Adult Spring Chinook Salmon Monitoring in Clear Creek, California,

2010 Annual Report

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Abstract.**—**The Central Valley Project Improvement Act, Clear Creek Fish Restoration Program, and California Ecosystem Restoration Program have directed several stream restoration actions to recover threatened Central Valley spring Chinook salmon in Clear Creek. The Red Bluff Fish and Wildlife Office has monitored adult spring Chinook salmon (SCS) in Clear Creek since 1999, and this report summarizes our monitoring efforts for 2010. In 2010, the spring Chinook salmon August Index (SCS AI) snorkel count was 21. Two temporary picket weirs were installed because a proportion of the SCS AI was located between the weir sites, and initially undetected during the snorkel survey that determined the weir location. The intention of having a weir at each site was to protect more SCS. Of the SCS AI, 67% was upstream of the Reading Bar weir, 14% was between the weirs, and 19% was downstream of both weirs. Although the Shooting Gallery weir was not fully effective at blocking fall Chinook salmon (FCS), the Reading Bar was effective at protecting the majority of the SCS, by separating FCS from SCS during spawning. Water temperature criteria, ≤60°F mean daily temperature (MDT), was met during the SCS holding period (June 14–September 14), however, 38% percent of the adult SCS were located downstream of the compliance point at the Igo gaging station (IGO) and exposed to temperatures >60°F. During the spawning temperature criteria period, MDTs exceeded 56°F at IGO through October 18, and 74% of the period. The SCS redd count was 10, and 40% were downstream of IGO. On average, SCS redds were exposed to MDT >56°F, 21% "minimum" and 30% "maximum" of incubating days. The spawning temperature criteria was not met in part because of higher Whiskeytown Reservoir water temperatures, and a reduced cold water pool. Since increased water releases out of the reservoir did not cool water temperatures sufficiently to meet spawning criteria, changes to reservoir operations may need to be considered. It was difficult to evaluate the effectiveness of the spring pulse flows to attract SCS into Clear Creek because of the low numbers of adult salmon observed during snorkel surveys.

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Introduction

The National Marine Fisheries Service (NMFS) listed Central Valley spring Chinook Salmon (*Oncorhynchus tshawytscha*) as a threatened species in 1999 under the Federal Endangered Species Act (ESA) (NOAA 1999). Their threatened status was reaffirmed in 2005 following the NMFS' hatchery listing policy (NOAA 2005). The Central Valley Project Improvement Act (CVPIA) Clear Creek Fish Restoration Program and the California Ecosystem Restoration Program have directed several stream restoration actions to recover Central Valley spring Chinook Salmon (SCS) in Clear Creek, Shasta County, California, which include increased flows, dam removal, and spawning gravel supplementation (BOR and USFWS 2009). Beginning in 1995, the Bureau of Reclamation (BOR) maintained water releases from Whiskeytown Dam to improve salmonid holding, spawning, and rearing habitat on Clear Creek. The removal of Saeltzer Dam in the fall of 2000 provided salmonid passage and access to an additional 12 miles habitat. In addition, the Western Shasta Resource Conservation District (WSRCD) has implemented spawning gravel supplementation projects since 1996 in an effort to improve and increase salmonid spawning habitat.

The Red Bluff Fish and Wildlife Office (RBFWO) has monitored adult SCS in Clear Creek since 1999. The purpose of our monitoring is to assess the population status of SCS, thereby assessing the effectiveness of stream restoration actions and providing input for future restoration efforts on Clear Creek. Our monitoring consists of (1) conducting snorkel surveys to obtain a SCS population estimate through live, redd and carcass counts, (2) installation and monitoring of a temporary picket weir to separate fall Chinook salmon (FCS) from SCS during spawning, (3) collection and evaluation of water temperature data to determine if temperature criteria developed to protect SCS holding and spawning was met, and (4) assessment of spawning gravel supplementation projects using redd counts. We recognized the need for the weir after the removal of Saeltzer Dam because snorkel survey results showed there was not a complete spatial or temporal separation between SCS and FCS during spawning, which threatened efforts to restore SCS to Clear Creek (Newton and Brown 2004).

In addition to our regular monitoring, in 2010, we monitored effects of two pulse flows (controlled high flow water releases at Whiskeytown Dam) that occurred in May and June, to determine if they were effective at attracting SCS into Clear Creek. The pulse flows were designed to fulfill "Action I.1.1. Spring Attraction Flows" of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion for the Bureau of Reclamation's Operations Criteria and Plan for the Central Valley Project page 587 (NMFS 2009). This annual report summarizes our adult SCS monitoring data for 2010.

Study Area

Clear Creek is a western tributary of the Sacramento River, located in Shasta County, California (Figure 1). Our study area extends from Whiskeytown Dam (river mile (RM) 18.3) downstream to the RBFWO lower rotary screw trap (LCC RST) at RM 1.8 (Figure 1). The BOR controls water releases into Clear Creek at Whiskeytown Dam, which is a complete barrier to fish passage. We divided our snorkel survey area into reaches based upon distance, accessibility, and the location of our temporary picket weir (Table 1; Figure 1). The first two miles downstream of Whiskeytown Dam are alluvial (Reach 1). In Reaches 2, 3, and 4 (RM 16.1 (Need Camp Bridge) to RM 8.5 (Clear Creek Road Bridge)), steep canyon walls confine the creek and habitat consists of falls, high gradient riffles, and deep pools. Downstream of river mile 8.5 (Reaches 5a, 5b, 5c and 6) the creek is alluvial.

Our picket weir divides Reach 5 from late August to early November. There are two weir locations that we choose from, depending on the holding distribution of SCS. From 2003–2009, we adjusted the boundary of Reach 5a and 5b depending on where the weir was placed, and Reach 1–5a was always upstream of the weir. In 2010, we decided to make the Reach 5 breaks consistent, independent of the weir location, and added Reach 5c. Reach 5a was Clear Creek Road Bridge to Reading Bar site (RM 8.2), Reach 5b was Reading Bar to Shooting Gallery site (RM 7.5), and Reach 5c was from Shooting Gallery site to Gorge Cascade (RM 6.5).

A steep cascade (Gorge Cascade) is located at RM 6.5, divides Reach 5 from Reach 6, and is a partial barrier to FCS (Newton and Brown 2004). We have two rotary screw traps used to estimate juvenile salmonid production. The RBFWO upper rotary screw trap (UCC RST) is located at RM 8.4 and used to estimate SCS juvenile production (Earley et al 2011). The LCC RST is used to estimate FCS, late fall Chinook salmon, and steelhead juvenile production.

Methods

Survey timing

Based upon our past monitoring results, SCS begin to migrate into Clear Creek in April, and spawning begins in late August or early September (Giovannetti and Brown 2008). We generally schedule one full creek snorkel survey in June, August, and every two weeks from September through early November. Our June survey gives an indication of the population size and holding distribution, and provides an opportunity to train and refresh field staff of snorkeling and safety protocols. The August snorkel survey in Reaches 1–6 provides our annual population index, which we refer to as the August Index (SCS AI). The August snorkel survey provides the best estimate of the SCS spawning population because flows are low and visibility is good, SCS are staging to spawn, and few FCS have entered the creek. We close the picket weir during the snorkel survey of Reach 5 on the AI snorkel survey. We monitor the picket weir during the separation period to keep it fish tight, and to sample salmon carcasses found on the weir.

After the AI snorkel survey and installation of the weir, we schedule snorkel surveys every two weeks from September through early November to count redds and sample carcasses. In Clear Creek, SCS spawning generally begins in early September and peaks by the end of September (Giovannetti and Brown 2009). We survey more frequently during the spawning period so new redds are not missed. Redds become less visible over time due to algae growth, flows, and redd superimposition. Frequent surveys are also important for carcass recovery because carcasses decompose quickly and predators scavenge them.

We continue to snorkel downstream of the picket weir after it is closed. Spring Chinook salmon are often present downstream after the weir is closed, and fall Chinook begin to migrate into Clear Creek in early September. It is important to monitor FCS upstream of the Gorge Cascade to determine if they are passing the weir, and live counts determine when we remove the weir. If more than 20 live adult Chinook salmon are observed in downstream of the weir in Reach 5 during our late October snorkel survey, we leave the weir in until the middle of November to prevent negative impacts to SCS redds. We end our snorkel surveys in Reach 6 at the end of September after adult FCS begin to move into Clear Creek in large numbers, and then our surveys are replaced by California Department of Fish and Game (CDFG) walking carcass surveys (which begin in early October) to estimate FCS escapement. Our final September Reach 6 snorkel survey is a redd count that may include FCS and SCS redds.

Snorkel survey technique

Stream flow, water turbidity, and water temperature can all influence the effectiveness of snorkel surveys (Thurow 1994). Snorkel crews collected water samples at the beginning and end of each survey, and then used a Hach Turbidimeter to obtain turbidity values. Using a hand held submersible thermometer, crews measured water temperature at the beginning and end of each survey. Crews obtained stream flows from the U.S. Geological Survey gaging station (www.waterdata.usgs.gov) near Igo (IGO; 11372000) (RM 11.0).

Snorkel surveys usually began at the upstream most reach (Reach 1) and continued downstream on consecutive days. Each survey required a three-person snorkel crew and it took three to five days to complete all reaches. The snorkelers moved downstream with the current and counted Chinook salmon live adults, carcasses, and redds. Snorkelers divided the width of the creek into thirds and each snorkeler focused on counting within their lane.

Crews counted and collected location waypoints for live adult Chinook salmon, carcasses, redds, and their associated survey data using a Trimble® GeoExplorer 2008 XH GPS (Trimble®). We used Garmin® Extrex GPS units and paper datasheets as a backup if the Trimble was not available. At the end of each survey day, we transferred data files from the Trimble to the desktop computer. Waypoints from the Trimble were differentially corrected in Pathfinder Office® at the end of the survey week.

Live counts

Our annual SCS population index (SCS AI) was the number of live adult Chinook salmon observed during the August snorkel survey in Reaches 1–6. Live adult Chinook salmon were counted as they were observed swimming upstream under snorkelers. If a salmon was only observed once headed downstream and not seen again, it was also counted. When approaching large pools, one or two snorkelers walked around and quietly entered the pool from downstream. After entering the pool, snorkelers first looked for holding salmon in bubble curtains, and then signaled the other snorkelers to go through the rapid with the intention of flushing hiding salmon tucked up at the head of the pool. Snorkelers always conferred at pool tails to ensure no salmon were missed or double counted. We recorded the number of live adult Chinook salmon and took a GPS location waypoint at each observation.

Redd counts

The redd count upstream of the temporary picket weir was the SCS annual redd count. Redds counted downstream of the weir may have been either SCS or FCS. We use redd counts to determine the spawning SCS population and assess juvenile production success by relating counts to UCC RST catch. In addition, redd location data helps assess benefits of spawning habitat restoration projects.

We counted and marked the location of redds with the Trimble®. To differentiate new redds from those counted on previous surveys, we (1) tied flagging to nearby vegetation at the most upstream part of the redd, (2) kept track of the age of the redd, and (3) used our Trimble® to relocate the redd when necessary. In addition, one or two members of the crew from the previous survey were always present on the same Reach survey to differentiate between old and new redds. Redds needed to have a clearly defined pit and tail-spill and the crew needed to come to a consensus when identifying a redd. We did not count test redds, areas of clean substrate that fish may have scratched but did not clearly display both a pit and tail, but marked with a different color flag for crews to check on the next survey.

Redd measurements—We took redd measurements to describe the physical characteristics of redds and the spawning habitat used. All redds upstream of the weir were measured. Redds were measured when first observed, unless there was a female guarding it, and then it was measured on a subsequent survey. Water depth measurements were taken at the pre-redd depth (measured in the undisturbed substrate immediately upstream of redd), maximum pit depth, and minimum tail-spill depth. Mean column velocity was measured at the same location as the pre-redd depth and taken with a General Oceanics® model 2030 mechanical flow meter, which was run for a minimum of 100 seconds. Velocity was calculated by subtracting the start and end read of the meter, dividing by 100 and multiplying by 0.0875. Velocities were taken at 60 percent from the water surface if the water depth was <2.5 feet. If it was greater, we took flow measurements at 20 percent and 80 percent from the water surface and took the average between the two. We measured redd length parallel to the flow and redd width perpendicular to the length, both at the widest part of the disturbed area. Redd area was calculated by using the formula for an ellipse (area = πX½ widthX½ length). We classified redd substrate size using methods described in USFWS (2005).

