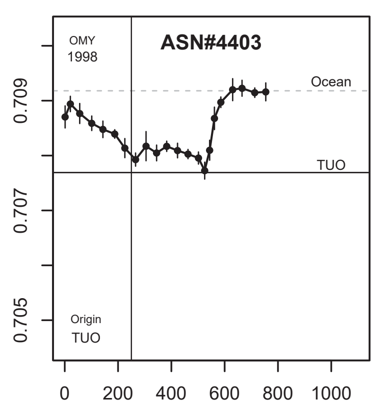
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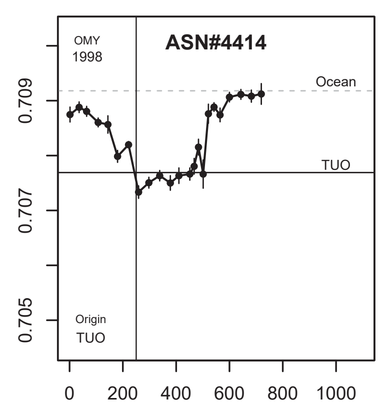
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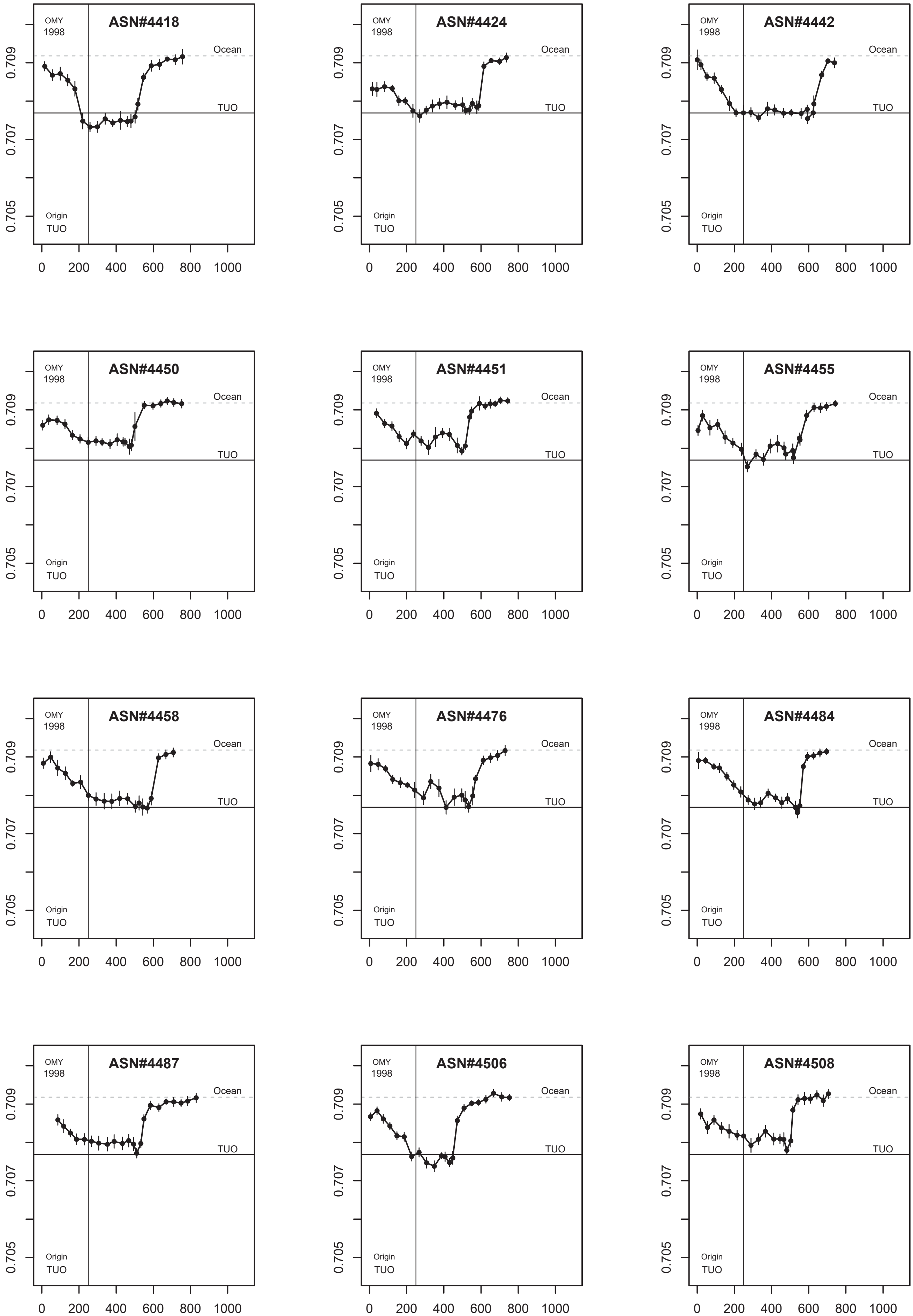
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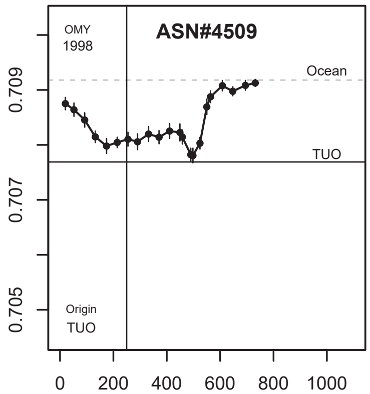
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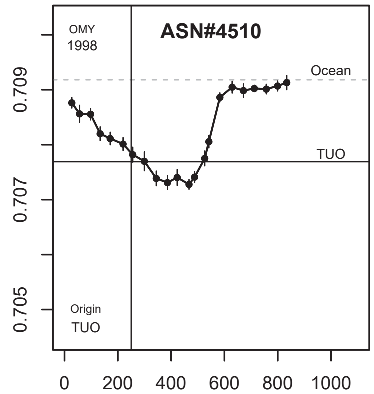
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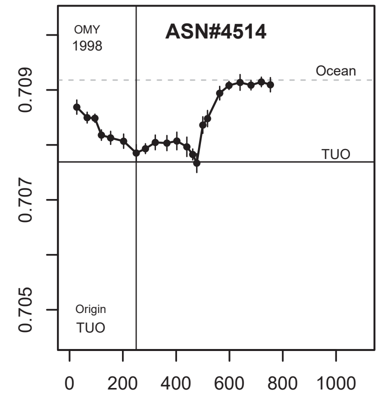
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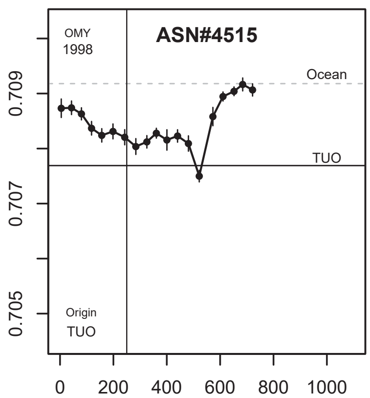
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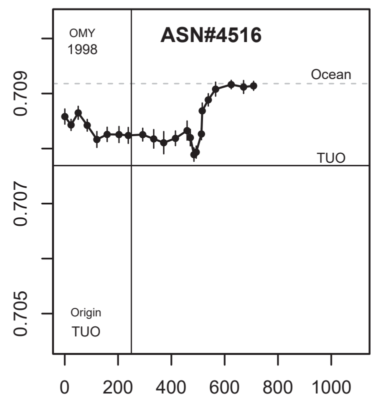
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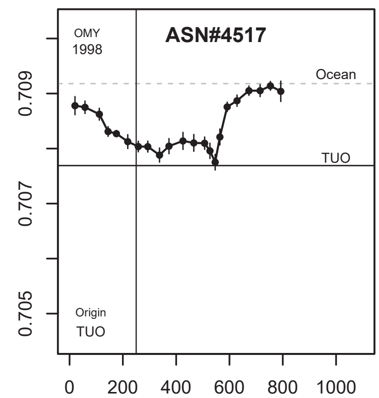
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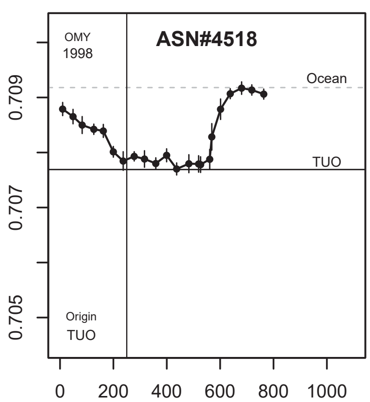
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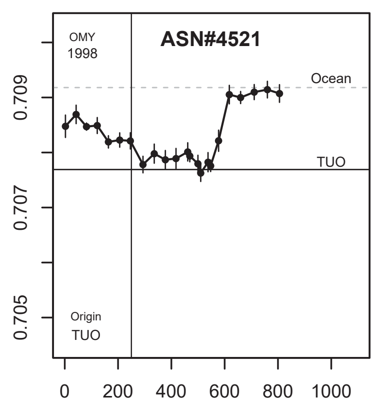
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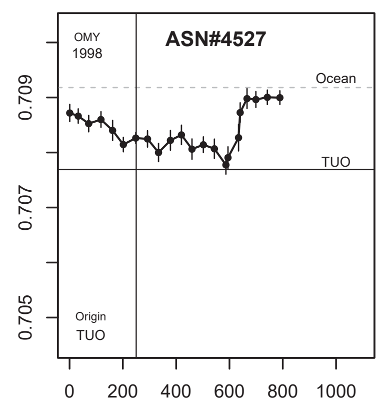
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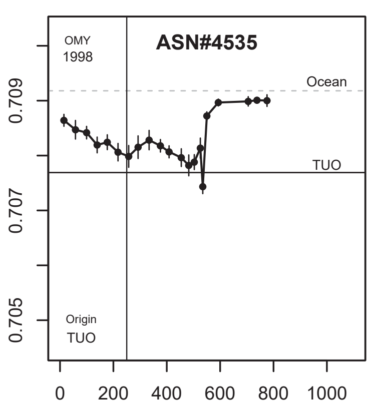
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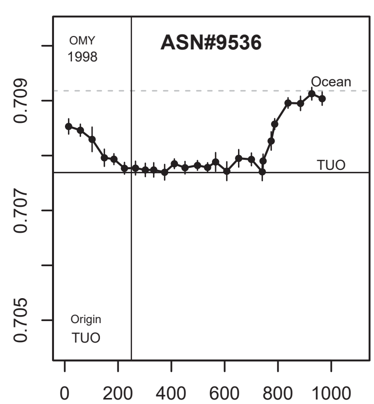
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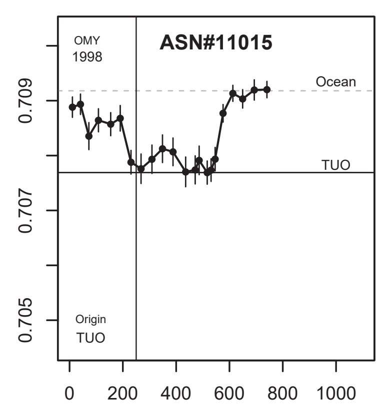
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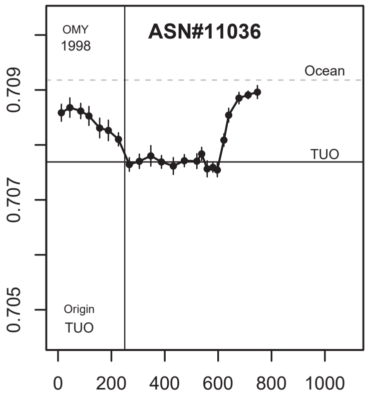
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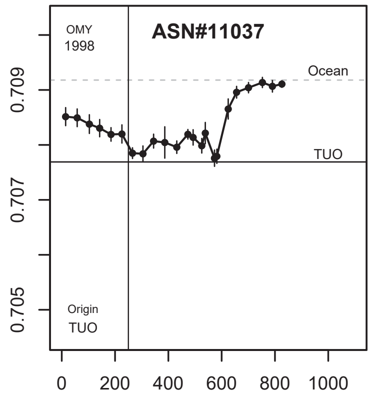
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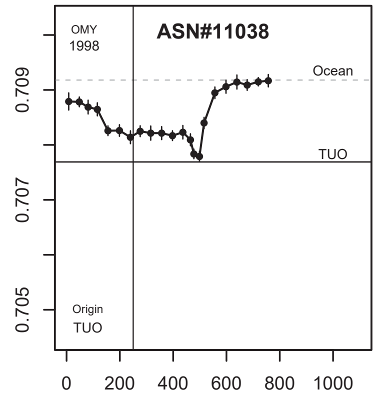
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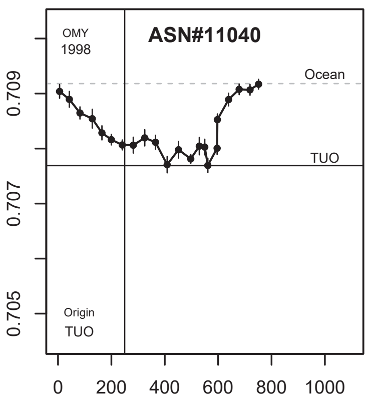
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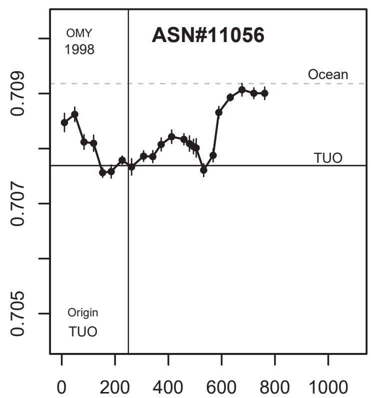
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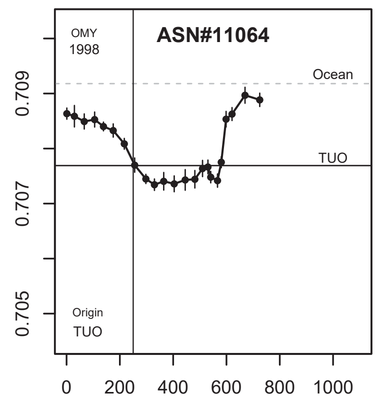
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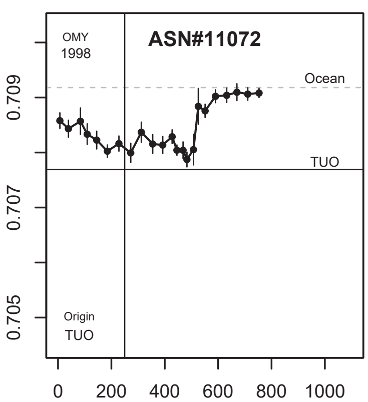
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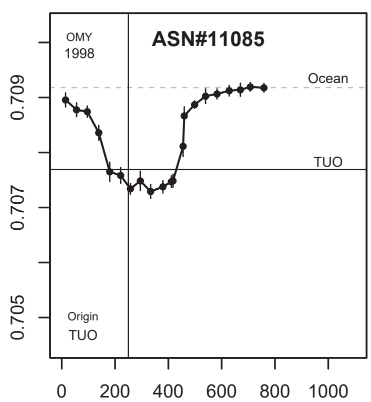
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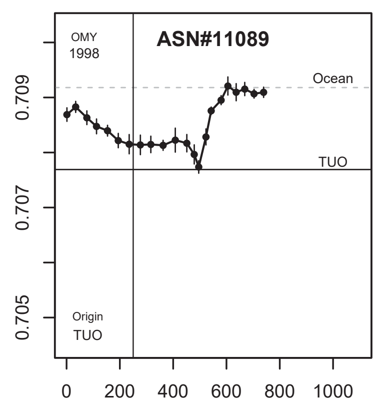
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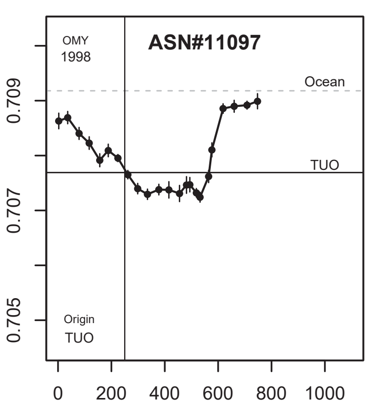
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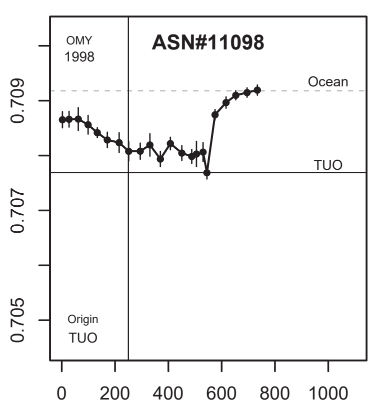
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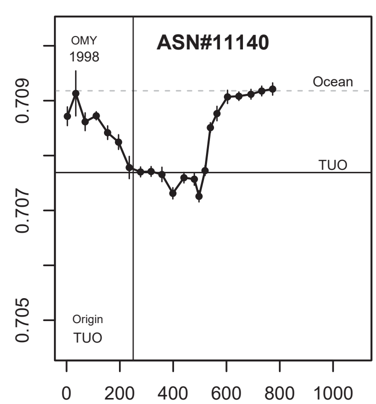
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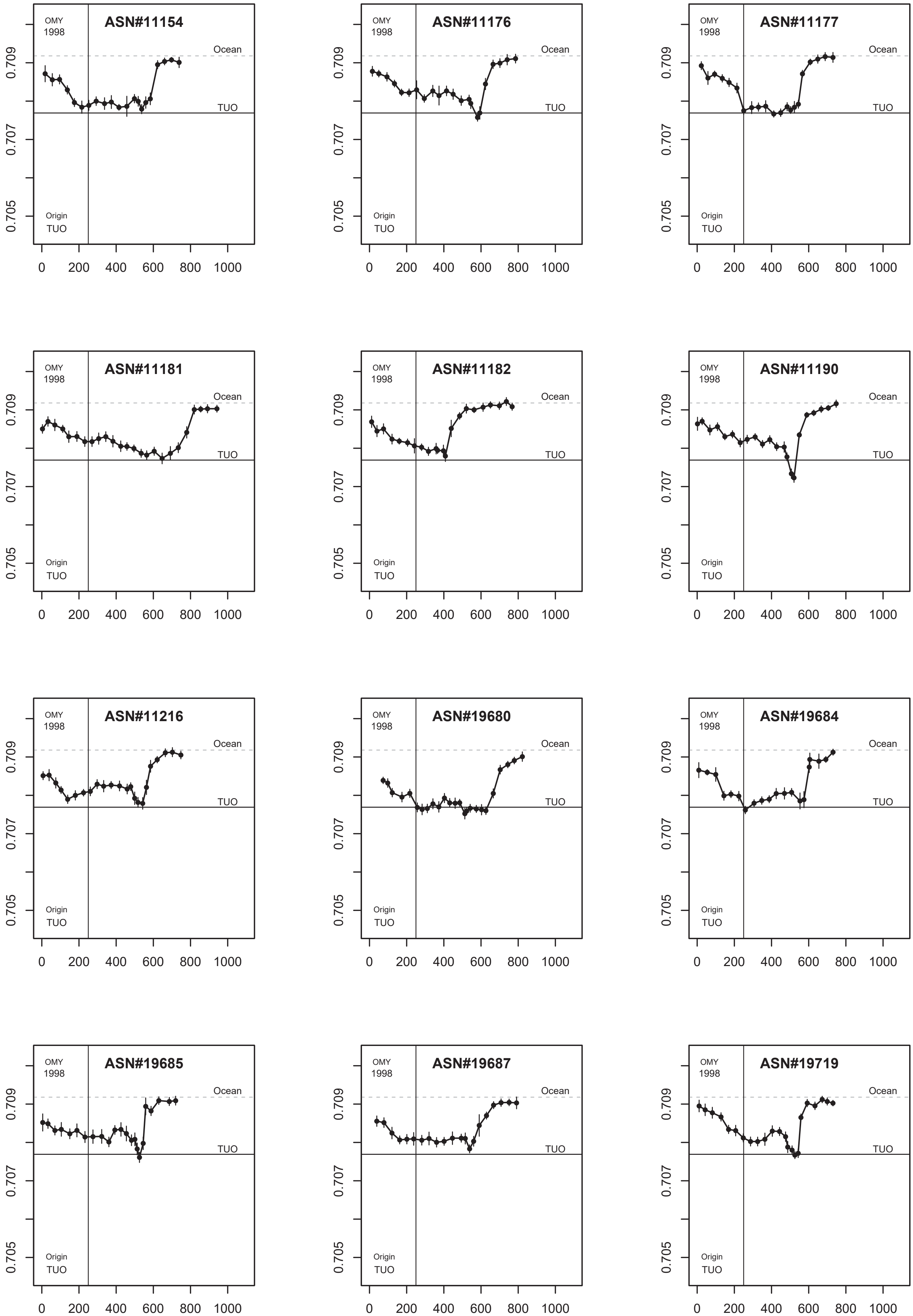
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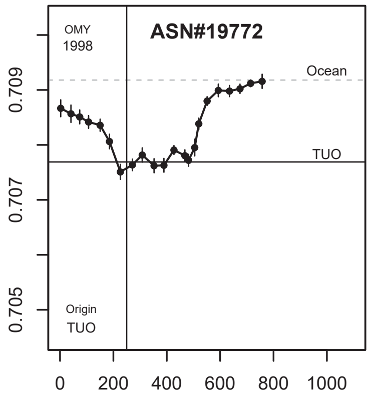
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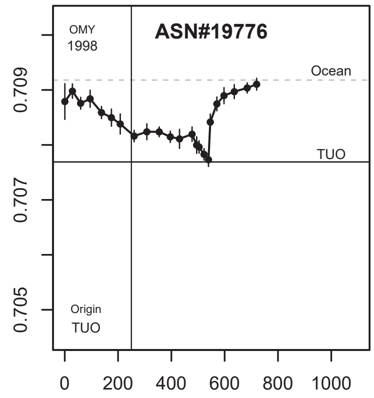
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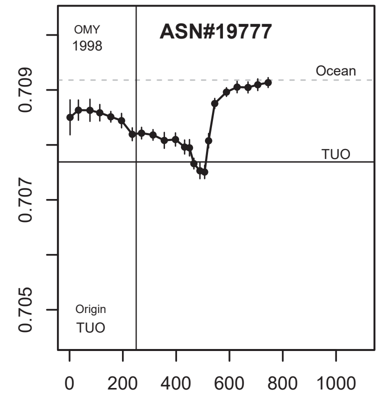
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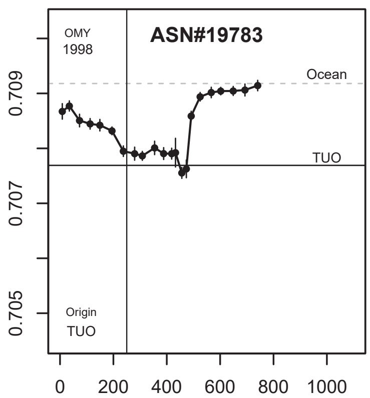
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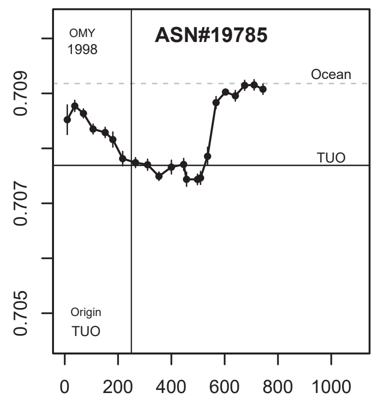
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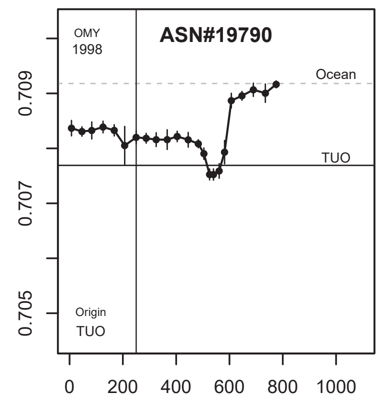
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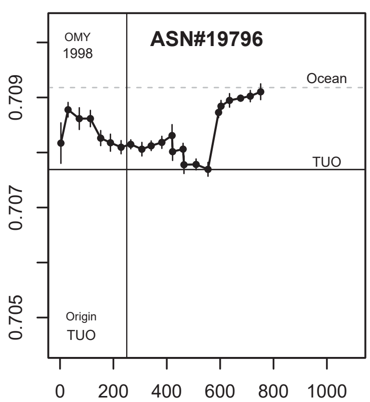
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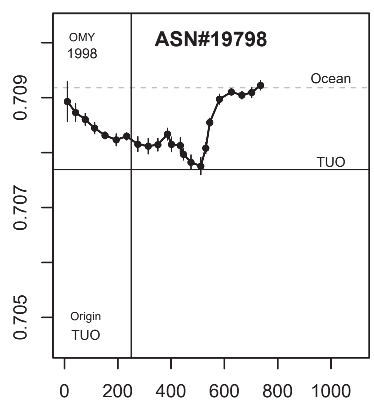
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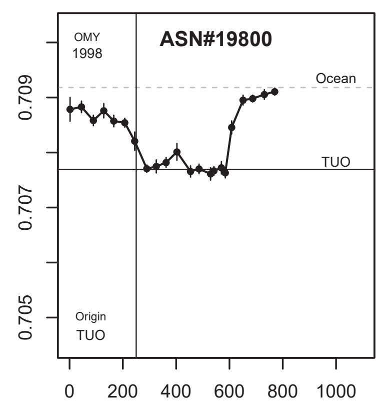
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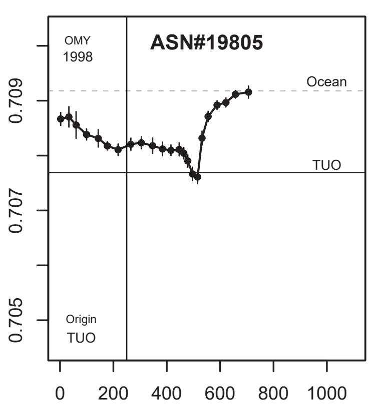
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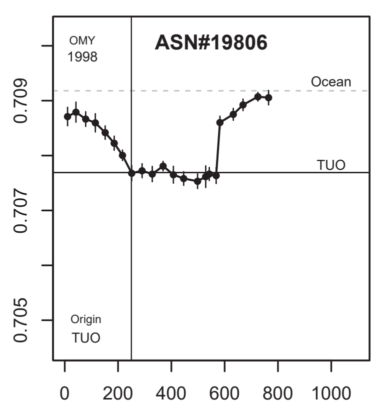
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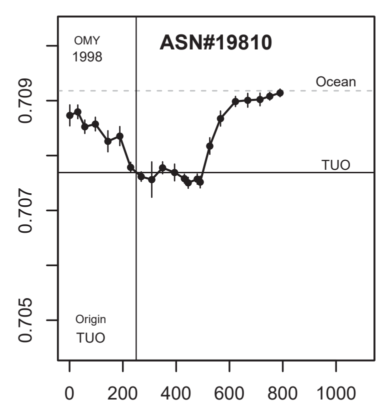
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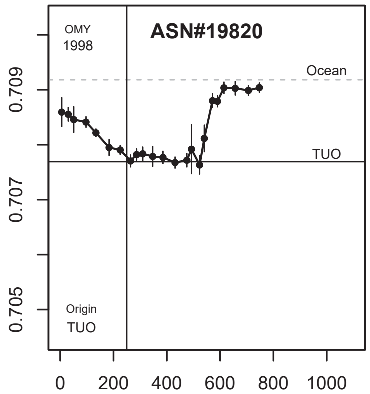
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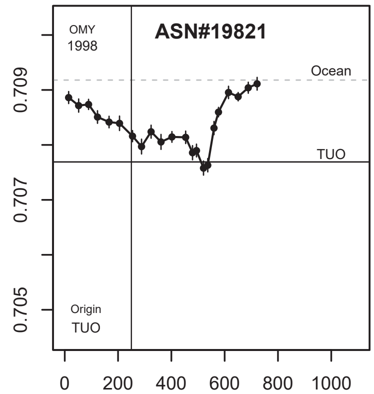
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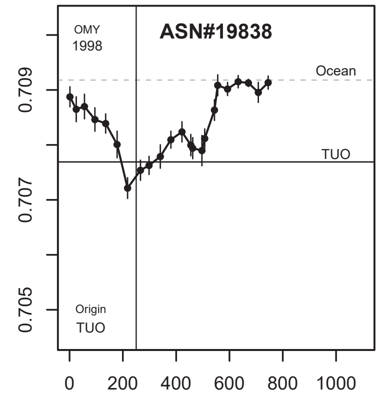
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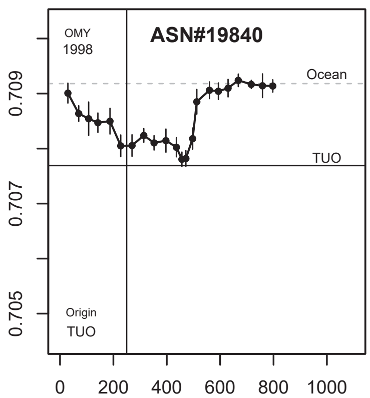
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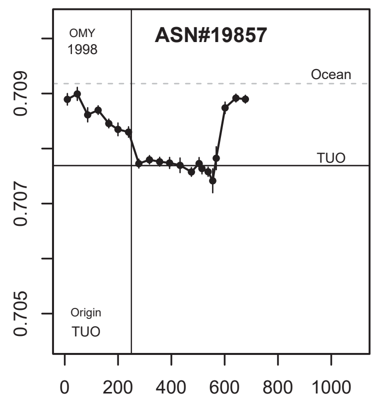
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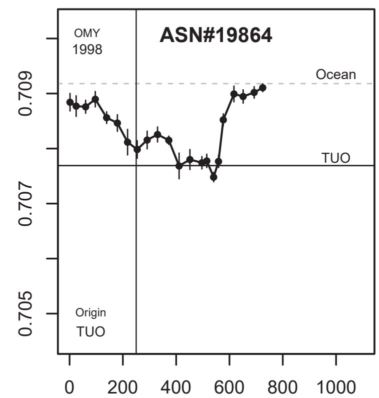
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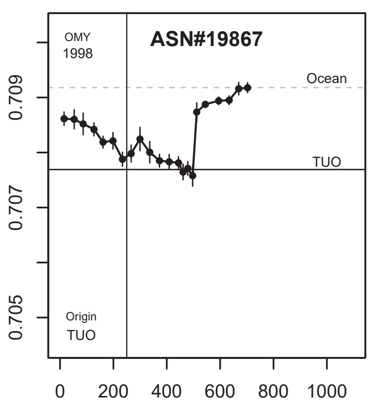
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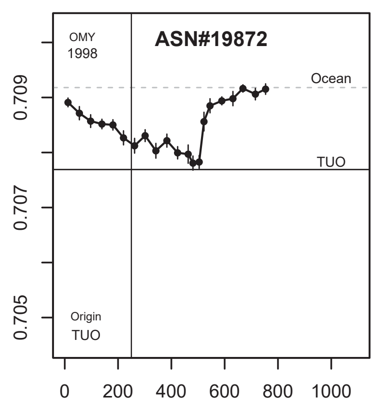
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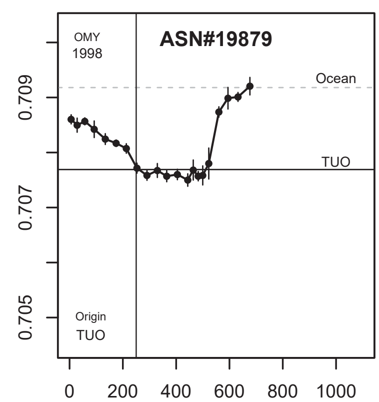
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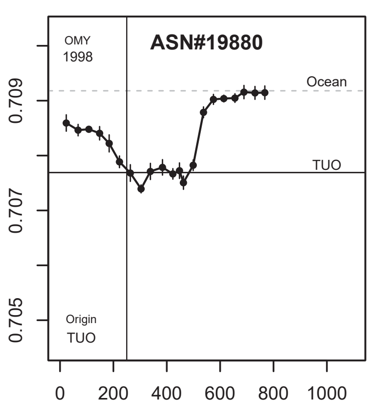
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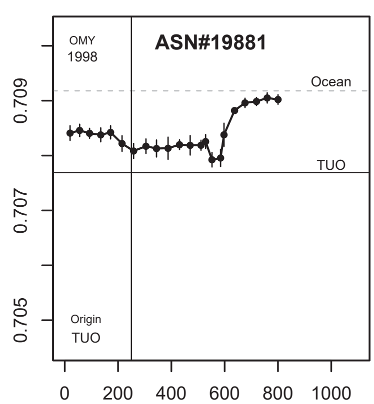
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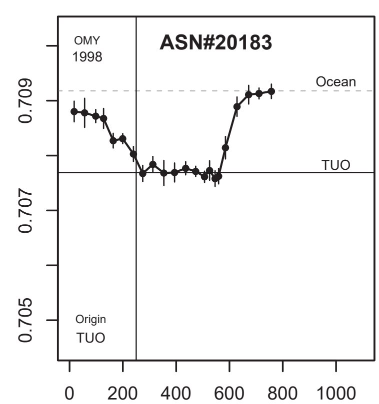
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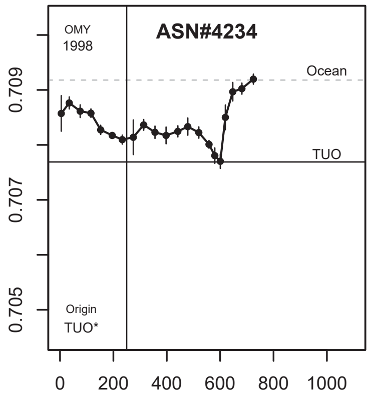
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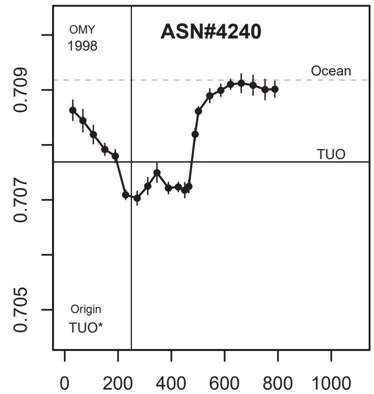
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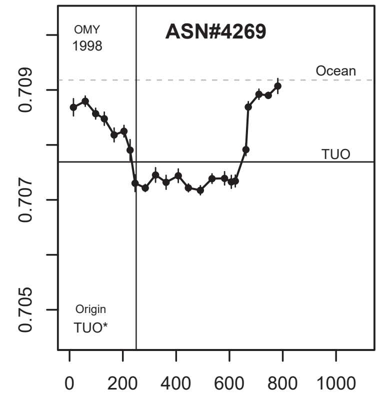
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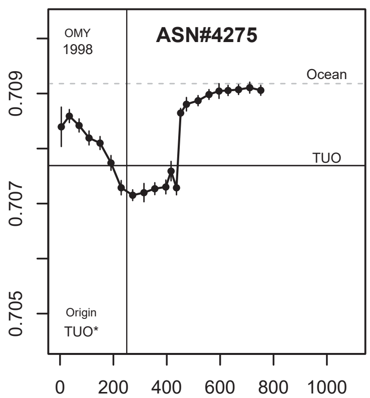
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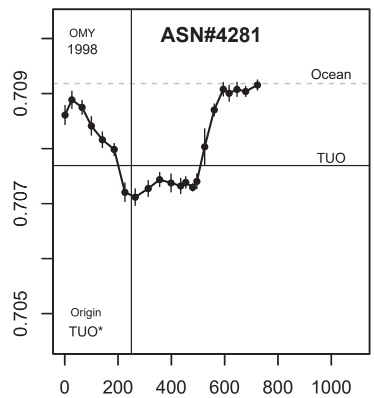
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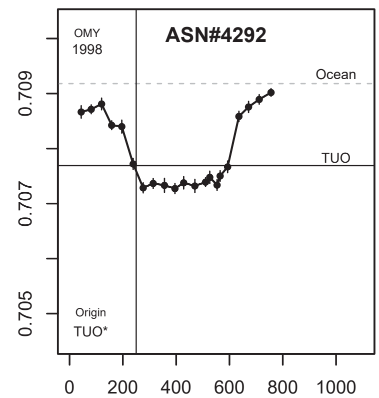
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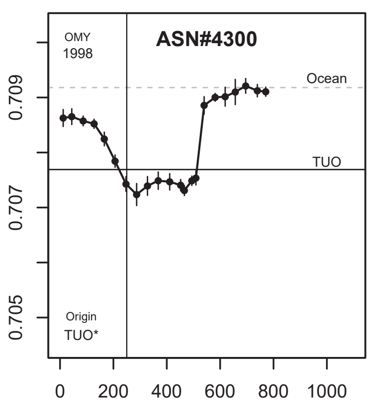
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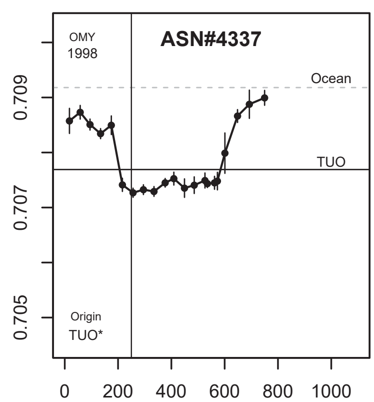
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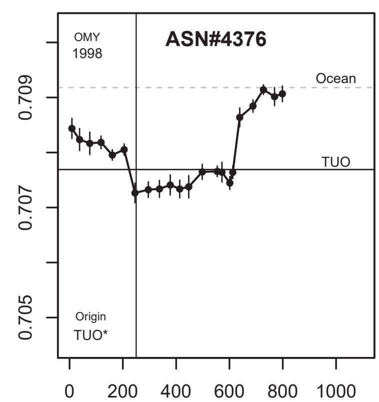
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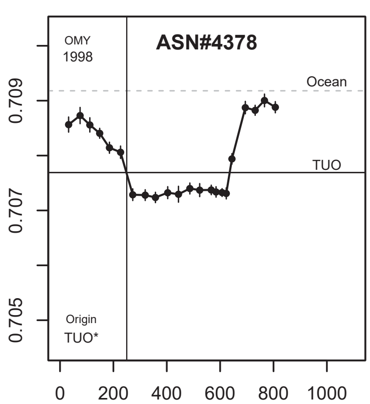
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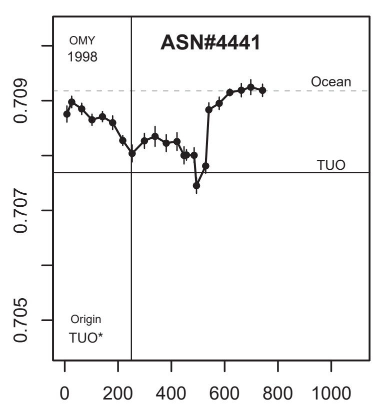
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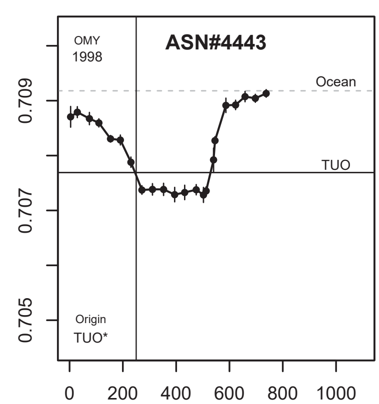
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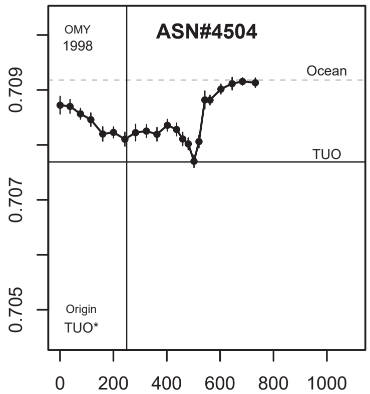
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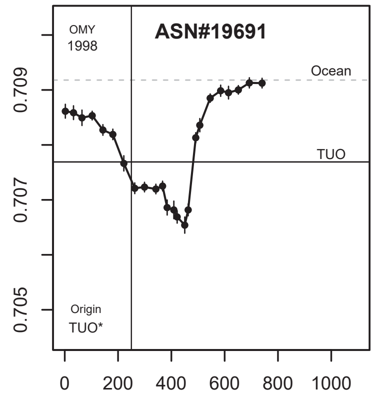
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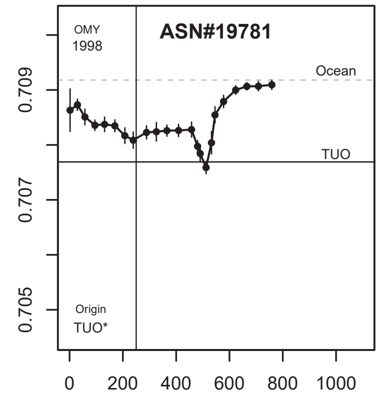
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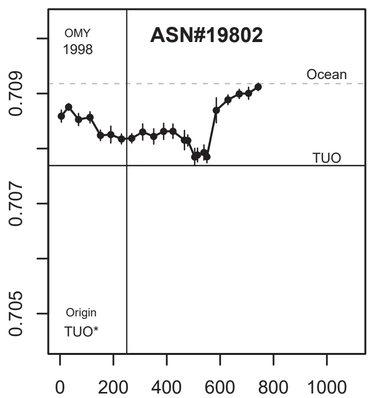
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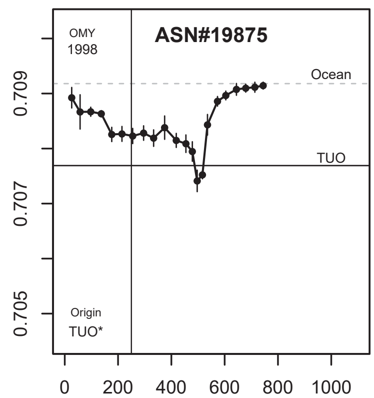
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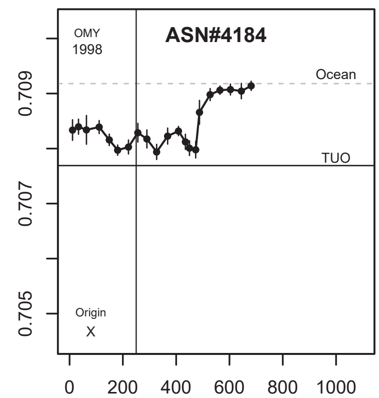
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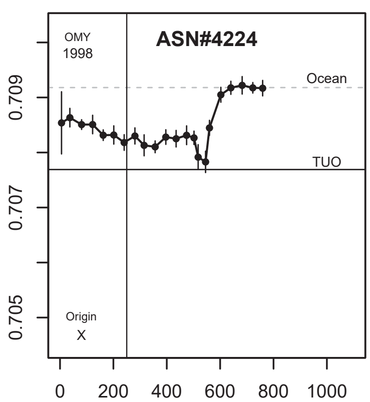
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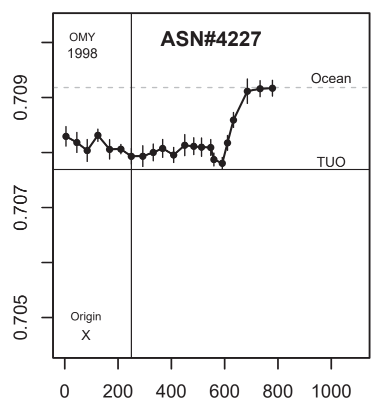
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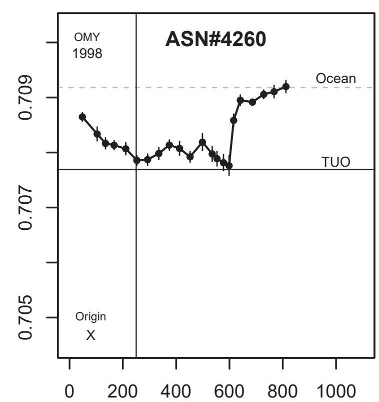
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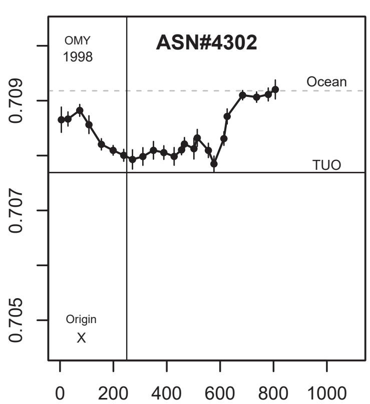
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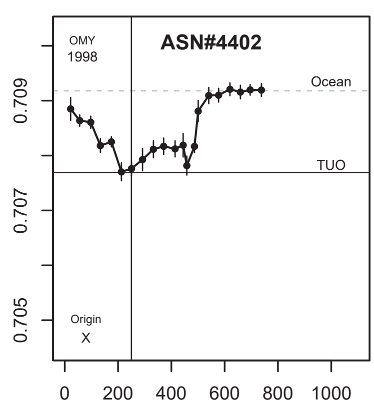
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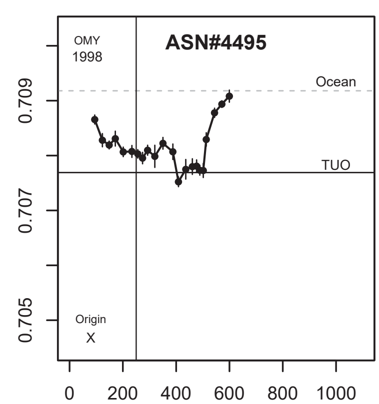
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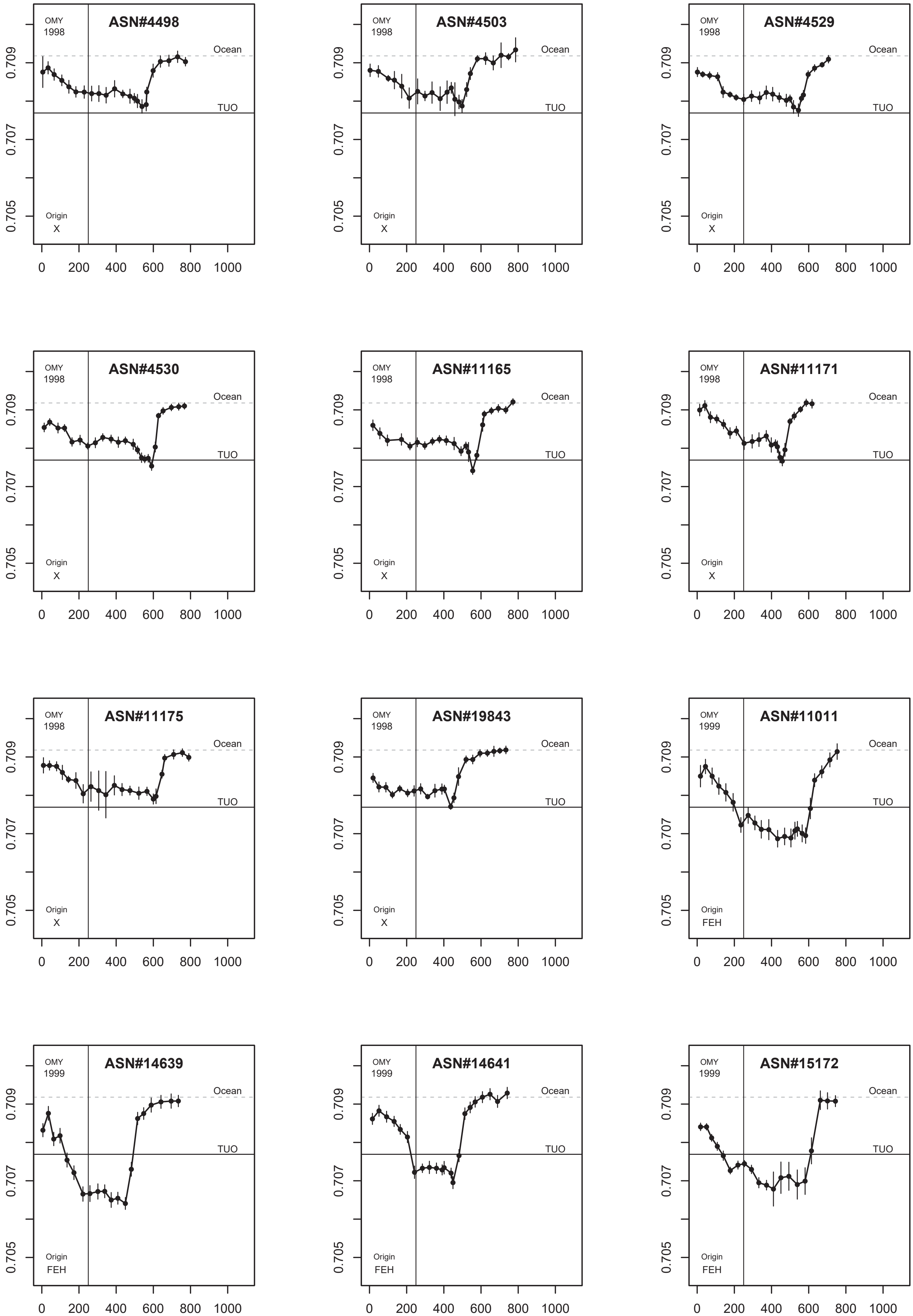

