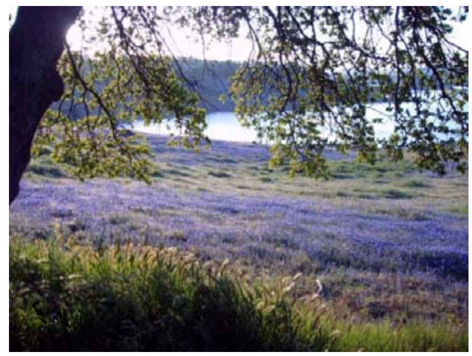
PREDATION

STUDY REPORT
DON PEDRO PROJECT
FERC NO. 2299



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Modesto Irrigation District

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

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FISHBIO

January 2013

Predation
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

ADA ....Americans with Disabilities Act

ALJ.............................Administrative Law Judge

APE ....Area of Potential Effect

ARMR........................Archaeological Resource Management Report

ATR…………………Acoustic Tag Receiver

ATS…………………Acoustic Tag Tracking System

BA ....Biological Assessment

BDCP ....Bay-Delta Conservation Plan

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

CalEPPC ....California Exotic Pest Plant Council

CalSPA.......................California Sports Fisherman Association

CAS ....California Academy of Sciences

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
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
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.............................California Threatened Species
CTR...........................California Toxics Rule
CTS...........................California Tiger Salamander
CVRWQCB...............Central Valley Regional Water Quality Control Board
CWA.........................Clean Water Act
CWHR.......................California Wildlife Habitat Relationship
Districts......................Turlock Irrigation District and Modesto Irrigation District
DLA..........................Draft License Application
DPRA........................Don Pedro Recreation Agency
DPS...........................Distinct Population Segment

EA ....Environmental Assessment
EC ....Electrical Conductivity
EFH ....Essential Fish Habitat
EIR ....Environmental Impact Report
EIS..............................Environmental Impact Statement
EPA ............................U.S. Environmental Protection Agency
ESA ....Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU ....Evolutionary Significant Unit
EWUA........................Effective Weighted Useable Area
FERC..........................Federal Energy Regulatory Commission
FFS ....Foothills Fault System
FL ....Fork length
FMU ....Fire Management Unit
FOT ....Friends of the Tuolumne
FPC ....Federal Power Commission
ft/mi............................feet per mile
FWCA ....Fish and Wildlife Coordination Act
FYLF..........................Foothill Yellow-Legged Frog
g..................................grams
GIS ....Geographic Information System
GLO ....General Land Office
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
ISR ....Initial Study Report
ITA ....Indian Trust Assets
kV...............................kilovolt
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
MRH………………...Merced River Hatchery
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
NAS ....National Academy of Sciences
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
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
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
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
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
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
SWE............................Snow-Water Equivalent
SWRCB.......................State Water Resources Control Board
TAC.............................Technical Advisory Committee
TAF ....thousand acre-feet
TCP ....Traditional Cultural Properties
TDS.............................Total Dissolved Solids
TID..............................Turlock Irrigation District
TMDL ....Total Maximum Daily Load
TOC.............................Total Organic Carbon
TRT.............................Tuolumne River Trust

TRTAC ....Tuolumne River Technical Advisory Committee
UC ....University of California
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
VRM ....Visual Resource Management
WPT ....Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP ....Water System Improvement Program
WWTP ....Wastewater Treatment Plant
WY ....water year
µS/cm ....microSeimens per centimeter

1.0 INTRODUCTION

1.1 General Description of the Don Pedro Project

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 formed by the dam extends 24-miles upstream at the 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).

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 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 the requirements of the Raker Act passed by Congress in 1913 and agreements between the Districts and City and County of San Francisco (CCSF), the Project reservoir also includes a "water bank" of up to 570,000 AF of storage. CCSF may use the water bank to more efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. CCSF's "water bank" within Don Pedro Reservoir provides significant benefits for its 2.6 million customers in the San Francisco Bay Area.

The 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 Project are recreation, protection of the anadromous fisheries in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from approximately one mile downstream of the dam to approximately RM 79 upstream of the dam. Upstream of the dam, the Project Boundary runs generally along the 855 ft contour interval which corresponds to the top of the Don Pedro Dam. The Project Boundary encompasses approximately 18,370 ac with 78 percent of the lands owned jointly by the Districts and the remaining 22 percent (approximately 4,000 ac) is 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 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 Project and its primary facilities is shown in Figure 1.1-1.

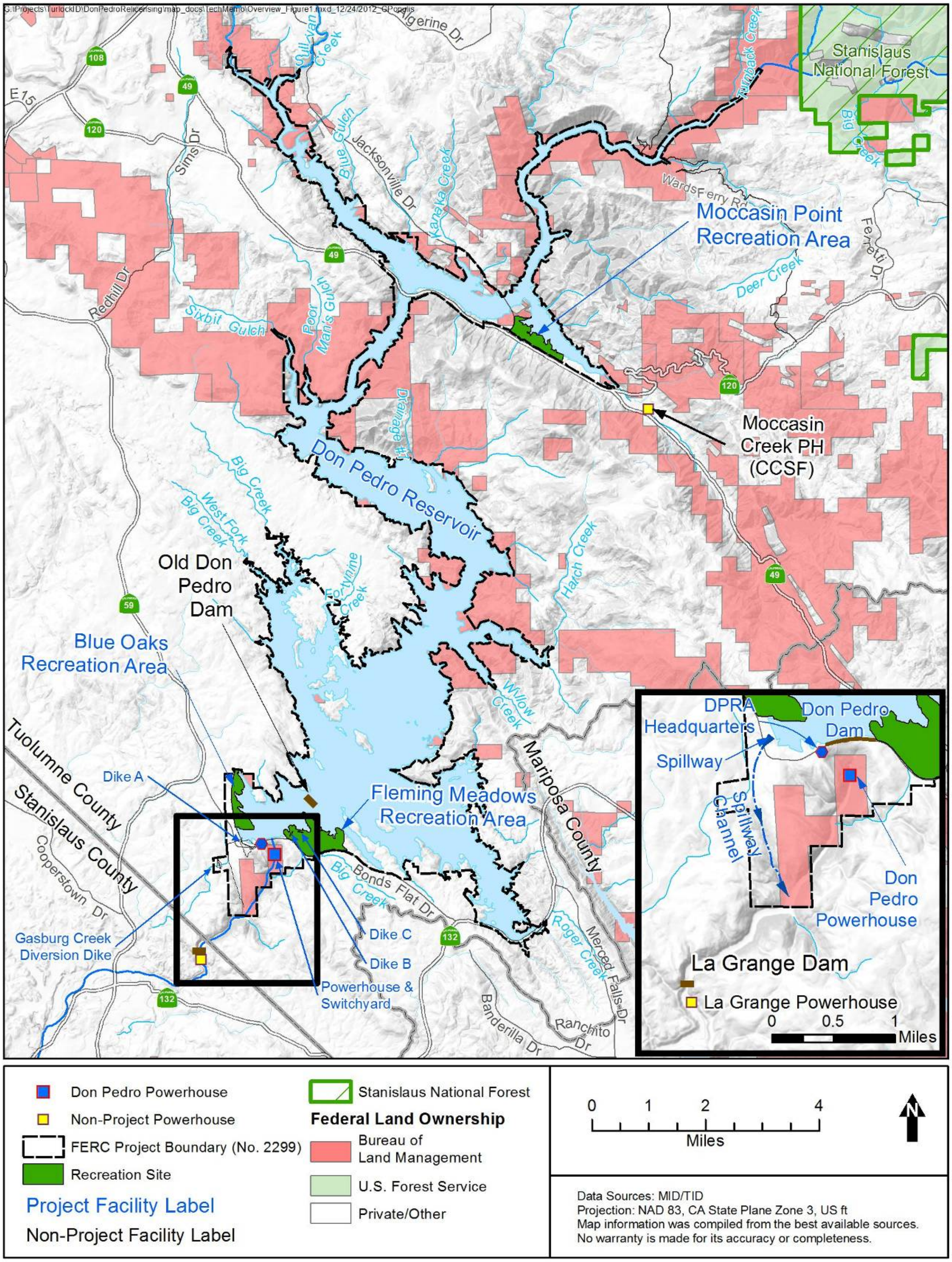

Figure 1.1-1. Don Pedro Project location.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts will apply for a new license no later than April 30, 2014. The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, following the regulations governing the Integrated Licensing Process (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.

This study report describes the objectives, methods, and results of the Predation Study (W&AR-07) as implemented by the Districts in accordance with FERC's SPD and subsequent study modifications and clarifications. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at www.donpedro-relicensing.com.

1.3 Study Plan

FERC's *Scoping Document 2* identified potential effects of the Project on fish populations in Project-affected reaches. The continued operation and maintenance (O&M) of the Project may contribute to cumulative effects on salmonid fish habitat in the Tuolumne River downstream of La Grange Dam, including the effects of predation on survival of juvenile Chinook salmon and *O. mykiss* in the lower Tuolumne River.

FERC's SPD approved with modifications the Districts' Predation study plan as provided in the Districts' RSP filing. In its SPD, FERC ordered that the Districts include the following provisions: (1) a goal to ensure the ratio of tag to fish weight is less than five percent, (2) any additional hatchery reared fish should be coded-wire-tagged, and (3) if the results of the predation study and the FWS's GIS floodplain inundation study suggest that a second year of study may be needed, the Districts should propose such a study in its initial study report or explain why such a study is not needed.

2.0 STUDY GOALS AND OBJECTIVES

The goal of this study was to increase understanding of the current effects of predation on rearing and outmigrating juvenile Chinook salmon and *O. mykiss* in the lower Tuolumne River. The study consisted of the following three components related to salmonid predation by native and non-native species in the lower Tuolumne River:

(1) Predator abundance - estimate relative abundance of predator fish species such as largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), Sacramento pikeminnow (*Ptychocheilus grandis*), and striped bass (*Morone saxitalis*)

(2) Predation rate - update estimates of predation rate from previous surveys (e.g., TID/MID 1992)

(3) Predator movement tracking - determine relative habitat use by juvenile Chinook salmon and predator species at typical flows encountered during the juvenile salmonid outmigration period.

3.0 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) (Figure 3.0-1). Study sites were selected in habitat units or river reaches that provide suitable habitat for predators and where predators have been documented in prior studies (TID/MID 1992; Brown and Ford 2002; Stillwater Sciences and McBain & Trush 2006). As the majority of predators in the lower Tuolumne River are non-native and are most abundant downstream of approximately RM 31 (Brown and Ford 2002), and the Section 10 permit issued by the National Marine Fisheries Service (NMFS) for take of Central Valley Steelhead limited sampling to locations downstream of RM 31.5 during September - March, predation study sites were generally concentrated in this downstream reach. Specific locations of sampling sites are described in Sections 4.2, 4.3, and 4.4 of this report.

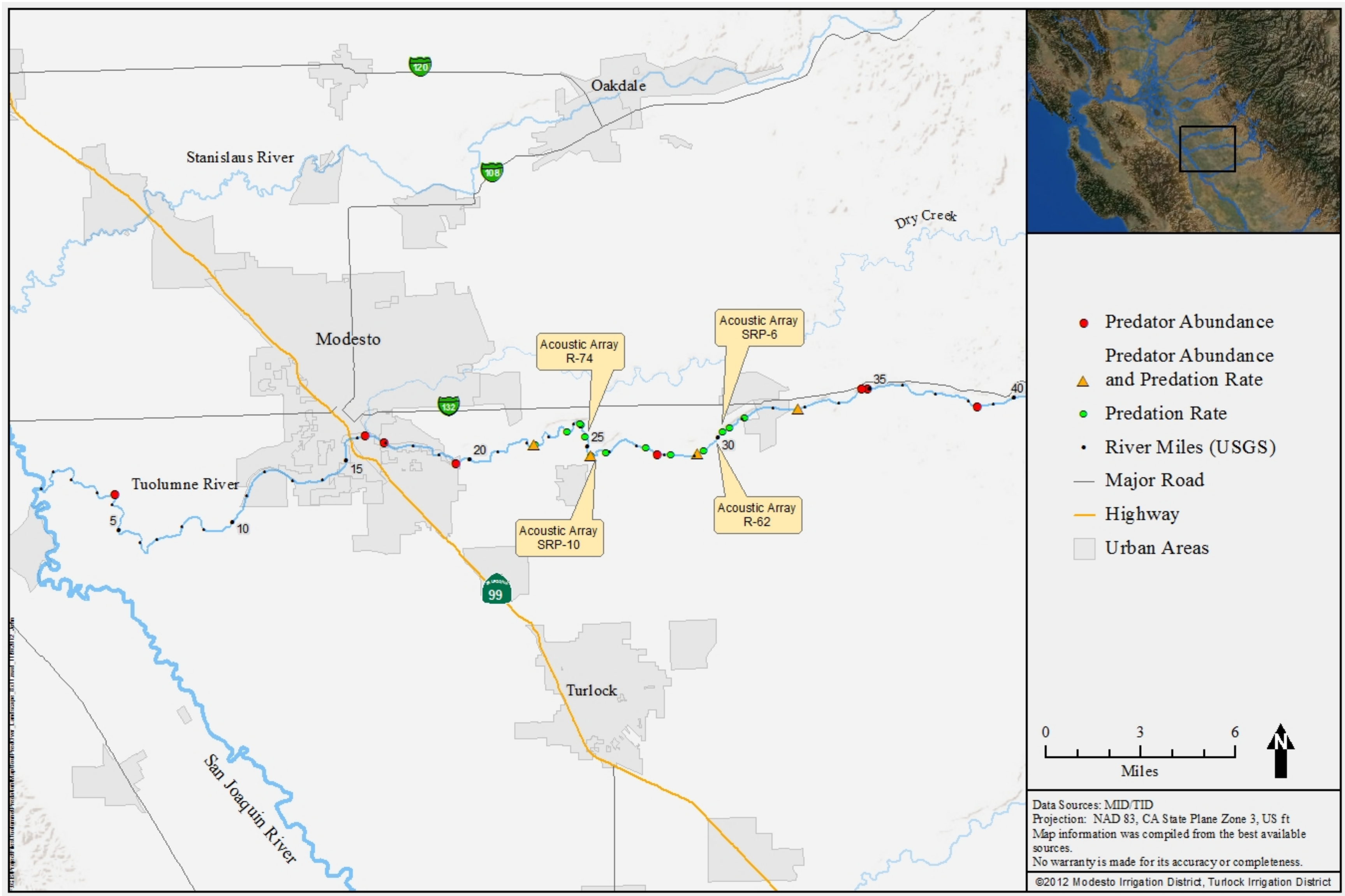

Figure 3.0-1. Map of study area.

4.0 METHODOLOGY

4.1 River Conditions

Provisional daily average flow data for the Tuolumne River at La Grange was obtained from the U.S. Department of the Interior, Geological Survey (USGS) at http://waterdata.usgs.gov/ca/nwis/uv/?site_no=11289650&agency_cd=USGS. Water temperature data were obtained from hourly recording Hobo Pro v2 water temperature data loggers (Onset Computer Corporation) maintained by the Districts at Roberts Ferry Bridge (RM 39.4), Hickman Bridge (RM 31.6), Waterford (RM 29.8), SRP 10 (RM 25.5), Tuolumne River Weir (RM 24.4), and Grayson (RM 5.0).

Daily instantaneous turbidity samples were collected at Waterford (RM 29.8), Tuolumne River Weir (RM 24.4), and Grayson (RM 5.0). Samples were also collected prior to electrofishing each site sampled for predator abundance and predation rate.

4.2 Predator Abundance

4.2.1 Sampling Methods

4.2.1.1 Sampling Locations

Fourteen sampling locations from RM 3.7 to RM 41.3 were selected based on the ability to launch the electrofishing boat at the site or very close by, and a desire to represent three habitat types: (1) slow-water (pools and special run pools [SRP]), (2) fast-water (riffles and runs), and (3) run-pools in the sand-bedded reach downstream of RM 25. Twelve of the selected sites were sampled between RM 3.7 and 38.5 (Figure 4.2-1) during July 25-August 8. On August 8 an adult *O. mykiss* was captured while sampling at RM 38.5, and sampling was suspended in accordance with Section 10 permit terms which required that all electrofishing must cease if any adult *O. mykiss* were captured.

4.2.1.2 Habitat Measurements

Habitat areas and shoreline lengths of each sampled unit were calculated using Geographic Information System (GIS) layers obtained from Turlock Irrigation District (Stillwater Sciences 2010). River flow at La Grange during the inundation mapping and habitat calibration (using 2009 NAIP 1-meter resolution aerial photography) was 230 cubic feet per second (cfs). River flow at La Grange during the sampling period (July 25 to August 8, 2012) was 98 cfs (range = 83 – 130 cfs). As a result of this difference in river flows, estimated habitat areas, and to a lesser degree shoreline lengths, are slightly overestimated relative to actual dimensions at the time fish sampling was conducted. Overestimation of habitat area or shoreline length results in slight underestimation of fish densities. For example, if the actual wetted area of a unit at the time of sampling was 100 m^2 and ten fish were captured in this location the actual density would be one fish per 10 m^2. However, if the mapping conducted at a higher flow estimated the unit area to be 110 m^2, the estimated density would be one fish per 11 m^2. Underestimation of fish density contributes to underestimation of predator abundance as discussed in Section 4.2.2 Data Analysis.

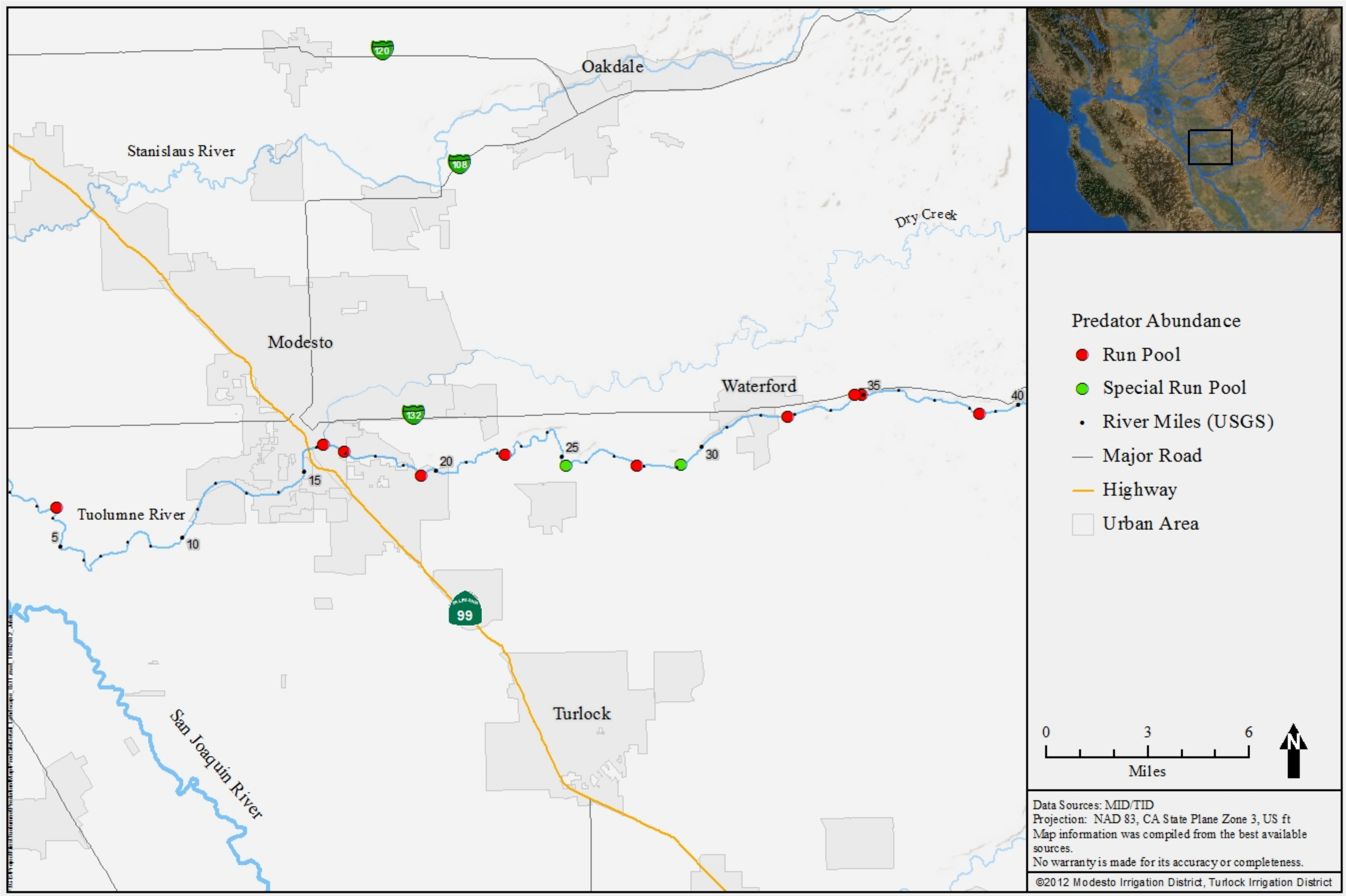

Figure 4.2-1. Map of the predator abundance sampling sites.

