Stillwater Sciences
279 Cousteau Place, Suite 400, Davis, CA 95618
phone 530.756.7550 fax 530.756.7586

TECHNICAL MEMORANDUM

DATE: December 13, 2013

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, Sacramento splittail, and non-native predatory fish habitat assessment: Final 1-D PHABSIM habitat suitability criteria

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This Technical Memo has been updated with additional information that was developed in response to relicensing participant comments on the draft habitat suitability criteria (HSC), distributed for 30-day review on October 30, 2013. Comments were received from relicensing participants requesting that additional HSC be included in the assessment. Any new text provided in this Technical Memo is shaded. Any changed or new figures have shaded captions and any changed or new tables have shaded table titles.

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 summarizes the final 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. The habitat assessment for Pacific lamprey and Sacramento splittail will be distributed separately in January 2014 for a 30-day review and comment period on the documents; the final report will be provided in the Districts' Final License Application to be filed with FERC by April 30, 2014. The habitat assessment for bass is scheduled for completion in conjunction with the Districts' Predation Study, scheduled for March 2015.[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
- Smallmouth bass: fry, juvenile, spawning, embryo/incubation, and adult
- Largemouth bass: fry, juvenile, spawning/embryo, and adult
- Striped bass: juvenile, spawning/embryo, and adult

[1] Pursuant to the *Additional Fish Species Flow/Habitat Assessments Schedule Update*, filed with FERC on October 4, 2013.

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 and Tables 2–3). 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 and Tables 4–5).

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). Adult HSC from these sources 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). In their November 21, 2013 letter to the Districts, the USFWS commented that, while previous studies were focused on the adult life stage of predators, additional life stage considerations may prove useful in understanding the relationship between Project operations and predator abundance in the lower Tuolumne River. Thus, HSC for additional life stages of smallmouth bass and largemouth bass provided in Edwards et al. (1983) and Stuber et al. (1982) have been included. However, because depth HSC for largemouth bass are not described in Stuber et al. (1982), the prior studies on the lower Tuolumne River substituted adult smallmouth bass depth HSC from Edwards et al. (1983) for adult largemouth bass. For this assessment, the same approach was used for smallmouth bass fry and juveniles, where smallmouth bass depth HSC from Edwards et al. (1983) were substituted for largemouth bass.

Spawning depth preferences of largemouth bass are expected to vary too much from smallmouth bass to substitute depth HSC for this life stage between these two species, thus ranges reported in Moyle (2002) were used to develop largemouth bass spawning depth HSC. Index values of 1.00 were assigned to depths within the reported optimal range (1.64–6.56 ft), an index value of 0.20 to the upper observed limit (16.25 ft) and index values of 0.00 were assigned to depths below 0.50 ft and above 18.00 ft. Intermediate values were defined by a straight line between the two zero index value points and the nearest non-zero index value. Smallmouth bass HSC are presented in Figures 12–14 and in Table 6. Largemouth bass HSC are presented in Figures 15–17 and in Table 7.

Juvenile and adult striped bass depth and temperature HSC is described in Crance et al. (1984); however, no velocity HSC are 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 juveniles and adults were developed using reported ranges from Hassler (1988) and assigning an index value of 1.00 to velocities within the optimal range (0.00–3.28 fps) and an index value of 0.00 to all velocities beyond the tolerance range (>16.40 fps); intermediate values between the upper optimal range and the upper tolerance range were defined by a straight line between the two points. Spawning/embryo HSC for striped bass were adapted from EA (1994) as used in HDR (2011). Striped bass HSC are presented in Figures 18–20 and in Table 8.

Table 1. Habitat suitability criteria summary for target species and life stages.

Species	Life stage	Depth	Velocity	Substrate	Cover	Temperature	Source
Pacific lamprey	Ammocoete	Yes	Yes	Yes	No	No	Merced ID 2011
	Spawning	Yes	Yes	Yes	No	No	Merced ID 2011
Sacramento splittail	Juvenile	Yes	Yes	No	No	No	Merced ID 2013
	Spawning	Yes	Yes	Yes	Yes	No	Merced ID 2013
Smallmouth bass	Fry	Yes[1]	Yes[1]	Yes	No	Yes[1]	Edwards et al. 1983
	Juvenile	Yes[1]	Yes[1]	Yes	No	Yes[1]	Edwards et al. 1983
	Spawning	Yes[1]	Yes[1]	Yes	No	Yes[1]	Edwards et al. 1983
	Embryo/incubation	Yes[1]	Yes[1]	Yes	No	Yes[1]	Edwards et al. 1983
	Adult	Yes[1]	Yes[1]	Yes	No	Yes[1]	Edwards et al. 1983
Largemouth bass	Fry	No[2]	Yes[1]	No	No	Yes[1]	Stuber et al. 1982 (velocity and temperature); Edwards et al. 1983 (depth from smallmouth bass)
	Juvenile	No[2]	Yes[1]	No	No	Yes[1]	Stuber et al. 1982 (velocity and temperature); Edwards et al. 1983 (depth from smallmouth bass)
	Spawning/embryo	Yes	Yes[1]	Yes	No	Yes[1]	Stuber et al. 1982 (velocity and temperature); Moyle 2002 (depth)
	Adult	No[2]	Yes[1]	No	No	Yes[1]	Stuber et al. 1982 (velocity and temperature); Edwards et al. 1983 (depth from smallmouth bass)
Striped bass	Juvenile	Yes	Yes	No	No	Yes	Crance 1984 (Depth and temperature); Hassler 1988 (velocity)
	Spawning/embryo	Yes[1]	Yes[1]	No	No	Yes	EA 1994 adapted from HDR 2011(depth and velocity); Crance 1984 (temperature)
	Adult	Yes	Yes	No	No	Yes	Crance 1984 (depth and temperature); Hassler 1988 (velocity)

[1] Coordinates from Edwards et al. (1983) and Stuber et al. (1982) were developed from the graphical data.

[2] 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 1–20 and listed in Tables 2–8.

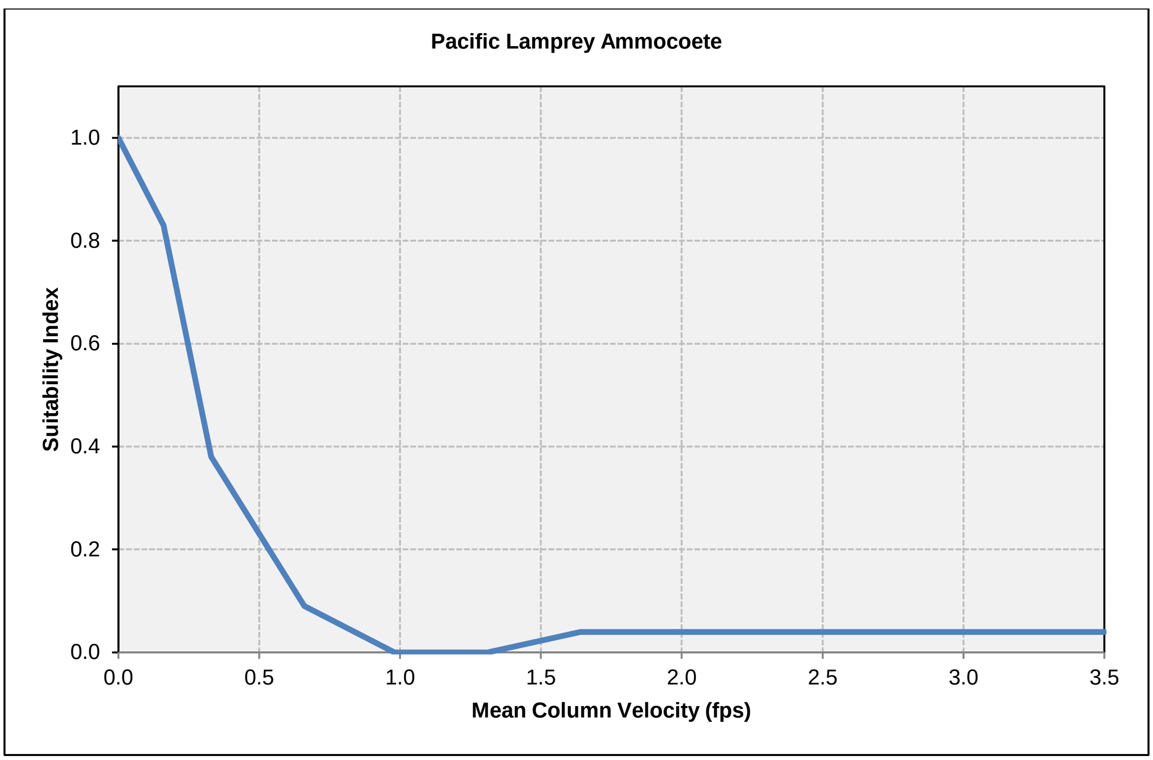

Figure 1. Pacific lamprey ammocoete velocity suitability criteria for the lower Tuolumne River.