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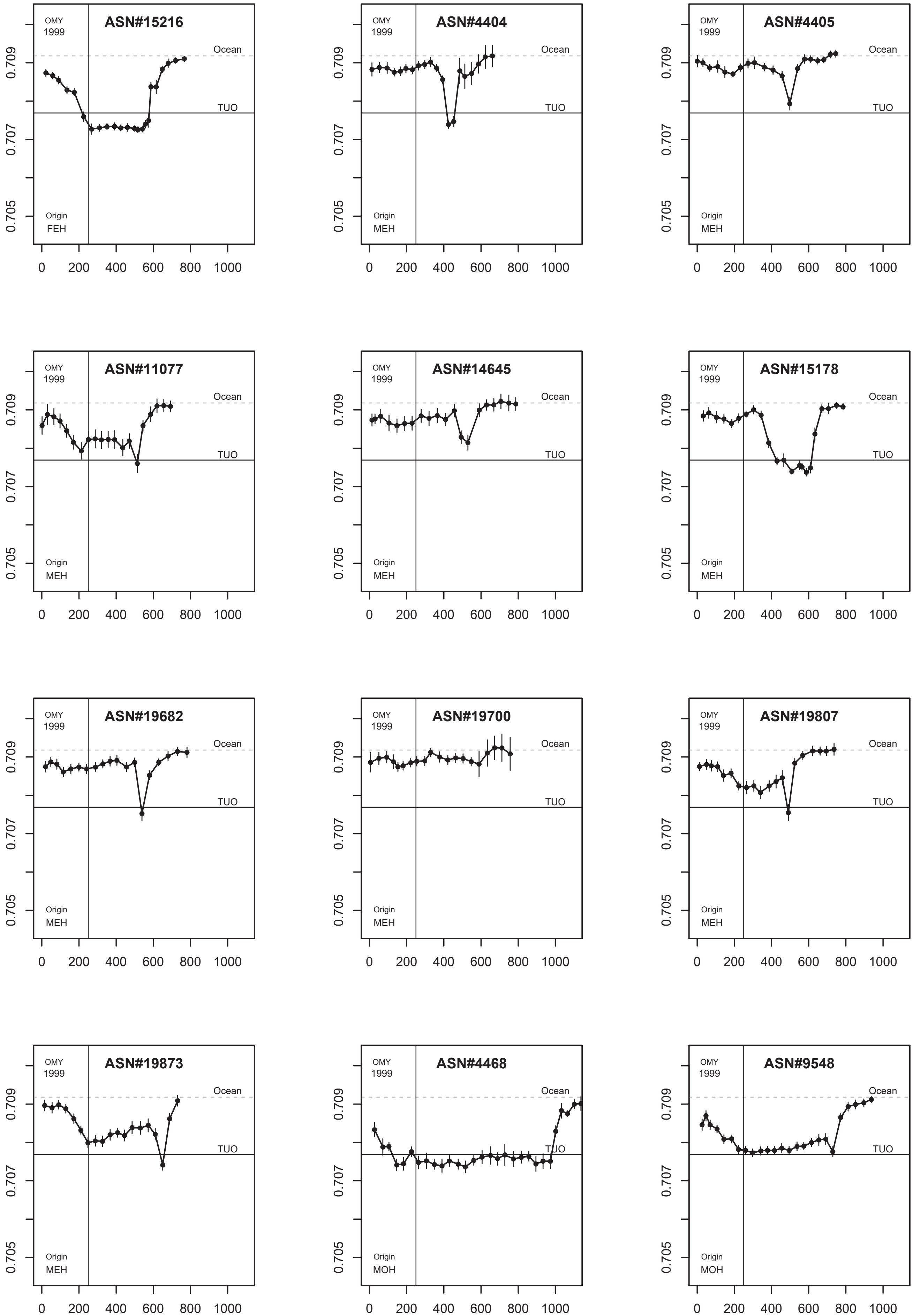
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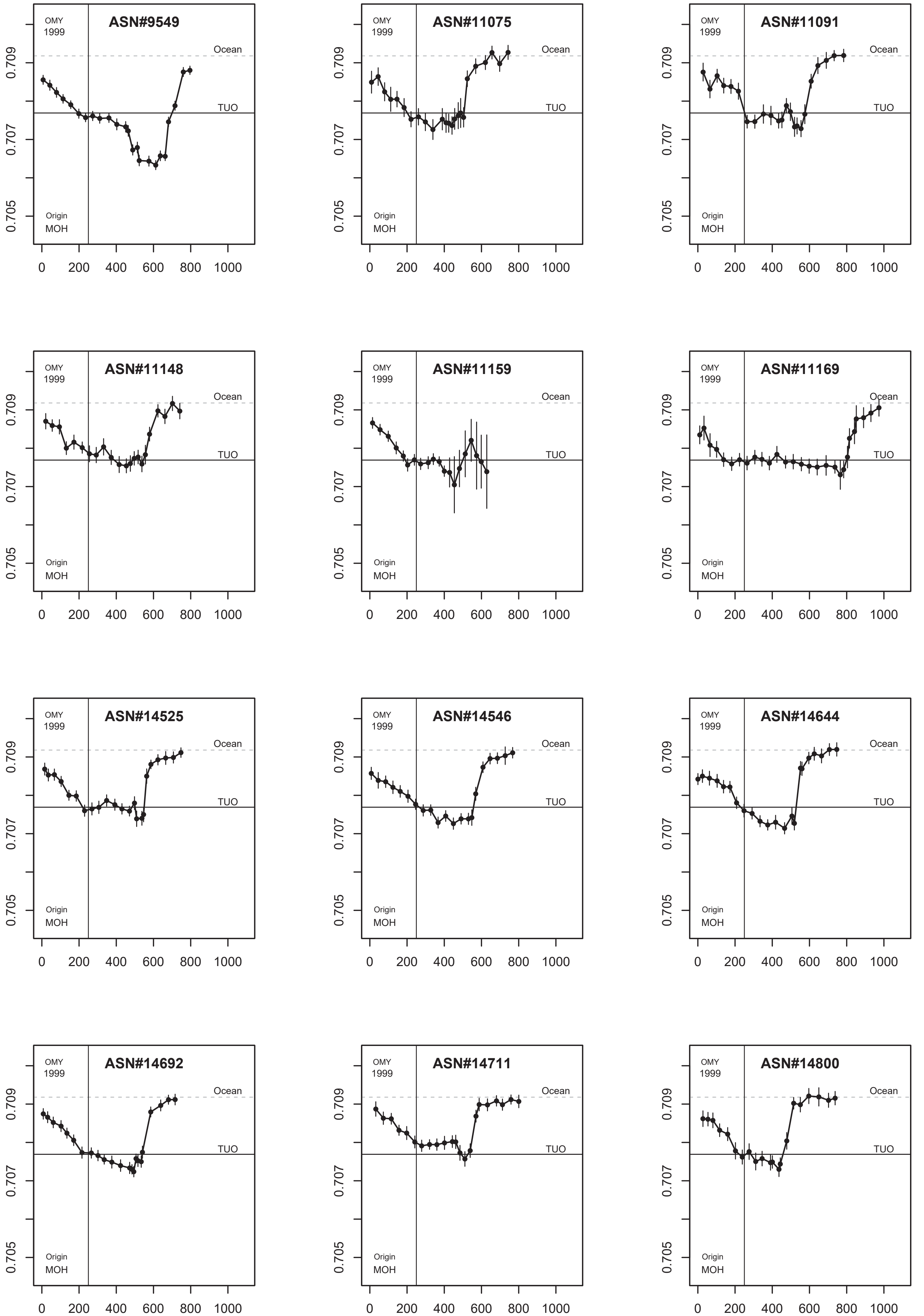
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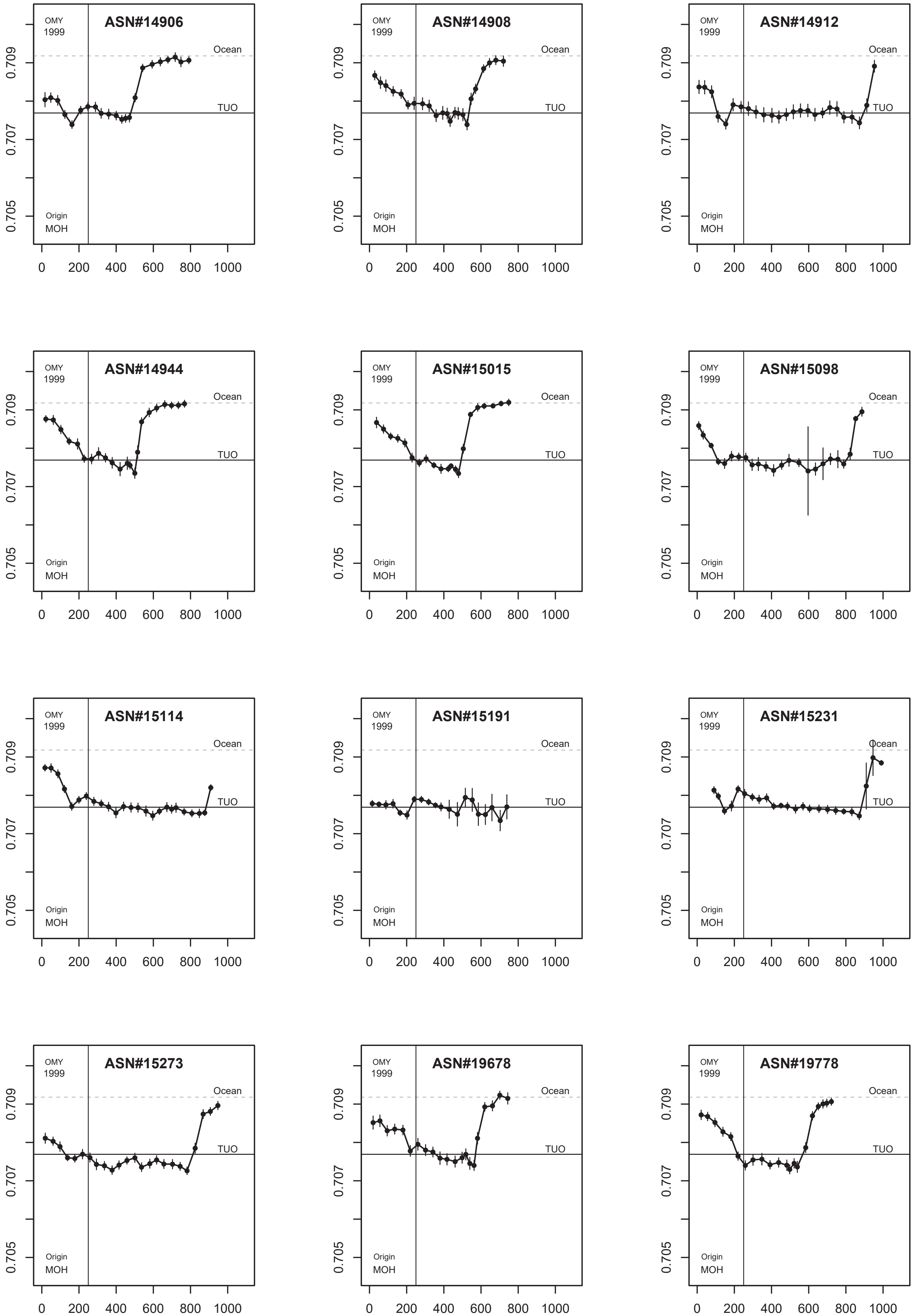
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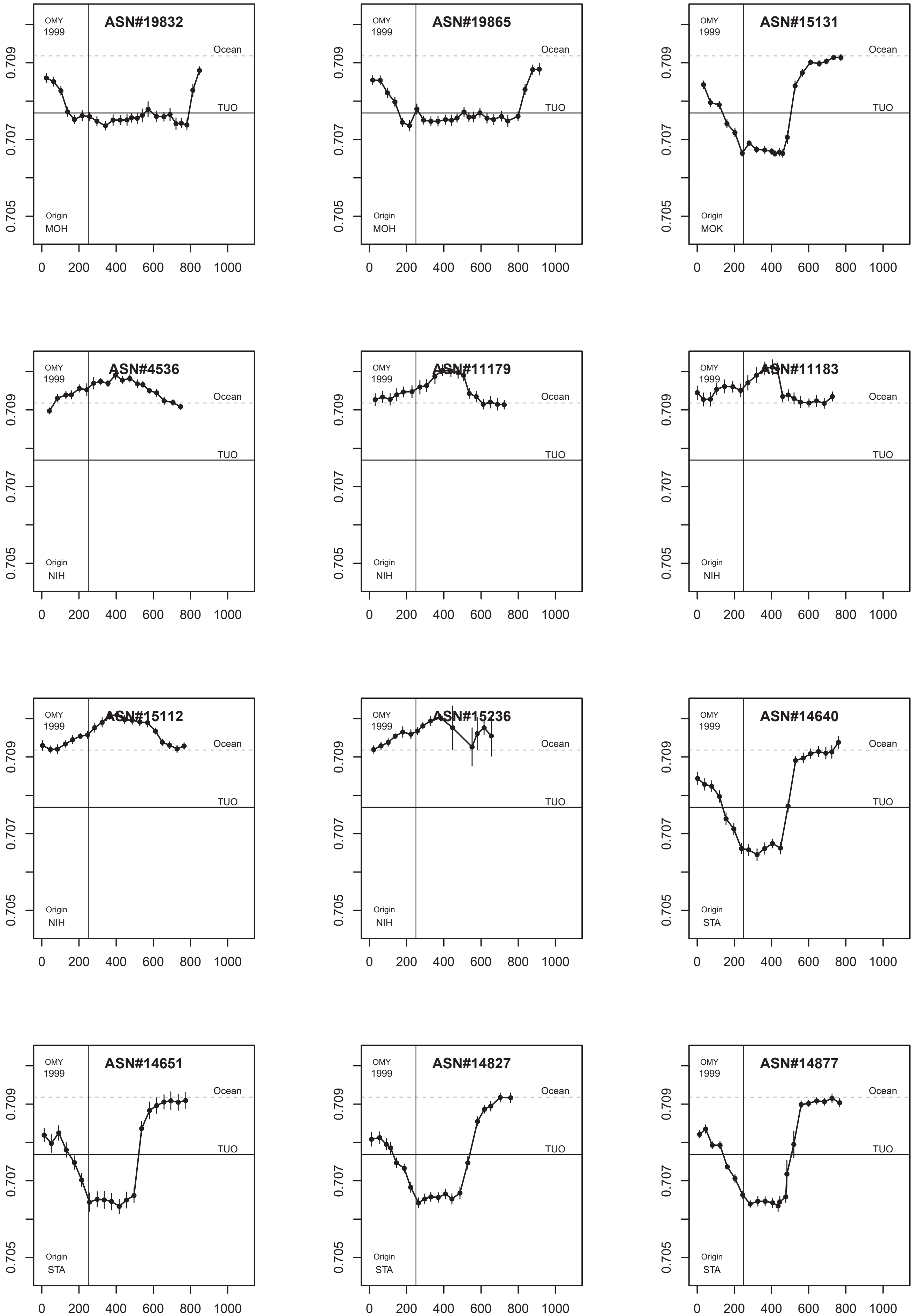
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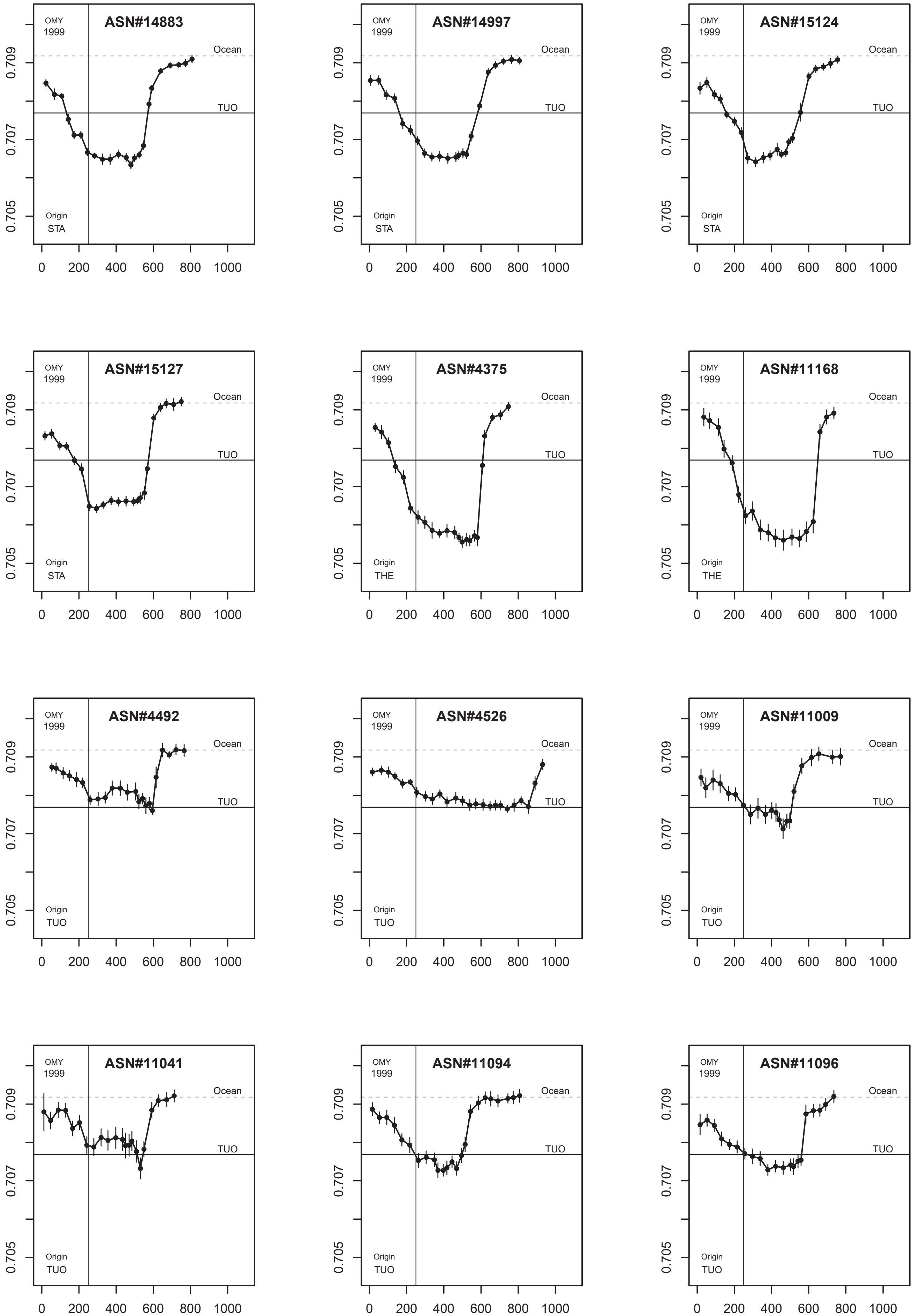
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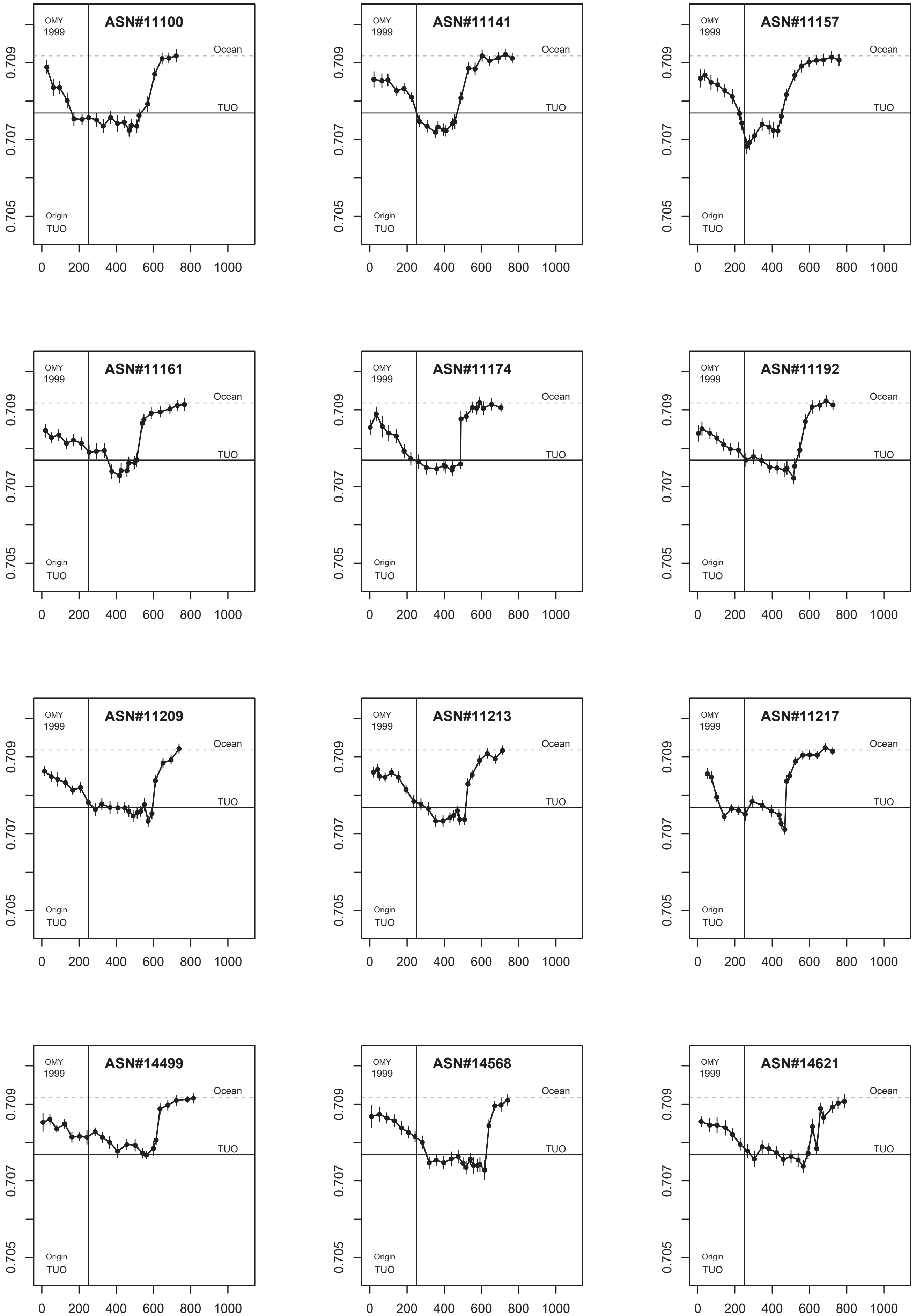