4.2.1.3 Electrofishing Methods

A portable 5.0 (5,000 W) generator powered pulsator electrofishing unit (Smith-Root, Vancouver, WA) was mounted on a 16 ft. North River jet boat. All electrofishing was conducted in accordance with NMFS (2000) electrofishing guidelines and electrofishing duration (effort in seconds) at each sampling site was recorded in an electrofishing logbook. Sampling was conducted between July 25 and August 8, 2012. In order to maximize capture rates and to maintain consistency with previous studies (TID/MID 1992; McBain & Trush and Stillwater Sciences 2006), sampling began at around dusk and was conducted until 0200 or 0300 hours the next morning. Each survey began at the downstream of the site and continued upstream along one bank then downstream along the opposite bank. During each pass, the boat was steered in a zigzag pattern through the shallow zone along each bank. Sampling was also conducted in a zigzag pattern through the mid-channel section of each unit.

Block nets were deployed at the upstream and downstream ends of each unit to prevent fish movement into or out of the unit during sampling such that each unit was a closed population. The population was repeatedly sampled *k* times (minimum of three and maximum of four) with the similar effort during each pass (duration of each pass within +/- 10 percent of duration of first pass) amount of effort (shocking time in seconds). On each pass, the number of individuals of each target species greater than 150 mm fork length (FL) was recorded and held in aerated tanks during subsequent passes.

4.2.2 Data Analysis

4.2.2.1 Depletion Estimates

The k-pass removal method was used to estimate abundance of each target species in each sampled unit. Two main assumptions are commonly applied to this type of removal method. First, the population is closed (e.g. animals cannot enter or escape the area); and, second, the probability of capture for an animal is constant for all animals from pass to pass.

If both assumptions are met, then the likelihood function for the vector of successive catches, $\vec{C}$, given the population size, N_0, and probability of capture is:

$$L(\vec{C} \mid N_0, p) = \frac{N_0!\, p^T q^{N_0 k - X - T}}{(N_0 - T)! \prod_{i=1}^{k} C_i!}$$

where $q = 1 - p$ (probability of escape); C_i is the number of animals captured in the *i*th removal period; *k* is the total number of removal periods, and:

$$T = \sum_{i=1}^{k} C_i$$

and:

$$X = \sum_{i=1}^{k}(k-i)C_i$$

The likelihood function is iteratively solved for q and N_0, where the smallest $N_0 > T$ that solves

$$(N_0 + \frac{1}{2})(kN_0 - X - T)^k - (N_0 - T + \frac{1}{2})(kN_0 - X)^k \geq 0$$

is the maximum likelihood estimate (Carle and Strub 1978; Ogle 2011). When the likelihood has been maximized the standard error of the estimate can be calculated with:

$$SE_{\hat{N}_0} = \sqrt{\frac{\hat{N}_0(1-q^k)q^k}{(1-q^k)^2 - (pk)^2 q^{k-1}}}$$

This k-pass removal estimator will fail (not produce an estimate) or will produce very large error bounds if depletion is not achieved (Carle and Strub 1978; Ogle 2011). The estimator will not produce an estimate if more animals are captured on the *k*th pass than the first pass. Additionally, the standard error of $\hat{N}_0$ can be quite large if catches from pass to pass are not sufficiently reduced.

In the two instances that the Carle-Strub estimator failed, a k-pass jackknife depletion estimator was used because it does not fail under the same conditions as the Carle-Strub estimator. The total number of fish ($\hat{y}_i$) and sampling variance, $\hat{V}(\hat{y}_i)$ in the two units where the Carle–Strub estimator failed were estimated using:

$$\hat{y}_i = \sum_{j=1}^{r_i - 1} c_{i \bullet j} + r_i c_{r_i}$$

and:

$$\hat{V}(\hat{y}_i) = r_i(r_i - 1)c_{r_i}$$

where r_i = the number of electrofishing passes in the i^{th} habitat unit; c_{r_i} = the number of fish captured in the r^{th} (last) pass in the i^{th} habitat unit; and $c_{i \bullet j}$ = the number of fish captured in the j^{th} pass of the i^{th} habitat unit.

4.2.2.2 Density Estimates

Density of predators by area and shoreline length was calculated using the 95 percent upper and lower confidence bounds for each site-specific abundance estimate. For example, the high areal density estimate was calculated as the upper bound of the abundance estimate for each species in each sampled unit. To be comparable to previous abundance estimates, all densities are reported in fish per acre and fish per shoreline mile.

4.2.2.3 River Wide Abundance Estimates

Two abundance estimates for each target species were produced for the lower Tuolumne River. Estimates of abundance for each species based on density estimates (shoreline length and area) were calculated using the following general estimator:

$$\hat{\tau}_{Density} = \hat{\mu}_{Density} A_T$$

where $\hat{\tau}_{Density}$= estimated total abundance based on either shoreline length or area, $\hat{\mu}_{Density}$ = the estimated mean number of fish per unit ($\hat{y}_i$), and A_T = the total unit area available. The variance of $\hat{\tau}_{Density}$ was estimated using:

$$\hat{V}(\hat{\tau}_{Density}) = \frac{A_T}{A_S}\sum_{i=1}^{n}(\hat{y}_i - \hat{\bar{y}})^2 + \frac{A_T}{A_S}\sum_{i=1}^{n}\hat{V}(\hat{y}_i)$$

where A_S = the total unit area sampled and $\hat{\bar{y}}$ = the grand mean of depletion estimates.

According to the FERC Study Plan (Study Plan W&AR-07 - Page 6), overall abundance estimates by habitat type were also to be estimated by expansion of the sampled portions of the Tuolumne River to unsampled portions using (ratio-type) two-phase regression estimators (Särndal et al. 1991) to provide appropriate confidence bounds on the overall abundance estimate.

This type of ratio estimator requires a strong, positive correlation between x_i (the auxiliary variable; generally easy or inexpensive to measure) and y_i (variable of interest; generally difficult or costly to measure) (Thompson 2002). However, we found no strong, positive correlation (visual inspection of x-y plots) between unit size (x_i) and abundance of each of the target species (y_i) (see Attachment A). Only two of the relationships met the requirements of the two-phase regression estimator (corr >0.50): (1) shoreline length of units and depletion estimates of largemouth bass and (2) area of habitat units and depletion estimates of largemouth bass.

4.3 Predation Rate

4.3.1 Collection of Stomach Samples

Sampling was conducted from an 18 ft. Smith-Root EH jet boat equipped with a 5.0 generator powered pulsator electrofishing unit (GPP) and a portable 5.0 (5,000 W) GPP electrofishing unit (Smith-Root, Vancouver, WA) mounted on a 16 ft. North River jet boat. All electrofishing was conducted in accordance with NMFS (2000) electrofishing guidelines and an electrofishing logbook was maintained and updated at each sampling site with a record of electrofishing duration (effort in seconds). Sampling was conducted at twelve sites (5 run-pools and 7 SRPs) between RM 22.4 and RM 31.1 (Figure 4.3-1) during March 22-29 and May 1-9. To maintain consistency with previous studies (TID/MID 1992; McBain & Trush and Stillwater Sciences 2006) and because juvenile salmon and predators are most active during crepuscular periods (Adams et al. 1987; Clark and Levy 1988; Angradi and Griffith 1990; Benkwitt et al. 2009), sampling began after dark to increase the likelihood that prey in predator stomachs would be freshly consumed.

Prey items were collected from piscivorous fish, specifically largemouth bass, smallmouth bass, striped bass and Sacramento pikeminnow > 150 mm FL by inserting an acrylic tube through the esophagus into the stomach and flushing the stomach with water to disgorge the contents (Van Den Avyle and Roussel 1980; Kamler and Pope 2001). Stomach contents from target species (noted above) < 150 mm FL were not collected as predation on juvenile salmonids by predators of this size class has not been observed (TID/MID 1992). Stomach contents were placed in plastic vials and preserved in 70 percent ethanol. The vials were labeled with site, date, and a unique identification number for each individual sampled.

4.3.2 Identification of Prey Items

In the laboratory, all identifiable prey items found in predator stomachs were classified to order and for fish prey, to genus and species. All intact prey items were measured to the nearest millimeter (mm). Standard lengths (SL), fork lengths (FL), and total lengths (TL) of fish were taken when possible. All identifiable prey items, regardless of taxon, were enumerated. Observations of prey items such as amphibians or reptiles were also recorded.

Hard parts from digested fish (e.g. cleithra and dentaries) were used to help identify fish to genus and when possible, were measured to estimate the original prey length. Diagnostic bones from Chinook salmon were identified using bone keys developed by Hansel et al. (1988) and Frost (2000). The diagnostic bones only allow identification to genus (e.g. presence of a cleithrum would allow identification of presence of *Oncorhynchus spp.* but not allow distinction between *O. tshawyscha* or *O. mykiss*). Despite this limitation, we feel justified in calling all cleithrum identified as *Oncorhynchus spp.* as belonging to juvenile Chinook salmon because: (1) of the 30 identifiable *Oncorhynchus spp.*, all were identified as juvenile Chinook, and (2) only one juvenile *O. mykiss* was captured during rotary screw trap monitoring conducted at RM 29.8 near Waterford. Nearly all (>99.9 percent) salmonid captures in the Waterford rotary screw trap during spring 2012 were juvenile Chinook salmon (Sonke and Fuller 2012). The presence of cleithra and dentaries from juvenile Chinook salmon within a particular stomach sample allowed for the identification of highly digested prey items. To aid in the identification of the diagnostic bones from stomach samples, we dissected juvenile Chinook (mortalities from other monitoring programs). The cleithra and dentaries from known Chinook were placed in vials for future reference.

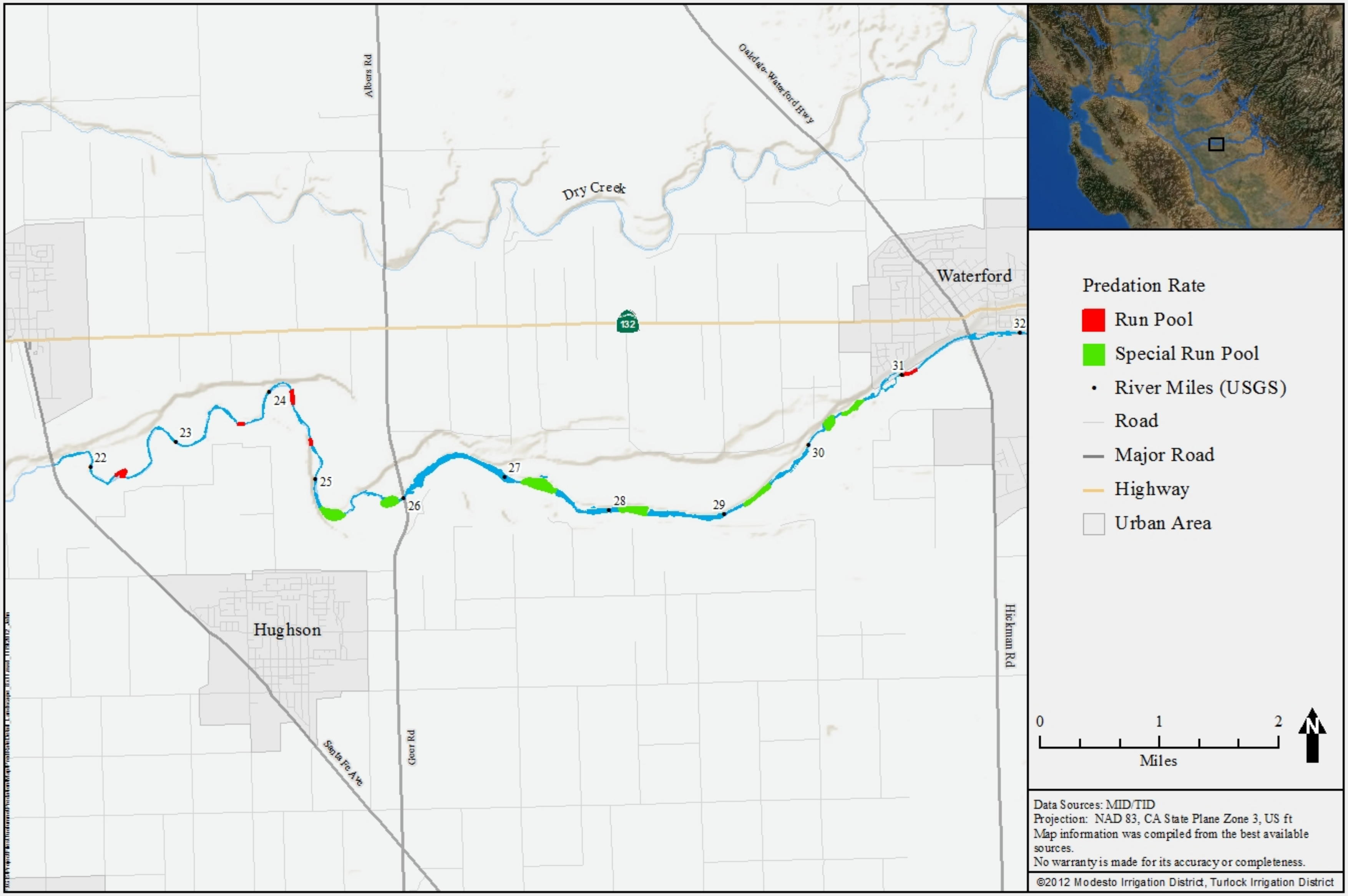

Figure 4.3-1. Predation rate sampling sites.

4.3.3 Data Analysis

4.3.3.1 Water Temperatures Prior to Time of Capture

Water temperature data from 18 h prior to capture was summarized for each captured predator based on capture time and location (refer to section 4.3.3.2 for further explanation). Four temperature recorders (Tuolumne Weir, SRP10, Waterford, and Hickman Bridge) were located within the reach sampled. Based on geographic proximity, sampling locations at Santa Fe, Hughson, Below Tuolumne Weir, Above Tuolumne Weir, and Charles Road used temperature readings from the temperature recorder located at the Tuolumne Weir. Other temperature recorders and associated sampling locations are described in Table 4.3-1. The mean, standard deviation, minimum, and maximum water temperature values were calculated using data from the temperature recorder nearest the capture location of each predator. The minimum and maximum temperatures for any given sampling location and period were used to determine "global" temperature values for the calculation of the gastric evacuation rates.

Table 4.3-1. Location information of temperature recorders and predation rate sampling locations on the lower Tuolumne River during Spring and Summer 2012.

Temperature Recorder Site	River Mile	Associated Sampling Sites
Tuolumne Weir	24.4	Santa Fe, Hughson, Below Tuolumne Weir, Above Tuolumne Weir, and Charles Road
SRP10	25.5	SRP10 and SRP9
Waterford	29.8	SRP8, lower SRP7, and upper SRP7
Hickman Bridge	31.6	Waterford Wastewater Facility

4.3.3.2 Gastric Evacuation Rates

Gastric evacuation rates, the time it takes for food items to be digested, of fish is largely determined by water temperature. Generally, gastric evacuation rates are higher when water temperature is higher, and conversely, rates are lower when water temperatures are lower.

Gastric evacuation rates used for this study were adapted from rates used by TID/MID (1992) based on differences in temperature between the 1992 study and this study. The 1992 study used 10-15 hours for a juvenile Chinook salmon to become unrecognizable at approximately 17°C. Since gastric evacuation rates are slower at cooler temperatures and water temperatures were cooler during 2012 (13-18°C), using the same gastric evacuation rates could inflate estimated predation rates. To adjust for the difference in temperature, gastric evacuation rates of 16 hours and 20 hours were used for this study. Both times were chosen to provide lower and upper estimates of predation rates, similar to the approach used TID/MID study (1992).

4.3.3.3 Predation Ratio and Predation Rates

Predation ratios, or the average number of juvenile Chinook salmon consumed per predator sampled, were calculated for each species, sampling event and habitat type (run-pool or special run-pool). For example, during the first sampling event in run-pools, 19 largemouth bass were sampled. The total number of salmon consumed by those 19 largemouth bass was one, which leads to a predation ratio of 1/19 = 0.053. Confidence intervals for predation ratios were estimated using a normal approximation to the Poisson distribution using the "epitools" package and the software R.2.14.1 (Aragon 2010; R Development Core Team 2010).

Predation rates were then calculated using the gastric evacuation times and predation ratios for each species, sampling event, and habitat type. Using the example from above, the predation ratio for largemouth bass in run-pools during the first sampling event was 0.053 juvenile Chinook consumed per predator. The predation rate at the high digestion rate (using 16 h or 0.667 d) would be equal to 0.053 / 0.667 which is 0.08 juvenile Chinook salmon consumed per largemouth bass per day in run-pool habitats during the first sampling event.

To determine if predation rates were different between sampling events and habitat types, the number of predators that consumed salmon was divided by the total number of predators captured (by species, habitat type and event). To determine if the proportions were different, a two-sample test for equality of proportions with continuity correction was conducted (Crawley 2007). All tests were conducted at $\alpha = 0.05$.

4.4 Predator Movement Tracking

4.4.1 Acoustic Tag System Overview

Fish movements were monitored with an acoustic tracking system. The project incorporated an HTI Acoustic Tag Tracking System (ATS), which uses a fixed array of underwater hydrophones to track movements of fish implanted with acoustic tags. As fish approached the array, the transmitted signal from each tag was detected and the arrival time recorded at several hydrophones. The difference in tag signal times at each hydrophone were used to calculate a two-dimensional (2-D) position.

All tags used in this study operated at 307 kilohertz (kHz) frequency and were encapsulated with a non-reactive, inert, low toxicity resin compound. The tags utilized "pulse-rate encoding" which provided increased detection range, improved the signal-to-noise ratio and pulse-arrival resolution, and decreased position variability when compared to other types of acoustic tags (Ehrenberg and Steig 2003). Pulse-rate encoding uses the interval between each transmission to detect and identify the tag. Each tag was programmed with a unique pulse-rate to track movements of individual tagged fish.

The pulse-rate is measured from the leading edge of one pulse to the leading edge of the next pulse in sequence. By using slightly different pulse-rates, tags can be individually identified. The timing of the start of each transmission is precisely controlled by a microprocessor within the tag. Each tag was programmed to have its own tag period to uniquely identify between tags. Test tag periods ranged between 2.007 and 4.086 seconds. The amount of time that the tag actively transmits is the pulse length. For this study, the transmit pulse length was 3.0 milliseconds.

In addition to the tag period, the HTI tag subcode option can be used to increase the number of unique tag ID codes available. Using this tag coding option, each tag is programmed with a defined primary tag period, and also with a defined secondary transmit signal, called the subcode. This subcode defines a precise elapsed time period between the primary and secondary tag transmissions. Two subcodes were used for this study; with subcode 8 used for predators, and subcode 5 for Chinook.