Redd age tracking— To gain a better understanding about about the length of time redds were visible on Clear Creek, we tracked the age of all SCS redds following methods from the 2009 snorkel surveys (Giovannetti and Brown 2013). Each survey, new redds were assigned an age, and then on subsequent surveys, revisited, and aged again. Age classification was as follows: Age 2: clearly visible and clean (no periphyton or fines); Age 3: older and darker (periphyton growth, flattened tailspill, or fines) but defined pit and tail; Age 4: hard to discern without using flagging or Trimble® to locate (pit or tail definition lacking and excessive periphyton growth); or, Age 5: no redd visible, only flagging. We summarized the range of days redds were visible by adding the number of days from the previous survey when the redd was first observed, and then adding the number of days between subsequent surveys until the redd was no longer visible. If the redd was no longer visible, we added half the number of days between surveys. We considered redds that were Age 4 and Age 5 not visible to surveyors.

Redd distribution— Using GIS, we summarized redds per mile upstream of the picket weir. River miles (RM) begin at the confluence at RM 0 and end at Whiskeytown Dam at RM 18.3. From 2003 through 2005, the picket weir was located at RM 8.2, so RM 7 was not available for SCS spawning. From 2006 through 2009, the location of the picket weir was at RM 7.4.

Redds in injection gravel— Approximately 152,360 tons of supplemental spawning gravel (injection gravel) has been added to Clear Creek from 1996–2010 (GMA 2011; Giovannetti et al 2013). Sites are located from Whiskeytown Dam downstream to river mile 2.5 (Figure 1). Gravel supplementation projects consist of placing 3/8–6 inch sized spawning gravel into the creek using several different methods including talus cones, channel reconstruction, riffle construction, and lateral berms. Spawning gravel from talus cones and lateral berms are dependent on high creek flows for transport downstream to become usable spawning habitat. Riffle and channel reconstruction make gravel available for immediate use by spawning salmonids. Many sites are replenished on a regular basis, as gravel moves downstream following high flows. There are several gravel injection sites in Reaches 1–5 in SCS habitat (Figure 1). In August and September 2010 additional gravel was added to some of these sites. The WSRCD contractors added 1,000 tons to Dog Gulch, 1,000 tons to Need Camp, 1,450 tons to Clear Creek Road Bridge (GMA 2011).

To evaluate the use of spawning habitat created by the spawning gravel supplementation projects, we recorded the boundaries of gravel injection sites and noted when redds contained injection gravel. For talus cone sites, we took a GPS location point at the downstream extent of the gravel to track the distance gravel moved downstream following the winter storm season. For created instream riffles, we used the Trimble® to trace the boundary of the injection gravel yearly until it is no longer discernible from native gravel. Following high flows, injection gravel from each site mixes with native spawning gravel. Redds described as containing injection gravel were usually mixed with native material. Crews identified supplemental gravel (injection gravel) in redds based on (1) their proximity to the gravel injection site, (2) how far injection gravel moved downstream, and (3) the presence of tracer rock (chert, not native to the watershed, which is present in some but not all of the sites), and (4) uniform size (2–4") and shape (rounded edges).

Picket weir monitoring

Since 2003, we have installed a temporary picket weir across Clear Creek to separate FCS from SCS during spawning to prevent hybridization and redd superimposition between the runs (Newton and Brown 2005; Giovannetti and Brown 2009). During Clear Creek Technical team meetings, fishery biologists from our office, CDFG, BOR, and NMFS determined weir installation and removal dates and site location after considering the timing of migration and spawning of SCS, FCS, late fall Chinook Salmon (LFCS), and steelhead in Clear Creek. Weir monitoring involves ensuring the weir remains fish tight, and sampling carcasses found on the upstream side of the weir.

Timing and location of weir— We install the weir in late August and remove it in early November. The weir is closed during the August Index snorkel survey after we complete the snorkel survey in Reaches 1–5. The weir operation period provides time for the majority of the SCS to spawn before allowing FCS access to SCS spawning habitat. The weir installation date allows maximum time for SCS to migrate upstream of the weir before FCS begin to migrate into Clear Creek, while the removal date occurs prior to peak of the steelhead or LFCS migration and beginning of spawning.

We chose the weir location to maximize the number of SCS upstream of the weir without affecting FCS spawning habitat availability. The weir is located approximately one mile upstream of the Gorge Cascade, a partial barrier that blocks the majority of the FCS upstream migration. Each year, we perform supplemental snorkel surveys prior to the weir installation to count holding salmon in the large pool between the weir sites. Based upon the number of salmon counted, we determined the weir location. From 2003 through 2005, the weir site was located at Reading Bar at river mile 8.2. However, we moved the weir downstream to the Shooting Gallery site at river mile 7.4 from 2006 through 2008 to isolate a higher percentage of the SCS population upstream of the weir (Giovannetti and Brown 2009). In 2006 and 2009, Shooting Gallery site was initially used but due tampering in 2006 and high flow and storm events in 2009, a second weir was installed at Reading Bar (Giovannetti and Brown 2013). In 2010, both sites were used due an unforeseen circumstance, which is explained in the results.

Construction— The weir was constructed of wooden frames set eight feet apart and connected with aluminum channel beams into which are inserted six-foot-long ¾" aluminum conduit, spaced 2" on center. The conduit extended to the stream bottom and gaps were filled with native cobbles or sandbags. The weir was anchored to iron fence posts driven vertically into the streambed. We did not attach hose clamps to individual pieces of conduit as we did in previous years. Hose clamps were used to deter unauthorized people from removing conduit, allowing FCS passage. After the storms in 2009, we learned that the hose clamps may have inhibited the conduit from functioning properly and dropping down and causing undercutting, and difficulty for crews when removing a damaged weir. For public safety, we posted signs in the creek to warn rafters and swimmers of the location of the weir. We also posted informative signs along the shore to inform the public of the purpose of the weir and to alert anglers of the regulation prohibiting fishing within 250 feet of a weir.

Monitoring—The weir was checked a minimum of three times per week (with increased monitoring based on environmental conditions) to be sure it was fish tight, remove debris, detect vandalism, and biologically sample Chinook Salmon carcasses (as described under carcass methods). Crews searched for any gaps resulting from bent conduit, conduit not in contact with the streambed, or breaches around the sides of the weir. Crews removed debris from the upstream face of the weir, collected and quantified it in 10-gallon plastic tubs using categories; low (<three tubs), moderate (three-six tubs), and high (>six tubs). If more than 20 live adult Chinook salmon were observed in Reach 5b during our late October snorkel survey, the weir would remain in until the middle of November to prevent negative impacts to SCS redds. In addition, we monitored steelhead downstream of the weir. If snorkel crews counted more than ten adult steelhead (greater than 22 inches fork length) within 100 feet of the weir, we would temporarily remove pickets to allow steelhead to pass upstream.

Carcass counts

During snorkel surveys and weir monitoring, crews counted and biologically sampled salmonid carcasses. Crews recorded carcass locations with the Trimble and removed the caudal fin so they were not recounted on subsequent surveys. For carcasses that could not be retrieved, crews took notes concerning the status of the carcass (sex, spawning condition, adipose fin presence, etc.).

Bio-sampling— Crews collected biological data from each carcass unless they could not retrieve it, or it was extremely decomposed. Data included fork length, gender, spawning status, presence of an adipose fin, and carcass condition. Heads were collected from adipose fin clipped and unknown adipose fin clipped carcasses (due to predation or decomposition) for coded-wire tag retrieval. Coded-wire tags were extracted from heads in the laboratory. Crews collected quadruplicate tissue samples for genetic analysis. Samples were usually collected from a fin but the operculum was sampled if the fins were highly decayed. Three samples were placed in vials containing ethanol and one was dried. Crews also collected scales and otoliths. All samples were archived at the RBFWO.

Age structure— We collected and read scales to determine the age of SCS carcasses recovered upstream of the temporary picket weir. Crews collected 5 to 10 scales from the left side of a carcass from the second and third row of scales above the lateral line, in the region bisected by a line drawn between posterior insertion of the dorsal fin to the anterior insertion of the anal fin. Back at the office, scales were dried for 24 hours then stored them in scale envelopes until they were prepared for reading. To prepare for reading, scales were hydrated and cleaned in soapy water, and then mounted sculptured side up between two glass microscope slides held together with tape. Scale readers used a microfiche reader to count the number of annuli and the age was determined to be the number of annuli plus one (Borgerson 1998). Scale readers were trained using FCS and LFC of known age from Coleman National Fish Hatchery. Two scale readers independently aged each scale. If results were incongruent, the scale was read a third time cooperatively by the same two readers. If the scale readers did not reach an agreement after the third read, the scale was not included in our data set.

Stream flow and water temperature criteria

Temperature criteria was established for SCS holding and spawning in the Anadromous Fish Restoration Program Restoration Plan, and the Biological Opinion for the Central Valley Project and State Water Project operations (USFWS 2001; NMFS 2004). The BOR manages water temperatures in Clear Creek by manipulating flows at Whiskeytown Dam. The BOR releases 200 cubic feet per second (cfs) from October 1 to June 1 from Whiskeytown Dam to provide sufficient habitat and water temperatures for SCS, FCS, LFC, and STT egg incubation and rearing. Beginning on June 1, the BOR reduces flows and maintains them at a level to keep mean daily water temperature (MDT) ≤ 60°F at IGO for adult SCS holding and juvenile salmonid rearing. On September 14, the BOR increases flows to maintain MDT ≤ 56°F at IGO for SCS spawning and egg incubation. Flows may be increased above 200 cfs in an attempt to meet temperature criteria for spawning.

The RBFWO has 11 water temperature monitoring sites located throughout Clear Creek (Table 1; Figure 1). We use Onset Hobo® Water Temp Pro v2 or Optic StowAway® temperature loggers, which are accurate to 0.36°F and calibrated before deployment in the field. At each site, we deploy two temperature loggers to prevent loss of data due to lost or malfunctioning loggers. The USGS also maintains a water temperature monitoring site at IGO, which we use to determine if temperature criteria is met for SCS holding and spawning (www.cdec.water.ca.gov).

Holding and spawning period— To determine if water temperature criteria was met during the SCS holding period, we totaled the number of days MDT exceeded 60°F at IGO between June 1 and September 14. For the spawning criteria period, we totaled the number of days MDT exceeded 56°F at IGO from September 15 to October 31. We also calculated the number of days in the criteria period adult SCS were exposed to temperatures exceeding criteria, both upstream and downstream of the IGO. For the holding and spawning period, we summarized flow releases used to achieve temperature targets at IGO.

Redd incubation and temperature exposure— To evaluate water temperatures at individual redds and estimate the timing of fry emergence, we assigned river miles for each redd and temperature monitoring site. We interpolated MDT at redd locations by using the equation of a straight line connecting two adjacent temperature monitoring sites. We calculated Daily Temperature Units (DTU), which equals MDT minus 32°F, to estimate hatching time at each redd. We used the criteria that 1,850 DTUs were required for egg development to time of emergence. We selected this criteria based on catch data from the URST, which is operated to estimate SCS juvenile production (Earley et al. 2008).

After calculating emergence dates for each redd, we tallied the total days redds were exposed to water temperatures ≤ 56°F. We summarized "minimum" and maximum days" redds were exposed to temperatures ≤ 56°F based on redd age and survey date. For redds that were Age 2 when first observed, we calculated "minimum" days of exposure beginning the first day the redds were observed, and "maximum" days of exposure beginning the day after the previous snorkel survey (approximately 2 weeks earlier). If redds were Age 3 when first observed, the start date of "minimum" days of exposure was one week before they were first observed.