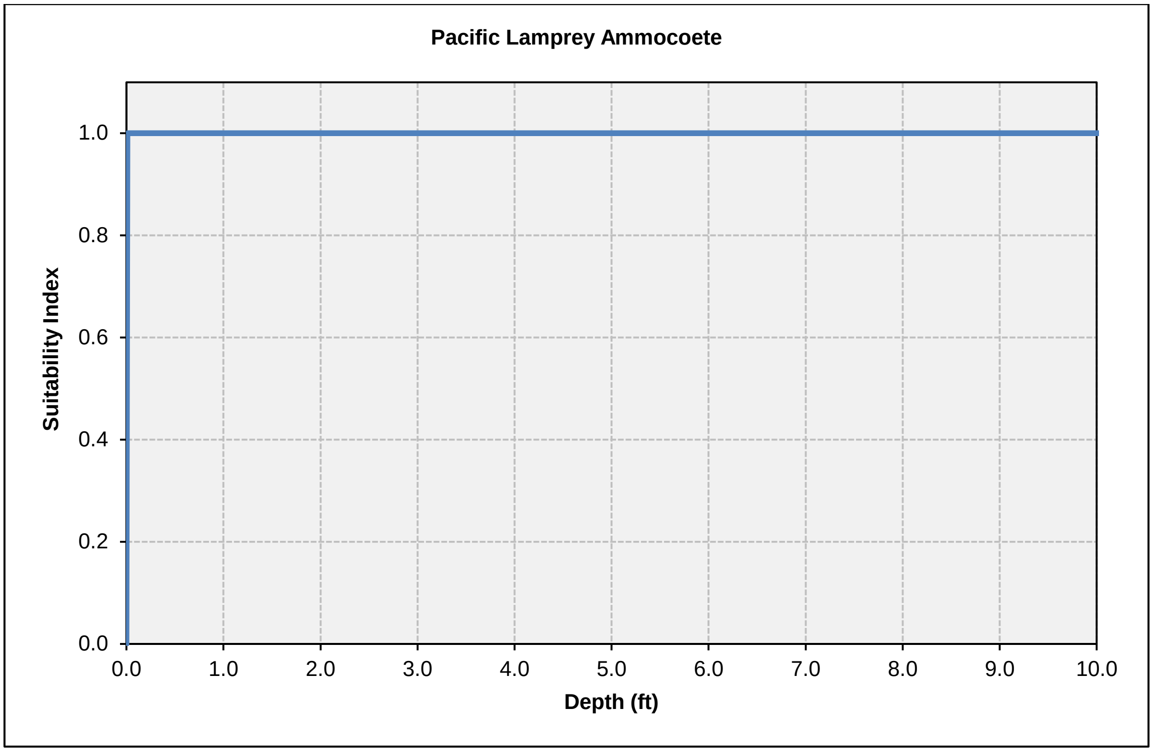

Figure 2. Pacific lamprey ammocoete depth suitability criteria for the lower Tuolumne River.

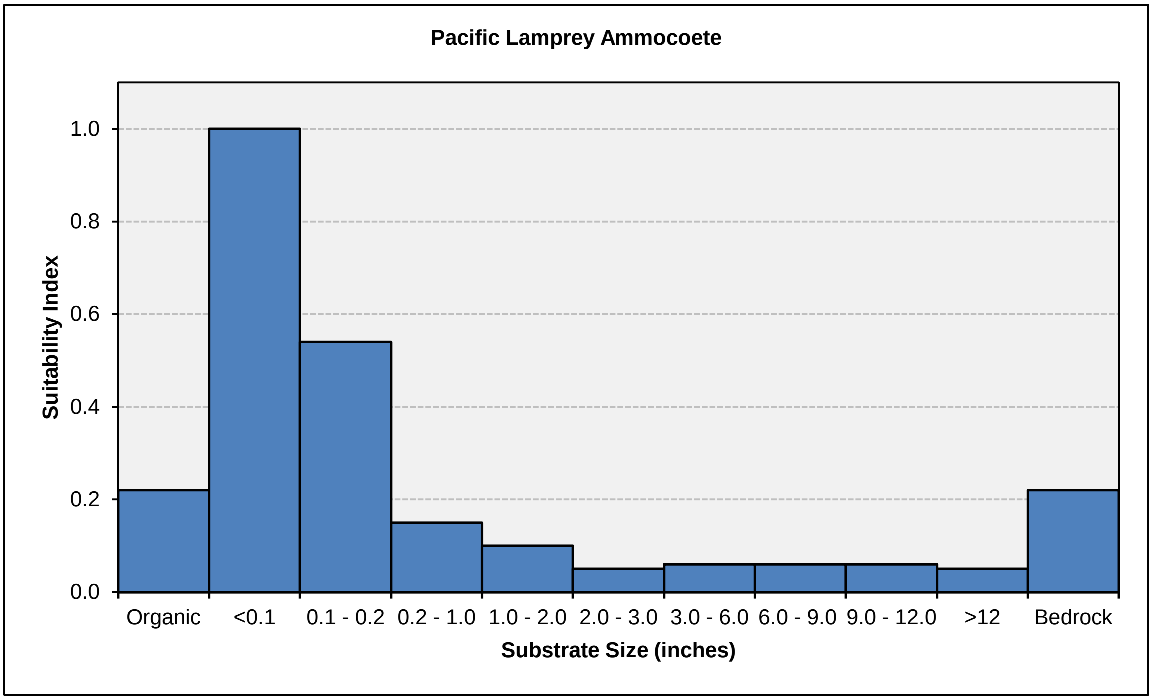

Figure 3. Pacific lamprey ammocoete dominant substrate suitability criteria for the lower Tuolumne River.

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

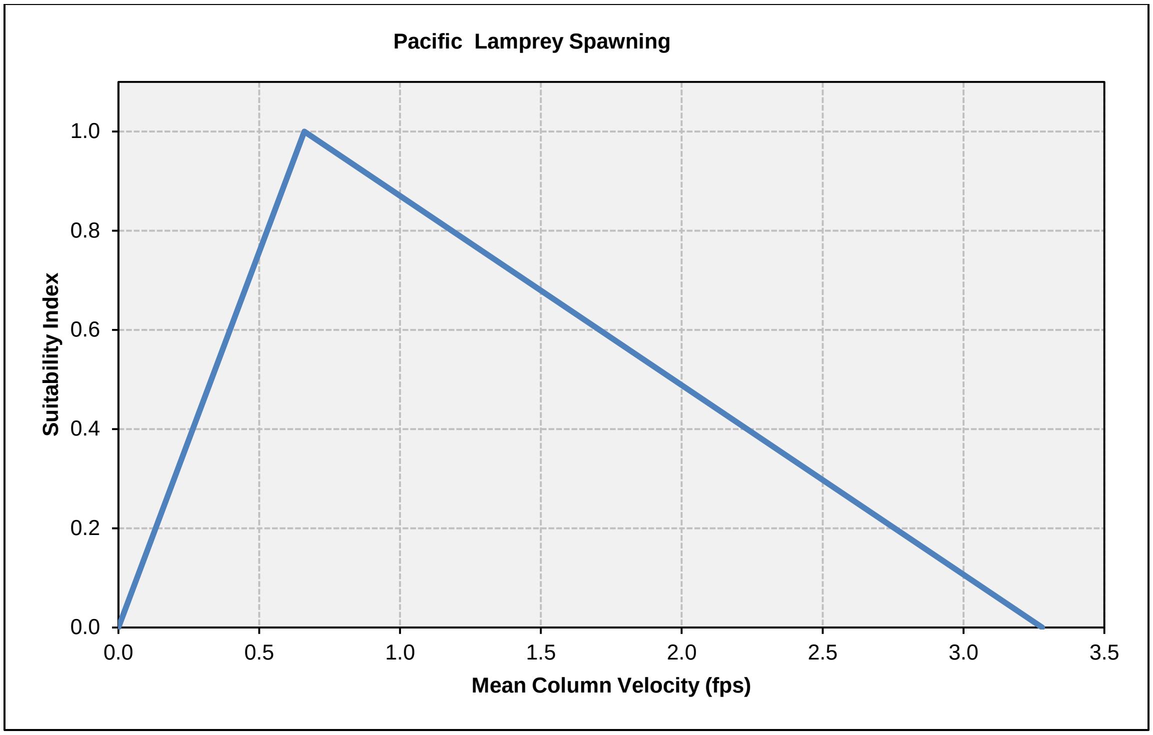

Figure 4. Pacific lamprey spawning velocity suitability criteria for the lower Tuolumne River.

