Lower Tuolumne River Predation Assessment Final Report

Prepared for
The Tuolumne River Technical Advisory Committee
Turlock and Modesto Irrigation Districts
USFWS Anadromous Fish Restoration Program
California Bay-Delta Authority

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Table of Contents

List of Tables

List of Figures

List of Appendices

1 Introduction

The lower Tuolumne River corridor, which extends 52.2 miles from La Grange Dam to the San Joaquin River, has been extensively altered by flow regulation and diversion, instream and floodplain gold dredging, instream and floodplain aggregate mining, and agricultural and urban development. Downstream of La Grange Dam, the river and its floodplain were dredged for gold in the early and mid-20th century. Dredging occurred primarily from near the town of La Grange to near the Roberts Ferry Bridge (RM 40). Large-scale aggregate mining in the river began in the 1930s and continues today. Historically, aggregate mines excavated sand and gravel directly from the river channel, creating large, in-channel pits now referred to as "special run-pools" (SRPs).

Mining that created these SRPs replaced riverine habitat with large, lake-like pits that provide favorable conditions for non-native largemouth bass (*Micropterus salmoides*). Past studies of Chinook salmon (*Oncorhynchus tshawytscha*) population dynamics and outmigrant survival in the Tuolumne River concluded that predation by largemouth bass in these and other SRP reaches is a significant factor limiting Chinook salmon outmigrant survival, particularly during drier years (TID/MID 1992). Smallmouth bass (*M. dolomieu*) were also identified as a potentially important Chinook salmon predator. Smallmouth bass exhibited higher predation rates on Chinook salmon than largemouth bass, but their effect on Chinook salmon production was considered to be small due to their low abundance throughout the river (TID/MID 1992). In addition to harboring salmon predators, gravel pits also provide poor rearing conditions for Chinook salmon and impede sediment routing in the river by trapping sediment transported from upstream reaches.

The primary goals of the SRP 9 and SRP 10 restoration projects are to reduce habitat for largemouth bass, improve bedload routing through the reach, and construct a geomorphically functional channel and floodplain. Project objectives were presented in the Restoration Plan (McBain & Trush 2000) and reiterated in proposals to the California Bay-Delta Authority (CBDA) to fund restoration implementation. These objectives are to:

- reduce/eliminate habitat favored by predatory bass species and replace it with high quality Chinook salmon habitat;
- restore channel and planform morphology scaled to contemporary and future sediment and hydrologic regimes;
- restore sediment transport continuity through the reach; and
- revegetate reconstructed floodplains and terraces with native woody riparian species planted on fluvial surfaces appropriate for each species life cycle.

A monitoring plan was developed for SRPs 9 and 10 as an integral part of the Tuolumne River restoration projects and was designed to evaluate project effectiveness in meeting geomorphic and biological objectives. Monitoring provides data needed for adaptive management of the completed projects and for the design of future projects. The SRP 9 project was completed in 2001 and the former in-channel mining pit now consists of a riffle and long pool with newly constructed floodplains that are inundated during overbank flows. Post-project predator abundance monitoring was conducted in fall 2003 (McBain & Trush and Stillwater Sciences 2006).

One of the key monitoring hypotheses for the SRP 9 project is that elimination of the in-channel mining pit will reduce predator abundance (particularly largemouth bass) at the project site and increase Chinook salmon outmigrant survival through the site. The majority of post-project monitoring thus far has focused on bass abundance and bass habitat at SRP 9 and control sites. Monitoring conducted to date is described in McBain & Trush and Stillwater Sciences (2006). Several project hypotheses, however, have not yet been tested. No assessment has been conducted to document the effects of project construction on predation rates, flow-related habitat partitioning of predators and salmon, or Chinook salmon survival at the site.

Additional hypotheses were developed subsequent to analysis of post-project predator monitoring data and two-dimensional (2-D) habitat suitability modeling. Monitoring from September–October 2003 showed that largemouth and smallmouth bass were the most abundant potential salmon predators at all project and control sites. Estimated abundance of piscivore-sized (180–380 mm FL) smallmouth bass was highest at the Charles Road and Riffle 64 riffle control sites, with 24 and 49 fish respectively. Estimated abundance of piscivore-sized largemouth bass was highest at the SRP sites, ranging from 48–95 fish. At SRP 9, largemouth and smallmouth bass abundance was estimated to be 24 and 25 fish, respectively.

Two other potential salmon predators, Sacramento pikeminnow (*Ptychocheilus grandis*) and striped bass (*Morone saxatilis*), occurred at very low numbers. Estimated abundance of Sacramento pikeminnow was no more than 11 fish at either of the two riffle control sites, and 2 fish at each of the three SRP control sites. Estimated striped bass abundance was no more than 2 fish at either riffle control site, and no striped bass were captured at SRP control sites. No pikeminnow or striped bass were captured at the SRP 9 project site. River flow during the fall 2003 sampling ranged from 216–247 cfs.

Based on these findings and the 2-D habitat suitability modeling, initial hypotheses regarding salmon predators in the Tuolumne River focused on largemouth and smallmouth bass. These hypotheses, included in the Special Run Pool and 7/11 Reach Post-Project Monitoring Synthesis Report (McBain & Trush and Stillwater Sciences 2006) as recommendations for further monitoring, include the following[1]:

H13 In SRP 9, segregation of habitat selected by outmigrating Chinook salmon and foraging largemouth and smallmouth bass occurs at flows exceeding 300 cfs. For this reason, bass predation rates at flows ≥ 1,500 cfs are significantly less at SRP 9 than at SRP control sites. Predation rates by smallmouth bass are significantly higher than predation rates by largemouth bass.

H14 At flows exceeding 300 cfs, juvenile Chinook salmon migration rates are significantly faster at SRP 9 than at SRP control sites. During these flows, juvenile Chinook salmon remain oriented facing upstream as they migrate through SRP 9 but orient facing downstream and must actively swim through SRP control sites.

[1] Note that original hypothesis numbers are from the draft SRP 9 and 7/11 Reach: Post-project Monitoring Synthesis Report (McBain & Trush and Stillwater Sciences 2006).

Quantifying Chinook salmon survival and predation rates through the project reach is fundamental to evaluating the SRP 9 project's effectiveness in achieving its primary goal (i.e., increasing juvenile salmon outmigrant survival) and testing the validity of the conceptual models upon which the project is based (i.e., whether converting the mining pits to riverine channels reduces predator abundance and/or predation efficiency and whether reducing predator abundance increases Chinook salmon survival).

The CBDA provided funds to conduct a pilot predation study (the Predation Assessment) at the SRP 9 project site. The predation assessment was originally planned for spring 2005, but high flows forced postponement of the study until spring 2006. With spring 2006 flows in the Tuolumne River again greater than those for which the original study plan was designed, the study objectives and study plan were revised into high flow and low flow components, each to be conducted separately as conditions permit. Only the high flow study component was conducted in 2006. Low flow studies could be completed in subsequent years, as additional funding becomes available and spring flow conditions permit.

In an effort to expand the monitoring to include all potential salmon predators and to facilitate hypothesis testing given time and funding constraints, additional hypotheses were developed and existing hypotheses were broken into smaller parts, each of which is designed to be tested under high or low flow conditions (Table 1-1).

Table 1-1. Hypotheses regarding salmon predation in the lower Tuolumne River.

Hypothesis Number	*Hypothesis*	*Test Flow*	*Test Year*
H13A	In SRP 9, segregation of habitat selected by outmigrating Chinook salmon and predators occurs at flows exceeding 1,500 cfs.	≥ 1,500 cfs	2006
H13B	Predation rates at flows ≥ 1,500 cfs are significantly less at SRP 9 and the riffle control sites than at SRP control sites.	≥ 1,500 cfs	2006
H13C	Predation rates at flows ≤ 300 cfs are not significantly different at the SRP 9 and the SRP control site, but are significantly greater at the SRP 9 than at the riffle control site.	< 300 cfs	low-flow year (undetermined)
H13D	At the SRP 9, predation rates by smallmouth bass are significantly higher than predation rates by largemouth bass, Sacramento pikeminnow, and striped bass.	≥ 1,500 cfs and < 300 cfs	2006 and a low-flow year
H13E	At the SRP control site, a high percentage of the juvenile salmonids passing through the site are consumed by predators when flows are 300 cfs or less.	< 300 cfs	low-flow year (undetermined)

1.1 High Flow Study Objectives

The high flow objectives of the predation assessment are to:

1) Document the predation rate in SRP 9 and compare with predation rates at SRP and riffle control sites (H13B and H13D, above);
2) Document velocity-driven or temperature-driven spatial distribution of predators and salmon at SRP 9 and an SRP control site, and determine whether the two species are spatially segregated (H13A).

2 Methods

2.1 Study Locations and Dates

The predation assessment monitoring was conducted from May 3–24, 2006 at three sites on the Tuolumne River, located between RM 25.9 and RM 24.8: (1) the project site (restored SRP 9), (2) an SRP control site (SRP 10), and (3) a riffle control site (Charles Road) (Figure 2-1). All of the sites were located downstream of the Geer Road bridge and were accessed by boat via the Fox Grove fishing access. Predator capture and marking, as well as seine surveys and temperature monitoring, occurred during a three day period from May 3–5, 2006. Subsequent monitoring (tracking) of marked predators occurred weekly thereafter, concluding on May 24, 2006.