4.4.2 Predator Tagging

Hook and line (angling) surveys as well as electrofishing were conducted between April 26 and May 16, 2012, with the objective of capturing potential salmonid predators (largemouth bass, smallmouth bass, striped bass, and Sacramento pikeminnow) $\geq$150 mm total length.

Sampling was conducted at SRP 6 (RM 30.3), SRP 10 (RM 25.4), Riffle 62 (RM 30.2), and Riffle 74 (RM 24.9) (Figure 4.4-1), as well as areas near these sites where habitat conditions appeared to be suitable for predators. Light- and medium-weight spinning rod and reel combinations with monofilament 8-20 lb test fishing lines were used during sampling. Anglers used lures meant to mimic prey fish 60-150 mm in length, and fished from the surface down to the river bottom. Additional tagging was conducted opportunistically of predators captured by electrofishing as part of the predation rate sampling.

All predators captured were placed in holding containers with fresh river water. Fish were not anesthetized with tricaine methanesulfonate due to possible issues if released fish are subsequently captured and consumed by humans, and no other anesthetizing agents were used. Prior to tagging, fork length (nearest mm) and weight (nearest 0.1 g) were recorded for each fish. Non-biological data was also recorded including the time and location (GPS coordinates) of capture, specific habitat type at capture site, and general physical conditions (i.e., weather conditions, water temperature, turbidity, conductivity, and dissolved oxygen).

Predatory fish larger than 150 mm were tagged with an acoustic tag. All tagging was conducted near the original site of capture. Tags were placed externally and consisted of an HTI (Hydroacoustic Technology, Inc., Seattle WA) acoustic tag (LG-type) affixed directly under the dorsal fin. Acoustic tags were programmed just before entering the field. Tags were programmed with a three millisecond pulse width, and tag periods ranging from 2007–4086 milliseconds. At these settings, the predicted tag lives were 40–50 days. During the tagging process, fish were held in a canvas sling and submerged in running water to keep them calm. The acoustic tag, mounted to a thin rubber plate with a nylon coated wire leader, was attached by passing the wires through the body of the fish under the dorsal fin using hypodermic syringe needles. The wires and tag were secured in place by wire connector sleeves. A t-anchor Floy tag (Floy Tag Inc, Seattle, WA) was also attached directly below the posterior portion of the dorsal fin. Each Floy tag had unique ID and contact information for anglers to return tags from any captured fish. This tagging procedure is comparable to that used by California Department of Water Resources (CDWR) staff in the Delta for similar tracking studies.

Tagged fish were allowed to recover in a live well and released back into the river near the original site of capture. During the recovery period, tagged fish were monitored to confirm the operational status of each transmitter. Fish not selected for tagging were released immediately after necessary biological data was collected. All fish were acclimated to river conditions prior to release.

4.4.3 Chinook Salmon Releases

Acoustic tags were surgically implanted into 222 coded wire tagged Chinook salmon provided by CDFG from the Merced River Hatchery (MRH). An additional 600 coded wire tagged Chinook salmon, also provided from MRH, were marked photonically and were released to accompany the acoustic tagged fish. All tagging and marking was conducted at MRH.

4.4.3.1 Acoustic Tagging of Chinook Salmon

Acoustic tags were soaked for at least 24 hours prior to programming, and each tag was programmed with a unique code the day prior to tagging. After programming, tags were sniffed in a cup of water using a HTI sniffer and monitored through at least three transmission cycles. At least five attempts were made to program each tag. Function and coding of all activated tags was verified with a hydrophone immediately after programming and prior to surgical implantation in study fish to confirm tag function and programming. Only three tags failed to initialize, and all programmed tags were heard during validation immediately after programming. Tags were expected to remain active for 10-16 days after programming.

During each tagging session, fish were surgically implanted with HTI Model 795 Lm micro acoustic tags following implantation procedures outlined in Adams et al. 1998 and Martinelli et al. 1998. These tags weighed 0.63 g to 0.70 g, and were 16.4 mm long with a diameter of 6.7 mm. Prior to transmitter implantation, fish were anesthetized in 70 mg/L tricaine methanesulfonate buffered with an equal concentration of sodium bicarbonate until they lost equilibrium. Fish were removed from anesthesia, and were measured (FL to nearest mm) and weighed (to nearest 0.1 g), fish were surgically implanted with acoustic transmitters. Typical surgery times were less than 3 min.

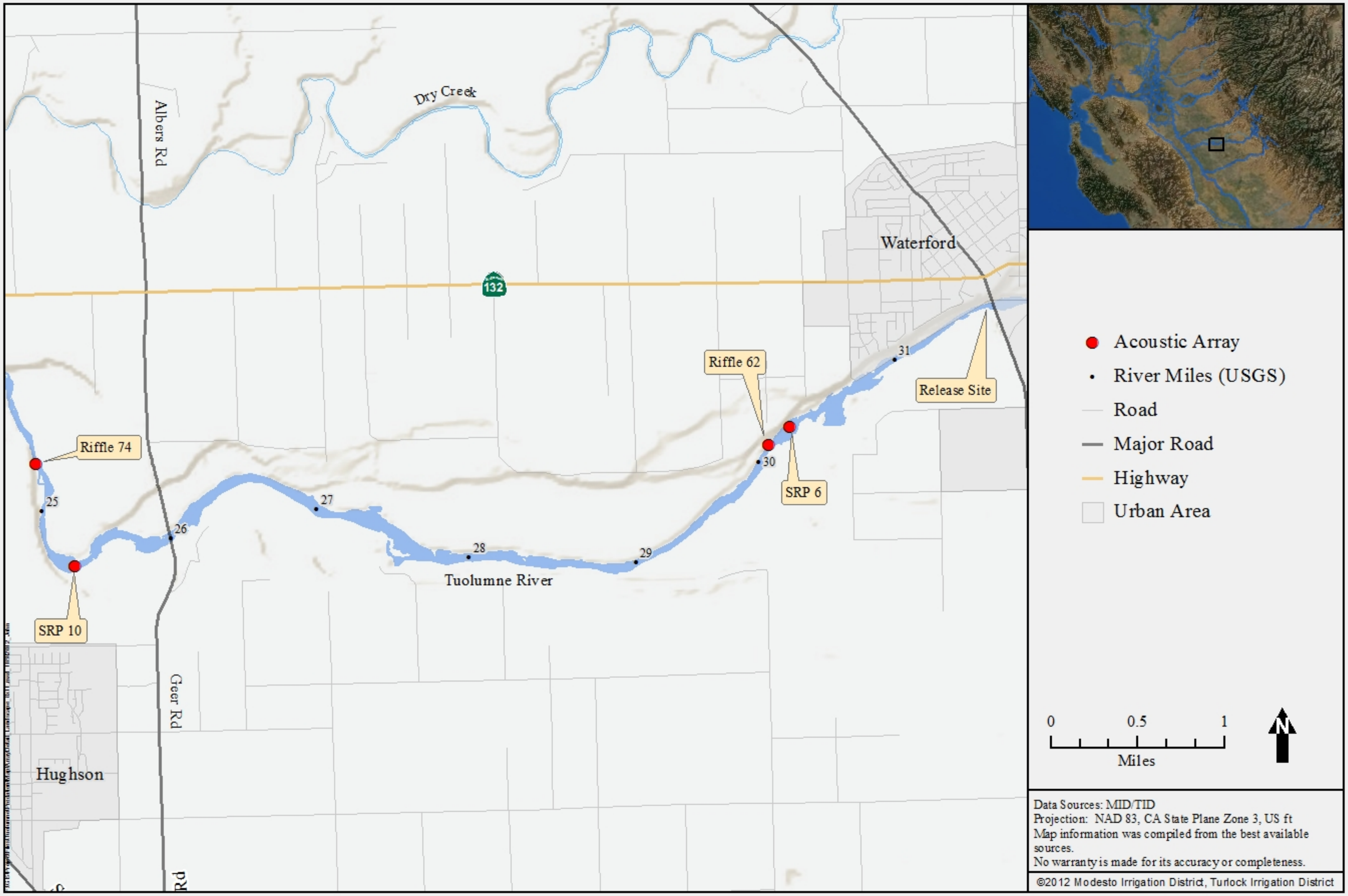

Figure 4.4-1. Acoustic array deployment locations.

Fish were then placed into perforated 19 L buckets in a tank inside the egg building at MRH to recover from anesthesia effects. Buckets were perforated, starting 15 cm from the bottom, to allow water exchange. The non-perforated section of the bucket held 7 L of water to allow transfer without complete dewatering and without the need to net fish, thereby reducing stress. Each bucket was stocked with up to three tagged fish, and was covered with a snap-on lid.

In order to evaluate the effects of tagging and transport, 12 Chinook salmon were implanted with inactive transmitters during each tagging session. Inactive tags were interspersed randomly into the tagging order for each release group. Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters. Dummy-tagged fish were evaluated for condition (i.e., percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration) and mortality after being held at the release site for approximately 40-60 hours.

4.4.3.2 Photonic Marking of Chinook Salmon

A photonic marking system was used for marking fish to accompany the acoustic tagged fish. All fish were anesthetized with tricaine methanesulfonate before marking. A marker tip was placed against the anal fin and orange photonic dye was injected into the fin rays. The photonic dye (DayGlo Color Corporation, Cleveland, OH) was chosen because of its known ability to provide a highly visible, long-lasting mark.

4.4.3.3 Transport and Holding of Chinook Salmon

Once each tagging session was complete, buckets containing acoustic tagged Chinook salmon were transferred to a dual chambered 250 gallon insulated aluminum hauling tank for transport to the release site at Hickman Bridge (RM 31.6). At the release site acoustic tagged Chinook salmon were transferred from the buckets to perforated 32 gallon trash cans suspended in the river in an area of low velocity along the south bank under the bridge. A total of 18-21 Chinook salmon were transferred to each of the four perforated trash cans.

Photonic marked Chinook salmon were netted from the transport tank and carried in buckets to live cars suspended in the river adjacent to the trash cans holding the acoustic tagged Chinook salmon. An in-river holding period prior to release provided time for study fish to recover from surgery and transport, and to adjust to in-river water quality for approximately 30-60 hours. Prior to release, tagged fish were monitored by hydrophones to confirm the operational status of each tag. All tags were confirmed to be functional during this evaluation.

4.4.3.4 Releases of Tagged and Marked Chinook Salmon

Releases of tagged and marked Chinook salmon were made on May 9-10, May 16-17, and May 21-22, and were timed to occur at flows of 2100 cfs, 280 cfs, and 415 cfs (Table 4.4-1). Each of the three releases groups of 73-75 acoustic tagged Chinook salmon was paired with a release 200 photonic marked Chinook salmon. To account for potential diurnal differences in Chinook salmon and predator behavior, approximately half of each group was released shortly before dawn and half shortly before dusk to allow observation of movement during day and night.

Releases were made by first inspecting the trash can (acoustic tagged) or live car (photonic marked) for any mortalities or Chinook salmon exhibiting abnormal behavior or otherwise appearing unhealthy. All Chinook salmon were in good condition at release and no mortality was observed during the periods between tagging and release. After inspection, the trash can or live car was tipped to allow fish to exit volitionally.

Table 4.4-1 Releases of acoustic tagged Chinook salmon.

Release	Date	Time	River flow at La Grange (cfs)	Number Released	Avg. fork length (mm)	Avg. weight (g)	Tag weight: body weight
1a	5/9/2012	20:00	2100	36	108.3	15.8	4.2%
1b	5/10/2012	4:00	2100	39	107.0	15.3	4.4%
2a	5/16/2012	20:00	280	36	108.2	15.7	4.3%
2b	5/17/2012	4:00	280	38	107.9	15.6	4.3%
3a	5/21/2012	20:00	415	36	108.6	16.3	4.1%
3b	5/22/2012	4:00	415	37	110.2	17.8	3.8%

4.4.4 Acoustic Array Deployment and Maintenance

A network of HTI acoustic receivers (Hydroacoustic Technology, Inc., Seattle WA) was deployed within the Tuolumne River to detect movements of both tagged Chinook and tagged predators. At SRP 6 and SRP 10, arrays capable of two-dimensional tracking of fish movement were deployed. These 2D arrays consisted of four hydrophones connected to a Model 291 Portable Acoustic Tag Receiver (ATR). Detection on one hydrophone confirms the presence of an acoustic tag, but to be accurately positioned in two-dimensions a tag must be detected on at least three hydrophones. Two-dimensional tag coordinates with sub-meter accuracy are achieved using hydrophones located in known positions, at the same horizontal plane and within direct line of sight of the tag. The precise location of hydrophones in each array was recorded using a GPS unit. The effective range of detection in the array was examined by actively moving transmitting tags through the array at various depths and verifying consistent detection and positioning of the tag. These arrays were both deployed and began receiving data on April 19, 2012 and recorded continuously through May 29, 2012.

Single hydrophone arrays were deployed directly above and directly below Riffle 62 and Riffle 74. These arrays consisted of a single hydrophone attached to a Model 295-G Acoustic Tag Data Logger, and detected tags as they moved past the hydrophones. Additionally, a single hydrophone array was deployed at Grayson (RM 5.0) in order to detect tagged fish moving out of the river.

At each acoustic monitoring site, the data loggers were secured on the streambank in a metal lock box. Receivers were powered by a bank of 12V deep-cycle batteries, and in some cases charged by a small solar array. The Model 291 ATR is designed to receive four separate channels; one channel assigned to each hydrophone. Each ATR is connected to a personal computer used to store the acoustic data. An individual raw data file is created for each sample hour. Filters in the ATR are set to identify the acoustic tag sound pulse and discriminate tags from ambient background noise. The ATR pulse measurements are reported for each single echo from each hydrophone and written to Raw Acoustic Tag files (*.RAT) using the AcousticTag program. Each *.RAT file contains header information for data acquisition settings followed by the raw echo data. Each raw echo data file contains all acoustic signals detected during the time period, including signals from tagged fish as well as some additional unfiltered acoustic noise. Receiver sites were visited a minimum of three days per week during the acoustic monitoring period. On each visit, acoustic data was saved to a USB drive and the 12V batteries were replaced as needed.

At the end of the monitoring period, all acoustic data were auto-marked using HTI's MarkTags software. After the data were marked, the files from the SRP6 and SRP 10 arrays were were geo-referenced and given 2D positions by HTI staff using AcousticTag software. The 2D positions were then imported into Eonfusion software (Myriax Software Pty Ltd) to allow for viewing of all of the acoustic tracks. The data were reviewed in Eonfusion and the fate of each acoustic tagged Chinook salmon was classified as either a successful passage, likely consumed by a predator, unknown, or not present. Tag fates were determined based on characteristics of the tag tracks including length of detection, direction of travel, habitat usage (near-shore vs. mid-channel) and comparison to tracks of known tagged predators. Predator tags were classified by species (largemouth bass, smallmouth bass, striped bass, or Sacramento pikeminnow).

Habitat use by tagged predators and Chinook salmon was evaluated by measuring the relative density of acoustic tracks within the 2D arrays at the 90 percentile level. These values were used to calculate the areas of overlap and non-overlap between the successful Chinook passages and the various predator species using the Eonfusion software package.

5.0 RESULTS

5.1 River Conditions

Flows during the study period ranged from 94 cfs to 2120 cfs (Figure 5.1-1). Predator abundance sampling was conducted July 25 to August 8, 2012 at an average flow of 98 cfs. Predation rate sampling was conducted on two occasions: March 22 to March 29 and May 1 to May 9, 2012. During the first sampling period flows were steady at 315 cfs. The second sampling event occurred on the front end of a pulse flow, with releases ranging from 667 cfs to 2120 cfs. Predator tracking occurred from April 19 to May 29, 2012, with flows ranging from 195 cfs to 2120 cfs.

Figure 5.1-2 shows the range of water temperatures between Roberts Ferry Bridge (RM 39.4) and Grayson (RM 5.0) throughout the study period.

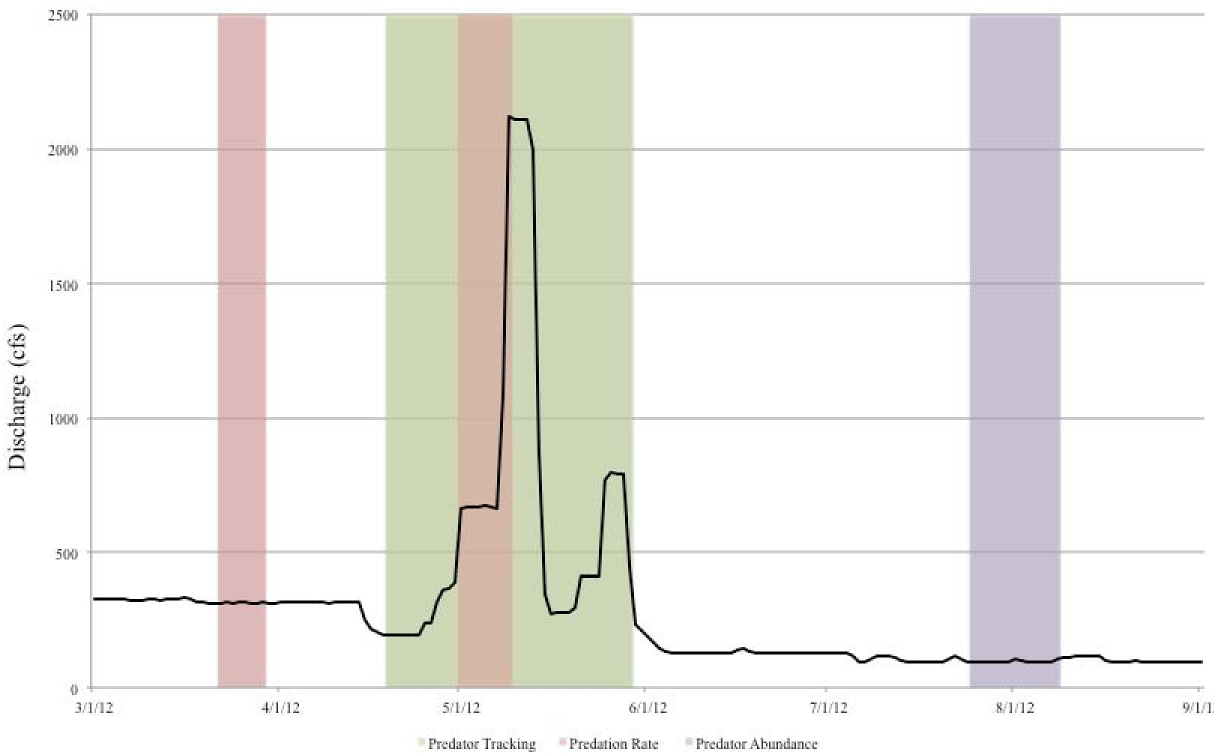

Figure 5.1-1. Daily mean discharge at La Grange (LGN) March 1 through August 31 and timing of sampling events.