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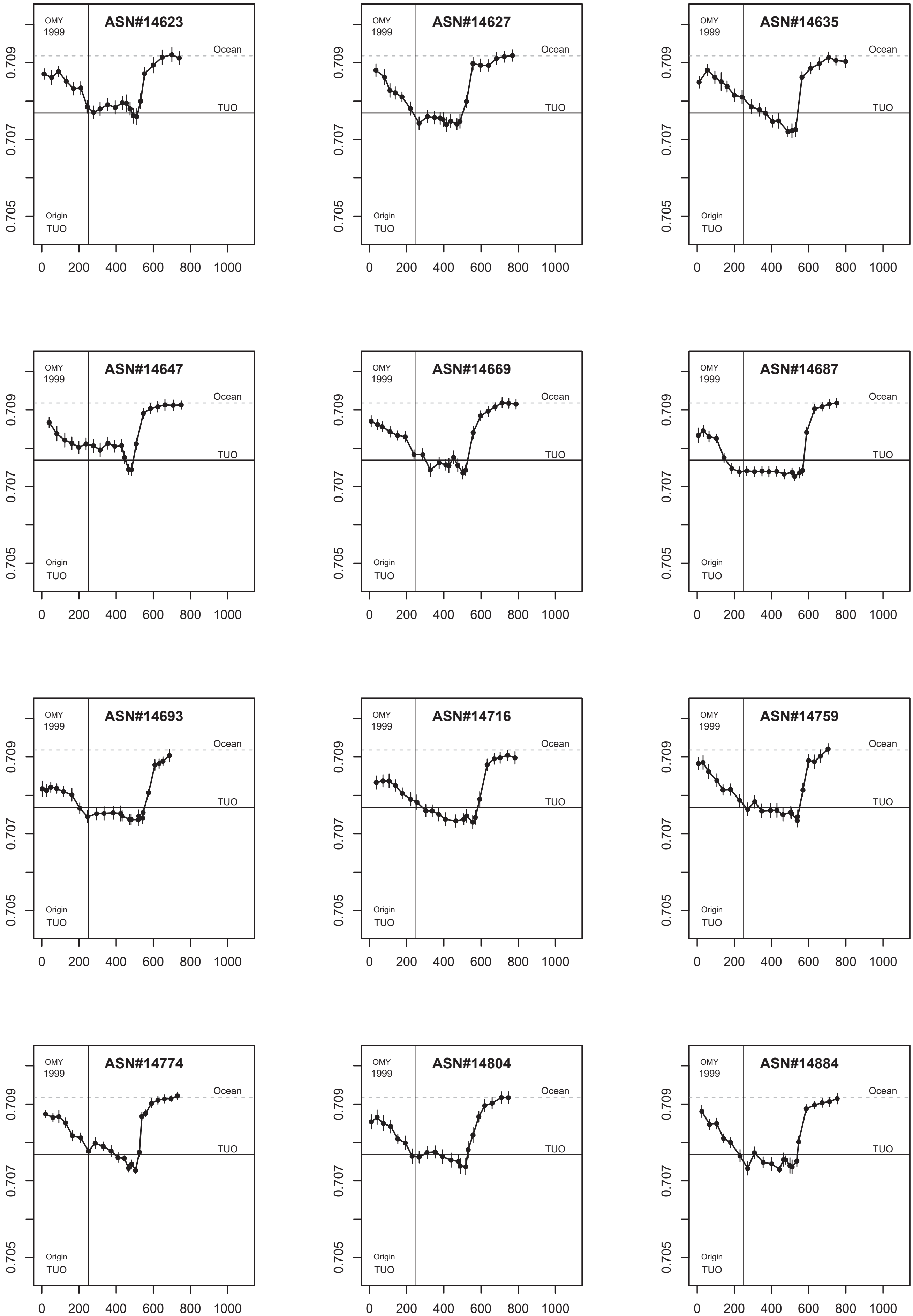
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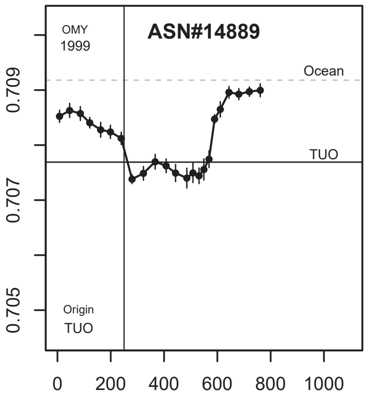
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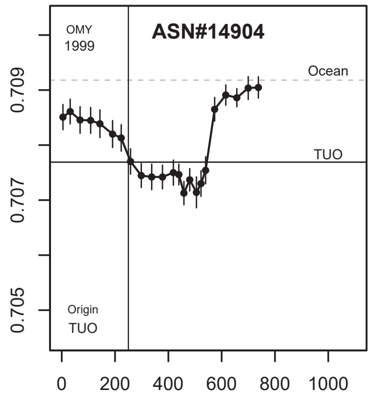
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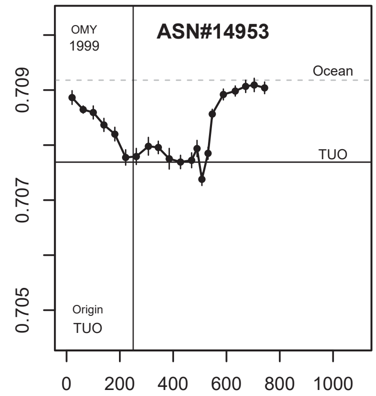
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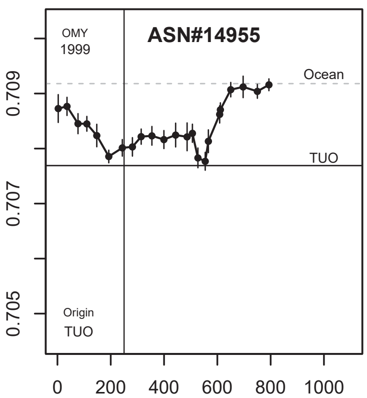
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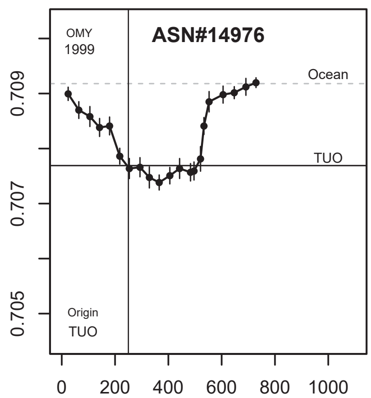
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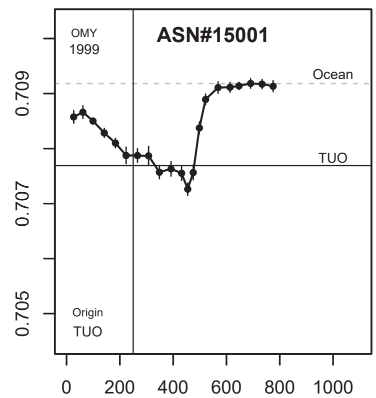
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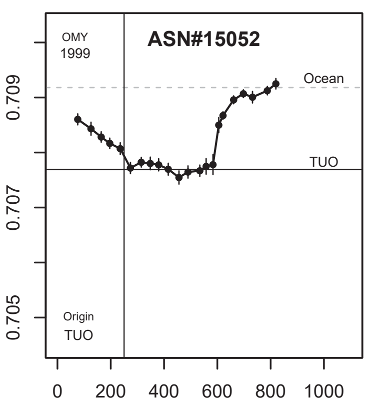
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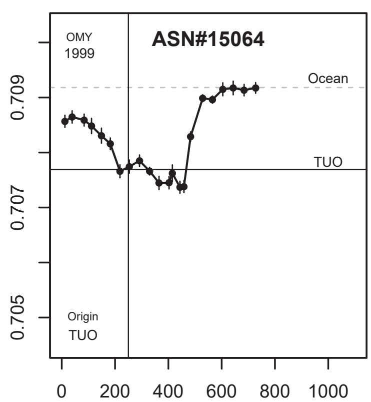
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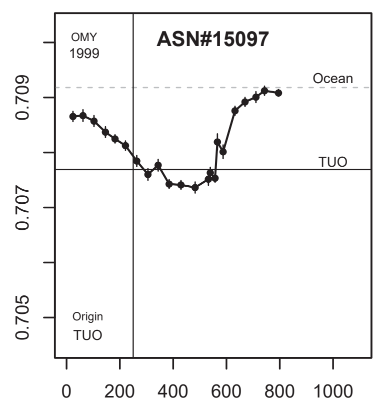
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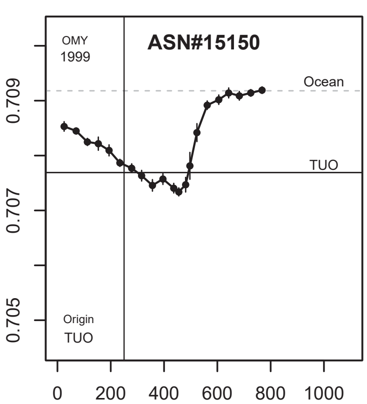
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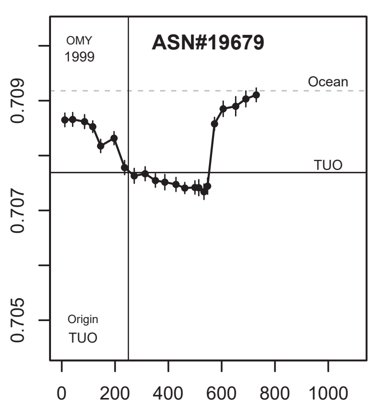
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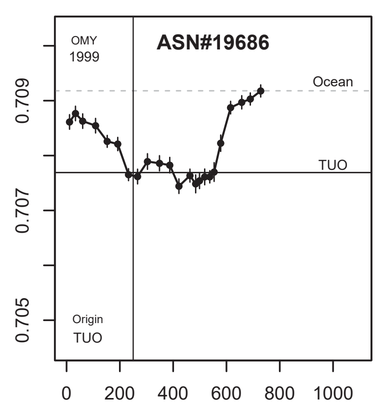
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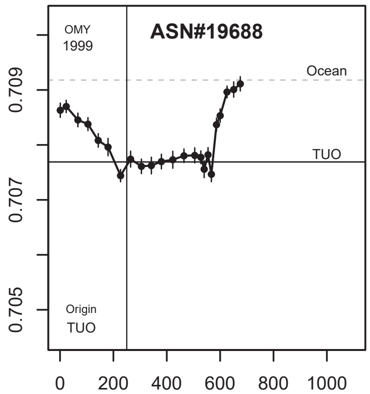
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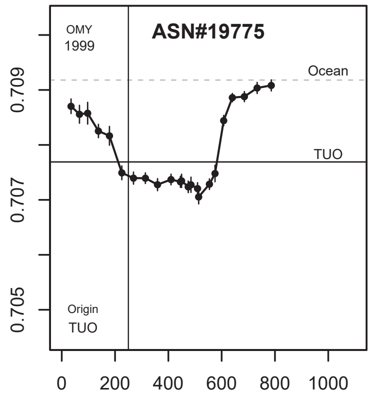
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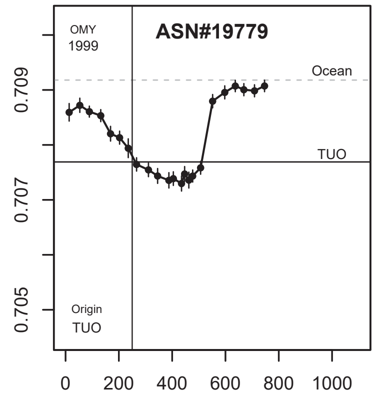
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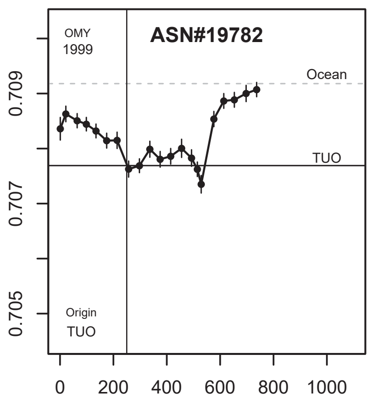
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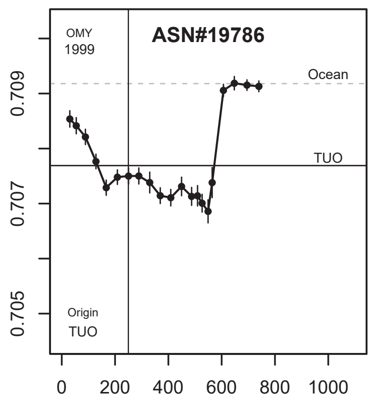
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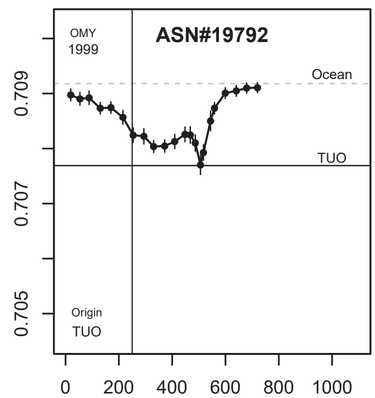
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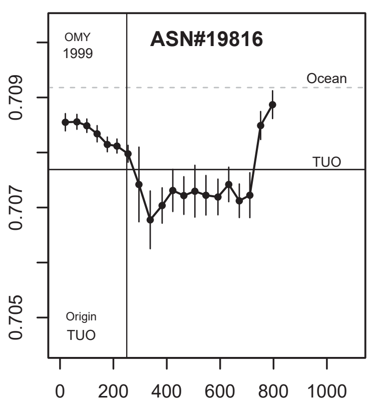
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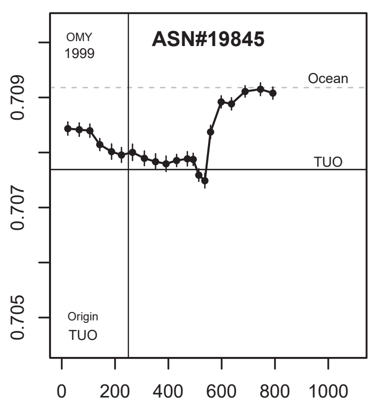
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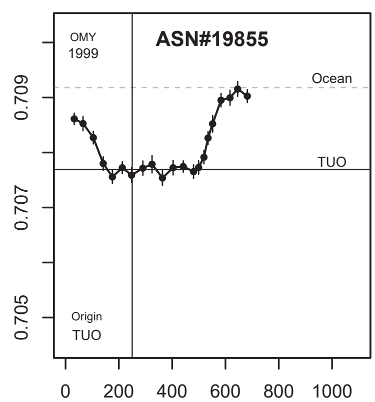
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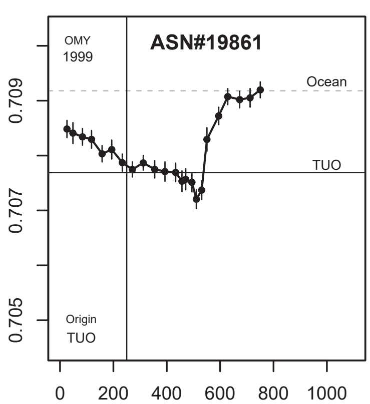
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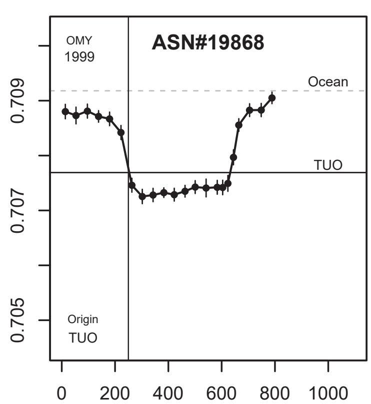
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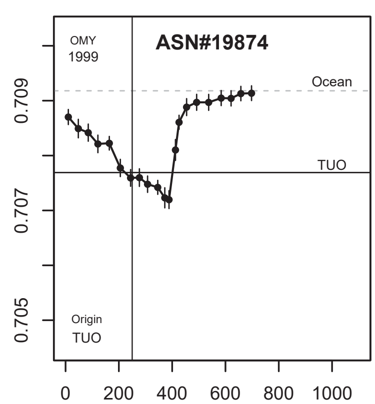
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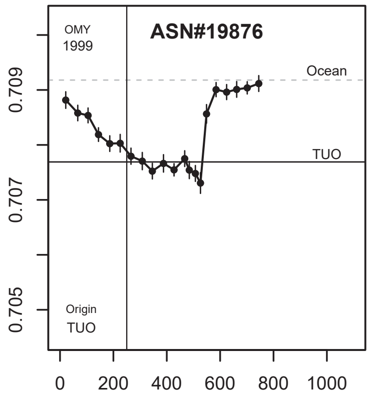
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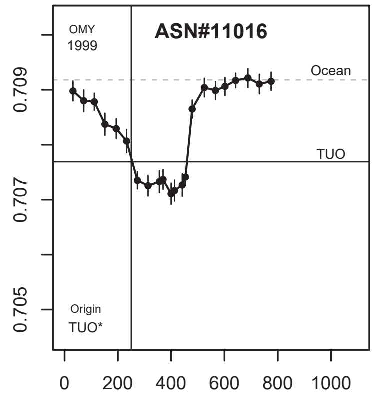
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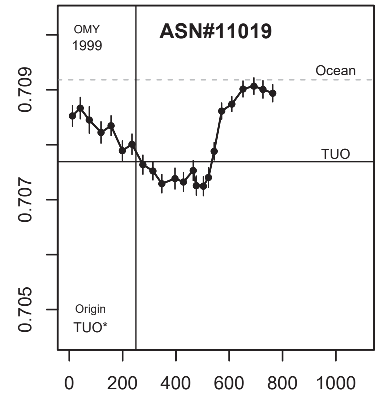
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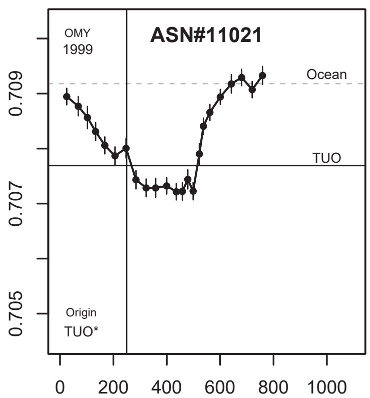
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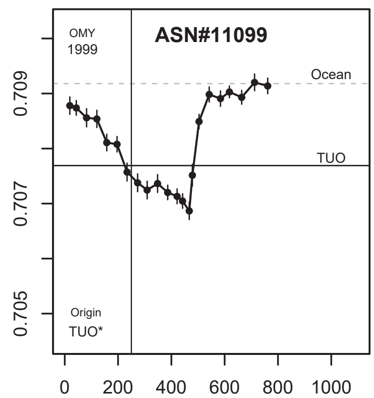
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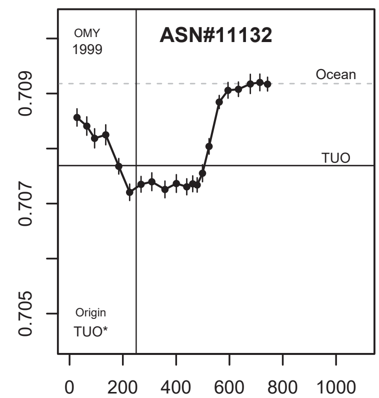
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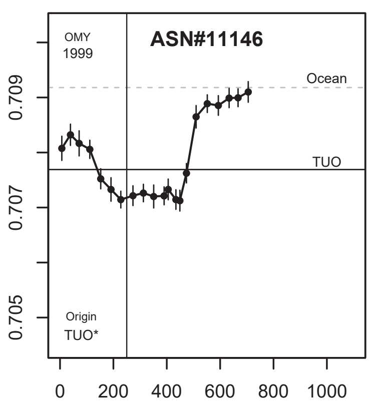
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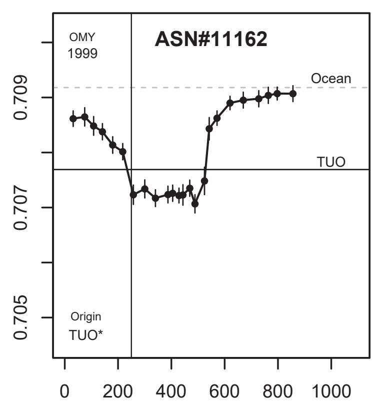
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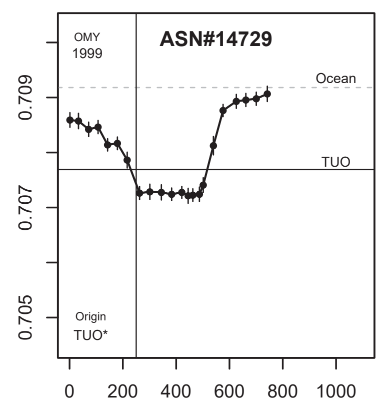
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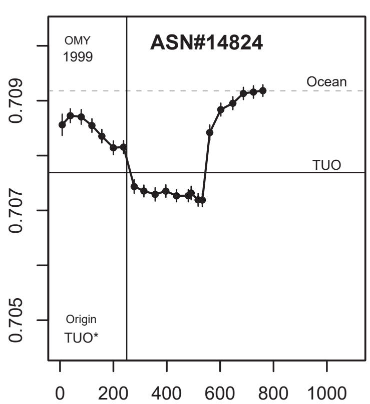
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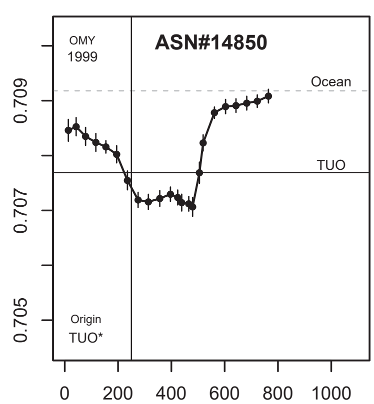
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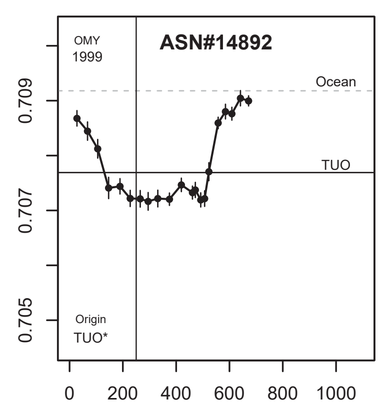
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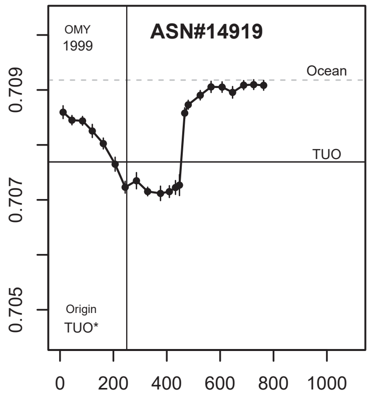
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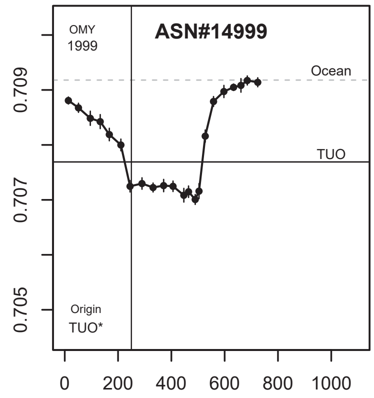
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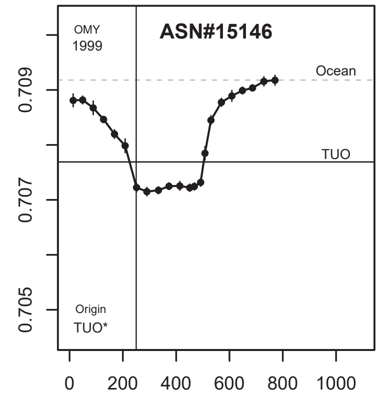
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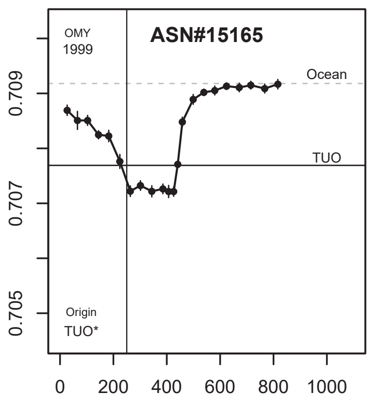
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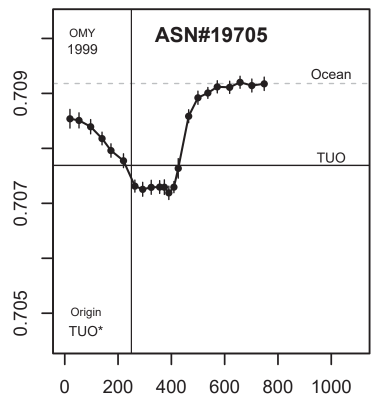
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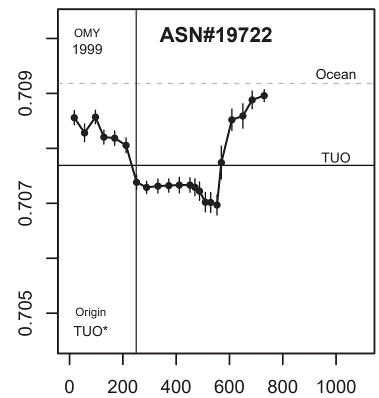
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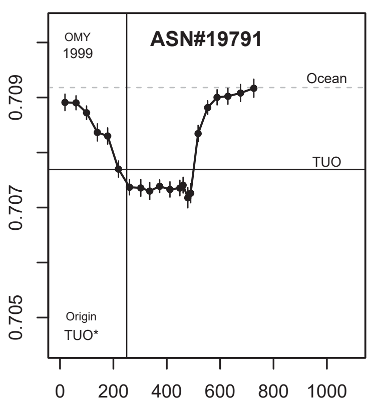
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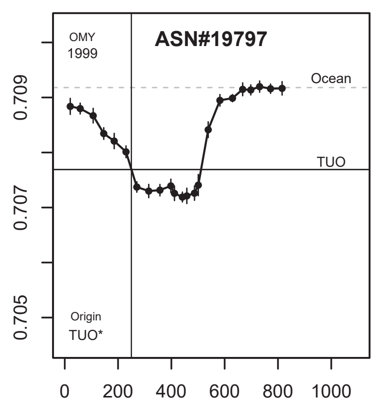
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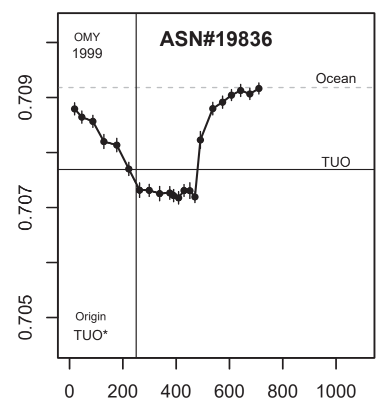
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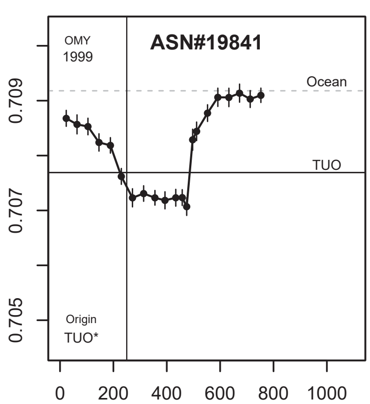
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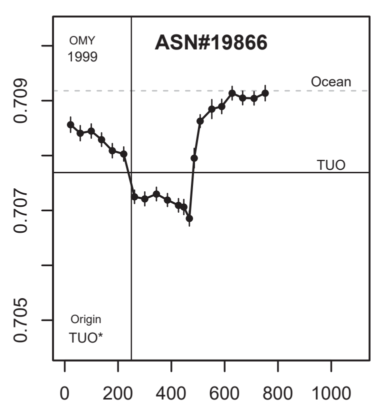
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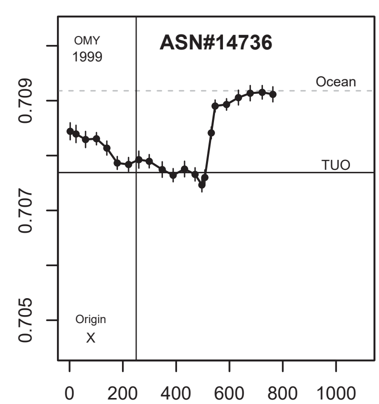
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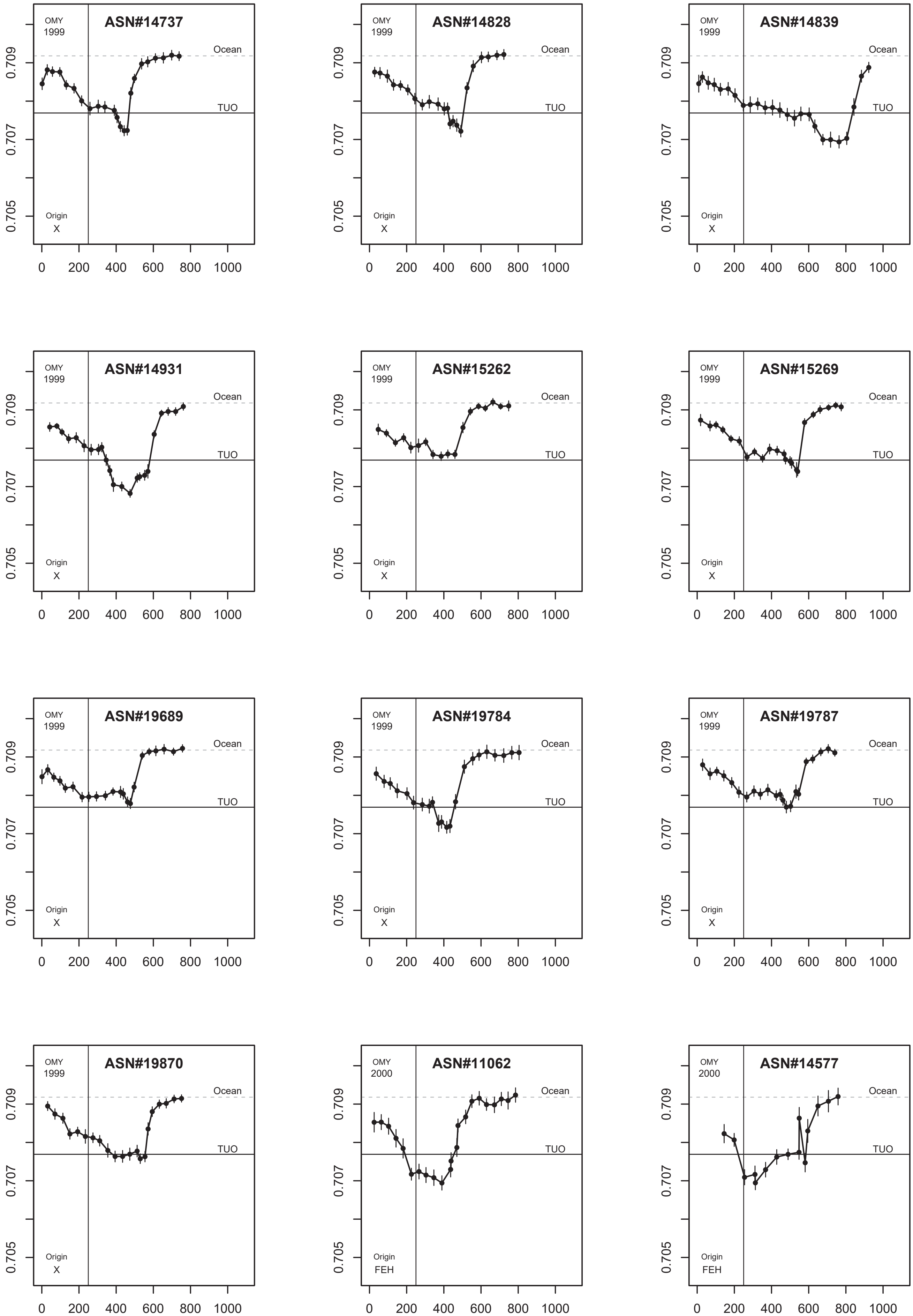
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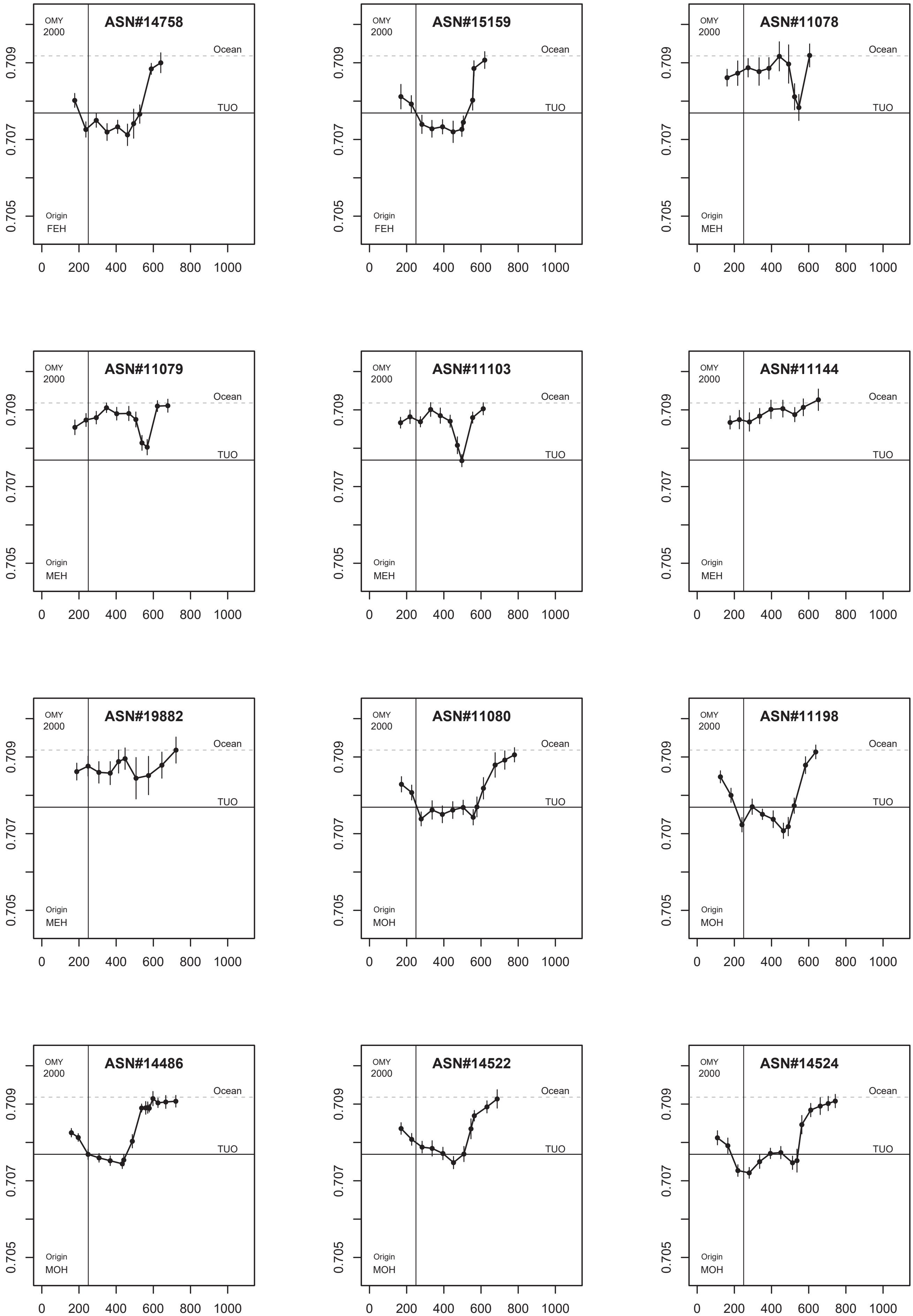
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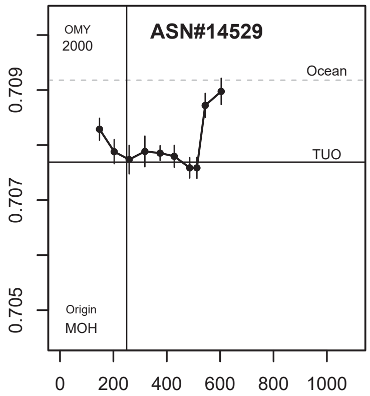
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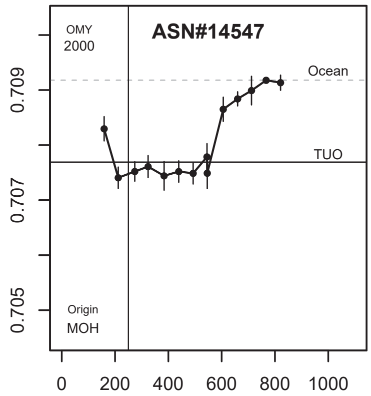
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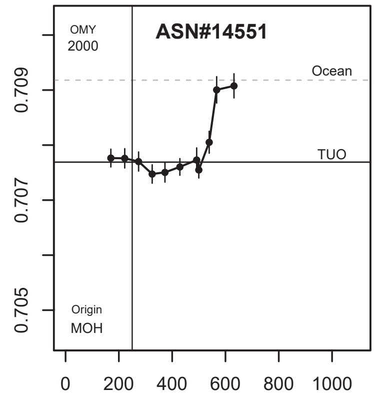
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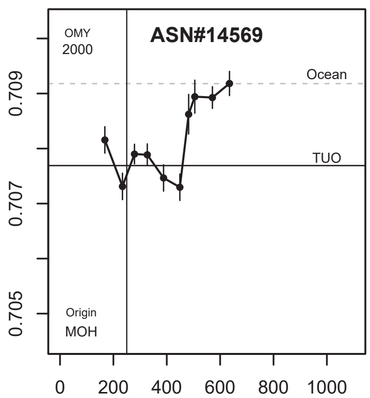
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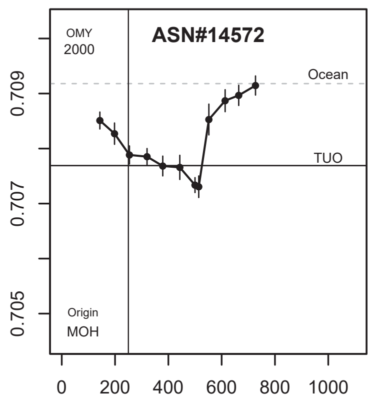
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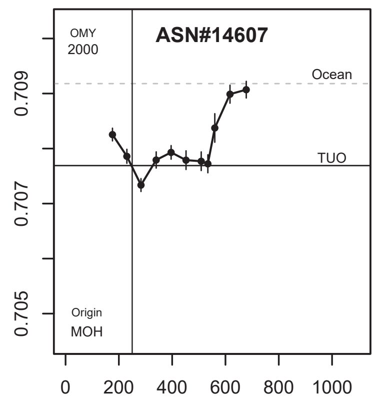
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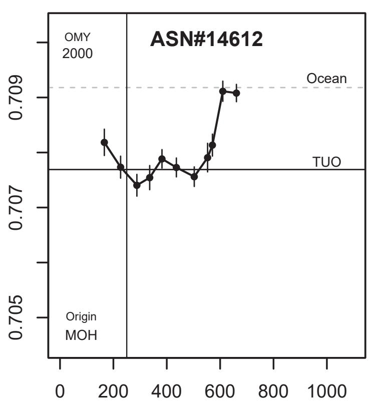
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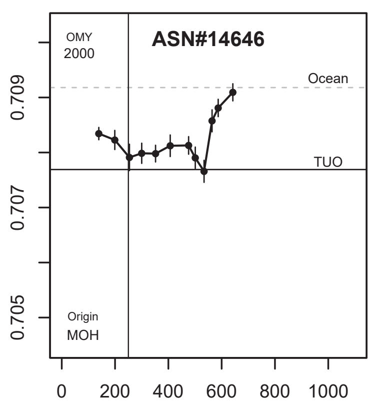
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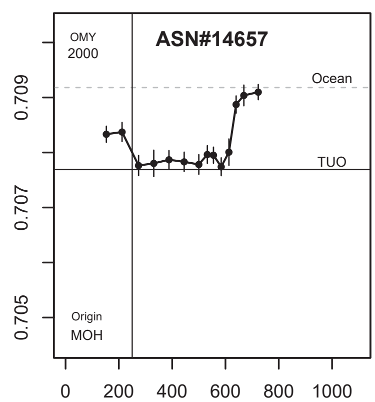
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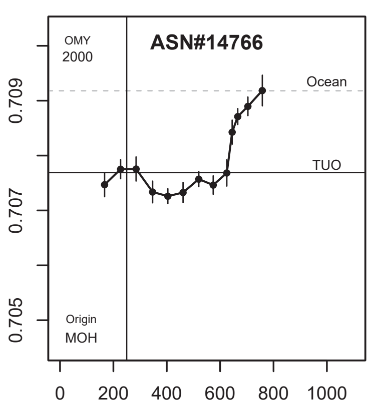
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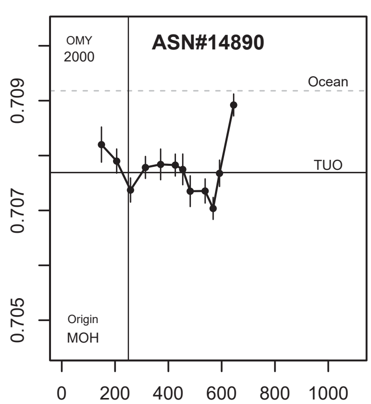
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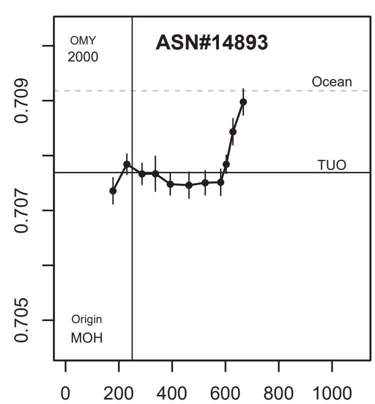
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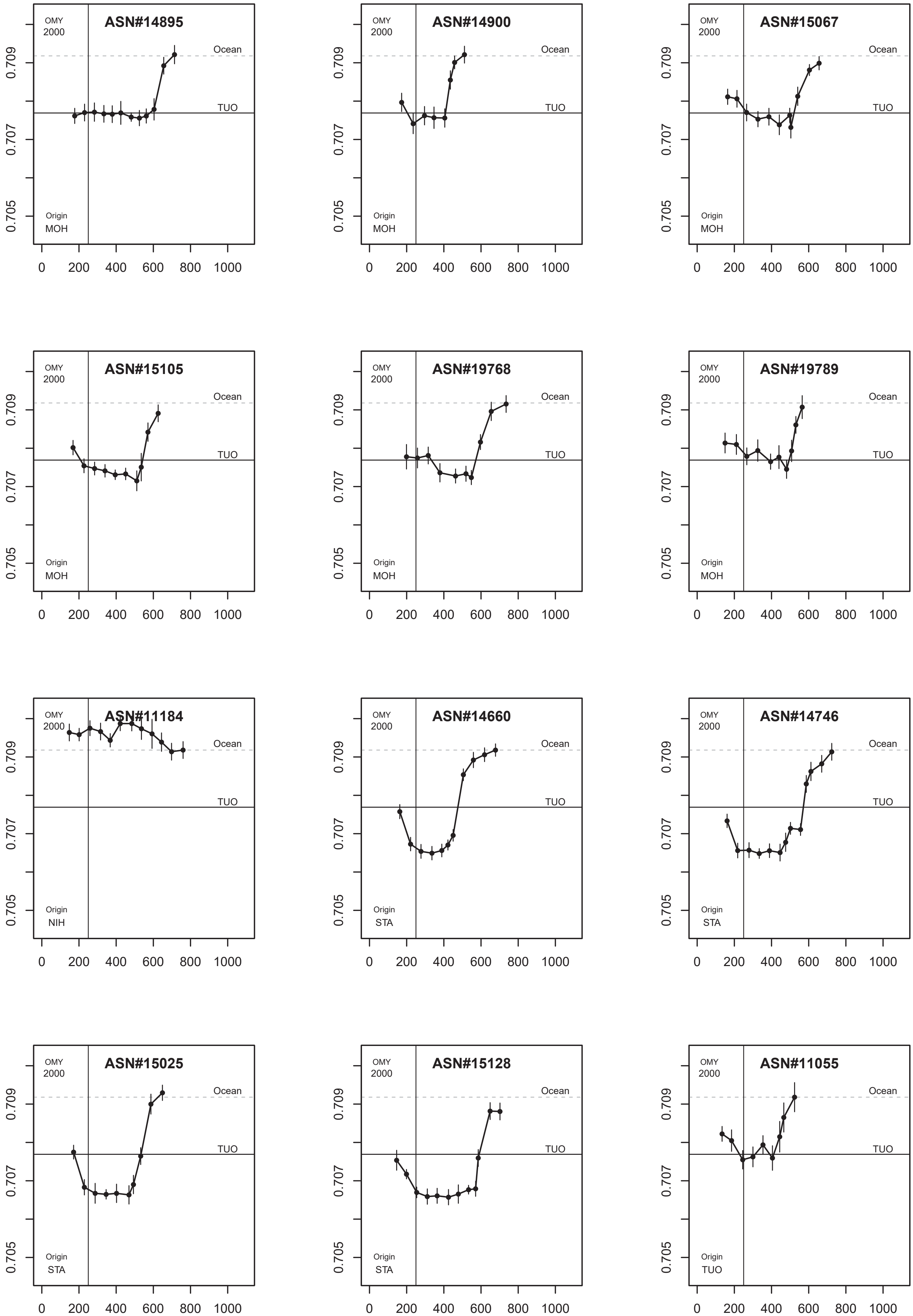
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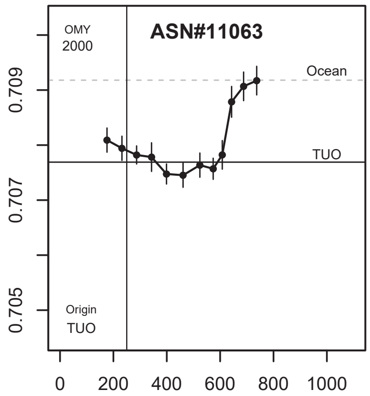
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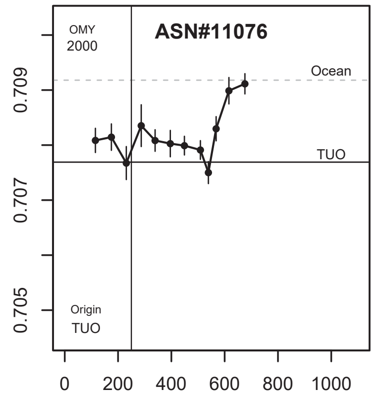
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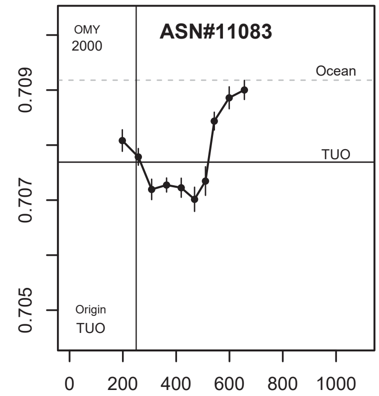
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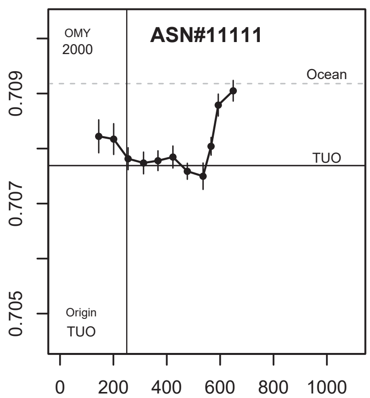
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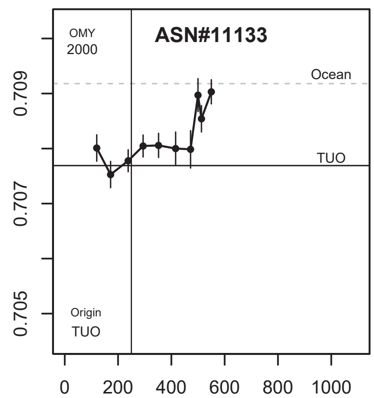
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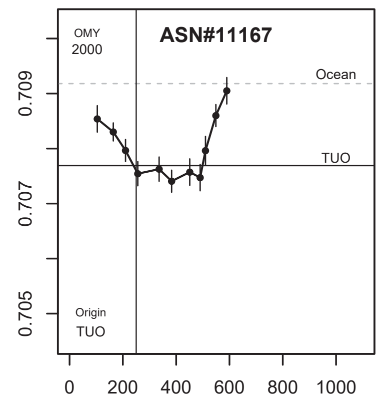
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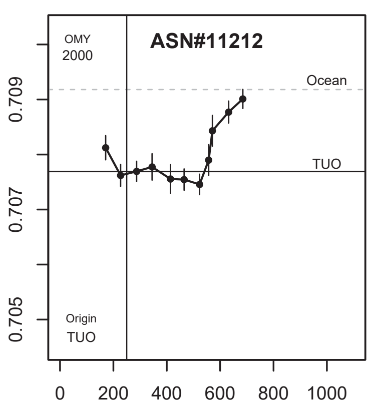
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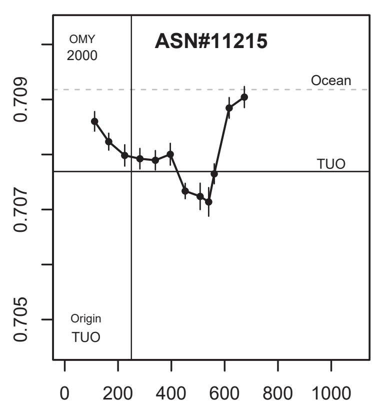
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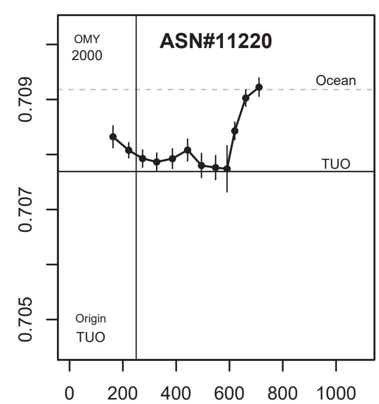
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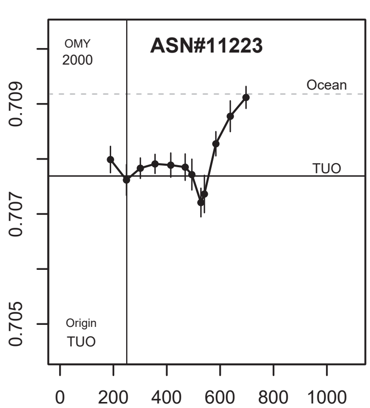
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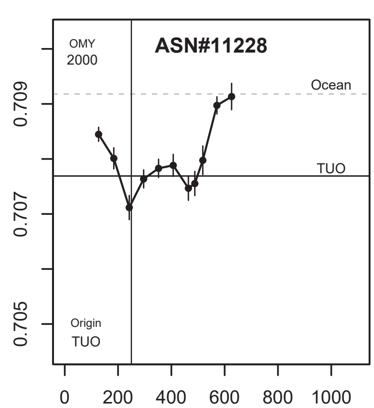
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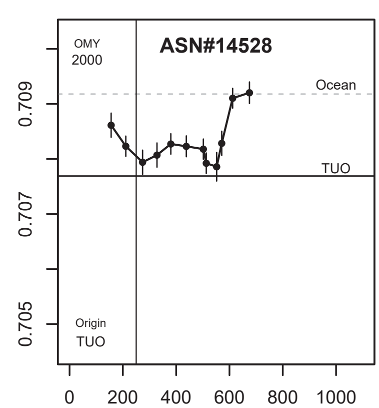
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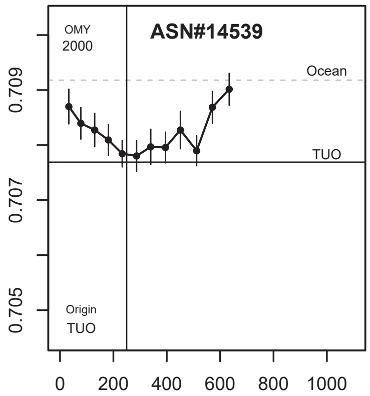
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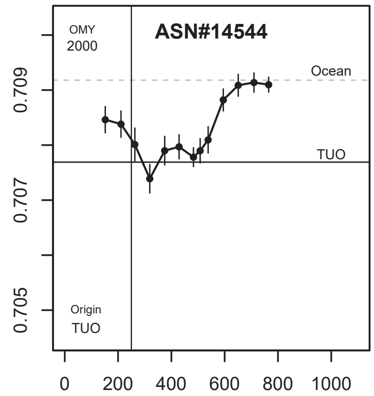
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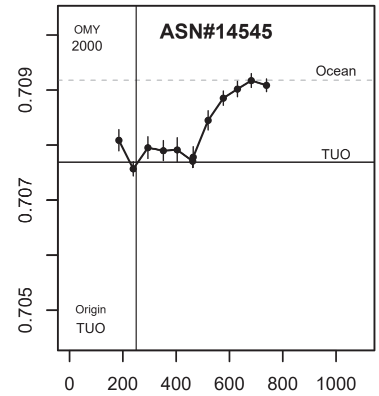
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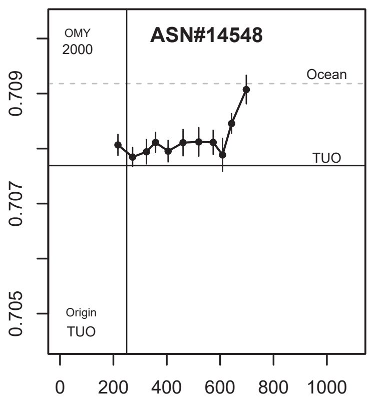
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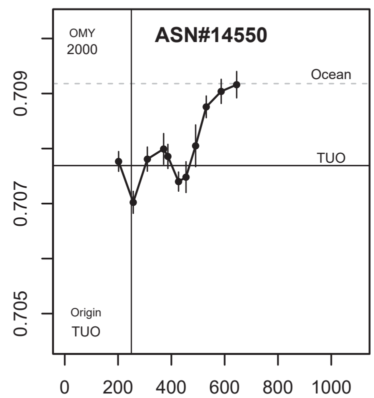
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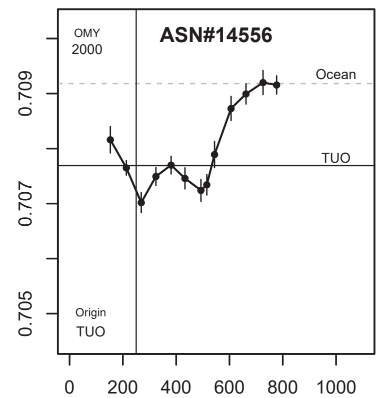
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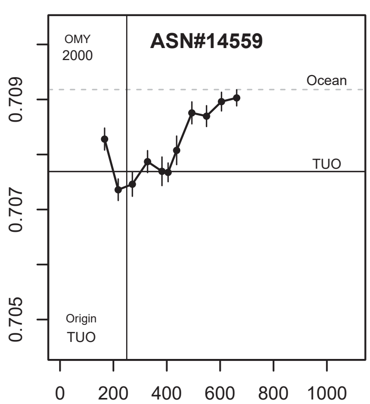
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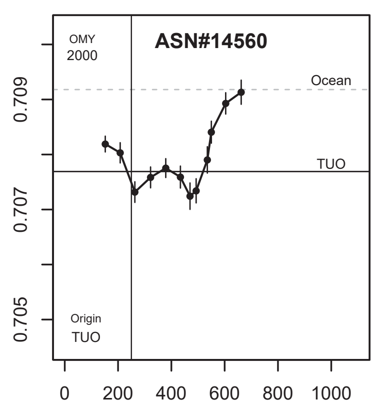
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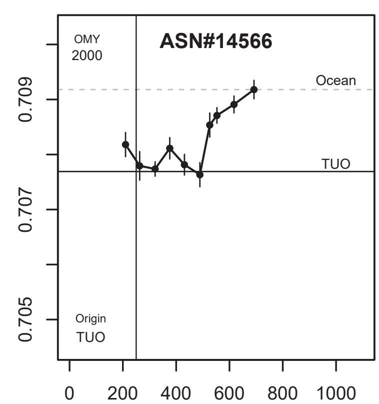
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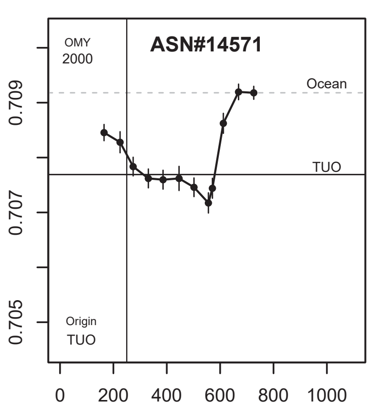
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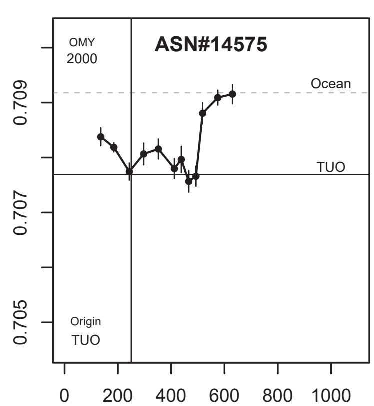
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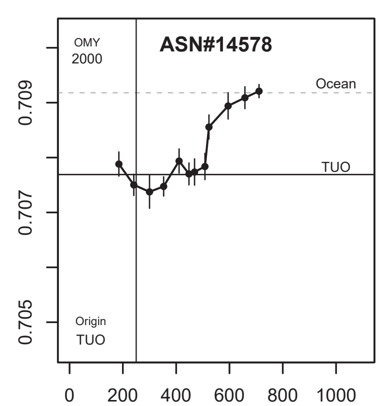
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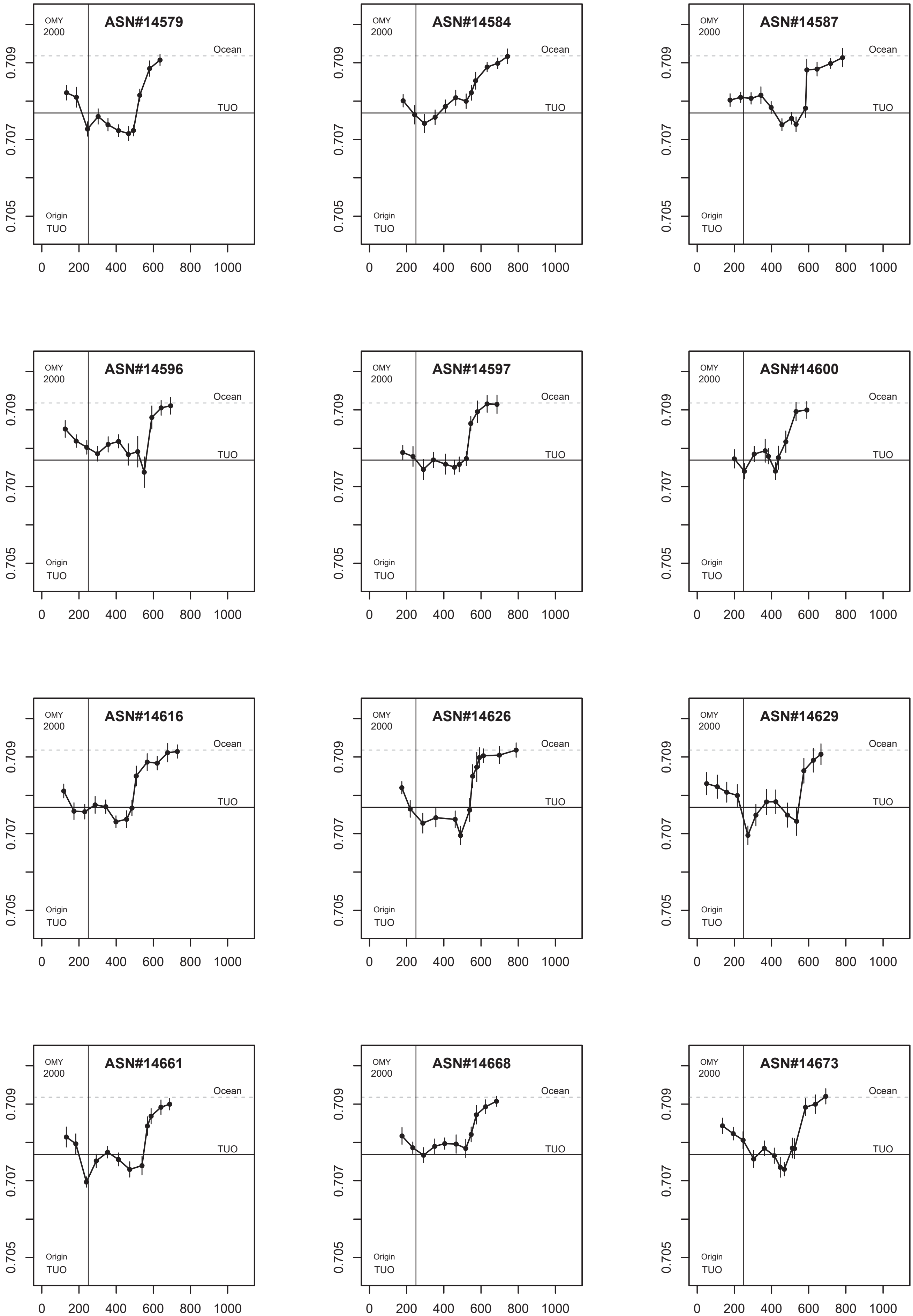
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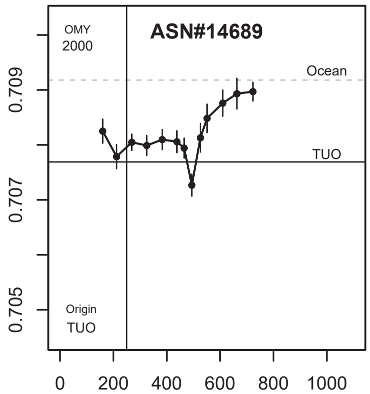
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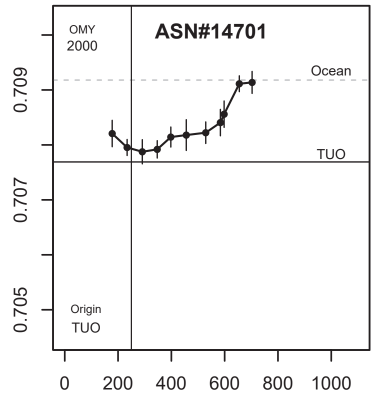
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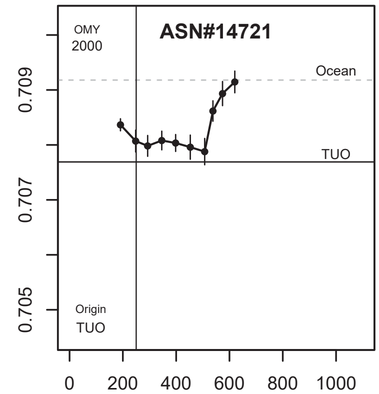
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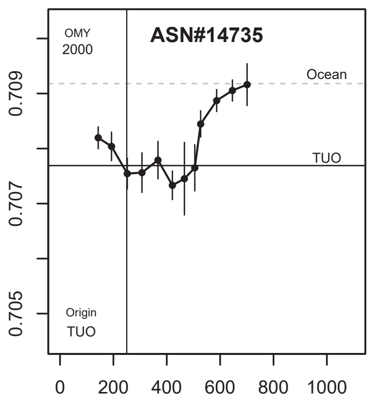
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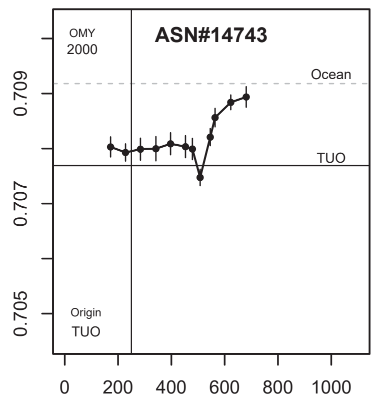
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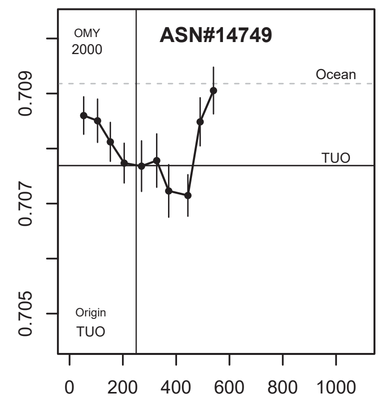
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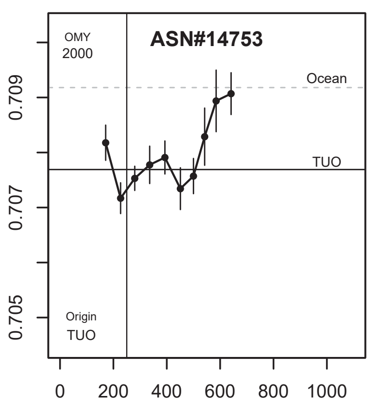
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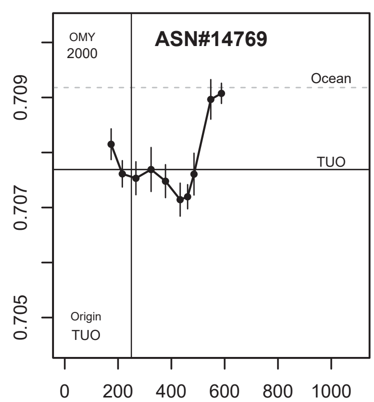
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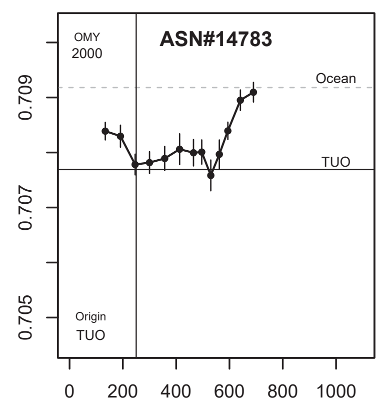
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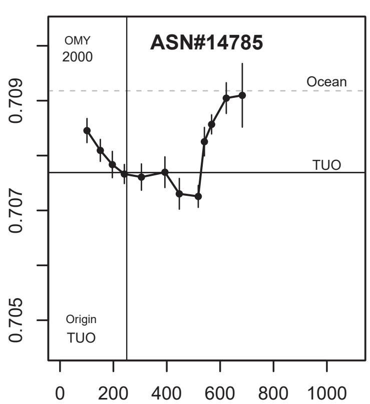
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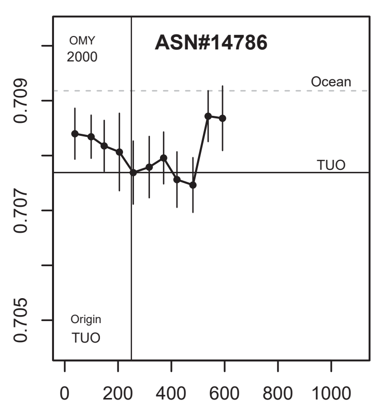
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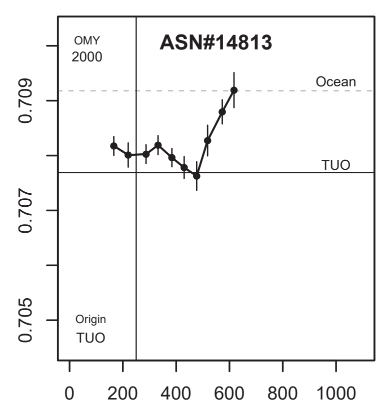
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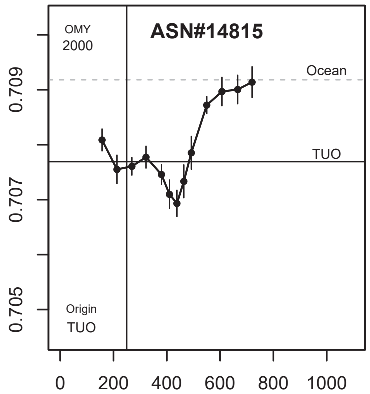
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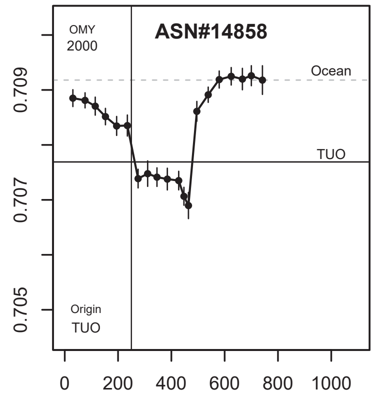
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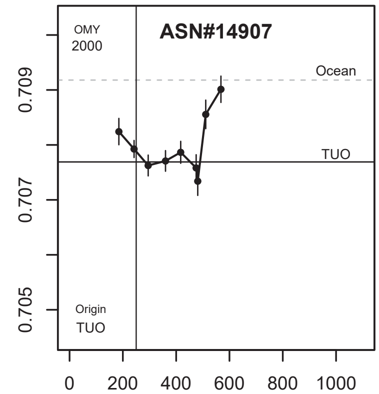
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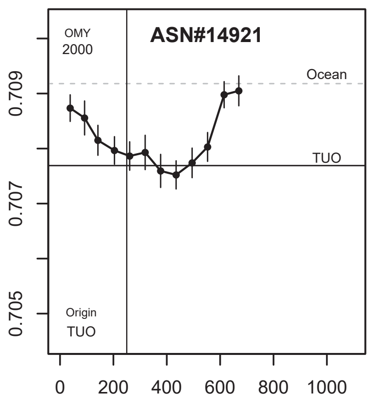
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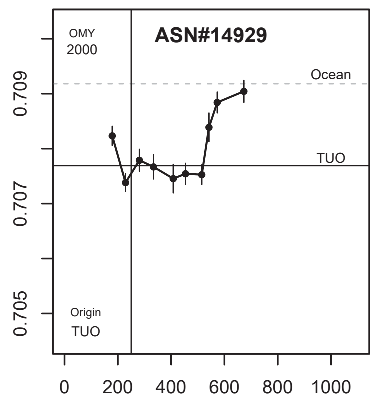
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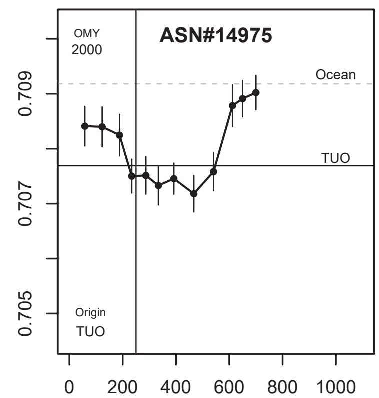
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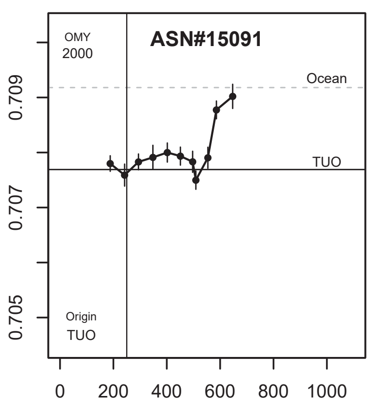
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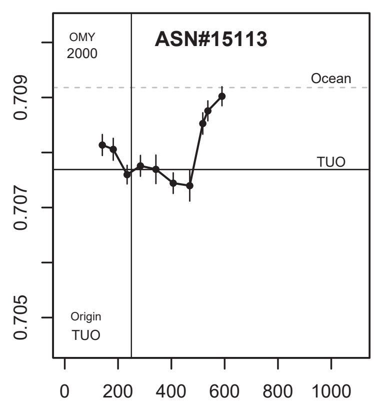
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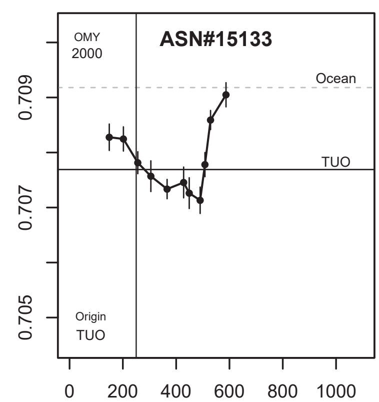
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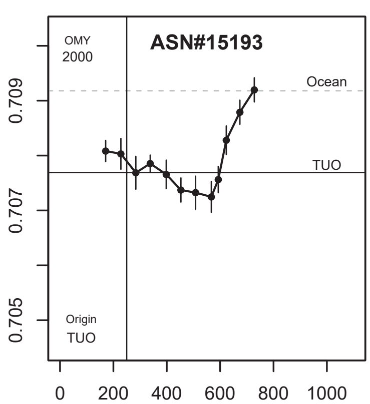
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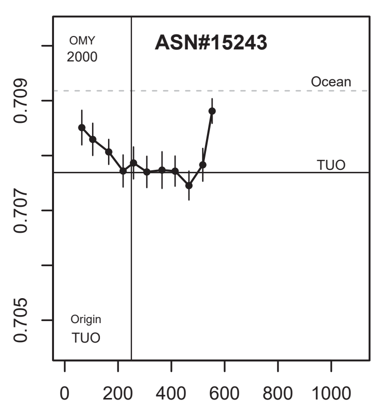
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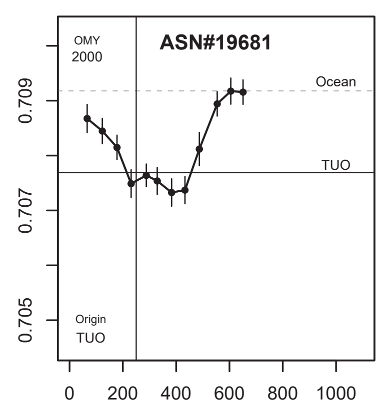
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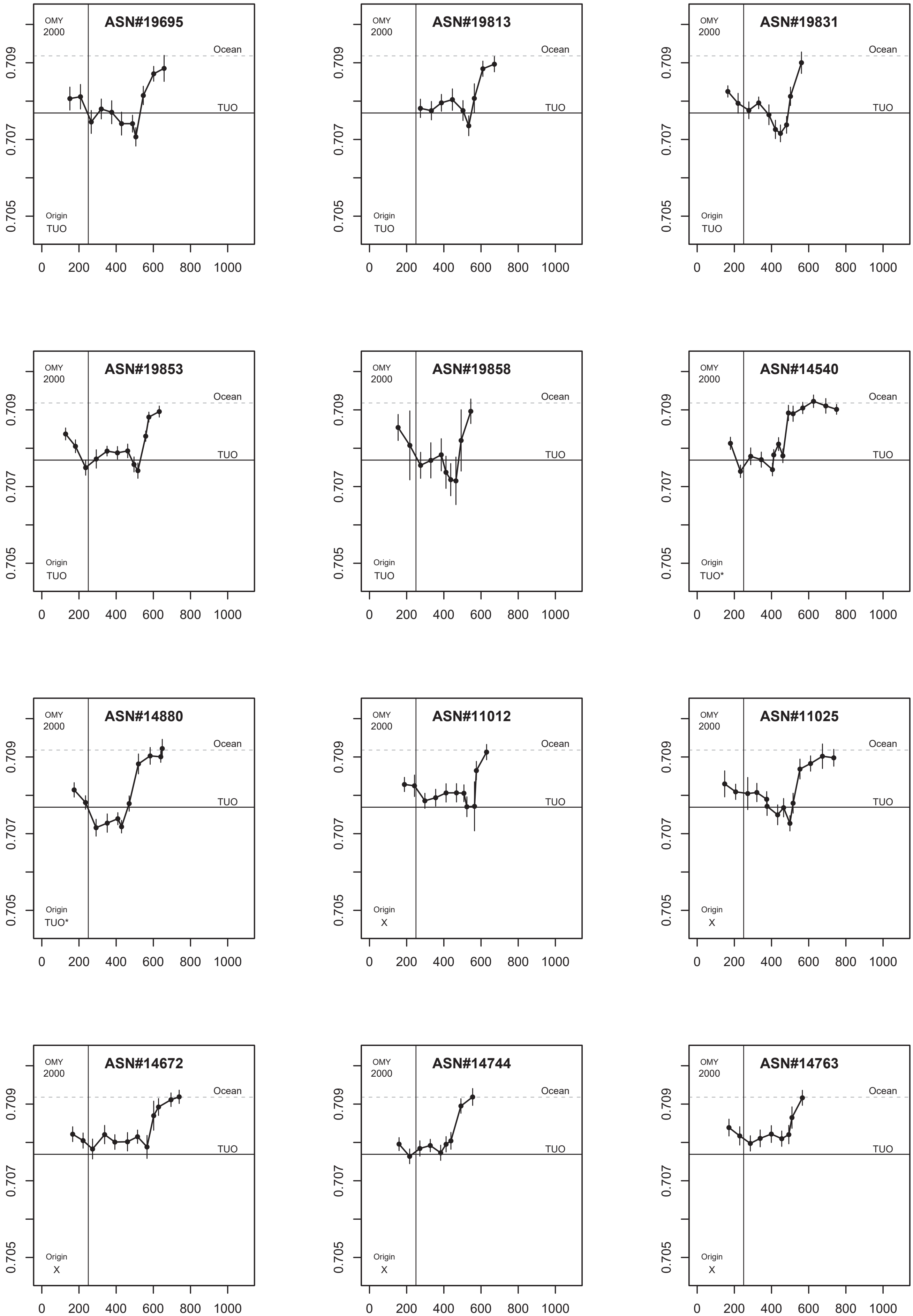
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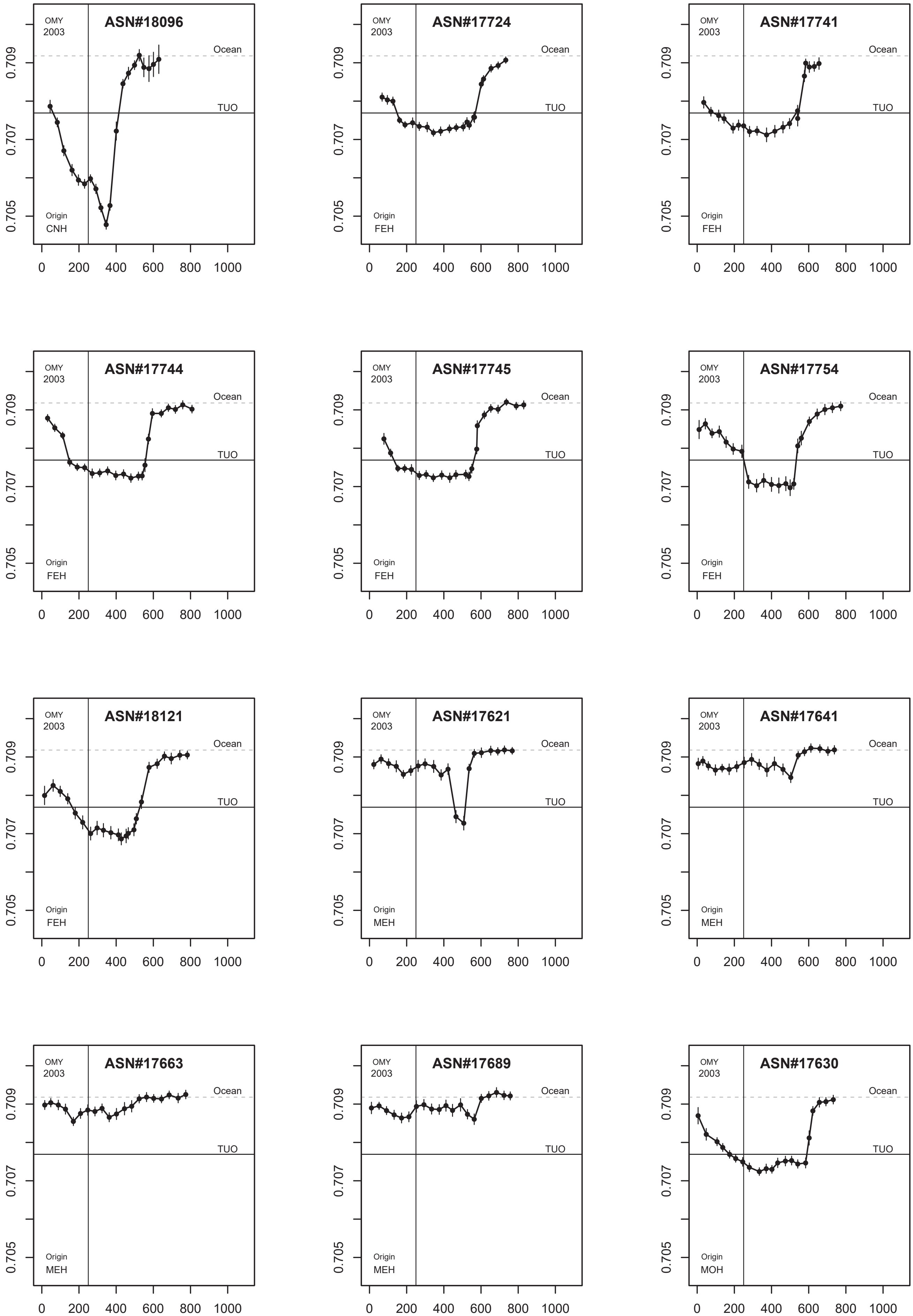
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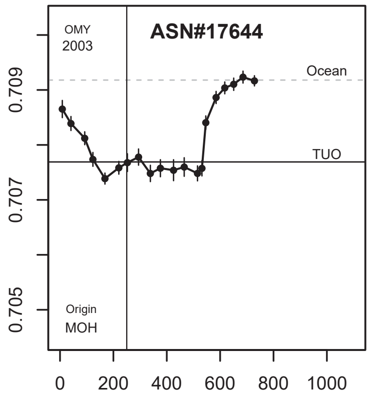
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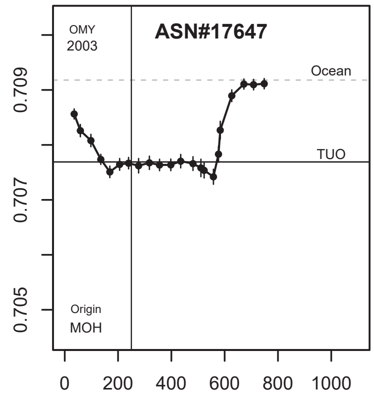
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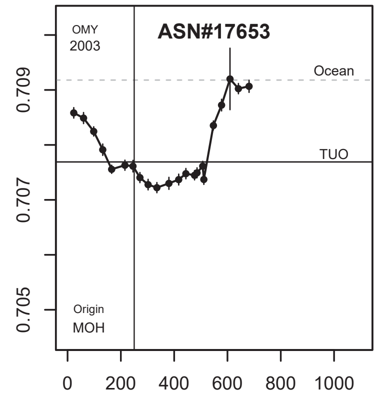
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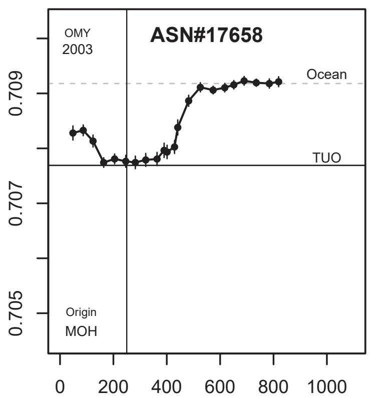
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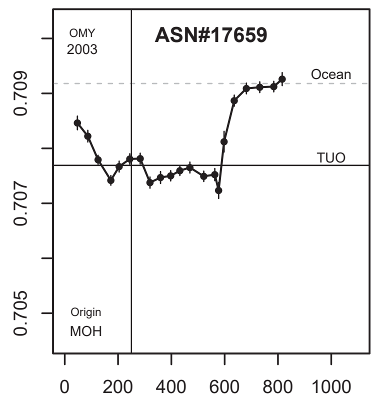
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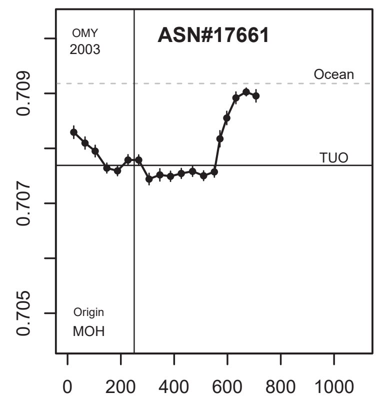
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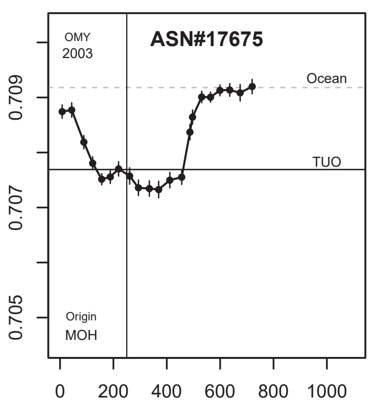
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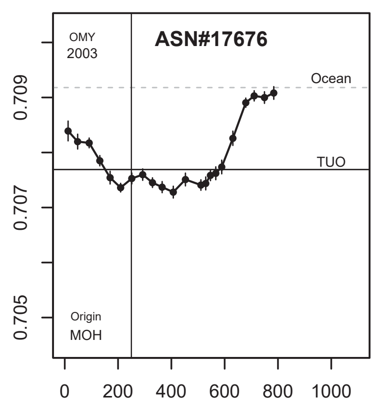
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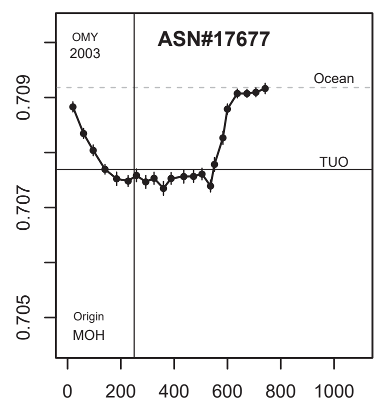
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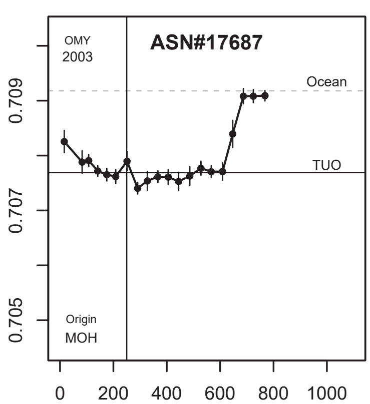
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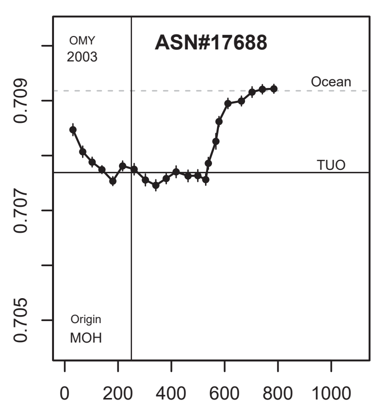
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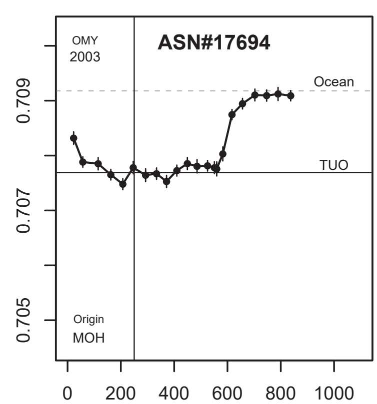
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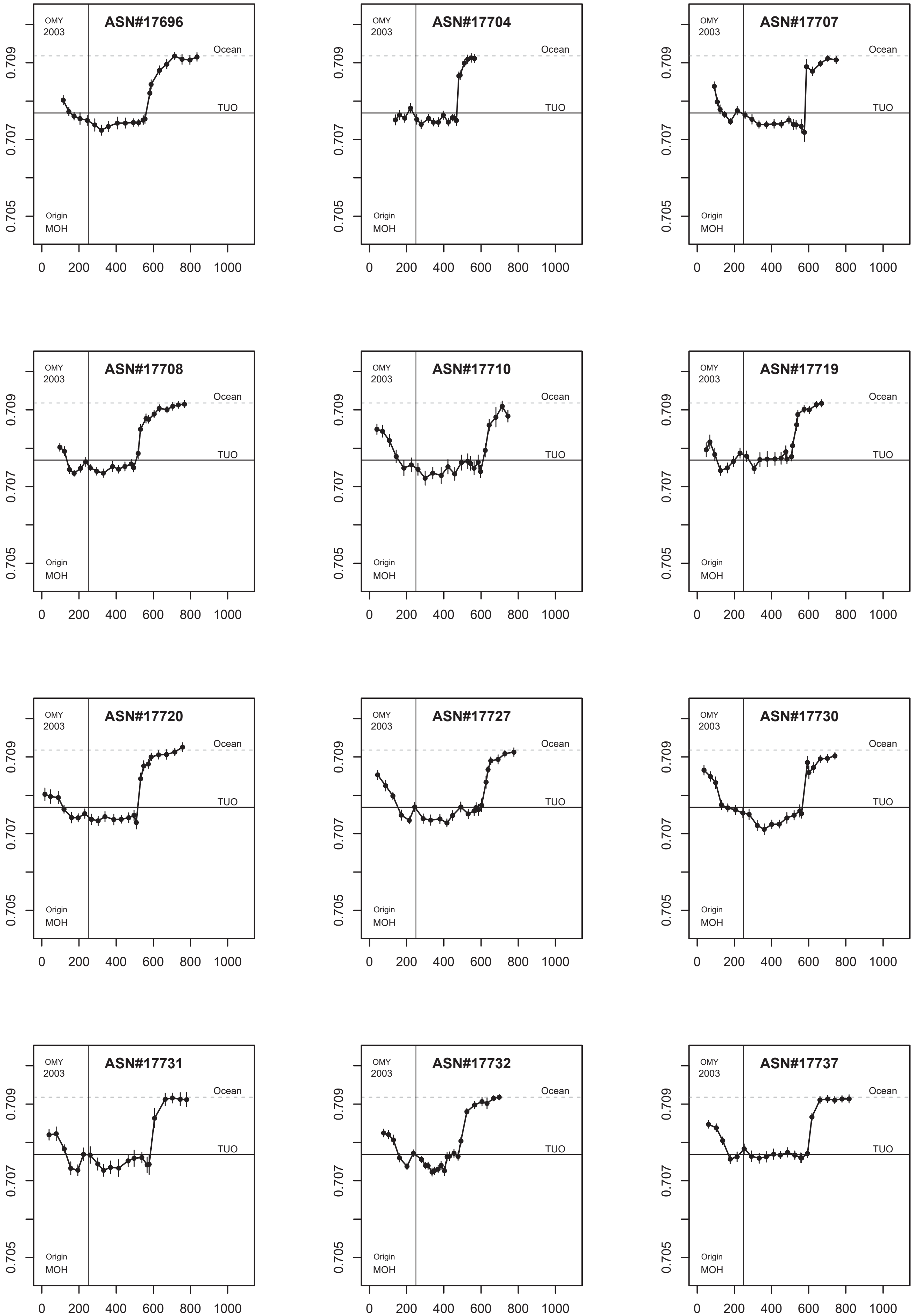
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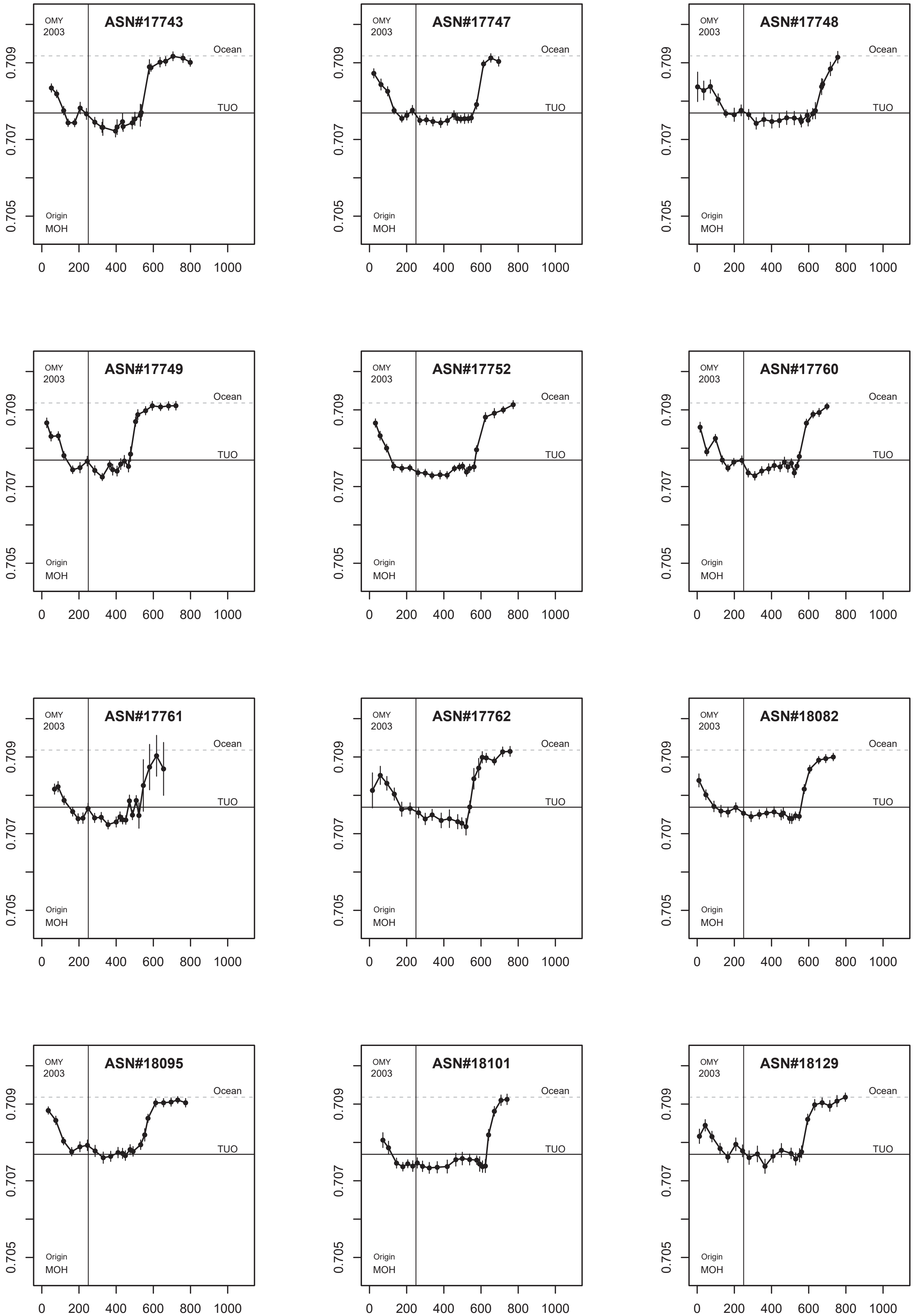
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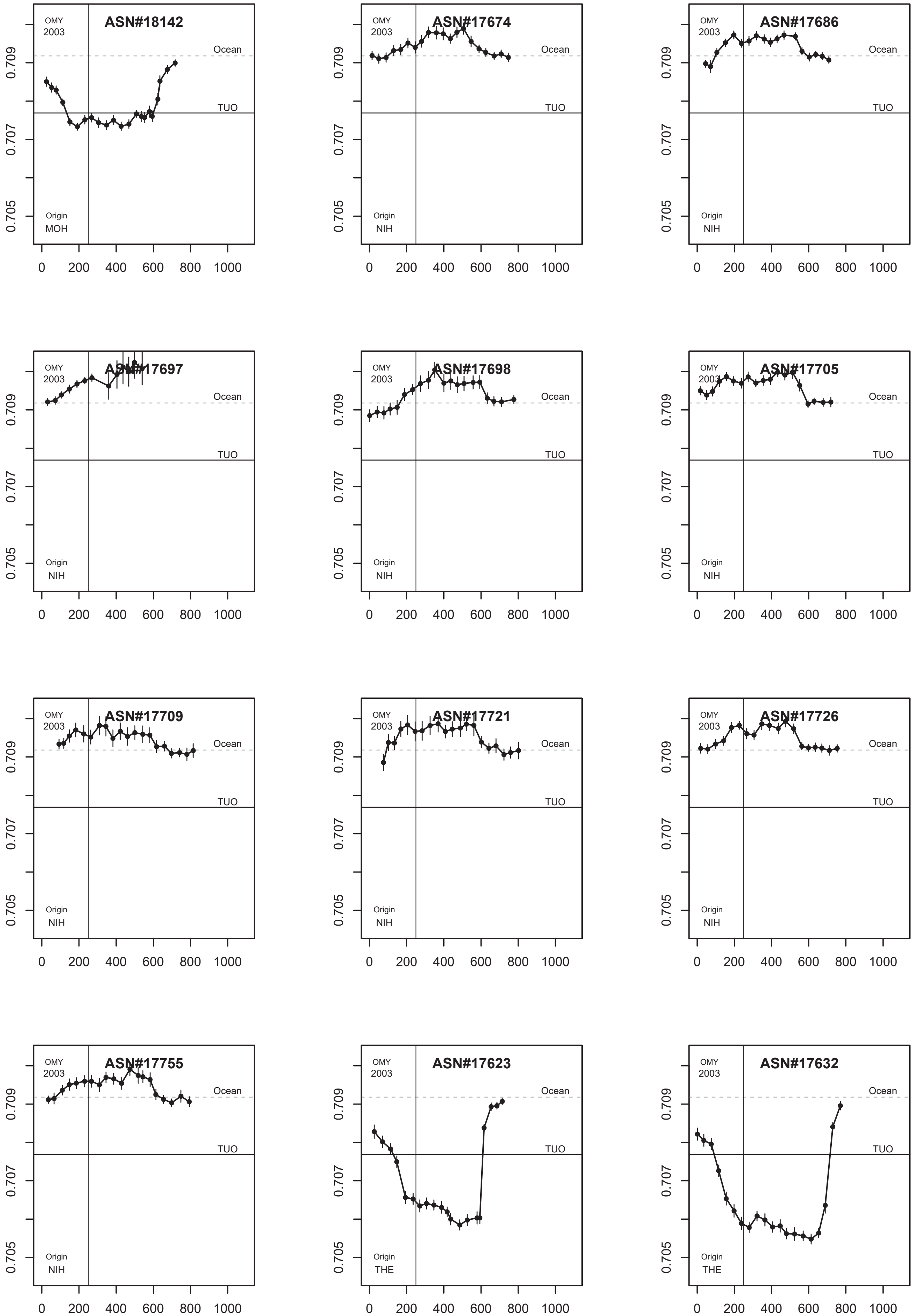