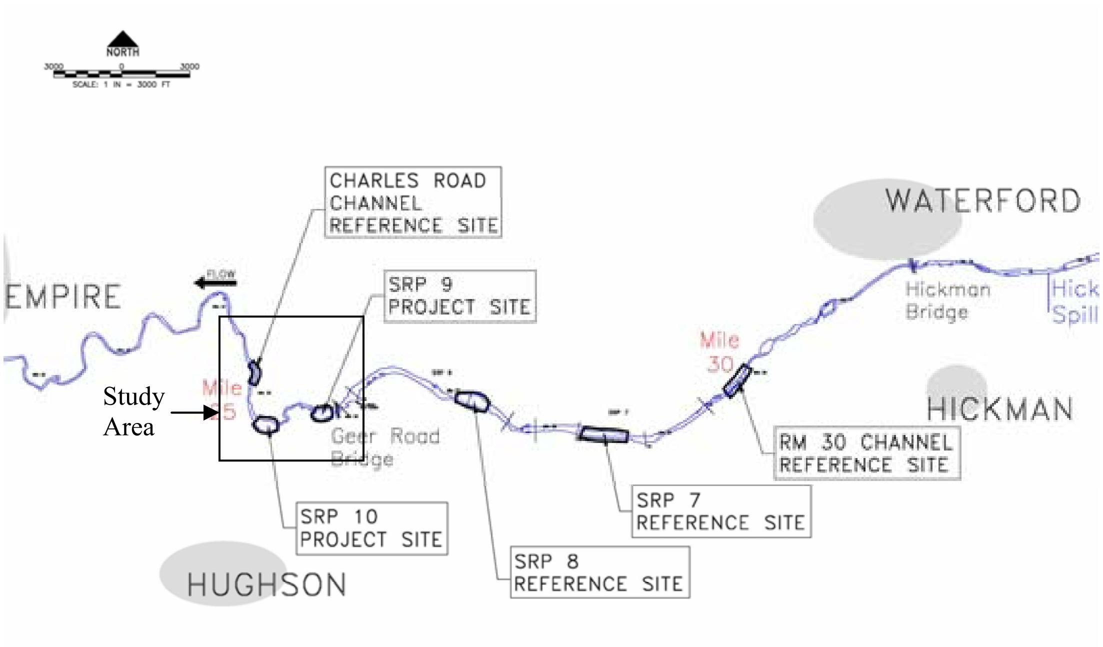

Figure 2-1. Tuolumne River predation assessment study area.

2.2 Water Temperature and Flow

2.2.1 Water Temperature

Water temperature at each monitoring site was recorded during the three-day sampling period using thermographs (Stowaway TidbiT - Onset Computer Corporation, Bourne, MA) set for data logging at 15-minute intervals. Biologists installed six thermographs in the stream channel by hanging them from flooded vegetation using fishing line and an attached weight. Two thermographs were installed at each of the three monitoring sites (SRP 9, and the control sites SRP 10 and at Charles Road); one was placed on a shallow flooded terrace, and the second was placed in deeper water near the main channel (see Appendix A for exact placement). The thermographs were installed in water 2.3–9 feet (0.7–2.8 m) deep, and were placed at approximately half the water depth.

Prior to installation, calibration checks were performed to confirm the manufacturer's specified accuracy (± 0.2˚C) using measurements from United States National Institute of Standards and Technology (NIST).

At the end of the marking period (May 5, 2006), the thermographs were removed and the data downloaded. Data points logged prior to deployment or following removal were excluded from the analysis. Data analyses included the calculation of daily statistics (min, max, and mean temperatures).

2.2.2 Flow

River flow data were collected from the USGS stream gage near La Grange (upstream of the study area) which is reported on the California Data Exchange Center (CDEC) website at http://cdec.water.ca.gov (data accessed on June 1, 2006). Data analyses included calculation of minimum, maximum, and mean daily flow for the study period which were then used to calculate the minimum, maximum, and mean daily flow for both the marking period and tracking period.

2.3 Predator Surveys

Hook and line (angling) surveys were conducted from May 3–5, 2006 by a crew of two anglers, with the objective of capturing potential salmon predators at each of the three sites. Potential salmon predators were considered to include any fish ≥150 mm total length belonging to the following species: largemouth bass, smallmouth bass, striped bass, or Sacramento pikeminnow. Although black bass (smallmouth and largemouth) >180 mm were identified as the most likely salmon predators (McBain & Trush and Stillwater Sciences 2006), based on the 1990 predation study data (TID/MID 1992), a lower size limit of 150 mm was used in this study with the objective of validating these results.

A 14 ft aluminum boat (Lund) with fish finder and hand-held GPS electronics (Garmin International, Inc.) was used to access the three sites and for all angling. Although the angling effort included sampling in a variety of habitat types and all areas of the channel (i.e., floodplain, channel margin, thalweg) at each site, the limited time available for sampling necessitated that angling focus primarily in areas where depth, velocity, and cover conditions were judged to provide likely predator habitat at the flows sampled. Angling therefore was largely targeted in areas near the channel margin and on inundated floodplains and backwaters (Appendix A, Figures A-1 through A-4).

Sampling took place at restored SRP 9, SRP 10, and Charles Road, as well as areas between these three sites where habitat conditions appeared suitable for predators. Total angling effort was 32 person-hours for the three study sites combined. Angling effort was partitioned approximately as follows: 30% at SRP 9, 25% at SRP 10, and 45% at Charles Road.

Light- and medium-weight spinning rod and reel combinations with monofilament 6–60 lb test fishing lines were used during sampling. Approximately 80% of the time, anglers used lures consisting of small, soft plastic baits meant to mimic prey fish 50–60 mm in length. These were accompanied with one or two split shot weights placed approximately 30 cm up from the plastic bait to allow fishing coverage from surface waters down to the river bottom. This setup was typically fished in waters 2–7 ft (0.6–2.1 m) deep in inundated floodplain and riparian areas where water velocity ranged from approximately 0–1 ft/s. The remaining 20%

of the time, when fishing in open, main channel and thalweg areas with higher current velocities and depths of 7–40 ft (2.1–12.2 m), deep-diving crank baits and ½–¾ oz feather jigs were used. These lures were fished by trolling the crank baits behind the boat and drift fishing the feather jigs with the current.

Once a fish was hooked and landed, it was placed in a holding container with river water for processing. The location of each capture was marked on aerial photographs, time of capture was recorded, and water depth was recorded using the on-board Lorance navigational equipment and fish finder. Water velocity was visually estimated at each capture location. Captured fish were processed by identifying the species, recording total length, recovering gut contents, and tagging the fish with a color- and number-coded Floy tag. Gut contents were recovered by stomach lavage, using a portable low-pressure pump sprayer to flush the gut with river water. Stomach contents were preserved in 70% ethanol for later identification.

After processing, fish were allowed to recover for several hours in a live well submerged and anchored in a shaded, off-channel location with minimal water velocity, protected from predators and the public. Each fish was later surgically implanted with a radio tag and released at the location of capture to allow tracking of individual predators (described below).

2.4 Floodplain and Channel Margin Surveys

The floodplain and stream margin habitat at each of the three monitoring sites was sampled for fish concurrently with angling surveys on May 3–4. Beach seine was the primary method used to collect fish on inundated floodplains and along the stream margins. Seines were 20 feet wide and 4 feet tall with 1/8-inch mesh. Each site was sampled multiple times with 2–5 net hauls per site. Individual net hauls were typically started near the shoreline or just off shore, and the net was pulled along the shoreline and then onto the bank in wadeable areas with no large woody vegetation or other submerged debris. Individual net hauls ranged from 15–50 feet in length and were fished in 2.5–4 feet of water (see Appendix A for seining locations).

After the seine was pulled onto the shore, fish were collected from the net and placed into buckets of water for processing. Individual fish were then identified to species, and the fork length measured (mm). All captured salmonids were weighed to the nearest tenth of a gram. Fish were then released at the original location of capture.

Habitat descriptors and physical habitat measurements were recorded at each seine location. Each seine location was characterized by habitat type (e.g., inundated floodplain). The length and width of each seine hall was estimated and the area of each seined location was calculated by multiplying length by width. The approximate maximum and average depths were recorded and substrates and fish cover were visually estimated.

The range of water velocities at each monitoring location was visually estimated for a given area then measured at representative locations using a flow meter and topset rod (Flo-Mate, Marsh McBirney, Inc. Frederick, Maryland). Measurements of water temperature, air-calibrated dissolved oxygen (DO), electrical conductivity, turbidity, and specific conductance were collected using a YSI 85 multi-parameter meter (Yellow Springs Instruments, Yellow Springs, Ohio) and/or a LaMotte 2020 multi-parameter meter at the time of the fish sampling.

In addition to beach seining, direct observation by snorkeling was attempted at one site. Biologists surveyed inundated floodplain habitat at SRP 9 for 24 minutes before determining that poor visibility precluded the ability to identified fish species. The survey was attempted at 11:30 AM at which time the vertical visibility was 5 feet and the horizontal visibility was 4 feet.

2.5 Outmigrant Salmon Data

Salmon capture data from Tuolumne Irrigation District and Modesto Irrigation District (TID/MID) regular bi-weekly spring seine surveys and rotary screw trap outmigration monitoring were obtained and analyzed to provide an indication of the abundance of juvenile Chinook salmon in the river during the predation assessment.

2.5.1 Seine Data

Juvenile Chinook salmon seining surveys are conducted bi-weekly from January through June each year by TID/MID. 2006 seining data (TID/MID unpublished) for the period January 20 January–May 31 were obtained from TID/MID and juvenile salmon density was summarized for the sites closest to the predation assessment study reach (Hickman [RM 31.6] and Charles Road [RM 24.9]). On April 12 and April 26, 2006, seining took place at Fox Grove (RM 26.0) instead of Charles Road. The area seined ranged from 1,650–2,500 ft^2 at Hickman and from 1,050–2,400 ft^2 at Charles Road/Fox Grove. Methods used in 2006 were consistent with methods used in previous years. A detailed description of methods will be available in the Lower Tuolumne River Annual FERC Report.

2.5.2 Rotary Screw Trap Data

Additional data on outmigrating Chinook salmon are provided by TID/MID rotary screw trap (RST) monitoring. Cramer Fish Sciences monitored RSTs at two locations in the Tuolumne River beginning on January 26, 2006: one RST at Waterford (RM 34) and two RSTs at Hughson (RM 5). Raw daily catch data for each trapping location were obtained from Cramer Fish Sciences. Expanded catch data were not available at the time of writing.

Methods used in 2006 were consistent with methods used in previous years. A detailed description of methods will be available in the Lower Tuolumne River Annual FERC Report.