Pulse flow monitoring

Two pulse flows occurred on Clear Creek this year that were designed to fulfill "RPA Action I.1.1. Spring Attraction Flows" of the 2009 National Marine Fisheries Service (NMFS) Biological Opinion for the Bureau of Reclamation's Operations Criteria and Plan for the Central Valley Project (NMFS 2009). The objectives of the pulse flows were to encourage adult SCS to Clear Creek from the Sacramento River, and to attract SCS to the furthest upstream habitats for holding and spawning where there are, a) colder water temperatures, b) large and remote holding pools, and c) spawning areas with newly provided spawning gravel. If adult SCS hold upstream of the picket weir, they can avoid hybridization and competition with FCS. Attracting SCS into Clear Creek may also reduce the chance of FCS from hybridizing with SCS in the Sacramento River (NMFS 2009). In addition, if the pulse flows attract Clear Creek SCS to the furthest upstream reaches, it would reduce the chance for SCS spawning in the lower reaches, where water temperatures may be inadequate (too warm) to support eggs and pre-emergent fry during September and October.

The Action requires that BOR annually conduct at least two pulse flows in Clear Creek in May and June of at least 600 cfs for at least three days for each pulse (NMFS 2009). The BOR controls flow releases into Clear Creek at Whiskeytown Dam up to a maximum of 1,200 cfs. Releases higher than this occur can only occur unregulated through the glory hole when water levels in the reservoir exceed the top of the glory hole. When determining dates to conduct pulse flows, the Clear Creek Technical Team chose the most appropriate time to attract SCS to Clear Creek successfully, while minimizing impacts to other species in the watershed. The team decided to have pulse flows later in the season 1) when SCS would be in the Sacramento River, 2) when there would be detectable benefit (after SCS normally move into Clear Creek in April and early May), 3) to avoid impacts to juvenile steelhead and late fall Chinook salmon (adults spawn through April), and 4) to reduce negative impacts to songbirds that nest in low-lying branches above the creek.

In 2010, the pulse flows occurred during the weeks of May 24 and June 7. Ten days before the first pulse flow, dam releases were reduced from 200 cfs to 175 cfs. During normal dam operations, operators decrease releases from 200 cfs to 150 cfs around June 1. Instead of having the first snorkel survey at 200 cfs and the last two at 150 cfs, flows were reduced to 175 cfs before and after pulse flows so conditions for viewing salmon were similar during each survey, thereby decreasing observer errors associated with different water flows.

Each pulse flow was scheduled to last 5 to 6 days, with 2 to 3 days at 600 cfs and 2 to 4 days for down ramping. Flows were planned to increase in 100 cfs increments an hour for public safety and for increased duration of turbidity. Down ramping rates were set to decrease juvenile salmonid stranding. Flow decreases were set to occur in the lowest reaches in the dark, when the likelihood of stranding juvenile salmonids is less. This was done to protect the majority of juvenile salmonids, which based on our snorkel observations, occur in the lower reaches time of the year. We allowed one week between pulse flows to conduct a snorkel survey.

We conducted snorkel surveys immediately before and after each pulse flow to detect changes in the number of Chinook salmon, and their distribution in Clear Creek. To determine if the pulse flows successfully attracted SCS, counts would need increase by 50%. We developed this measurement target based on data collected on snorkel surveys from years when we conducted monthly snorkel surveys beginning in April. From 1999 to 2005, the average change in proportion of adult Chinook salmon observed between May and June surveys was 29%. Theoretically, the average change in the proportion of Chinook observed in a two week period would be half that, or 14%. In those years, the maximum May to June change was 83%, so the theoretical two-week maximum change would be 42%. From these snorkel data results, we decided that we would need to see large percent changes, and evaluations may require many years of pulse flows. In addition, there needed to be more than fifty adult Chinook salmon counted during a survey, to reduced observer detection errors associated with snorkel surveys.

During surveys, we also assessed the impact flows may have had on steelhead and LFC redds (which were counted during our kayak redds surveys in April) by making observations concerning redd scour or aggradation of sand or gravel in the redd locations.

Results

Pulse flow monitoring

Flows were higher than expected during the first pulse flow, because the rating table for the Whiskeytown Dam outlet was inaccurate resulting in a larger release than intended and because a rainstorm occurred during the release. The release target for the first pulse flow was 600 cfs and increases began on May 24 at 13:00 (Figure 2). Increased flows were detected at IGO at 16:00, and flows stabilized by 20:00 on May 24. Mean daily flows averaged 878 cfs from May 24 at 20:00 to May 25 at 16:00. Prior to the pulse flow, IGO was 60 cfs higher than the Dam release due to tributary inflow. Excluding this input, MDF at IGO was 36% (218 cfs) higher than the 600 cfs target release at the Dam. We attribute the additional 218 cfs to setting inaccuracies at the release gate at the Dam. Additionally, a rainstorm began on May 25, which additionally increased flows during the pulse flow release. Brandy Creek rain gage station, located in the upper Clear Creek watershed, showed precipitation began to accumulate on May 25 at 11:15, and gained 2.68 inches by May 29 (http://cdec.water.ca.gov). The precipitation station at Whiskeytown Reservoir showed 0.06 inches of precipitation on May 25, with an accumulation of 3.18 inches by May 29. Precipitation accumulation increased flows beginning at 17:00 on May 25 at IGO, and flows reached 1,130 cfs by 4:00 on May 26 (Figure 2). Ramp down began at the Dam on May 27 and was complete by May 31. Releases from the Dam were set at 175 cfs following the pulse flow but were 270 cfs at IGO due to tributary input.

The second pulse flow began on June 7 and ramp down began on June 10 (Figure 2). During the second pulse flow, flows were approximately 670 cfs at IGO. Prior to the pulse flow, IGO was 70 cfs higher than the Dam release due to tributary inflow.

We conducted a snorkel survey before and after each pulse flow (Surveys 1–3) (Table 2, Figure 2). For each consecutive survey, MDF was 268 cfs, 252 cfs, and 186 cfs. Prior to the first pulse flow (Survey 1), we counted one Chinook salmon; after the first pulse flow, Survey 2, we counted ten; and following the second pulse flow during Survey 3, we counted 11 (Figure 2). We noted that two of the live adult male Chinook salmon observed in Reach 6 during Survey 2 displayed spawning characteristics, indicating they may have been late-fall Chinook salmon or winter Chinook salmon. One of these two fish observed had an adipose fin clip. According to our success criteria, we did not have enough Chinook salmon (>50) to determine if there was a significant increase in SCS, and therefore could not determine if the pulse flows attracted SCS into Clear Creek.

August Index, weir, and survey conditions

We conducted our August snorkel survey (Survey 4) from August 23–26 and the SCS AI was 21 (Table 2, Appendix A). Viewing conditions were good; average water turbidity was 1.7 NTU and MDF was 95 cfs. We closed the weir at Reading Bar on August 26 after completing Reach 5a of the survey, and 14 SCS (66%) were upstream of the weir (Table 3). However, because the AI snorkel survey results revealed that more than 10% of the SCS AI was holding between the weir sites, we installed a second weir at Shooting Gallery. With Shooting Gallery weir in place, 81% (17) of the SCS AI was protected upstream of the weir.

When we initially surveyed Reach 5 on August 18 (Survey 3.5) to determine the placement of the weir, there was one SCS in Carcass Pool (the holding pool between the weir sites). Based on our June snorkel survey, our initial estimate of the SCS population was eleven. Since the one salmon between the weir sites constituted less than ten percent of our June estimate, we decided to place the weir at Reading Bar. Subsequently, after completing the AI snorkel survey and closing Reading Bar weir, crews observed three salmon in Carcass Pool. Since the SCS AI was 21 (14 upstream of Reading Bar weir), these three salmon now were 14% of the SCS AI (or 18% of the SCS AI upstream of the Shooting Gallery site). Through consultation with NOAA fisheries and the Clear Creek Technical Team, we determined to install a second weir at the Shooting Gallery site and open up Reading Bar weir. Since the SCS population was low, these three SCS were potentially an important contribution to the spawning population.

We installed and closed the Shooting Gallery weir on September 1 and lifted the center pickets at Reading Bar weir to permit upstream passage of the three salmon in Carcass Pool. By leaving Reading Bar weir open, the three salmon had an opportunity to be part of the SCS spawning population upstream of Reading Bar weir. We also decided to keep the Reading Bar to have as a backup. In 2009, there was several weir tampering incidents and high flow events, both of which allowed FCS passage. If tampering or high flows affected Shooting Gallery weir, we would have Reading Bar as an alternative. Similarly, in 2006, we installed a second weir at Reading Bar to backup Shooting Gallery weir after there was extensive tampering.

After the AI snorkel survey, we conducted five snorkel surveys (Surveys 5–9) from September 8 through November 10 (Appendix A, Table 2). Rain events increased flows on October 24, which caused us to postpone the final survey one week. During surveys, average creek flows ranged from 98–253 cfs and average turbidities ranged from 1.4 to 1.8 NTUs (Table 2).

During each consecutive survey after the AI survey, live Chinook salmon counts decreased upstream of the Reading Bar weir (from 14 to zero by Survey 9) (Figure 3). In Reach 5b (between the weirs) there was one live Chinook salmon on Survey 5 and one on Survey 6, but counts increased to 12 by Survey 7, and 29 by Survey 8, and then decreased to one by Survey 9 (Figure 3). These increases indicated FCS were passing the closed Shooting Gallery Weir but likely blocked by Reading Bar weir. In Reach 5c, live Chinook salmon counts increased from one on Survey 6, to ten by Survey 7, and to 15 by Survey 8, and then decreased to zero by Survey. In Reach 6, live counts increased each survey, from four on Survey 4, to 22 by Survey 5, and to 111 by Survey 6 (which was the final survey of Reach 6).

Redd counts

The redd count upstream of Shooting Gallery weir (Reaches 1–5b) was 14 (Table 4 and Figure 4). Nine redds were upstream of Reading Bar (Reaches 1–5a). Since there were no weir breaches prior to September 22, we considered one redd in Reach 5b constructed before the breach to be a SCS redd, and the later four (one on Survey 7 and three on Survey 8) to be potential FCS. Our best estimate of the SCS redd count was ten (Table 4). River mile 10 had the highest number of redds; 30% of the SCS redd count (Table 5). In Reach 5c, we observed one new redd on Survey 6, four new redds on Survey 7, five new redds on Survey 8, and one new redd on Survey 9 (Table 4). In Reach 6, we observed 27 redds on Survey 6 (which was the final survey of Reach 6).

Sixty percent of the SCS redd count was located upstream of IGO (Reaches 1–3), similar to the average since 2003 (Table 4, Table 5). Ninety percent (nine) of the SCS redd count was upstream of the UCC RST, compared to an average of 92% since 2003 (Table 4). Sixty percent of SCS redds (six) contained injection gravel, compared to an average of 31% since 2003 (Table 4). Of the redds in injection gravel, two were at Need Bridge in Reach 2, one was at Guardian Rock in Reach 2, and three were in Reach 4 at Placer. Two redds in Reach 1 were in native gravel, and there were no SCS redds located in the 2009 instream gravel placement sites.

We measured seven SCS redds, and five redds in Reaches 5b and 5c that were potentially FCS. For SCS redds (n = 7), average redd surface area was 84 ft^2, average pre-redd water depth was 1.5 feet, average pre-redd water velocity was 2.3 feet/second, and median substrate size was 1–3 inches (n = 5) (Table 6). For redds downstream of the weir (n = 5), average redd surface area was 108 ft^2, average pre-redd water depth was 1.2 feet, average pre-redd water velocity was 2.6 feet/second, and median substrate size was 2–4 inches.

We tracked the age of ten SCS redds. We observed six new redds on Survey 6, four new redds on Survey 7, and no new redds on Survey 8 (Table 7). There were more than two weeks between Survey 8 and 9 because a rain event that increased creek flows to over 1,000 cfs on October 24 and caused us to postpone the final survey one week. Fifty percent of the redd count was visible by Survey 8, and no redds were visible during Survey 9.

Picket weir

The Reading Bar weir was closed on August 25 and the Shooting Gallery weir was installed and closed on September 1 (Table 8). After Shooting Gallery was closed, we opened Reading Bar until September 24. It was closed for the weekend, reopened on September 27, and then closed permanently on October 1. We checked and cleaned the weirs approximately five days per week (Monday through Friday) with assistance from Gary Diridoni from the Redding BLM, who checked the weir Tuesdays and Thursdays through September and over one weekend.