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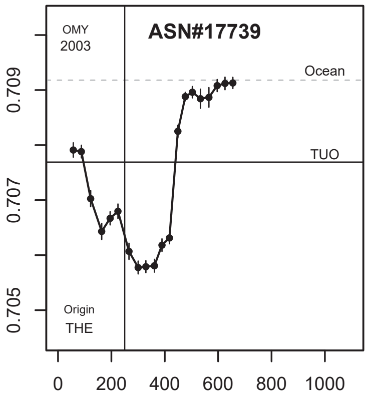
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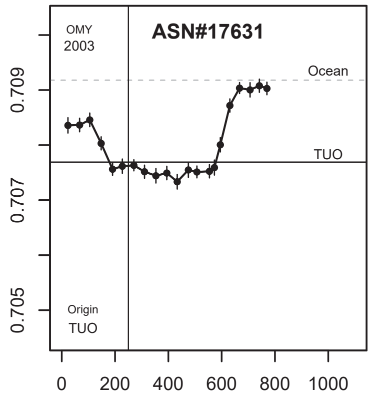
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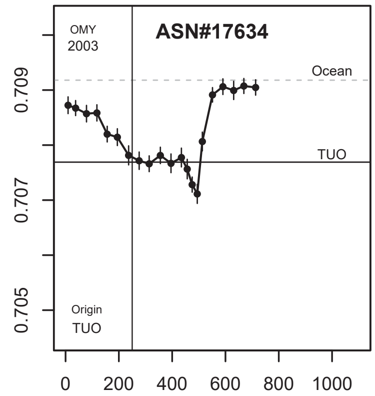
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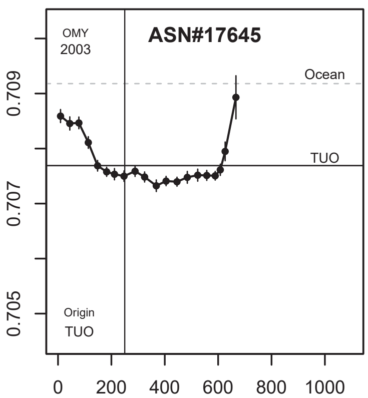
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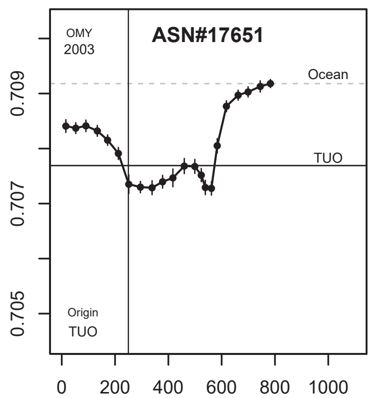
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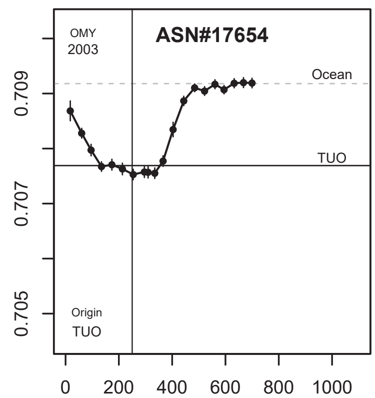
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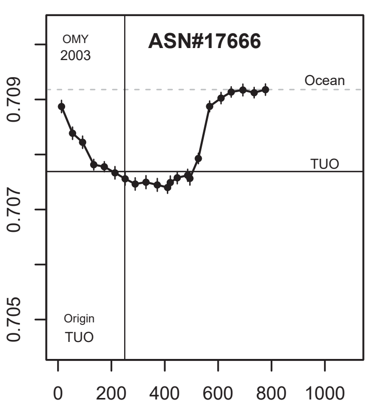
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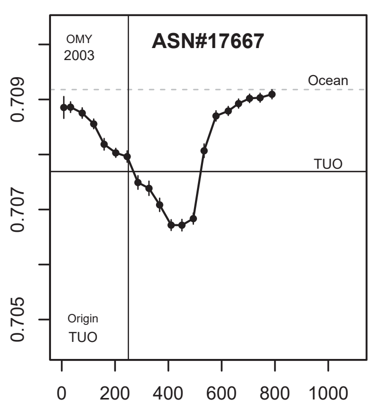
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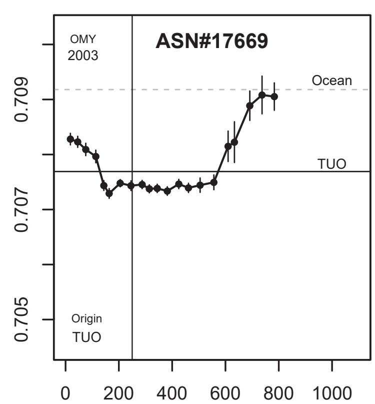
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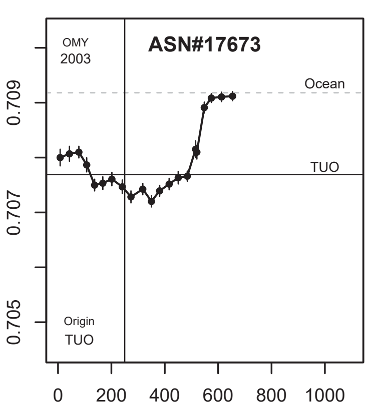
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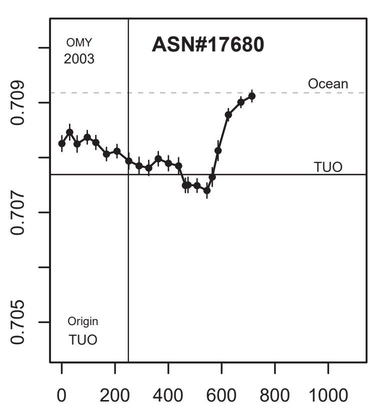
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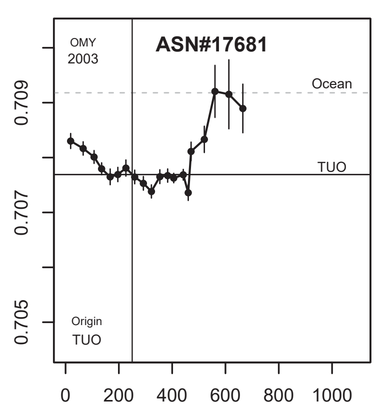
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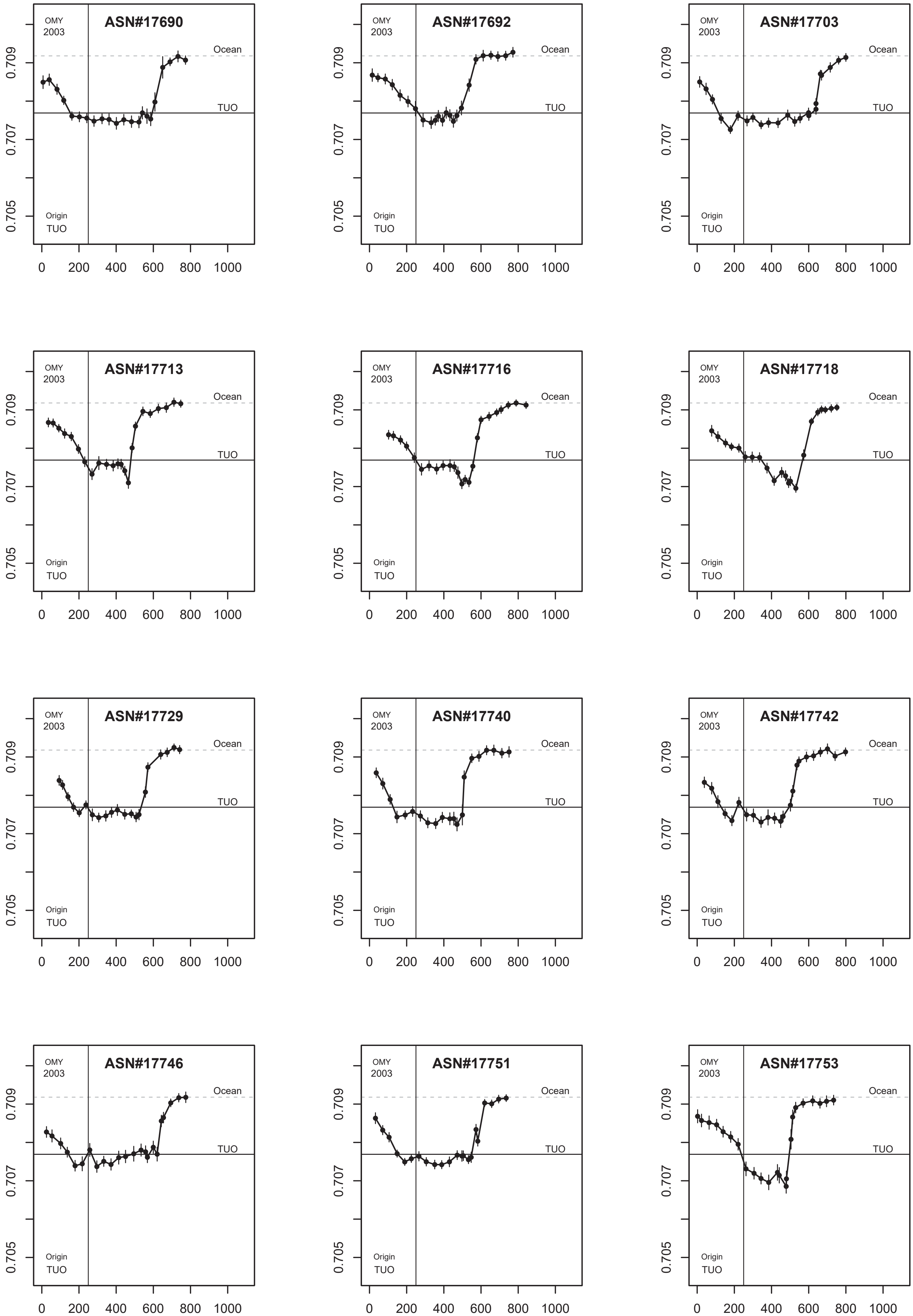
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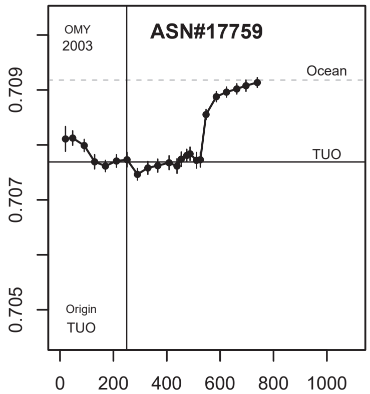
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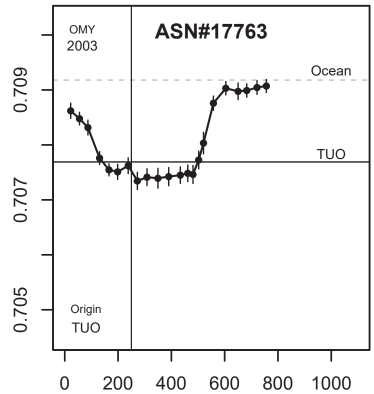
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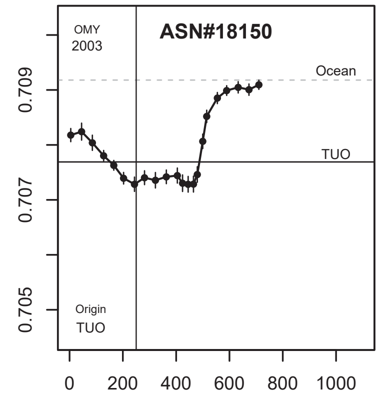
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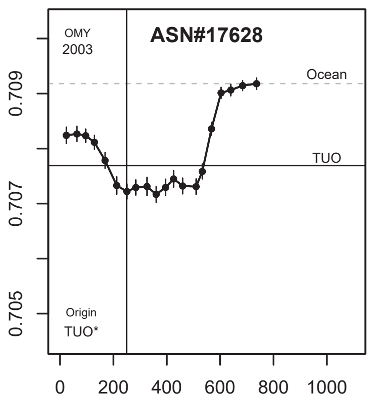
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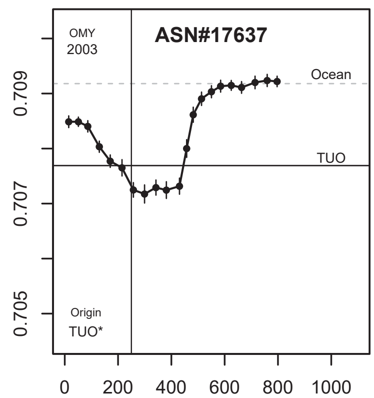
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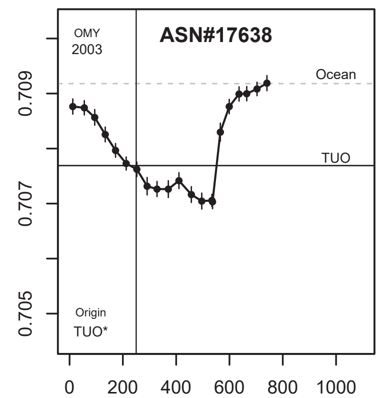
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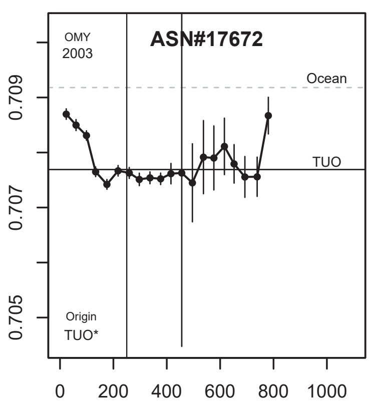
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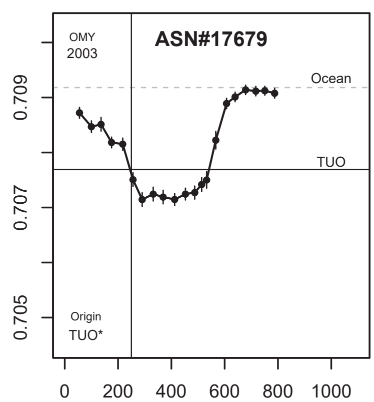
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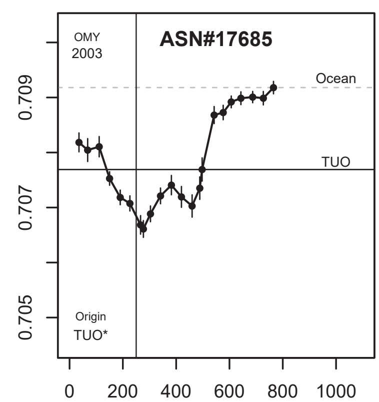
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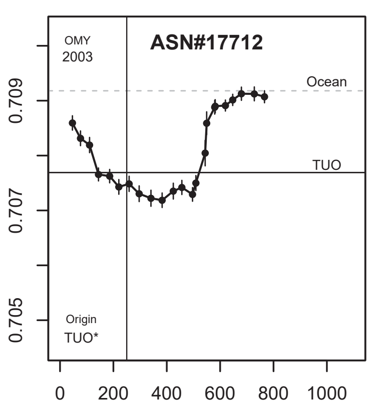
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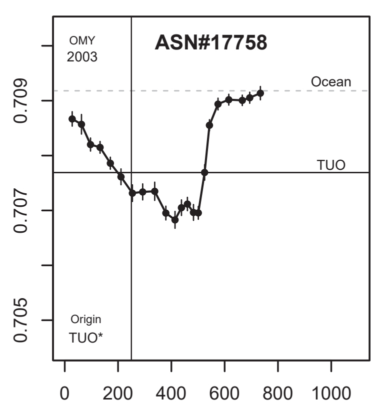
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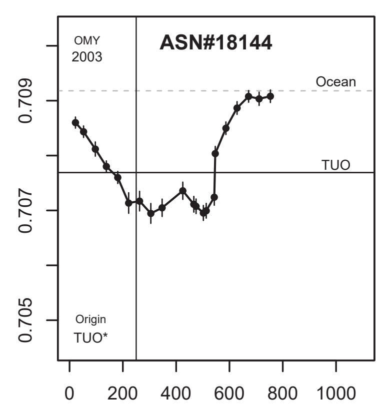
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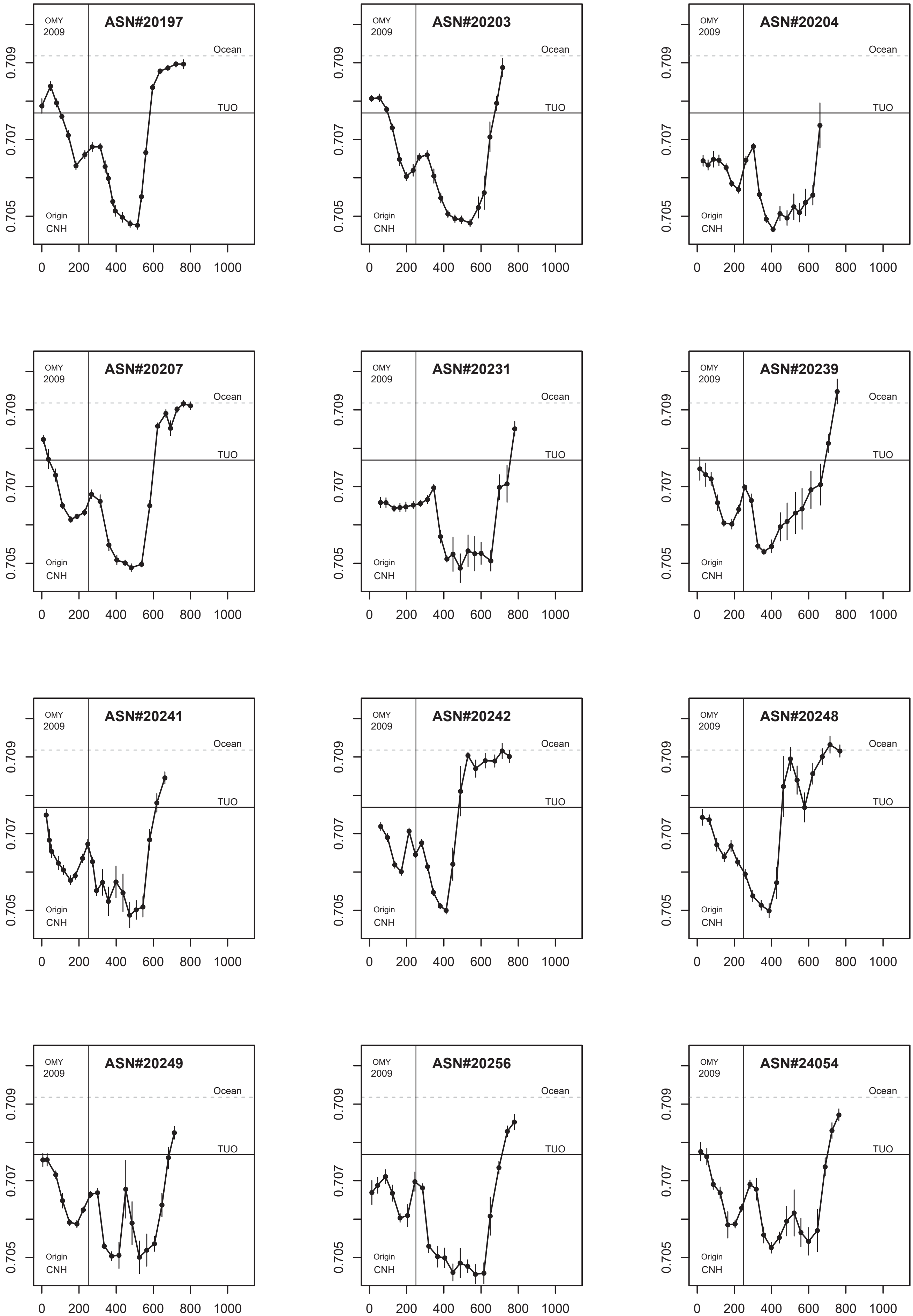
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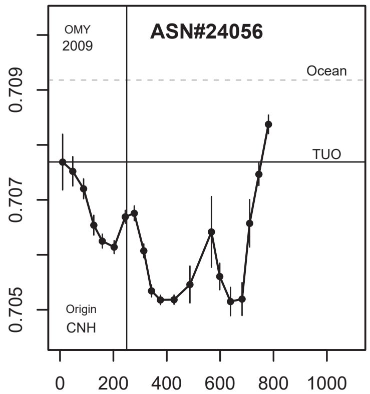
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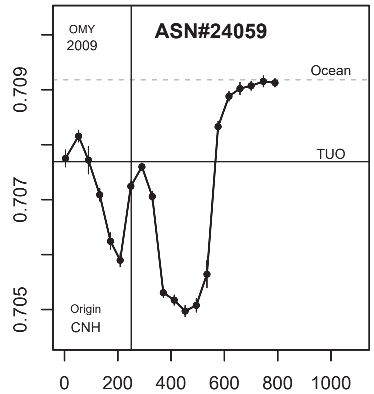
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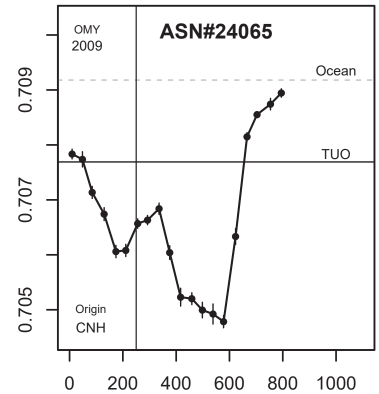
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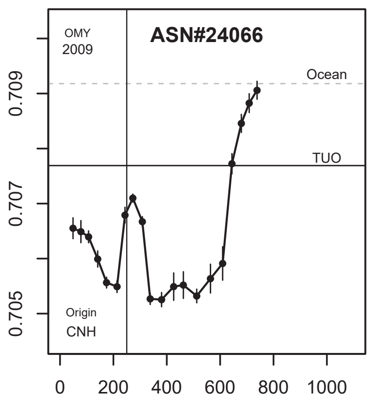
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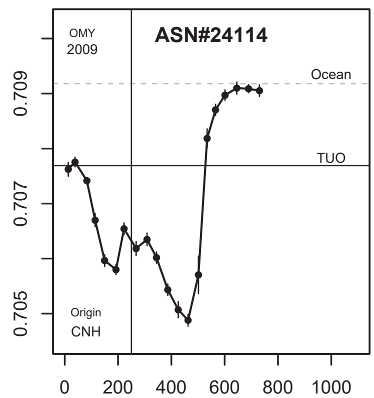
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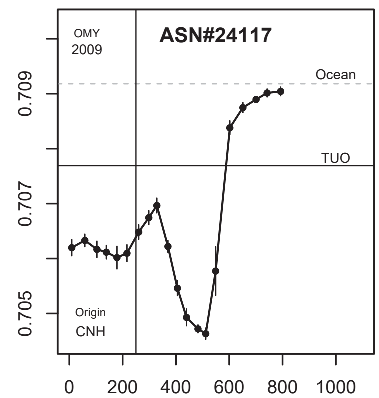
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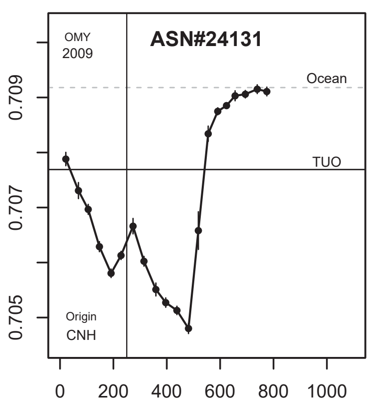
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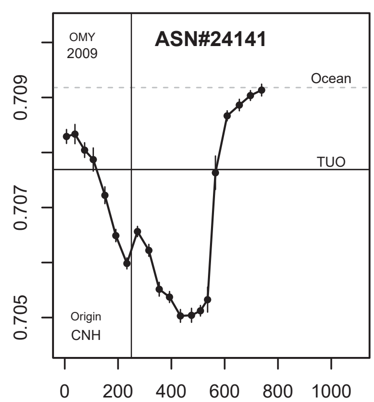
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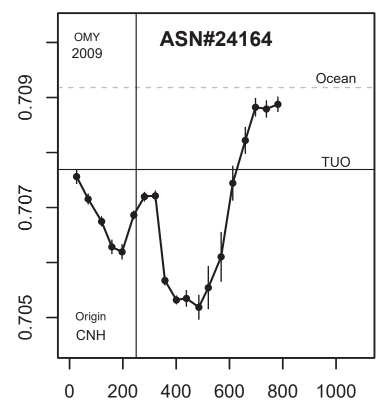
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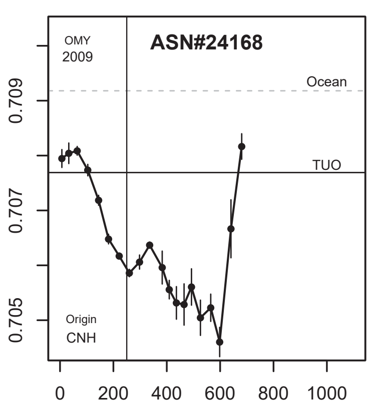
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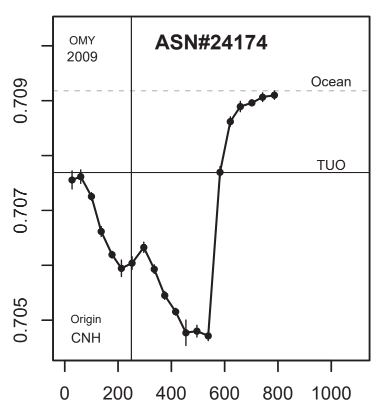
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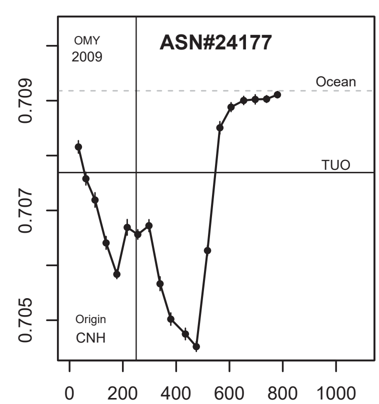
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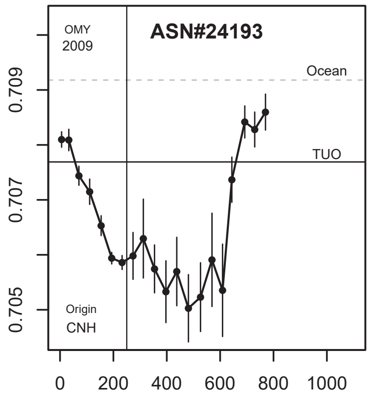
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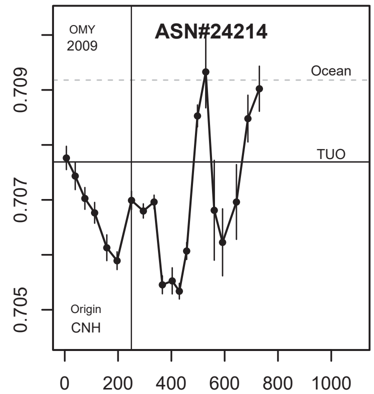
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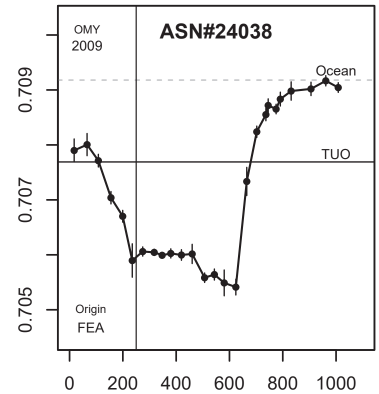
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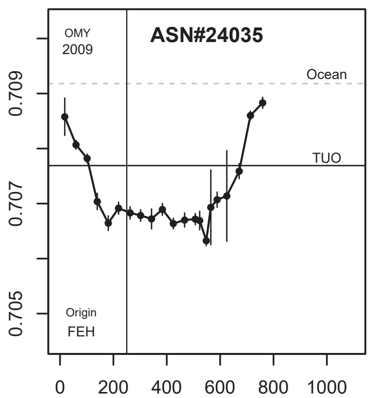
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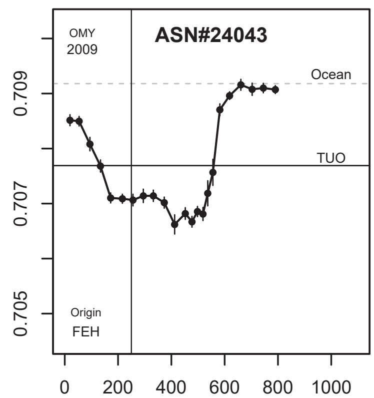
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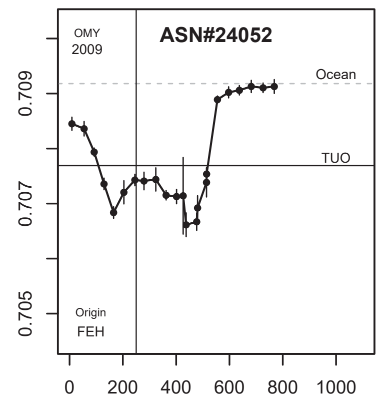
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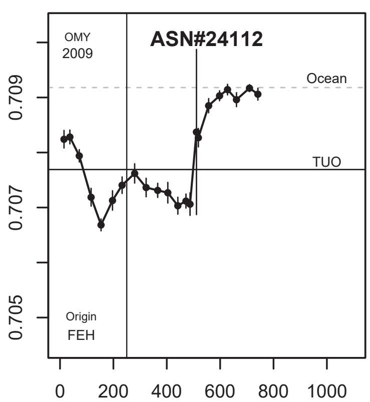
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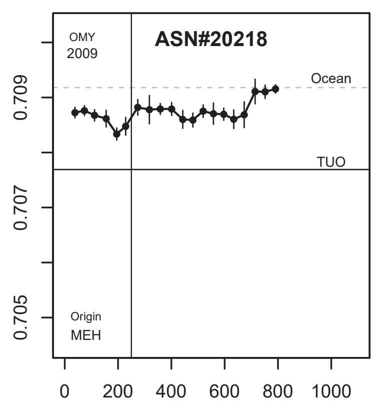
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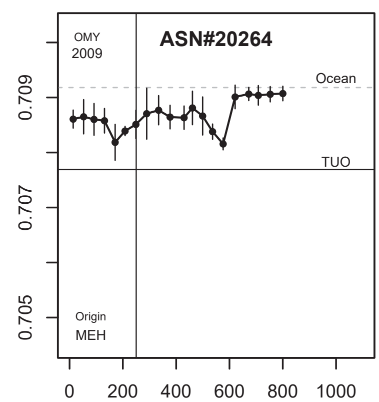
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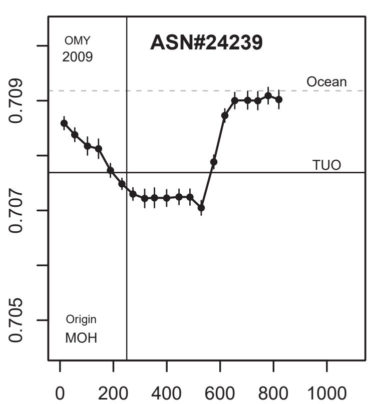
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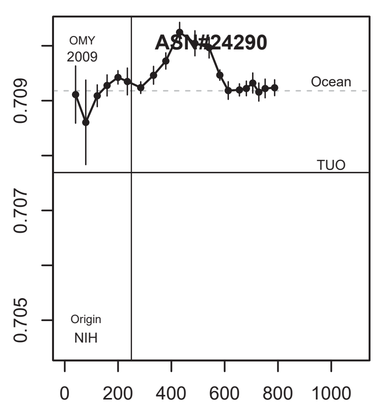
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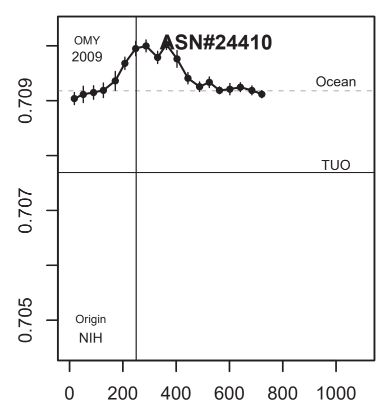
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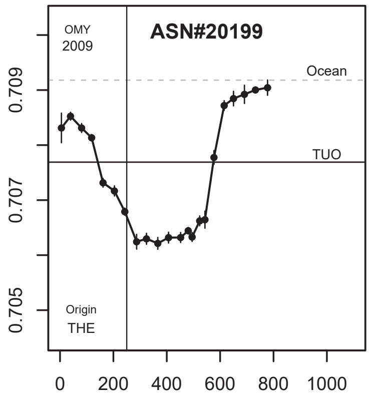
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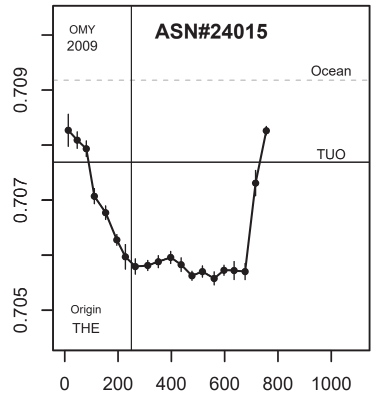
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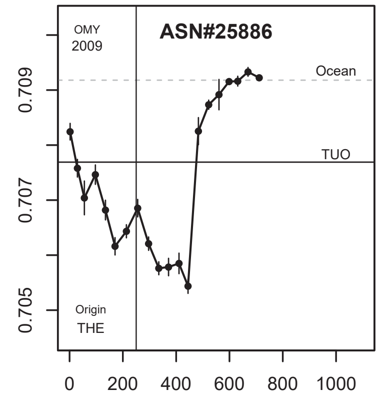
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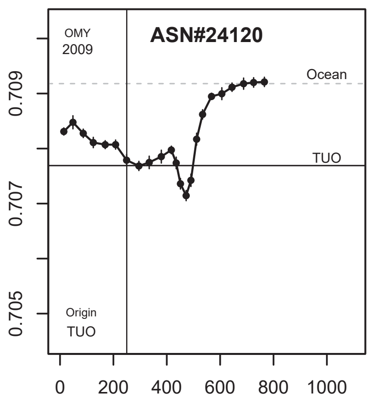
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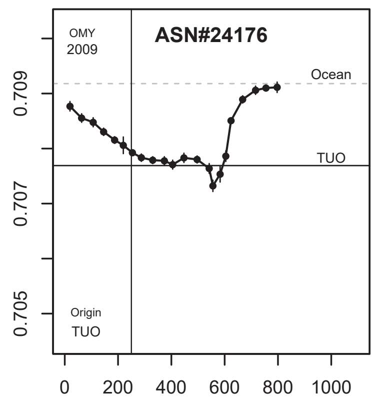
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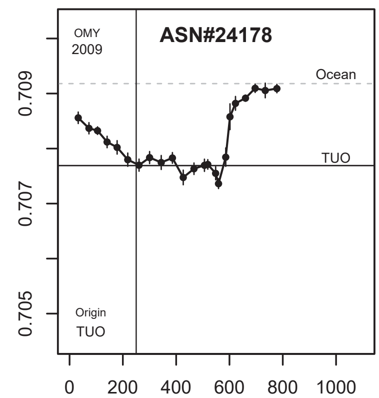
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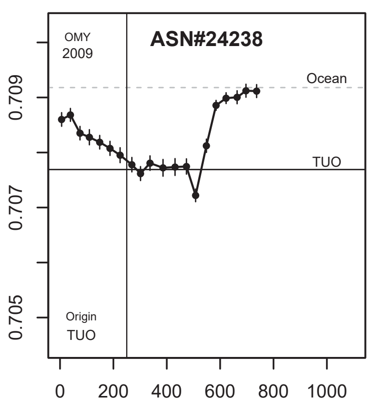
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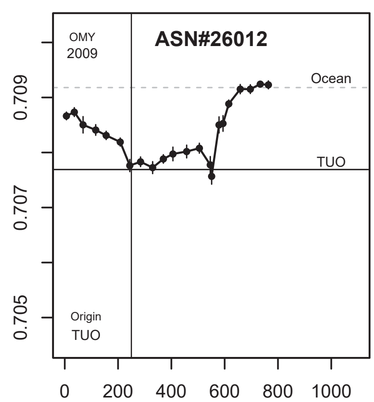
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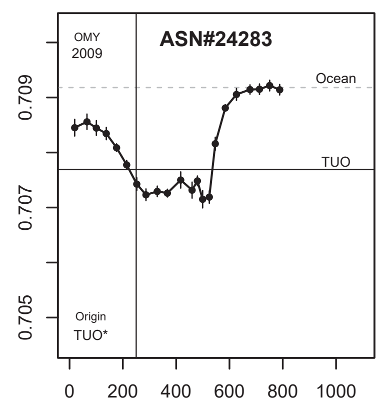
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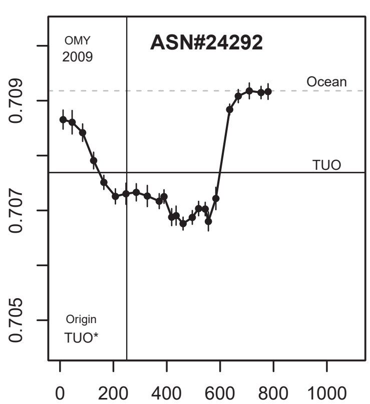
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Study Report W&AR-11
Chinook Salmon Otolith Study