2.6 Predator Marking and Tracking

2.6.1 Marking and Tag Implantation

Adult predator fish captured during the surveys were marked with an individualized Floy tag. Adults larger than 150 mm then received a surgically implanted radio transmitter with a trailing antenna which transmitted a unique signal for each fish. The transmitters used were built by Advanced Telemetry Systems (model 1560) and weighed 2.5 g which was less than 2% of the body mass of each host fish.

Prior to the radio transmitter implantation, the fish were held in live wells for 2 to 20 hours. The holding time was greatly reduced during the process due to the agonistic behaviors of the fish in the live wells. Fish were then transferred to an aerated holding container prior to the implantation process. Immediately prior to implantation of radio transmitters, individual fish were anesthetized with MS-222 (Schoettger and Steucke 1970). Once sedated, fish were transferred out of water to a cradle coated with Poly Aqua (Figure 2-2). This allowed for a sterile environment for the implantation process

Figure 2-2. Photo of surgery setup.

Figure 2-3. Implanting a radio transmitter into a piscivore-sized largemouth bass.

Aerated water containing the anesthetic was supplied to the fish through a gravity fed tube inserted into the fish's mouth which allowed water to flow past the gills. Care was taken so no water flowed into the open incision. Prior to making the incision into the body cavity, the fish scales were removed from the incision location (Figure 2-3). A small 15mm incision was made 3mm away from, and parallel to, the mid-ventral line in the anterior portion of the body cavity. The antenna was first inserted into a catheter through the body wall of the fish and the transmitter was then implanted into the body cavity of the fish. The catheter was then removed and the antenna was loosely sutured to the caudal portion of the body. A small amount of dilute liquid antibiotic (Oxytetracycline) was added to the body cavity before suturing the incision. An antibiotic ointment (Bacitracin Zinc Ointment USP) was then added to the external incision points and suture locations before the fish was placed back into an aerated recovery container. After surgery, fish were allowed to recover for at least 20 minutes before being transported to a live well near their release location. Fish were then released to their location of capture after a limited recovery (2-4 hours). Surgical equipment was sterilized using Nolvasan prior to each implantation session.

2.6.2 Tracking

The locations of individual fish implanted with a radio transmitter were tracked to a micro-habitat level on four occasions to document the habitat use and movement of each predator. Tracking occurred on May 5, 9, 17, and 24, 2006. Fish were tracked by boat using an ATS R2000 radio transmitter receiver (Advanced Telemetry Systems, Isanti, Minnesota) with a handheld Yagi antenna (Figure 2-4). Individual fish were located using triangulation techniques and were pinpointed by moving closer to the fish using the same techniques. The specific locations of each fish were then documented on aerial photographs of the study area and the habitat types where the fish were found including water temperature, dissolved Oxygen (DO), nearby cover types, and water velocity were recorded.

Figure 2-4. Radio tracking a tagged bass.

3 Results and Discussion

3.1 River Conditions

Water temperatures during the May 3–5 predator sampling period were consistent across the three study sites (SRP 9, SRP 10, and Charles Road) (Table 3-1). The temperatures ranged from 10.7°C to 12.8°C (51–55°F) and showed a slight warming trend from upstream to downstream (Appendix C; Figures C-1 through C-3).

Table 3-1. Water temperatures at sites sampled during the predator survey period.

Site	*Temperature (°C)*		
	Minimum	*Maximum*	*Mean*
SRP 9	10.7	12.4	11.6
SRP 10	10.9	12.4	11.6
Charles Road	10.9	12.8	11.8

The water temperature also varied at each site according to the location of the thermograph; the temperatures near the main channel were slightly different from the temperatures near the shoreline or on floodplain habitat. At the restored SRP 9, the water temperature on the floodplain was similar to the temperatures within the main channel, but the warmer temperatures persisted for a longer period on the floodplain (Appendix Figure C-1).

At SRP 10, the water temperature on the floodplain was similar to the temperatures in the main channel. However there was a short time-lag between temperature response in the main channel and along the shoreline (Appendix Figure C-2).

At Charles Road, the water temperature on the floodplain was slightly lower than the temperature in the main channel. The floodplain at this site was heavily shaded, which may account for the differences (Appendix Figure C-3).

Flow in the Tuolumne River (measured at LaGrange) rose sharply in January 2006 and then again in the spring of 2006, peaking in April and May. The predator surveys (May 3–5) occurred at a time when flows were at their highest during the 2005–2006 water year (Figure 3-2, Table 3-2). Flows showed little daily fluctuation during the study period (May 3–24), but began to decline in early May following the predator surveys.

Water temperatures during the predation assessment study period were within the range of suitability for juvenile salmon, but were at the low end of the preferred range for Chinook salmon rearing (Brett 1952) and growth (Rich 1987, Cech and Myrick 1999). Water temperatures were also at the low end of the range suitable for foraging and growth by largemouth and smallmouth bass (Coutant 1975, Zweifel et al. 1999).

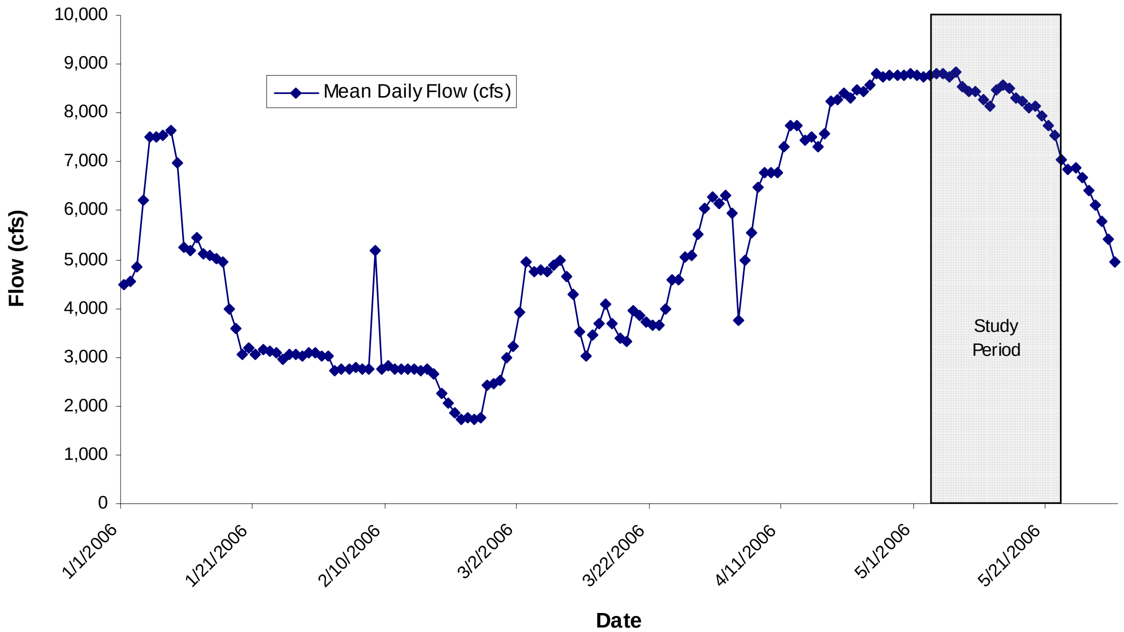

Figure 3-1. 2006 Tuolumne River mean daily flow at LaGrange.

Table 3-2. Tuolumne River flows at LaGrange during the predation assessment study period.

Study Period	***Flow (cfs)***[1]		
	Minimum	***Maximum***	***Mean***
Marking period	8540	8990	8796
Tracking period	6740	9120	8154

[1] Calculated from instantaneous hourly peak flow data.

Figure 3-2. Inundated floodplain habitat at Charles Road, May 2006.

3.2 Floodplain and Channel Margin Surveys

Floodplain and stream margin habitats were sampled at each of the three study sites with a beach seine. The sample locations are displayed in Appendix Figure A-1. The seine locations were on inundated floodplains or along stream margins that were recently submerged. The habitat therefore typically contained submerged vegetation including grasses, inundated shrubs and trees, as well as large woody debris. The habitat and water quality characteristics at each of the sample locations are summarized in Table 3-3.

Table 3-3. Habitat and water quality characteristics at seine survey locations in floodplain habitat.

Date	Temp (°C)	Visibility (ft)	Conductivity (µS)	Turbidity (NTU)	Dissolved Oxygen (mg/l)	Haul No.	Avg. Length (ft)	Avg. Width (ft)	Total Seined Area (ft^2)	Avg. Depth (ft)	Max. Depth (ft)	Velocity (ft/s)	Substrate Dominant	Substrate Subdominant 1	Substrate Subdominant 2
SRP 9															
5/3/2006	11.9	2.5	44.6	7.9	12.7	1	30	10	300	3.0	4.5	0.0 to 0.5	Veg.	Sand	-
5/3/2006	11.9	2.5	44.6	7.9	12.7	2	25	10	250	3.0	4.5	0.0 to 0.5	Veg.	Sand	-
5/3/2006	11.9	2.5	44.6	7.9	12.7	3	20	10	200	2.5	4.0	0.0 to 0.5	Veg.	Sand	-
5/4/2006	12.2	3.0	44.5	4.0	12.6	4	20	15	300	2.5	3.0	0.04	Veg.	Sand	-
5/4/2006	12.2	3.0	44.5	4.0	12.6	5	30	10	300	2.0	2.5	0.04	Veg.	Sand	-
SRP 10															
5/3/2006	12.0	3.5	43.8	4.9	12.7	1	30	20	600	3.0	3.5	0.0 to 0.5	Veg.	Sand	Silt
5/3/2006	12.0	3.5	43.8	4.9	12.7	2	40	20	800	3.0	3.5	0.0 to 0.5	Veg.	Sand	Silt
5/3/2006	12.0	3.5	43.8	4.9	12.7	3	25	20	500	3.0	3.5	0.0 to 0.5	Veg.	Sand	Silt
5/4/2006	11.8	3.0	44.1	N/A	11.8	1	30	15	450	3.0	4.0	0.0 to 0.5	Veg.	Sand	Silt
5/4/2006	11.8	3.0	44.1	N/A	12.8	2	30	15	450	3.0	4.0	0.0 to 0.5	Veg.	Sand	Silt
5/4/2006	11.8	3.0	44.1	N/A	13.8	3	15	10	150	3.0	4.0	0.0 to 0.5	Veg.	Sand	Silt
Charles Road															
5/4/2006	11.4	3.0	42.3	3.5	12.7	1	50	15	750	3.5	4.0	0.7 to 0.8	Veg.	Sand	Silt
5/4/2006	11.4	3.0	42.3	3.5	12.7	2	40	15	600	3.5	4.0	0.7 to 0.8	Veg.	Sand	Silt
5/4/2006	11.4	3.0	42.3	3.5	12.7	3	40	15	600	2.0	2.5	0.7 to 0.8	Veg.	Sand	Silt
5/4/2006	11.4	3.0	42.3	3.5	12.7	4	50	15	750	2.0	2.5	0.7 to 0.8	Veg.	Sand	Silt