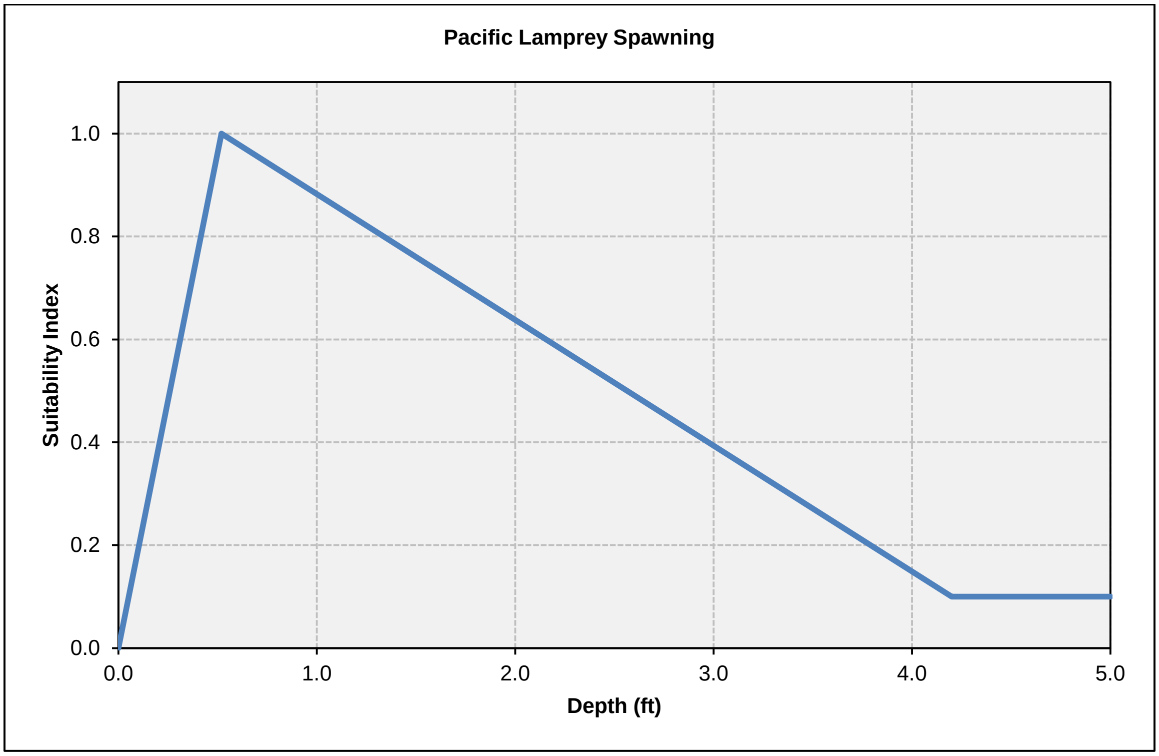

Figure 5. Pacific lamprey spawning depth suitability criteria for the lower Tuolumne River.

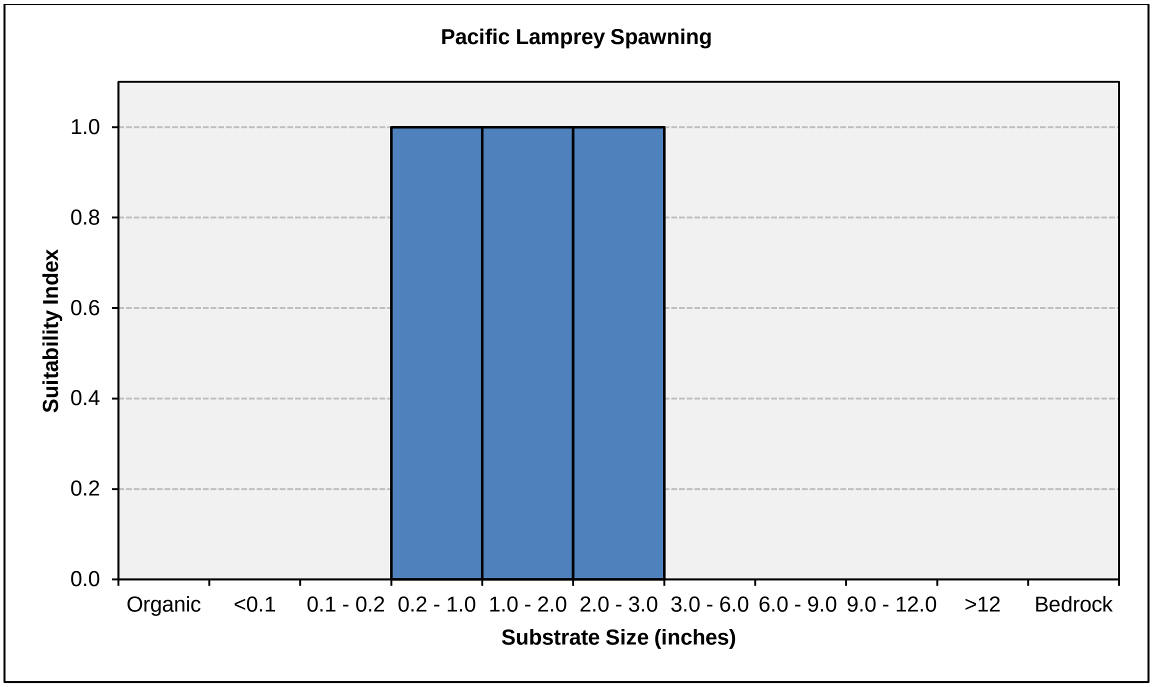

Figure 6. Pacific lamprey spawning dominant substrate suitability criteria for the lower Tuolumne River.

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

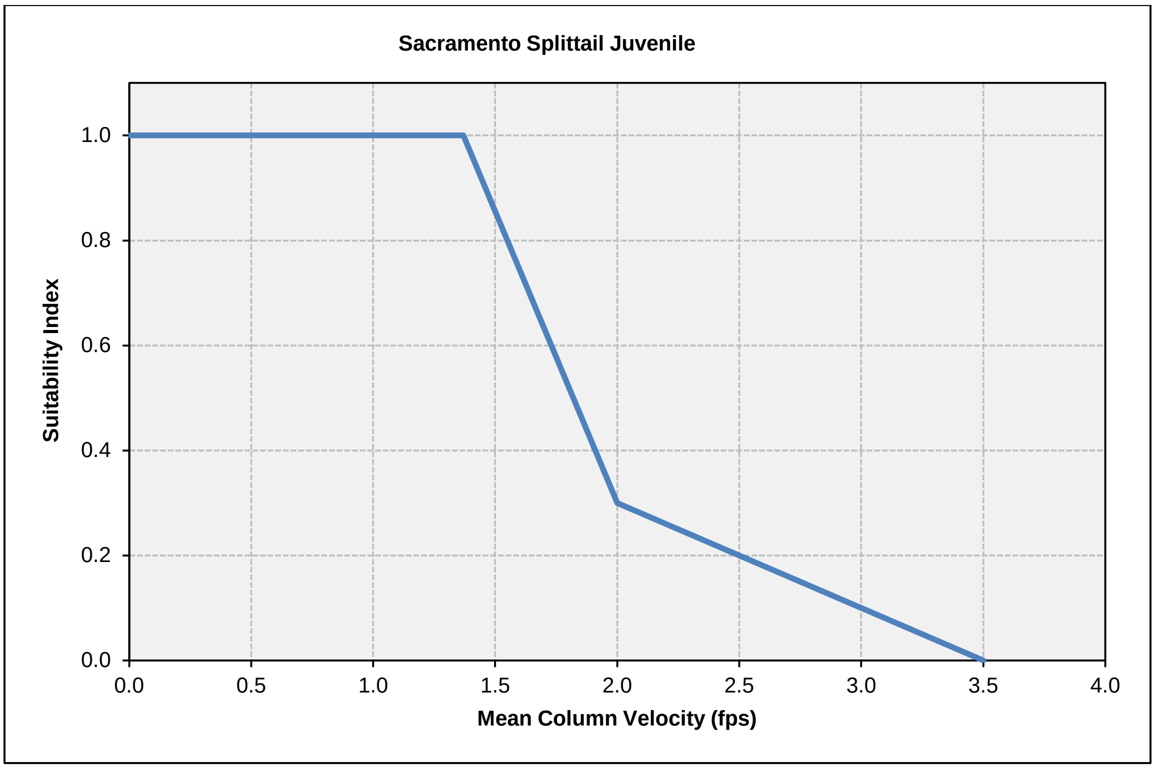

Figure 7. Sacramento splittail juvenile velocity suitability criteria for the lower Tuolumne River.