Appendix B

Response to Draft Study Report Comments by U.S. Fish and Wildlife Service

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RESPONSES TO DRAFT STUDY REPORT COMMENTS BY U.S. FISH AND WILDLIFE SERVICE

As part of the ongoing studies under the Integrated Licensing Process (ILP) for the Don Pedro Hydroelectric Project (Project), the Turlock Irrigation District and the Modesto Irrigation District, co-licensees of the Project (collectively, the Districts) conducted a study to identify the geographic origin and early life history rearing and emigration patterns of Tuolumne River fall-run Chinook salmon during above- and below-normal water year (WY) types. The draft report for W&AR-11 was provided to relicensing participants on March 16, 2015, for 30-day review. Comments on the draft report were provided on April 23, 2015 by the U.S. Fish and Wildlife Service (USFWS). This appendix repeats the USFWS comments and provides the Districts' response to each.

Page 4-5, Figure 4.2-2: How did the study address the overlap of the Tuolumne River with the Yuba River?

Although there is some geographic overlap of Sr isotope signature in various locations along the west slope of the Sierra Nevada, we are confident in the Tuolumne and Yuba River natal assignments made for this study. As stated in Appendix A, *Identification of Natal Origin*, the natal signature was determined by averaging the 87Sr/86Sr values that correspond with the otolith material deposited immediately after onset of exogenous feeding (but prior to emigration from the natal river). Linear discriminant function analysis (DFA) assignments for mean natal value were used to determine the river or hatchery of origin, with a mean 87Sr/86Sr value of 0.70823assigned to the Yuba River based upon 19 juvenile otolith samples collected in 2002, and mean 87Sr/86Sr values ranging from 0.70757 to 0.70783 assigned to the Tuolumne River based upon 54 juvenile otolith samples collected 1999–2011, as well as seven water samples collected in 1998 and 2013 (Table 3, Appendix A). However, fish that were assigned to the Yuba River by the DFA consistently had a low (<0.5) posterior probability of assignment to the Tuolumne River. As shown in Table 4 (Appendix A), the DFA assignments misclassified one of the 19 known Yuba River juvenile samples as originating from the Tuolumne River (5% error) and 5 of 61 known Tuolumne River juvenile samples as originating from the Yuba River (8% error). Since it is unlikely that a large number of wild Yuba River fish stray into the San Joaquin basin tributaries, individuals assigned to the Yuba River by the DFA were instead identified as of likely Tuolumne-origin (or "TUO*" in Appendix A) and excluded from further analysis because of the uncertainty.

Page 4-7: The report should perform a multivariate analysis to examine effects of flow regime, temperature and spawner density, similar to the analysis done by Zeug et al. (2014). In particular, the acre-days of floodplain inundation below (values based on U.S. Fish and Wildlife Service 2008) should be examined as a potential independent variable.

The comment invites an analysis of juvenile abundance in relation to potential explanatory factors analyzed by Zeug et al (2014) (i.e., spawner density, flow, temperature) as well as the influence of the duration of floodplain inundation during rearing. While the present study was not designed to examine interannual variations in juvenile production or subsequent escapement, the fact that no consistent differences in estimated growth rates were found for the outmigration years sampled (see also response to comment on Page 5-11) indicates that such a factorial data exploration would not be expected to provide additional insights into factors affecting juvenile growth trajectories or early ocean survival.

Page 5-11: Are there any density-dependent effects that might partially explain the observed year to year variation on growth rates? The statistical significant difference in growth rates given in Figure 9 of Appendix A should be given here. There is a limited ability to draw conclusions based on the small sample size (26 fish in 2003 and 5 fish in 2009).

As stated in several locations in the report, the evaluation of patterns in size and age at exit and growth rates for the below normal WY types represented in this study should consider the relatively small sample size (n=31 from outmigration years 2003 and 2009) vs. above normal/wet WY types (n=238 from outmigration years 1998–2000). However, the comment also appears to suggest that density-dependent competition for food resources within riverine, floodplain, and estuarine environments may be reflected in inter-annual variations in growth rates of juvenile fall-run Chinook salmon originating from the Tuolumne River. Although the present study was not designed to compare rearing densities by year or location, we undertook an additional analysis of individual growth trajectories accounting for ontogeny (i.e., variation in growth rates with size/age of fish) in order to further explore whether the mean increment widths (mean ±1SD) reported in Table 5.2-1 (and shown in Figure 9 of Appendix A) indicate variation in growth rate by WY and/or rearing location. Results indicate that no consistent differences in juvenile growth rates were observed by location, outmigration year or WY type in this study (see new Figures 5.2-2 and 5.2-3 in the report).

Page 6-1: "While these patterns are suggestive of a positive relationship between flow and the successful emigration of wild fish that later return as adults, confirmation of this relationship based on (Water Year) WY type should consider the relatively small sample size for below normal/dry WY types (n=31) vs. above normal/wet WY types (n=238)." While it *is* true that care must be taken when making inferences from small sample sizes, *it* is also true that the small sample sizes are the result of poor conditions. That is, that the sample size would likely have been larger had conditions during WY s 2003 and 2009 been adequate to ensure sufficient juvenile survival. Lateral, off-channel habitats (e.g. floodplain and side-channel habitats) are more likely to inundate during wetter year types, and have been shown to increase growth and survival in rearing juvenile Chinook salmon (Jeffres et al. 2008; Sommer et al. 2001; Junk et al 1989).

The Districts are well aware of the existing literature comparing fish sizes reared in floodplain and riverine environments by Sommer et al (2001) as well as studies showing increased growth in warmer side channel habitats (e.g., Jeffres et al. 2008, Limm and Marchetti 2009). While the commenter appears to suggest that inter-annual growth variations may be evident on the Tuolumne River, there is no support for this assertion in the current study because no consistent growth rate patterns were observed between WY type or rearing location (Tuolumne River vs Delta) in the present study (see also response to comment on Page 5-11).

Periods of high and low escapement of Chinook salmon originating from the Central Valley tributaries have been associated with climate driven changes in ocean conditions (MacFarlane et al 2005; Lindley et al 2009) and have been correlated with runoff patterns resulting in flood control releases and extended San Joaquin River basin outflows during spring (Speed 1993; TID/MID 1997, Report 96-5). For this reason, the low sample sizes of fish originating from below normal WY types may be attributable to a combination of factors potentially ranging from high predation rates in the Tuolumne River and Delta, to potentially poor growth conditions in riverine and estuarine habitats leading to reduced size at ocean entry, or to poor growth conditions in the Pacific Ocean. The present study was not designed to examine interannual variations in juvenile production or subsequent escapement, only the contributions of various size classes at emigration to subsequent spawner returns.

Page 6-2 states: "Based on Sr isotope ratios (87Sr/86Sr) and otolith microstructural features, the study results suggest that mean fish size at exit from the Tuolumne River showed no apparent relationship with WY type, with the exception of outmigration year 2000 when mean fish size was significantly different ($p<0.005$) from the other four years of the study. Mean fish size at freshwater exit from the Delta also did not exhibit a relationship with WY type." Is it reasonable to draw conclusions on whether or not there exists a relationship between WY type and mean fish size, given the small sample size representing below normal WY type? The sample size for dry WY types was significantly lower (2003 and 2.009 sample size = 31 fish; 15.5 fish on average per year) than wet year types (1998, 1999, & 2000 sample size = 238 fish; 79.3 fish on average per year).

As indicated in literature referenced in other comments, because studies of floodplain habitat rearing have indicated differences in fish sizes for fish reared within in-channel vs. floodplain and off channel habitats (e.g., Sommer et al 2001, Jeffres et al 2008) there is some basis to compare the results of the present study by WY type. That is, if floodplain habitats consistently provided growth benefits for rearing salmon, the high flows occurring during the above normal/wet WY types (i.e., 1998–2000) would be expected to provide evidence of enhanced growth conditions in comparison to the below normal/dry WY types represented (i.e., 2003, 2009).

Although the present study was not designed to examine interannual variations in juvenile production or subsequent escapement (see also response to comment on Page 5-11), additional analysis to standardize estimated growth rates to fish size (age), and thereby correctly account for ontogeny, indicates a high degree of growth rate variability within and between WYs and across otolith size (age) (see new Figure 5.2-3 in the report). While WY 2003 (dry) exhibits the highest estimated growth rates, variability during this year was also relatively high, and within the uncertainty of the data, it is not possible to state whether specific growth rates were in fact greater in WY 2003 than other years included in the study. The final report text has been modified accordingly.

Page 6-3: Under this discussion (Section 6.2) on growth and residence, the Districts should consider adding language discussing the potential that density-dependent factors may play a significant role in the variation in growth rate observed across years for Tuolumne River. For 2003 & 2009, a relationship could potentially exist between the low sample sizes and

the higher growth rates estimated for these years (if the low sample size is indeed indicative of low numbers of rearing fish) (see Table 5.2-1). Assuming a relationship between adult escapement numbers and juvenile rearing fish numbers: CDFW escapement values for 2003 and 2009 were 2,693 and 124 respectively; and escapement for 1998, 1999, and 2000 were 8,910, 8,232, and 17,873 respectively (representing the 3 highest escapement years over the past 28 years) (Azat 2014). This implies that significantly fewer numbers of rearing fish were present in 2003 and 2009 as compared to 1998-2000. Fewer rearing fish potentially means less competition and more resources (food & suitable rearing habitat) available, which could help to explain the higher growth rates.

While the commenter appears to suggest that inter-annual growth variations may be evident on the Tuolumne River, no consistent growth rate patterns were observed between WY type or rearing location (Tuolumne River vs Delta) in the present study (see also response to comments on Page 5-11). As stated in response to comment on page 6-1, the present study was not designed to examine interannual variations in juvenile production or subsequent escapement, only the contributions of various size classes at emigration to subsequent spawner returns.

Appendix A, Page 7, last paragraph: the text should say Fig. 9, Table 7, instead of Fig. 7, Table 9. There is no Table 9 in Appendix A.

Appendix A text has been corrected.

REFERENCES CITED IN THE RESPONSE TO COMMENTS

Jeffres, C., J. Opperman, and P. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83:449-458.

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APPENDIX I

REGIONAL ECONOMIC IMPACT CAUSED BY A REDUCTION IN IRRIGATION WATER SUPPLIED TO TURLOCK IRRIGATION DISTRICT AND MODESTO IRRIGATION DISTRICT: METHODOLOGY MEMORANDUM

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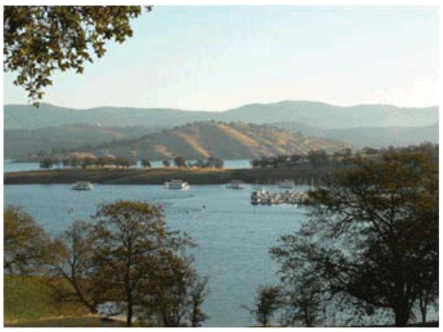

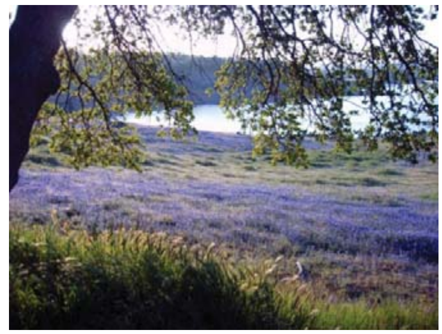

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Modesto Irrigation District

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
Susan Burke, Ph.D.
Cardno ENTRIX
Barbara Wyse, M.S.
Highland Economics
Under subcontract to: HDR Engineering, Inc.

March 2017

Estimating Changes in Agricultural Production Impact Assessment Methodology Technical Memorandum

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List of Acronyms and Abbreviations

CPI ....consumer price index

ET...............................evapotranspiration

FERC..........................Federal Energy Regulatory Commission

MID............................Modesto Irrigation District

Project ....Don Pedro Project

RDI............................regulated deficit irrigation

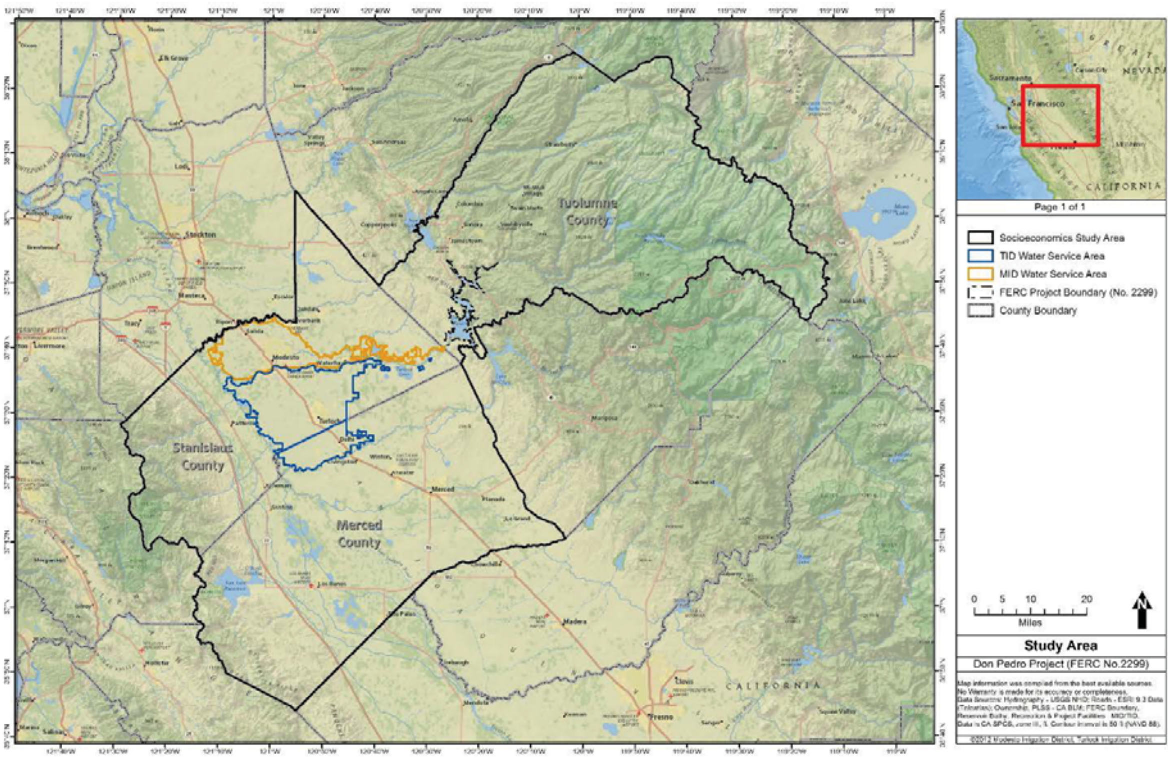
TID ....Turlock Irrigation District

WAR-15 ....Water & Aquatic Resources-15 Socioeconomics Study

1.0 INTRODUCTION

1.1 Purpose

This document presents estimates of potential effects to agricultural production and related sectors of the Merced, Stanislaus and Tuolumne Counties' economy from potential changes in allowable surface water diversions from the Don Pedro Project (Project) (Figure 1). The document is a companion piece to work previously completed for the Federal Energy Regulatory Commission (FERC) relicensing of the Project. Specifically, the document extends work presented in the Final License Application, Attachment C Study Report: Water & Aquatic Resources-15 Socioeconomics Study (WAR-15; TID/MID 2014a).



Source: TID/MID 2014a

Figure 1. Study area.

1.2 Overview

Assumptions and data used to estimate the effects to agricultural production and related sectors of the potential reduction in allowable surface water diversions to the Project are described below.

1.2.1 Project Life

The number of years analyzed corresponds to the 42 years (1971-2012) included in the hydrologic model of the Project (Table 1).

1.2.2 Data Sources

1.2.2.1 Water Supply

The hydrologic model estimated the annual changes in allowable surface water diversions for a 42-year period assuming a reduction in allowable surface water diversions. The example of the hydrologic operations model output shown in Table 1 includes an estimate of the number of acre feet diverted in the baseline year, assuming no reduction in allowable surface water diversions, and the number of acre feet diverted under a change in allowable diversions. The last column in Table 1 shows the model output as a percent of the baseline estimate. For example, in the model-year 1976, the estimated baseline water diversions are 923 thousand acre feet, compared to modeled output of 604 thousand acre or 65.5 percent of baseline.

Groundwater was assumed to be available up to historic pumping volumes. Annual average volumes were estimated to meet approximately 15 percent of total annual demand for irrigation supplies.

The analysis also assumes that water is not transferred between growers and water rates are unchanged from 2014 levels.

Table 1. Example of hydrologic model output, 40 % unimpaired flow.

Water Year	Water Year Type	Baseline 000s (000s acre feet)	Model Output (000 acre feet)	Model Output as a Percent of Baseline
1971	BN	881	881	100.0%
1972	D	972	972	100.0%
1973	AN	872	872	100.0%
1974	W	831	831	100.0%
1975	W	880	880	100.0%
1976	C	923	604	65.5%
1977	C	718	500	69.7%
1978	W	759	750	98.8%
1979	AN	884	884	100.0%
1980	W	859	859	100.0%
1981	D	923	923	100.0%
1982	W	777	777	100.0%
1983	W	759	759	100.0%
1984	AN	919	919	100.0%
1985	D	902	902	100.0%
1986	W	845	845	100.0%
1987	C	902	609	67.5%

Water Year	Water Year Type	Baseline 000s (000s acre feet)	Model Output (000 acre feet)	Model Output as a Percent of Baseline
1988	C	765	542	70.8%
1989	C	750	536	71.5%
1990	C	777	486	62.6%
1991	C	780	477	61.2%
1992	C	652	456	69.9%
1993	W	814	805	98.9%
1994	C	842	484	57.4%
1995	W	781	757	97.0%
1996	W	847	847	100.0%
1997	W	924	924	100.0%
1998	W	763	763	100.0%
1999	AN	896	896	100.0%
2000	AN	804	804	100.0%
2001	D	871	871	100.0%
2002	D	905	619	68.4%
2003	BN	891	869	97.5%
2004	BN	946	633	66.9%
2005	W	881	861	97.8%
2006	W	837	837	100.0%
2007	D	927	927	100.0%
2008	BN	889	578	65.0%
2009	BN	910	890	97.8%
2010	AN	832	832	100.0%
2011	W	831	831	100.0%
2012	D	897	897	100.0%
2013	C	819	718	88.0%
2014	C	700	382	55.0%
2015	C	645	341	53.0%

Source: Personal e-mail communication sent from Rob Sherrick, HDR to Susan Burke, Cardno, dated January 29, 2014. Water-Year Type based on the SWRCB SED categorization

The hydrologic model predicts that in only 24 of the 42 years (57 percent of years) water supply is 100 percent of baseline (Figure 2). In 6 of the 42 years (14 percent of years) water supply is predicted to be between 90 percent and 95 percent of baseline supplies. In 12 years (29 percent of years) the available water supply is predicted to be below 75 percent of baseline, with 5 of those 12 years (12 percent of years) below 65 percent of baseline supply.

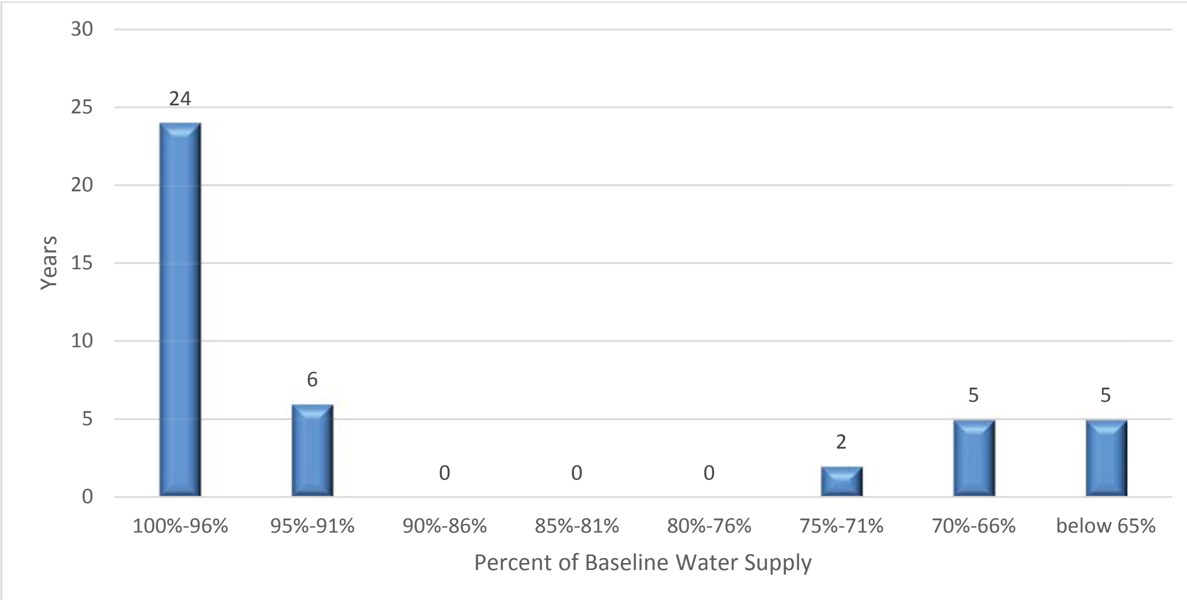


Figure 2. Number of Years of Predicted Available Water Supply as a Percent of Baseline

1.2.2.2 Economic Data

For a full description of all the data used in the economic model including, crop acreage, crop enterprise budgets, crop prices, crop yields, water rates, etc. see WAR-15, Section 5.1.3 and Section 6.

2.0 METHODOLGY

2.1 Background

The Districts provide irrigation supplies to over 230,000 acres, contributing an estimated annual average of $4.1 billion to the local economy through agricultural production and processing (TID/MID 2014a). This contribution can be understood by considering three components of agricultural production and processing (Figure 3).

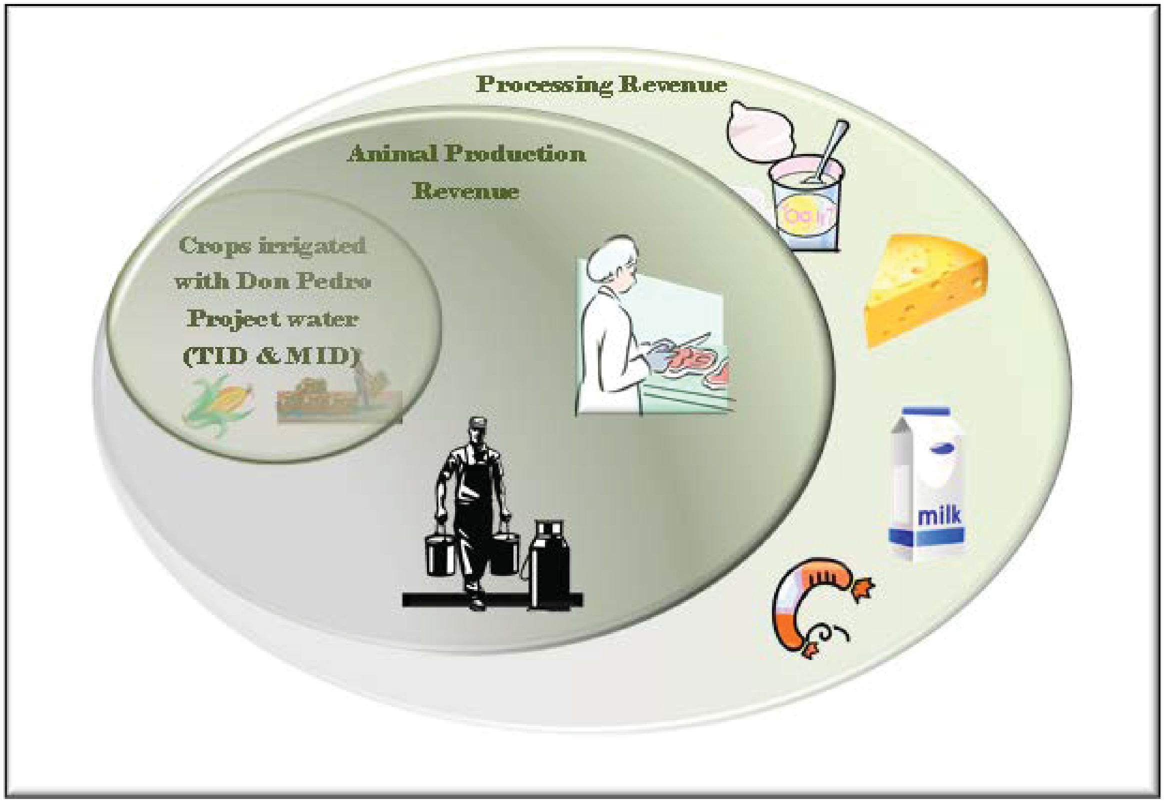
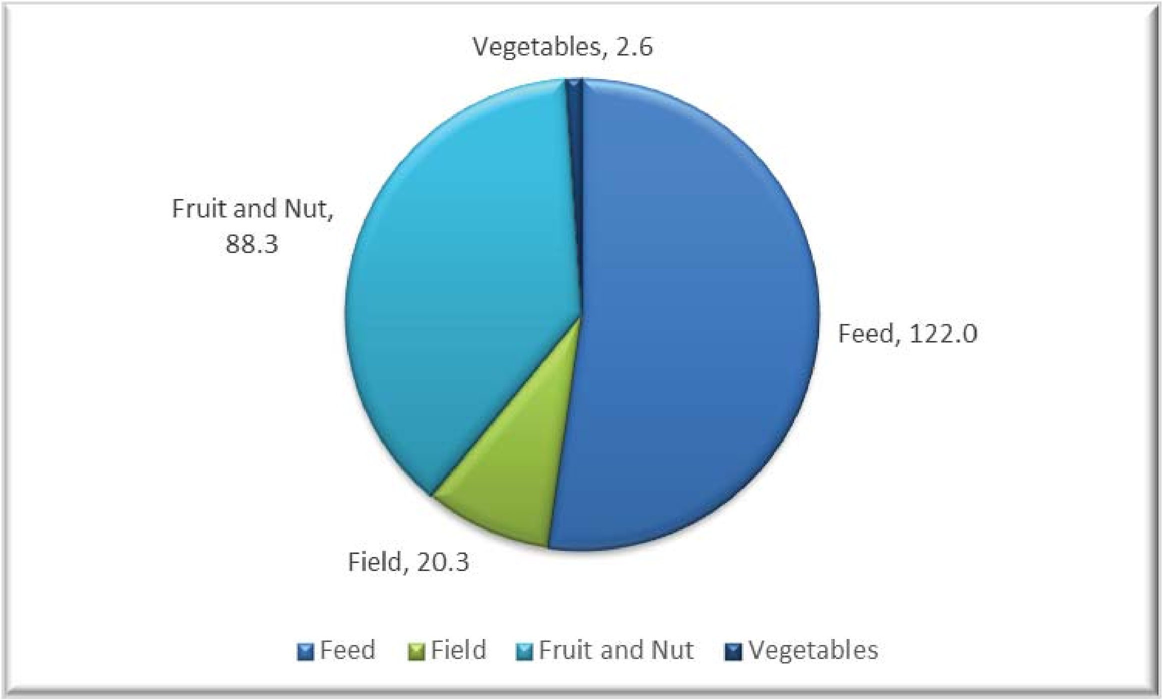


Figure 3. Components of the agricultural economy.

The first component is the value of the crop commodities grown on the approximately 230,000 acres that are irrigated with Project water. The agricultural industry is heavily invested in high value permanent crops, such as trees and vines and animal feed crops that support dairies and cattle and calf operations (Figure 4). Of the 230,000 acres approximately 23,000 acres, or 10 percent, is planted in annual crops not devoted to animal feed (vegetables and field crops). Feed crops comprise more than half the irrigated acres, with fruit and nut crops comprising approximately 38 percent of irrigated acres.

The estimated economic impacts presented in this memo include the value of all the inputs to crop production, referred to as “backward linkages”. These include seed and fertilizer costs as well as labor for planting, harvesting, pruning, etc. and costs such as pollination services are also examples of "backward linkages". Backward linkages are also referred to as indirect and induced effects.

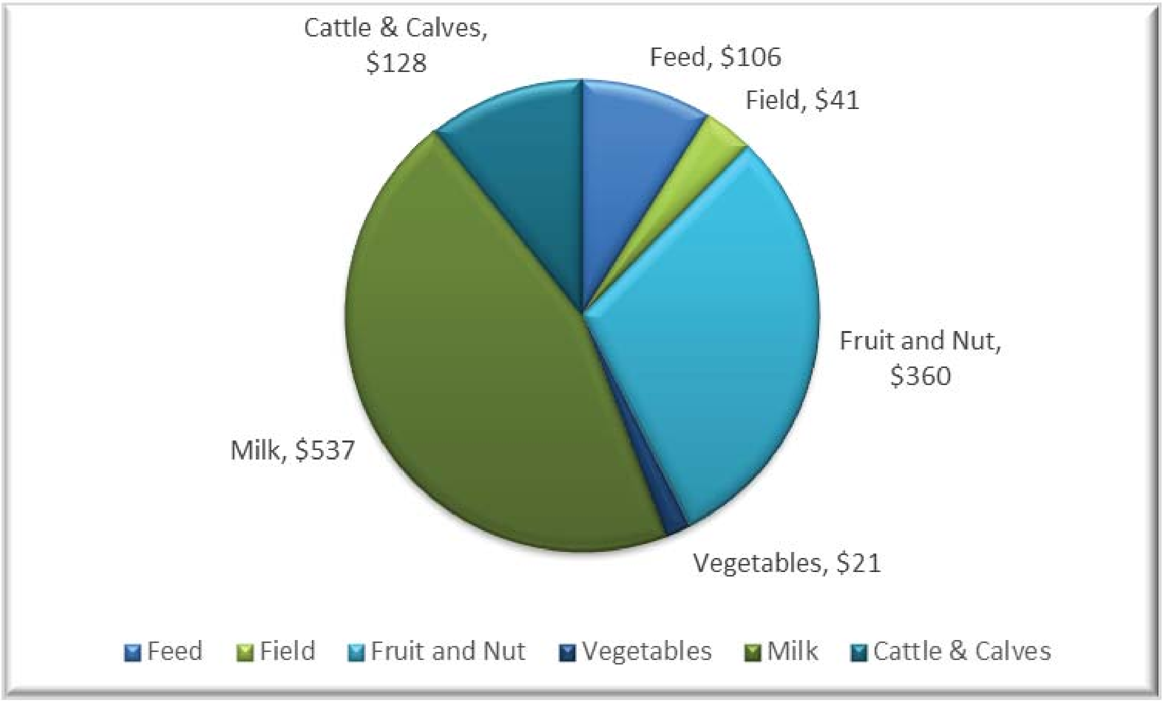


Source: TID/MID

Figure 4. Average annual acres irrigated with Project water by crop type (MID/TID, 2007 – 2011).

The second component of the agricultural economy is the value of animal commodities. The feed crops grown are used to produce milk and beef. Milk comprises the largest percent of total commodity value, estimated to be $537 million (annual average from 2007-2011). Cattle and Calves produce another $128 million. Combined animal production makes up 55 percent of the commodity value supported by crops grown with water delivered by the Project (Figure 5).

The estimates shown in Figure 4 are only the "direct" economic contribution to the local economy, measured as the production value of animal production and do not include the production value of the "backward linkages", or the "indirect" and "induced" economic contribution, which increase the total value of animal production.



Source: Cardno ENTRIX estimate

Figure 5. Average annual direct production value of commodity, 2007–2011, (2012 $ thousands)

The third and final component of the agricultural industry is the processing sector. The magnitude of production output in the region has given rise to a large agricultural processing sector in the region. See WAR-15 for the list of agricultural processing employers operating in Merced and Stanislaus counties. Conservative estimates place the number of jobs created by the agricultural processing sector alone at 6,540 (TID/MID 2014a). Combined with all the crop and animal production jobs, including backward linkages, the number of jobs in the region supported by crops irrigated with Project water is approximately 18,900.

The above summary of the value of the crop and animal production and the processing industry is used as the baseline against which impacts of a reduction in allowable surface water diversion are estimated. This analysis uses the following models to estimate potential impacts for each component of the agricultural economy: (1) modeled on-farm irrigated crops revenue using SWAP; (2) dairy and livestock production using spreadsheet model; and (3) three-county processing using IMPLAN. All backward linkages of on-farm irrigated crops using IMPLAN. See WAR-15 for a detailed description of these models.

The models were run sixteen times, each time reducing the percent of surface water available, compared to baseline, in 5 percent steps. This produced an array of estimated impacts that are used in combination with the hydrologic operational model output to estimate the impact of a reduction in surface irrigation supplies over the 42-year project life. Results of the three models are displayed below. Following the representation of the three individual models' results is a summary that combines the individual model results with an example hydrologic output to show how the model results are used to estimate the impact of any particular scenario.

2.2 On-Farm Irrigated Crops – Modified Statewide Agricultural Production Model

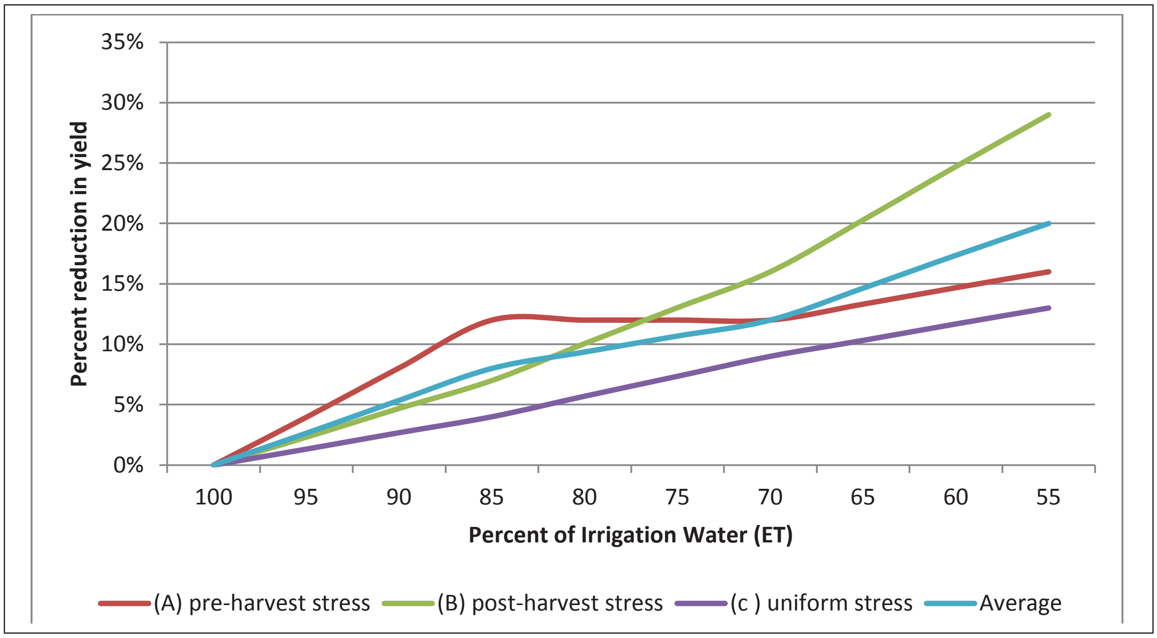
See WAR-15 for a description of the modified SWAP model as well as the reasoning for using this model. A few modifications were made to the model to accurately represent Modesto Irrigation District (MID) and Turlock Irrigation District (TID). Those changes included "turning-off" the water transfer mechanism because there is no inter-district transfer policy and TID does not have an intra-district water transfer policy. The other modification made was to modify the way the model estimates the response of growers that are growing perennial crops (trees and vines). For perennial crops the revised model estimates a reduction in irrigation supplies as a reduction in yield, rather than a reduction in acres.

The yield responses to perennial crops was estimated based on a literature review of studies that test the yield response of trees and vines to stress irrigation. This literature is described below.

2.2.1 Perennial crops

2.2.1.1 Almonds

Although almond trees are considered drought tolerant (Fereres and Goldhamer 1990; Hutmacher et al. 1994; Torrecillas et al. 1996), there is no doubt that irrigation is critical in producing high yields of top quality nuts (Castel and Fereres 1982; Prichard et al. 1993; Nanos et al. 2002). Water stress can negatively affect both the primary yield components in almond, kernel size (Girona et al. 1993) and fruit load (Goldhamer and Smith 1995; Goldhamer and Viveros 2000; Esparza et al. 2001). Figure 6 shows the results of a field trial that tested yield (measured as kernel yield) over a range of reductions in ET, as well as a range of delivery patterns (Goldhamer, D.A. 2006). The yield ranges between a 4.0 percent reduction when ET is 85.0 percent (under a uniform stress delivery pattern) of full ET up to a 29.0 percent reduction when ET is 55.0 percent of full ET (under a post-harvest delivery pattern). The average of the yield response curves presented in Figure 5 was used to estimate impacts of a reduction in allowable surface water diversions in this study. Where the hydrologic model results estimated reduction in allowable water diversions greater than 55 percent, the average curve was extrapolated



Source: Goldhamer, D.A. 2006. NOTE: the Goldhamer study estimated the yield response to an 85.0 percent, 70.0 percent and 55.0 percent change in crop ET. For exposition purposes the data presented in the graph includes a liner extrapolation for the points in between the data available in Goldhamer.

Figure 6. Percent change in almond yield for variations in applied water.

2.2.1.2 Peaches

In a deep soil under flood irrigation, peach trees have been shown to survive and remain productive for four consecutive years with no irrigation between June and October (Larson et al., 1988; Johnson et.al., 1992). However, 'Water stress in late summer also interferes with flower bud development and can cause fruit defects the following year. Fruit doubles (see photos), deep sutures (see photos), split pits and smaller fruit size can all result from water stress (Handley and Johnson, 2000; Johnson and Phene, 2008).

Without information on which to base an annual yield response of peaches to stress irrigation the assumption was made to use a linear yield response curve. So that a 10 percent reduction in irrigation water would induce a 10 percent reduction in peach yield.

Source: University of California Fruit Report., http://ucanr.edu/sites/fruitreport/Irrigation/Deficit_Irrigation_Strategies/

Deep suture in nectarine cause by water stress.

Source: University of California Fruit Report., http://ucanr.edu/sites/fruitreport/Irrigation/Deficit_Irrigation_Strategies/

Water stress late in the previous summer

2.2.1.3 Grapes

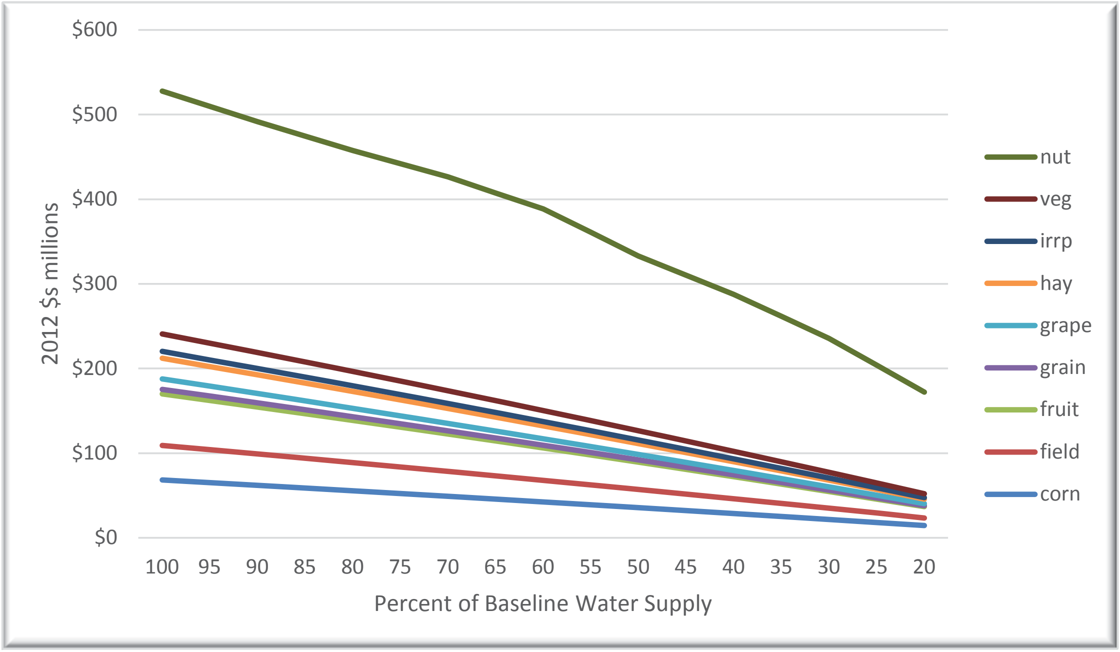
In the late 1990s growers began adopting a practice called regulated deficit irrigation (RDI) on wine grapes. RDS means applying less than the full potential water requirement on vines with a drip irrigation system to achieve properly timed mild water stress. The results are improved wine quality and conservation of water and energy. For the purposes of the SWAP model we assume that grapes grown in TID and MID are already being given the desired volume of water under the RDI practice and reductions in irrigation supplies that could result from the relicensing go beyond the desired RDI levels.

The SWAP model estimates a range of yield reductions between 2 percent for a 90 percent irrigation water supply, up to a 13.0 percent reduction in yield, for a 60 percent irrigation water supply.

2.2.2 SWAP Results

The SWAP model was run multiple times, each time reducing surface water irrigation in 5-percent steps relative to baseline irrigation supplies. As a consequence of constraining water transfers the modeled response of the crops to a reduction in irrigation supplies is linear, except for nut crops, where the yield curves were modified as described above (Figure 7).

When surface water irrigation supplies are 100 percent of baseline the value of crop production is estimated to be greater than $500 million. As the percent of surface water irrigation supplies declines relative to baseline the crop values also decline.



Source: Cardno ENTRIX

Figure 7. Estimate of Crop Production Value for Declining Surface Irrigation Supplies (direct only)

2.2.3 SWAP Model limitations and shortcomings

SWAP is a short-term model, estimating one-year impacts to a change in surface water irrigation supplies. The model does not account for carry-over impacts from one year to the next. The implications of that on the estimated economic impacts of a change in surface water is described below.