On September 22, the snorkel crew found 14 pickets lifted out of the water at Shooting Gallery weir (Table 9). There was no damage to the weir and the crew pushed the pickets back down. We serviced the weir the previous day so the maximum time the weir was open was 24 hours. There was one live Chinook salmon observed in Reach 5b on the snorkel survey that day (same count as the previous survey week) and Reading Bar weir was open. Since high numbers of FCS were observed in Reach 6 on the following day snorkel survey, FCS likely had moved into Clear Creek and may have passed both weirs during this breach. We closed Reading Bar weir the following day, so both weirs were closed. Both weirs remained fish tight over the weekend. On September 27, we reopened Reading Bar weir, then closed it permanently on October 1. We felt that keeping Reading Bar weir closed would help protect SCS redds if there were breaches in Shooting Gallery weir. In addition, at this point, the majority of SCS had spawned and there was no longer a need to allow the SCS between the weirs to pass upstream.

On October 5, we found a gap below twelve pickets large enough to allow fish passage at Reading Bar (Table 9). There was a similar occurrence at Shooting Gallery weir on October 6, where there was a six-inch gap below four pickets. The gaps were caused by increased debris loads, which did not allow the pickets to drop to the substrate. Both openings were repaired when they were first observed and were not open more than 24 hours. However, during the October 7 snorkel survey of Reach 5, we observed 27 live adults between weirs. Either these salmon passed through the small gap, or, there was weir tampering that went undetected by us since the last snorkel survey, which allowed passage.

The Clear Creek rain gage reported 9.76 inches of precipitation accumulation on October 23 and 24. Both of weirs suffered damage from the high flow event that exceeded 1,000 cfs on October 24, and we removed both weirs. We decided to pull the weirs before the normal November 1 removal date because 1) they both needed repair, 2) SCS appeared to have finished spawning (no new redds on Survey 8) so there was no threat of hybridization, 3) redd superimposition by FCS was unlikely due to the few number of redds upstream of the weirs, and 4) there was a storm event predicted within two days that could further damage the weirs.

Carcass counts

We recovered 53 Chinook salmon carcasses in Reaches 1–5b (upstream of Shooting Gallery weir) during snorkel surveys and weir monitoring (Table 10). Twelve carcasses were upstream of Reading Bar weir (Reaches 1–5a), and 41 were between weirs. Fall Chinook salmon likely passed both weirs after the September 22 breach at Shooting Gallery weir (since Reading Bar was left open) (Figure 5). No carcasses upstream of Reading Bar had distinguishing features that indicated they were FCS. The majority of carcasses recovered between the weirs (Reach 5b) were probably FCS, but the earliest recovered carcasses may have been SCS.

Of the carcasses recovered in Reaches 1–5a, 58% were collected on the Reading Bar weir. In Reach 5b, 85% were recovered on the Shooting Gallery weir. The first carcass was collected on September 29 in Reach 5b and on October 5 in Reaches 1–5a. The majority of carcasses were male (85%), 6% were female, and 9% were unknown gender. All female carcasses were spawned. Median carcass fork length was 745 mm (n = 50). Upstream of Reading Bar weir, median fork length was 665 mm (n = 11), and in Reach 5b, it was 790 mm (n = 39).

We took 53 genetic samples (79% from fresh carcasses), extracted 50 otoliths, and collected 50 scale samples (Table 11). Three carcasses had adipose fin clips, and two were unknown clip status due to predation. All heads from adipose clipped and unknown status clip carcasses were processed by crews in the laboratory. We extracted and read two coded wire tags, both were from Feather River Hatchery (one SCS, and one FCS), and both were from juvenile off-site releases (Table 12). There was a tag in the third head, but the tag was lost before it was read. Coded wire tags were not detected in the two unknown clip status carcass heads, and therefore these carcasses were considered non-hatchery origin. After verifying the status of the unknown clips, 6% of the recovered carcasses were hatchery origin (8% upstream of Reading Bar Weir, and 5% in Reach 5b) (Table 10).

We combined all carcasses from Reaches 1–5b for age analysis. Scale reading results indicated that 75% of carcasses were age 3 (n = 36), 19% were age 2 (n = 9), and 6% were age 4 (n = 3). Three scales were unreadable because they were damaged, but one was from a coded wire tag so we added the age from the tag read into our results. The median fork length of 2-year-olds was 580 mm (n = 9), 3-year-olds was 800 mm (n = 36), and 4-year-olds was 875 mm (n = 3). (Figure 6).

Two carcasses were observed in Reach 5c during Survey 8, and three were observed in Reach 6 during Survey 6, but none were sampled.

Stream flow and water temperature criteria

The BOR gradually reduced flows at Whiskeytown Dam following the second pulse flow and releases were 150 cfs by June 14 (Figure 7). Flows were decreased on July 21 to 135 cfs, 120 cfs on July 31, and 95 cfs on August 6. During the water temperature criteria period (June 1 to September 14), average MDF at IGO was 163 cfs (range = 93–680). In the period after the pulse flow (June 14–September 14) average MDF at IGO was 132 cfs (range = 93–189 cfs). Mean daily water temperatures at IGO did not exceed 60°F during the criteria period and were an average of 57.3°F (range = 53.1–59.3°F). Based on holding during the August snorkel survey, 62%, of the SCS AI were holding upstream of IGO in MDT ≤60°F (Table 13). Thirty-eight percent of SCS AI was holding downstream of IGO and exposed to MDT >60°F for an average of 47 days (44% of the 106 day criteria period) (Table 13).

On September 14, the BOR increased flows to meet the ≤56°F spawning criteria on September 15 (Figure 7). Flow increases began on September 14 and transitioned to 200 cfs by September 21 (IGO was 219 cfs). The initial flow increase to 150 cfs on September 14 did not sufficiently decrease water temperatures to meet spawning criteria on September 15, so the BOR continued to increase flows until they reached 220 cfs at IGO by September 21 (Figure 7). From September 15 to October 31, MDT at IGO was an average of 56.5°F (range = 53.9–58.2°F). Mean daily water temperatures at IGO exceeded 56°F for 74% of the 47-day spawning criteria period. Water temperatures exceeded 56°F through October 18 (average MDT 57.0°F). Sixty percent of the SCS redd count was upstream of IGO.

Based on the 1,850 DTU criteria, the average estimated number of days for fry emergence was 85 days for "maximum" and 93 days for "minimum". We estimated the range of average fry emergence to occur between December 5–22, emerging as early as November 27, and as late as January 8. The SCS redds were exposed to MDT >56°F an average of 21% "minimum" and 30% "maximum "of incubating days (Table 14).

Discussion

It was difficult to evaluate the effectiveness of the spring pulse flows to attract SCS into Clear Creek because of the low numbers of adult salmon observed during snorkel surveys. We suspect that some of the Chinook salmon observed during the snorkel survey after the first pulse flow were winter Chinook salmon, based on their condition (fungus and spawning attributes). There was an increase in snorkel counts of SCS between the final pulse flow in June to the August survey, indicating SCS came into Clear Creek after the pulse flows. However, the difference in counts between surveys may be within observational error. The Clear Creek SCS August Index was the lowest since we began installing the weir on Clear Creek in 2003. Similar population trends were observed in other Central Valley spring run tributaries and the spring run estimate for the Valley was well below average (Azat 2013).

Temperature criteria was met for the entire SCS holding period, but 38% of the population was holding downstream of IGO and not fully protected by the criteria. Temperature criteria was met for only 26% of the SCS spawning period. The spawning temperature criteria was not met in part because of higher Whiskeytown Reservoir water temperatures and a reduced cold water pool. Since increased water releases out of the reservoir did not cool water temperatures sufficiently to meet spawning criteria, changes to reservoir operations may need to be considered. We recommend that the fisheries agencies work closely with Reclamation's Central Valley Operations group to improve diversion schedules and releases to maximize success of meeting IGO temperature criteria. When considering implementing projects that could affect Whiskeytown Reservoir cold pool or temperature of releases to Clear Creek, Reclamation should coordinate with other agencies to discuss options to avoid negative impacts to temperature control.

There were several breaches in the weirs this year that may have allowed FCS passage, but we do not believe they passed upstream of Reading Bar weir, and the SCS spawning population upstream of Reading Bar weir was separated from FCS. The SCS redd count upstream of Reading Bar weir was slightly higher than expected compared to the SCS AI upstream of the Reading Bar weir, but this was likely within the observational error of the AI snorkel live counts. We also did not have large increases of live Chinook salmon upstream of Reading Bar weir on snorkel surveys after the weir was closed in August. However, live adult Chinook salmon snorkel counts and carcass recovery indicated that FCS passed upstream of the Shooting Gallery weir.

The intention of installing the second weir at Shooting Gallery was to protect the proportion of the SCS index between the weir sites that were not detected before we already installed Reading Bar weir, and potentially allow these salmon to move upstream. We were able to keep Reading Bar open early in the season while keeping Shooting Gallery closed. Carcass and live counts between the weirs indicated that FCS were continually passing Shooting Gallery. The SCS between the weirs may have moved upstream of Reading Bar when it was open, however they may have hybridized with FCS that passed Shooting Gallery. Aside from the known breaches, FCS continued to pass the Shooting Gallery weir, after no more breaches were documented during monitoring. The high flow storm event that occurred at the end of October damaged both weirs this year, and we did not have enough supplies to reconstruct the weir quickly, so we removed it slightly earlier than expected (Figure 13). This high flow event was similar to the one in October 2009 that also damaged the weir (Giovannetti and Brown 2013).

Our redd tracking data emphasized the importance of conducting surveys every two weeks so that redds are not missed due to aging from time and high flow events. Although 90% of the total redd count was visible on the early October survey, only 50% of the redds already observed were still visible on the following survey. After the high flow event, no redds were visible. It will continue to be important to survey after the majority of SCS spawning is complete to observe impacts of FCS passing upstream of the weirs, especially because as we saw this year, they may go undetected without known breaches in the weir.

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References

Azat, J. 2013. GrandTab California Central Valley Chinook Population Database Report. California Department of Fish and Wildlife. www.calfish.org/tabid/213/Default.aspx

Borgerson, L.A. 1998. Scale analysis. Oregon Department of Fish and Wildlife, Fish Research Project F-144-R-09, Annual Progress Report, Portland.

BOR (U.S. Department of the Interior Bureau of Reclamation) and USFWS (U.S. Fish and Wildlife Service). 2009. Draft CVPIA Fiscal Year 2010 Annual Work Plan October 1, 2009. Program Title: Clear Creek Restoration - CVPIA Section 3406(b) (12). http://www.usbr.gov/mp/cvpia/docs_reports/awp/2010/10_3406b12.pdf

Earley, J. T., D. J. Colby, and M.R. Brown. 2008. Juvenile salmonid monitoring in Clear Creek, California, from October 2006 through September 2007. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Earley, J. T., D. J. Colby, and M.R. Brown. 2011. Juvenile salmonid monitoring in Clear Creek, California, from October 2009 through September 2010. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Giovannetti, S. L., and M. R. Brown. 2008. Adult spring Chinook salmon monitoring in Clear Creek, California: 2007 annual report. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Giovannetti, S. L., and M. R. Brown. 2009. Adult spring Chinook salmon monitoring in Clear Creek, California: 2008 annual report. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Giovannetti, S. L., and M. R. Brown. 2013. Adult spring Chinook salmon monitoring in Clear Creek, California: 2009 annual report. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

GMA (Graham Matthews & Associates). 2011. Clear Creek Geomorphic Monitoring 2003–2010. Report submitted to U.S. Bureau of Reclamation.

GMA (Graham Matthews & Associates). 2009. Clear Creek Gravel Injection Monitoring 2007–2009. Report submitted to U.S. Bureau of Reclamation.

Newton, J. M., and M. R. Brown. 2004. Adult spring Chinook salmon monitoring in Clear Creek, California, 1999–2002. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

NMFS (National Marine Fisheries Service). 2004. Biological Opinion on Central Valley Project (CVP) and State Water Project (SWP) Operations, April 1, 2004 through March 31, 2006. February 27, 2004.

NOAA (National Oceanic and Atmospheric Administration). 1999. Endangered and threatened species: threatened status for two Chinook salmon evolutionarily significant units (ESUs) in California, Final Rule. Federal Register 64:179 (16 September 1999):50394–50415.