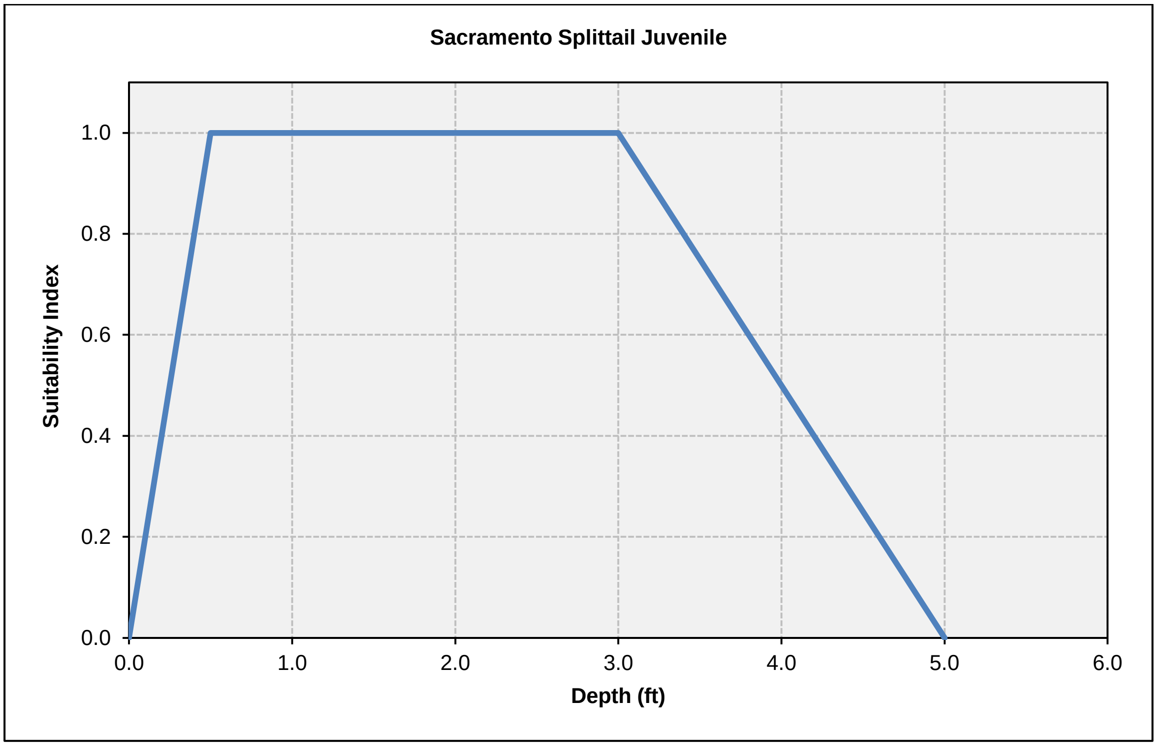

Figure 8. Sacramento splittail juvenile depth suitability criteria for the lower Tuolumne River.

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

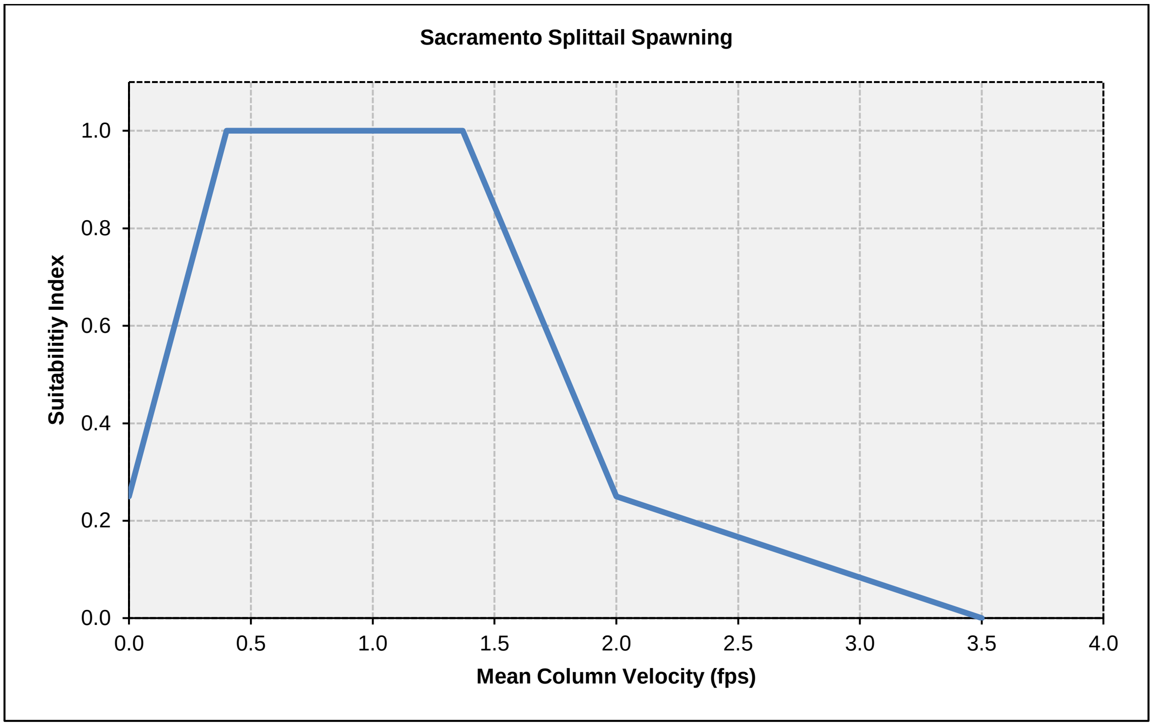

Figure 9. Sacramento splittail spawning velocity suitability criteria for the lower Tuolumne River.

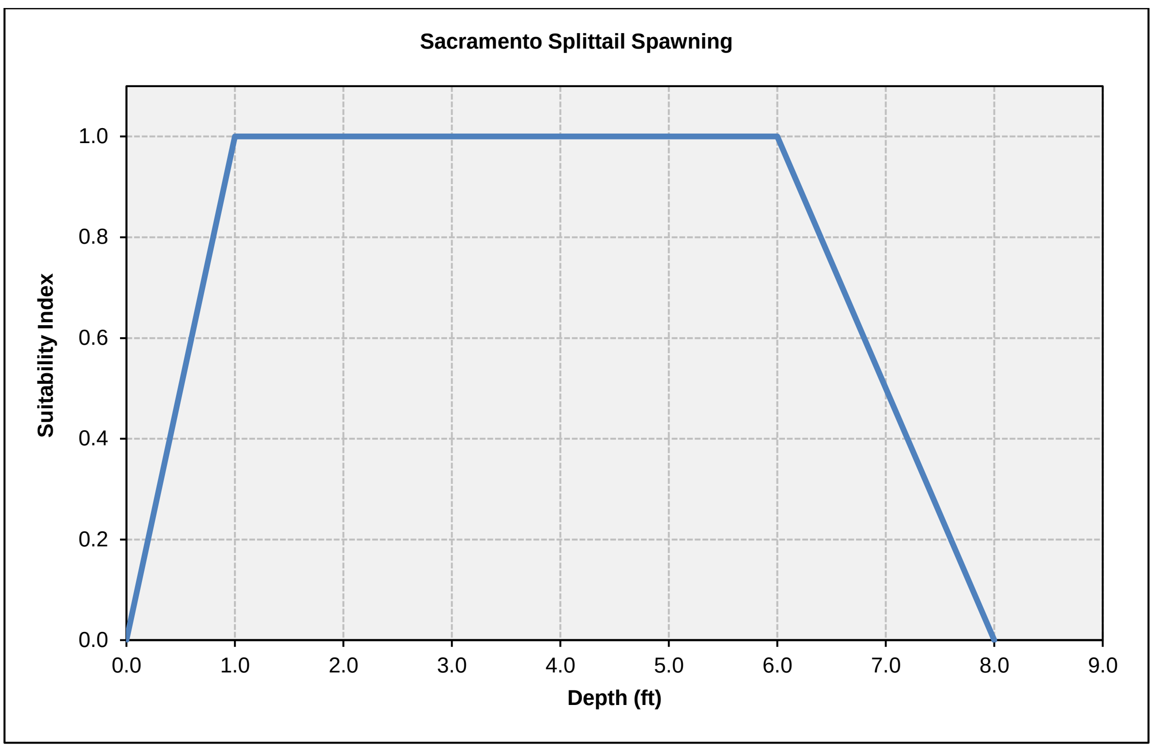

Figure 10. Sacramento splittail spawning depth suitability criteria for the lower Tuolumne River.