- The impact that stress irrigation has on tree yield is felt in both the year in which the stress occurs and in the subsequent year, however SWAP does not account for this lag effect from stress irrigation.
- If changes in surface water availability occur with significant frequency over the 42-year study period it could be assumed that a structural change would occur in the agricultural sector. For example, the hydrologic model estimates that in nearly 30 percent of years available water supply will be less than 75 percent of baseline. A reduction of water supply reliability of this magnitude could change the structure of the agricultural industry. The number of cattle than can be supported with feed crops may decline, or current operations may consolidate. Processing plants could relocate, reduce shifts (e.g. run at less than full capacity) or close as a consequence of increasing uncertainty in the availability of raw inputs. This could cause a change in the cropping patterns that is not currently accounted for in the annual SWAP model.

- The relatively high percentage of both perennial crops (trees and vines) and crops that support animal operations reduces the number of short-term (annual) grower responses that the model can represent.

2.3 Dairy and livestock Production

Estimating the response of livestock (dairy and cattle/calf) operations to a change in irrigation supplies, and consequently a reduction in the supply of animal feed crops, is made difficult because of the diversity of responses available to operators. The economic model assumes, as rational economic agents, with the objective of maximizing profit, dairy farmers and ranchers respond to a change in locally grown feed supplies with the least cost (i.e., reduction in profit) solution. Solutions may increase cost, reduce revenue, or both. An operation's ability to respond can depend on several individual characteristics of the operation including the degree to which land and other capital is leveraged, reliance on purchased feed, current scale relative to the minimum efficient scale, and marketing and contractual commitments.

The model assumes that groundwater is not available above historical pumping volumes and as such livestock operations may have limited ability to find alternative sources of feed supply particularly roughage. Roughage, in the form of corn silage and alfalfa hay, accounts for approximately 40 percent of feed costs in the diet of dairy cows. Irrigated pasture accounts for the majority of roughage feed to beef cattle. All of these crops are grown with irrigation water supplied by the Project. See TID/MID 2015 for a full description of animal feeding requirements.

The estimated reduction in animal production (e.g., milk and beef) caused by a reduction in feed crops grown with Project water was modeled two ways, representing the ends of a continuum of likely outcomes, e.g. a minimum impact and a maximum impact. The maximum impact was modeled assuming a linear relationship between the number of acres of feed crops and the volume of animal production. Tying the change in the value of animal production to a change in the availability of feed assumes that it is not economical to transport feed crops to replace the crops that could not be grown locally due to lack of irrigation water. This is a reasonable assumption given that corn silage, one of the main components of roughage, is heavy and therefore expensive to transport, and irrigated pasture is also not 'transportable'. However it is likely that some portion of the animal feed crops no longer grown locally could be imported. The estimated minimum impact assumes that all of the roughage can be imported and or the animal diet can be modified to replace roughage which cannot **be imported.**

The maximum impact assumes that a reduction in animal production could be the result of either reducing herd size or switching feeds, or a combination of both. Reducing herd size is an expensive option for animal operations as profits are sensitive to the scale of production. However, in cases of extreme drought this has happened; in Texas, for example, herd size fell 12 percent from 2011 to 2012 (Thibodeaux 2013). Operations could also be moved out of state. Several states have been enticing California dairies to move to their states (Daniels 2015).

Finding substitute rations for cows when high-quality roughage is not available can also be expensive. This minimum impact is assumed to maintain the production volume of milk. The impact is reflected in an estimate of declining profit for animal operations and is discussed in more detail in the regional economic section (2.4) that follows because the impact is measured in terms of declining labor income for operators versus a reduction in the value of animal commodity production.

Figure 8 shows the estimated value of animal production under the maximum impact assumptions, the minimum impact assumptions and the average of the two. Under the maximum impact the value of animal production declines from approximately $660 million per year to a low of $234 million when available water supplies decline to 20 percent of baseline. Under the minimum impact there is no change in the production value regardless of the percent of available water supplies.

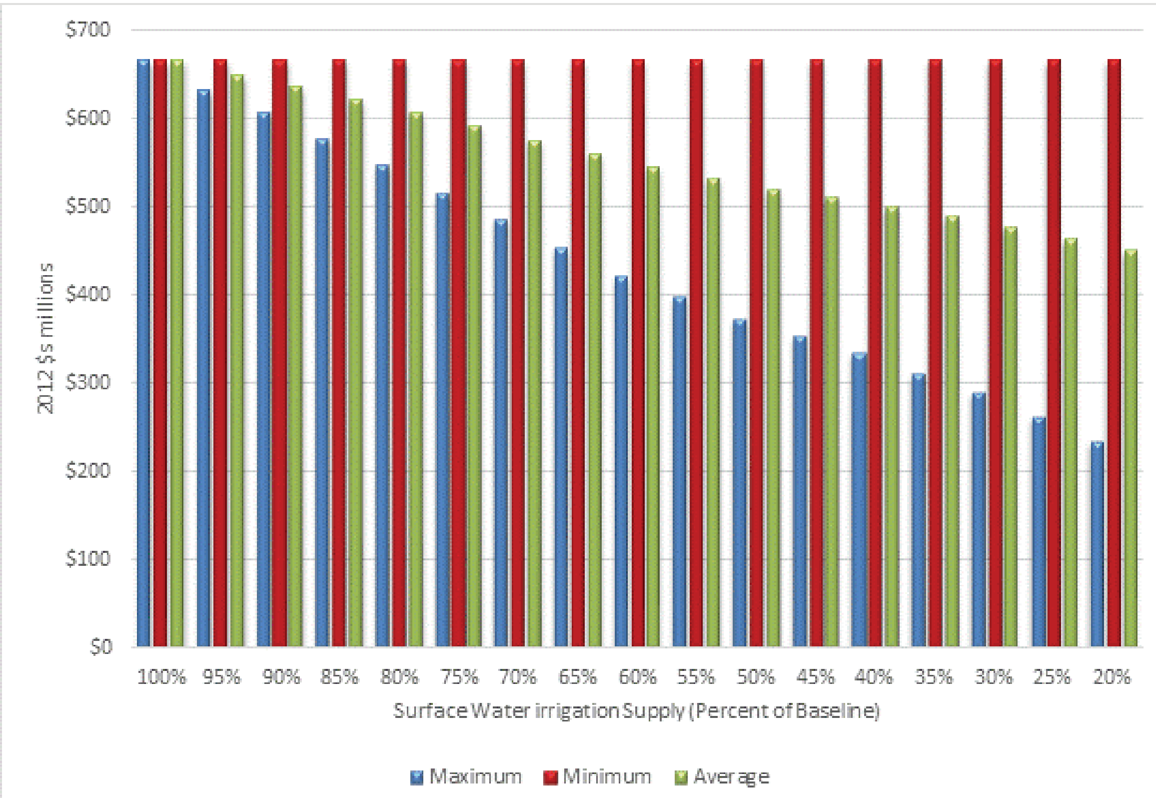


Figure 8. Estimate Minimum, Maximum and Average Reduction in Animal Production Measured in Value of Production (direct only)

Figure 9 shows the same information that was presented in Figure 8, except the values are expressed as a percent of the baseline value of production. As before, under the minimum impact assumptions the value of animal production is 100 percent of baseline regardless of the percent of available surface water supply. Under the maximum impact assumptions, the value of animal production falls to approximately 34 percent of baseline when available water supply is 20 percent of baseline, reflecting some flexibility in the operators' ability to manage for a shortage in roughage.

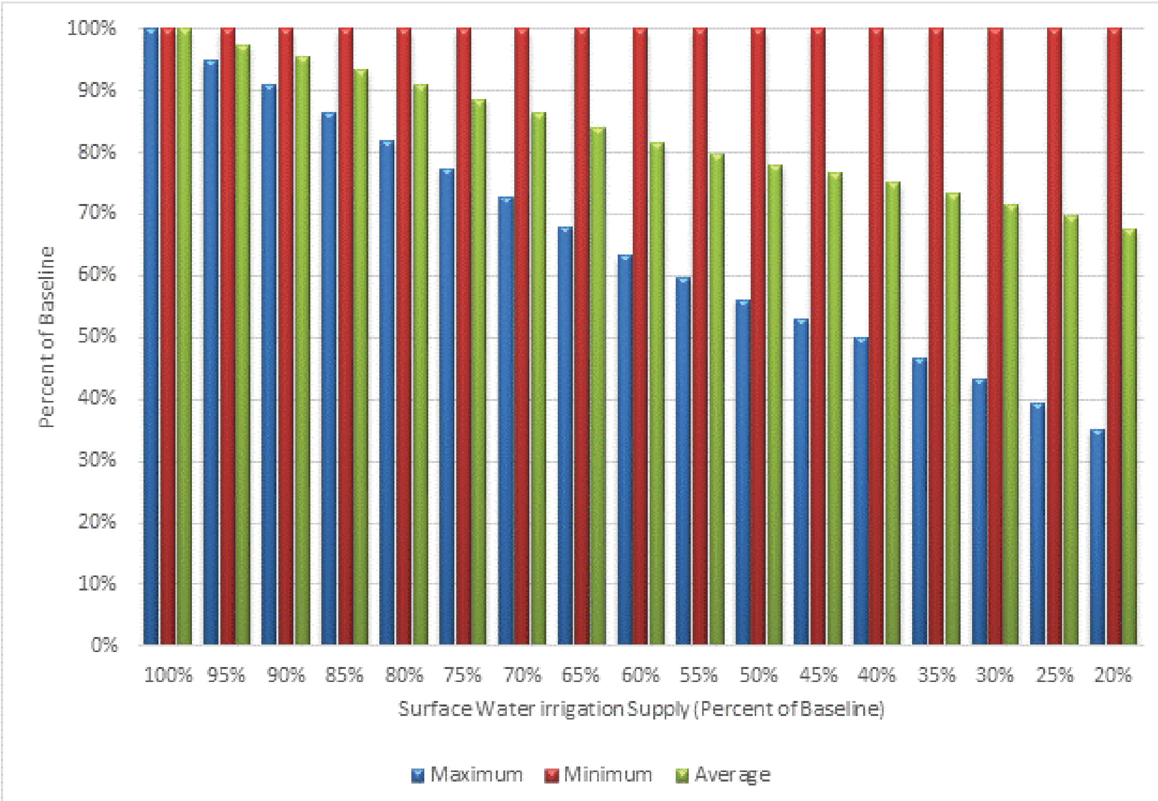


Figure 9. Estimate Minimum, Maximum and Average Reduction in Animal Production, Measured as a Percent of Baseline (direct only)

2.4 Regional Economics

This section presents estimates of how changes in crop production and animal production, presented above, translate into economic impacts (jobs, income, and output) in all sectors throughout the regional economy. The IMPLAN model was used to estimate economic impacts. This is the same model that was used to estimate the baseline economic benefits presented in WAR-15.

Economic impacts are estimated and presented in terms of total output, employment, and income supported by irrigation water deliveries from the Districts. As described in detail above, total economic impacts include not just the direct benefits of crop production in the agricultural sector, but also indirect benefits to other sectors that are closely tied to agriculture, such as agricultural suppliers and food processors. A reduction in allowable surface water supplies that affects the level of crop production (such as wine grapes), reduces the amount of farm labor, chemicals, trucking, warehousing, packing, and other inputs purchased by farms – sometimes referred to as backward linkages.

Additionally, as fewer crops are produced, there is less availability of crops as inputs to canneries, wineries, and frozen food facilities to process into higher valued products, potentially resulting in less processing - sometimes called forward linkages. Consequently, reduced agricultural production in the Districts' service area may affect the level of economic activity and associated jobs and income in economic sectors throughout the study area.

Another impact included in the analysis is a measure of the effects that reductions in household income may have to restaurants and shops in the study area. If farm workers, farmers and manufacturing processor employees have less disposal income to spend. These impacts are referred to as induced impacts. Total impacts refer to the sum of direct, indirect and induced impacts.

The magnitude of total economic impacts depends not only on the magnitude of the initial water supply and subsequent crop production changes, but also on several other variables. For example, a ten percent reduction in crop production does not necessarily mean a ten percent reduction in crop processing. Processing sectors may be able to adjust to obtain required crop inputs, or if some portion of crop production is currently exported outside the three-county study area, then changes in production may affect exports only and not local processing plants. Likewise, effects may not be linear. For example, a twenty percent reduction in crop production may cause an impact on processing that is more than double the impact of a ten percent reduction in crop output. Processors may be able to make adjustments to small changes in crop production, but may reach a point where adjustments are no longer feasible and may be required to reduce output. In the extreme case, processing plants could close if reliable local crop supplies are not available. Recognizing that effects on processors may not be proportionately the same as impacts on irrigated agricultural production, a range of potential impacts is estimated for forward-linked industries such as food processing and animal production.

Findings indicate that reducing irrigation water supply to the Don Pedro service area will impact output, employment, and income, with the largest expected impact on local area income.[1] Estimated adverse annual employment impacts vary from a reduction of 460 to 1,420 jobs in a 90 percent water year to a reduction of 4,110 to 10,960 jobs in a 25 percent water year. Estimated adverse annual income impacts vary from a reduction of $38.0 million to $72.2 million in a 90 percent water year to a reduction of $351.6 million to $595.7 million in a 25 percent water supply year. The decline in employment in the 25 percent water supply year equates to a 22 to 58 percent decrease from employment supported by the Districts under baseline water supply conditions, while the reduction in labor income equates to a 48 to 81 percent decrease in income supported by the Districts under baseline water supply conditions.

The following sections provide detail on the approach and results.

2.4.1 Approach to Impact Estimation

This section describes the approach to impact estimation, including general steps and methods for backward and forward linkages, and limitations and assumptions.

[1] Income impacts are higher than employment impacts, particularly in the lowest water supply years due to our assumption that any change in permanent crop revenue (i.e., a yield reduction) directly translates, dollar for dollar, into an income reduction.[1] As the same acres are in cultivation, we conservatively assume no direct reduction in farm employment on permanent crop acreage.

2.4.1.1 Backward Linkages: Crop Production

For backward linked industries providing inputs to District agricultural operation, and in accordance with IMPLAN and general I-O methods, we assume linearly proportionate impacts. However, our approach differs for annual versus permanent crops.

For annual crops, the reduction in output is expected to be largely due to a change in harvested acreage, with a consequent reduction in all variable input costs. The change in estimated annual crop production value is the direct output change to be modeled in IMPLAN, e.g. for every one percent change in irrigated annual crop production value, there is a one-percent drop in the direct and total employment, output, and income supported by agriculture in the Districts' service area. Employment reported in this analysis represents both full and part-time jobs. Note, employment in particular may be impacted differently, as employers may reduce hours or wages in response to reduced agricultural production, but not total number of jobs.

For permanent crops, fallowing for a single year at a time is not an option. The assumption used in the model is that growers can deficit irrigate but do not reduce acres of vines or trees. Reduction in crop production are caused by reduced yields, not reduced acreage. Reduced yields in permanent crops reduce revenue, but will have no effect on fixed costs (which are high for permanent crops), and little effect on non-labor variable costs. In other words, reduced water supplies and associated reduced yields would be expected to lower such variable costs as irrigation labor costs and harvest labor costs, but are expected to have relatively little effect on other, non-labor input costs. As such, the permanent crop reduction in revenue translates nearly dollar for dollar into an income change, either to farm laborers or farm proprietors (rather than an output effect)[2], with no effect on direct farm employment and no effect on demand for indirect inputs. As such, all multiplier effects associated with reduced water supply and deficit irrigation on permanent crops are induced effects related to reduced income to, and associated reduced spending by, farming households.

2.4.1.2 Forward Linkages: Crop and Animal Product Processing

In terms of forward linkages, there is significant uncertainty regarding the level of dependence of local processors on local crop production although close geographic proximity is important. In particular, for fruit and vegetable manufacturing facilities, geographic proximity is important because: 1) less transportation time means fruits and vegetables can fully ripen before harvest to minimize spoilage and maximize flavor, and 2) smaller distances mean transportation costs are lower. For the dairy processing sector, close proximity is also very important as fluid milk is heavy and costly to transport.

The question is: if local crop production declines, will local processors continue to obtain sufficient raw crop inputs, or will processing production also potentially decline? If so, to what extent will it decline? Ideally, an analysis of impacts on local animal producers and processors would draw from extensive local data on these relationships, including interviews with local processors and industry experts. However, due to lack of available information from the local

[2] We enter the change in crop production revenue as a direct 'income effect' in IMPLAN.

processing industry due to confidentiality concerns, several types of published data sources, largely based on inter-industry industry data in IMPLAN, were used to understand potential forward linkages effects of reduced water supplies.

The drawback to using IMPLAN inter-industry relationship data as the main source of information on the processing sector dependence on local crop and animal production is that IMPLAN crop categories are aggregated such that all vegetables are grouped together, and all fruits (including grapes) are grouped together. This aggregation can obscure an understanding of the dependence of processors on specific crops.

Furthermore, IMPLAN data as well as anecdotal evidence indicate that there is significant 'cross-hauling' in the Central Valley within each crop category, with similar crops shipped back and forth across county lines. This is due not only to the aggregation of crops into crop categories, but also due to contractual arrangements and specific demand requirements within each crop type. For most crop production sectors, IMPLAN data simultaneously indicate substantial importing and exporting of each crop type, which limits our understanding of how changes in production would influence processing sectors.

Aside from IMPLAN data, impacts of reduced crop production on processing sectors will be greater if sourcing of crops from other areas is not attractive due to such factors as cost, reliability, and quality. Neighboring counties to the study area include San Joaquin, Madera, and Fresno Counties, all of which are significant agricultural production counties, produce many of the same crops at similar quality to those in the study area. However, despite the abundant nearby agricultural production, for several reasons it is not clear to what extent local processors would be able to obtain crops from neighboring counties (or from other agricultural areas within the study area) to offset reductions in crop production in the Districts' water service area. First, growers and processors have established relationships and contracts, and it may be very difficult for processors to obtain sufficient supplies on a short-term basis to offset production reductions that would occur in just the low water years. Second, water scarcity is affecting agricultural areas throughout California. It is likely that low water supply years in the Districts' service area will also be low water supply years for many other agricultural areas in California, thereby reducing agricultural output throughout the State and severely limiting the availability of alternative crop sources for study area processors.

Due to this significant uncertainty regarding the effect on local processors, two scenarios of possible 'direct' crop and animal product processing sector impacts are developed:

- <u>High Impact Estimate:</u> The high impact estimate assumes that output from animal producers and crop processors is impacted immediately and proportionately with a change in crop production. This scenario assumes that the market for feed and food crops, particularly in low water years, is highly competitive and that alternative sources of crops are not economically feasible for animal producers and food processors to purchase (due either to high cost or lack of crop availability due to pre-existing contracts or other supply chain factors). Consequently, in the high impact estimate, if Districts' feed crop production declines by 10 percent, animal production supported by the Districts declines 10 percent. Similarly, if fruit production in the Districts declines by 10 percent, then local processing of fruit supported by the Districts declines 10 percent. These impacts are all estimated as direct output impacts, both in the animal production sectors and the crop processing sectors.

- Low Impact Estimate. The low impact estimate assumes that animal producers and crop processors can find alternative crop sources to offset 100 percent of the reduction in Districts' crop production in reduced water years. We assume no impact on crop processors as IMPLAN data indicates that, even in 25 percent water years, there may be sufficient local supply to meet local processor demand (i.e., local production still exceeds local demand within aggregated crop categories). Consequently, in the low impact estimate, crop processing in all water years is the same as in baseline water supply years. Furthermore, we assume no increased crop transportation cost as there may be available crop supplies locally that could be obtained by local processors.

  Forward linkage impacts in the l impact scenario are limited to income effects to dairies and cattle ranchers of increased feed hauling costs. We assume that dairies and cattle ranchers are able to maintain herd size and production levels despite decreased local feed crop production. We assume that there is availability and feasibility of importing adequate silage and hay crops from other areas to offset decreased local production. The increased cost of transporting feed crops from outside the study area is analyzed as an income effect in IMPLAN to determine the total induced impacts in the local economy, based on the assumption that cattle and dairy farmers reduce their spending as their disposable income declines. Thus, for animal production in the low estimate, there are direct income effects (and induced employment, income, and output effects), but no direct employment or output effects. As there are assumed to be no changes in animal production, there are no impacts on processing in the low estimate.

2.4.1.3 Limitations and Assumptions

Key assumptions and limitations include:

- Short-Term vs. Long-Term Impacts As estimated, adverse impacts include all effects on industries that are currently reliant on baseline crop production activities, either through supplying inputs such as machinery and seed to agriculture (backward linkages) or using crop outputs for animal production or food processing (forward linkages). As is typical professional practice, this analysis does not consider the extent to which, in the long-term, individuals and industries could identify alternative economic activities that could offset declines in the agricultural economy and absorb labor and other resources (thereby diminishing long-term adverse effects).
- No Carry-Over of Annual Impacts. This analysis estimates each water supply year as a one-year event, and does not consider the potential consequences of low water year effects on subsequent production years. This likely results in an underestimate of impacts, for several reasons. First, deficit irrigation of permanent crops, particularly in very low water years, can affect quality and quantity of yields in subsequent years. Second, lack of reliability in acreage and yields in all crops may affect supplier relationships. Third, multiple low water years in a row, in which producers and processors may experience higher than normal transportation and other costs, may result in closure of some firms. Finally, in low water

years with low feed crop production, animal producers may reduce herd size, which would likely impact output in subsequent years.

- Linearity. As discussed in WAR-15, standard economic impact analysis assumes a linear level of impact – for every $1 of output in a given crop sector, there is the same level of impact in other economic sectors, both for industries supplying agriculture (back-linked) and for industries processing crop and animal products (forward-linked). In other words, IMPLAN uses fixed, proportional relationships, with the result that it predicts the same incremental income and employment impact for every $1 change in industry output. In reality, impacts may be larger or smaller than estimated by the model, depending on the size of the change and the response by businesses. For example, IMPLAN estimates may overstate job impacts if employers reduce employee hours but not jobs, or if people who lose a job in agriculture are able to easily transition and start a new position. IMPLAN estimates may understate job and income impacts if output changes are large and result in business closures and/or relocations.
- Potential Magnification of Modeling Limitations. Inputs to the regional economic impact analysis are results from the modeling of agricultural crop production and animal production, as described in previous sections. Any modeling limitations or estimation discrepancies from previous steps become magnified in the economic impact analysis.

2.4.1.4 Regional Economic Impacts: Crop Production

Table 2 presents the total regional economic impacts associated with crop production supported by the Project at different water supply levels. (Total effects account for changes across all industries with economic linkages to agricultural production, including direct, indirect, and induced impacts.) Overall, the total annual direct value of crops grown in the Districts' service area under baseline water supplies is $527.9 million. Adding to this the regional economic impacts of the indirect and induced effects brings the contribution of crops produced with irrigation water supplied from the two Districts to a total of $860.2 million. This total output value of agricultural production declines linearly to $365.9 million in the lowest water supply modeled, 25 percent of baseline water supply. Correspondingly, labor income and jobs declines also; $281.3 million in labor income, and 7,340 jobs (full and part-time) in the baseline water supply year down to $365.9 in output, *negative* $20.7 million in income (due to substantial income losses by permanent crop farmers as costs remain high and revenues drop), and 3,560 jobs (full and part-time).

Table 2. Annual regional economic impacts by water year type – crop production (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Impact Value	$860.2	$804.5	$752.5	$704.3	$646.2	$562.0	$493.0	$413.9	$365.9
Decline from Baseline		*-$55.8*	*-$107.7*	*-$155.9*	*-$214.0*	*-$298.2*	*-$367.2*	*-$446.3*	*-$494.3*
% Change from Baseline		*-6%*	*-6%*	*-6%*	*-8%*	*-13%*	*-12%*	*-16%*	*-12%*
Total Labor Income ($millions)									
Impact Value	$281.3	$249.7	$222.3	$198.9	$166.5	$108.2	$65.7	$13.6	-$20.7
Decline from Baseline		*-$31.6*	*-$59.0*	*-$82.3*	*-$114.7*	*-$173.1*	*-$215.6*	*-$267.6*	*-$302.0*
% Change from Baseline		*-11%*	*-11%*	*-10%*	*-16%*	*-35%*	*-39%*	*-79%*	*-252%*
Total Employment (full and part-time jobs)									
Impact Value	7,340	6,920	6,490	6,110	5,670	5,040	4,510	3,920	3,560
Decline from Baseline		-420	-850	-1,230	-1,670	-2,300	-2,830	-3,420	-3,780
% Change from Baseline		*-6%*	*-6%*	*-6%*	*-7%*	*-11%*	*-11%*	*-13%*	*-9%*

Source: Highland Economics (based on IMPLAN modeling)

[1] Monetary values reported in constant 2012 dollars adjusted using the California consumer price index (CPI)

[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

2.4.1.5 Agriculture-Dependent Industries (Forward Linkages)

As described above in detail in WAR-15, three industries particularly dependent on local agricultural production are dairy, beef cattle ranching, and food and beverage processing. The forward linkage analysis for each of these three industries is presented below.

2.4.1.6 Dairy and Beef Cattle Ranching

The results of the forward-linkage impact analysis by water supply year for the dairy industry are presented in Tables 3 (high estimate) and Table 4 (low estimate). The high impact estimate for dairy milk production assumes that milk production declines at the same rate as the decline in District feed crop production. The low impact estimate for milk production assumes no drop in dairy milk production, but a decline in dairy milk producers’ income equal to the increased cost to transport feed from other areas. As modeled in the low impact scenario for milk production, there is no direct output and employment effect, but there is a direct income effect and induced effects on output, employment, and income. Total benefits to the regional economy are expected to vary from 3,630 full and part-time jobs and $75.3 million in labor income in baseline water years, to 1,090 to 3,390 full and part-time jobs and $22.7 million to $38.8 million in 25 percent water supply years.

Table 3. High estimate: annual regional economic impacts by water year type – dairy milk production (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$816.7	$731.5	$645.3	$557.6	$468.1	$401.2	$346.6	$284.1	$245.9
Decline from Baseline		*-$85.2*	*-$171.4*	*-$259.1*	*-$348.6*	*-$415.5*	-$470.1	-$532.7	-$570.8
% Change from Baseline		*-10%*	*-21%*	*-32%*	*-43%*	*-51%*	-58%	-65%	-70%
Total Labor Income ($millions)									
Impact Value	$75.3	$67.4	$59.5	$51.4	$43.1	$37.0	$31.9	$26.2	$22.7
Decline from Baseline		*-$7.9*	*-$15.8*	*-$23.9*	*-$32.1*	*-$38.3*	-$43.3	-$49.1	-$52.6
% Change from Baseline		*-10%*	*-21%*	*-32%*	*-43%*	*-51%*	-58%	-65%	-70%
Total Employment (full and part-time jobs)									
Impact Value	3,630	3,250	2,870	2,480	2,080	1,780	1,540	1,260	1,090
Decline from Baseline		*-380*	*-760*	*-1,150*	*-1,550*	*-1,850*	-2,090	-2,370	-2,540
% Change from Baseline		*-10%*	*-21%*	*-32%*	*-43%*	*-51%*	-58%	-65%	-70%

Source: Highland Economics (based on IMPLAN modeling)
[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI
[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

Table 4. Low estimate: annual regional economic impacts by water year type – dairy milk production (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$816.7	$812.0	$807.3	$802.2	$797.2	$792.4	$787.7	$783.0	$780.6
Decline from Baseline		*-$4.7*	*-$9.5*	*-$14.5*	*-$19.6*	*-$24.3*	*-$29.0*	*-$33.8*	*-$36.2*
% Change from Baseline		*-1%*	*-1%*	*-2%*	*-2%*	*-3%*	*-4%*	*-4%*	*-4%*
Total Labor Income ($millions)									
Impact Value	$75.3	$70.5	$65.7	$60.6	$55.5	$50.7	$45.9	$41.2	$38.8
Decline from Baseline		*-$4.8*	*-$9.6*	*-$14.7*	*-$19.8*	*-$24.5*	*-$29.3*	*-$34.1*	*-$36.5*
% Change from Baseline		*-6%*	*-13%*	*-19%*	*-26%*	*-33%*	*-39%*	*-45%*	*-49%*
Total Employment (full and part-time jobs)									
Impact Value	3,630	3,600	3,570	3,530	3,500	3,470	3,430	3,400	3,390
Decline from Baseline		*-30*	*-60*	*-100*	*-130*	*-160*	*-200*	*-230*	*-240*
% Change from Baseline		*-1%*	*-2%*	*-3%*	*-4%*	*-4%*	*-6%*	*-6%*	*-7%*

Source: Highland Economics (based on IMPLAN modeling)
[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI
[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

The results of the forward-linkage analysis for the cattle ranching industry are presented in Table 5 (high estimate) and Table 6 (low estimate). Cattle ranching production supported by District water is estimated to directly and indirectly support total economic benefits varying from approximately 1,200 full and part-time jobs and $22.7 million labor income in baseline water years, down to 940 to 1,130 full and part-time jobs and $9.7 to $17.6 million in labor income in 25 percent water years. As described for milk production, high estimates of the impact of reduced water supplies on cattle production assume that reductions in feed crop availability result in a proportionate change in cattle production. The low estimates assume that cattle ranchers maintain herd size (and total animal production value) by purchasing feed from outside the region, incurring increased transportation costs that reduce their profit. This decreased local area income then results in reduced household spending, with subsequent adverse effects on study area total output, income, and employment.

Table 5. High estimate: annual regional economic impacts by water year type – cattle ranching production supported by crops from Districts' water service area (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$233.0	$226.2	$219.3	$212.2	$205.1	$198.0	$190.9	$183.8	$180.3
Decline from Baseline		*-$6.8*	*-$13.7*	*-$20.8*	*-$27.9*	*-$35.0*	*-$42.1*	*-$49.2*	*-$52.7*
% Change from Baseline		*-3%*	*-6%*	*-9%*	*-12%*	*-15%*	*-18%*	*-21%*	*-23%*
Total Labor Income ($millions)									
Impact Value	$22.7	$22.1	$21.4	$20.7	$20.0	$19.3	$18.6	$17.9	$17.6
Decline from Baseline		*-$0.7*	*-$1.3*	*-$2.0*	*-$2.7*	*-$3.4*	*-$4.1*	*-$4.8*	*-$5.1*
% Change from Baseline		*-3%*	*-6%*	*-9%*	*-12%*	*-15%*	*-18%*	*-21%*	*-23%*
Total Employment (full and part-time jobs)									
Impact Value	1,220	1,190	1,150	1,110	1,070	1,040	1,000	960	940
Decline from Baseline		*-30*	*-70*	*-110*	*-150*	*-180*	*-220*	*-260*	*-280*
% Change from Baseline		*-2%*	*-6%*	*-9%*	*-12%*	*-15%*	*-18%*	*-21%*	*-23%*

Source: Highland Economics (based on IMPLAN modeling)
[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI
[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

As discussed in detail WAR-15, different sectors of the food and beverage processing industry are dependent on food crop production, dairy production, and cattle ranching. Separate forward linkage results of these three types of processing sub-sectors are presented in Tables 7 through 12, with a separate table for high and low impact estimates within each subsector.

At baseline water supply, the direct value of processing output supported by the Districts' food crop production is estimated at $569.1 million annually (see Table 6.3-5 in WAR-15). Adding to this the indirect and induced impacts brings total contribution from Districts' water supply up to $854.9 million (Table 7). This includes output in the following processing sectors: winery; other animal food manufacturing; frozen food manufacturing; fruit and vegetable canning, pickling and drying; and 'snack food manufacturing.

Table 6. Low estimate: annual regional economic impacts by water year type – cattle ranching production supported by crops from Districts' water service area (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$233.0	$231.3	$229.7	$227.9	$226.2	$224.4	$222.7	$220.9	$220.1
Decline from Baseline		*-$1.7*	*-$3.3*	*-$5.1*	*-$6.8*	*-$8.6*	*-$10.3*	*-$12.1*	*-$12.9*
% Change from Baseline		*-1%*	*-1%*	*-2%*	*-3%*	*-4%*	*-4%*	*-5%*	*-6%*
Total Labor Income ($millions)									
Impact Value	$22.7	$21.0	$19.3	$17.6	$15.8	$14.0	$12.3	$10.5	$9.7
Decline from Baseline		*-$1.7*	*-$3.4*	*-$5.1*	*-$6.9*	*-$8.7*	*-$10.4*	*-$12.2*	*-$13.1*
% Change from Baseline		*-7%*	*-15%*	*-22%*	*-30%*	*-38%*	*-46%*	*-54%*	*-57%*
Total Employment (full and part-time jobs)									
Impact Value	1,220	1,210	1,200	1,190	1,170	1,160	1,150	1,140	1,130
Decline from Baseline		*-10*	*-20*	*-30*	*-50*	*-60*	*-70*	*-80*	*-90*
% Change from Baseline		*-1%*	*-2%*	*-2%*	*-4%*	*-5%*	*-6%*	*-7%*	*-7%*

Source: Highland Economics (based on IMPLAN modeling)
[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI
[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

The associated total annual economic benefits of this processing activity are estimated at nearly 2,860 full and part-time jobs and $165.8 million in labor income. The effect on these economic benefits of a change in water supplies depends on the availability of alternative crop inputs. On the low end, it is feasible that there could be no impacts on processors, as available data indicates that there may be sufficient alternative local sources to meet processor demand without impacting output (Table 8).

On the other hand, due to pre-existing contractual arrangements and possible water shortages in other agricultural producing areas within California, low water years in the Districts' service area could proportionately impact food processors. We thus estimate that, at the high end, the level of output, employment, and income associated with crop processing that is supported by District crop production may closely mirror the water supply level. In this case, for every 10 percent reduction in water supply to the Districts' service area, the level of income, employment, and output would fall by nearly 10 percent as well, until at the 25 percent water year supply level, regional economic benefits may fall by up to 73 percent compared to baseline supply water years. This would equate to a fall from nearly 2,900 full and part-time jobs and $165.8 million in labor income to 770 full and part-time jobs and $44.6 million in income (Table 7).

Table 7. High estimate: annual regional economic impacts by water year type – food and beverage processing dependent on crop production in the Districts' water service area (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**25%**
Total Output ($millions)									
Total Impact Value	$854.9	$777.0	$696.8	$616.3	$535.2	$449.1	$363.1	$275.2	$229.9
Decline from Baseline		*-$77.9*	*-$158.1*	*-$238.6*	*-$319.8*	*-$405.9*	*-$491.8*	*-$579.8*	*-$625.1*
% Change from Baseline		*-9%*	*-18%*	*-28%*	*-37%*	*-47%*	*-58%*	*-68%*	*-73%*
Total Labor Income ($millions)									
Impact Value	$165.8	$150.7	$135.1	$119.5	$103.8	$87.1	$70.4	$53.4	$44.6
Decline from Baseline		*-$15.1*	*-$30.7*	*-$46.3*	*-$62.0*	*-$78.7*	*-$95.4*	*-$112.4*	*-$121.2*
% Change from Baseline		*-9%*	*-18%*	*-28%*	*-37%*	*-47%*	*-58%*	*-68%*	*-73%*
Total Employment (full and part-time jobs)									
Impact Value	2,860	2,600	2,340	2,070	1,790	1,510	1,220	920	770
Decline from Baseline		*-260*	*-520*	*-790*	*-1,070*	*-1,350*	*-1,640*	*-1,940*	*-2,090*
% Change from Baseline		*-9%*	*-18%*	*-28%*	*-37%*	*-47%*	*-57%*	*-68%*	*-73%*

Source: Highland Economics (based on IMPLAN modeling)
1 Monetary values reported in constant 2012 dollars adjusted using the California CPI
2 Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

Table 8. Low estimate: annual regional economic impacts by water year type – food and beverage processing dependent on crop production in the Districts' water service area (direct, indirect and induced effects).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**25%**
Total Output ($millions)									
Total Impact Value	$854.9	$854.9	$854.9	$854.9	$854.9	$854.9	**$854.9**	**$854.9**	**$854.9**
Decline from Baseline		*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Total Labor Income ($millions)									
Impact Value	$165.8	$165.8	$165.8	$165.8	$165.8	$165.8	**$165.8**	**$165.8**	**$165.8**
Decline from Baseline		*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*	*$0*
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Total Employment (full and part-time jobs)									
Impact Value	2,860	2,860	2,860	2,860	2,860	2,860	**2,860**	**2,860**	**2,860**
Decline from Baseline		*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*

Source: Highland Economics (based on IMPLAN modeling)
1 Monetary values reported in constant 2012 dollars adjusted using the California CPI
2 Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

The effect on these economic benefits of a change in water supplies depends on the impact on local dairy production of a change in feed crop availability, and also the availability and economic feasibility of purchasing alternative milk supplies. On the low end, it is feasible that there could be no impacts on processors, if milk producers are able to obtain alternative feed and maintain herd size and milk output.

On the other hand, due to pre-existing contractual arrangements and possible water shortages in other agricultural producing areas within California, milk producers may be unable to obtain alternative feed supplies in low water years in the Districts' service area, resulting in a decline in milk production proportionate to the change in feed crop production. Due to the high transport cost of milk, and potential lack of availability of supplies from elsewhere, in this high impact scenario, decline in milk production may then proportionately impact dairy processors. We thus estimate that, at the high end, the level of output, employment, and income associated with dairy processing that is supported by District crop production may closely mirror the water supply level. In this case, for every 10 percent reduction in water supply to the Districts' service area, the level of income, employment, and output would fall by nearly 10 percent as well, until at the 25 percent water year supply level, regional economic benefits from dairy processing (that is supported indirectly by the District feed crops) may fall by up to 70 percent compared to baseline supply water years. This would equate to a fall from over 3,000 full and part-time jobs and $156.3 million in labor income to 910 full and part-time jobs and $47.1 million in income.

Table 9. High estimate: annual regional economic impacts by water year type – food and beverage processing dependent on milk production supported by crops grown in the Districts' water service area (direct, indirect and induced).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**25%**
Total Output ($millions)									
Total Impact Value	$1,143.1	$1,023.7	$903.1	$780.4	$655.1	$561.5	$485.1	$397.6	$344.2
Decline from Baseline		*-$119.3*	*-$239.9*	*-$362.6*	*-$487.9*	*-$581.6*	-$658.0	-$745.5	-$798.9
% Change from Baseline		*-10%*	*-21%*	*-32%*	*-43%*	*-51%*	-58%	-65%	-70%
Total Labor Income ($millions)									
Impact Value	$156.3	$140.0	$123.5	$106.7	$89.6	$76.8	$66.3	$54.4	$47.1
Decline from Baseline		*-$16.3*	*-$32.8*	*-$49.6*	*-$66.7*	*-$79.5*	-$90.0	-$101.9	-$109.2
% Change from Baseline		*-10%*	*-21%*	*-32%*	*-43%*	*-51%*	-58%	-65%	-70%
Total Employment (full and part-time jobs)									
Impact Value	3,030	2,720	2,400	2,070	1,740	1,490	1,290	1,060	910
Decline from Baseline		*-310*	*-630*	*-960*	*-1,290*	*-1,540*	-1,740	-1,970	-2,120
% Change from Baseline		*-10%*	*-21%*	*-32%*	*-43%*	*-51%*	-57%	-65%	-70%

Source: Highland Economics (based on IMPLAN modeling)

[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI

[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

Table 10. Low Estimate: Annual regional economic impacts by water year type – food and beverage processing dependent on milk production supported by crops grown in the Districts' water service area (direct, indirect and induced).[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$1141.3	$1141.3	$1141.3	$1141.3	$1141.3	$1141.3	$1141.3	$1141.3	$1141.3
Decline from Baseline		*$0*	*$0*	*$0*	*$0*	*$0*	$0	$0	$0
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	0%	0%	0%
Total Labor Income ($millions)									
Impact Value	$156.3	$156.3	$156.3	$156.3	$156.3	$156.3	$156.3	$156.3	$156.3
Decline from Baseline		*$0*	*$0*	*$0*	*$0*	*$0*	$0	$0	$0
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	0%	0%	0%
Total Employment (full and part-time jobs)									
Impact Value	3,030	3,030	3,030	3,030	3,030	3,030	3,030	3,030	3,030
Decline from Baseline		*0*	*0*	*0*	*0*	*0*	0	0	0
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	0%	0%	0%

Source: Highland Economics (based on IMPLAN modeling)
[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI
[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

Finally, cattle ranching supported by crops irrigated by the Districts' water is, in turn, estimated to support approximately $119.8 million of animal processing output. In total, animal processing associated with the Don Pedro baseline water supply supports an estimated $24.2 million in labor income, and over 600 full and part-time jobs (in addition to the effects in the dairy production sector, and in the cattle ranching and feed crop production sectors estimated above). The effect on these economic benefits of a change in water supplies depends on the impact on local cattle production of a change in feed crop availability, and also the availability and economic feasibility to animal processors of purchasing alternative animal products. On the low end, it is feasible that there could be no impacts on processors, if animal producers are able to obtain alternative feed and maintain herd size and cattle production.

On the other hand, due to pre-existing contractual arrangements and possible water shortages in other agricultural producing areas within California, if cattle producers are unable to obtain alternative feed supplies in low water years in the Districts' service area, the result could be a decline in beef cattle production, and a reduction in beef cattle availability to cattle processors. Based on the estimated relationships between local feed crop production, local cattle production, and local cattle processing, we estimate how changing water supplies would impact cattle processing in Table 11. Impacts on cattle processing are commensurate with estimated impacts on cattle production: approximately a three percent reduction in the total output, employment, and income supported by crops in the Districts' service area for every 10 percent decline in water supply. Thus, at the maximum impact, regional economic benefits would fall from over 600 full and part-time jobs and $24.2 million in labor income (baseline water supply year) to 480 full and part-time jobs and $18.7 million in income in a 25 percent of baseline supply water year (Table 11).

Table 11. High estimate: annual regional economic impacts by water year type – regional food processing dependent on cattle supported by crops grown in the Districts' water service area.[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$166.0	$161.2	$156.3	$151.2	$146.2	$141.1	$136.1	$131.0	$128.5
Decline from Baseline		*-$4.8*	*-$9.8*	*-$14.8*	*-$19.9*	*-$24.9*	-$30.0	-$35.0	-$37.6
% Change from Baseline		*-3%*	*-6%*	*-9%*	*-12%*	*-15%*	-18%	-21%	-23%
Total Labor Income ($millions)									
Impact Value	$24.2	$23.5	$22.7	$22.0	$21.3	$20.5	$19.8	$19.1	$18.7
Decline from Baseline		*-$0.7*	*-$1.4*	*-$2.2*	*-$2.9*	*-$3.6*	-$4.4	-$5.1	-$5.5
% Change from Baseline		*-3%*	*-6%*	*-9%*	*-12%*	*-15%*	-18%	-21%	-23%
Total Employment (full and part-time jobs)									
Impact Value	630	610	590	570	550	530	510	490	480
Decline from Baseline		*-20*	*-40*	*-60*	*-80*	*-100*	-120	-140	-150
% Change from Baseline		*-3%*	*-6%*	*-10%*	*-13%*	*-16%*	-19%	-22%	-24%

Source: Highland Economics (based on IMPLAN modeling)
1 Monetary values reported in constant 2012 dollars adjusted using the California CPI
2 Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

Table 12. Low estimate: annual regional economic impacts by water year type – food and beverage processing dependent on milk production supported by crops grown in the Districts' water service area.[1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$166.0	$166.0	$166.0	$166.0	$166.0	$166.0	$166.0	$166.0	$166.0
Decline from Baseline		*$0.0*	*$0.0*	*$0.0*	*$0.0*	*$0.0*	$0.0	$0.0	$0.0
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	0%	0%	0%
Total Labor Income ($millions)									
Impact Value	$24.2	$24.2	$24.2	$24.2	$24.2	$24.2	$24.2	$24.2	$24.2
Decline from Baseline		*$0.0*	*$0.0*	*$0.0*	*$0.0*	*$0.0*	$0.0	$0.0	$0.0
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	0%	0%	0%
Total Employment (full and part-time jobs)									
Impact Value	630	630	630	630	630	630	630	630	630
Decline from Baseline		*0*	*0*	*0*	*0*	*0*	0	0	0
% Change from Baseline		*0%*	*0%*	*0%*	*0%*	*0%*	0%	0%	0%

Source: Highland Economics (based on IMPLAN modeling)
1 Monetary values reported in constant 2012 dollars adjusted using the California CPI
2 Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

2.4.2 Summary of Regional Economic Effects

Under the baseline assumptions, accounting for all directly-supported activities and forward-linked sectors, and including hydropower and recreation benefits, the Project is estimated to support approximately 18,900 total jobs and $737.9 million in total labor income annually. Figures 10 and 11 and Tables 13 and 14 summarize how this total income and employment benefit decline in lower water supply years.

Estimated adverse annual employment impacts vary from a reduction of 460 to 1,420 jobs in a 90 percent water year to a reduction of 4,110 to 10,960 jobs in a 25 percent water year. Estimated adverse annual income impacts vary from a reduction of $38.0 million to $72.2 million in a 90 percent water year to a reduction of $351.6 million to $595.7 million in a 25 percent water supply year. The decline in employment in the 25 percent water supply year equates to a 22 to 58 percent decrease from employment supported by the Districts' service area in a baseline water year, while the reduction in labor income equates to a 48 to 81 percent decrease in income supported by the Districts' service area in a baseline water year.

Income impacts are higher than employment impacts, particularly in the lowest water supply years primarily due to our assumption that any change in permanent crop revenue (i.e., a yield reduction) directly translates into reduced income, dollar for dollar, into an income reduction.[3] As the same acres are in cultivation, we conservatively assume no direct reduction in farm employment on permanent crop acreage.

[3] As discussed above, all effects on permanent crops are reduced yields, not reduced acreage. We expect that reduced yields in permanent crops will reduce revenue, but will have no effect on fixed costs, and little effect on non-labor variable costs. In other words, water supplies and associated reduced yields would be expected to reduce such labor variable costs as irrigation labor costs and harvest labor costs, but are expected to have relatively little effect on other input costs. We conservatively model this as a proprietor income effect, with no effect on direct farm employment.

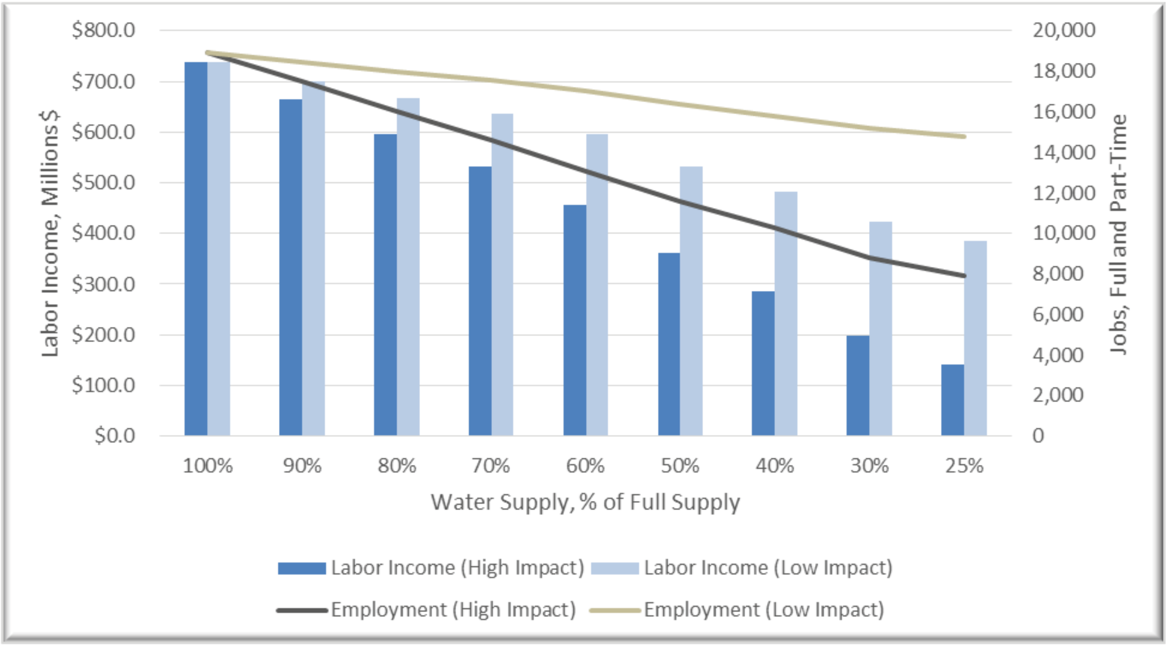


Figure 10. **Summary of jobs and labor income impacts by water supply type.[1,2]**

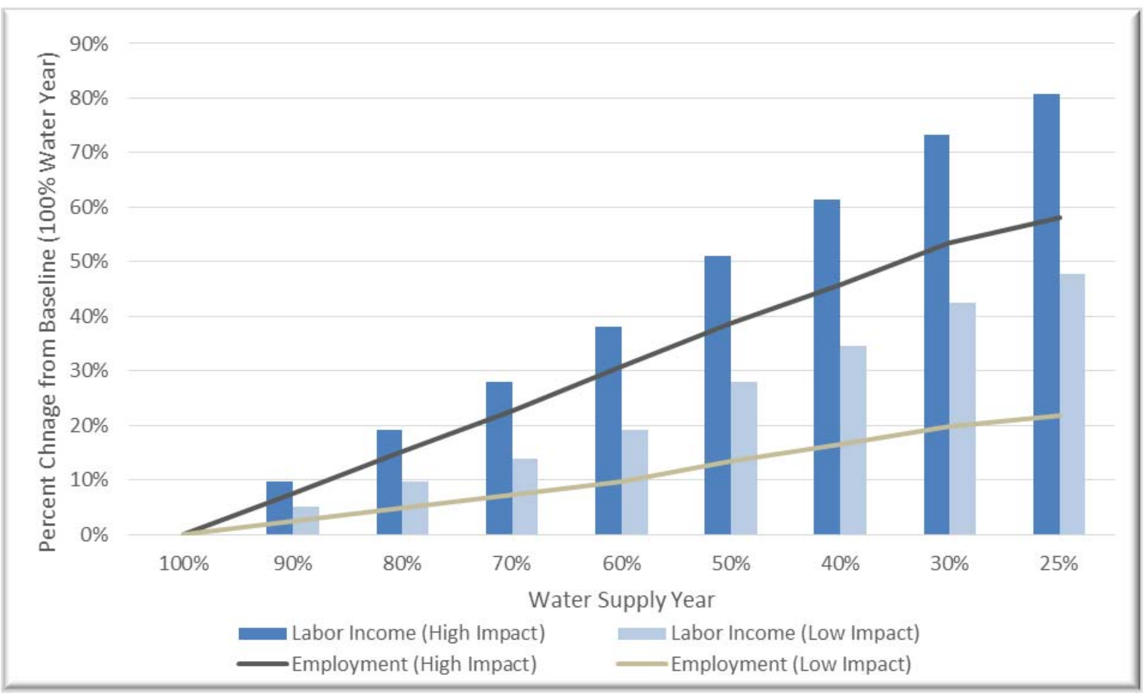


Figure 11. **Percent change (from baseline water year) in jobs and labor income by water Supply year.[1,2]**

Table 13. High estimate: changes in annual regional economic impacts by water year–summary of impacts to crop production, animal production, and processing dependent on water supply from Districts.[1,2,3]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**25%**
Total Output ($millions)									
Total Impact Value	$4,073.9	$3,765.0	$3,414.3	$3,063.0	$2,696.8	$2,353.8	**$2,055.7**	**$1,726.5**	**$1,494.6**
Decline from Baseline		-349.8	-700.6	-1,051.9	-1,418.1	-1,761.1	**-2,059.2**	**-2,388.4**	**-2,579.4**
% Change from Baseline		*-9%*	*-17%*	*-26%*	*-34%*	*-43%*	**-50%**	**-58%**	**-63%**
Total Labor Income ($millions)									
Impact Value	$737.9	$665.7	$596.9	$531.7	$456.8	$361.3	**$285.2**	**$197.0**	**$142.2**
Decline from Baseline		-$72.2	-$141.0	-$206.3	-$281.2	-$376.7	**-$452.7**	**-$541.0**	**-$595.7**
% Change from Baseline		*-10%*	*-19%*	*-28%*	*-38%*	*-51%*	**-61%**	**-73%**	**-81%**
Total Employment (full and part-time jobs)									
Impact Value	18,900	17,480	16,030	14,600	13,090	11,580	**10,260**	**8,800**	**7,940**
Decline from Baseline		-1,420	-2,870	-4,300	-5,810	-7,320	**-8,640**	**-10,100**	**-10,960**
% Change from Baseline		*-8%*	*-15%*	*-23%*	*-31%*	*-39%*	**-46%**	**-53%**	**-58%**

Source: Highland Economics (based on IMPLAN modeling)

1 Monetary values reported in constant 2012 dollars adjusted using the California CPI

2 Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

3 Results do not include economic benefits from hydropower and recreation that are not expected to change by water year type.