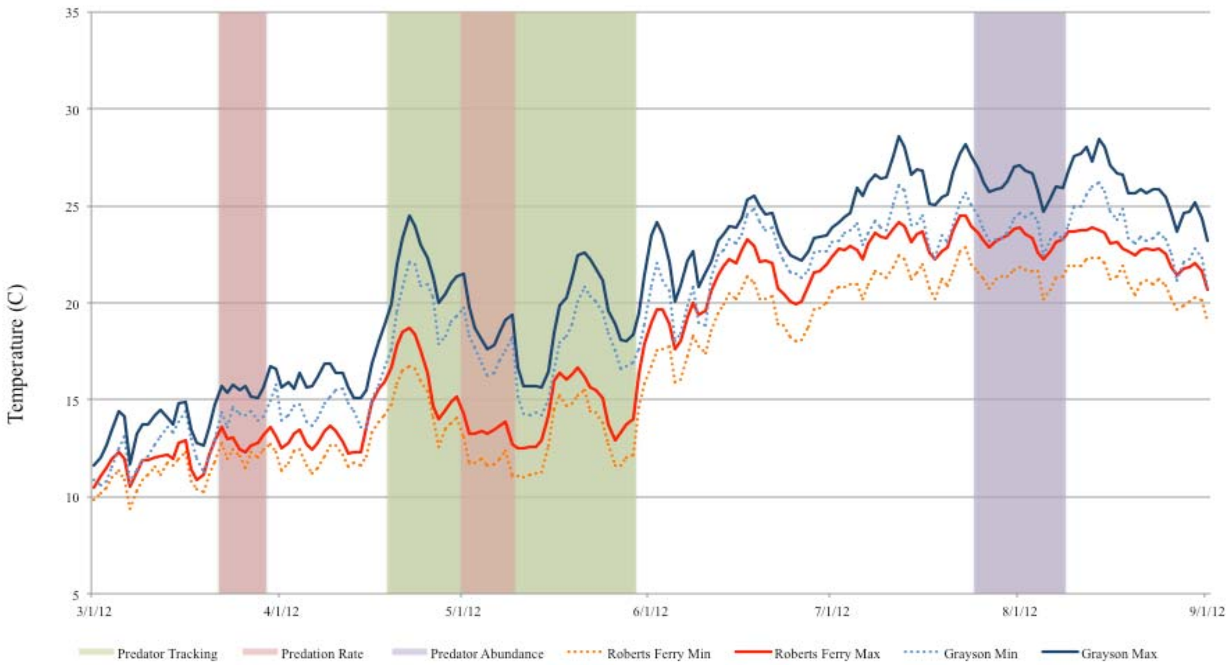

Figure 5.1-2. Daily minimum and maximum water temperatures at Roberts Ferry (RM 39.4) and Grayson (RM 5.0) March 1 through August 31 and timing of sampling events.

5.2 Predator Abundance

5.2.1 Habitat Measurements

Measurements of each run-pool and special run-pool are provided in Table 5.2-1. Ten run-pools ranging in size from 0.69 acres to 2.44 acres and two special run-pools measuring 1.61 and 10.46 acres in area were sampled between Shiloh (RM 3.7) and 7-11 Gravel (RM 38.4).

Table 5.2-1. Habitat sizes of sampled units in the lower Tuolumne River measured in GIS.

Site Name	Habitat Type	River Mile	Shoreline Length (m)	Area (m^2)	Shoreline Length (ft)	Area (ft^2)	Area (ac)
Shiloh	Run-Pool	3.7	482	7,972	1,580	85,609	1.97
7th Street Bridge	Run-Pool	16.2	215	3,116	704	33,669	0.77
Legion Park	Run-Pool	17.1	950	11,412	3,117	122,679	2.82
Mitchell Rd	Run-Pool	19.5	296	4,532	972	48,954	1.12
Hughson Nut Farm (Santa Fe)	Run-Pool	22.4	211	2,752	692	29,645	0.68
SRP 10	SRP	25.5	953	42,330	3,128	455,540	10.46
Fox Grove	Run-Pool	27.8	221	4,047	725	43,764	1.00
SRP 7	SRP	29.2	346	6,515	1,136	70,238	1.61
Waterford	Run-Pool	32.9	562	9,874	1,842	106,312	2.44
George Reed (d/s of bridge)	Run-Pool	34.8	419	4,816	1,375	51,787	1.19
George Reed	Run-Pool	35.0	430	6,354	1,412	68,571	1.57
7-11 Gravel	Run-Pool	38.4	401	4047	1317	43385	1.00

5.2.2 Site-Specific Abundance and Density

Largemouth bass >150 mm were captured in all units sampled between RM 3.7 and RM 32.9, and no largemouth bass >150 mm FL were captured in sites at or above RM 34.8. Depletion estimates using the Carle-Strub estimator could not be generated for one of the nine units. Instead, the k-pass jackknife estimator was used for this particular unit. Site-specific abundance estimates of largemouth bass >150 mm FL ranged from 2 to 42 (Table 5.2-2).

Smallmouth bass >150 mm FL were captured in all twelve sampled units (Table 5.2-3). Below RM 25, abundance estimates of smallmouth bass >150 mm FL ranged from 7 to 37. Above RM 25, site-specific abundance estimates of smallmouth bass ranged from 2 to 50.

Striped bass >150 mm FL were captured in four of the twelve units sampled (Table 5.2-4). Depletion estimates using the Carle-Strub estimator could not be generated for one of the four units. Instead, the k-pass jackknife estimator was used for this particular unit. Site-specific abundance estimates of striped bass ranged from two to nine.

Sacramento pikeminnow greater than 150 mm FL were only captured in units above RM 27 (Table 5.2-5). In units above RM 27, Sacramento pikeminnow were captured in five of six sampled units. Estimated abundance of Sacramento pikeminnow in the five units where they were captured ranged from 2 to 15.

Table 5.2-2. Site-specific depletion estimates of largemouth bass >150 mm and associated density estimates on the lower Tuolumne River during summer 2012.

River Mile	Habitat Type	Estimated Abundance $\hat{N}$	SE	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Density (# / acre)	Density (# / Bank Mile)
3.7	Run-Pool	27	4.1	19	35	10 - 18	63 - 117
16.2	Run-Pool	6	3.9	0	14	0 - 18	0 - 103
17.1	Run-Pool	35	5.3	24	46	9 - 16	41 - 77
19.5	Run-Pool	2	2.0	0	6	0 - 5	0 - 33
22.4	Run-Pool	13	1.5	10	16	15 - 24	76 - 122
25.5	SRP	17	2.6	12	22	1 - 2	20 - 37
27.8	Run-Pool	16	3.6	9	23	9 - 23	64 - 169
29.2	SRP	3	1.4	0	6	0 - 4	1 - 27
32.9	Run-Pool	42[1]	17.0	8	76	3-31	23-218
34.8	Run-Pool	0	--	--	--	--	--
35.0	Run-Pool	0	--	--	--	--	--
38.4	Run-Pool	0	--	--	--	--	--

[1] Carle-Strub depletion estimator failed, used k-pass jackknife depletion estimator

Table 5.2-3. Site-specific depletion estimates of smallmouth bass >150 mm and associated density estimates on the lower Tuolumne River during summer 2012.

River Mile	Habitat Type	Estimated Abundance $\hat{N}$	SE	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Density (# / acre)	Density (# / Bank Mile)
3.7	Run-Pool	37	7.1	23	51	12 - 26	76 - 171
16.2	Run-Pool	7	3.1	1	13	1 - 17	7 - 98
17.1	Run-Pool	9	1.8	5	13	2 - 4	9 - 21

River Mile	Habitat Type	Estimated Abundance $\hat{N}$	SE	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Density (# / acre)	Density (# / Bank Mile)
19.5	Run-Pool	26	5.1	16	36	14 - 32	86 - 197
22.4	Run-Pool	14	1.5	11	17	16 - 25	83 - 130
25.5	SRP	9	5.6	0	20	0 - 2	0 - 34
27.8	Run-Pool	15	1.8	11	19	11 - 19	82 - 136
29.2	SRP	2	2.0	0	6	0 - 4	0 - 28
32.9	Run-Pool	15	1.4	12	18	5 - 7	35 - 51
34.8	Run-Pool	50	7.7	35	65	29 - 55	132 - 251
35.0	Run-Pool	2	2.9	0	8	0 - 5	0 - 29
38.4	Run-Pool	32	1.3	29	35	29 - 35	118 - 139

Table 5.2-4. Site-specific depletion estimates of striped bass >150 mm and associated density estimates on the lower Tuolumne River during summer 2012.

River Mile	Habitat Type	Estimated Abundance $\hat{N}$	SE	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Density (# / acre)	Density (# / Bank Mile)
3.7	Run-Pool	9	3.0	3	15	2 - 8	10 - 50
16.2	Run-Pool	0	--	--	--	--	--
17.1	Run-Pool	0	--	--	--	--	--
19.5	Run-Pool	0	--	--	--	--	--
22.4	Run-Pool	0	--	--	--	--	--
25.5	SRP	0	--	--	--	--	--
27.8	Run-Pool	4	1.5	1	7	1 - 7	7 - 51
29.2	SRP	0	--	--	--	--	--
32.9	Run-Pool	0	--	--	--	--	--
34.8	Run-Pool	4[1]	0	4	4	3-3	15-15
35.0	Run-Pool	2	5.5	0	13	0 - 8	0 - 48
38.4	Run-Pool	0	--	--	--	--	--

[1] Carle-Strub depletion estimate failed, used k-pass jackknife depletion estimator.

Table 5.2-5. Site-specific depletion estimates of Sacramento pikeminnow >150 mm and associated density estimates on the lower Tuolumne River during summer 2012.

River Mile	Habitat Type	Estimated Abundance $\hat{N}$	SE	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Density (# / acre)	Density (# / Bank Mile)
3.7	Run-Pool	0	--	--	--	--	--
16.2	Run-Pool	0	--	--	--	--	--
17.1	Run-Pool	0	--	--	--	--	--
19.5	Run-Pool	0	--	--	--	--	--
22.4	Run-Pool	0	--	--	--	--	--
25.5	SRP	0	--	--	--	--	--
27.8	Run-Pool	2	2.9	0	8	0 - 8	0 - 57
29.2	SRP	0	--	--	--	--	--
32.9	Run-Pool	15	1.8	11	19	5 - 8	32 - 54
34.8	Run-Pool	3	3.5	0	10	0 - 8	0 - 38
35.0	Run-Pool	12	4.0	4	20	2 - 13	15 - 75
38.4	Run-Pool	12	1.8	8	16	8 - 16	34 - 62

5.2.3 River Wide Abundance Estimates

Correlation values between habitat size (shoreline lengths and habitat areas) and site-specific abundance estimates were low and ranged from .033 to .606 (Attachment A). With the exception of largemouth bass, all correlations between habitat size and predator abundance estimates failed to meet the minimum suggested level of 0.5 to use a ratio-regression estimator (Thompson 2002; Hankin, unpublished); therefore the ratio-regression estimator could not be used to generate river-wide abundance estimates.

Two abundance estimates for each species were produced for the lower Tuolumne River. The first is based on areal density and the second is based on shoreline density (Table 5.2-6). River wide abundance estimates (for all run-pools and special run-pools from RM 0 to RM 39.4) derived from area density estimates were slightly higher than those derived from shoreline density estimates. Smallmouth bass were estimated to be the most abundant predators, with 9,092 and 6,764 based on area and shoreline length, respectively. A standard error term could not be produced for either of the striped bass estimates since depletion was not achieved at RM 34.8.

Table 5.2-6. Abundance estimates and associated standard errors based on estimated densities (by area and shoreline length of run-pools and special run-pools) of each target species on the lower Tuolumne River (RM 0 to RM 39.4).

Species	Area $\hat{\tau}$	SE
Bass < 150 mm	121,756	4,360
Largemouth bass	4,794	252
Sacramento pikeminnow	1,590	98
Smallmouth bass	9,092	251
Striped bass	692	55
Species	**Shoreline Length** $\hat{\tau}$	
Bass < 150 mm	95,198	4,506
Largemouth bass	4,185	261
Sacramento pikeminnow	1,161	101
Smallmouth bass	6,764	260
Striped bass	588	57

5.3 Predation Rate

A total of 295 piscivores > 150 mm FL were captured during the two sampling occasions. The first sampling occasion took place from March 22, 2012 to March 29, 2012 and the second sampling took place from May 1, 2012 to May 9, 2012. No further sampling to estimate predation rates was conducted after May 9, 2012. Smallmouth and largemouth bass were the most common piscivores collected. A total of 49 piscivores had no food contents in their stomach when examined. Similar numbers of empty stomachs were observed for smallmouth bass (15.2 percent) and largemouth bass (14.5 percent). About 35 percent of striped bass sampled (9 of 26) had empty stomachs when examined (Table 5.3-1).

Table 5.3-1. Numbers of predatory fish (> 150 mm FL) stomachs sampled and number and percentage of predatory fish with empty stomachs during electrofishing on the lower Tuolumne River during spring 2012.

Species	Number Sampled	Number Empty	Percentage of Predators with Empty Stomach
Smallmouth bass	132	20	15.2%
Largemouth bass	131	19	14.5%
Striped bass	26	9	34.6%
Sacramento pikeminnow	6	1	16.7%

5.3.1 Diet Composition

At the taxonomic class level, insects (many orders) made up a majority (74 percent) of identifiable prey items observed in the 246 stomach samples examined. Other notable prey items included fish (various orders) at approximately 13.5 percent of all identifiable prey items and crayfish at approximately 4 percent of all identifiable prey items (Figure 5.3-1). All other prey items combined made up only eight percent of the identifiable prey items observed in the stomach samples.

The most frequently occurring prey items were macroinvertebrates of the orders Tricoptera and Ephemeroptera (Figure 5.3-2). Of the 246 stomach samples examined, 100 (41 percent) contained at least one trichopteran (either larvae or adult) and 92 (37 percent) contained at least one ephemeropteran (larvae or adult). Seventy-nine or about 32 percent of stomach samples examined contained at least one unidentified fish (no identifiable juvenile Chinook salmon were included in this count). Crayfish were present in about 26 percent of all stomach samples examined. Thirty fish identified as juvenile Chinook salmon occurred in about 12 percent of the stomach samples.

When identifiable prey items were counted by order, nearly 46 percent were of the order Ephemeroptera (Figure 5.3-3). The second-most frequent prey item by order was Trichoptera (13 percent).

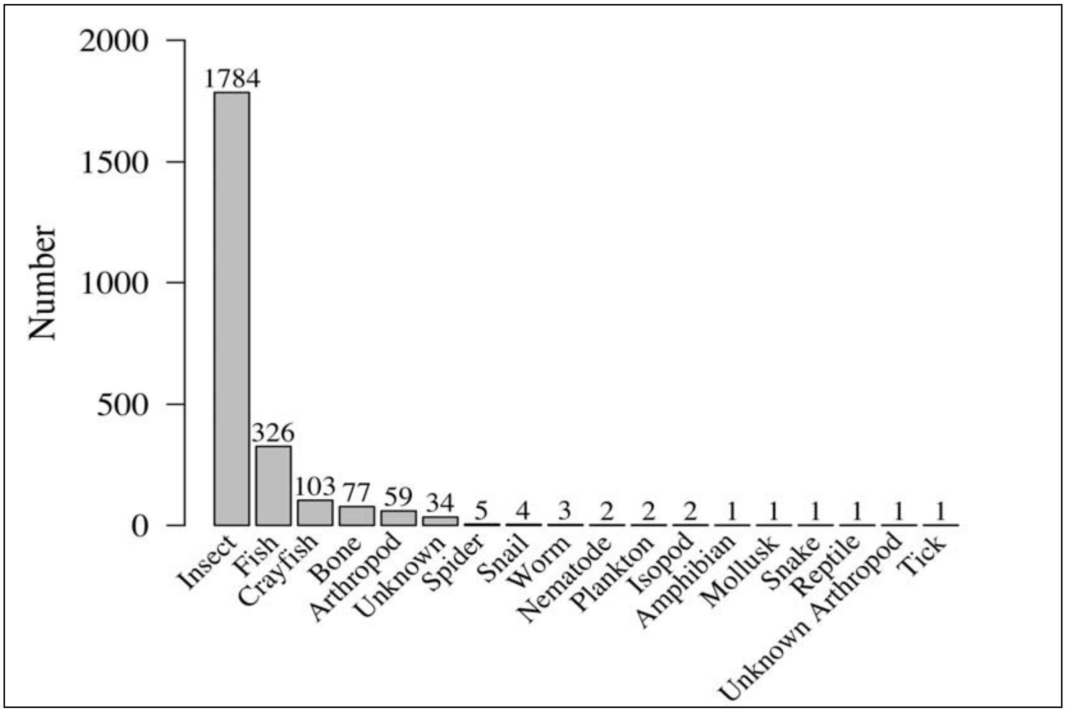

Figure 5.3-1. Number of identifiable prey items observed in stomach samples (n = 246) collected in the lower Tuolumne River. Invertebrates (insects and crayfish) and fish (various species) made up the majority of identifiable prey items.

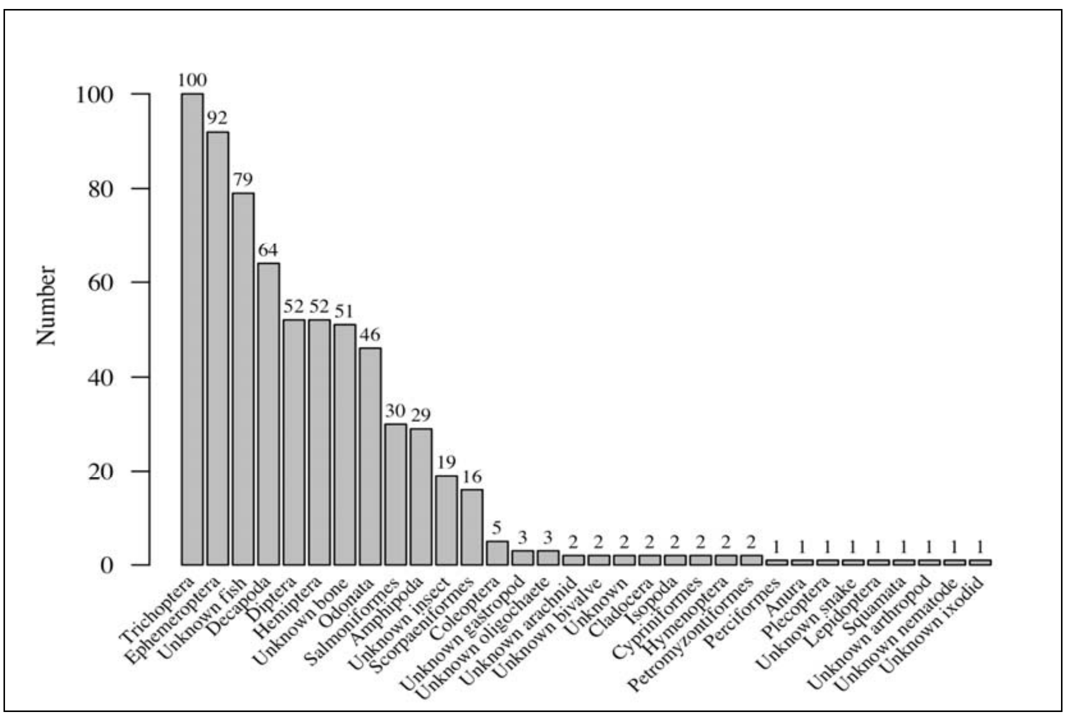

Figure 5.3-2. Number of stomach samples (n = 246) that contained at least one of each type of prey item collected on the lower Tuolumne River.

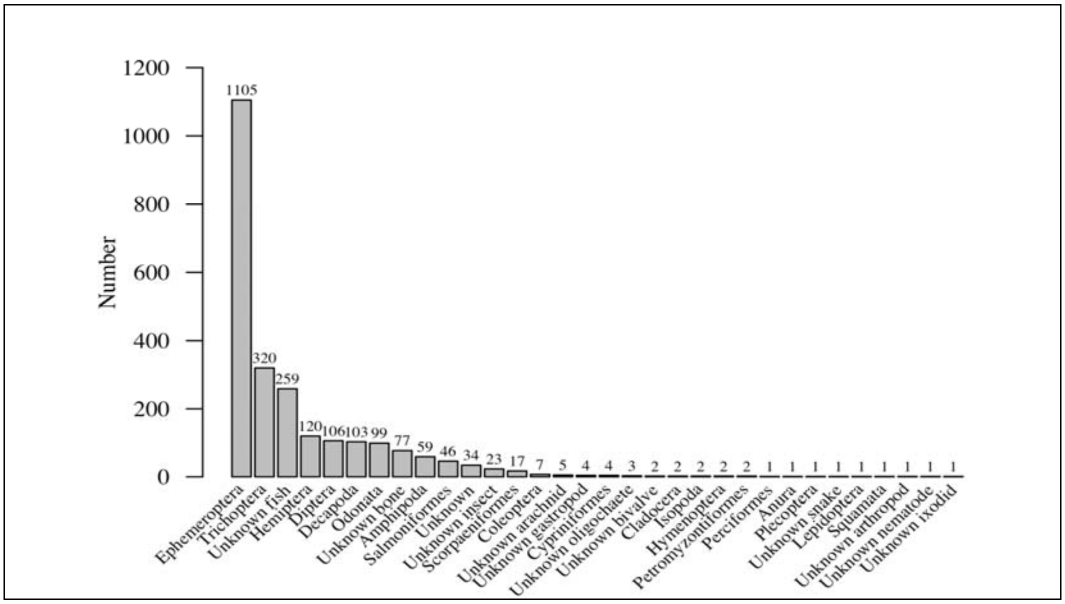

Figure 5.3-3. Number of prey items (by order) observed in stomach samples (n = 246) collected in the lower Tuolumne River.