The seine surveys captured both cold-water (e.g., salmon) and warm-water (e.g., sunfish) fish species. All of the sample locations were along or near shoreline habitat on inundated floodplain terraces. Fish species observed were similar at all three sites and included Sacramento pikeminnow, hardhead (*Mylopharodon conocephalus*), Mosquitofish (*Gambusia affinis*), Sculpin spp.(*Cottidae* family), Chinook salmon, bluegill (*Lepomis macrachirus*), Sacramento sucker (*Catostomus occidentalis*), and redear sunfish (*Lepomis microlophus*) (Table 3-4). Most fish observed were young-of-year or juveniles, however adult sunfish were also observed.

Table 3-4. Species observed during seine surveys in floodplain habitat[1].

Date:	*Species*	*Number of Fish*	*Fork Length (mm)*	*Weight (g)*
SRP 9				
5/3/2006	Chinook salmon	1	67	3.2
5/3/2006	Chinook salmon	1	80	6.2
5/3/2006	Bluegill	1	161	-
5/3/2006	Cyprinid sp.	1	young of year	-
5/4/2006	Hardhead	4	25-35	-
5/4/2006	Cyprinid sp.	1	12	-
SRP 10				
5/3/2006	Chinook salmon	1	63	3.2
5/3/2006	Redear sunfish	1	161	-
5/3/2006	Sacramento sucker	1	34	-
5/3/2006	Sacramento pikeminnow	14	30-41	-
5/3/2006	Sculpin spp.	1	31	-
5/3/2006	Bluegill	1	27	-
5/4/2006	Gambusia	6	15-20	-
5/4/2006	Bluegill	1	81	-
5/4/2006	Sacramento sucker	3	35-45	-
5/4/2006	Sacramento pikeminnow	5	25-45	-
Charles Road				
5/4/2006	Chinook salmon	1	77	5.4
5/4/2006	Chinook salmon	1	82	6.4
5/4/2006	Bluegill	1	136	-
5/4/2006	Hardhead	3	30-35	-
5/4/2006	Sacramento pikeminnow	1	30	-
5/4/2006	Sculpin spp.	5	25-35	-

[1] Chinook salmon are reported individually, regardless of date of capture.

3.3 Prey Abundance and Habitat Use

Data from bi-weekly seining surveys and daily rotary screw trap monitoring conducted by TID/MID indicate that the abundance of juvenile Chinook salmon (i.e., prey) in the lower Tuolumne River during the predation assessment was extremely low. No juvenile salmon were captured in seining surveys at Charles Road (RM 24.9) during the three weeks prior to the predation studies (April 12, and 26 survey dates) or the four weeks following the surveys (May 10 and 31 survey dates) (Figure 3-4). Upstream of the study reach, seining surveys at Hickman

(RM 31.6) and Fox Grove (RM 26) recovered only one juvenile salmon (on May 10) during this seven week period. Salmon density reported from the bi-weekly seining surveys was relatively high at both locations during the March 31 survey, but declined to near zero in subsequent surveys, possibly in response to river flows, which increased rapidly during the first week of April and remained above 6,000 cfs during the remainder of April and most of May (Figure 3-4). Seining surveys conducted on inundated floodplains in the study reach during this study, however, documented juvenile Chinook salmon at each of the three study sites (restored SRP 9, SRP 10, and Charles Road) (Table 3-4), indicating that salmon were present, albeit in low numbers, during the predation assessment study period.

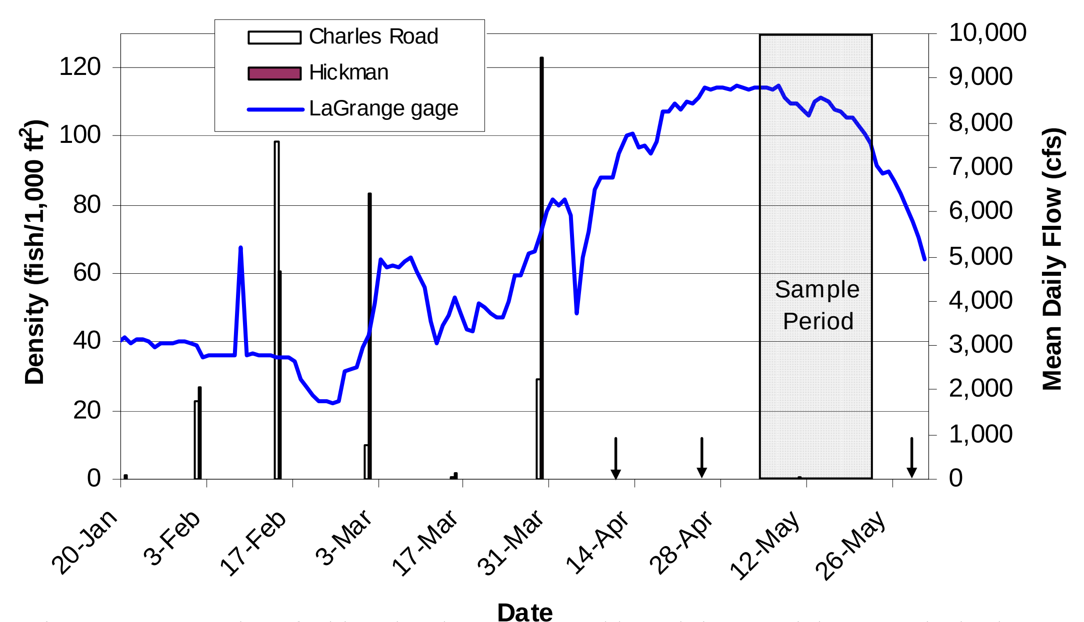

Figure 3-3. Density of Chinook salmon captured by seining at Hickman and Charles Road.

Note: ↘ *Denotes survey dates for which no fish were captured at Charles Road or Hickman.*

RST capture data also indicate that salmon density in the river during this period was very low. Raw RST data from the upstream trap at Waterford (RM 34) and the dual traps located downstream at Grayson (RM 5) show daily capture rates during the early part of the predation assessment study period ranging from 0–5 salmon per trap (Figure 3-5). Daily captures at the Waterford trap increased in mid- and late-May, but captures at the Grayson traps remained at very low levels through the study period. Because these are raw capture data and have not been expanded for trap efficiency, actual numbers of outmigrating salmon during this period are likely considerably higher. Considering that the predation assessment study period occurred relatively late in the typical January–June salmon outmigration period, it is reasonable to assume that most salmon had moved downstream prior to the study period. Based on the seining and RST data, it appears that the salmon remaining in the river during this time were occupying both low-velocity inundated floodplain habitat and high-velocity mid-channel habitat.

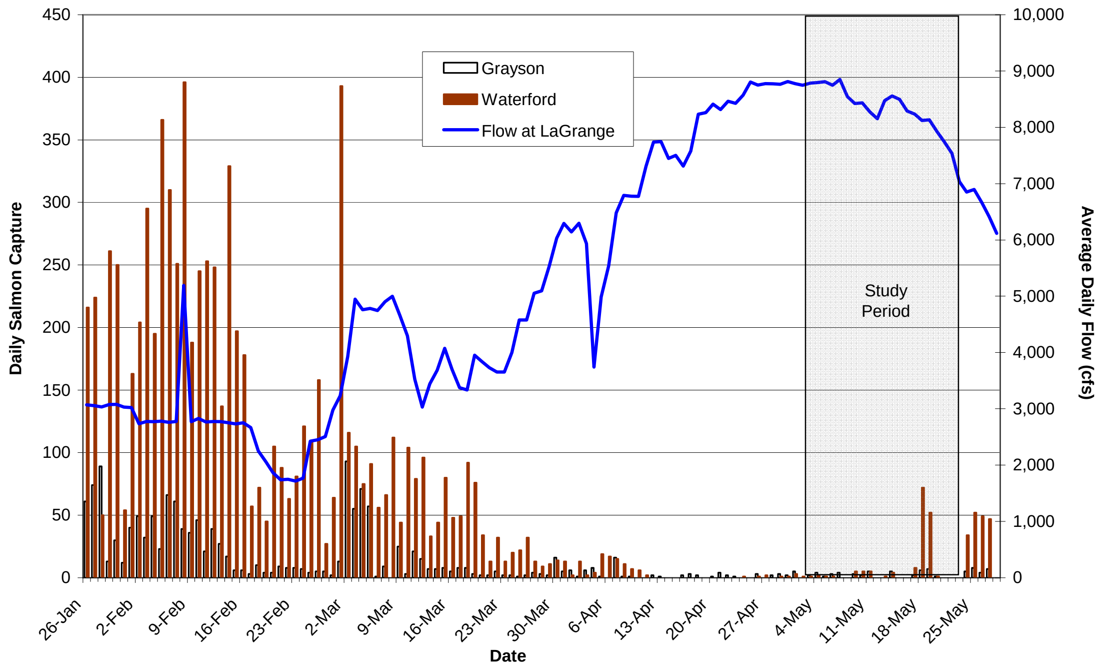

Figure 3-4. Number of salmon captured in Tuolumne River rotary screw traps, 2006.