Table 14. Low estimate: changes in annual regional economic impacts by water year–summary of impacts to crop production, animal production, and processing dependent on water supply from Districts. [1,2]

Economic Metric	Water Supply (Percentage of Baseline Supply)								
	100%	90%	80%	70%	60%	50%	40%	30%	25%
Total Output ($millions)									
Total Impact Value	$4,073.9	$4,052.7	$3,994.4	$3,939.4	$3,874.5	$3,783.8	**$3,708.3**	**$3,622.7**	**$3,571.5**
Decline from Baseline		-62.2	-120.5	-175.5	-240.4	-331.1	**-406.6**	**-492.2**	**-543.4**
% Change from Baseline		*-2%*	*-3%*	*-4%*	*-6%*	*-8%*	**-10%**	**-12%**	**-13%**
Total Labor Income ($millions)									
Impact Value	$737.9	$699.9	$666.0	$635.8	$596.6	$531.6	**$482.6**	**$424.0**	**$386.3**
Decline from Baseline		-$38.0	-$72.0	-$102.1	-$141.4	-$206.3	**-$255.4**	**-$313.9**	**-$351.6**
% Change from Baseline		*-5%*	*-10%*	*-14%*	*-19%*	*-28%*	**-35%**	**-43%**	**-48%**
Total Employment (full and part-time jobs)									
Impact Value	18,900	18,440	17,970	17,540	17,050	16,380	**15,800**	**15,170**	**14,790**
Decline from Baseline		-460	-930	-1,360	-1,850	-2,520	**-3,100**	**-3,730**	**-4,110**
% Change from Baseline		*-2%*	*-5%*	*-7%*	*-10%*	*-13%*	**-16%**	**-20%**	**-22%**

Source: Highland Economics (based on IMPLAN modeling)
[1] Monetary values reported in constant 2012 dollars adjusted using the California CPI
[2] Results represent regional effects in three-county study area (Stanislaus, Merced, and Tuolumne counties)

2.4.2.1 Results in Study Area Context

This section puts the economic impact results in the context of the total study area economy. Table 15 focuses on the role of the Districts' agricultural production in supporting study area employment. Of the 18,900 jobs supported in a baseline water year by the project, 18,710 are supported directly and indirectly by agriculture (the other 190 are supported by recreation and hydropower generation). This represents six percent of the total three-county study area employment. The Districts' service area produces approximately 22 percent of the agricultural value produced in Stanislaus and Merced counties. If we extrapolate employment supported by agricultural lands in the Districts' water service area to all county agricultural lands, then agriculture in Stanislaus and Merced counties supports approximately 25 percent of total study area employment (Table 15).

Table 16 shows how this employment base would be eroded under different water supply levels. The reductions in employment at the 90 percent water year would result in a reduction of study area employment of approximately 0.1 percent to 0.4 percent, increasing to a reduction in study area employment of approximately 1.2 percent to 3.3 percent in the lowest modeled water year of 25 percent of baseline water supply. This could equate to an equivalent rise in the unemployment rate during these reduced water years.

Table 17 provides corresponding data on how total study area income would change under different water supply levels. Under baseline assumptions agricultural production in the Districts' service area directly and indirectly supports $725.5 million in labor income. This represents approximately 4 percent of the study area's total earnings of $16,248.4 million (see Table 4.4-3 of TID/MID 2014). The reductions in income at the 90 percent water year would result in a reduction of study area income of approximately 0.2 percent to 0.4 percent, increasing to a reduction in study area employment of approximately 2.2 percent to 3.7 percent in the lowest modeled water year of 25 percent of baseline water supply.

Table 15. District and all county agricultural lands support of study area employment.

Employment Data	Total 3-County Employment Supported
	100%
Geographic Area	
District Agricultural Acreage *(Estimated in Study)*	18,710[1]
3-County Area All Employment *(BEA data, see Table 4.4-1)*	332,083
Proportion 3-County Baseline Employment Supported	
District Agriculture	5.6%
Extrapolated All Agriculture in 3-County Area[2]	25.2%

1 Total District supported employment is 18,900, of which 190 jobs is generated through recreation and hydropower. As this table is focused on agriculture-supported jobs, we use a District-supported employment base of 18,710 to exclude the hydropower and recreation-related jobs.

2 Agricultural acreage in Districts' water service produces an estimated $526.5 million in output. Agricultural output in Stanislaus and Merced counties totals approximately $2,352.8 million (see Section 4.5.2.2 of TID/MID 2014), or approximately 450% of the value in the Districts. Assuming District and non-District agricultural lands contribute equally, on a production value basis, to total employment base in the study area, then all farmland in the county supports approximately 25 percent of all employment in the 3-County area (5.6% multiplied by 4.5).

Table 16. District agricultural lands' support of regional employment.

Impact Metric	Water Supply (% of Baseline Water Year)			
	100%	**90%**	**60%**	**25%**
Employment Supported by District Agriculture	18,710	17,290 to 18,250	12,900 to 16,860	7,750 to 14,600
Regional Employment Base	332,083	N/A	N/A	N/A
Percent Reduction in 3-County Employment Base		0.1%-0.4%	0.6% to 1.7%	1.2% to 3.3%

Table 17. District agricultural lands' support of regional labor income (millions $).

Impact Metric	Water Supply (% of Baseline Water Year)			
	100%	**90%**	**60%**	**25%**
Income Supported by District Agriculture	$725.5	$653.3 to $687.5	$444.4 to $584.2	$129.8 to $373.9
Regional Income Base	$16,248.4			
Percent Reduction in 3-County Earnings Base		0.2% to 0.4%	0.9% to 1.7%	2.2% to 3.7%

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3.0 RESULTS

3.1 Estimating Impacts of Various Hydrologic Scenarios

Estimating the impact of any hydrologic scenario (e.g. a 40 percent unimpaired flow) is accomplished in two-steps:

(1) The estimated change in output, labor income and employment, as described in section 2.0 above, is calculated for decreasing steps (in 5 percent increments) of surface water irrigation compared to baseline, e.g. 100 percent (baseline), 95 percent, 90 percent, 85 percent, etc.
(2) The estimated change in output, labor income and employment are matched with the appropriate estimate of the percent surface water available from the hydrologic model.

Each of these two steps are described below

3.1.1 Estimated Change in Output, Labor Income and Employment

The maximum and minimum estimated impact to total output, total labor income and total employment expressed as a percent of baseline are summarized in Figures 12 through 14. As expected, estimated output declines as the supply of surface water irrigation declines from 100 percent of baseline to 20 percent of baseline. However under both the maximum and the minimum impact estimates, the percent decline in output is not as rapid as the percent decline in surface water supply.

For example, when water supply is 65 percent of baseline output is estimated to be between 95 percent (minimum impact) to 70 percent (maximum impact) of baseline levels. The estimated minimum impact is bolstered by the assumptions discussed above, namely: 1) animal feed crops are imported from outside the region maintaining animal product yield (e.g. cwt of milk) and 2) raw inputs of crops and animal products are imported from outside the region to keep processing plants running at baseline capacity. The average of the minimum and maximum impacts estimates is 82 percent of baseline output.

The estimated maximum percent decline in output more closely approximates the percent decline in surface water supplies. In the example cited above, when surface water irrigation supply is 65 percent of baseline estimated output is 70 percent of baseline. Recall the assumption for the maximum scenario is that animal production and processing output fall in proportion to the reduction in crops. The only reason the percent reduction in output is not the same as the percent reduction in surface irrigation water is because, as discussed above, the literature describing the results of stress irrigation field trials suggest the yield of almond trees does not decline in proportion to the decline of evapotranspiration.

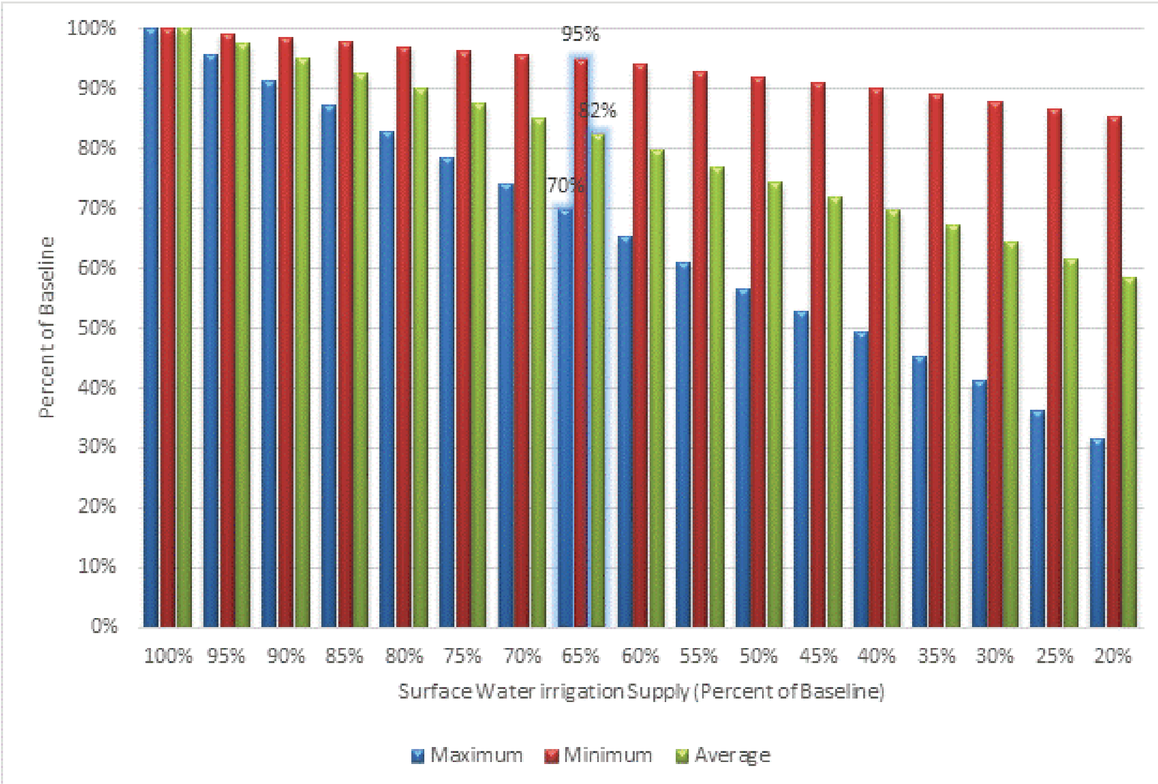

Figure 12. **Estimated maximum and minimum percent change in total output caused by a reduction in surface water irrigation supply.**

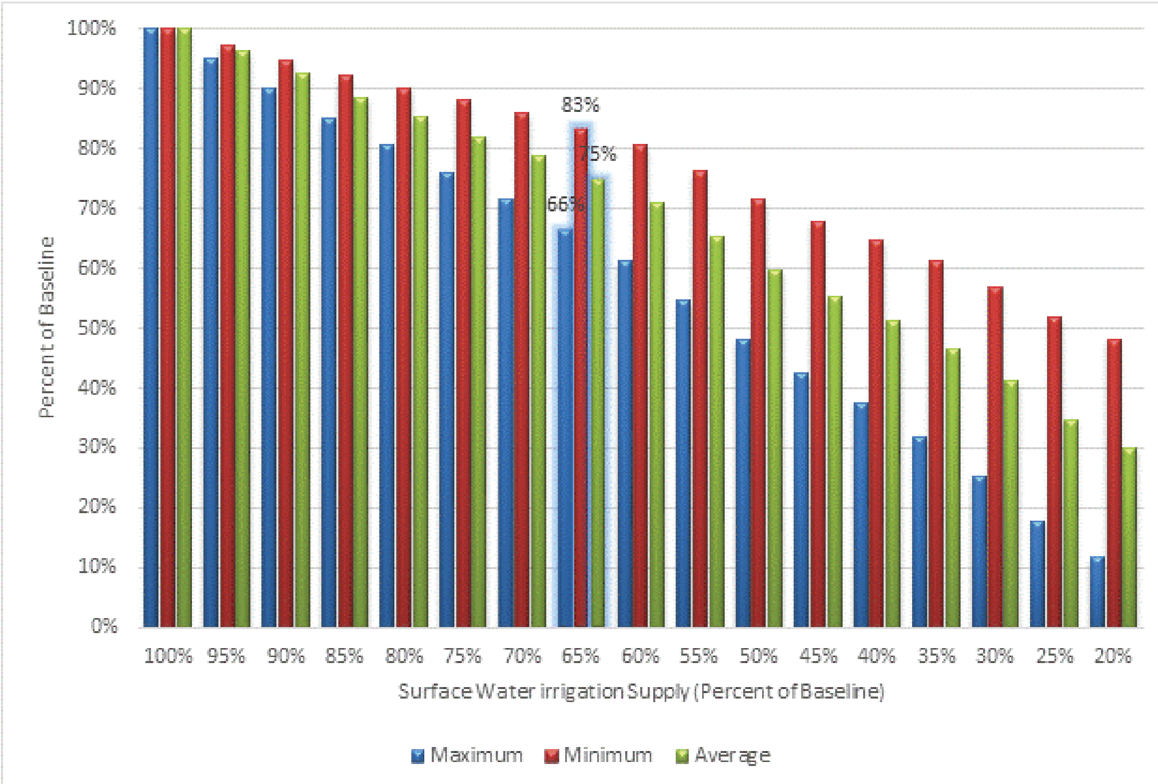

Figure 13. Estimated maximum and minimum percent change in total labor income caused by a reduction in surface water irrigation supply.

The disparity between estimated maximum and minimum impacts of a reduction in surface water irrigation on total labor income is not as great as the estimated impacts on output. When surface irrigation water supply is 65 percent of baseline the estimated minimum and maximum impact on labor income is 83 percent of baseline and 66 percent of baseline, respectively. Recall that the assumptions for the minimum impact on labor income includes the reduction in dairy ranch owners' income as a consequence of increases in feed price due to limited supply. The average impact is estimated to by 75 percent of baseline.

The estimated percent change in total employment from reduced surface water irrigation supply is relatively close to the estimated percent change in total output. When surface water irrigation supply is 65 percent of baseline the estimated percent change in total employment is 73 percent of baseline and 92 percent of baseline for the maximum and minimum scenarios, respectively. The average impact is estimated to be 82 percent of baseline.

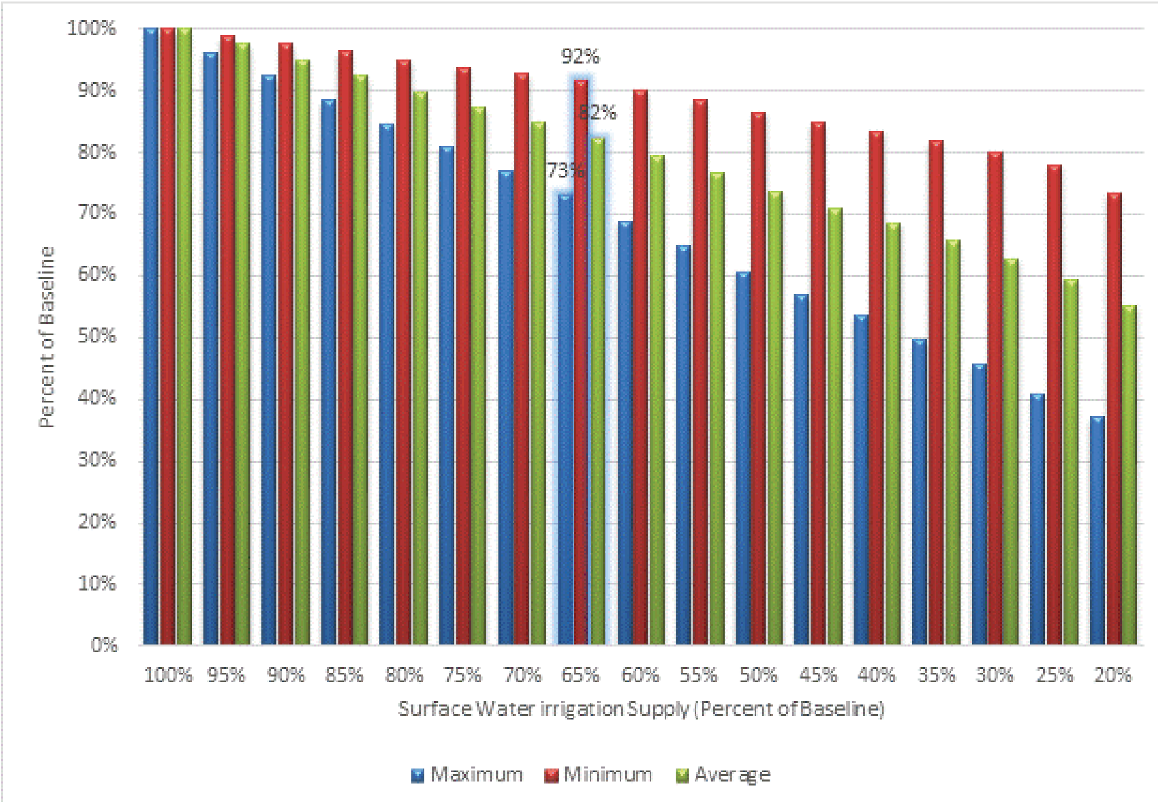

Figure 14. **Estimated maximum and minimum percent change in total on-farm, animal production and processing, employment caused by a reduction in surface water irrigation supply.**

3.1.2 Combining Model results with Hydrology

Figure 15 presents an example of how data from the hydrologic model is combined with the output from the economic model to create an annual estimate of direct output value for each of the 42 years in the study. In the example scenario presented in Figure 15 the economic model "rounds the estimated water supply availability from the operations model to the nearest 5 percent. For example, the operations model estimated that canal deliveries in water year 1976 would have been 68.1 percent of baseline. In the economic model water year 1976 rounds to 70 percent of water availability. The last step in combining the operations model results with the economic model results is to correspond the rounded estimate of water availability with the appropriate estimates of output, labor income and employment.

Figure 15 shows that the estimated total agricultural economic output of the Project ranges between approximately 95 percent of baseline to 65 percent of baseline, in the years in which there are shortages in available surface water supply. In the example water supply scenario presented in this memorandum available water supply reductions occur in nearly 30 percent of the years in the model. Therefore, this example estimates that 30 percent of years would experience a reduction in output between 10 percent of baseline and 30 percent of baseline.

For example, the 8 years between 1987 and 1994 the estimated agricultural output would have declined between approximately 65 percent and 95 percent of baseline under the example water supply scenario. Or conversely in those eight years there is between a 5 percent and 30 percent reduction in agricultural output in the years in which there are water shortages.

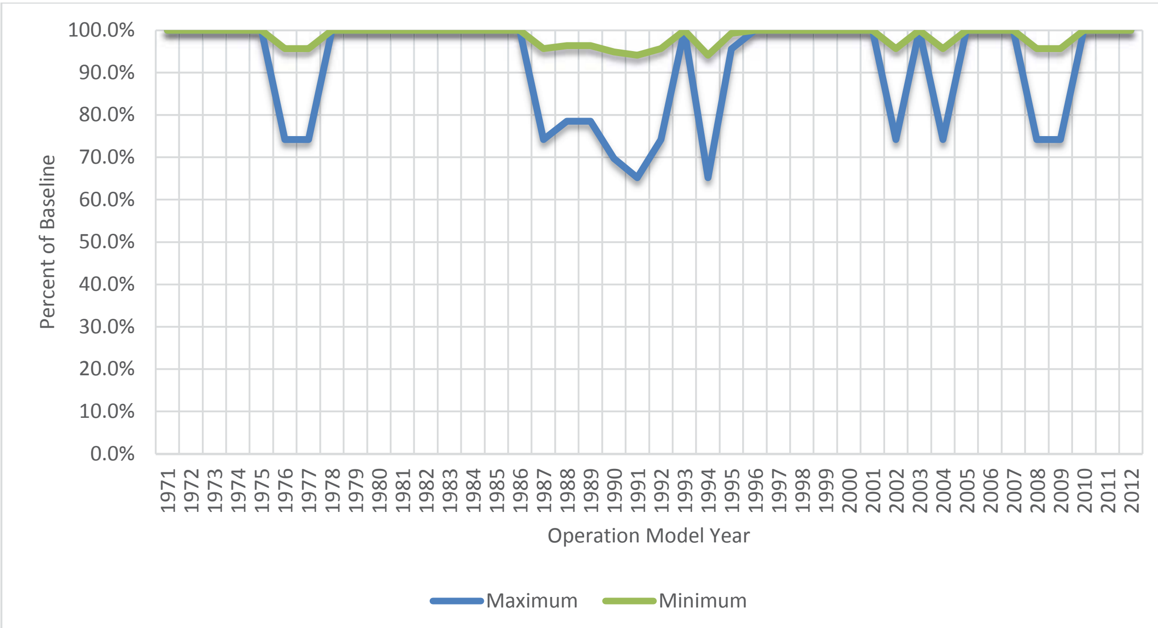

Figure 15. Estimated Agricultural Output as a Percent of Baseline Output, All Years.

Labor income under the example water supply scenario is estimated to range between approximately 60 percent of baseline to 85 percent of baseline for the 30 percent of years in which there are reductions in available water supply (Figure 16). The estimated economic impact to labor income from a reduction in available water supply is greater than the estimated impact to output. Recall that for the minimum economic impact the production value of animal commodities did not decline, rather the shortage in feed crops was assumed to be replaced with imported supply. However, the cost of this imported feed supply is greater than the cost of local grown supply. So the economic impact of increased costs is reflected in the results as a reduction in the profits of animal operations, which results in a reduction in operator's labor income.

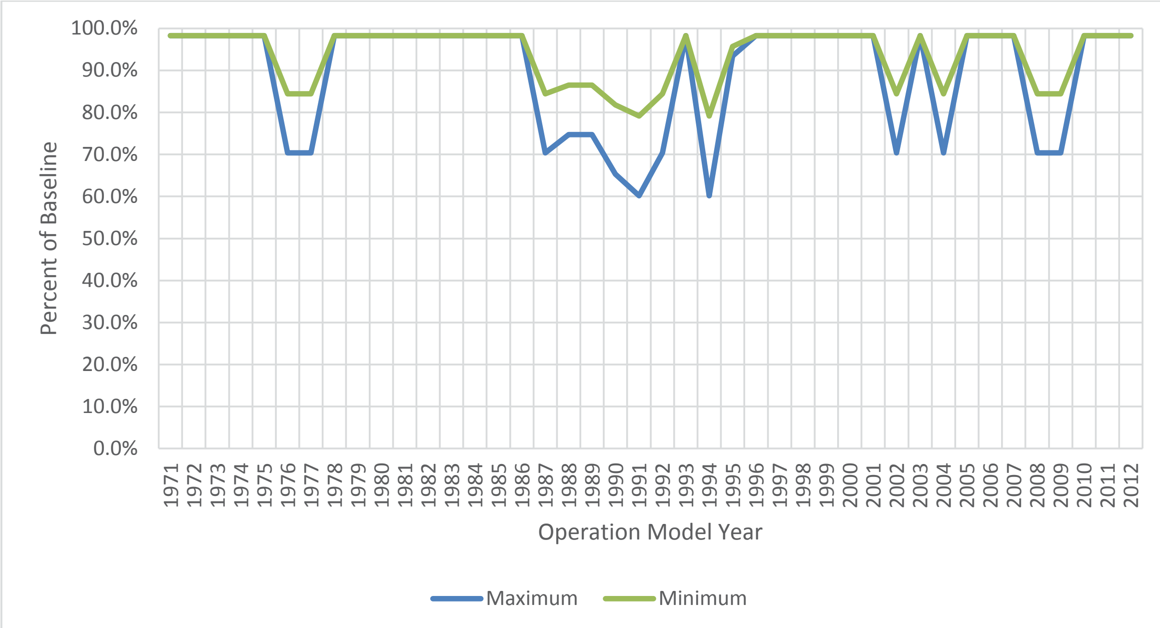

Figure 16. Estimated Agricultural Labor Income as a Percent of Baseline Output, All Years.

Employment under the example water supply scenario is estimated to range between approximately 70 percent of baseline to just over 90 percent of baseline for the 30 percent of years in which there are reductions in available water supply (Figure 17). The impact is similar to the estimated impact in labor income.

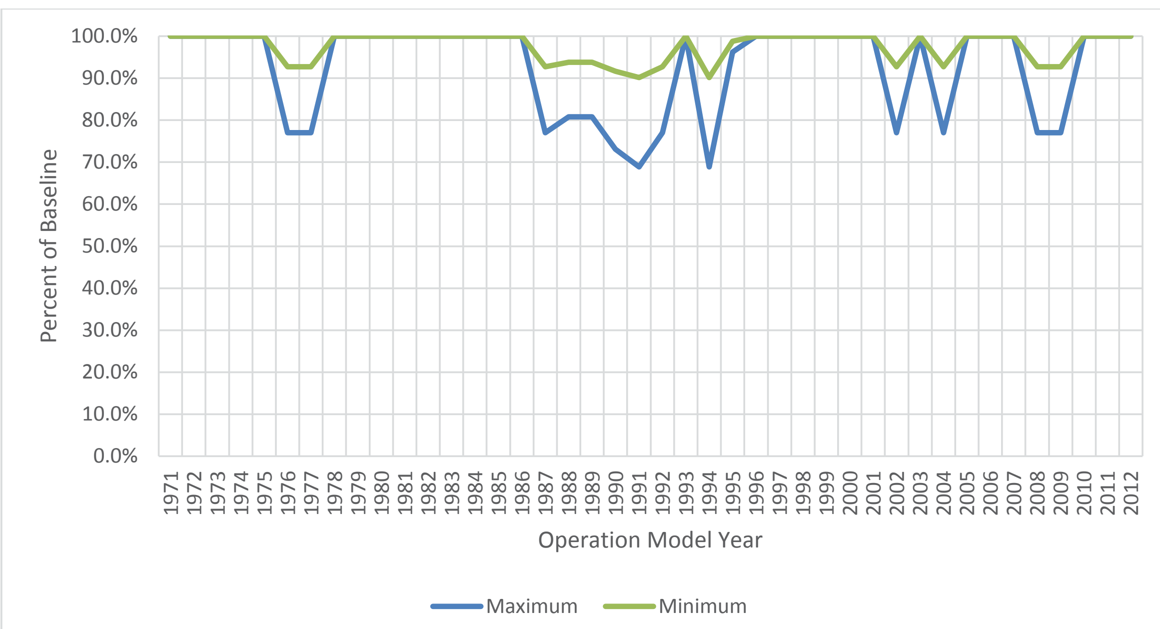

Figure 17. Estimated Agricultural Employment as a Percent of Baseline Output, All Years.

The information that is represented in Figure 15, Figure 16 and Figure 17 is represented in tabular form, including the dollar value estimates, in Tables 18 through Table 23.

Table 18. Estimated maximum impact in output by hydrologic water year (2012 $s millions)

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Maximum Output ($ 000,000s)	Maximum Difference	% of Base Case
1971	N	100.0%	100.0%	4,074	-	100.0%
1972	BN	100.0%	100.0%	4,074	-	100.0%
1973	N	100.0%	100.0%	4,074	-	100.0%
1974	AN	100.0%	100.0%	4,074	-	100.0%
1975	AN	100.0%	100.0%	4,074	-	100.0%
1976	C	68.1%	70.0%	3021.7	(1,052.2)	73.2%
1977	C	69.9%	70.0%	3021.7	(1,052.2)	73.2%
1978	W	98.8%	100.0%	4,074	-	100.0%
1979	N	100.0%	100.0%	4,074	-	100.0%
1980	W	100.0%	100.0%	4,074	-	100.0%
1981	D	100.0%	100.0%	4,074	-	100.0%
1982	W	100.0%	100.0%	4,074	-	100.0%
1983	W	100.0%	100.0%	4,074	-	100.0%
1984	AN	100.0%	100.0%	4,074	-	100.0%
1985	BN	100.0%	100.0%	4,074	-	100.0%
1986	W	100.0%	100.0%	4,074	-	100.0%
1987	C	68.2%	70.0%	3021.7	(1,052.2)	73.2%
1988	C	73.9%	75.0%	3198.45	(875.5)	77.8%
1989	BN	74.7%	75.0%	3198.45	(875.5)	77.8%
1990	D	63.0%	65.0%	2841	(1,232.9)	68.6%
1991	BN	61.9%	60.0%	2655.9	(1,418.0)	64.0%
1992	C	69.9%	70.0%	3021.7	(1,052.2)	73.2%
1993	AN	98.9%	100.0%	4073.9	-	100.0%
1994	D	57.6%	60.0%	2655.9	(1,418.0)	64.0%
1995	W	97.0%	95.0%	3894	(179.9)	95.6%
1996	AN	100.0%	100.0%	4,074	-	100.0%
1997	W	100.0%	100.0%	4,074	-	100.0%
1998	W	100.0%	100.0%	4,074	-	100.0%
1999	AN	100.0%	100.0%	4,074	-	100.0%
2000	N	100.0%	100.0%	4,074	-	100.0%
2001	BN	100.0%	100.0%	4,074	-	100.0%
2002	N	69.0%	70.0%	3021.7	(1,052.2)	73.2%
2003	N	97.7%	100.0%	4073.9	-	100.0%
2004	BN	69.3%	70.0%	3021.7	(1,052.2)	73.2%

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Maximum Output ($ 000,000s)	Maximum Difference	% of Base Case
2005	W	97.9%	100.0%	4073.9	-	100.0%
2006	W	100.0%	100.0%	4073.9	-	100.0%
2007	D	100.0%	100.0%	4073.9	-	100.0%
2008	BN	67.7%	70.0%	3021.7	(1,052.2)	73.2%
2009	N	68.6%	70.0%	3021.7	(1,052.2)	73.2%
2010	N	97.5%	100.0%	4,074	-	100.0%
2011	W	100.0%	100.0%	4,074	-	100.0%
2012	D	100.0%	100.0%	4,074	-	100.0%
Average		89.8%	90.2%	3,730.6	(343.3)	91.3%
Total				156,686.5	(14,760.6)	

Table 19. Estimated minimum impact in direct output by hydrologic year (2012 $s millions)

		Percent of Baseline		Example Economic Impact		
Water Year	Water Year Type	Operations Model Canal Deliveries	Economic Model Surface Water	Minimum Output ($ 000,000s)	Minimum Difference	% of Base Case
1971	N	100.0%	100.0%	4073.9	-	100.0%
1972	BN	100.0%	100.0%	4073.9	-	100.0%
1973	N	100.0%	100.0%	4073.9	-	100.0%
1974	AN	100.0%	100.0%	4073.9	-	100.0%
1975	AN	100.0%	100.0%	4073.9	-	100.0%
1976	C	68.1%	70.0%	3,898.2	(175.7)	95.7%
1977	C	69.9%	70.0%	3,898.2	(175.7)	95.7%
1978	W	98.8%	100.0%	4073.9	-	100.0%
1979	N	100.0%	100.0%	4073.9	-	100.0%
1980	W	100.0%	100.0%	4073.9	-	100.0%
1981	D	100.0%	100.0%	4073.9	-	100.0%
1982	W	100.0%	100.0%	4073.9	-	100.0%
1983	W	100.0%	100.0%	4073.9	-	100.0%
1984	AN	100.0%	100.0%	4073.9	-	100.0%
1985	BN	100.0%	100.0%	4073.9	-	100.0%
1986	W	100.0%	100.0%	4073.9	-	100.0%
1987	C	68.2%	70.0%	3,898.2	(175.7)	95.7%
1988	C	73.9%	75.0%	3,925.4	(148.5)	96.4%
1989	BN	74.7%	75.0%	3,925.4	(148.5)	96.4%
1990	D	63.0%	65.0%	3,866.5	(207.4)	94.9%
1991	BN	61.9%	60.0%	3,833.7	(240.2)	94.1%
1992	C	69.9%	70.0%	3,898.2	(175.7)	95.7%
1993	AN	98.9%	100.0%	4073.9	-	100.0%
1994	D	57.6%	60.0%	3,833.7	(240.2)	94.1%
1995	W	97.0%	95.0%	4,042.8	(31.2)	99.2%
1996	AN	100.0%	100.0%	4073.9	-	100.0%
1997	W	100.0%	100.0%	4073.9	-	100.0%
1998	W	100.0%	100.0%	4073.9	-	100.0%
1999	AN	100.0%	100.0%	4073.9	-	100.0%
2000	N	100.0%	100.0%	4073.9	-	100.0%
2001	BN	100.0%	100.0%	4073.9	-	100.0%
2002	N	69.0%	70.0%	3,898.2	(175.7)	95.7%
2003	N	97.7%	100.0%	4073.9	-	100.0%
2004	BN	69.3%	70.0%	3,898.2	(175.7)	95.7%
2005	W	97.9%	100.0%	4073.9	-	100.0%
2006	W	100.0%	100.0%	4073.9	-	100.0%

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Minimum Output ($ 000,000s)	Minimum Difference	% of Base Case
2007	D	100.0%	100.0%	4073.9	-	100.0%
2008	BN	67.7%	70.0%	3,898.2	(175.7)	95.7%
2009	N	68.6%	70.0%	3,898.2	(175.7)	95.7%
2010	N	97.5%	100.0%	4073.9	-	100.0%
2011	W	100.0%	100.0%	4073.9	-	100.0%
2012	D	100.0%	100.0%	4073.9	-	100.0%
Average		89.8%	90.2%	4,016.2	(57.7)	98.6%
Total				168,682.3	(2,421.6)	98.6%

Table 20 summarizes the estimated maximum impacts by water-year type and category, highlighting the most recent drought in 2015 and 2016. Estimated baseline output is just over $4 billion. In wet and above normal years (46 percent of the years in the model) there is not reduction in output. In below normal and dry water year types agricultural output falls by between $629.1 million and $530 million, approximately 15 percent of baseline. In critical water year types output falls over $1 billion to $2.9 billion. And in 2015/2016 output is estimated to fall by $1.6 billion to $2.4 billion, or just under 40 percent of baseline.

Under a 40 percent unimpaired flow output is estimated to decline in more than half of all years by between 13 percent and 39 percent of baseline.

Table 20. Estimated Agricultural Output, Water Year Type Baseline ($s millions)

Water-Year Type	Baseline	Wet and Above Normal	Below Normal	Dry	Critical	2015/2016
Frequency of Water-Year Type	**100%**	**46%**	**11%**	**16%**	**22%**	**4%**
Crop commodities	$527.9	$527.9	$466.7	$475.9	$417.9	$361.0
Indirect and Induced on crop commodities	$332.3	$332.3	$298.7	$304.6	$267.5	$199.4
Animal commodities (dairy, cattle)	$665.5	$665.5	$557.0	$573.9	$471.1	$399.3
Indirect and induced on animal commodities	$384.2	$384.2	$325.7	$334.9	$280.8	$230.5
Processing of crops, milk, animals	$1,476.5	$1,476.5	$1,226.5	$1,265.7	$1,053.5	$885.9
Indirect and Induced on processing	$687.5	$687.5	$570.2	$588.7	$498.7	$412.5
Total Impact	$4,073.9	$4,073.9	$3,444.8	$3,543.7	$2,989.5	$2,488.6
Difference from Baseline	$0.0	$0.0	-$629.1	-$530.2	-$1,084.4	-$1,585.3
Percent difference from baseline	*0%*	*0%*	*-15%*	*-13%*	*-27%*	*-39%*

Table 21. Estimated maximum impact in direct labor income by hydrologic year (2012 $s millions)

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Maximum Labor Income ($ 000,000s)	Maximum Difference	% of Base Case
1971	N	100.0%	100.0%	725.4	-	98.3%
1972	BN	100.0%	100.0%	725.4	-	98.3%
1973	N	100.0%	100.0%	725.4	-	98.3%
1974	AN	100.0%	100.0%	725.4	-	98.3%
1975	AN	100.0%	100.0%	725.4	-	98.3%
1976	C	68.1%	70.0%	519.1	(206.3)	70.3%
1977	C	69.9%	70.0%	519.1	(206.3)	70.3%
1978	W	98.8%	100.0%	725.4	-	98.3%
1979	N	100.0%	100.0%	725.4	-	98.3%
1980	W	100.0%	100.0%	725.4	-	98.3%
1981	D	100.0%	100.0%	725.4	-	98.3%
1982	W	100.0%	100.0%	725.4	-	98.3%
1983	W	100.0%	100.0%	725.4	-	98.3%
1984	AN	100.0%	100.0%	725.4	-	98.3%
1985	BN	100.0%	100.0%	725.4	-	98.3%
1986	W	100.0%	100.0%	725.4	-	98.3%
1987	C	68.2%	70.0%	519.1	(206.3)	70.3%
1988	C	73.9%	75.0%	551.4	(174.0)	74.7%
1989	BN	74.7%	75.0%	551.4	(174.0)	74.7%
1990	D	63.0%	65.0%	482.1	(243.3)	65.3%
1991	BN	61.9%	60.0%	444.3	(281.1)	60.2%
1992	C	69.9%	70.0%	519.1	(206.3)	70.3%
1993	AN	98.9%	100.0%	725.4	-	98.3%
1994	D	57.6%	60.0%	444.3	(281.1)	60.2%
1995	W	97.0%	95.0%	689.5	(36.0)	93.4%
1996	AN	100.0%	100.0%	725.4	-	98.3%
1997	W	100.0%	100.0%	725.4	-	98.3%
1998	W	100.0%	100.0%	725.4	-	98.3%
1999	AN	100.0%	100.0%	725.4	-	98.3%
2000	N	100.0%	100.0%	725.4	-	98.3%
2001	BN	100.0%	100.0%	725.4	-	98.3%
2002	N	69.0%	70.0%	519.1	(206.3)	70.3%
2003	N	97.7%	100.0%	725.4	-	98.3%
2004	BN	69.3%	70.0%	519.1	(206.3)	70.3%
2005	W	97.9%	100.0%	725.4	-	98.3%
2006	W	100.0%	100.0%	725.4	-	98.3%

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Maximum Labor Income ($ 000,000s)	Maximum Difference	% of Base Case
2007	D	100.0%	100.0%	725.4	-	98.3%
2008	BN	67.7%	70.0%	519.1	(206.3)	70.3%
2009	N	68.6%	70.0%	519.1	(206.3)	70.3%
2010	N	97.5%	100.0%	725.4	-	98.3%
2011	W	100.0%	100.0%	725.4	-	98.3%
2012	D	100.0%	100.0%	725.4	-	98.3%
Average		89.8%	90.2%	657.8		89.1%
Total				27,627.0	(2,839.9)	89.1%

Table 22. Estimated minimum impact in direct labor income by hydrologic year (2012 $s millions)

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Minimum Labor Income ($ 000,000s)	Minimum Difference	% of Base Case
1971	N	100.0%	100.0%	725.4	-	98.3%
1972	BN	100.0%	100.0%	725.4	-	98.3%
1973	N	100.0%	100.0%	725.4	-	98.3%
1974	AN	100.0%	100.0%	725.4	-	98.3%
1975	AN	100.0%	100.0%	725.4	-	98.3%
1976	C	68.1%	70.0%	623.3	(102.1)	84.5%
1977	C	69.9%	70.0%	623.3	(102.1)	84.5%
1978	W	98.8%	100.0%	725.4	-	98.3%
1979	N	100.0%	100.0%	725.4	-	98.3%
1980	W	100.0%	100.0%	725.4	-	98.3%
1981	D	100.0%	100.0%	725.4	-	98.3%
1982	W	100.0%	100.0%	725.4	-	98.3%
1983	W	100.0%	100.0%	725.4	-	98.3%
1984	AN	100.0%	100.0%	725.4	-	98.3%
1985	BN	100.0%	100.0%	725.4	-	98.3%
1986	W	100.0%	100.0%	725.4	-	98.3%
1987	C	68.2%	70.0%	623.3	(102.1)	84.5%
1988	C	73.9%	75.0%	638.6	(86.9)	86.5%
1989	BN	74.7%	75.0%	638.6	(86.9)	86.5%
1990	D	63.0%	65.0%	603.8	(121.7)	81.8%
1991	BN	61.9%	60.0%	584.0	(141.4)	79.1%
1992	C	69.9%	70.0%	623.3	(102.1)	84.5%
1993	AN	98.9%	100.0%	725.4	-	98.3%
1994	D	57.6%	60.0%	584.0	(141.4)	79.1%
1995	W	97.0%	95.0%	706.4	(19.1)	95.7%
1996	AN	100.0%	100.0%	725.4	-	98.3%
1997	W	100.0%	100.0%	725.4	-	98.3%
1998	W	100.0%	100.0%	725.4	-	98.3%
1999	AN	100.0%	100.0%	725.4	-	98.3%
2000	N	100.0%	100.0%	725.4	-	98.3%
2001	BN	100.0%	100.0%	725.4	-	98.3%
2002	N	69.0%	70.0%	623.3	(102.1)	84.5%
2003	N	97.7%	100.0%	725.4	-	98.3%
2004	BN	69.3%	70.0%	623.3	(102.1)	84.5%
2005	W	97.9%	100.0%	725.4	-	98.3%

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Minimum Labor Income ($ 000,000s)	Minimum Difference	% of Base Case
2006	W	100.0%	100.0%	725.4	-	98.3%
2007	D	100.0%	100.0%	725.4	-	98.3%
2008	BN	67.7%	70.0%	623.3	(102.1)	84.5%
2009	N	68.6%	70.0%	623.3	(102.1)	84.5%
2010	N	97.5%	100.0%	725.4	-	98.3%
2011	W	100.0%	100.0%	725.4	-	98.3%
2012	D	100.0%	100.0%	725.4	-	98.3%
Average		89.8%	90.2%	691.7		93.7%
Total				29,052.8	(1,414.0)	93.7%

Table 23. Estimated maximum impact in direct employment by hydrologic year (full and part-time jobs)

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Maximum Employment (jobs)	Maximum Difference	% of Base Case
1971	N	100.0%	100.0%	18,710	-	100.0%
1972	BN	100.0%	100.0%	18,710	-	100.0%
1973	N	100.0%	100.0%	18,710	-	100.0%
1974	AN	100.0%	100.0%	18,710	-	100.0%
1975	AN	100.0%	100.0%	18,710	-	100.0%
1976	C	68.1%	70.0%	14,410	(4,300)	77.0%
1977	C	69.9%	70.0%	14,410	(4,300)	77.0%
1978	W	98.8%	100.0%	18,710	-	100.0%
1979	N	100.0%	100.0%	18,710	-	100.0%
1980	W	100.0%	100.0%	18,710	-	100.0%
1981	D	100.0%	100.0%	18,710	-	100.0%
1982	W	100.0%	100.0%	18,710	-	100.0%
1983	W	100.0%	100.0%	18,710	-	100.0%
1984	AN	100.0%	100.0%	18,710	-	100.0%
1985	BN	100.0%	100.0%	18,710	-	100.0%
1986	W	100.0%	100.0%	18,710	-	100.0%
1987	C	68.2%	70.0%	14,410	(4,300)	77.0%
1988	C	73.9%	75.0%	15,115	(3,595)	80.8%
1989	BN	74.7%	75.0%	15,115	(3,595)	80.8%
1990	D	63.0%	65.0%	13,680	(5,030)	73.1%
1991	BN	61.9%	60.0%	12,890	(5,820)	68.9%
1992	C	69.9%	70.0%	14,410	(4,300)	77.0%
1993	AN	98.9%	100.0%	18,710	-	100.0%
1994	D	57.6%	60.0%	12,890	(5,820)	68.9%
1995	W	97.0%	95.0%	18,000	(710)	96.2%
1996	AN	100.0%	100.0%	18,710	-	100.0%
1997	W	100.0%	100.0%	18,710	-	100.0%
1998	W	100.0%	100.0%	18,710	-	100.0%
1999	AN	100.0%	100.0%	18,710	-	100.0%
2000	N	100.0%	100.0%	18,710	-	100.0%
2001	BN	100.0%	100.0%	18,710	-	100.0%
2002	N	69.0%	70.0%	14,410	(4,300)	77.0%
2003	N	97.7%	100.0%	18,710	-	100.0%
2004	BN	69.3%	70.0%	14,410	(4,300)	77.0%
2005	W	97.9%	100.0%	18,710	-	100.0%

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Maximum Employment (jobs)	Maximum Difference	% of Base Case
2006	W	100.0%	100.0%	18,710	-	100.0%
2007	D	100.0%	100.0%	18,710	-	100.0%
2008	BN	67.7%	70.0%	14,410	(4,300)	77.0%
2009	N	68.6%	70.0%	14,410	(4,300)	77.0%
2010	N	97.5%	100.0%	18,710	-	100.0%
2011	W	100.0%	100.0%	18,710	-	100.0%
2012	D	100.0%	100.0%	18,710	-	100.0%
Average		89.8%	90.2%	17,306		92.5%
Total				18,710	-	100.0%

Table 24. Estimated minimum impact in employment by hydrologic year (full and part-time jobs)

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Minimum Employment (jobs)	Minimum Difference	% of Base Case
1971	N	100.0%	100.0%	18,710	-	100.0%
1972	BN	100.0%	100.0%	18,710	-	100.0%
1973	N	100.0%	100.0%	18,710	-	100.0%
1974	AN	100.0%	100.0%	18,710	-	100.0%
1975	AN	100.0%	100.0%	18,710	-	100.0%
1976	C	68.1%	70.0%	17,350	(1,360)	92.7%
1977	C	69.9%	70.0%	17,350	(1,360)	92.7%
1978	W	98.8%	100.0%	18,710	-	100.0%
1979	N	100.0%	100.0%	18,710	-	100.0%
1980	W	100.0%	100.0%	18,710	-	100.0%
1981	D	100.0%	100.0%	18,710	-	100.0%
1982	W	100.0%	100.0%	18,710	-	100.0%
1983	W	100.0%	100.0%	18,710	-	100.0%
1984	AN	100.0%	100.0%	18,710	-	100.0%
1985	BN	100.0%	100.0%	18,710	-	100.0%
1986	W	100.0%	100.0%	18,710	-	100.0%
1987	C	68.2%	70.0%	17,350	(1,360)	92.7%
1988	C	73.9%	75.0%	17,550	(1,160)	93.8%
1989	BN	74.7%	75.0%	17,550	(1,160)	93.8%
1990	D	63.0%	65.0%	17,140	(1,570)	91.6%
1991	BN	61.9%	60.0%	16,860	(1,850)	90.1%
1992	C	69.9%	70.0%	17,350	(1,360)	92.7%
1993	AN	98.9%	100.0%	18,710	-	100.0%
1994	D	57.6%	60.0%	16,860	(1,850)	90.1%
1995	W	97.0%	95.0%	18,480	(230)	98.8%
1996	AN	100.0%	100.0%	18,710	-	100.0%
1997	W	100.0%	100.0%	18,710	-	100.0%
1998	W	100.0%	100.0%	18,710	-	100.0%
1999	AN	100.0%	100.0%	18,710	-	100.0%
2000	N	100.0%	100.0%	18,710	-	100.0%
2001	BN	100.0%	100.0%	18,710	-	100.0%
2002	N	69.0%	70.0%	17,350	(1,360)	92.7%
2003	N	97.7%	100.0%	18,710	-	100.0%
2004	BN	69.3%	70.0%	17,350	(1,360)	92.7%
2005	W	97.9%	100.0%	18,710	-	100.0%
2006	W	100.0%	100.0%	18,710	-	100.0%

Water Year	Water Year Type	Percent of Baseline		Example Economic Impact		
		Operations Model Canal Deliveries	Economic Model Surface Water	Minimum Employment (jobs)	Minimum Difference	% of Base Case
2007	D	100.0%	100.0%	18,710	-	100.0%
2008	BN	67.7%	70.0%	17,350	(1,360)	92.7%
2009	N	68.6%	70.0%	17,350	(1,360)	92.7%
2010	N	97.5%	100.0%	18,710	-	100.0%
2011	W	100.0%	100.0%	18,710	-	100.0%
2012	D	100.0%	100.0%	18,710	-	100.0%
Average		89.8%	90.2%	18,265		97.6%
Total				N/A	N/A	N/A

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ATTACHMENT 1

Table TR-1

Review team comments on the SED's citations related to natural flow regime and "unimpaired" flow regime

Attachment 1

Table TR-1. Review Team comments on the SED's citations related to natural flow regime and "unimpaired" flow regime.