5.3.2 Predation of juvenile Chinook salmon

Of the 246 stomach samples examined, 30 contained juvenile Chinook salmon, with eight of these samples from smallmouth bass, 11 from largemouth bass, and 11 from striped bass. No juvenile Chinook salmon were observed in the stomach contents of Sacramento pikeminnow. Smallmouth bass that consumed juvenile Chinook salmon were at least 185 mm FL, largemouth bass were at least 207 mm FL, and striped bass were at least 180 mm FL (Figure 5.3-4).

During the March sampling event, standard lengths (SL) (measured from snout to hypural plate) of 13 intact juvenile Chinook salmon found in the stomach contents of sampled predators were measured. The mean SL was 51.6 mm (sd = 11.0). The smallest observed juvenile Chinook salmon during the March sampling event was 30 mm SL and the largest was 68 mm SL.

Standard lengths of 14 intact juvenile Chinook salmon were measured from specimens observed in stomach samples collected during the May sampling event. The mean standard length was 71.4 mm (sd = 5.3), about 20 mm larger on average than mean SL observed in the March sampling event. The smallest observed juvenile Chinook salmon during the May sampling event was 62 mm SL and the largest was 78 mm SL.

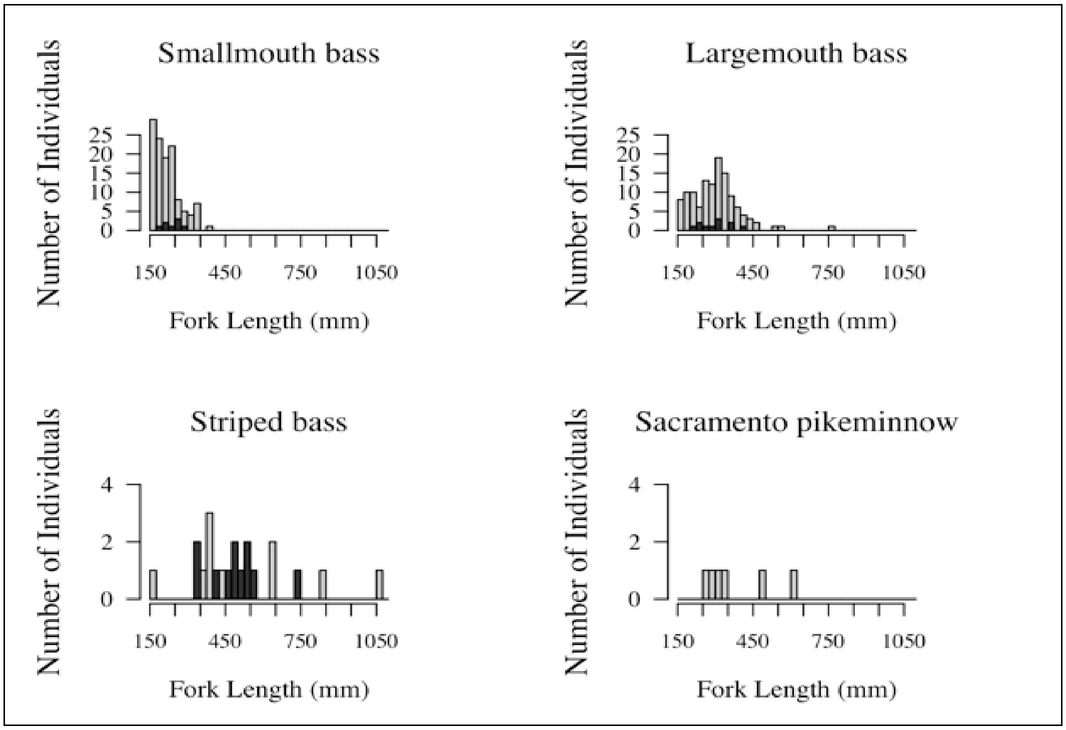

Figure 5.3-4. Lengths of captured smallmouth bass, largemouth bass, striped bass, and Sacramento pikeminnow that consumed juvenile Chinook salmon (dark bars) and those that did not (light bars).

5.3.3 Differences between sampling events and habitat types

With one exception, no significant differences in frequencies of predators consuming at least one juvenile Chinook salmon were found. All frequencies used for these tests can be derived from Table 5.3-2 by dividing the number of predators with salmon by the number of predators sampled. When frequencies were calculated using all predators sampled during March, the proportion that consumed at least one juvenile Chinook salmon was significantly higher in special run-pools than in run-pools (p-value = 0.0176). During the first sampling event in SRPs, 15 predators examined contained salmon out of 114 total (0.132) while only 1 of 66 (0.015) predators captured in RPs contained at least one salmon (Test 1; Figure 5.3-5). A similar test conducted for sampling during May showed that there was no significant difference between the two habitat types (Test 2; Figure 5.3-5; p-value = 1.000).

No significant differences were found for tests between the pooled frequencies (all predators from sampling during March, 16/180 or 0.089) compared to the pooled frequencies from sampling during May (14/115 or 0.122; p-value = 0.4759) (Test 3; Figure 5.3-5). Additionally, no significant difference was found between frequencies from habitat types (both events pooled; p-value = 0.093), though the predation frequency in special run-pools was 0.130 (22/169) compared to 0.063 (8/126) in run-pools (Test 4; Figure 5.3-5).

No statistically significant differences were found when comparing predation frequencies for smallmouth bass, largemouth bass, or striped bass between sampling events or between habitat types. However, no comparisons could be made for striped bass during March, since no striped bass were captured in run-pool habitats during that sampling period. No species-specific tests were conducted for Sacramento pikeminnow since only six Sacramento pikeminnow > 150 mm FL were captured during March and May.

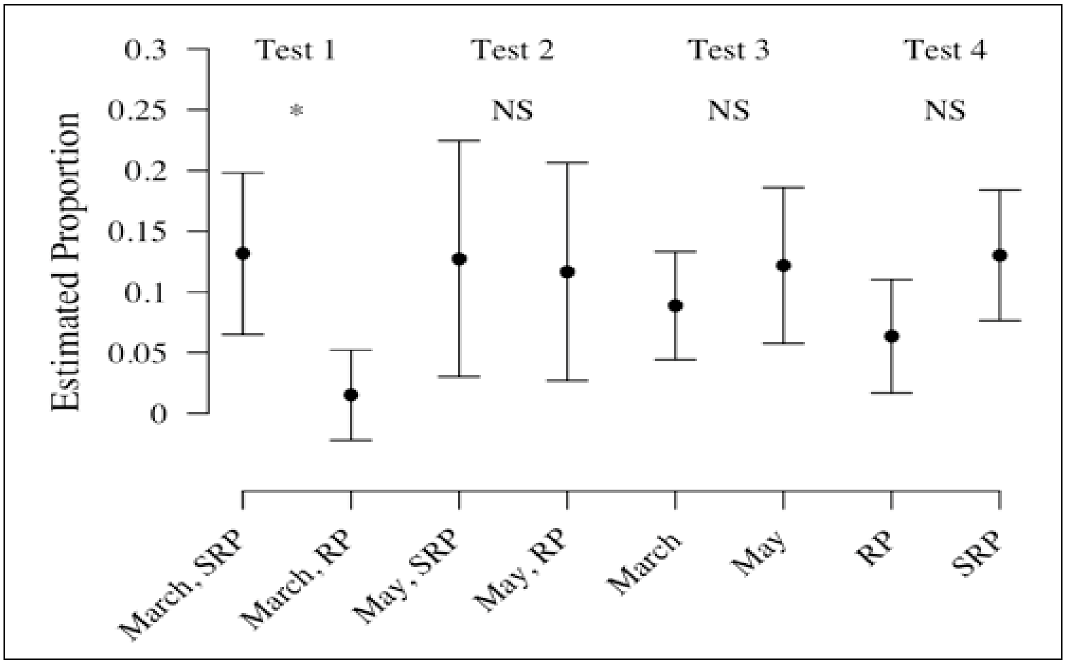

Figure 5.3-5. Comparison of estimated predation frequency and 95 percent confidence intervals by habitat type and event. Statistically significant difference denoted by "*"and "NS" indicates no significant difference.

5.3.4 Water temperatures

Water temperatures during the 18 hours prior to the time of capture of each predator ranged from 13°C to 16°C during March and from 14°C to 17°C during May depending upon location of capture.

5.3.5 Predation rates on juvenile Chinook salmon

Predation ratios and predation rates are summarized in Table 5.3-2. During the first sampling event, 180 predators > 150 mm FL were captured. Twenty-two juvenile Chinook salmon were detected upon examination of the 180 stomach samples collected (total includes empty stomachs). No predation ratios could be calculated for striped bass or Sacramento pikeminnow in run-pool habitats since neither of those species were captured in this habitat type during the first sampling event. Predation ratios, or the mean consumption of juvenile Chinook per predator, ranged from 0.0 to 1.2 salmon consumed per predator. For sampling conducted in March, and using the slow gastric evacuation rate of 20 hours, predation rates ranged from 0.00 to 1.44 juvenile Chinook consumed per predator per day (Table 5.3-2). If the faster gastric evacuation rate of 16 hours is used, predation rates range from 0.00 to 1.80. Striped bass predation rates were the highest (1.44–1.80) in SRP habitats during the first sampling event. Predation rates were similar between smallmouth bass and largemouth bass in SRP habitats. No salmon were consumed by the 4 Sacramento pikeminnow captured.

During the second sampling event, 115 predators > 150 mm FL were captured. Twenty-three juvenile Chinook salmon were detected upon examination of the 115 stomach samples collected (total includes empty stomachs). Predation ratios ranged from 0.0 to 1.0 salmon consumed per predator. For sampling conducted in May, and using the slow gastric evacuation rate of 20 hours, predation rates ranged from 0.00 to 1.20 juvenile Chinook consumed per predator per day (Table 5.3-2). With the faster gastric evacuation rate of 16 hours, predation rates ranged from 0.00 to 1.50 juvenile Chinook consumed per predator per day. Similar to March, predation rates during May were highest for striped bass in comparison to the other predator species examined. No salmon were consumed by the two Sacramento pikeminnow captured.

Table 5.3-2. Summary of largemouth bass (LMB), smallmouth bass (SMB), striped bass (STB), and Sacramento pikeminnow (SASQ) predation of juvenile Chinook salmon in the lower Tuolumne River during March and May 2012.

	Habitat Type	Species	Number With Salmon	Number Without Salmon	Largest Number Salmon In One Predator	Total Number Salmon	Predation Ratio	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Low Predation Rate	High Predation Rate
MARCH	SRP	SMB	3	26	1	3	0.10	0.00	0.73	0.12	0.16
		LMB	6	65	2	6	0.08	0.00	0.65	0.10	0.13
		STB	6	4	5	12	1.20	0.00	3.35	1.44	1.80
		SASQ	0	4	0	0	0.00	0.00	0.00	0.00	0.00
	RP	SMB	0	47	0	0	0.00	0.00	0.00	0.00	0.00
		LMB	1	18	1	1	0.05	0.00	0.50	0.06	0.08
		STB	0	0	--	--	--	--	--	--	--
		SASQ	0	0	--	--	--	--	--	--	--
MAY	SRP	SMB	2	18	2	3	0.15	0.00	0.91	0.18	0.23
		LMB	4	28	2	5	0.16	0.00	0.93	0.19	0.23
		STB	1	1	2	2	1.00	0.00	2.96	1.20	1.50
		SASQ	0	1	0	0	0.00	0.00	0.00	0.00	0.00
	RP	SMB	3	33	2	5	0.14	0.00	0.87	0.17	0.21
		LMB	0	9	0	0	0.00	0.00	0.00	0.00	0.00
		STB	4	10	4	8	0.57	0.00	2.05	0.69	0.86
		SASQ	0	1	0	0	0.00	0.00	0.00	0.00	0.00

5.4 Predator Movement Tracking

5.4.1 Predator Tagging

Total hook and line sampling effort was 112 hours at SRP 10 and SRP 6, with the time split equally between the two sites. Hook and line sampling resulted in 17 predators of suitable size captured, and 15 of these successfully tagged. Additionally, predators were captured by electrofishing and opportunistically tagged during spring predation rate sampling. Electrofishing occurred in the area of the four acoustic monitoring sites on six nights, providing 60 captured predators of which 57 were tagged.

A total of 72 predators >150 mm were acoustic tagged consisting of: 36 largemouth bass, 16 smallmouth bass, 19 striped bass, and 1 Sacramento pikeminnow. The fork length of tagged largemouth bass ranged from 250–572 mm (avg. 340 mm), and weight 200–2,468 g (avg. 677 g); smallmouth bass ranged from 168–345 mm (avg. 240 mm), and weight 56–739 g (avg. 264 g); striped bass ranged from 260–1,070 mm (avg. 556 mm), and weight 567–15,141 g (avg. 3,040 g); and the single Sacramento pikeminnow captured was 508 mm and weighed 907 g. The tag weights of the HTI G-type tags used for predator tagging ranged from 4.20–4.48 g, for a tag-body weight ratio ranging from 0.0003–0.0755 (Table 5.4-1).

Twenty-eight tagged predators were released into SRP 6; consisting of 18 largemouth bass, 2 smallmouth bass, 7 striped bass, and 1 Sacramento pikeminnow. Two additional predators (one largemouth bass and one smallmouth bass) were released directly downstream in Riffle 62. Twenty-nine predators were tagged at SRP 10; consisting of 15 largemouth bass, 5 smallmouth bass, and 9striped bass. The remaining 13 tagged predators were released near Riffle 74; consisting of two largemouth bass, eight smallmouth bass, and three striped bass.

Table 5.4-1. Summary of predator species acoustically tagged.

Tag Period	Sub Code	Tag wt (g)	Species[1]	Fork length (mm)	Fish wt (g)	Release Date	Location	Floy Tag #
2028	8	4.32	SMB	325	680.4	26-Apr	SRP 10	52
2049	8	4.27	LMB	295	453.6	26-Apr	SRP 10	53
2070	8	4.27	LMB	310	68.4	26-Apr	SRP 10	54
2091	8	4.38	LMB	290	367.4	1-May	SRP 6	39
2112	8	4.28	LMB	410	1360.8	1-May	SRP 6	40
2133	8	4.32	SMB	275	367.4	1-May	SRP 6	41
2154	8	4.35	STB	665	3460.9	26-Apr	SRP 6	26
2175	8	4.29	STB	260	1247.4	26-Apr	SRP 6	27
2196	8	4.26	LMB	375	626.0	27-Apr	SRP 6	28
2217	8	4.32	LMB	334	567.0	27-Apr	SRP 6	31
2238	8	4.33	LMB	250	199.6	28-Apr	SRP 10	55
2259	8	4.35	LMB	325	567.0	28-Apr	SRP 10	56
2280	8	4.42	LMB	340	480.8	1-May	SRP 6	38
2301	8	4.35	LMB	360	680.4	29-Apr	SRP 10	32
2322	8	4.38	LMB	335	--	1-May	SRP 10	58
2343	8	4.35	LMB	305	426.4	5-May	R74	63
2364	8	4.26	SMB	230	186.0	5-May	R74	64
2385	8	4.4	LMB	572	1732.7	5-May	R74	66
2406	8	4.24	SMB	228	170.1	5-May	R74	67

Tag Period	Sub Code	Tag wt (g)	Species[1]	Fork length (mm)	Fish wt (g)	Release Date	Location	Floy Tag #
2427	8	4.28	SMB	168	56.7	5-May	R74	68
2448	8	4.33	LMB	315	538.6	1-May	SRP 6	42
2469	8	4.4	SMB	265	283.5	4-May	SRP 10	59
2490	8	4.31	SMB	345	739.4	1-May	SRP 6	45
2511	8	4.32	STB	350	567.0	1-May	SRP 6	47
2532	8	4.31	STB	385	766.6	1-May	SRP 6	48
2553	8	4.48	LMB	250	226.8	4-May	R62	60
2574	8	4.35	SMB	260	313.0	4-May	R62	62
2595	8	4.32	LMB	340	623.7	1-May	SRP 6	34
2616	8	4.28	LMB	325	567.0	1-May	SRP 6	35
2637	8	4.3	LMB	305	567.0	1-May	SRP 6	36
2658	8	4.43	LMB	310	510.3	1-May	SRP 6	33
2679	8	4.32	SMB	183	140.6	5-May	R74	69
2700	8	4.2	SMB	169	56.7	5-May	R74	71
2721	8	4.31	STB	389	680.4	5-May	SRP 10	72
2805	8	4.35	SMB	225	204.1	7-May	SRP 10	83
2826	8	4.36	STB	1070	15140.9	5-May	SRP 10	78
2847	8	4.35	STB	750	4735.5	5-May	SRP 10	75
2868	8	4.43	STB	445	1192.9	5-May	SRP 10	80
2889	8	4.41	SMB	195	85.0	5-May	R74	74
2910	8	4.36	STB	645	3855.5	5-May	SRP 10	79
2931	8	4.36	LMB	267	412.8	7-May	SRP 10	85
2952	8	4.32	SMB	220	255.1	5-May	R74	77
2973	8	4.3	LMB	262	299.4	7-May	SRP 10	86
2994	8	4.42	LMB	272	317.5	7-May	SRP 10	87
3015	8	4.33	STB	572	2494.8	8-May	SRP 6	90
3036	8	4.41	STB	332	1728.2	8-May	SRP 6	89
3057	8	4.3	STB	490	1501.4	8-May	SRP 6	88
3078	8	4.32	LMB	302	426.4	8-May	SRP 6	91
3099	8	4.34	LMB	310	399.2	8-May	SRP 6	92
3120	8	4.32	LMB	394	880.0	8-May	SRP 6	93
3141	8	4.35	LMB	310	480.8	8-May	SRP 6	94
3162	8	4.41	LMB	540	2467.5	8-May	SRP 6	95
3183	8	4.32	LMB	318	426.4	8-May	SRP 6	96
3204	8	4.38	LMB	352	739.4	8-May	SRP 6	97
3225	8	4.31	LMB	257	226.8	8-May	SRP 6	102
3246	8	4.3	LMB	321	453.6	8-May	SRP 10	103
3267	8	4.31	LMB	440	1388.0	8-May	SRP 10	106
3288	8	4.3	LMB	409	1192.9	8-May	SRP 10	107
3309	8	4.35	SMB	255	255.1	8-May	SRP 10	108
3330	8	4.38	LMB	356	707.6	8-May	SRP 10	109
3351	8	4.36	SMB	245	254.0	8-May	SRP 10	110
3372	8	4.36	LMB	367	821.0	8-May	SRP 10	111
3414	8	4.32	SMB	245	170.1	9-May	R74	113
3435	8	4.3	STB	650	3515.3	9-May	R74	114
3456	8	4.33	STB	410	793.8	9-May	R74	115
3477	8	4.32	STB	850	7257.5	9-May	R74	116
3498	8	4.26	LMB	395	880.0	9-May	SRP 10	117
3519	8	4.38	STB	535	1900.6	9-May	SRP 10	118
3540	8	4.37	STB	730	4449.7	9-May	SRP 10	119
3561	8	4.35	STB	615	1701.0	16-May	SRP 10	120

Tag Period	Sub Code	Tag wt (g)	Species[1]	Fork length (mm)	Fish wt (g)	Release Date	Location	Floy Tag #
3582	8	4.33	SASQ	508	907.2	16-May	SRP 6	121
3603	8		STB	419	766.6	16-May	SRP 10	122

[1] SMB= smallmouth bass, LMB= largemouth bass, STB= striped bass, SASQ= Sacramento pikeminnow

5.4.2 Detections of Acoustic Tagged Fish

Fate determinations for fish detection in the arrays at SRP 6 and SRP 10 are summarized in Table 5.4-2. Of the 75 acoustic tagged Chinook salmon released at Hickman Bridge (RM 31.6) on May 9–10 at a flow level of 2,100 cfs, 69 were detected in SRP 6 (RM 30.3). Sixty-three (91.3 percent) of these successfully passed through SRP 6, two (2.9 percent) were likely consumed by predators, and the fates of four tags (5.8 percent) were classified as unknown (Table 5.4-2). Travel time from the release site of Chinook that successfully passed through SRP 6 ranged from 0.4 to 9.5 hours (median= 0.5 hours), and duration of detection within SRP 6 ranged from 0.6 to 87.4 minutes (median= 3.7 minutes). The total area covered by tagged Chinook that successfully passed was 4,546 m^2. The overlap of the 90th percentile of acoustic tracks between tagged Chinook and predator species was 8.0 percent for largemouth bass and 27.4 percent for striped bass (Figure 5.4-1, Table 5.4-3).