3.4 Predators

A total of four potential salmon predators were captured during the three day angling survey: one smallmouth bass and three largemouth bass (Table 3-5). No striped bass or Sacramento pikeminnow were captured or observed during sampling and no fish of any species measuring <150 mm were captured by angling. No largemouth bass, smallmouth bass, striped bass, or Sacramento pikeminnow of any size were captured by seining.

Table 3-5. Location, habitat characteristics, and stomach contents of potential salmon predators captured and tagged in the lower Tuolumne River, May 3–5, 2006.

***Species*[1]**	***Total Length (mm)***	***Capture Date***	***Capture Location***	***Approx. Depth (ft)***	***Approx. Velocity (ft/s)***	***Stomach Contents***	***Salmon in Stomach***
SMB	273	3 May	Upstream of SRP 10; inundated floodplain/backwater on River Left	3–5	0–0.5	1 crayfish and 1 damselfly nymph	0
LMB	385	3 May	Charles Road; inundated floodplain on River Left	5–6	0	stomach empty	0
LMB	235	4 May	Upstream of SRP 10; inundated floodplain/backwater on River Right	3–5	0–0.5	stomach empty	0
LMB	386	5 May	Charles Road; inundated floodplain near water's edge on River Left	2–3	0–0.5	2 earthworms	0

[1] SMB = smallmouth bass; LMB = largemouth bass

3.5 Habitat Use

All predators were captured in slow-moving water near the bank (Table 3-5), in areas where complex cover was provided by instream vegetation, inundated terrestrial vegetation, and overhanging vegetation (Appendix A). The amount of cover at predator capture locations could not be accurately measured, but can be characterized as relatively dense, typically comprising at least 50% of the habitat area in the immediate vicinity of capture. Estimated water velocity at capture locations ranged from 0–0.5 ft/s, and depth ranged from 2–6 ft (Table 3-5). Bottom substrate characteristics were not recorded, but can be assumed based on the predominant substrate characteristics in the study reach (McBain & Trush and Stillwater Sciences 1999) to include predominantly sand and gravel, with some cobble and silt.

Habitat characteristics where predators were captured were within the range of those reported in the literature (Table 3-6) and used for habitat mapping and modeling in previous predator monitoring efforts (McBain & Trush and Stillwater Sciences 2006).

Table 3-6. Habitat suitability criteria for largemouth and smallmouth bass.

Criterion		***Largemouth Bass[1]***	***Smallmouth Bass[2]***
Velocity (ft/s)	usable	0-0.7	0-0.7
	preferred	0-0.2	0-0.3
Depth (ft)	usable	1.6-19.7	1.6-9.8
	preferred	3.3-19.7	3.3-9.8
Cover (%)	usable	20-80	25-100
	preferred	40-60	25-50
Predominant substrate	usable	coarse gravel/cobble	silt/sand
	preferred	silt/sand with gravel	gravel/boulder with interstitial spaces

[1]Stuber et al. (1982), [2]Edwards et al. (1983)

3.6 Diet and Predation Rate

Stomach contents of predators indicated that feeding activity was low during the predator capture period (May 3–5, 2006). Two of the three largemouth bass captured had empty stomachs, while the third stomach contained only two earthworms (Table 3-5). Stomach contents of the single smallmouth bass captured consisted of one crayfish and one damselfly nymph. Crayfish are a preferred prey item for adult smallmouth bass (Moyle 2002). No salmon were recovered from predator stomachs, and the predation rate on salmon was therefore determined to be zero.

Relatively low water temperatures during the predator capture period may have been the primary cause of low predator feeding rates. Water temperatures in inundated floodplain and shoreline areas, where all of the predators were captured, ranged from 10.9°C to 12.4°C (52–54°F) (Appendix C) during the capture period. Although these water temperatures are not low enough to completely preclude foraging by largemouth or smallmouth bass, feeding rates are greatly influenced by temperature and are reportedly low in this temperature range (Coutant 1975, Zweifel et al. 1999).

Foraging by largemouth bass begins at 5°C (41°F) and increases until water temperatures reach approximately 27°C (81°F) (Figure 3-5) (Coutant 1975, Zweifel et al. 1999). For smallmouth bass, maximum prey consumption rate peaks at approximately 22°C (72°F) and declines at higher temperatures (Zweifel et al. 1999). At temperatures below 10°C (50°F), however, largemouth and smallmouth bass exhibit little, if any, feeding behavior (Coutant 1975). The estimated prey consumption rate by largemouth bass, at the temperatures encountered during the predator sampling period, was approximately 1.3–1.7 prey per bass per week (Figure 3-5). Larger bass (which are more likely to prey on juvenile salmon) are reported to initiate feeding at slightly higher temperatures than smaller bass (Markus 1932, Stroud 1948; both as cited in Coutant 1975), although we did not review the original studies and specific sizes and temperatures are therefore not known. Growth in largemouth bass reportedly begins at temperatures of about 10°C (50°F) (Markus 1932, Bennett 1954; both as cited in Coutant 1975). Growth rates at temperatures lower than about 14°C (57°F) are apparently very low, however, and most known studies of black bass growth do not test or report smallmouth bass growth below 16.5–18°C (62–64° F) (Coble 1967, Zweifel et al. 1999), or largemouth bass growth below 18°C (Strawn 1961, Coutant 1975, Zweifel et al. 1999). While spring water temperatures in the Tuolumne River are never low enough to preclude bass foraging, the low temperatures during the high spring flows in 2006 were likely sufficient to depress bass foraging and growth rates.

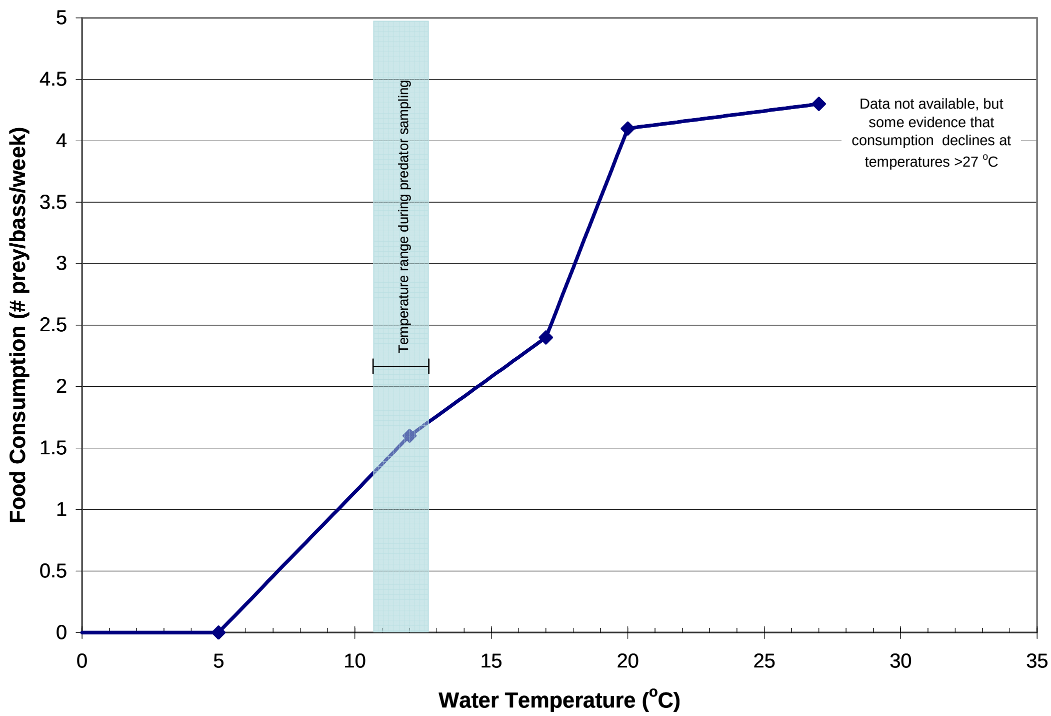

Figure 3-5. Influence of water temperature on prey consumption rate of largemouth bass. Source: Coutant (1975).

3.7 Telemetry

As discussed above, two of the predators were originally captured near SRP 10 and the other two were captured at the riffle control site at Charles Road. No predators were captured in or near the restored SRP 9. The four predators captured during the angling surveys were each implanted with a radio transmitter tuned to a unique frequency which allowed each individual fish to be tracked and located within specific microhabitats. The individual tracking frequencies of each predator used in the habitat-use analysis are listed in Table 3-7 along with the species, size, and locations observed during the tracking period.

Following their release, all predators remained in nearshore or inundated floodplain habitats with low water velocities, abundant cover, and depths ranging from 4–12 feet (Table 3-7, Appendices A and B). The two predators captured at SRP 10 (largemouth bass 1.031 and smallmouth bass 1.302) were found near each other in the same area and habitat type soon after their release. These bass were observed in flooded riparian vegetation (primarily willows and alders) in backwater habitat with little to no velocity (Figure 3-6). However, the location initially occupied by these two fish was near a velocity break, immediately adjacent to faster water (Appendix Figure A-3). On May 9, 2006 the smallmouth bass (1.302) was located across the river near a flooded island in a location with low water velocity and submerged vegetation. This bass remained at this location at least until May 17, but was not located during the final monitoring survey on May 24. The largemouth bass (1.031) remained at the original release location through the end of the monitoring period on May 24. The predator capture and tracking locations are displayed in Appendix A, Figures A-1 through A-4.

Figure 3-6. Inundated riparian trees (willow and alder) upstream of SRP 10, May 2006.

The two predators captured at Charles Road (riffle control) (largemouth bass 1.382 and 1.540) were also found near each other in the same area and habitat type following their release (Table 3-7). These two largemouth bass were observed in flooded vegetation (primarily willows and alders) between the main channel and an inundated pond on the floodplain terrace (left bank). This area was considered backwater habitat and had little to no velocity. One of these largemouth bass (1.382) remained in the pond area for about a week but on May 24 was relocated about 1.1 miles downstream. This bass was found occupying steeply sloping shoreline habitat among submerged woody debris, in an area with low water velocity and no overhead cover. The other largemouth bass originally captured and released at Charles Road (1.540) remained in the inundated pond for the duration of the study.