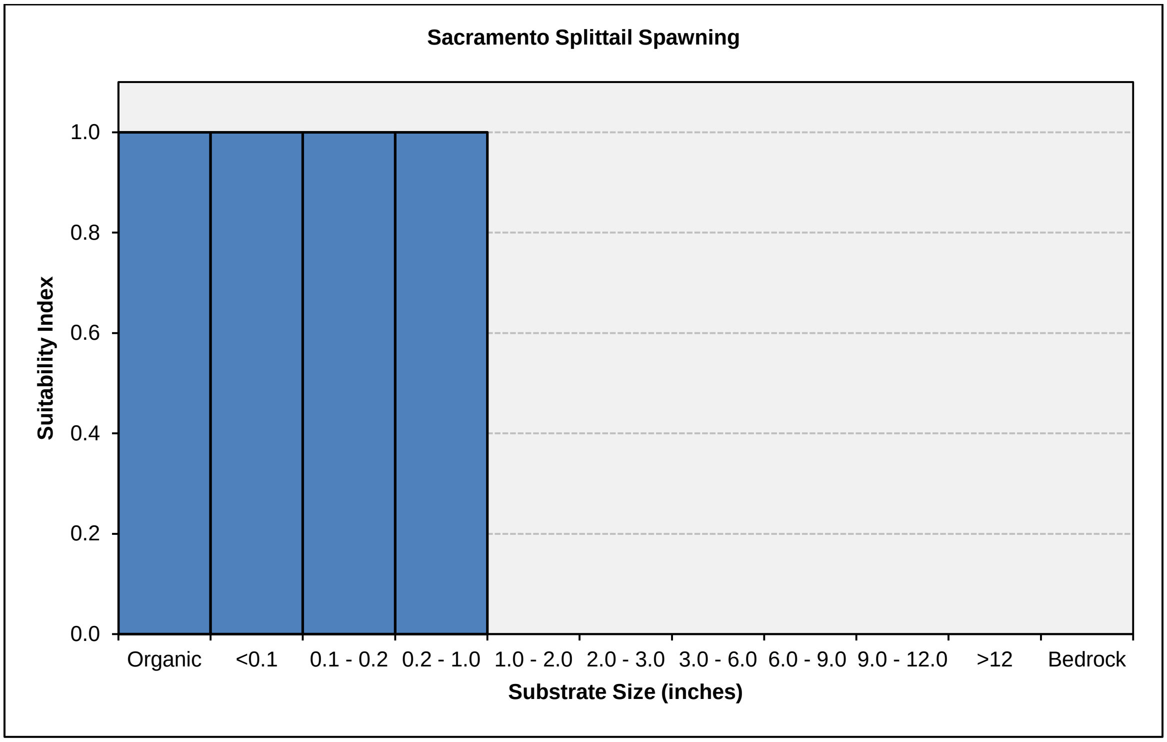

Figure 11. Sacramento splittail spawning dominant substrate suitability criteria for the lower Tuolumne River.

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

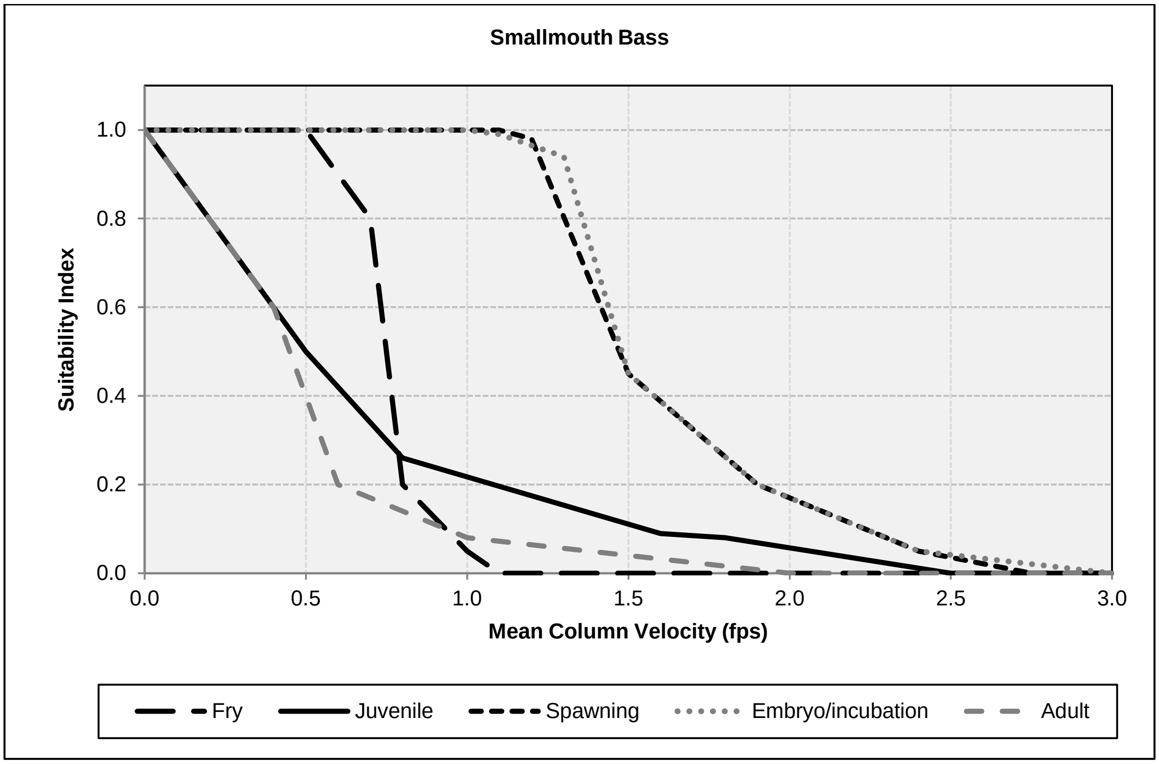

Figure 12. Smallmouth bass velocity suitability criteria for the lower Tuolumne River.

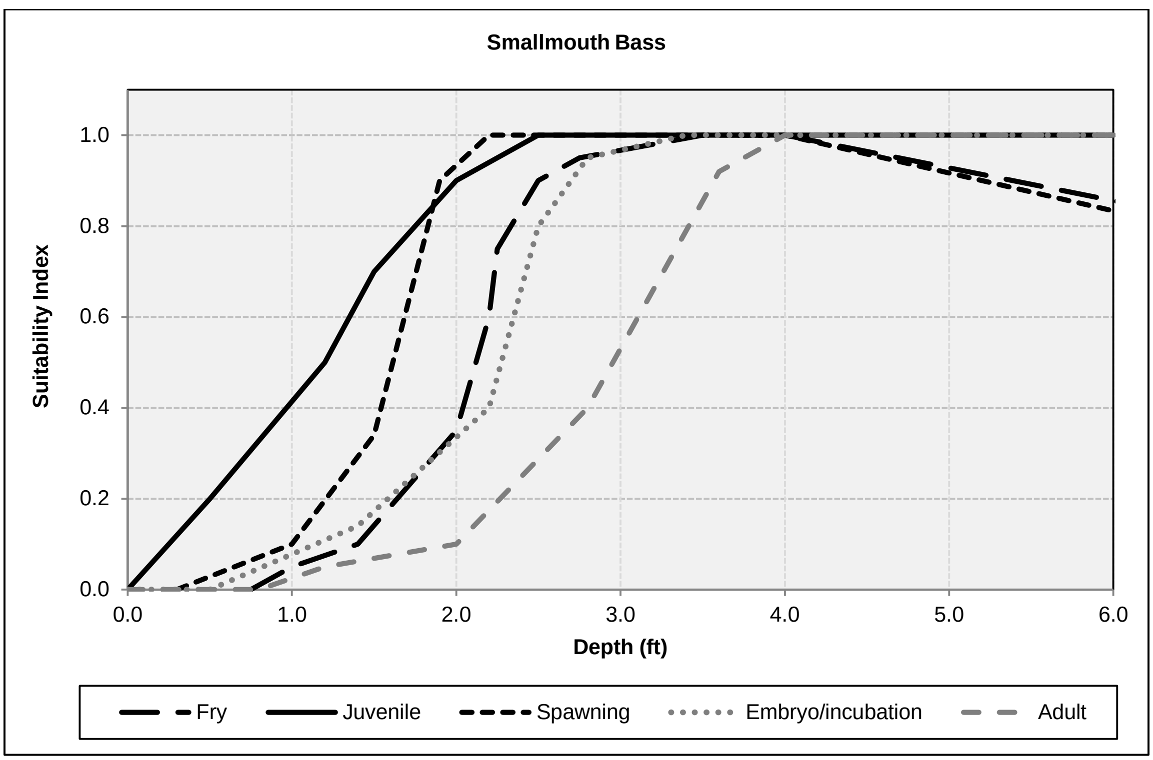

Figure 13. Smallmouth bass depth suitability criteria for the lower Tuolumne River.