NOAA (National Oceanic and Atmospheric Administration). 2005. Endangered and threatened species: final listing determinations for 16 ESUs of West Coast salmon and final 4(d) protective regulations for threatened salmonid ESUs. Federal Register 70:123(28 June 2005):37160–37204.

Thurow, R. F. 1994. Underwater methods for study of salmonids in the Intermountain West. U.S. Forest Service General Technical Report, INT-GTR-307. Ogden, Utah.

USFWS (U.S. Fish and Wildlife Service). 2001. Final Restoration Plan for the Anadromous Fish Restoration Program. A plan to increase natural production of anadromous fish in the Central Valley of California. Prepared for the Secretary of the Interior by the United States Fish and Wildlife Service with the assistance from the Anadromous Fish and Restoration Program Core Group under authority of the Central Valley Project Improvement Act.

USFWS (U.S. Fish and Wildlife Service). 2005. Monitoring of restoration projects in Clear Creek using 2-dimensional modeling methodology. Prepared by The Energy Planning and Instream Flow Branch, Sacramento Fish and Wildlife Office, California.

Tables

Table 1. 2010 Clear Creek snorkel survey reach breaks and temperature monitoring stations. Under ‘Site Name’, (T) indicates water temperature monitoring site.

Reach breaks	Site name	River mile
Start of Reach 1	Whiskeytown Dam (T)	18.29
Start of Reach 2	Need Camp Bridge (T)	16.14
Start of Reach 3	Kanaka Creek (T)	13.17
Start of Reach 4	Igo Gaging Station (T)	11.00
Start of Reach 5a	Clear Creek Road Bridge (T)	8.59
Reach 5a	Upper Rotary Screw Trap (T)	8.42
Start of Reach 5b	Reading Bar Picket Weir Site	8.20
Start of Reach 5c	Shooting Gallery Picket Weir Site	7.48
Start of Reach 6	Gorge Cascade (T)	6.54
Reach 6	Gorge Spawning Curve (T)	5.94
Reach 6	Renshaw Riffle (T)	5.12
Reach 6	Restoration Grove (T)	3.62
End of Reach 6	Lower Rotary Screw Trap (T)	1.77

Table 2. 2010 Clear Creek snorkel survey results by survey week. Counts of Chinook salmon live adults, redds, and carcasses are displayed as Reaches 1–5a (Reach 5b) [Reach 5c] {Reach 6}. Reaches 1–5a are located upstream of the Reading Bar picket weir. Reach 5b is the section between Reading Bar weir and Shooting Gallery weir. Reach 5c is the section downstream of Shooting Gallery weir. NS = no survey. Bold zero values indicate all reaches were surveys with no observations. Surveys 1–3 were pulse flow snorkel surveys. Survey 3.5 was the weir location snorkel survey, and Survey 4 was the August Index snorkel survey (AI). Table includes average flow, temperature, and turbidity to show environmental conditions during each survey.

Survey week	Live	Carcass	Redd	Flow (cfs)	Water temperature (°F)	Turbidity (NTU)
1 (May 17–21)	0 (0) [0] {1} = *1*	**0**	**0**	268	51	2.5
2 (June 1–3)	1 (0) [2] {7} = *10*	**0**	**0**	252	54	1.9
3 (June 15–17)	7 (0) [0] {4} = *11*	**0**	**0**	186	54	1.5
3.5 (Aug 18)[a]	1 (1) [NS] {NS}	0 (0) [NS] {NS}	0 (0) [NS] {NS}	95	57	1.4
4 (Aug 23–26)	14 (3) [0] {4} AI = *21*	**0**	**0**	94	58	1.7
5 (Sept 8–10)	12 (1) [0] {22}	**0**	**0**	98	56	1.4
6 (Sept 20–23)	10 (1) [1] {111}	0 (0) [2] {3}	5 (1)[c] [1] {27}	210	55	1.8
7 (Oct 5–7)	5 (12) [10] {NS}	4[b] (0) [0] {NS}	4 (1) [4] {NS}	220	56	1.7
8 (Oct 18–21)	1 (29) [15] {NS}	3 (13)[d] [2] {NS}	0 (3) [5] {NS}	220	56	1.5
9 (Nov 8–10)	0 (1) [0] {NS}	**0**	0 (0) [1] {NS}	253	54	1.6

[a] Reaches 1–4 were not surveyed.
[b] Two carcasses were recovered on Reading Bar weir during snorkel survey.
[c] Counted as part of the SCS redd count.
[d] Seven carcasses were recovered on Shooting Gallery weir during snorkel survey.

Table 3. Live adult spring Chinook salmon (SCS) counts on Clear Creek during June and August Index (AI) snorkel surveys, 1999–2010. The USGS gauging station at Igo (IGO) is where SCS spawning and holding water temperature criteria are set. We have installed a temporary weir since 2003 to separate fall Chinook salmon from SCS during spawning and the weir is closed following the AI snorkel survey. Weir location depends on the percentage of SCS holding between the two weir sites immediately prior to closure. Since 2006, if greater than 10% of the SCS AI was between the weir sites, the weir was placed at the Shooting Gallery site (SG). The weir was placed at river mile 8.2, the Reading Bar site (RB) from 2003–2005, and river mile 7.4, the SG from 2006–2009. A weir was placed at the RB Site in 2009 after the collapse of the weir at SG following a storm. In 2010, the weir was placed at the RB site initially, and a second weir was placed at SG a week later due to unexpected SCS counts between weir sites.

Survey year	June survey	AI survey	Percent AI upstream of IGO (Reaches 1–3)	Weir site	Percent AI upstream of weir (Reaches 1–5a)	Percent AI between RB and SG weir sites	Percent downstream SG weir site
1999	6	35	0%	NA	NA	0%	100%
2000	16	9	56%	NA	NA	0%	0%
2001	2	0	0%	NA	NA	0%	0%
2002	51	66	55%	NA	NA	0%	30%
2003	28	25	64%	RB	72%	0%	28%
2004	111	98	39%	RB	69%	14%	16%
2005	59	69	54%	RB	86%	12%	3%
2006	67	77	68%	SG	99%	12%	1%
2007	100	194	56%	SG	94%	10%	6%
2008	129	200	31%	SG	86%	34%	15%
2009	NS	120	33%	SG and RB	73%	12%	27%
2010	11	21	62%	SG and RB	81% and 67%	14%	19%

[a] A second weir was placed at RB site in 2006 following several incidents of lifted pickets at the SG weir.
[b] A second weir was placed at RB site in mid-October in 2009 following the collapse of the SG weir during a high flow storm event.

Table 4. Chinook salmon redd counts in Clear Creek during snorkel surveys, 2003–2010. Redds in Reaches 1–5a were upstream of the picket weir and the total was the spring Chinook salmon (SCS) redd count. 'Upstream of IGO' was the percent of the SCS redd count in Reaches 1–3, which is located upstream of the SCS water temperature target location at the USGS gaging station at Igo (IGO). 'Upstream of UCC RST' was the percent of the SCS redd count upstream of the Red Bluff Fish and Wildlife Offices' Upper Clear Creek rotary screw trap (UCC RST), where estimates of juvenile SCS production are made. 'Injection gravel' is the percent of redds in the SCS redd count that contained injection gravel. From 2003–2009, we adjusted the boundary of Reach 5a and 5b, based on where the weir was placed each year, and Reach 1–5a was always upstream of the weir. In 2010, we added Reach 5c and made the location of Reach 5a and Reach 5b breaks consistent, independent of the weir location. Reach 5a was Clear Creek Road Bridge to Reading Bar site, Reach 5b was Reading Bar site to Shooting Gallery site, and Reach 5c was from Shooting Gallery site to Gorge Cascade. Most redds downstream of the weir (Reach 5b and Reach 6) were fall Chinook salmon (FCS), although some may have been SCS, based on the presence of holding adult SCS during the August snorkel survey. Reach 6 snorkel surveys ended in late September and were replaced by a FCS mark-recapture carcass survey.

Year	R1	R2	R3	R4	R5a	SCS redd count	Upstream of IGO	Upstream UCC RST	Injection gravel	R5b	R5c	R6
2003	11	19	5	16	2	*53*	66%	98%	15%	19	NA	98
2004	6	9	3	14	5	*37*	49%	97%	32%	27	NA	62
2005	16	15	4	14	3	*52*	67%	98%	35%	123	NA	38
2006	11	16	20	22	13	*82*	57%	84%	32%	30	NA	82
2007	18	17	2	7	5	*49*	76%	96%	35%	35	NA	99
2008	14	22	10	18	22	*86*	53%	79%	41%	10	NA	157
2009	15	15	6	19	9	*64*	56%	92%	27%	15	NA	161
2010	2	4	0	3	0	*10*[a]	60%	90%	60%	5[a]	11	27
Mean	23%	27%	11%	27%	13%	*60*	61%	92%	31%	37	NA	100

a Because two weirs were installed in 2010 and adult holding SCS were present between weirs, the SCS redd count includes one redd from Reach 5b that was observed during the September 22 snorkel survey.

Table 5. Distribution of spring Chinook salmon redds (SCS) in Clear Creek, 2003–2010. River miles (RM) begin at the confluence at RM 0 and end at Whiskeytown Dam at RM 18.3. River miles 11–18 are upstream of IGO. Both RM 7 (0.6 miles) and RM 18 (0.3 miles) are incomplete miles. The SCS redd count is redds upstream of the picket weir location. From 2003 through 2005, the picket weir was located at RM 8.2 (Reading Bar) so RM 7 was not available for SCS spawning. From 2006 through 2009, the location of the picket weir was at RM 7.4 (Shooting Gallery). In 2010, weirs were installed at both sites.

Year	RM 7	RM 8	RM 9	RM 10	RM 11	RM 12	RM 13	RM 14	RM 15	RM 16	RM 17	RM 18	Total
2003	NA	4	5	9	2	3	0	15	3	4	5	3	**53**
2004	NA	9	1	9	2	0	2	4	3	3	4	0	**37**
2005	NA	4	2	11	4	0	1	4	10	3	11	2	**52**
2006	4	11	8	12	13	7	0	4	8	10	5	0	**82**
2007	0	6	1	5	0	2	1	1	7	15	11	0	**49**
2008	8	18	3	11	4	6	0	11	5	13	6	1	**86**
2009	3	8	2	15	4	1	4	6	4	4	13	0	**64**
2010	1 [a]	1	0	3	0	0	0	1	1	2	1	0	**10**
Mean	4%	14%	5%	17%	7%	4%	2%	11%	9%	12%	13%	1%	

[a] The SCS redd count includes one redd from Reach 5b (between weirs). Others redd in Reach 5b were counted as fall Chinook and not included here.

Table 6. Characteristics of spring Chinook salmon (SCS) redds in Clear Creek in 2010. Mean characteristics of SCS redds in Clear Creek from 2003–2008 are presented for comparison. Substrate refers to the dominant size class range.

	Length (ft)	Width (ft)	Area (ft^2)	Pre-redd (ft)	Pit (ft)	Tail-spill (ft)	Velocity (ft/s)	Substrate (in)
2003–2008								
Mean	15.3	7.7	100.6	2.2	2.6	1.6	2.3	1–3
Median	15.2	7.2	85.9	1.9	2.3	1.3	2.2	
Standard deviation	5.8	3.1	73	1.1	1	0.9	0.8	
n	320	319	319	325	320	319	318	326
2010								
Mean	11.9	8	84.4	1.5	1.9	1.2	2.3	1–3
Median	12.3	8.3	80.7	1.3	1.4	0.8	2.5	
Standard deviation	5.3	3	62.2	0.9	1.2	0.9	0.8	
n	7	7	7	7	7	7	7	5

Table 7. Redd age tracking results for spring Chinook salmon redds (SCS) in Clear Creek, 2010. Redds were identified as new on the first survey then revisited and aged by surveyors subsequent surveys. Percent of SCS redd count visible includes new redds observed, and subtracts redds that are no longer visible.

				Redds visible			
Survey	Mean survey date	Mean days between surveys	New redds	Survey 6	Survey 7	Survey 8	Survey 9
6	21-Sept	13	6	6	5	1	0
7	06-Oct	15	4		4	4	0
8	20-Oct	14	0				
9	09-Nov	20	0				
	Percent of SCS redd count visible			*60%*	*90%*	*50%*	*0%*

Table 8. Picket weir installation dates and monitoring days on Clear Creek, 2003–2010. Beginning in 2006, the location of the picket weir was either at Reading Bar (RB) or at Shooting Gallery (SG), based upon the percent of the SCS August index holding in the large pool between the weir sites.