The water temperature at these locations did not exceed 13°C (55°F) and the average dissolved oxygen concentration remained high (11.2 mg/l). The locations and habitat conditions are summarized in Appendix Table B-1.

Table 3-7. Predator capture and tracking locations.

Species	*Total Length (mm)*	*Transmitter Frequency*[1]	**Floy tag Number & Color**	**Date and Location Observed**				
				Capture	**May 5, 2006**	**May 9, 2006**	**May 17, 2006**	**May 24, 2006**
LMB	235	1.031	0072 green	Upstream of SRP 10; inundated floodplain -backwater habitat on River Left	Same as previous	Same as previous	Same as previous	Same as previous
SMB	273	1.302	0069 green	Upstream of SRP 10; inundated floodplain -backwater habitat on River Left	Same as previous	Upstream of SRP 10; inundated island in mid channel (River Right bank under low flow)	Same as previous	Did not locate
LMB	385	1.382	0070 green	Charles Rd; inundated floodplain on River Left near water's edge	Charles Rd; Moved to flooded trees between main channel and flooded pond.	Same as previous	Did not locate	~1.1 mi downstream of Charles Rd.
LMB	386	1.540	0073 green	Charles Rd; inundated floodplain on River Left near water's edge	Day of release	Charles Rd; Moved to edge of flooded pond near LWD cover.	Charles Rd; Moved to innundated floodplain upstream edge of pond.	Charles Rd; Moved to edge of flooded pond near River Left edge of water.

[1] Radio transmitters are expected to transmit through June 24, 2006 and may transmit through August 13, 2006.

3.8 Hypotheses and Study Objectives

Due to high flows and the low number of captures of predators and salmon at the study sites, it was not possible to thoroughly test the high flow hypotheses (13A, 13B, and 13D; see Table 1-1) or meet the study objectives. The hypotheses are listed below, with a brief discussion of relevant study results.

3.8.1 Hypotheses

H13A In SRP 9, segregation of habitat selected by outmigrating Chinook salmon and predators occurs at flows exceeding 1,500 cfs.

No predators were captured at SRP 9 in either the mid-channel or on inundated floodplains. Two juvenile Chinook salmon were captured by seining on the inundated floodplain, but high flows and low visibility precluded sampling for salmon (seining or snorkeling) in higher velocity areas closer to mid-channel. The hypothesis that high flow habitat segregation occurs between Chinook salmon and predators at the restored SRP 9 could not be tested.

H13B Predation rates at flows ≥ 1,500 cfs are significantly less at SRP 9 and the riffle control sites than at SRP control sites.

No salmon were recovered from the stomachs of the four predators captured, and predation rate was therefore determined to be zero. Although two predators were captured near SRP 10, no predators were captured within this SRP control site and none were captured at SRP 9. Therefore, this hypothesis could not be tested.

H13D At SRP 9, predation rates by smallmouth bass are significantly higher than predation rates by largemouth bass, Sacramento pikeminnow, and striped bass.

No predators were captured at SRP 9. One smallmouth bass and three largemouth bass were captured, but no salmon were recovered from bass stomachs. No Sacramento pikeminnow or striped bass were captured. Because predation rate could not be determined for SRP 9, this hypothesis could not be tested.

3.8.2 Study Objectives

1) Document the predation rate in SRP 9 and compare with predation rates at SRP and riffle control sites (H13B and H13D, above).

This study objective could not be met due to the lack of salmon in predator stomachs and our inability to determine predation rate at SRP 9. Although the two predators with prey in their stomachs were captured in different areas, these and the other two predators (which had empty stomachs) were all captured in similar habitat types: inundated floodplains with low water velocity and cover provided by submerged vegetation.

2) Document velocity-driven or temperature-driven spatial distribution of predators and salmon at SRP 9 and an SRP control site, and determine whether the two species are spatially segregated (H13A).

This study objective was only partially met because all salmon and predators captured during this study were located in inundated floodplain habitat. High flow conditions precluded sampling for salmon in mid-channel areas. Angling was repeatedly attempted in mid-channel areas at each site, but due to a lack of success most angling effort was focused in nearshore areas and on inundated floodplains. Velocity-driven or temperature-driven spatial segregation between salmon and predators could not be unequivocally documented. However, it appears that some segregation between bass and salmon occurred at the microhabitat level during the study, apparently due to the use of areas with dense instream cover and low water velocity by bass.

3.9 Summary

The lack of predator captures at SRP 9 and in the main pit area of SRP 10 may have been influenced by the relatively small amount of suitable habitat during the predation assessment surveys. Although depth and bottom substrate were presumably suitable, it is likely that water velocity and cover in much of SRP 9 was either unsuitable or marginally suitable for bass. At SRP 9, areas of complex instream cover and low-velocity or backwater habitat were notably lacking at the flow conditions that occurred during the surveys. This is attributable to the channel and floodplain morphology, the relative lack of dense, inundated riparian vegetation or woody debris, and the high flows that occurred during the surveys. At SRP 10, cover was undoubtedly present (as documented in previous habitat surveys), but it is possible that high water velocity rendered much habitat unusable by bass.

The low number of bass captures may also be an artifact of the sampling method that was used and the low water temperatures during the predator surveys. Fish capture by angling relies on feeding behavior by the target fish. Evidence from stomach content analysis of the bass we captured, and from published studies of the relationship between temperature and bass feeding behavior (Coutant 1975, Zweifel et al. 1999), indicates that feeding by bass was probably minimal during the study due to low water temperatures. This temperature effect almost certainly influenced the rate of predation by bass on salmon during the study. Despite the documented presence of both salmon and bass on inundated floodplains, the observed predation rate was zero. It appears, then, that predation by bass on salmon may be negligible at the temperatures encountered during the study (10.7–12.8°C), even in areas where bass and salmon co-occur.

Segregation between bass and salmon at the flows occurring during the study (approximately 7,000–8,800 cfs) was not documented at the macrohabitat level. The juvenile Chinook salmon and piscivore-sized bass captured during the surveys were all found on inundated floodplains or in nearshore areas. However, bass and salmon did appear to occupy habitat with slightly different depth, velocity, and cover characteristics. The range of depths and water velocities at capture locations indicates that, when captured, bass were occupying somewhat deeper and slower water (2–6 ft and 0–0.5 ft/s, respectively) than salmon (2–3.5 ft and 0–0.8 ft/s, respectively). It is possible, however, that this apparent difference in habitat use was the result of the shallower habitats sampled by seining. Differences in instream cover between bass and salmon capture locations may have played a more important role in the minimal but apparent microhabitat segregation of bass and juvenile salmon. Whereas bass were captured in areas with complex cover provided primarily by instream or flooded vegetation, salmon were captured in areas largely devoid of substantial instream cover. Although this difference may be primarily due to the infeasibility of seining in areas with obstacles such as inundated vegetation or woody debris, angling in areas with bottom and instream cover characteristics similar to seined areas (see Appendix A) resulted in no predator captures. Largemouth bass prefer habitat with 40–60%

cover, and smallmouth bass prefer 25–50% cover (Table 3-6). The use of instream cover by juvenile salmon during the predation assessment surveys is not known, but it is reasonable to assume that salmon would avoid areas that were occupied by bass. Furthermore, because suitable habitat for salmon includes higher water velocities than those preferred by bass (USFWS 1995, Stuber et al. 1982, Edwards et al. 1983), salmon may not occupy the slower-moving water among inundated vegetation that typified bass capture locations.

Our inability to test the predation hypotheses and fully meet the study objectives is due largely to the high flows and low temperatures that occurred in the lower Tuolumne River in spring 2006. Still, the data collected during this study are an important first step in filling the data gap regarding predation and habitat use by bass during high river flows. However, because of the lack of data on predation by bass on salmon, and the unanswered questions related to high-flow habitat segregation between predators and salmon, the primary project hypothesis remains untested.

Future studies to document predation rate and assess velocity-driven and temperature-driven habitat segregation between salmon and predators should be conducted at lower flows when mid-channel areas can be more effectively surveyed and higher water temperatures facilitate increased predator feeding rates. Additional methods, possibly including underwater video, snorkeling, or electrofishing, should be used to more effectively capture predators in all habitat types. If possible, future predation studies should be conducted earlier in the outmigration period when prey density and predation rates are higher and predator diets are more likely to include salmon. In addition, the low salmon escapement in 2005 and subsequently low abundance of juveniles in spring 2006 are not typical of recent years (TID/MID 2005), in which predation rates may have been considerably higher. Additional predation studies should be attempted during a period of relatively high juvenile salmon abundance that is representative of recent population levels.