Reference	Where Cited in the SED	Relevant Definition of Terms
Poff et al. 1997	Chapter 19 and Appendix C, pages 3-40; 3-41; 3-43; 3-47	Natural flow regime is that unaltered by human intervention. Poff et al. promotes this concept as the management goal/baseline for river basin ecological restoration decisions, but acknowledges the importance of functional flows. Poff states that for "many rivers, it is land-use activities, including timber harvest, livestock grazing, agriculture, and urbanization, rather than dams, that are the primary causes of altered flow regimes." Alterations of natural flow regimes also include draining of wetlands and construction of levees.
Tennant 1976	3-40	Suggests using varying percentage of the mean annual flow for seasonal minimum flow targets. Uses *"undepleted"* USGS hydrology data that refer to the stream in its pristine, natural conditions (e.g., before dams, levees, urbanization, diversions, pumps, etc.).
Orth and Maughan 1981	3-40	Provides an evaluation of Tennant Method – i.e., percentage of "undepleted" (Tennant 1976) mean annual flow (aka "Montana Method") for Oklahoma streams. Recommended that slightly different percentages of the "undepleted" mean annual flow was applicable for streams in Oklahoma.
Marchetti and Moyle 2001	3-40	Collected empirical fisheries data during dry and wet years in Putah Creek, CA, following two wet years which resulted in the displacement of non-native species to downstream reaches. Final flow regime to support native species employed patterns of a natural flow regime, not a pure unaltered (i.e., mimicking the timing and duration of flow variation in the natural flow regime, but not necessarily the overall magnitude or volume).
Mazvimavi et al. 2007	3-40	The study hypothesized that in order to maintain slightly modified to natural habitats along the rivers of Zimbabwe, the environmental flow recommendation should be 30–60% of mean annual runoff in regions with perennial rivers. The MAR statistic attempts to mimic a natural flow regime by calculating runoff without human intervention.
Moyle et al. 2011	3-40; 3-41	This is a large document that reviews and critiques past Environmental Flow Methodologies used in FERC licensing throughout CA. The last Section (4.0) of the report describes a follow up to the study published by Marchetti and Moyle 2001, a test of the functional flow regime concept in Putah Creek, CA, and is the apparent target for use as a reference. The minimum flow release schedule implemented in 2000 as a result of the Putah Creek Water Accord provided a test of a functional flow regime concept. The release schedule was explicitly designed to mimic the natural flow regime, principally in terms of the seasonal timing of increases and decreases in streamflow, but not the full magnitude of the natural flow regime. After eight years of fisheries monitoring under the new flows, the authors conclude that implementation of the new flow regime has allowed native species to regain dominance of more than 20 km of lower Putah Creek. This favorable outcome was achieved by manipulating stream flows at key times of the year and only required a small percentage of the available water during most water years. While the authors call the new Putah Creek flows a "natural flow regime", it was not a pre-human perturbation "natural flow regime" (per

Reference	Where Cited in the SED	Relevant Definition of Terms
		Poff et.al. 1997) as described in the Section 3.1.1 Terminology (p 3-1) of Appendix C. Rather, the new Putah Creek flow regime seems to most closely align with the definition of functional flow regime.
Arthington et al. 1992	3-40	The methodology described is to first estimate the unregulated hydrograph preferably from analysis of historical unregulated flow records if available (as a surrogate for the Poff et al. 1997 "natural flow regime") as the ecological baseline. With the unregulated hydrograph defined, elements of the hydrograph with ecological importance are identified, and a modified flow regime that incorporates the ecologically important features is defined within the site specific constraints of the river basin. The difficulty is in the identification of those certain features of the natural hydrological regime that are of value (timing, duration, and magnitude) to the ecosystem versus those that are not. This approach appears to use the Poff et al. 1997 "natural flow regime" as baseline to inform flow modifications.
Arthington et al. 2004	3-40	This is another international scope paper that reviews some of the more that 200 environmental flow assessment (EFA) methodologies in use worldwide today. Emphasis is placed on two primary types of EFA used in Australia and southern Africa: (1) A proactive response, intended to maintain the hydrological regimes of undeveloped rivers as close as possible to the un-regulated condition, or at least to offer some level of protection of natural river flows and ecosystem characteristics, and (2) A reactive response, intended to restore certain characteristics of the pre-regulation flow regime and ecosystem in developed rivers with modified/regulated flow regimes. The paper favors an approach referred to as "Holistic Methodologies". This type of approach reasons that if certain functional ecological features of the natural hydrological regime can be identified and adequately incorporated into a modified flow regime, then, all other things being equal, the extant biota and functional integrity of the ecosystem should be maintained (Arthington et al. 1992; King and Tharme 1994). These methodologies are underpinned by the concept of the "natural flow paradigm" (Poff et al. 1997) and basic principles guiding river corridor restoration. The difficulty is in the identification of those certain features of the natural hydrological regime that are of value (timing, duration, and magnitude) to the ecosystem versus those that are not.
NRDC 2005	3-40	Information provided is not from the NRDC review cited but rather the Texas Water Development Board (TWDB 2008) Texas Instream Flow Technical Manual. The study approach adopted for the instream flow program focuses on the flow requirements of the entire riverine ecosystem. Studies will be multidisciplinary in nature, including the disciplines of hydrology and hydraulics, biology, geomorphology, and water quality. Studies will also address connectivity and linkages between each discipline. Multidisciplinary studies will be integrated to develop a flow regime composed of several flow components such as subsistence and base flows, high flow pulses, and overbank flow components. Flow components will be identified for wet, average, and dry hydrologic conditions, as appropriate.

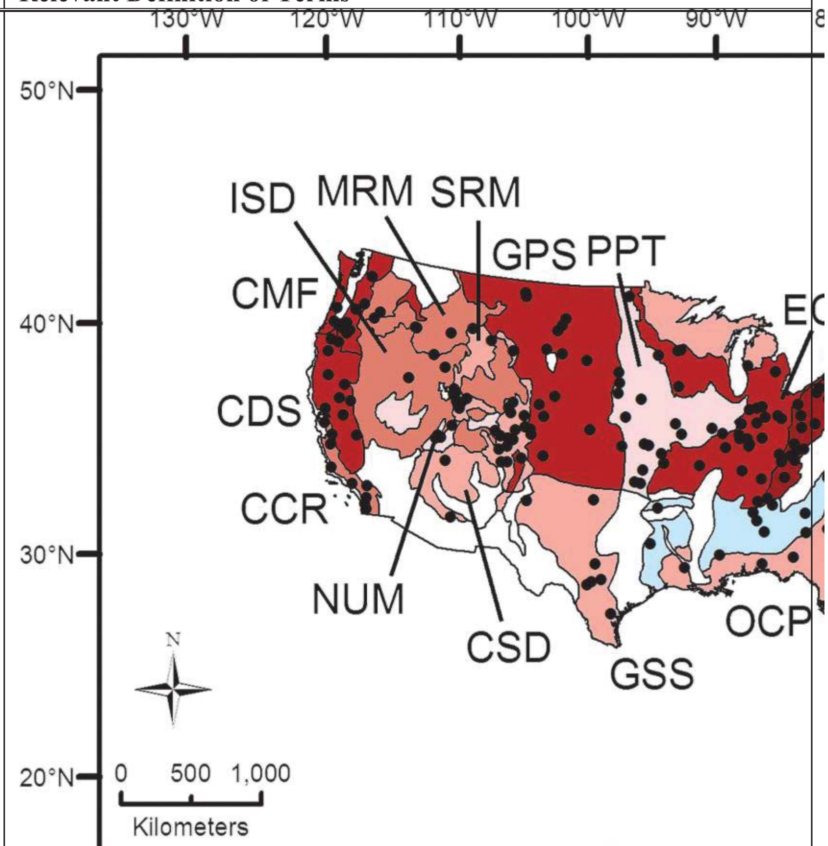
Reference	Where Cited in the SED	Relevant Definition of Terms
		This is a comprehensive study-based approach that does not purport to mimic the Poff et al. 1997 "natural flow regime" but rather attempts to determine through study those aspects of the river flow regime that are important to preserving or enhancing a broad array of ecosystem functions.
Florida Administrative Code 2010	3-40	Information is obtained from a program summary document (SFWMD 2007). The south Florida Natural System Regional Simulation Model (NSRSM) is designed to simulate south Florida's pre-development hydrology to assist in the development of restoration strategies outlined in the Comprehensive Everglades Restoration Plan (CERP). The CERP was designed to restore the Everglades ecosystem while maintaining adequate flood protection and water supply for south Florida. The CERP requires an understanding of the south Florida regional system hydrology prior to drainage and development. Natural system modeling has been used in south Florida, in combination with other adaptive management tools, to formulate restoration plans and set targets. The model applicable to the unique hydrologic processes and geologic features in pre-drainage south Florida, such as storage and flows through a flat but microtopographically varied ridge and slough landscape.
Hirji and Davis 2009	3-40	This is another broad based international publication of the World Bank to develop policies and practices for environmental flow assessments (EFA) to incorporate in lending decisions. Similar to Arthington et al. 2004, it covers a broad range of EFA methods but favors holistic methods. Although there are various methods for undertaking EFAs, they fall into four discrete groups, namely hydrological index methods, hydraulic rating methods, habitat simulation methods, and holistic methodologies. Holistic methodologies, which typically incorporate all components of the flow regime, are at the cutting edge of EFA methodology. Applying these methods involves a wide range of water users and sometimes includes considerations of the social and economic dependence of communities on environmental flows. Holistic methods were developed in South Africa and Australia, but are increasingly being tried in other parts of the world.
Sparks 1995	3-40; 3-41	This paper discusses the importance of large river-floodplain ecosystems and the consequences of altering their natural processes, functions, and connectivity. The focus is on the Mississippi basin floodplains and the importance of floodplain connectivity, both longitudinal and lateral, to the basin ecosystem. A major thrust of the paper describes the ecological harm caused by flood control channelization and levees because of the resulting loss of floodplain connectivity. Nutrient enrichment, plankton blooms, and deoxygenation of Gulf of Mexico in the Delta region is also aggravated by flood control projects, as floodplain inundation removes nutrients from the river. The author promotes ecosystem management with the goal of attaining biotic integrity via reestablishment of floodplain connectivity. A pre-disturbance ecosystem as a reference point is proposed using available hydrologic data from 1870 to 1893 as representative of a relatively undisturbed condition before draining and leveeing of the floodplains.

Reference	Where Cited in the SED	Relevant Definition of Terms
		The paper concludes that restoring an annual flood pulse (presumably of a manageable magnitude) would do much to restore biotic integrity in the river basin. While pre-human disturbance flow regimes are used as a reference point for timing of floods, the focus of this paper is really on the ecological damage caused by channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization, which CA chooses to ignore in its use of "unimpaired flow" as the reference condition.
Walker et al. 1995	3-40	This paper focuses on the ecosystem functions supported by the natural flow regime in arid and semi-arid river basins. Similar to Sparks (1995), the focus is on flood pulse timing and magnitude to recover missing ecosystem functions of the floodplain. The authors note that in arid and semi-arid regions, baseline unaltered flow estimates require a longer period of recorded to establish flood frequency and magnitude because floods are less frequent and more variable in these dryer climates. Similar to Sparks (1995), the authors note that *"small weirs, barrages, causeways, levees and river training structures may be no less influential than dams, by virtue of their numbers and ubiquity. Their effects are compounded by offstream storages, selective manipulation of tributary flows and interbasin transfers, so that the cumulative effects may represent a far more extensive level of regulation than that suggested by dams alone"*. They suggest an IHA analysis similar to Richter et al. methods (in development at the time of publication) to establish an estimated pre-human natural flow regime as the ecological baseline.
Richter et al. 1996	3-40	This is the well-known Richter paper introducing the Indicators of Hydraulic Alteration (IHA) methodology which utilizes various metrics to determine the magnitude of deviation a present day hydraulic regime and a natural flow regime (pre-human influence).
Tharme and King 1998	3-40	Information is from the updated version of the manual published in 2008 (King et al. 2008). The building block method (BBM) described in this manual does not dwell on unaltered or natural flow regimes. Instead, five major assumptions that are prevalent in riverine ecology, and are fundamental to the credibility of the BBM, are analyzed: • There is spare water in rivers. • Rivers will recover from most perturbations. • The natural disturbance regime of rivers is important for the maintenance of their biodiversity. • The maintenance of habitat will ensure the persistence of species. • Riverine communities, particularly those of semi-arid regions, are driven by abiotic rather than biotic processes. The hydrological functioning of the river is not important per se. Rather, it is the impact of different hydrological regimes on the ecological functioning of the river that is of primary concern. The hydrological information can therefore be viewed as 'service' data.

Reference	Where Cited in the SED	Relevant Definition of Terms
		It has been common practice to base flow assessments using the BBM on the natural flow regime of the river that is, with all impacts of upstream developments removed, on the assumption that this is the condition against which the future modified regime should be compared. This is a logical approach, given that the designated EMC for the river can range from totally natural (pristine) to critically modified (Chapter 11). It would not be logical to consider only the present-day regime if the EMC were to be set at a closer to natural level, as there would be no information on the natural upper limit of flows to guide discussions on how to upgrade the condition of the river. Ideally, information on both regimes (natural and present day) should be made available, so that the new recommended flow regime can be logically described in terms of both present and past flow conditions.
Bunn and Arthington 2002	3-40; 3-41; 3-42; 3-44	This is a literature review on a world-wide scale prepared by two Australian investigators. The purpose of the literature review was to highlight the important mechanisms that link hydrology and aquatic biodiversity and to illustrate the consequent impacts of altered flow regimes. As a literature review document, the discussions contrasting natural to altered flow regimes are often vague and undefined. However, when the concept of "natural flow regime" is mentioned on several occasions in the text it is accompanied by a citation to Poff et al. (1997), which implies a pre-human alteration hydrologic baseline perspective.
Richter et al. 2003	3-40	As with earlier Richter papers, the concept of the "natural flow regime" is promoted as the baseline standard resulting in the "natural state of freshwater ecosystems" having maximum richness of native species and high complexity of biophysical habitats. However there is an evolution of sorts being promoted that recognizes human needs must also be considered and that the key in water management lies in the ability to maintain/balance aspects of the natural flow regime that drive important ecological aspects while also accommodating human needs similar to the BBM method described by Tharme and King 1998. <u>Quotes from Richter et al. 2003:</u> '*When natural variability in river flows is altered too much, marked changes in the physical, chemical, and biological conditions and functions of natural freshwater ecosystems can be expected. When changes to natural flow regimes are excessive, causing a river ecosystem to degrade toward an altered character, the costs are high to both biodiversity and society.'* "*In this paper we have sketched what we believe to be a useful roadmap for finding ecological sustainability in water management. We are inspired by growing evidence proving that water management does not need to compromise freshwater ecosystems while providing for human needs.*"
Richter and Thomas 2007	3-47	*"Assessing the potential benefits of dam re-operation begins by characterizing the dam's effects on the river flow regime, and formulating hypotheses about the ecological and social benefits that might be restored by releasing water from the dam in a manner that more closely resembles natural flow patterns."*

Reference	Where Cited in the SED	Relevant Definition of Terms
		"Of all the environmental changes wrought by dam construction and operation, the alteration of natural water flow regimes has had the most pervasive and damaging effects on river ecosystems and species (Poff et al. 1997, Postel and Richter 2003)." *"In this paper we discuss opportunities and strategies for modifying dam operations, hereafter referred to as "re-operation" for restoring natural flow regimes and associated ecosystem health and services, which are important to society. We focus on restoration of natural flow regimes as a general principle of dam re-operation because sustaining river-dependent biodiversity and ecosystem services requires maintaining some semblance of natural flow characteristics (Poff et al. 1997, Richter et al. 2003, Postel and Richter 2003).* *"It is important to acknowledge that given multiple and often competing objectives imposed upon any water management system, both the volume and timing of water releases from a dam will likely differ from natural flows."* *"We begin by describing the primary ways in which dams of various types alter the natural flow regime. We then offer a conceptual framework for assessing opportunities and constraints in restoring natural flow characteristics, and conclude by describing a variety of dam re-operation strategies that can be used to restore environmental flows and associated benefits."* *"When environmental flow criteria such as minimizing departures from the natural flow regime are included in the optimization scheme, the considerable flexibility in a multi-dam operation can be effectively tapped for environmental flow restoration."*
Tharme 2003	3-40	This paper aims to provide a global overview of the current status of development and application of methodologies for addressing the environmental flow needs of riverine ecosystems, against the background of an ever-increasing rate of hydrological alteration of such systems worldwide and the resultant environmental impacts. It outlines the main types of environmental flow methodologies available and explores the extent to which they have been utilized in different countries and world regions, with emphasis on the identification of emerging global trends.
Poff et al. 2006	3-40	This paper evaluates similarities and differences at different spatial scales and geomorphic scales in how streamflow variability relates to natural ecological integrity. <u>Quotes from Poff et al. 2006:</u> *"The importance of hydrologic variability in sustaining natural riverine ecosystems is now well accepted."* *"….however, some critical questions have arisen concerning the degree to which generalizations about flow regime characteristics are geographically dependent both within and among regions, and the degree to which flow variability alone captures critical environmental variability."*

Reference	Where Cited in the SED	Relevant Definition of Terms
		"First, we examined hydrologic variability among 463 readily available daily streamflow gauges from five continents/countries around the world: Australia, New Zealand, South Africa, Europe, and the United States." *"Second, within the continental United States, we examined how hydrologic variability changes along river profiles as catchment area increases for five river basins arrayed across a gradient of hydroclimatic variation."* *"Third, we used a modeling approach to illustrate how geomorphic setting provides a context for assessing the ecological consequences of flow variation at the local scale of stream reaches."* *"Among river ecologists there is now a general consensus that 'natural' or 'normative' flows are a desirable goal to sustain riverine function and native biodiversity (Poff et al., 2003). This viewpoint is supported by numerous case studies that clearly indicate the importance of natural flow variability for both ecological processes (see reviews in Poff et al., 1997; Bunn and Arthington, 2002) and evolutionary adaptations (Lytle and Poff, 2004)."*
Poff et al. 2007	3-40; 3-41; 3-44	This paper examines the cumulative regional pattern of the loss of natural flow regimes (or homogenization of flow regimes) across the continental US. <u>Quotes from Poff et al. 2007:</u> *"Here, we use 186 long-term streamflow records on intermediate-sized rivers across the continental United States to show that dams have homogenized the flow regimes on third- through seventh-order rivers in 16 historically distinctive hydrologic regions over the course of the 20th century."* *"For 317 undammed reference rivers, no evidence for homogenization was found, despite documented changes in regional precipitation over this period."* *"By strongly modifying natural flow regimes, dams have the potential to reduce these natural regional differences and thus impose environmental homogeneity across broad geographic scales."* (See figure below)

Reference	Where Cited in the SED	Relevant Definition of Terms
		
Brown and Bauer 2009	3-40; 3-41; 3-48	This is a publication by Larry Brown regarding California's Central Valley Rivers (including the San Joaquin River drainage) and the effect of hydrologic infrastructure on native and alien fish species. <u>Quotes from Brown and Bauer 2009:</u> *"In this paper, we evaluate how existing hydrologic infrastructure and management affect streamflow characteristics of rivers in the Central Valley, California and discuss those characteristics in the context of habitat requirements of native and alien fishes. We evaluated the effects of water management by comparing observed discharges with estimated discharges assuming no water management ('full natural runoff')."* *"The reduced discharges in the San Joaquin River drainage streams are favorable for spawning of many alien species, which is consistent with observed patterns of fish distribution and abundance in the Central Valley. However, other factors, such as water temperature, are also important to the relative success of native and alien resident fishes."* *"We use the Indicators of Hydrologic Alteration (IHA) software (TNC, 2007) to address our rimary question: How does the existing hydrologic infrastructure and management affect the streamflow characteristics of each river compared to natural flows?"* *"Our basic approach was to compare estimates of 'full natural runoff' (FNR) with measured streamflow (observed; OBS) for the time period*

Reference	Where Cited in the SED	Relevant Definition of Terms
		after completion of the most recent major unpassable downstream dam (Table I).” *“Estimates of FNR are calculated based on a number of measurements from the upper watershed, including precipitation, gauge records and reservoir levels. Basically, inflows from precipitation are adjusted for water storage, water diversions and reservoir releases to estimate flows in the absence of such manipulation (CDEC; http://cdec.water.ca.gov/). These estimates should not be interpreted as ‘true’ unimpaired historical streamflows because the reconstructions do not account for changes in the historic channel configuration (e.g. loss of side channels) or changes in land use (e.g. deforestation, agriculture).”* *“In California and elsewhere, a major impediment to developing river management strategies is the paucity of data on the linkages between hydrologic modification and biological responses (Pringle et al., 2000; Arthington et al., 2006; Murchie et al., 2008).”* *“Thus, changes in water management can affect hundreds of kilometers of river habitat. The effects of such changes should be evaluated for the entire ecosystem rather than selected species of management interest (e.g. Chinook salmon).”*
Resh et al. 1988	3-40	The authors define disturbance in stream ecosystems to be: any relatively discrete event in time that is characterized by a frequency, intensity, and severity outside a predictable range, and that disrupts ecosystem, community, or population structure and changes resources or the physical environment. The purpose of the publication is to provide a literature review and propose methods for comparing the responses of different streams and their biotic communities to flow disturbances.
Power et al. 1995	3-40	This paper presents a model to explore how temporal and spatial relationships of hydrology and hydraulics in floodplain rivers influence the dynamics of the food chain, including humans as top predator. This paper is similar to Sparks et al. (1995), as the focus is on floodplain connectivity and the potential harm (to the food chain) caused by flood management infrastructure (levees, dams, and agriculture on floodplains).
Naiman et al. 2008	3-41	This is another paper focusing on the importance inter- and intra-annual variability of the hydrologic regime using examples from the Sabie River in South Africa and the Queets River, Washington, USA. Emphasis is also placed on the difficult challenge of establishing appropriate environmental flows. Quotes from Naiman et al. 2008: “*Our objective is to illustrate how variability in flow and water temperature shapes the biophysical attributes and functioning of river systems. We explain the ecological rationale for sustaining flow variability. We examine case studies from rivers in two contrasting climate regions – a semi-arid savanna river in South Africa and a temperate rainforest river in North America – that illustrate connections between flow variability, large wood, and the development of river-specific ecological characteristics. We conclude by exploring the*

Reference	Where Cited in the SED	Relevant Definition of Terms
		importance of variability in establishing environmental flows for rivers – flows needed to sustain ecological systems." *"….degradation of freshwater biodiversity and environmental quality is ongoing…. Much of this degradation is a direct result of flow homogenization of the world's rivers by dams and by water withdrawals that undermine natural flow variability [10,52,71]. Nevertheless, it is recognized that flow regulation, land fragmentation and development are a suite of tightly interacting factors, often implemented simultaneously, making it difficult to assign cause and effect to one or the other."*
Lytle and Poff 2004	3-41; 3-42; 3-47	This paper examines (ponders?) the relationships between extreme flow variation (floods, droughts) and short term (population ecology) long term (evolution) adaptation over both local and regional spatial scales. <u>Quotes from Lytle and Poff 2004:</u> *"The natural flow regime paradigm (Box 2) has become a fundamental part of the management and basic biological study of running water ecosystems [2–4]. Although some of the ecological consequences of altered natural flow regimes have been reviewed [3,5], little attention has been paid to how organisms have evolved in response to floods and droughts."*
Fleenor et al. 2010	3-41	This paper discusses methods used for establishing environmental flows for the Bay-Delta. The text of Appendix C cites this source in the following context: two methods for determining flow needs: 1) flows based on the unimpaired flow, and 2) flows based on the historical flow. As indicated in the fourth quote from the source below, four methods are actually discussed. <u>Quotes from Fleenor et al. 2010:</u> *"Any serious scientifically-based effort to establish flows for desirable fishes, including our work, is therefore exploratory and cannot be a finished product. Moreover, it is not possible to resolve scientifically the major uncertainties over flow prescriptions within current planning timeframes. Managing uncertainty during the indefinite period of implementation for flow prescriptions will pose a far greater technical and institutional challenge than setting the initial prescriptions."* *"The larger professional literature contains much on environmental flows for rivers and other water bodies, with little consensus on method."* *"For the Delta, these difficulties are compounded by major geological, biological, and engineering challenges, particularly the return of diked, subsided lands to aquatic habitat (subtidal, intertidal and floodplains), changes in water management within and upstream of the Delta, including likely peripheral diversions of much of the water currently exported through the Delta, new invasive species, and water contamination from upstream and in-Delta uses. These massive ongoing and potential changes cast doubt on the future value of empirical relationships often used to establish required Delta flows."*

Reference	Where Cited in the SED	Relevant Definition of Terms
		"Additional flows are needed upstream of the Delta to support fish migration, spawning, and rearing. However, at this time riverine environmental flows seem better handled by other efforts." *"Here we examine four approaches for prescribing environmental flows for the Sacramento-San Joaquin Delta: (1) unimpaired (quasi-natural) inflows, (2) historical impaired inflows that supported more desirable ecological conditions, (3) statistical relationships between flow and native species abundance, and (4) the appropriate accumulation of flows estimated to provide specific ecological functions for desirable species and ecosystem attributes based on available literature."* *"Engineers have developed a surrogate for upstream natural inflow called ""unimpaired" inflows that the Delta would likely have seen without interference from upstream dams or diversions, or in-Delta diversions. These flows have been estimated for the 1921— 2003 period by the California Department of Water Resources for use in various models of Central Valley water projects (DWR 2006). These are only estimates of stream flows for this period, and are unlikely to capture the effects of longer attenuation of spring flows by upstream marshlands and floodplains, evapotranspiration from vast floodplains and marshlands, riparian forests and unimpaired stream-aquifer interaction of the natural system. All were prominent features of the pre-development hydrology."* *"Pre-development flow, habitat, and water quality variability are likely to remain somewhat uncertain since precise pre-development measurements are imperfect and estimates are questionable because it is difficult to understand the full extent of changes in climate, base flow from groundwater, floodplain areas, and modified Delta channels."* *"Flows needed to support desirable Delta fishes are likely to have changed from pre-European settlement conditions because of extreme landscape changes, illustrated by the 1873 map of the Central Valley in Figure 1 with vast often-connected areas of seasonal and permanent wetlands. The changes include upstream watershed changes, tidal marsh reclamation and channelization of the upstream and in-Delta landscape, impacts of biological invasions, and on-going climate change and sea level rise. Greater or lesser flows might be needed to adjust for the conversion of most of the Delta from marshland to agriculture and the severing of river channels from floodplains."* *"During the post landscape-development period of the 1940s – 1970s, native populations were still reasonably robust, although some fishes had already gone extinct (e.g., Sacramento perch and thicktail chub). By this time most Delta marshland had been converted to agriculture, floodplains had been greatly reduced, dam development and upstream diversions reduced inflows and increased salinity intrusions, channelization of the Delta greatly reduced shallow water and intertidal habitat, and many invasive species had arrived. However, this period differed substantially from the contemporary era of rapidly declining populations, in part, because major water exports from the Delta had not yet begun. Contrasting flows from this period with unimpaired*

Reference	Where Cited in the SED	Relevant Definition of Terms
		flows (when native fishes had more robust populations) and more recent flow conditions (when dam development was complete and native fishes fared worse) provides some indications for how much fresh water is needed to keep native fish populations healthy." *"Table 2 contains historical flow volumes for three periods: 1949 – 1968, 1969 – 1985 and 1986— 2005. The early 20-year period represents a time when fish were known to be doing better and the last 20-year time frame when fish were doing worse (Moyle and Bennett 2008). The middle 17 years represents a transitional water export period and contains extreme wet and dry periods."* *"Historical flows under which native fish were more successful should have greater relevance for establishing fish flows for the current highly altered Delta."* *"Basing environmental flows solely on historical and estimated pre-development conditions, or on past aggregate correlations between flows and fish populations might not be the best approach alone."* *"Thus, fish relationships to flow that are established using past data might lead us astray, if not considered in light of how they may be influenced by changing conditions".*
Petts 2009	3-41	This paper is a review of the instream flow policy development and offers a critical and international state-of-the-science perspective of environmental flows. It is written from environmental flow advocacy perspective. <u>Quotes from Petts 2009:</u> *"The ecological integrity of riverine ecosystems depends on their natural dynamic character (Poff et al., 1997). The fundamental ecological principle for the sustainable management of riverine ecosystems is the need to sustain flow variability that mimics the natural, climatically-driven variability of flows at least from year to year and from season to season, if not from day to day (Naiman et al. (2002). Thus, the two fundamental general principles are:* *1. the natural flow regime shapes the evolution of aquatic biota and ecological processes; 2. every river has a characteristic flow regime and an associated biotic community."* *"Second is the issue of 'naturalizing' the gauged flow regime. In many areas the pristine catchment has no relevance to the modern day. The hydrology of catchments characterized by long-term human interference – such as urban conurbations and intensive agriculture – bears little resemblance to the hydrologic character of unmodified catchments in a given ecoregion. The concept for such catchments may be to produce functionally diverse, self-regulating ecological systems that provide medium-term enhancements and allow longer-term catchment-scale planning (Petts et al., 2000). In reality this requires determination of the flow regime that would be sustained under current or future catchment conditions in the absence of existing dams, reservoirs, diversions and abstractions."*
Freeman et al. 2001	3-41	This is a study looking at differences in the fish communities in the tailwater of a large peaking project and an unregulated river reach

Reference	Where Cited in the SED	Relevant Definition of Terms
		upstream of the peaking project on the Tallapoosa River. Definitions of unimpaired flow or natural flow are not directly addressed.
Moyle and Mount 2007	3-41	This is an editorial type commentary in a technical journal discussing the linkage between regulated river reaches, loss of biodiversity, loss of native fish species, and establishment of invasive alien species. Quotes from Moyle and Mount 2007: *"We suggest that the following measures are some of the key alternatives for recreating alluvial rivers below dams: dam removal, alteration of flow regimes, protection of tributaries below dams, recreation of floodplains, and active management of channels as habitat. Often these measures must be used in conjunction with one another for successful reestablishment of native biota."* *"Alteration of flow regimes is one of the most widely used options because of the perception, often wrong, that large benefits can be achieved at low cost. As a consequence, methodologies have developed worldwide to determine how much water should be left in rivers to maintain ecological function (11). Increasingly, these methodologies focus on restoring a flow regime that mimics in some respects the historic flow regime, but that requires much less water. This concept of the natural flow regime (12) is achieving wide acceptance as a useful model for bringing back native organisms adapted to local flows."* *"A common consequence of flow regulation is the disconnection of floodplains from river channels through a combination of incision, levee construction, and lack of sufficient flood pulses for frequent floodplain inundation. For many species, regular connection to the floodplain at the appropriate time of year is essential for persistence (17). Even partial reconnection of a river to its floodplain through increased flows and levee setbacks can favor native fishes and other organisms."* *"Unfortunately, even intensive management of a regulated river often cannot prevent invasions by alien species. In fact, in our experience, alien fishes are generally present in low numbers even in ''restored'' streams with natural flow regimes. The numbers of aliens can quickly increase under favorable conditions, such as prolonged low flows created by drought."*
Brown 2000	3-41;	*"Twenty sites in the lower San Joaquin River drainage, California, were sampled from 1993 to 1995 to characterize fish communities and their associations with measures of water quality and habitat quality. The feasibility of developing an Index of Biotic Integrity was assessed by evaluating four fish community metrics, including percentages of native fish, omnivorous fish, fish intolerant of environmental degradation, and fish with external anomalies. Of the thirty-one taxa of fish captured during the study, only 10 taxa were native to the drainage."*
Freyer and Healey 2003	3-41	*"We sampled 11 sites in the southern Sacramento-San Joaquin Delta from 1992–1999, to characterize fish communities and their associations with environmental variables. Riparian habitats were dominated by rock-reinforced levees, and large water diversion facilities greatly influenced local hydrodynamics and water quality. We captured 33 different taxa, only eight of which were native. None of the native species represented more than 0.5% of the total number of individuals collected."*

Reference	Where Cited in the SED	Relevant Definition of Terms
		"Additionally, dams associated with the water projects highly regulate river inflow to the region and compromise the natural hydrograph. The south Delta is arguably the most altered region of the system considering the influence of the water export facilities and associated river flow control structures (Nichols et al. 1986, Arthur et al. 1996), as well as degraded habitat quality in the lower San Joaquin River (SJR) drainage (Saiki 1984, Brown 2000)."
Brown and May 2006	3-41; 3-48	This paper summarizes results of a study using seining data from two monitoring programs to provide an integrated view of spring near shore resident fish species composition and life history characteristics in five regions: the San Joaquin River, the upper Sacramento River, the lower Sacramento River, the northern Sacramento-San Joaquin Delta (North Delta), and the Interior Delta. Quotes from Brown and May 2006: *"The potential benefits of San Joaquin River native fish restoration appear high because there is so much potential for improvement; however, it is unclear how to best manipulate the system to achieve such restoration. Addressing such uncertainties is necessary if society desires the preservation and restoration of native biodiversity as human demands on water resources increase."* *"However, it is unclear how to manipulate the San Joaquin River system to renew the connection of the tributary populations of native fishes with the mainstem San Joaquin River, through the Interior Delta, and into the North Delta. The responses of alien fishes to restoration actions will be critical to determining success. The costs of such restoration actions, once identified, might outweigh the potential benefits, especially if similar or greater benefits for native fishes could be accomplished elsewhere in the system with less difficulty."*
Brown and Michniuk 2007	3-41	This study was very similar to Brown and May 2006 except that littoral zone electrofishing data were examined as opposed to the near-shore sein data used in Brown and May 2006.
Gido and Brown 1999	3-41	This paper summarizes an analysis of data from the literature that were used to document colonization patterns by introduced freshwater fishes in 125 drainages across temperate North America. The study found that drainages with a high number of impoundments, large basin area and low native species diversity had the greatest number of introduced species.
King et al. 2003	3-42	*"Floodplain inundation in rivers is thought to enhance fish recruitment by providing a suitable spawning environment and abundant food and habitat for larvae."* *"The observed low use of the inundated floodplain for recruitment in this study contradicts previous models. We propose a model of the optimum environmental conditions required for use of the inundated floodplain for fish recruitment. The model suggests that the notion of the flood pulse alone controlling fish recruitment is too simplistic to describe all strategies within a system. Rather, the life history adaptations in the fauna of the system and aspects of the hydrological regime such as duration and timing of inundation will control the response of a river's fish fauna to flooding."*

Reference	Where Cited in the SED	Relevant Definition of Terms
McElhany et al. 2000	3-42	This document introduces the viable salmonid population (VSP) concept, identifies VSP attributes, and provides guidance for determining the conservation status of populations and larger-scale groupings of Pacific salmonids. <u>Quotes from McElhany et al. 2000:</u> *"Practically speaking, applying our definition of a population will involve an assumption about the degree of independence individual fish groups experienced under historical or "natural" conditions (i.e., before the recent or severe declines that have been observed in many populations). It is necessary to consider historical conditions to ensure that a population designation is not contingent on relative conservation status among groups of fish. In some cases, it may be determined that environmental conditions are so altered that either it is impossible to evaluate an ESU's pre-decline population structure or the population structure of the recovered ESU would be substantially different from what it was historically."*

ATTACHMENT 2

Figures TR #5 through TR #11

Attachment 2

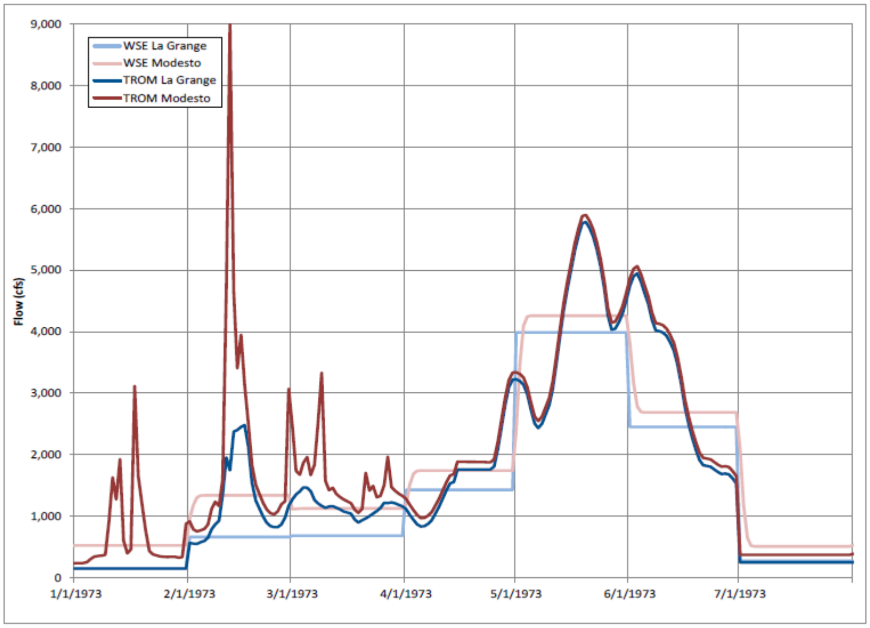


Figure TR-5. Plot comparing modeled Tuolumne River flow variability for 1973 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

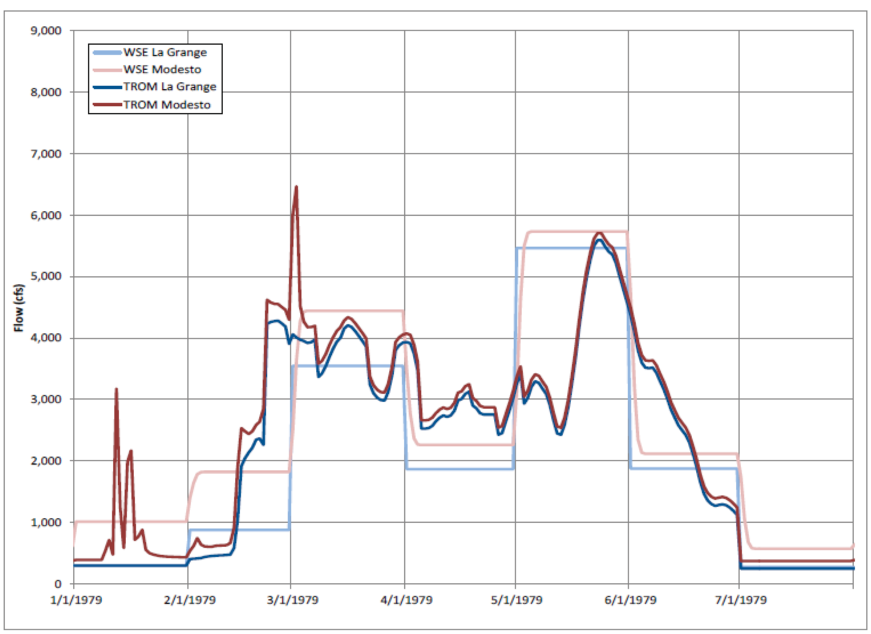


Figure TR-6. Plot comparing modeled Tuolumne River flow variability for 1979 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

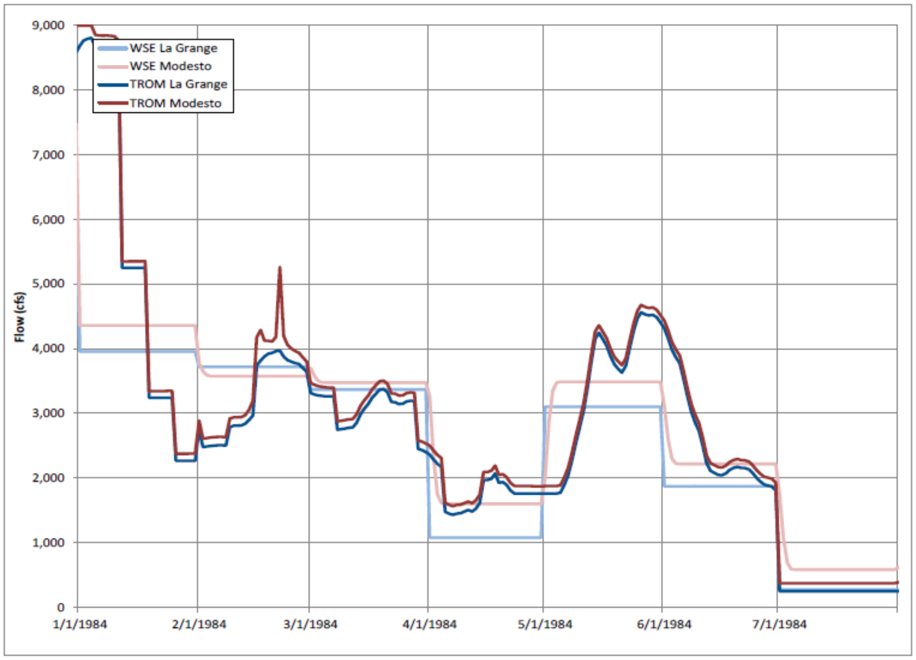


Figure TR-7. Plot comparing modeled Tuolumne River flow variability for 1984 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

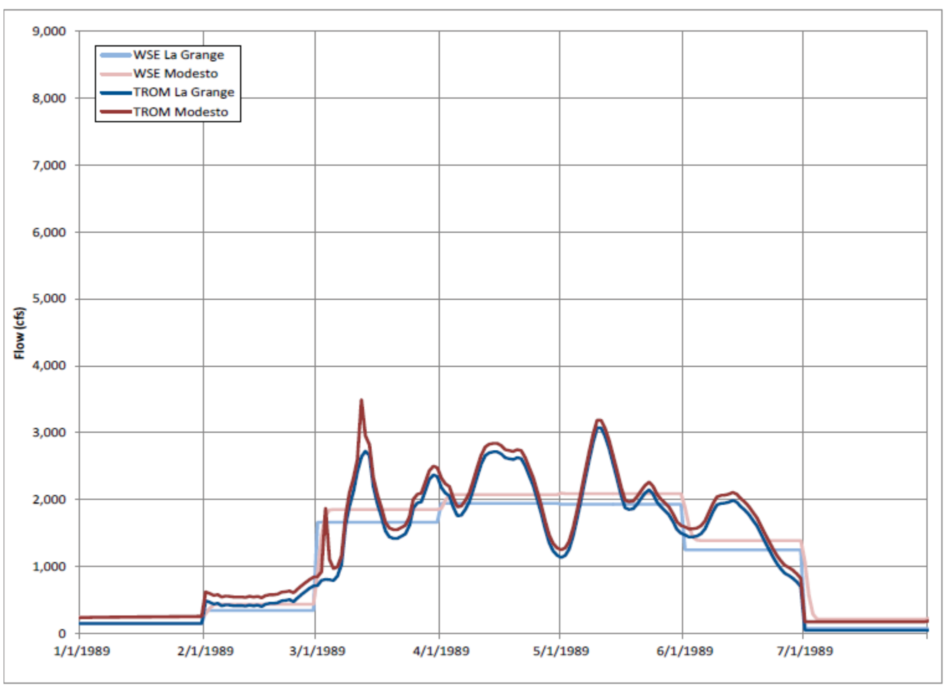


Figure TR-8. Plot comparing modeled Tuolumne River flow variability for 1989 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

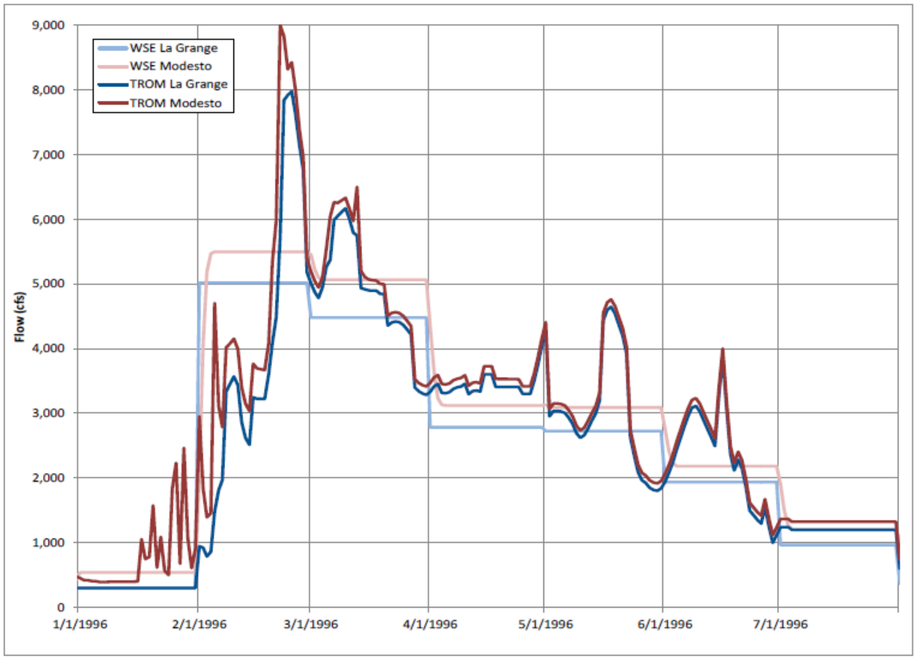


Figure TR-9. Plot comparing modeled Tuolumne River flow variability for 1996 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

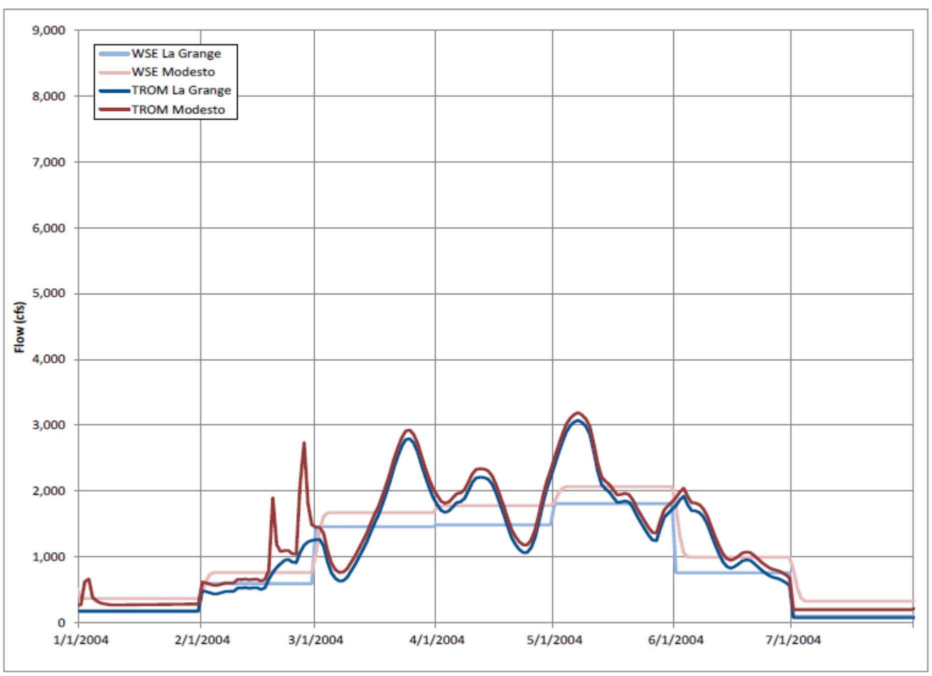


Figure TR-10. Plot comparing modeled Tuolumne River flow variability for 2004 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.

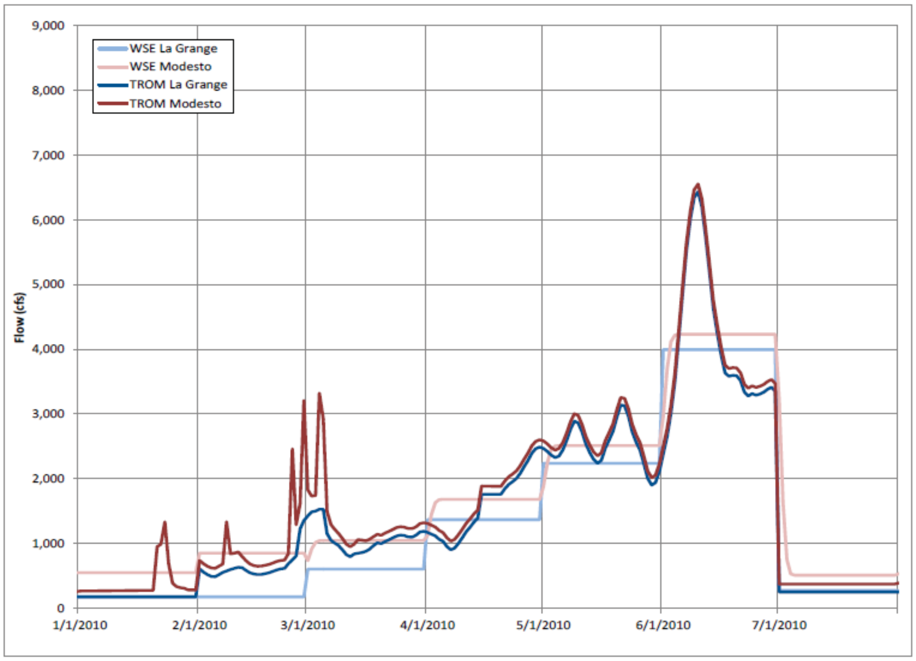


Figure TR-11. **Plot comparing modeled Tuolumne River flow variability for 2010 at the La Grange and Modesto USGS gages from (1) SWB's WSE model's flat, constant monthly flows and (2) the 7-day running average flow in from the daily flow record in the Tuolumne River Operations Model developed by TID and MID as part of the Don Pedro Project FERC relicensing.**