Survey year	Weir location[a]	Date installed	Date removed	Days installed	Days monitored
2003	RB	2-Sep	3-Nov	63	48
2004	RB	26-Aug	1-Nov	68	67
2005	RB	25-Aug	15-Nov	83	72
2006	SG and RB	24-Aug	1-Nov	70	38
2007	SG	23-Aug	1-Nov	71	44
2008	SG	21-Aug	31-Oct	72	43
2009	SG and RB	27-Aug	3-Nov	69	36
2010	SG and RB	26-Aug	25-Oct	60	38

[a] In 2006, the weir was installed at the SG site but after several incidents when pickets were lifted and fish passage was allowed, we installed a second weir at the RB site on October 6. The second weir was in the creek for 27 days and monitored 11 days. In 2009, the weir was located at Shooting Gallery until October 20 after it was damaged by high flows, at which point a new weir was installed at Reading Bar. In 2010, two weirs were installed because more than 10% of the SCS AI was between weir sites, and this was determined after the Reading Bar was already installed.

Table 9. Picket weir breaches that occurred on Clear Creek during weir monitoring period in 2010. Two weirs were installed in 2010; one at Reading Bar (RB) and one at Shooting Gallery (SG). 'Maximum hours open' refers to the period from when the breach was discovered and fixed to the time and date it was last checked. 'Risk to SCS' refers to fall Chinook salmon (FCS) passing the weir and spawning in spring Chinook salmon (SCS) habitat, and was assigned as either 'High' or 'Low' depending when the breach occurred. 'Impact type' describes what may have occurred if FCS passed the weir and spawned, and was defined based on the timing of the weir breach.

Name	Date of last weir check	Date fixed	Maximum hours open	Cause	Risk to SCS	Impact type	Comments
Breach 1-SG	9/21/2010	9/22/2010	24	Tampering	High	Hybridization/ superimposition	13 pickets removed at SG, RB open
Breach 2-RB	10/04/2010	10/05/2010	24	Debris load/scour	Low	Hybridization/ superimposition	12 pickets not flush with bottom, from debris, FCS in 5B
Breach 3-SG	10/05/2010	10/06/2010	24	Debris load/scour	Low	Hybridization/ superimposition	Four pickets not flush with bottom, from debris, RB closed
Breach 4-RB and SG	10/24/2010	Removed	NA	High flows	Low	Superimposition	Weir inundated, eroded banks and scour, weir damaged

Table 10. Chinook salmon carcasses recovered on Clear Creek during snorkel surveys and weir monitoring, 2003–2010. 'Reaches 1–5a' refers to the total spring Chinook salmon (SCS) carcasses recovered upstream of the weir. 'Weir' refers to percent of total carcasses recovered on the weir. Table includes gender and clip status of carcasses from upstream of the weir. From 2003 to 2009, the boundaries of Reach 5a and Reach 5b were adjusted each year based on location of the weir. In 2010, Reach 5c was added to make the reach boundaries permanent. Reach 5a was Clear Creek Road Bridge to Reading Bar weir site, Reach 5b was Reading Bar to Shooting Gallery weir site, and Reach 5c was Shooting Gallery weir site to Gorge Cascade. In 2010, two weirs were installed, one at Reading Bar site, and one at Shooting Gallery site. 'Carcasses downstream of the weir' were considered fall Chinook salmon (FCS), although some may have been SCS based on the presence of holding adult SCS during the August snorkel survey. Carcasses in Reach 6 were only counted through the end of September because snorkel surveys were replaced with FCS walking carcass surveys.

	Carcasses upstream of weir						Carcasses downstream of weir		
Year	Reaches 1–5a	Weir	Female	Unknown gender	Adipose clip	Unknown clip	Reach 5b	Reach 5c	Reach 6
2003	25	32%	61%	28%	4%	16%	23	na	10
2004[a]	43 (21)	70% (90%)	23% (6%)	30% (14%)	2% (0%)	7% (0%)	22	na	1
2005	67	54%	35%	18%	0%	9%	321	na	1
2006	62	38%	61%	20%	0%	0%	3	na	4
2007	72	42%	32%	26%	3%	6%	7	na	8
2008	77	42%	39%	16%	0%	1%	7	na	3
2009[a]	41 (51)	49% (94%)	36% (4%)	5% (0%)	0% (5%)	2% (0%)	5	na	1
2010[b]	12	58% (85%)	17% (2%)	0% (12%)	(8%) (5%)	0% (0%)	41	2	3

[a]Due to potential fall Chinook salmon (FCS) passage during weir breaches in 2004 and 2009, run calls were made on carcasses upstream of the weir, based on their physical appearance and recovery date. The numbers in parenthesis represent FCS carcasses in those years.
[b]The number in parenthesis were recovered between Shooting Gallery and Reading Bar weir (Reach 5b).

Table 11. Tissue, otolith, and scale samples collected from Chinook salmon carcasses during 2010 Clear Creek snorkel and weir surveys. Table shows the samples taken upstream of the Reading Bar weir and between Reading Bar weir and Shooting Gallery weir. because two weirs were in place and there were breaches during fall Chinook salmon migration. Carcasses upstream of Reading Bar weir were more likely spring Chinook salmon, and fall Chinook salmon between weirs. However, both runs may have been at either location.

Sample type	Upstream of Reading Bar weir (Reaches 1–5a)	Between Reading Bar weir and Shooting Gallery weir (Reach 5b)	Total
Tissue	12	41	53
Otolith	11	39	50
Scale[a]	10	40	50

[a] Three scales collected in the field were unreadable.

Table 12. 2010 Clear Creek coded wire tag recoveries from Chinook salmon carcasses recovered during snorkel and weir surveys. Results from unknown adipose clip status carcasses that were scanned for coded wire tags are also presented here. NTD=No tag detected.

Creek	Date	Reach	Gender	Adipose	CWT code	Hatchery	Run	Brood year	Release site
Clear	10/7/2010	R5a	Male	Clip	068009	Feather River	Spring	2007	San Pablo Bay
Clear	10/18/2010	R5b	Male	Clip	068609	Feather River	Fall	2007	San Pablo Bay
Clear	10/18/2010	R1	Male	Unknown	NTD				
Clear	10/21/2010	R5b	Unknown	Unknown	NTD				
Clear	10/23/2010	R5b	Male	Clip	Lost Tag				

Table 13. Mean daily water temperatures (MDT) during the holding criteria period (June 1 through September 14) at various temperature logger sites in Clear Creek, 2010. IGO is the water temperature compliance point. Holding adult spring Chinook salmon (SCS) are associated with the closest temperature logger based on their location during the August index survey (SCS AI). Percent of days refers to the number of days within the criteria period that the site was exposed to MDT greater than 60°F.

Temperature logger site	**Need Camp**	**Kanaka Creek**	**Igo Gaging Station (IGO)**	**Clear Creek Road Bridge**	**Gorge Spawning Curve**	**Renshaw Riffle**	**Total**
Average MDT (°F)	52.9	54.6	55.7	58.8	60.3	60.6	
Minimum MDT (°F)	51.0	52.3	52.5	53.6	54.0	54.1	
Maximum MDT (°F)	54.5	55.9	57.3	61.3	63.4	63.8	
Standard deviation	0.9	1.0	1.1	1.7	2.1	2.2	
SCS AI	2	5	6	4	1	3	21
% of SCS AI	10%	24%	29%	19%	5%	14%	
Days over 60°F MDT in holding criteria period	0	0	0	24	66	70	
% of days	0	0	0	23%	62%	66%	

Table 14. Estimated mean percent of the minimum and maximum number of days that mean daily water temperatures were >56°F at Chinook salmon redd locations during snorkel surveys in Clear Creek, 2010. Redd locations and dates were associated with our temperature monitoring data and emergence dates were calculated based on 1,850 Daily Temperature Units (DTU) required for egg development. Minimum days is calculated assuming the redd was built the day before it was first observed. Maximum days assumes the redd was built the first day after the previous survey. Nine fall Chinook salmon redds observed in Reaches 5b and 5c on Surveys 6–8 are also included (five redds observed in Reach 5c during Survey 8, and one during Survey 9 are not included because they were later redds and not exposed to >56°F).

Reach	Redds	Minimum percent of days exposure to water temperatures >56°F	Maximum percent of days exposure to water temperatures >56°F
Reach 1	2	10%	20%
Reach 2	4	22%	23%
Reach 3	0	-	-
Reach 4	3	20%	38%
Reach 5a	0	-	-
Reach 5b	1	37%	54%
Mean	***10***	***21%***	***30%***
Reach 5b	4	6%	20%
Reach 5c	5	20%	39%

Figures

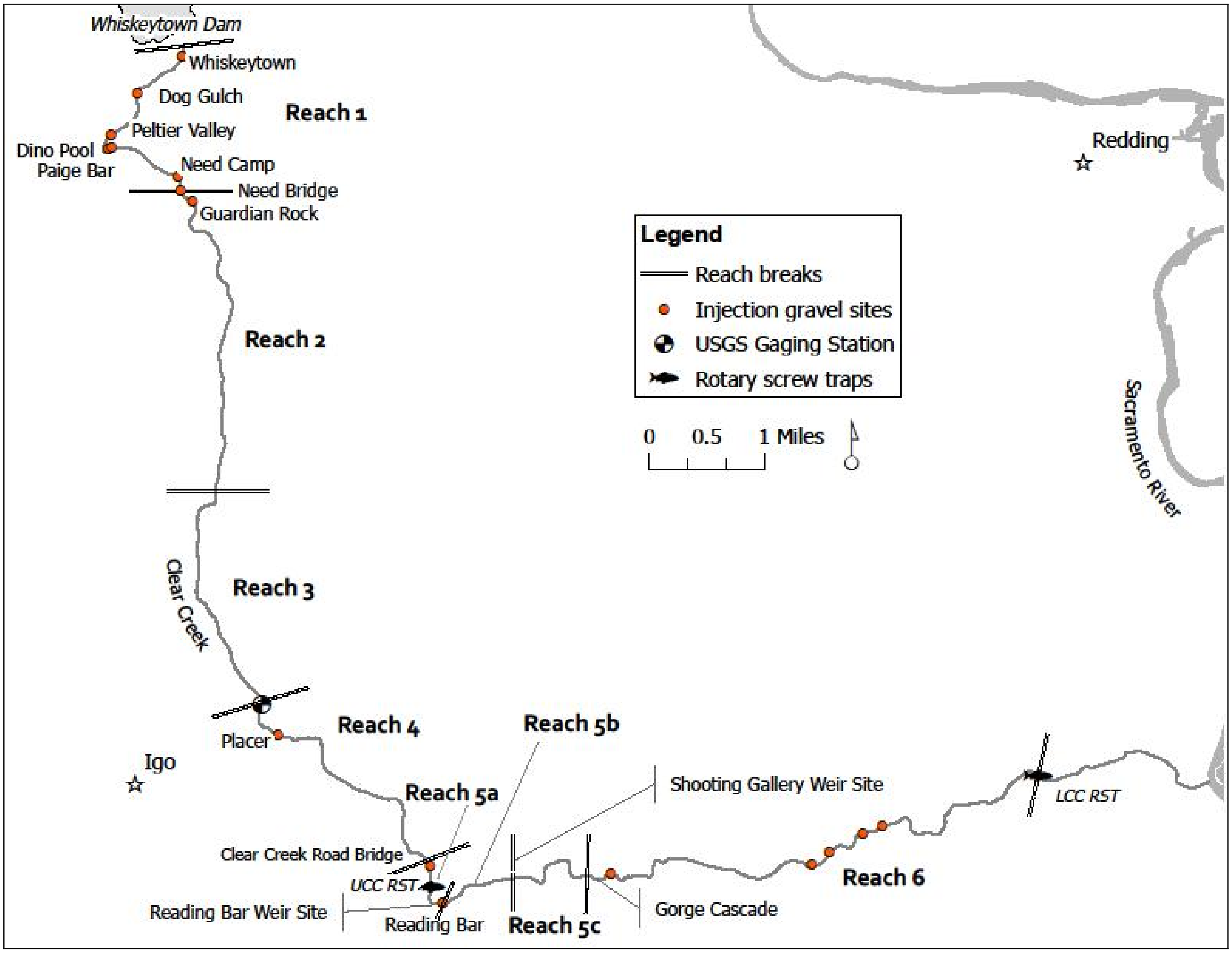

Figure 1. Map of study area, Clear Creek, Shasta County, California, 2010.