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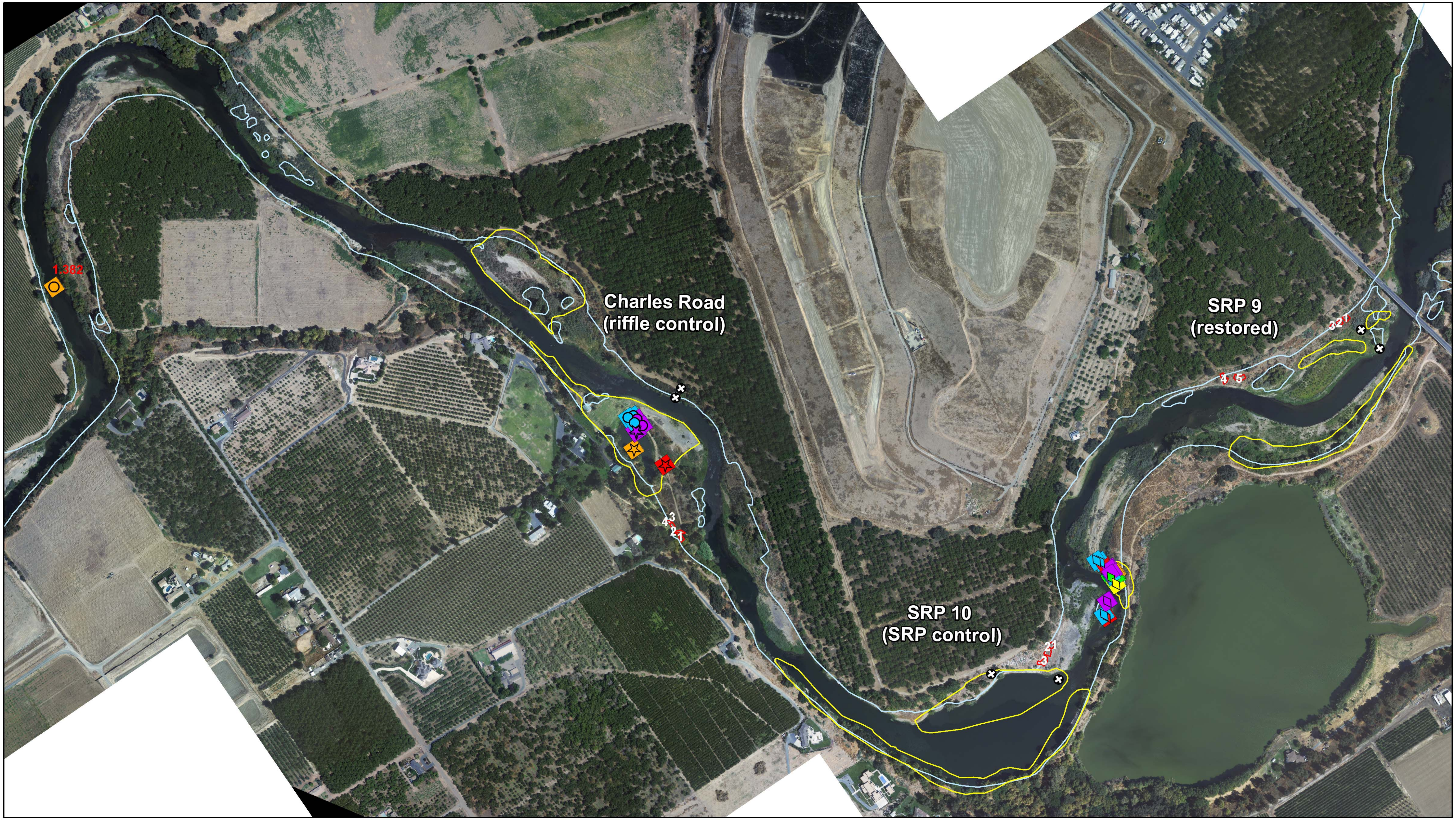
Appendix A

Aerial Photograph Maps of Study Sites and Predator Capture/Recapture Locations



Predator capture/tracking radio frequency tag ID

- □ 1.031 Largemouth bass
- ◯ 1.382 Largemouth bass
- ◇ 1.302 Smallmouth bass
- ☆ 1.540 Largemouth bass

Predator capture/tracking locations by date

- 3 May 2006
- 9 May 2006
- 4 May 2006
- 17 May 2006
- 5 May 2006
- 24 May 2006

- Thermograph locations
- Primary predator angling survey area
- Seining survey area
- Approximate 8000 cfs wetted perimeter

Figure A-1.
Tuolumne Predator Monitoring, May 2006

Flow direciton

Feet
0 200 400 600 800

Image source: Sept 2005, Sanborn, taken at 330 cfs.

Stillwater Sciences
6/21/2006

Predator capture/tracking radio frequency tag ID

- □ 1.031 Largemouth bass
- ◊ 1.302 Smallmouth bass
- ○ 1.382 Largemouth bass
- ☆ 1.540 Largemouth bass

Predator capture/tracking locations by date

- 3 May 2006
- 4 May 2006
- 5 May 2006
- 9 May 2006
- 17 May 2006
- 24 May 2006

- Thermograph locations
- Primary predator angling survey area
- Seining survey area
- Approximate 8000 cfs wetted perimeter

Figure A-2.
Tuolumne Predator Monitoring, May 2006
SRP 9 (restored) Site

Flow direciton

Feet
0 50 100 150 200

Image source: Sept 2005, Sanborn, taken at 330 cfs.

Stillwater Sciences

6/21/2006

Predator capture/tracking radio frequency tag ID

- □ 1.031 Largemouth bass
- ◊ 1.302 Smallmouth bass
- ○ 1.382 Largemouth bass
- ☆ 1.540 Largemouth bass

Predator capture/tracking locations by date

- 3 May 2006
- 4 May 2006
- 5 May 2006
- 9 May 2006
- 17 May 2006
- 24 May 2006

- Thermograph locations
- Primary predator angling survey area
- Seining survey area
- Approximate 8000 cfs wetted perimeter

Figure A-3.
Tuolumne Predator Monitoring, May 2006
SRP 10 (SRP control) Site

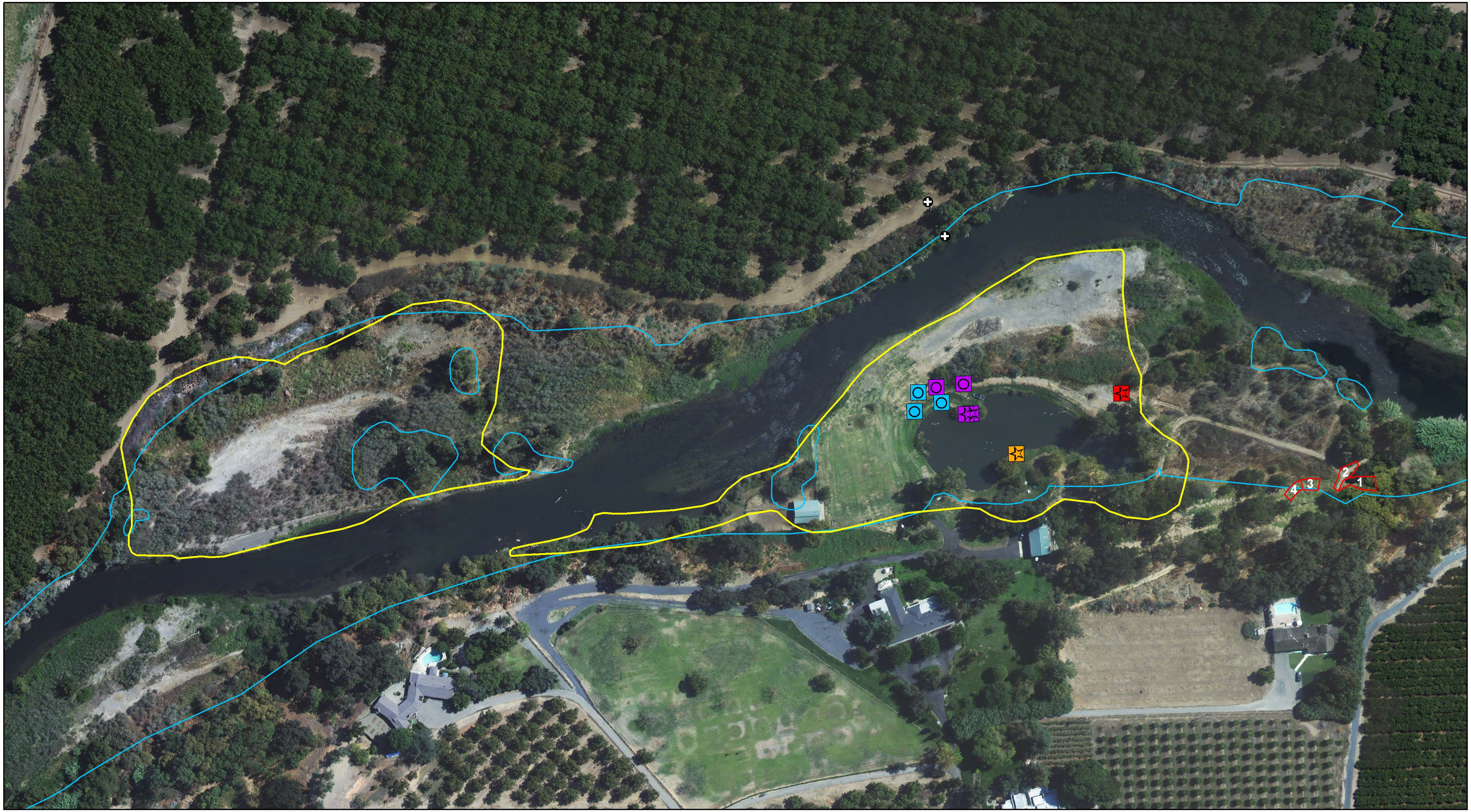
Flow direciton

Feet
0 50 100 150 200

Image source: Sept 2005, Sanborn, taken at 330 cfs.

Stillwater Sciences

6/21/2006



Predator capture/tracking radio frequency tag ID

- □ 1.031 Largemouth bass
- ◊ 1.302 Smallmouth bass
- ○ 1.382 Largemouth bass
- ☆ 1.540 Largemouth bass

Predator capture/tracking locations by date

- 3 May 2006
- 4 May 2006
- 5 May 2006
- 9 May 2006
- 17 May 2006
- 24 May 2006

- Thermograph locations
- Primary predator angling survey area
- Seining survey area
- Approximate 8000 cfs wetted perimeter

Figure A-4.
Tuolumne Predator Monitoring, May 2006
Charles Road (Riffle Control) Site

Flow direciton

Feet

0 50 100 150 200

Image source: Sept 2005, Sanborn, taken at 330 cfs.

Stillwater Sciences

6/21/2006

Appendix B

Predator Tracking Locations and Habitat Conditions

Table B-1. Predator tracking locations and habitat conditions.

Appendix Table B-1. Predator tracking locations and habitat conditions.

Species	*Transmitter Frequency*[1]	*Date*	*Location*	*Water velocity (fps)*	*Water Temp (°C)*	*Cover*	*Dissolved Oxygen (mg/l)*	*Conductivity to 25 °C*	*Conductivity (Adjusted to temp.)*
LMB	1.031	Capture 4-May	Upstream of SRP 10; inundated floodplain - backwater habitat on River Left	0-1	-	Submerged trees	-	-	-
		5-May	Same as previous	0	-	Submerged trees	-	-	
		9-May	Same as previous	0	11.4	Submerged trees	11.4	32.7	44.1
			May have moved out from trees and went back in as the boat approached	0	11.9	Submerged trees	11.22	32.8	44
		17-May	Same as previous	0	12.5	Submerged trees	11.78	35.7	46
		24-May	Same as previous	0.1	12.5	Submerged trees	11.82	31.7	41.6

Appendix Table B-1. Predator tracking locations and habitat conditions.