Table 5.4-2. Summary of fate determinations for acoustic tagged Chinook salmon in SRP 6 and SRP 10, and river flow at La Grange, and water temperature at Roberts Ferry.

	Release Group		
	1	2	3
Release Dates	May 9-10	May 16-17	May 21-22
Target Flow at La Grange (cfs)	2,100	280	415
Water Temperature at Roberts Ferry (°C)	12.6 (range: 11.0-14.3)	16.3 (range: 14.6-18.7)	16.7 (range: 13.8-17.1)
Total #Released	75	74	73
	--	--	--
SRP 6	--	--	--
Detected	69	55	63
Passed	91.3 % (n=63)	54.5% (n=30)	31.7% (n=20)
Consumed	2.9% (n=2)	30.9% (n=17)	60.3% (n=38)
Unknown	5.8% (n=4)	14.5% (n=8)	7.9% (n=5)
	--	--	--
SRP 10	--	--	--
Detected	57	22	7
Passed	75.4% (n=43)	50.0% (n=11)	28.6% (n=2)
Consumed	15.8% (n=9)	31.8% (n=7)	71.4% (n=5)
Unknown	8.8% (n=5)	18.2% (n=4)	0.0% (n=0)

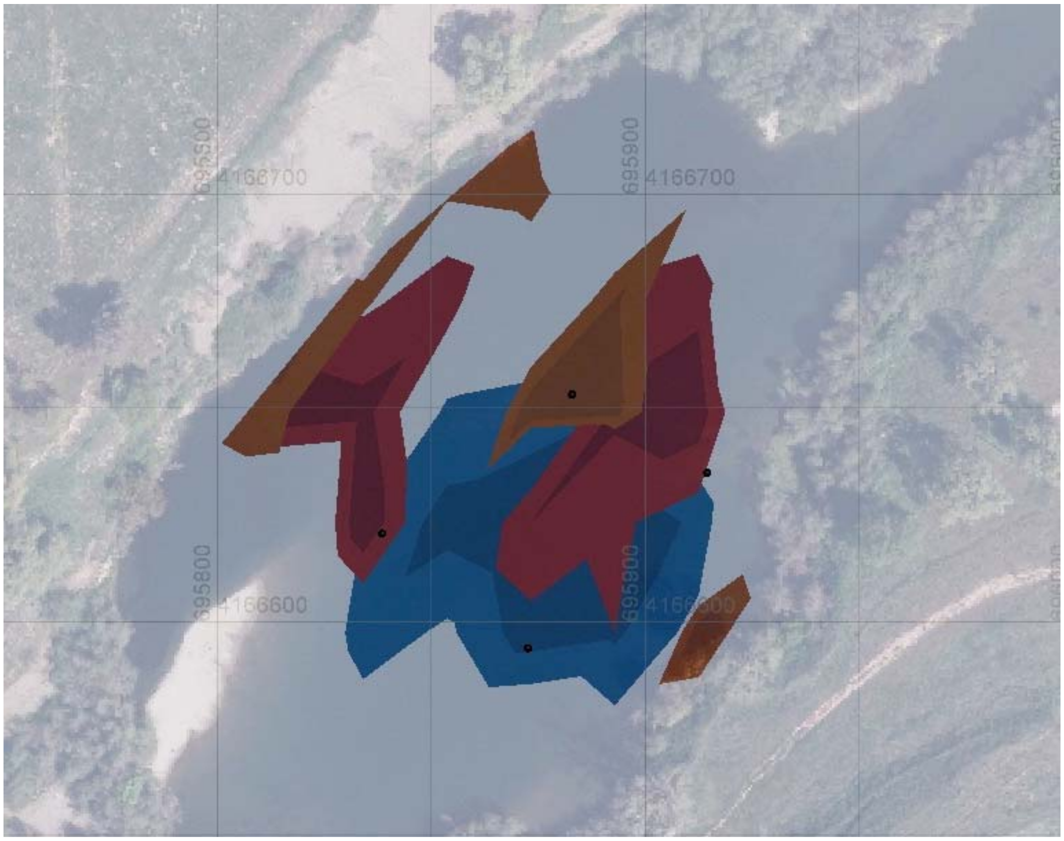

Figure 5.4-1. Densities of acoustic tagged Chinook salmon and predators in SRP 6 at 2,100 cfs (Chinook salmon: blue, largemouth bass: orange, and striped bass: red). Darker shaded areas represent 90th percentile, and lighter shading represents 95th percentile densities. Note: where polygons overlap, not all species present may be visible.

In SRP 10 (RM 25.4), 57 Chinook salmon tags were detected at 2,100 cfs. Forty-three (75.4 percent) tagged salmon were classified as successful passages, nine (15.8 percent) were likely consumed by predators, and five (8.8 percent) were unknown. The travel time from SRP 6 to SRP 10 of Chinook that successfully passed through SRP 10 ranged from 3.1 to 21.6 hours (median= 6.2 hours), and duration of detection within SRP 10 ranged from 0.8 to 67.8 minutes (median= 5.0 minutes). The total area covered by tagged Chinook that successfully passed was 7,569 m^2. The overlap of the 90th percentile of acoustic tracks between tagged Chinook and predator species was 6.4 percent for largemouth bass, 33.2 percent for smallmouth bass, and 19.9 percent for striped bass (Figure 5.4-2, Table 5.4-3).

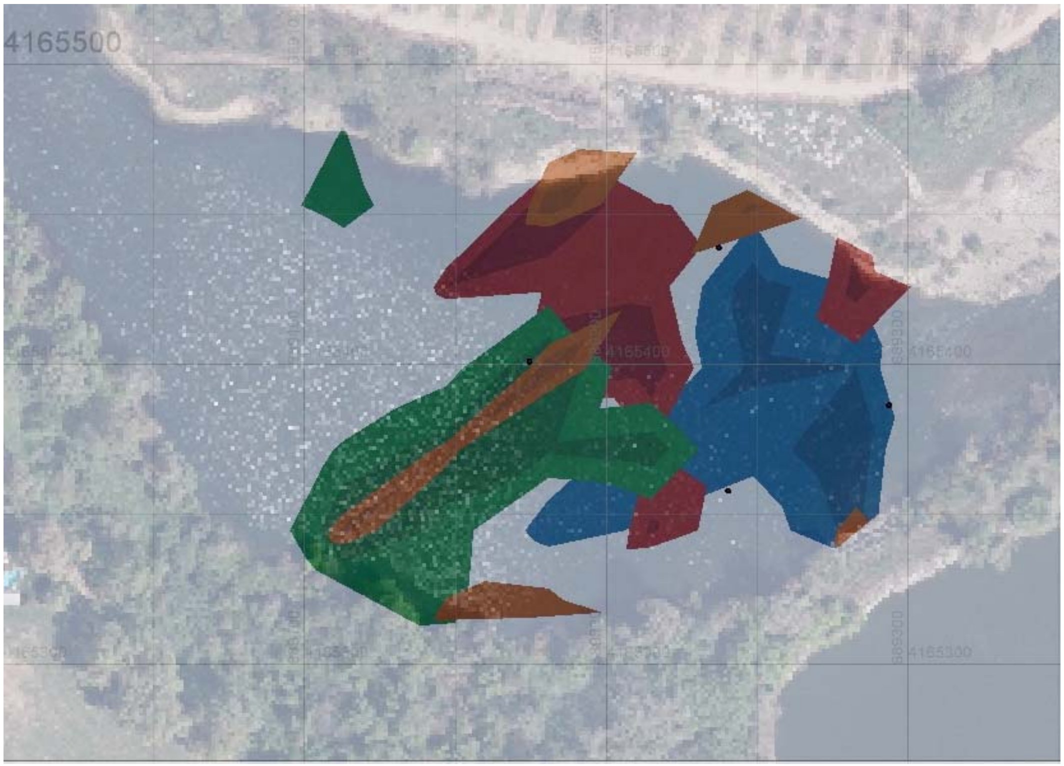

Figure 5.4-2. Densities of acoustic tagged Chinook salmon and predators in SRP 10 at 2,100 cfs (Chinook salmon: blue, largemouth bass: orange, smallmouth bass: green, and striped bass: red). Darker shaded areas represent 90th percentile, and lighter shading represents 95th percentile densities. Note: where polygons overlap, not all species present may be visible.

Of the 74 acoustic tagged Chinook salmon released at Hickman Bridge on May 16-17 at a flow level of 280 cfs, 55 were detected in SRP 6. Thirty (54.5 percent) of these successfully passed through SRP 6, seventeen (30.9 percent) were classified as likely consumed by predators, and eight (14.5 percent) were unknowns. The travel time from the release site of Chinook that successfully passed through SRP 6 ranged from 2.3 to 34.2 hours (median= 6.0 hours), and duration of detection within SRP 6 ranged from 1.0 to 25.1 minutes (median- 4.3 minutes). The total area covered by tagged Chinook that successfully passed was 2,839 m^2. The overlap of the 90th percentile of acoustic tracks between tagged Chinook and predator species was 6.9 percent for largemouth bass, 1.8 percent for smallmouth bass. 18.4 percent for striped bass, and 42.4 percent for Sacramento pikeminnow (Figure 5.4-3, Table 5.4-3).

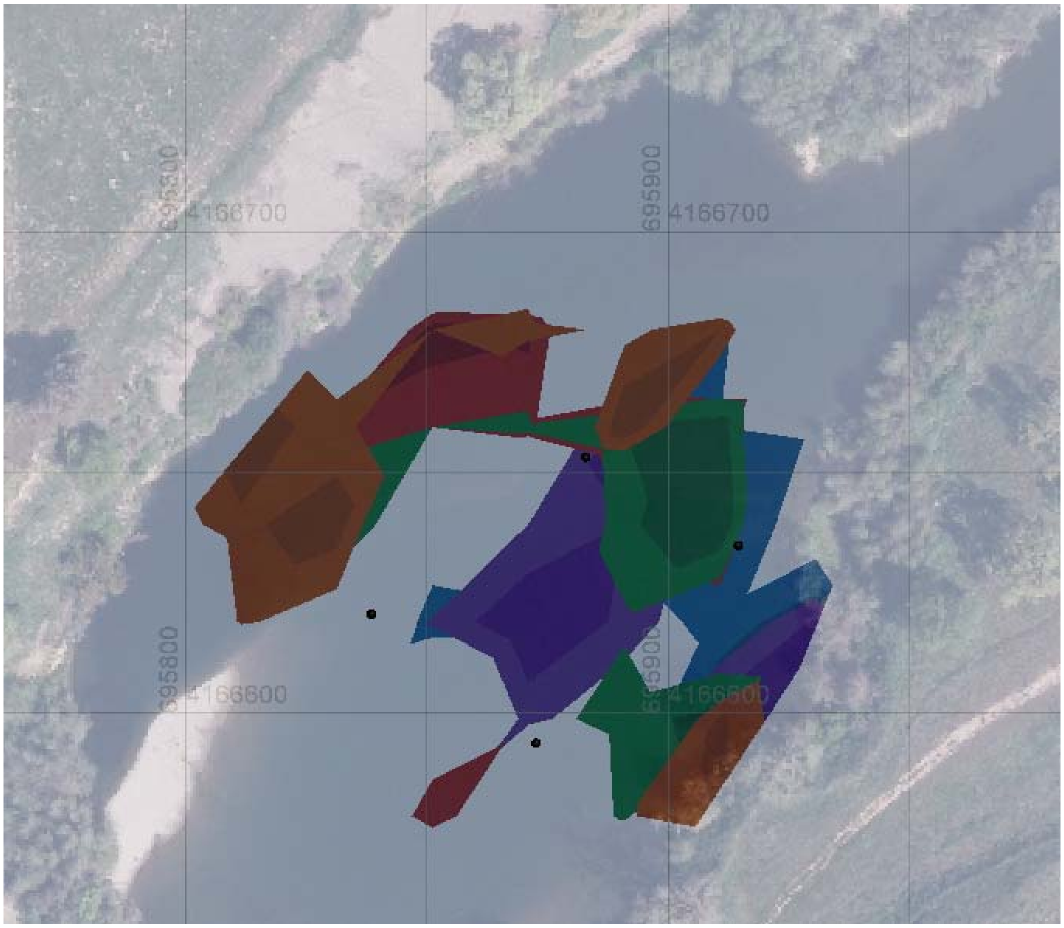

Figure 5.4-3. SRP 6 Low flow densities of tagged Chinook and predators (Chinook salmon: blue, largemouth bass: orange, smallmouth bass: green, striped bass: red, and Sacramento pikeminnow: purple). Darker shaded areas represent 90th percentile, and lighter shading represents 95th percentile densities. Note: where polygons overlap, not all species present may be visible.

In SRP 10, 22 of the Chinook salmon tags were detected at 280 cfs with 11 (50.0 percent) classified as passages, 7 (31.8 percent) as likely consumed by predators, and 4 (18.2 percent) as unknown. The travel time from SRP 6 of Chinook that successfully passed through SRP 10 ranged from 4.0 to 31.2 hours (median= 5.0 hours), and duration of detection within SRP 10 ranged from 3.3 to 12.7 minutes (median= 6.9 minutes). The total area covered by tagged Chinook that successfully passed was 7,958 m^2. The overlap of the 90th percentile of acoustic tracks between tagged Chinook and predator species was 30.5 percent for largemouth bass, 35.6 percent for smallmouth bass, 33.4 percent for striped bass, and 53.6 percent for Sacramento pikeminnow (Figure 5.4-4, Table 5.4-3).

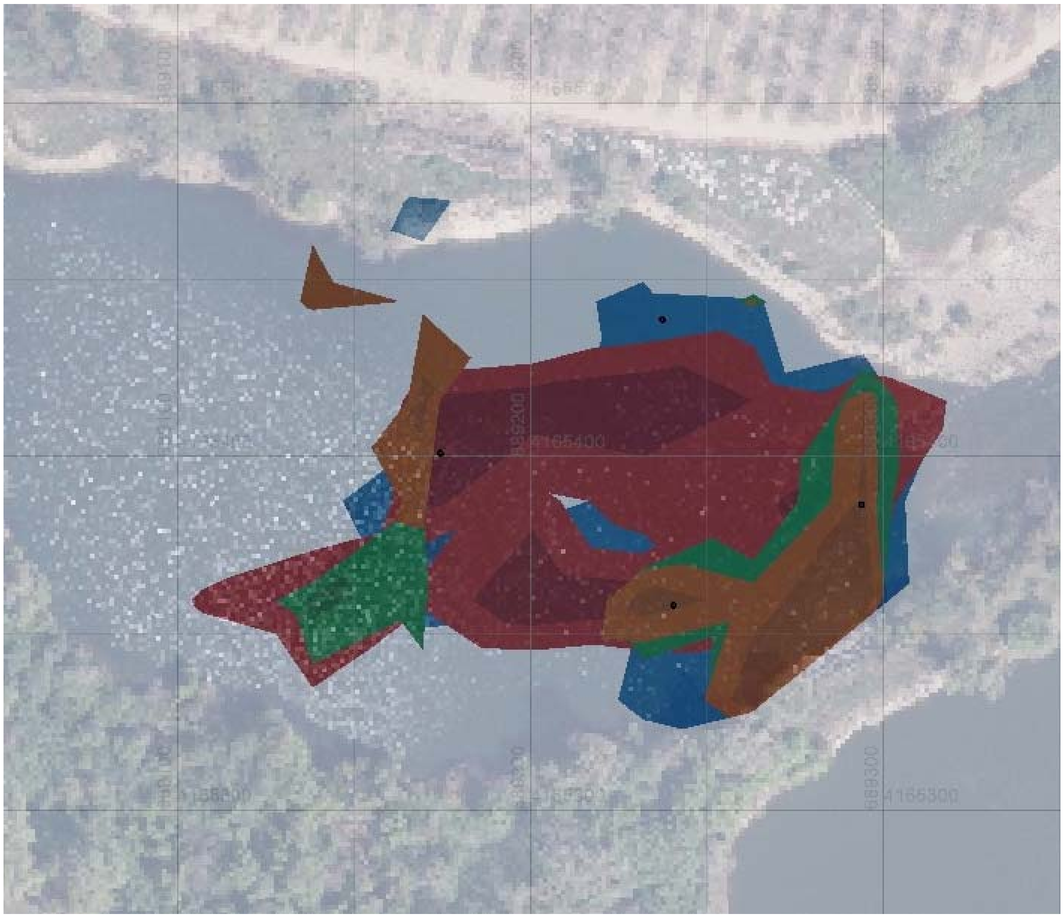

Figure 5.4-4. SRP 10 Low flow densities of tagged Chinook and predators (Chinook salmon: blue, largemouth bass: orange, smallmouth bass: green, and striped bass: red). Darker shaded areas represent 90th percentile, and lighter shading represents 95th percentile densities. Note: where polygons overlap, not all species present may be visible.

Of 73 acoustic tagged Chinook salmon released on May 21–22, 2012 at 415 cfs, 63 Chinook were detected in SRP 6. Twenty (31.7 percent) were classified as successful passages 38 (60.3 percent) were classified as likely consumed by predators and 5 (7.9 percent) were unknowns. The travel time from the release site of fish that successfully passed through SRP 6 ranged from 2.3 to 12.0 hours (median- 6.9 hours) and duration of detection within SRP 6 ranged from 0.4 to 42.7 minutes (median= 6.5 minutes). The total area covered by tagged Chinook that successfully passed was 4,037 m^2. The overlap of the 90th percentile of acoustic tracks between tagged Chinook and predator species was 16.6 percent for largemouth bass, 38.2 percent for smallmouth bass, and 39.1 percent for striped bass (Figure 5.4-5, Table 5.4-3).