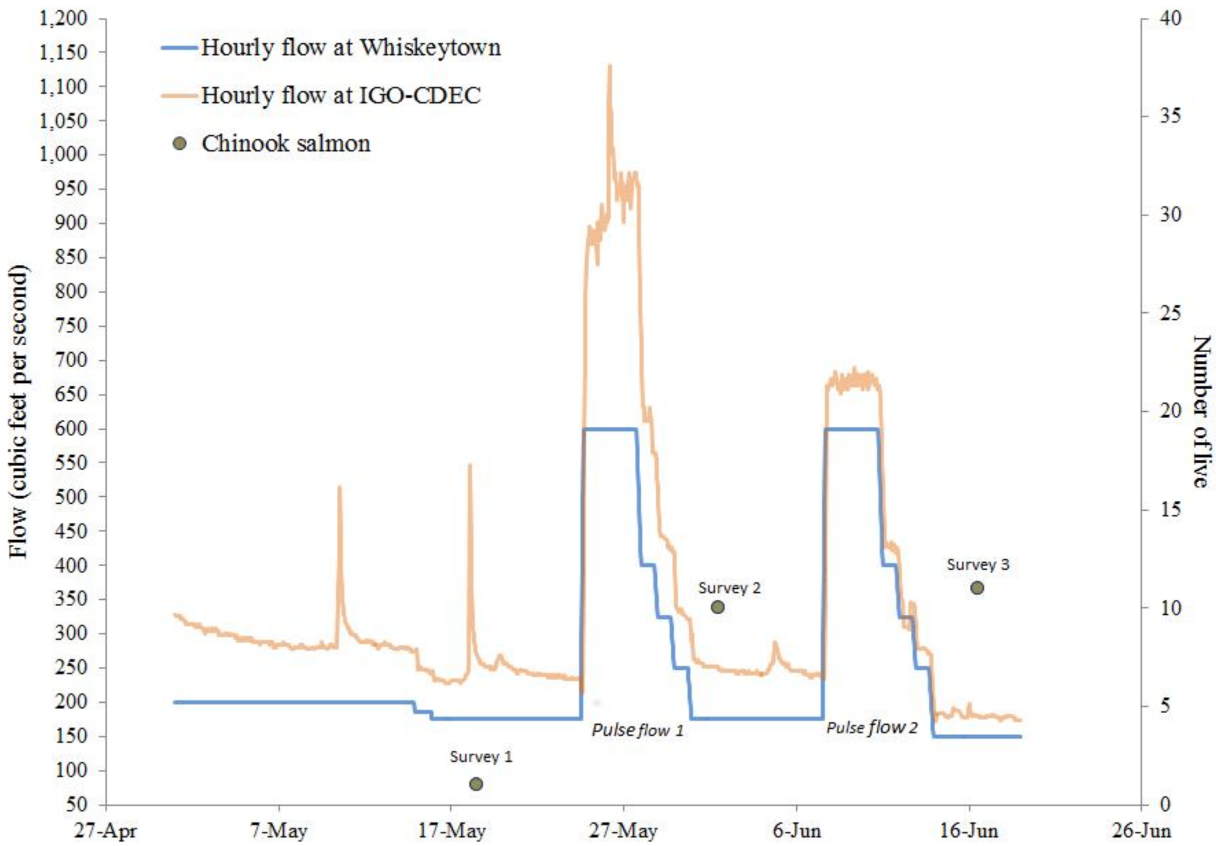

Figure 2. Pulse flows and snorkel survey results on Clear Creek, 2010. Hourly flows are shown from what was released at Whiskeytown Dam, and what was recorded the Igo Gaging Station. The number of live adult Chinook salmon counted on each snorkel survey between pulse flows are shown.

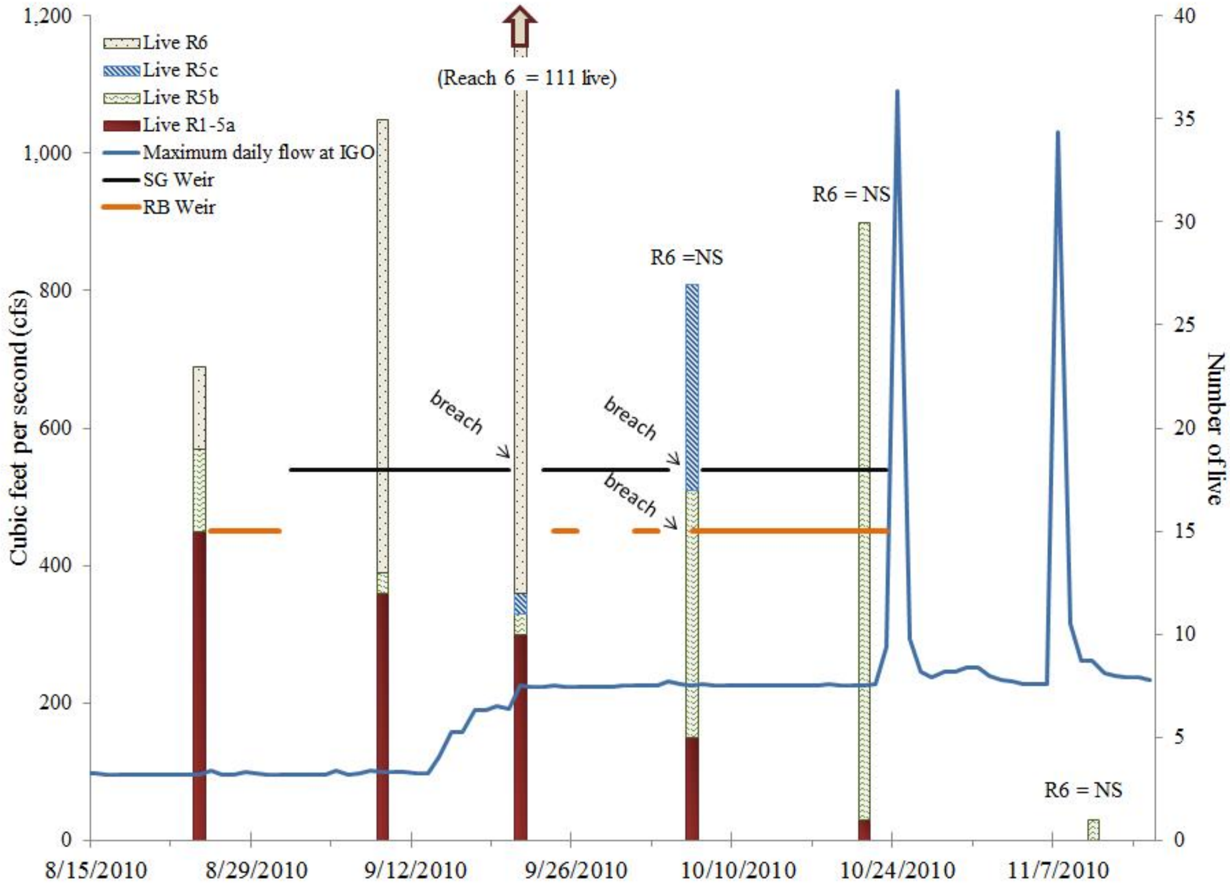

Figure 3. Live adult Chinook salmon observed in Clear Creek during snorkel surveys, 2010. Vertical bars represent salmon distribution upstream and downstream of the weirs. The picket weir was installed at Reading Bar after the spring Chinook salmon August Index (SCS AI) snorkel survey, to separate spring (SCS) and fall Chinook salmon (FCS) during spawning. A second weir was installed at Shooting Gallery to protect more SCS. Horizontal bars represent the periods when the weir was installed, and gaps represent periods when the weir was open. Reach 5c and Reach 6 were downstream of both weirs. Reach 6 snorkel surveys were ceased in late September.

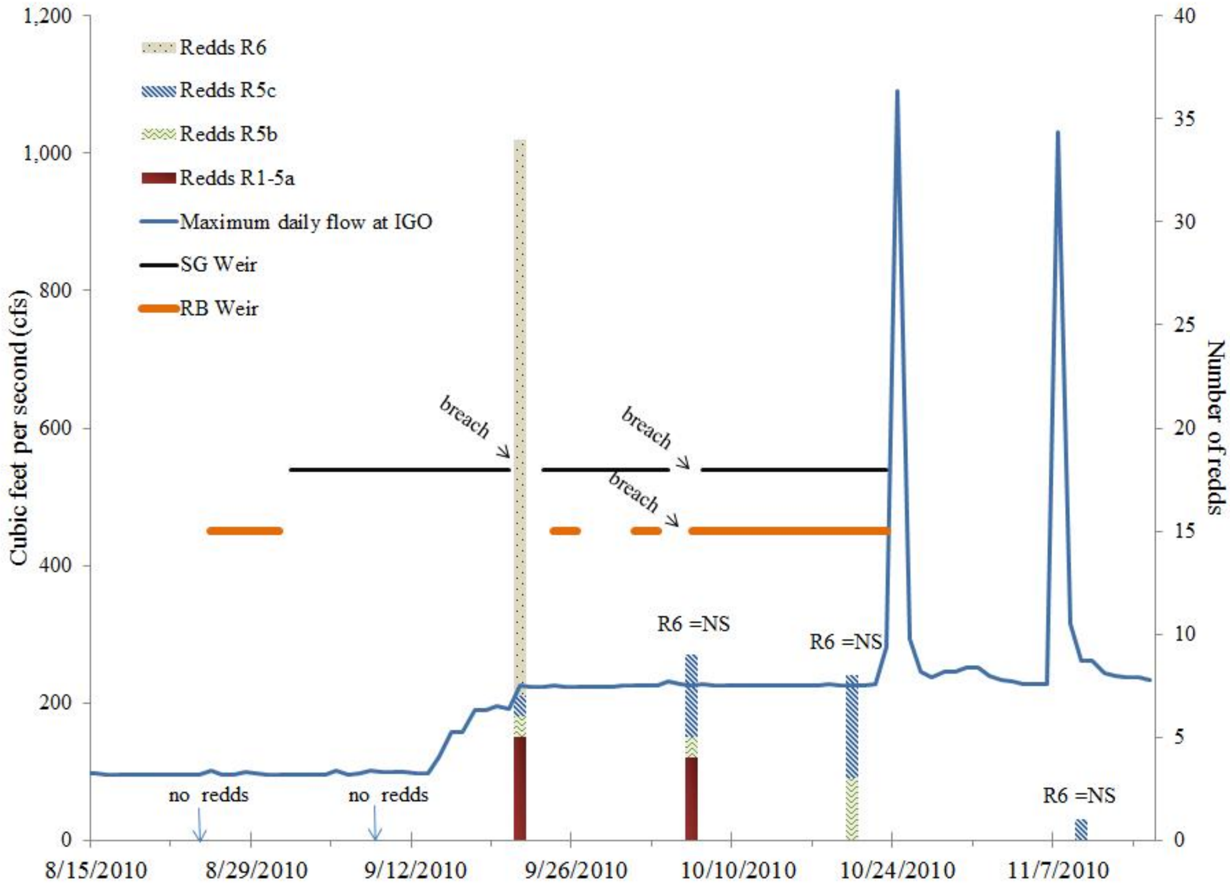

Figure 4. Chinook salmon redd counts in Clear Creek during snorkel surveys, 2010. Vertical bars represent redd distribution upstream and downstream of the weirs. The picket weir was installed at Reading Bar after the spring Chinook salmon August Index (SCS AI) snorkel survey, to separate spring (SCS) and fall Chinook salmon (FCS) during spawning. A second weir was installed at Shooting Gallery to protect more SCS. Horizontal bars represent the periods when the weir was installed, and gaps represent periods when the weir was open. Reach 5c and Reach 6 were downstream of both weirs. Reach 6 snorkel surveys were ceased in late September.