Species	Transmitter Frequency[1]	Date	Location	Water velocity (fps)	Water Temp (°C)	Cover	Dissolved Oxygen (mg/l)	Conductivity to 25 °C	Conductivity (Adjusted to temp.)
SMB	1.302	Capture 3-May	Upstream of SRP 10; inundated floodplain - backwater habitat on River Left	0-1	-	Submerged trees	-	-	-
		5-May	Same as previous	0-1	-	Large Wood Debris	-	-	
		9-May	Upstream of SRP 10; inundated island in mid channel (River Right bank under low flow)	0.4	11.4	Submerged trees	11.02	32.7	44.2
			Same as previous - moved slightly toward velocity break	0.5-1.5	11.7	Submerged trees	10.94	32.5	43.5
		17-May	Same as previous	0.5	12.4	Submerged trees	12.4	35	45.9
		24-May	Did not locate	-	-	-	-	-	-

Appendix Table B-1. Predator tracking locations and habitat conditions.

Species	***Transmitter Frequency***[1]	***Date***	***Location***	***Water velocity (fps)***	***Water Temp (°C)***	***Cover***	***Dissolved Oxygen (mg/l)***	***Conductivity***	
								to 25 °C	***(Adjusted to temp.)***
LMB	1.382	Capture 3-May	Charles Rd; inundated floodplain on River Left near water's edge	0	-	Overhanging vegetation	-	-	-
		5-May	Charles Rd; Moved to flooded trees between main channel and flooded pond.	0	-	Submerged trees and deep water	-	-	
		9-May	Same as previous	0	11.7	Submerged trees	11.17	32.8	43.9
			Same as previous	0.2	11.9	Submerged trees	10.25	32.9	43.9
		17-May	Did not locate	-	-	-	-	-	-
		24-May	~1.1 mi downstream of Charles Rd. along bank near Johansen Rd.	0.1	12.7	Large Wood Debris	10.9	34	45.1

Appendix Table B-1. Predator tracking locations and habitat conditions.

Species	Transmitter Frequency[1]	Date	Location	Water velocity (fps)	Water Temp (°C)	Cover	Dissolved Oxygen (mg/l)	Conductivity to 25 °C	Conductivity (Adjusted to temp.)
LMB	1.540	Capture 5-May	Charles Rd; inundated floodplain on River Left near water's edge	0	-	Overhanging vegetation	-	-	-
		5-May	Release date	-	-	-	-	-	
		9-May	Charles Rd; Moved to edge of flooded pond near LWD cover.	0.2	11.4	Large Wood Debris	10.63	32.7	44.1
			Same as previous	0	11.5	Large Wood Debris	11.02	32.7	44.0
		17-May	Charles Rd; Moved to innundated floodplain upstream edge of pond.	0.3	12.9	sumberged grasses with overhanging cover	11.5	34.1	44.3
		24-May	Charles Rd; Moved to edge of flooded pond near River Left edge of water.	0.1	12.5	Overhanging vegetation	11.4	32.5	42.8

[1] *Radio transmitters are expected to transmit through June 24, 2006 and may transmit through August 13, 2006.*

Appendix C

Water Temperatures at SRP 9, SRP10, and Charles Road During the Predator Capture Period.

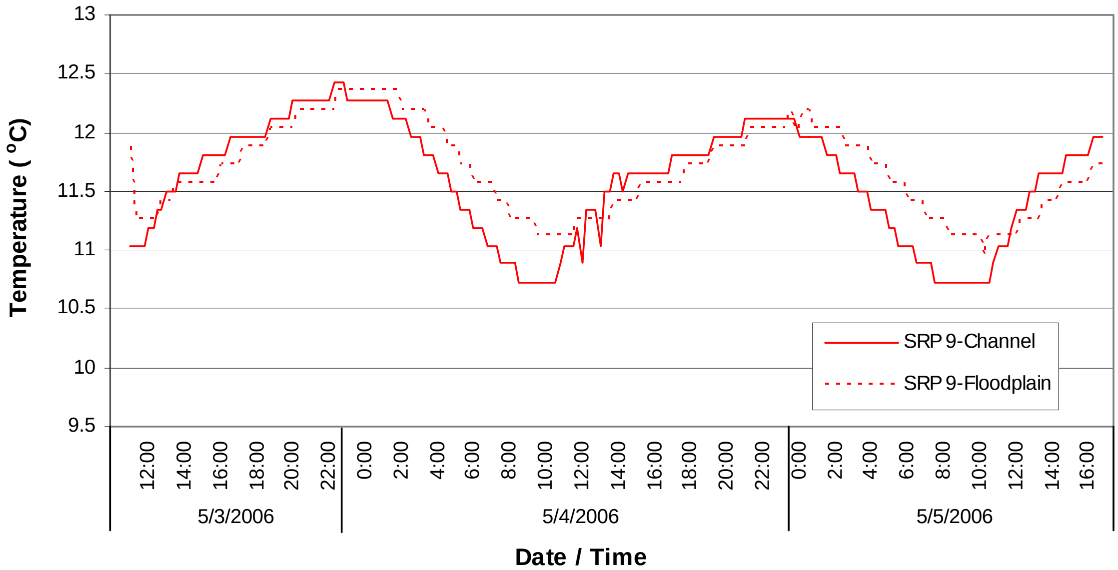


Figure C-1. Water temperatures at SRP 9 during the predator capture period.

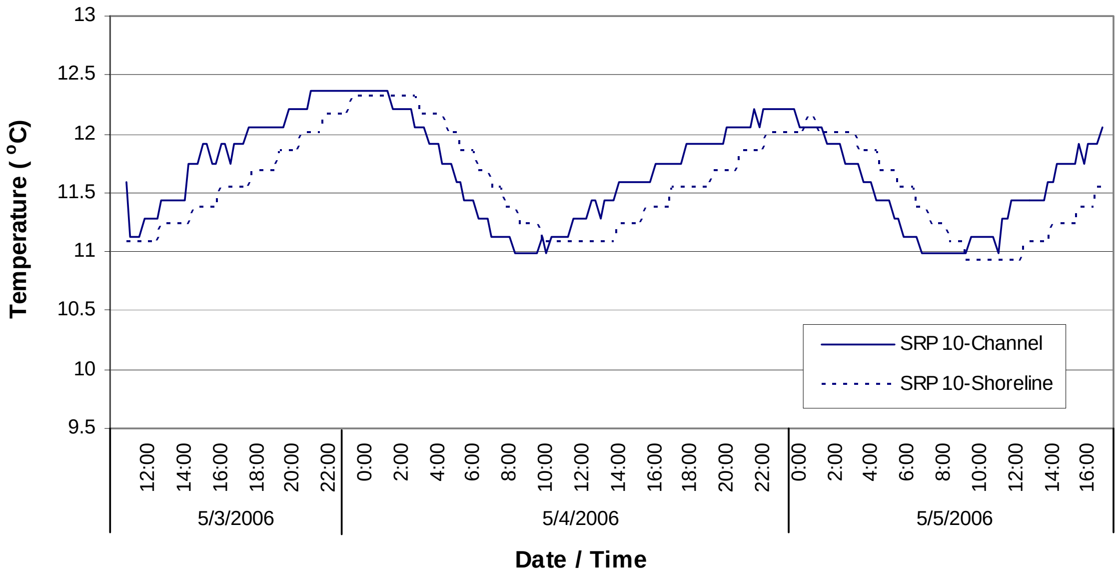


Figure C-2. Water temperatures at SRP 10 during the predator capture period.

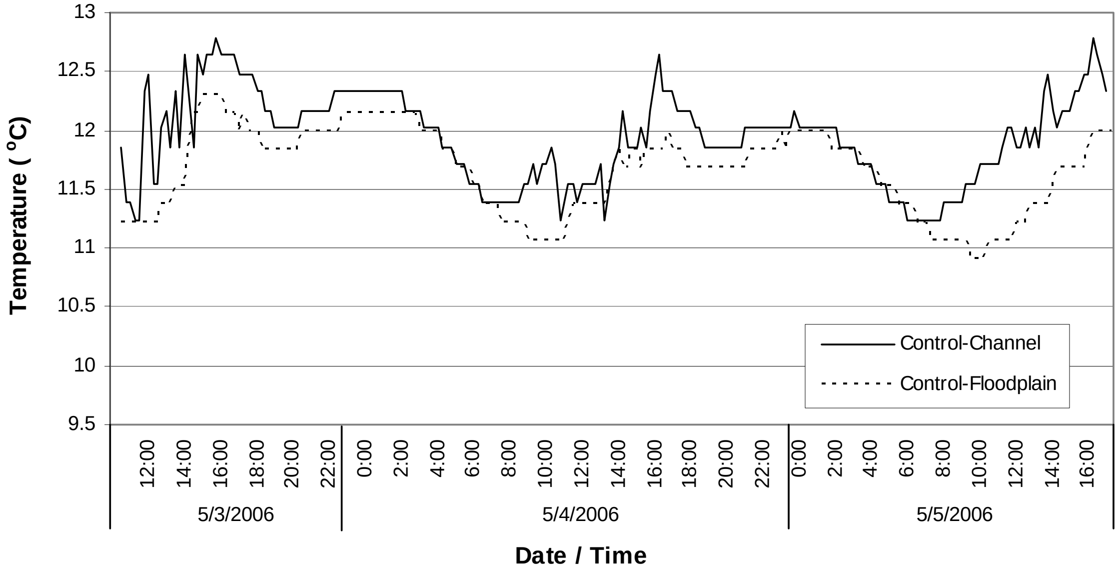


Figure C-3. Water temperatures at Charles Road during the predator capture period.