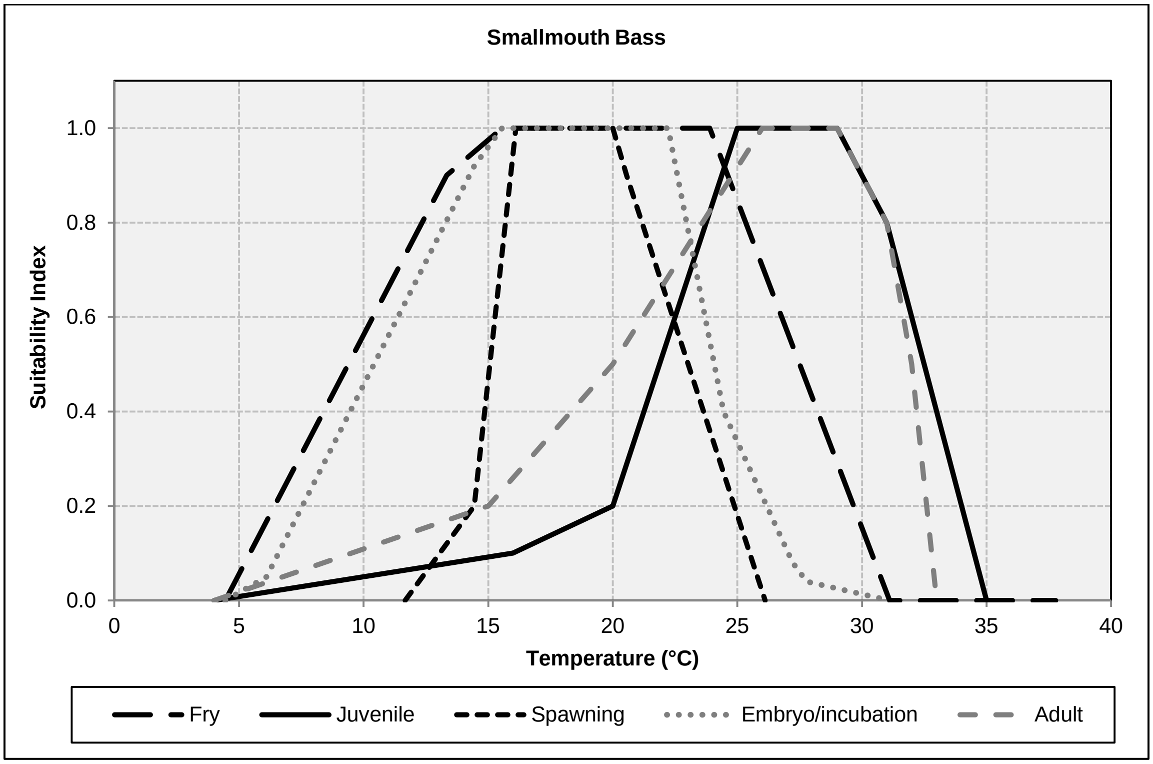

Figure 14. Smallmouth bass temperature suitability criteria for the lower Tuolumne River.

Table 6. Smallmouth bass suitability criteria.

Life stage	Velocity		Depth		Temperature	
	(fps)	Index[1]	(ft)	Index[1]	(°C)	Index[1]
Fry	0.00	1.00	0.75	0.00	4	0.00
	0.50	1.00	1.00	0.05	13	0.90
	0.60	0.90	1.40	0.10	16	1.00
	0.70	0.80	2.00	0.35	24	1.00
	0.80	0.20	2.20	0.60	31	0.00
	1.00	0.05	2.25	0.75	38	0.00
	1.10	0.00	2.50	0.90	--	--
	2.00	0.00	2.75	0.95	--	--
	3.00	0.00	3.50	1.00	--	--
	--	--	4.00	1.00	--	--
	--	--	15.09	0.20	--	--
	--	--	20.01	0.10	--	--
	--	--	22.00	0.00	--	--

Life stage	Velocity		Depth		Temperature	
	(fps)	**Index[1]**	**(ft)**	**Index[1]**	**(°C)**	**Index[1]**
Juvenile	0.00	1.00	0.00	0.00	4	0.00
	0.50	0.50	0.50	0.20	16	0.10
	0.80	0.26	1.20	0.50	20	0.20
	1.60	0.09	1.50	0.70	25	1.00
	1.80	0.08	2.00	0.90	29	1.00
	2.50	0.00	2.50	1.00	31	0.80
	3.00	0.00	4.00	1.00	35	0.00
	--	--	6.00	1.00	--	--
Spawning	00	1.00	0.30	0.00	12	0.00
	1.00	1.00	1.00	0.10	14	0.20
	1.10	1.00	1.50	0.34	16	1.00
	1.20	0.98	1.90	0.90	20	1.00
	1.50	0.45	2.20	1.00	21	0.90
	1.90	0.20	4.00	1.00	26	0.00
	2.40	0.05	10.00	0.50	--	--
	2.75	0.00	25.00	00	--	--
Embryo/(incubation)	0.00	1.00	0.00	0.00	4	0.00
	0.20	1.00	0.50	0.00	6	0.05
	0.50	1.00	1.40	0.14	14	0.92
	1.00	1.00	2.20	0.40	16	1.00
	1.10	0.99	2.50	0.80	22	1.00
	1.30	0.94	2.60	0.85	24	0.40
	1.50	0.45	2.80	0.95	27	0.08
	1.90	0.20	3.40	1.00	28	0.04
	2.40	0.05	6.00	1.00	31	0.00
	3.00	0.00	--	--	--	--
Adult	0.00	1.00	0.00	0.00	4	0.00
	0.40	0.60	0.80	0.00	15	0.20
	0.60	0.20	1.20	0.05	20	0.50
	1.00	0.08	2.00	0.10	26	1.00
	2.00	0.00	2.80	0.40	29	1.00
	3.00	0.00	3.60	0.92	31	0.80
	--	--	4.00	1.00	32	0.50
	--	--	6.00	1.00	33	0.00

[1] Edwards et al. 1983

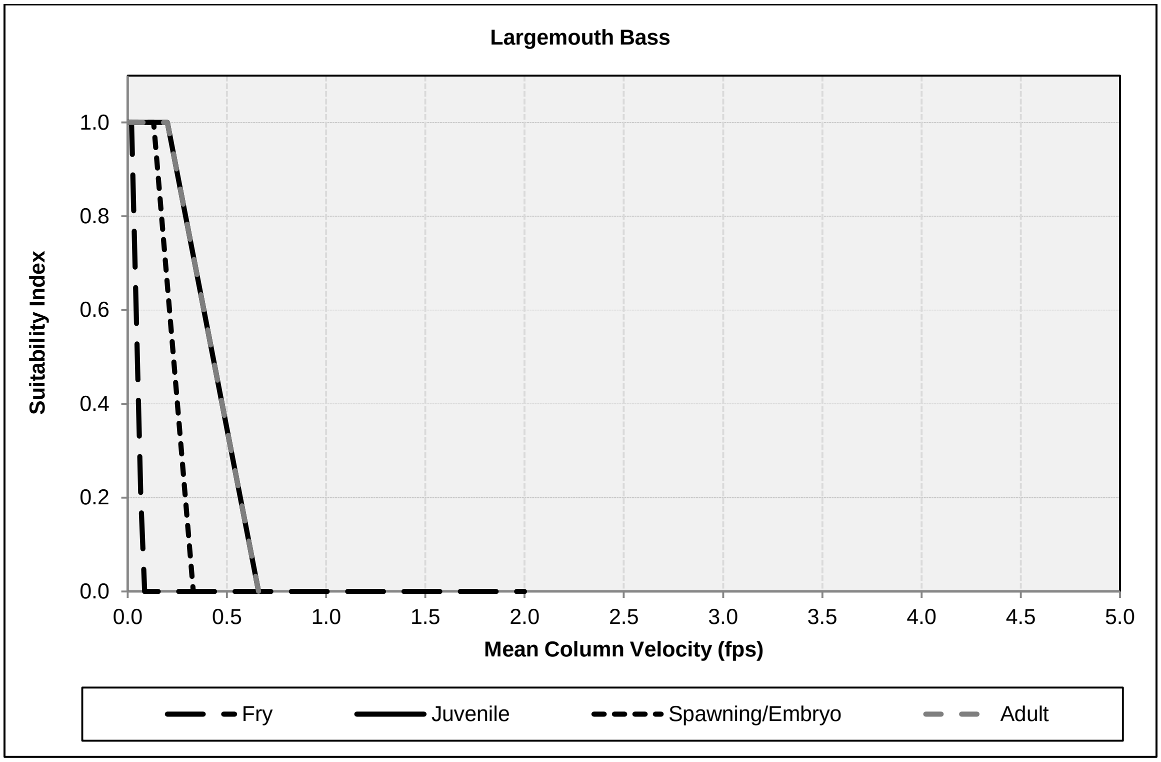

Figure 15. Largemouth bass velocity suitability criteria for the lower Tuolumne River.