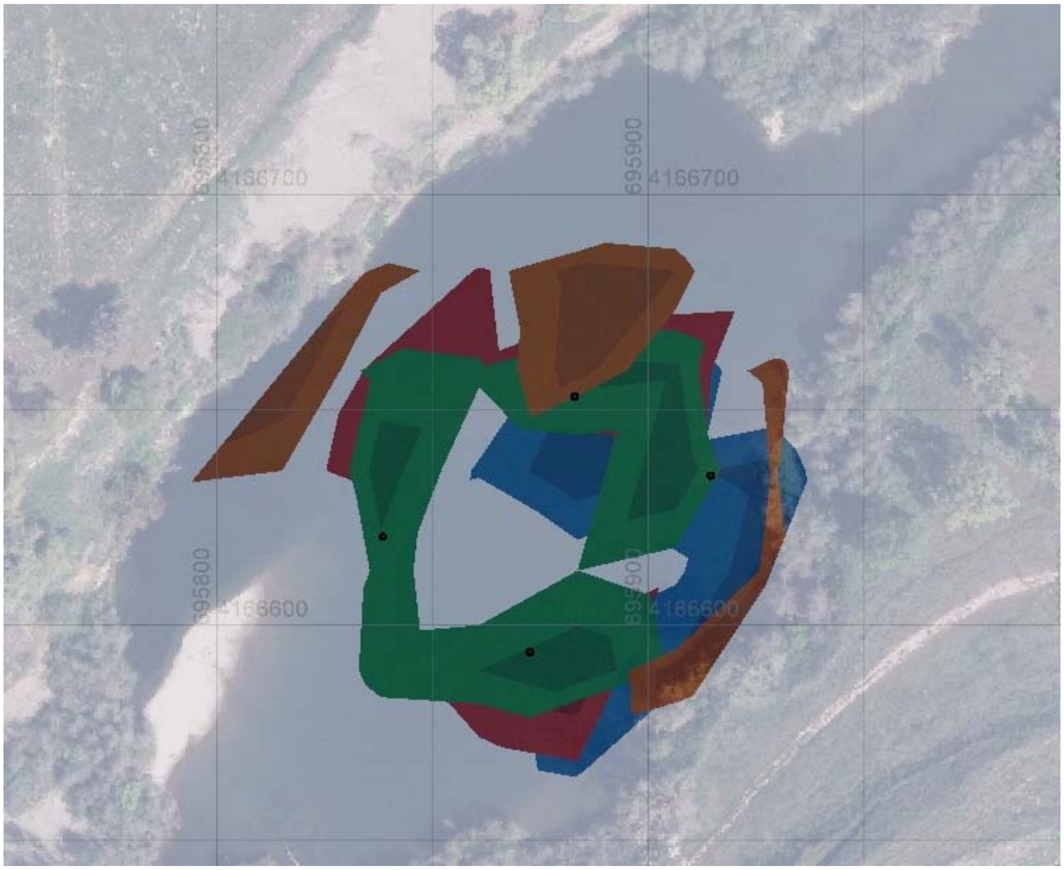

Figure 5.4-5. SRP 6 Mid flow densities of tagged Chinook and predators (Chinook salmon: blue, largemouth bass: orange, smallmouth bass: green, and striped bass: red). Darker shaded areas represent 90th percentile, and lighter shading represents 95th percentile densities. Note: where polygons overlap, not all species present may be visible.

In SRP 10 during the middle flow monitoring event, only seven tags entered the array; with five (71.4 percent) classified as likely consumed by predators and two (28.6 percent) successful passages. Travel time from SRP 6 to SRP 10 of Chinook that successfully passed through SRP 10 ranged from 14.1 to 69.9 hours, and duration of detection within SRP 10 ranged from 4.5 to 9.3 minutes. The total area covered by tagged Chinook that successfully passed was 5,847 m^2. The overlap between acoustically tagged Chinook and predator species was 5.8 percent for largemouth bass, 0.2 percent for smallmouth bass, and 46.3 percent for striped bass (Figure 5.4-6, Table 5.4-3).

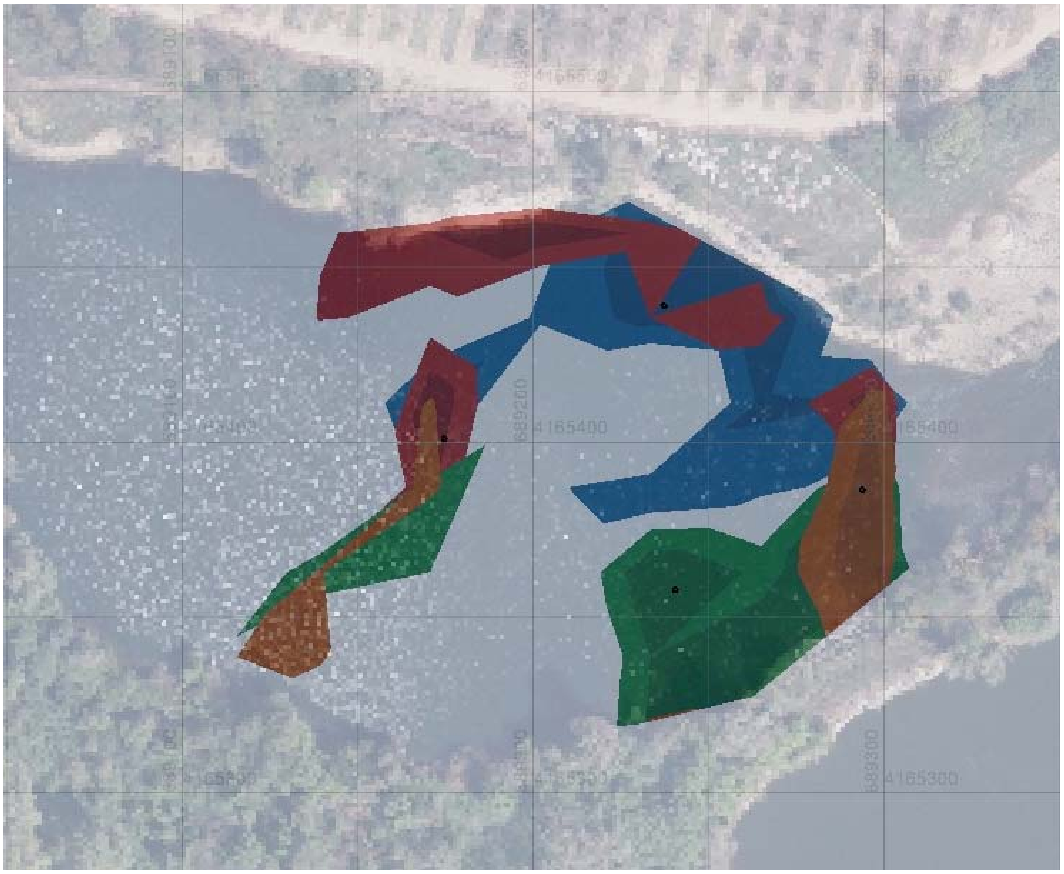

Figure 5.4-6. SRP 10 Mid flow densities of tagged Chinook and predators (Chinook salmon: blue, largemouth bass: orange, smallmouth bass: green, and striped bass: red). Darker shaded areas represent 90th percentile, and lighter shading represents 95th percentile densities. Note: where polygons overlap, not all species present may be visible.

Table 5.4-3. Summary of overlap in habitat use at the 90th percentile between acoustic tagged Chinook salmon and predators in SRP 6 and SRP 10.

Site	Release Group	Flow (cfs)	Chinook Passed	Chinook Area (m^2)	Percent Overlap			
					LMB	SMB	STB	SASQ
SRP 6	1	2,100	63	4,546	8.0	---	27.4	---
	2	280	31	2,839	6.9	1.8	18.4	42.4
	3	415	26	4,037	16.6	38.2	39.1	---
SRP 10	1	2,100	43	7,569	6.4	33.2	19.9	---
	2	280	11	7,958	30.5	35.6	33.4	53.6
	3	415	2	5,847	5.8	0.2	46.3	---

5.4.2.1 Transit Times of Acoustic Tagged Chinook Salmon

Transit times of acoustic tagged Chinook salmon from the release site to SRP 6 at 2,100 cfs were significantly less than transit times at 280 cfs (Wilcoxon rank sum test, p-value = < 0.00001) and 415 cfs (p-value = < 0.00001). The difference between the median transit times of Chinook salmon at 2,100 cfs and at 280 cfs was 4.3 hours. The difference between the median transit times of Chinook salmon at 2,100 cfs and at 415 cfs was 6.2 hours. No significant differences in median transit times of Chinook salmon were found between flows of 280 cfs and 415 cfs (p-value = 0.883) (Figure 5.4-7).

No significant differences in median transit times between SRP 6 and SRP 10 were found between 2,100 cfs and 280 cfs (Wilcoxon rank sum test, p-value = 0.3588) (Figure 5.4-8). The sample size of fish arriving at SRP 10 at 415 cfs was too small (n=2) for comparison.

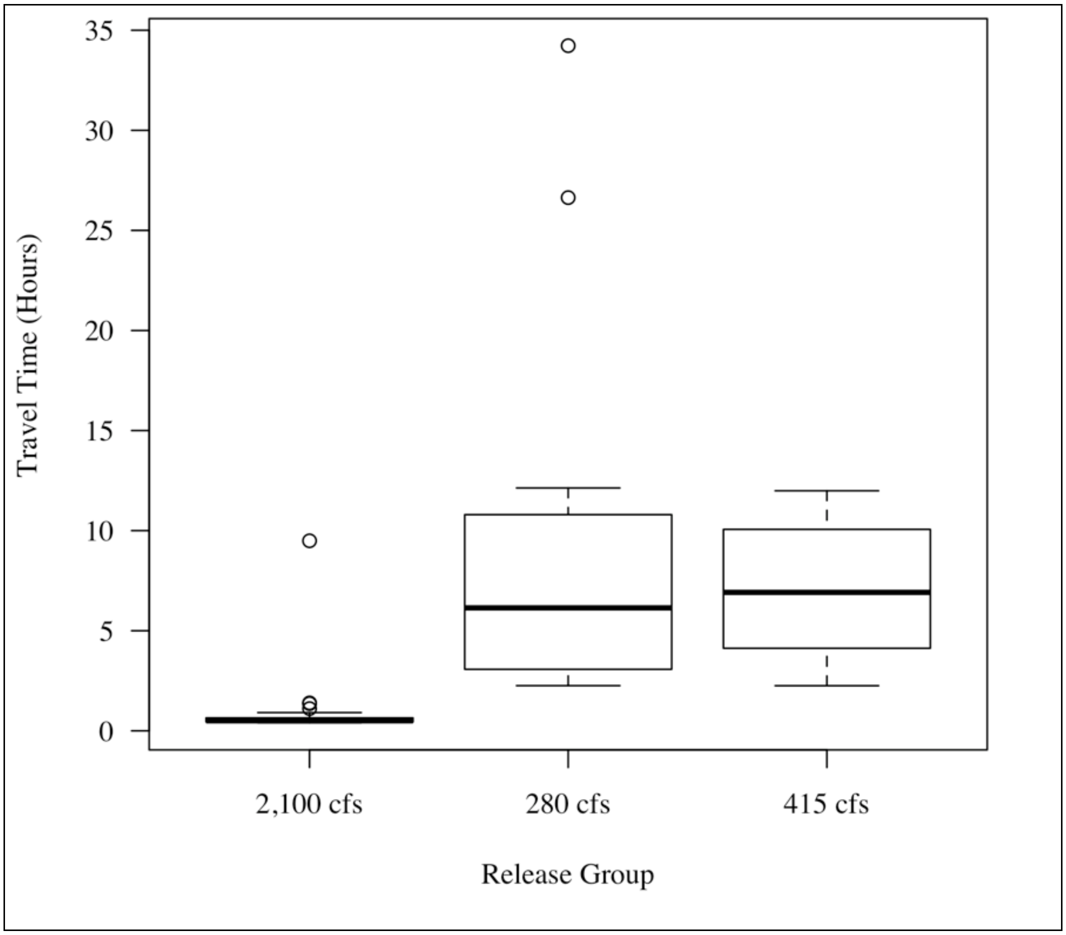

Figure 5.4-7. Transit times from Hickman Bridge to SRP 6 of acoustic tagged juvenile Chinook salmon (n = 109 total; n = 59 at 2,100 cfs; n = 30 at 280 cfs; and, n = 20 at 415 cfs).

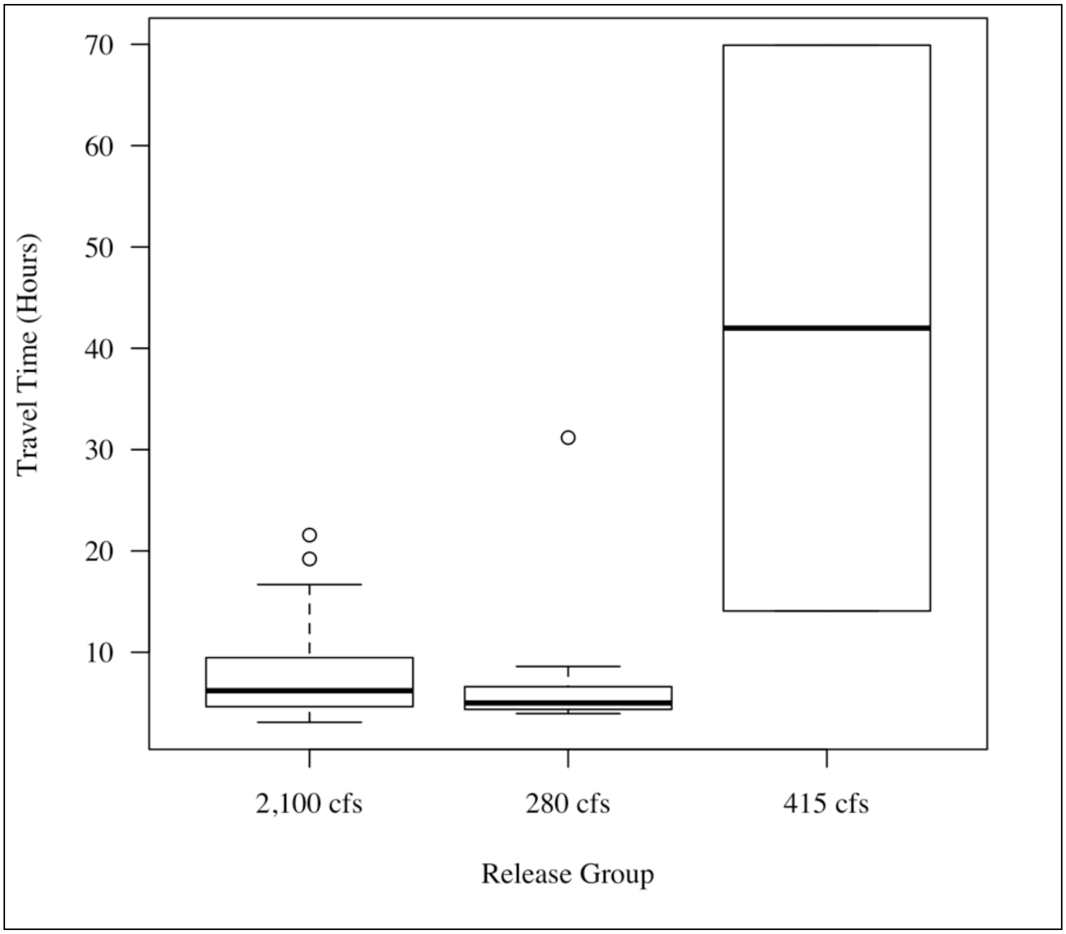

Figure 5.4-8. Transit times from SRP 6 to SRP 10 of acoustic tagged juvenile Chinook salmon (n = 53 total; n = 40 at 2,100 cfs; n = 11 at 280 cfs; and, n = 2 at 415 cfs).

5.4.2.2 Residence Times Within Special Run-Pools

Using a Wilcoxon rank sum test to compare differences in median residence times of juvenile Chinook salmon in SRP 6, residence time at 415 cfs was significantly higher (2.1 minutes higher) compared to the residence times at 280 cfs (Wilcoxon rank sum test, p-value = 0.02335). No other statistically significant differences (e.g. residence times at 2,100 cfs compared to 280 cfs) were found (Figure 5.4-9).

In SRP 10 no significant differences in median residence times were found between flows of 2,100 cfs and 280 cfs (Wilcoxon rank sum test, p-value = 0.3236). Differences in residence times at 415 cfs could not be assessed due to few detections of that release group in SRP 10 (n = 2) (Figure 5.4-10).

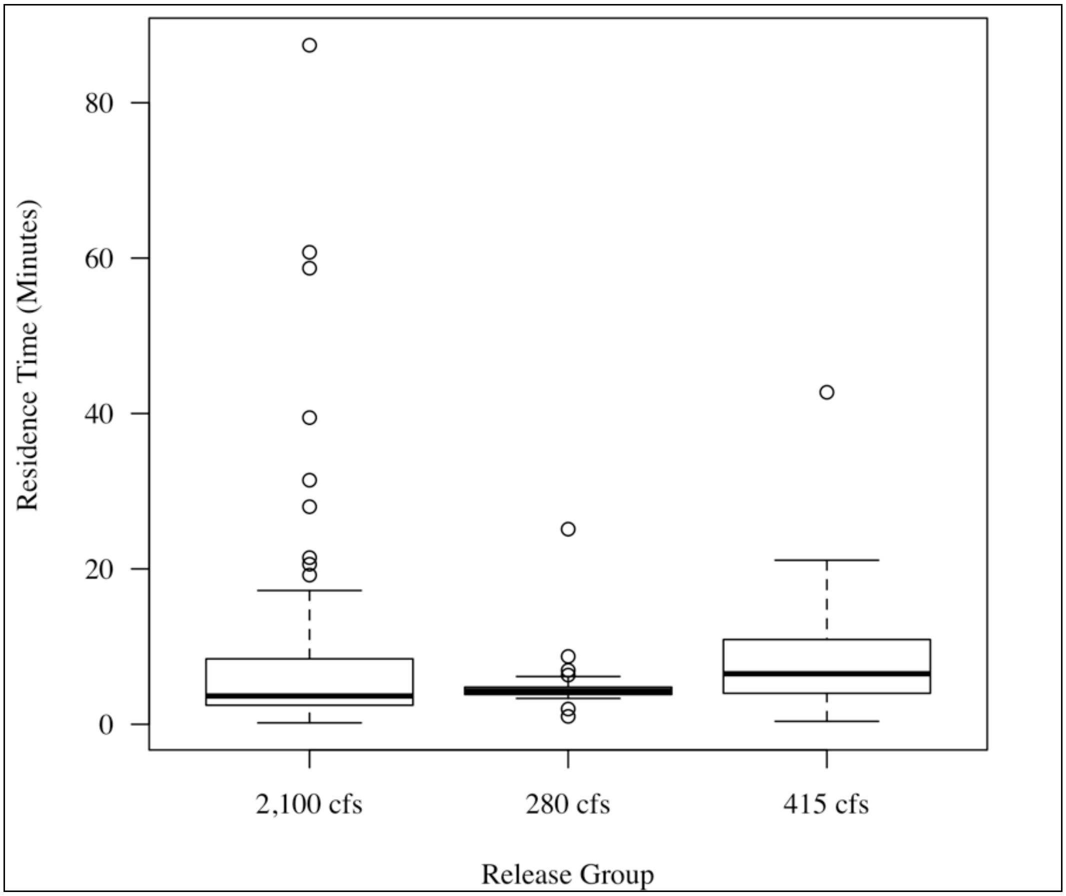

Figure 5.4-9. Residence times (in minutes) at SRP 6 of acoustic tagged juvenile Chinook salmon (n = 109 total; n = 59 for 2,100 cfs; n = 30 for 280 cfs; and, n = 20 for 415 cfs).