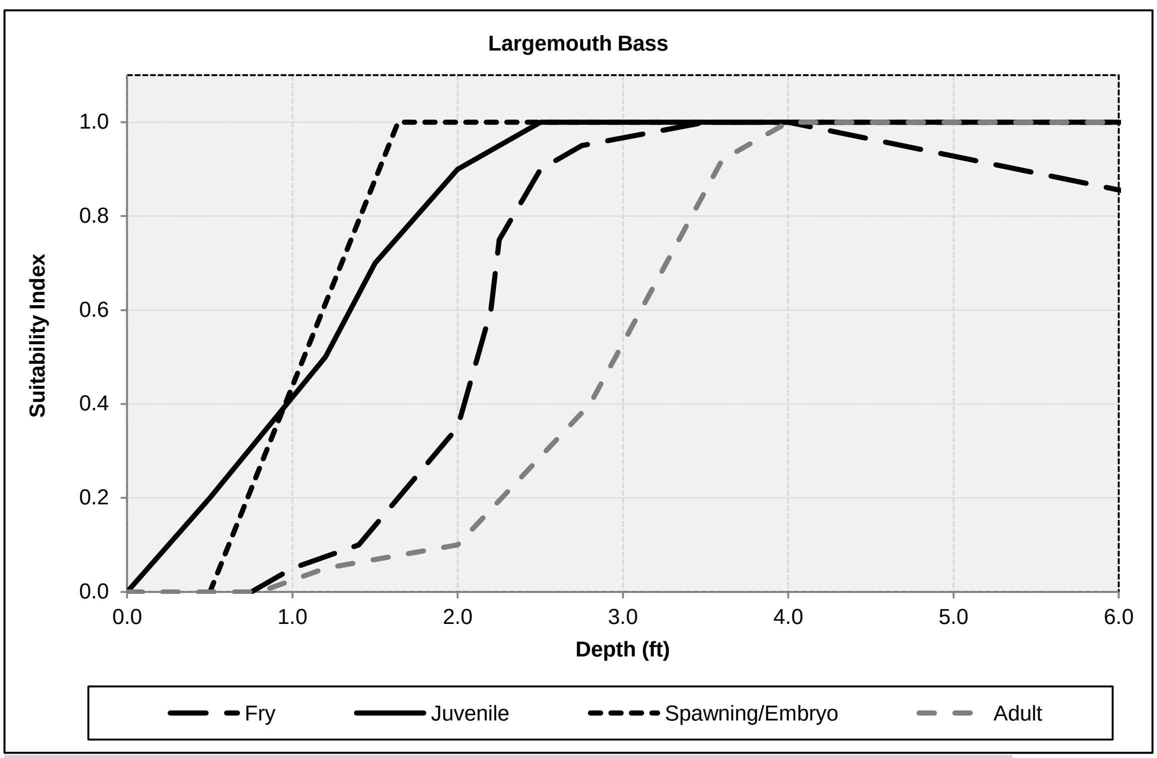

Figure 16. Largemouth bass depth suitability criteria for the lower Tuolumne River.

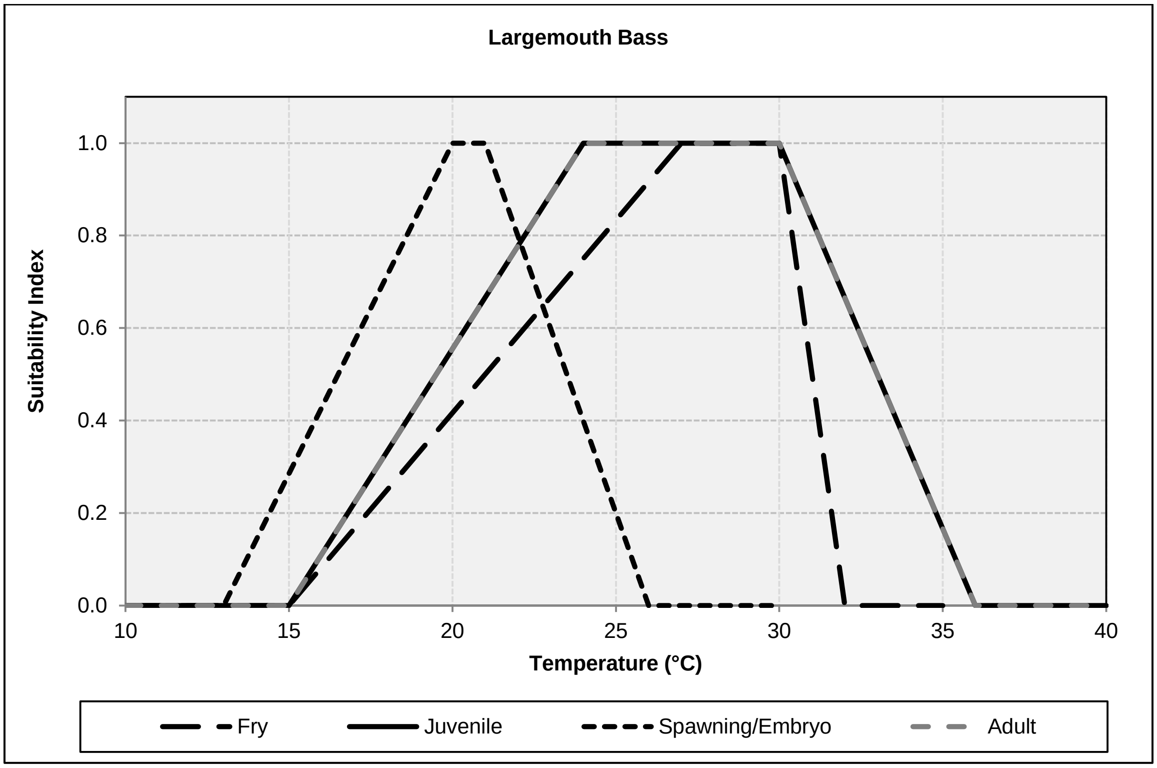

Figure 17. Largemouth bass temperature suitability criteria for the lower Tuolumne River.

Table 7. Largemouth bass suitability criteria.

Life stage	Velocity[1]		Depth[2,3]		Temperature[1]	
	Ft/sec	Index	Ft	Index	°C	Index
Fry	0.00	1.00	0.80	0.00	10	0.00
	0.02	1.00	1.00	0.05	15	0.00
	0.07	0.20	1.40	0.10	27	1.00
	0.09	0.00	2.00	0.35	30	1.00
	2.00	0.00	2.20	0.60	32	0.00
	--	--	2.25	0.75	35	0.00
	--	--	2.50	0.90	--	--
	--	--	2.75	0.95	--	--
	--	--	3.50	1.00	--	--
	--	--	4.00	1.00	--	--
	--	--	15.09	0.20	--	--
	--	--	20.01	0.10	--	--
	--	--	22.00	0.00	--	--

Life stage	Velocity[1]		Depth[2,3]		Temperature[1]	
	Ft/sec	**Index**	**Ft**	**Index**	**°C**	**Index**
Juvenile	0.00	1.00	0.00	0.00	10	0.00
	0.20	1.00	0.50	0.20	12	0.00
	0.66	0.00	1.20	0.50	15	0.00
	--	--	1.50	0.70	24	1.00
	--	--	2.00	0.90	30	1.00
	--	--	2.50	1.00	36	0.00
	--	--	4.00	1.00	38	0.00
	--	--	6.00	1.00	40	0.00
Spawning/ Embryo	0.00	1.00	0.50[3]	0.00[3]	10	0.00
	0.10	1.00	1.60[3]	1.00[3]	13	0.00
	0.13	1.00	6.60[3]	1.00[3]	20	1.00
	0.33	0.00	16.30[3]	0.20[3]	21	1.00
	--	--	18.00[3]	0.00[3]	26	0.00
	--	--	--	--	30	0.00
Adult	0.00	1.00	0.00	0.00	10	0.00
	0.20	1.00	0.80	0.00	12	0.00
	0.66	0.00	1.20	0.05	15	0.00
	--	--	2.00	0.10	24	1.00
	--	--	2.80	0.40	30	1.00
	--	--	3.60	0.92	36	0.00
	--	--	4.00	1.00	38	0.00
	--	--	6.00	1.00	40	0.00

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)
3 HSC for smallmouth bass spawning/embryo from Moyle 2002.

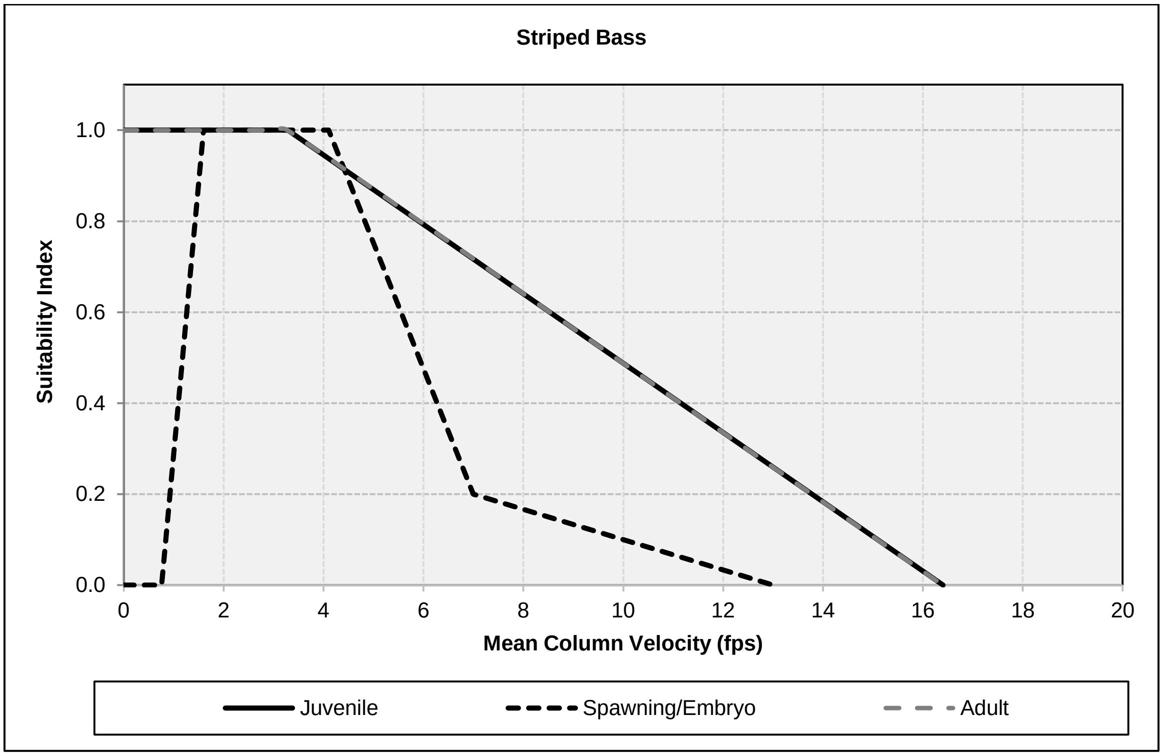

Figure 18. Striped bass velocity suitability criteria for the lower Tuolumne River.

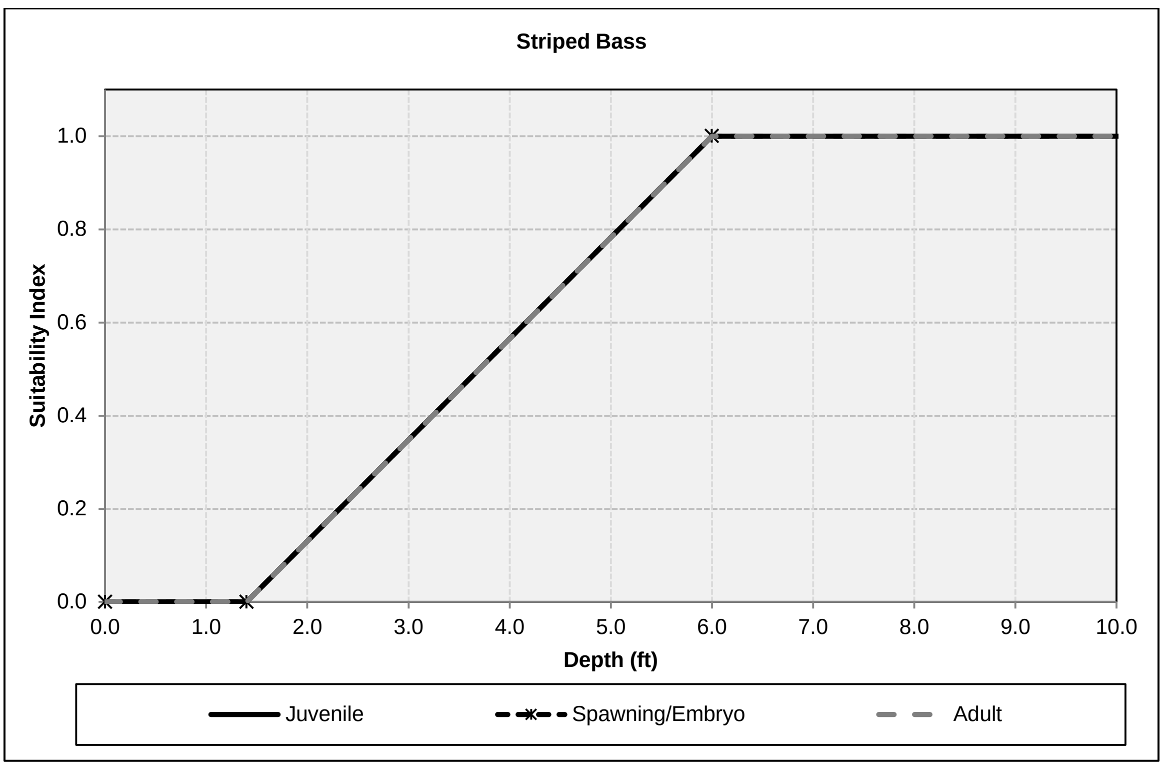

Figure 19. Striped bass depth suitability criteria for the lower Tuolumne River.

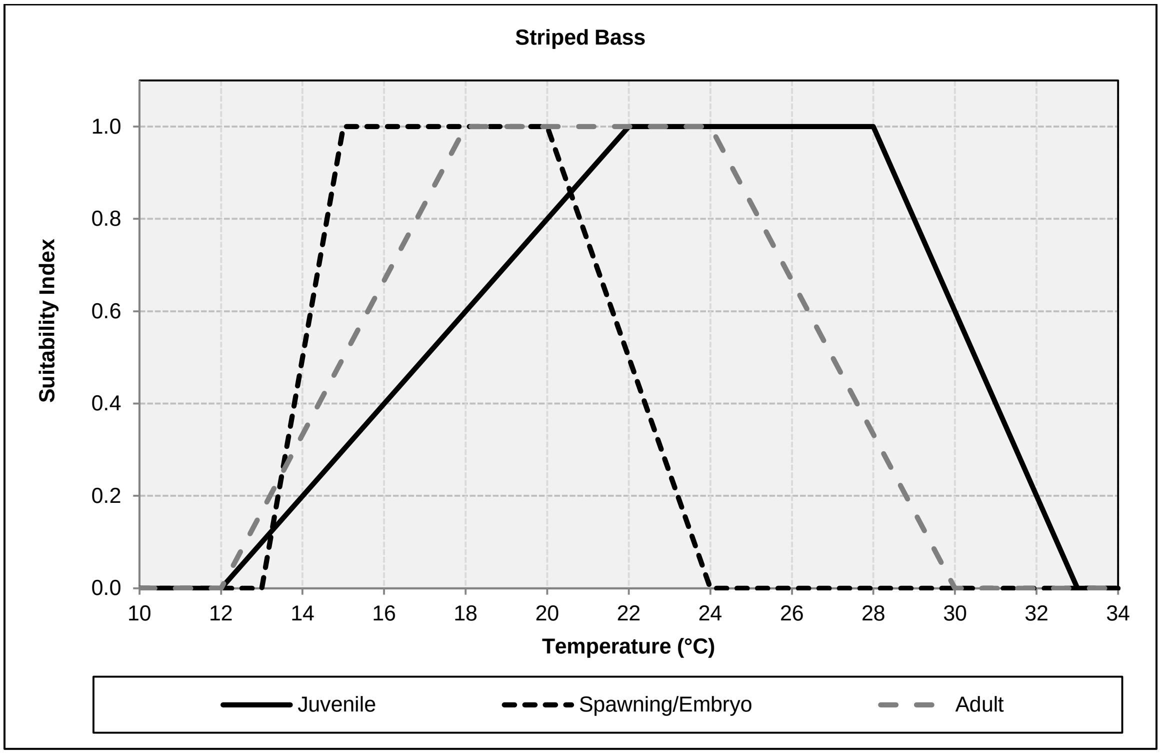

Figure 20. Striped bass temperature suitability criteria for the lower Tuolumne River.

Table 8. Striped bass suitability criteria.

Life Stage	Velocity[1,2]		Depth[2,3]		Temperature[4]	
	Ft/sec	Index	Ft	Index	°C	Index
Juvenile	0.00	1.00	0.00	0.00	10	0.00
	3.00	1.00	1.40	0.00	12	0.00
	3.28	1.00	6.00	1.00	22	1.00
	9.84	0.50	30.00	1.00	28	1.00
	16.40	0.00	100.00	0.00	33	0.00
	--	--	--	--	34	0.00
Spawning/Embryo	0.00	0.00	0.00	0.00	10	0.00
	0.76	0.00	1.40	0.00	13	0.00
	1.60	1.00	6.00	1.00	15	1.00
	4.10	1.00	30.00	1.00	20	1.00
	7.00	0.20	100.00	0.00	24	0.00
	13.00	0.00	--	--	34	0.00
Adult	0.00	1.00	0.00	0.00	10	0.00
	3.00	1.00	1.40	0.00	12	0.00
	3.28	1.00	6.00	1.00	18	1.00
	9.84	0.50	30.00	1.00	24	1.00
	16.40	0.00	100.00	0.00	30	0.00
	--	--	--	--	34	0.00

1 Juvenile and adult HSC developed using existing literature sources from Hassler (1988)
2 Spawning/embryo HSC from EA Engineering, Inc. (1994) as adapted from HDR (2011)
3 Juvenile and adult HSC from Crance et al. (1984)
4 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.

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).[2] 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.

[2] 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.

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). Periodicity for adult and juvenile bass life stages includes all months of the year, since the species are resident (Table 10). Periodicities for bass spawning and incubation periods are from Moyle (2002).

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

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	Fry	■	■	■					■	■	■	■	■
	Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
	Spawning								■	■	■		
	Adult	■	■	■	■	■	■	■	■	■	■	■	■
Largemouth bass	Fry	■						■	■	■	■	■	■
	Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
	Spawn/Embryo						■	■	■	■			
	Adult	■	■	■	■	■	■	■	■	■	■	■	■
Striped bass	Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
	Spawning/Embryo							■	■	■	■		
	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 include lamprey, splittail, and three bass species.

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 in January 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.

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 is being submitted to relicensing participants for review and comment as part of the Districts' USR in January 2014. The effective habitat analysis evaluation is expected to be completed (including a 30-day resource agency review period) following the relicensing participant review and comment on study W&AR-16, and will be filed with FERC by August 2014.

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