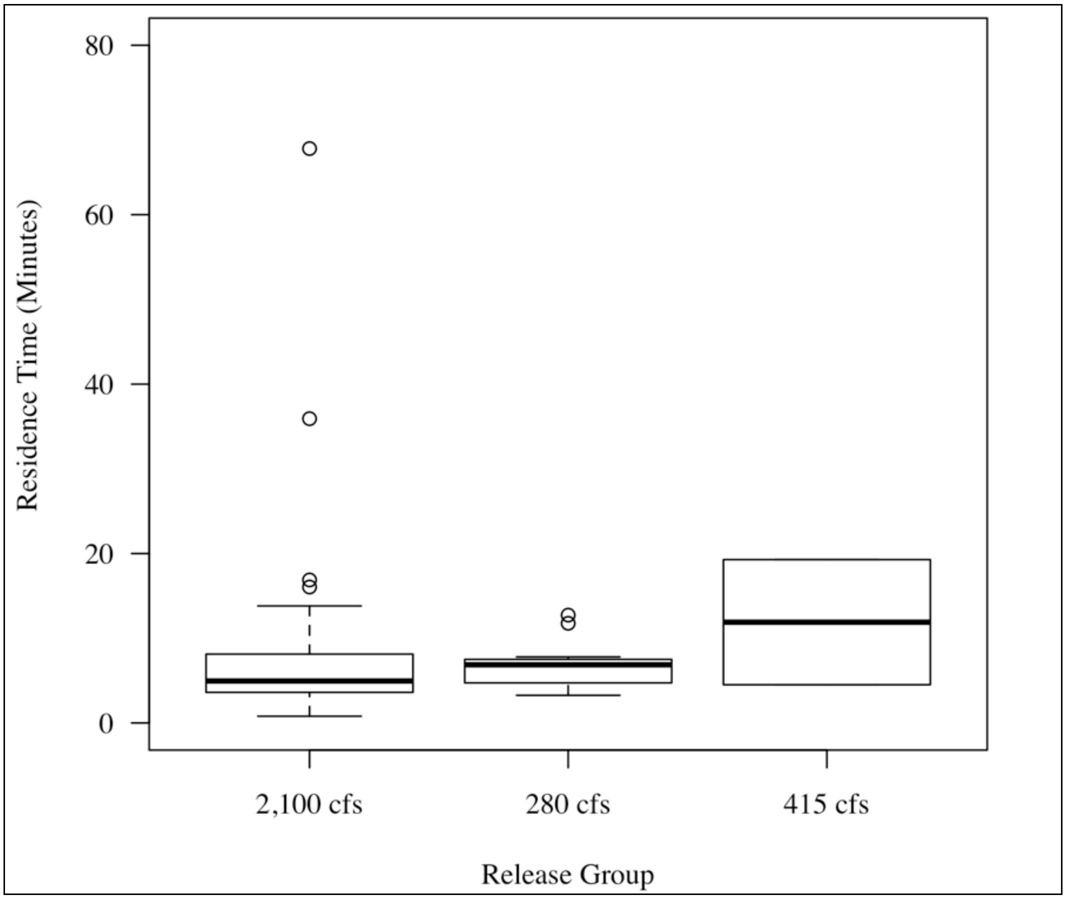

Figure 5.4-10. Residence times (in minutes) at SRP 10 of acoustic tagged juvenile Chinook salmon (n = 55 total; n = 42 for 2,100 cfs; n = 11 for 280 cfs; and, n = 2 for 415 cfs).

5.4.2.3 Riffle Monitoring

The goal of the single hydrophone arrays deployed above and below Riffle 62 and Riffle 74 was to evaluate differential habitat use between Chinook salmon and predator fish within these riffle habitats. Unlike monitoring in the SRPs, two-dimensional positioning was not possible due to the limited depth and increased background noise in the riffle habitats. Equipment malfunctions did not allow us to monitor Chinook movements through the riffles, however we did monitor movements of tagged predators though the riffles. A total of 101 riffle passage events (44 upstream, 57 downstream) were recorded at flows ranging from 244 cfs to 2,160 cfs. A riffle passage event was classified as detection at the upstream or downstream array and a subsequent detection at the opposite side of the riffle. Based on the difference in time of detection at the two arrays we were able to calculate residence times within the riffle habitats. Residence times within the monitored riffles were determined for 70 passage events and ranged from 0.9 to 83.5 minutes (median 15.8 minutes).

6.0 DISCUSSION AND FINDINGS

6.1 Predator Abundance

6.1.1 Riverwide Abundance Estimates

In 1990, largemouth bass abundance was estimated for the entire lower Tuolumne River (RM 0.0 to RM 52.0) based on shoreline lengths (TID/MID 1992). The abundance estimate for largemouth bass was 11,074 (Table 2; TID/MID 1992). During 2012, abundance of largemouth bass from RM 0.0 to RM 39.4 was estimated to be 3,323 based on shoreline length and 3,891 based on habitat area. However differences in study methods preclude making any conclusions based on comparison of these estimates. Notable differences include no use of block nets to create a closed population during the 1990 study, differences in geographic scope of sampling, and differences in length criteria used to estimate abundance.

For instance, the 1990 study included largemouth bass between 100 and 150 mm, whereas the 2012 study only estimated abundance of largemouth bass >150 mm. Bass <150 mm were not identified to species during 2012, and the estimated abundance of bass <150 mm (all species combined) was 95,198-121, and 756.

Capture rates of smallmouth bass, striped bass, and Sacramento pikeminnow were insufficient to produce abundance estimates during the 1990 study so no comparison can be made to estimated abundance in 2012.

6.1.2 Site-specific Abundance Estimates

Site-specific abundance estimates of piscivore-size (> 150 mm FL) largemouth bass ranged from 0 to 42 across 12 sites sampled (Table 5.2-2). McBain & Trush and Stillwater Sciences (2006) used similar depletion methods and reported that site-specific estimates of piscivore-size (180-380 mm FL) largemouth bass ranged from 0 to 18 in 1998 (5 sites sampled); from 2 to 40 in 1999 (6 sites sampled); and, from 5 to 95 in 2003 (6 sites sampled). Using various mark-recapture estimation methods, TID/MID (1992) reported that site-specific estimates averaged 80 largemouth bass (range = 11 – 181 largemouth bass).

Site-specific abundance estimates of piscivore-size (> 150 mm FL) smallmouth bass ranged from 2 to 50 across 12 sites sampled during late summer 2012 (Table 5.2-3). Site-specific estimates of piscivore-size (180-380 mm FL) smallmouth bass ranged from 0 to 2 in 1998 (5 sites sampled); from 0 to 13 in 1999 (6 sites sampled); and, from 2 to 49 in 2003 (6 sites sampled) (McBain & Trush and Stillwater Sciences 2006). Previous research, conducted by TID/MID (1992), showed that site-specific abundance estimates averaged 20 smallmouth bass (range = 9 – 29 smallmouth bass).

Site-specific abundance estimates of both Sacramento pikeminnow and striped bass are provided in Tables 5.2-4 and 5.2-5. We attempted to compare these estimates with previous estimates from McBain & Trush and Stillwater Sciences (2006), however, differences in length criteria for Sacramento pikeminnow and very low capture rates of striped bass during 1998, 1999, and 2003

(McBain & Trush and Stillwater Sciences 2006) do not allow for meaningful comparison.

6.1.3 Smallmouth and Largemouth Bass Densities

Density estimates for largemouth bass and smallmouth bass reported by McBain & Trush and Stillwater Sciences (2006) were converted from number of fish per 1000 ft of shoreline to number of fish per shoreline mile for comparison (Tables 5.2-2 and 5.2-3). However, densities calculated in the 2012 study used piscivores defined as 150 mm FL and above whereas the densities calculated in the McBain & Trush and Stillwater Sciences (2006) study used only piscivores between 180 and 380 mm TL.

Density estimates (converted to fish per mile) from McBain & Trush and Stillwater Sciences (2006) for smallmouth bass (collected in 1998, 1999, and 2003) ranged from 2 to 97 fish per mile. In comparison, site-specific density estimates of smallmouth bass from the current study ranged from 0 to 251 fish per mile (Table 5.2-3). For largemouth bass, site-specific density estimates ranged from 0 to 218 largemouth bass per mile, compared with 4 to 196 largemouth bass per mile (Table 12; McBain & Trush and Stillwater Sciences, 2006) (Table 5.2-2).

6.1.4 General Spatial Distribution

Twelve sites total were sampled for the predator abundance study from RM 3.7 to RM 38.4 during late July and early August 2012. Potential spatial patterns in presence and absence of target predator species emerged from examining Tables 5.2-2 through 5.2-5. Of the 12 sites, smallmouth bass and striped bass (> 150 mm FL) were captured at 12 and 4 sites, respectively. The capture locations of striped bass, however, were located in the entire reach, from RM 3.7 to RM 35.0. Similarly, capture locations of smallmouth bass were located from RM 3.7 to RM 38.4. In contrast, no largemouth bass (> 150 mm FL) were captured at or above RM 34.8 and no Sacramento pikeminnow (> 150 mm FL) were captured at or below RM 25.5.

If the spatial distributions of striped bass and smallmouth bass are nearly river wide, this may have implications for relating their predation rates with their relative abundances. One important assumption, however, is that the distribution of target species during abundance sampling (late summer) was relatively similar to the distribution during predation rate sampling (early to mid Spring). The combination of smallmouth bass and striped bass may account for more predation on juvenile Chinook salmon due to the combination of their widespread distribution, predation rates, and relative abundance. The distribution of largemouth bass during late summer may be determined in some part by river location (e.g. more largemouth bass in lower gradient, warmer lower reaches of the Tuolumne). Likewise, the distribution of Sacramento pikeminnow during late summer may be confined to the mid- to upper-portions of the lower Tuolumne River.

6.2 Predation Rate

Predation frequencies (# of predators with at least one Chinook salmon / total # of predators) were significantly higher in SRPs compared to RPs during March 2012, although no evidence of a difference in predation frequencies by habitat type was detected in May (Figure 5.3-6). No statistically significant differences in predation frequencies were found between sampling events or between habitat types when combined across sampling events.

Predation rates (# of Chinook salmon per predator) were generally highest for striped bass, followed by predation rates of smallmouth bass and largemouth bass. Average consumption per predator (not scaled by gastric evacuation rates) in a previous study ranged from 0 to 1.67 (TID/MID 1992; Table 3) compared to 0 to 1.2 in this study with striped bass having the three highest consumption rates (Table 5.3-3). Juvenile Chinook salmon consumption rates for largemouth and smallmouth bass (0 – 0.16) observed in this study were lower compared to the consumption rates for those species (0 – 1.67) in the TID/MID (1992) report. A review by Carey et al. (2011; Table 4) reported that predation rates (number Chinook salmon consumed per day) for smallmouth bass from Columbia River basin ranged from 0 to 3.89 Chinook consumed per day, with most values less than 0.1 Chinook salmon per day. The predation rate for striped bass on juvenile Chinook salmon in the lower Tuolumne River was reported to be zero (TID/MID 1992). However, only eight striped bass were examined in the course of that earlier study. No striped bass were captured during predation rate sampling subsequently conducted by Stillwater Sciences and McBain & Trush (2006).

Chinook salmon were only detected in the stomach samples of smallmouth bass, largemouth bass, and striped bass. No predation on juvenile Chinook salmon by Sacramento pikeminnow was observed, however, only six individuals were sampled. Previous research indicates that predation on juvenile Chinook salmon by Sacramento pikeminnow may be quite low in the lower Tuolumne River. Of 68 Sacramento pikeminnow captured and examined for the presence of juvenile Chinook salmon in 1992, none were found to have consumed juvenile Chinook salmon (TID/MID 1992). No Sacramento pikeminnow were captured during predation rate sampling conducted by Stillwater Sciences and McBain & Trush (2006).

Water temperatures were between 13°C and 16°C during the first sampling period (March 22 – March 29) among the sampling locations. During the second sampling period (May 1 – May 9), water temperatures ranged from 14°C to 17°C among the sampling locations. The water temperatures observed during this study may have partially influenced the predation rate compared with previous work conducted by Stillwater Sciences and McBain & Trush (2006). In that study, very few target species (n = 4) were captured, but of those captured, none contained juvenile salmon. Water temperatures were much lower during the earlier study, ranging from 10.7°C to 12.8°C, compared to 13°C to 17°C observed in the current study (Figure 5.1-2). Discharge during the previous study was significantly higher (6,740 cfs to 9,120 cfs) than discharges observed during predation rate sampling in this study (about 350 cfs to about 2,100 cfs) (Figure 5.1-1).

Turbidity during predation rate sampling ranged from 0.77 NTU to 2.83 NTU, and these levels were similar to those reported in the TID/MID (1992) study. The results of neither study suggested any connection between predation rates and turbidity, and while the ranges of turbidity during sampling were quite narrow, they are representative of the range of typical baseline turbidity conditions in the lower Tuolumne River. Other studies have found that turbidity greater than 25 NTU reduces the incidence and risk of piscivory on salmonid prey (Gregory and Levings 1998).

6.2.1 Diet Composition

Invertebrates (insects and crayfish) made up a large portion (by frequency of occurrence and by total count) of identifiable prey items among the stomach samples examined. Crayfish were present in about 26 percent of all stomach samples from the target species examined. This result is similar to the TID/MID (1992) report, where 17 percent and 33 percent of fish sampled (consisting of smallmouth bass, largemouth bass, Sacramento pikeminnow, striped bass, bluegill, redear sunfish, green sunfish, channel catfish, white catfish, and brown bullhead) contained crayfish.

Thirty fish identified as juvenile Chinook salmon occurred in about 12 percent of the stomach samples or 30 of the 246 non-empty stomach samples examined. However, juvenile Chinook salmon only made up about 10 percent of all the fish (n = 326) observed in stomach samples. Other fish consumed were unidentified larval fish (observed in 79 of 246 non-empty stomachs), sculpin (16 of 246), and lamprey and cyprinids (2 of 246).

6.3 Synthesizing Abundance and Predation Rates

The cumulative impact of predation was assessed by estimating the abundance of target species between RM 5.1 (location of the Grayson rotary screw trap) and RM 30.3 (location of the Waterford rotary screw trap). Methods to estimate abundance based on shoreline lengths in this reach are described in Section 4.2.2.3. The abundance in this reach was then combined with the species-specific predation rates observed in this study (see Sections 4.3.3.3 and 5.3.6 "Predation rates on juvenile Chinook salmon").

We estimated abundance of predatory fish based on a total shoreline distance (feet) of 298,163 between the Waterford and Grayson rotary screw traps. Density estimates of predators were calculated using only site-specific abundance estimates from sites sampled between RM 5.1 and RM 30.3, so that abundance data from only seven of the twelve sites was used. All estimators for abundance and variance for this calculation are provided in Section 4.2.2.3.

Abundance estimates of piscivore-sized fish (>150 mm FL) between Waterford and Grayson were 3,013 largemouth bass (SE±156), 117 (SE±18) Sacramento pikeminnow, 3,626 (SE±111) smallmouth bass, and 235 (SE±21) striped bass. Species-specific predation rates for the lower predation rate (e.g. the rate based on a 20-hour gastric evacuation time) were averaged for all habitat types and sampling events. Predation rates were 0.10 Chinook per predator per day for largemouth bass, 0.0 Chinook per predator per day for Sacramento pikeminnow, 0.11 Chinook per predator per day for smallmouth bass, and 1.1 Chinook per predator per day for striped bass (see Table 5.3-3). To be conservative in the cumulative impact assessment of predation between the two rotary screw traps, we used the lower 95 percent confidence bounds for each species abundance estimate which were 21,701 largemouth bass, 81 Sacramento pikeminnow, 3,404 smallmouth bass and 193 striped bass. The total estimate of juvenile Chinook salmon potentially consumed was estimated by multiplying the number of predators, the migration period (in days), and the estimated predation rate (in number of juvenile Chinook salmon consumed per day). For example, the estimated number of juvenile Chinook salmon consumed by largemouth bass over a 90-day migratory period was 24,309 (2,701 * 90 * 0.1). We used 60-, 90-, or 120-day migratory periods which assumed that the daily numbers of juvenile Chinook migrating was uniformly distributed and that all equally vulnerable to predation at the average rate.

The estimated numbers of juvenile Chinook consumed in the reach between the Waterford and Grayson rotary screw traps are reported in Table 6.3-1. Despite making up only a small fraction (< 4 percent) of the total of piscivore-sized fish (> 150 mm FL), striped bass were estimated to consume nearly 25 percent of the total potential juvenile Chinook salmon consumed. Smallmouth bass were estimated to consume about 44 percent of juvenile Chinook salmon and largemouth bass were estimated to consume about 32 percent of juvenile Chinook salmon.

Table 6.3-1. Estimated cumulative impact of predation in the lower Tuolumne River between RM 30.3 and RM 5.1 under a low predation rate (gastric evacuation time set at 20-hours) by length of migratory period of juvenile Chinook salmon.

Species	$\hat{N}$	Predation Rate	60-Day Migratory Period	90-Day Migratory Period	120-Day Migratory Period	Percent of Impact
Largemouth bass	2,701	0.1	16,206	24,309	32,412	31.5%
Sacramento pikeminnow	81	0	0	0	0	0.0%
Smallmouth bass	3,404	0.11	22,466	33,700	44,933	43.7%
Striped bass	193	1.1	12,738	19,107	25,476	24.8%
		Total	**51,410**	**77,116**	**102,821**	

Total potential consumption of juvenile Chinook salmon was estimated to be about 77,000 for a 90-day migratory period (Table 6.3-1). Estimated abundance of juvenile Chinook salmon at the Waterford rotary screw trap during January 3 - June 15, 2012 was 68,650, suggesting that consumption of juvenile Chinook salmon by predators between the Waterford and Grayson rotary screw traps could equal or exceed the number passing the Waterford trap. Only 2,969 Chinook salmon were estimated to have survived migration through the 25 miles between the trapping sites (Sonke and Fuller 2012), making it plausible that most, if not all, losses of juvenile Chinook salmon in the lower Tuolumne River between Waterford and Grayson during 2012 could be attributed to non-native predatory species.

Predation rate sampling and predator abundance sampling did not temporally overlap, it was assumed that predator abundance in summer was similar to predator abundance during the juvenile Chinook salmon migration. Given the similarity in densities of predatory species between this study and previous studies conducted on the lower Tuolumne River, and the similarities between predation rates between this study and other predation rates observed from the same species, we feel justified that the cumulative impacts of predation on juvenile Chinook salmon in the lower Tuolumne River during the spring of 2012 were substantial.

Losses of juvenile Chinook salmon between the rotary screw traps at Waterford and Grayson ranged between approximately 76 percent and 98 percent during 2007-2011, with the actual numbers of individuals estimated to be lost ranging from approximately 22,000 to 330,000. If the predation rates and predator abundances in these years were similar to those documented in the 2012 study, it is plausible that the overwhelming majority of Chinook salmon mortality was due to predation.

6.4 Differential Habitat Use

Two-dimensional acoustic tracking was used to evaluate the role of flow in segregating potential predators from outmigrating Chinook salmon within the special run-pools. Results showed overlap between acoustically tagged Chinook and predators at the three tested flows (280 cfs, 415 cfs, and 2,100 cfs). Striped bass were found to have the greatest overlap in habitat use with Chinook salmon (18.4 percent - 46.3 percent), followed by largemouth bass (5.8 percent -30.5 percent), and smallmouth (0.2 percent - 38.2 percent).

Residence times of Chinook salmon within SRPs were also found to be similar between release groups, with the only significant difference in the medians found between 415 cfs and 280 cfs in SRP 6. It should be noted that the highest range in residence times at both SRPs was found during the 2,100 cfs event. Based on review of individual acoustic tracks, extended residence times were due to fish circling within the array rather than passing directly through the SRP. Circling was likely caused by hydraulic conditions within the SRPs at the higher flows.

An earlier study on the Tuolumne River (McBain & Trush and Stillwater Sciences, 2006) hypothesized that at flows exceeding 300 cfs, higher velocities would increase Chinook salmon migration rates through SRP sites. The results of this study do not support this hypothesis as transit times across SRP 6 and SRP 10 were fastest at 280 cfs, suggesting that higher flows actually decrease transit rates through the SRPs. Comparison of transit rates at each site at a given flow found no statistically significant difference in transit rates between sites, suggesting that this trend may also apply to other SRP sites that were not studied in 2012.

Acoustic detections within riffle 62 and riffle 74 and estimated residence times within riffles suggest that predator species (largemouth bass, smallmouth bass, and striped bass) were able to move unrestricted through riffle habitats at all test flows. Tracking technology did not allow for precise determination of tagged fish locations within the riffles.

6.5 Potential Additional Studies to Be Conducted in 2013

The Districts are considering conducting an additional year of predator abundance and predation rate sampling in 2013 using the same methodology as employed in the 2012 study. It is apparent from the 2012 results that predation is a significant factor affecting salmon smolt survival on the Tuolumne River. Additional information may provide greater detail related to potential protection, mitigation and enhancement measures.

7.0 STUDY VARIANCES AND MODIFICATIONS

The study was conducted consistent with the approved study plan. No variances occurred.

The study is complete. No modifications are proposed.

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