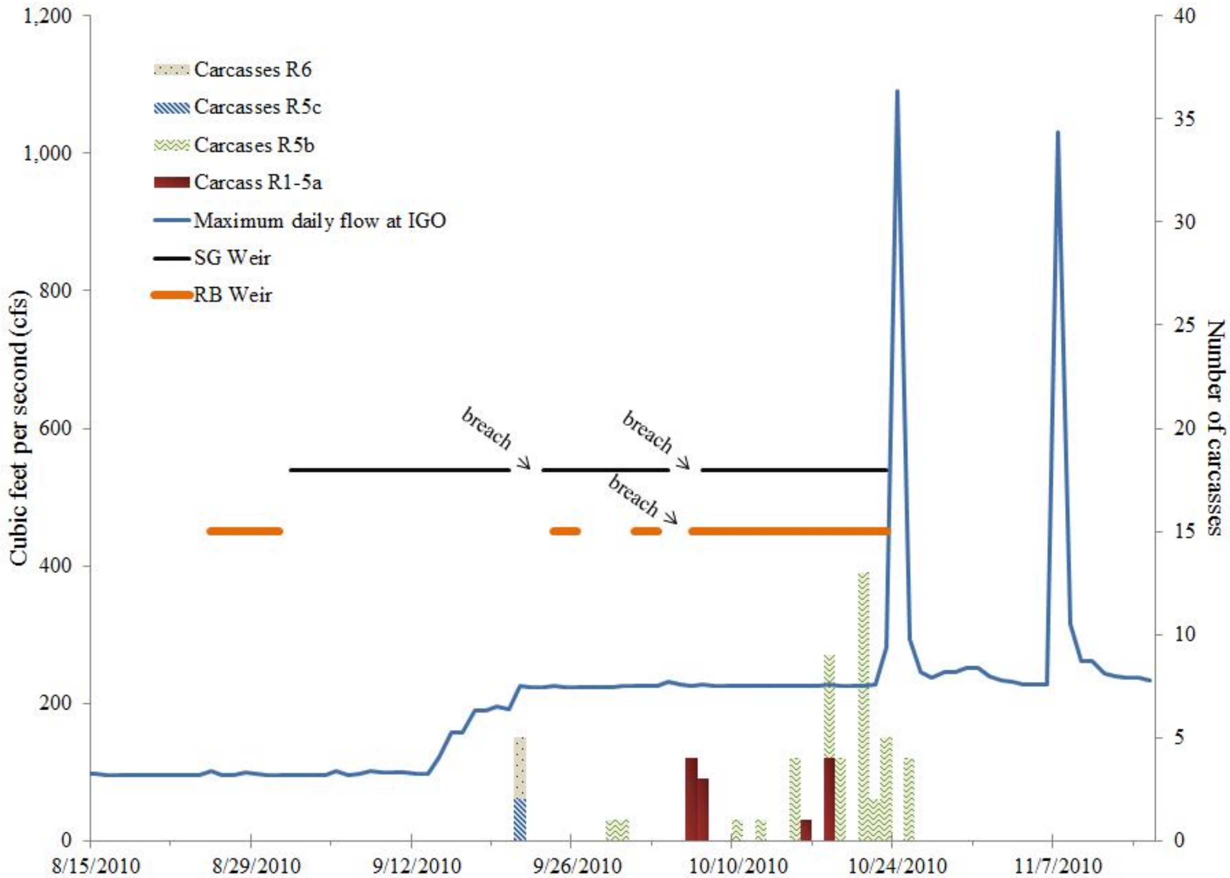

Figure 5. Chinook salmon carcass counts in Clear Creek during snorkel and weir monitoring surveys, 2010. Vertical bars represent salmon distribution upstream and downstream of the weirs. Due to weir breaches, we made run calls on fall Chinook salmon (FCS) and spring Chinook salmon (SCS) carcasses based on their physical attributes, and the dates of the breaches. The temporary picket weir was installed after the August snorkel survey to separate SCS and FCS during spawning. A second weir was installed at Shooting Gallery to protect more SCS. Horizontal bars represent the periods when the weir was installed, and gaps represent periods when the weir was open. Reach 5c and Reach 6 were downstream of both weirs. Reach 6 snorkel surveys were ceased in late September.

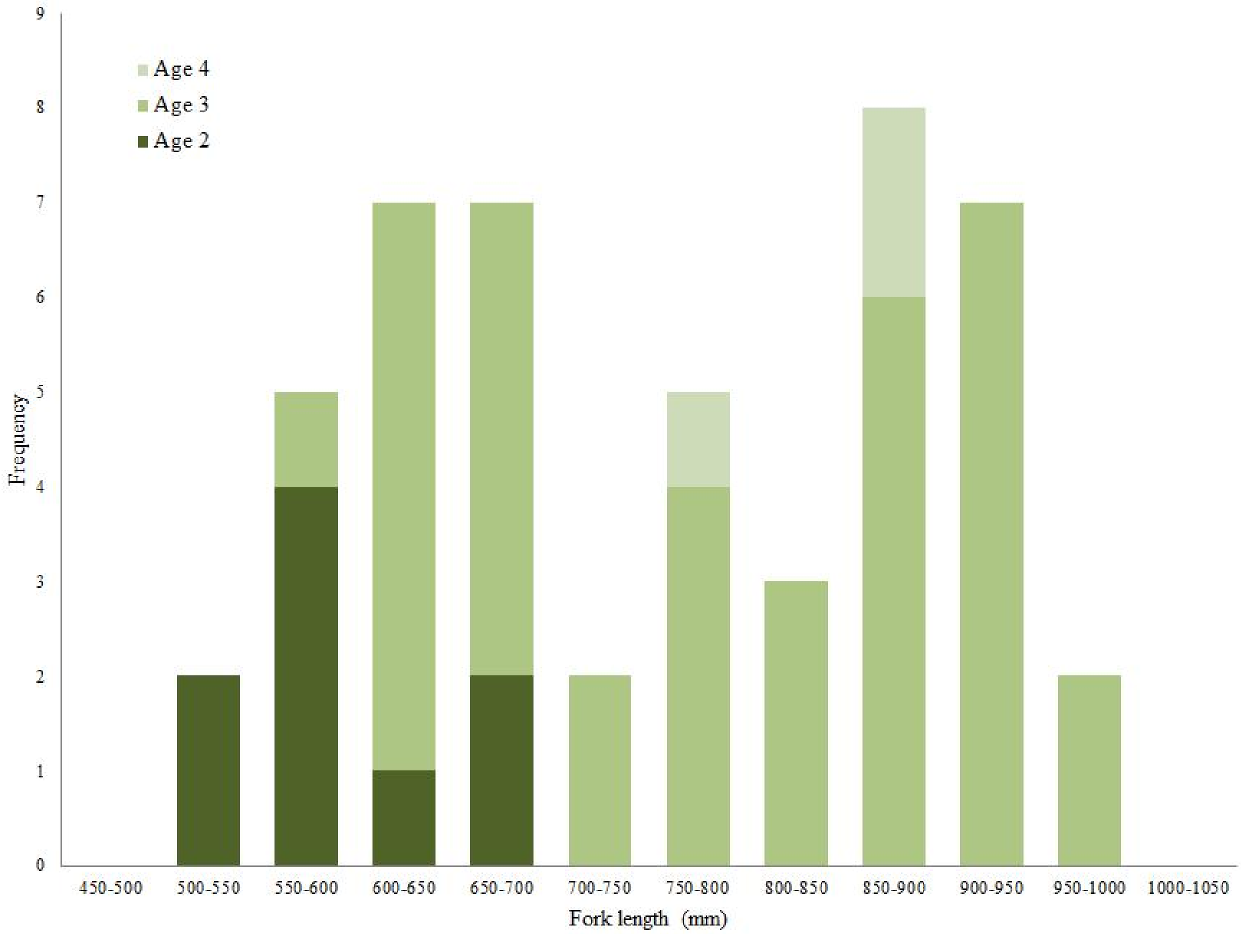

Figure 6. Frequency distribution for age composition and fork lengths of Clear Creek Chinook salmon carcasses retrieved upstream of the weir during snorkel surveys and picket weir monitoring, 2010.

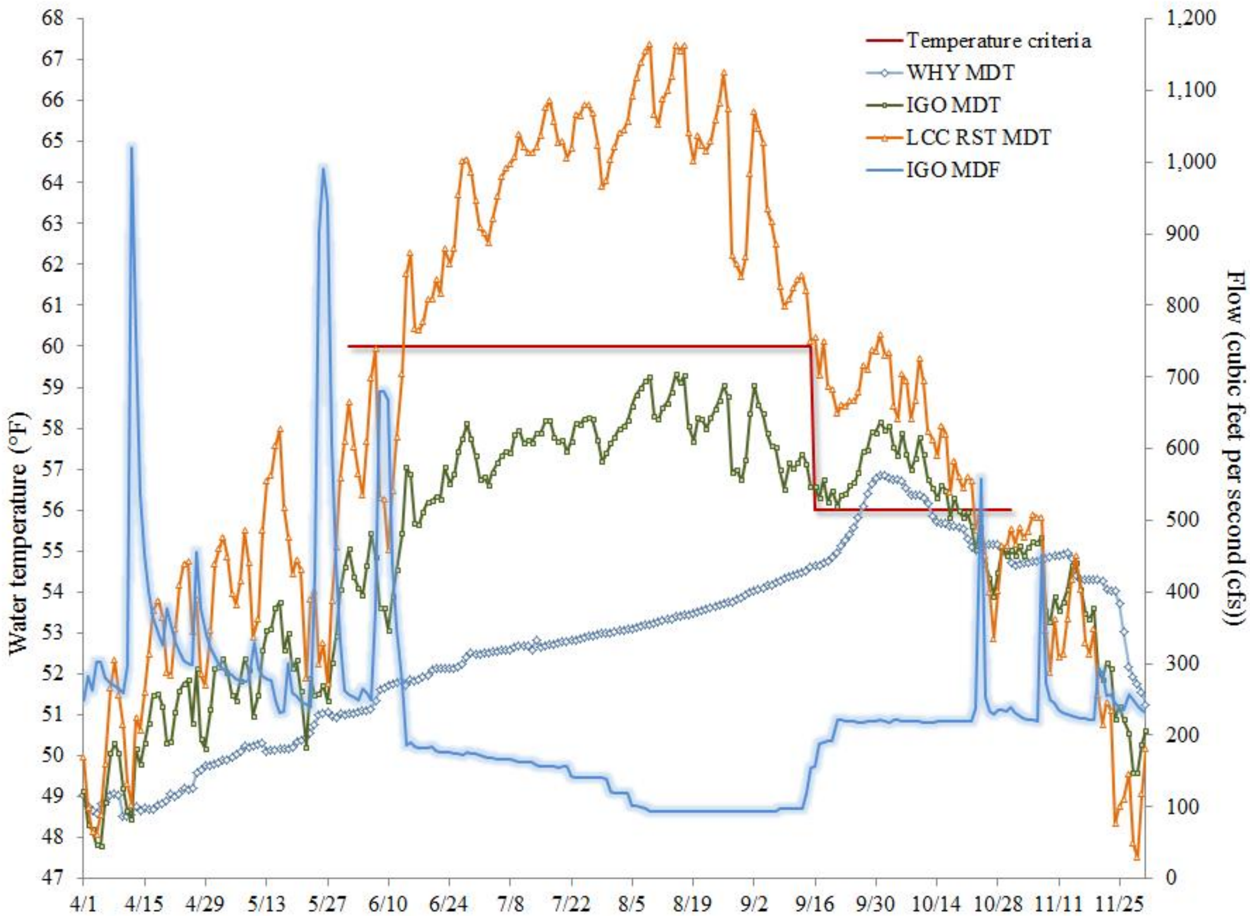

Figure 7. Mean daily water temperature (MDT) and mean daily flow (MDF) at the USGS Igo gaging station (IGO), Clear Creek, 2010. The solid red line represents MDT criteria maintained at IGO for spring Chinook salmon holding, and egg incubation. The Whiskeytown Dam (WHY) temperature logger records water temperature coming in to Clear Creek from the reservoir. The Red Bluff Fish and Wildlife Offices' lower rotary screw trap (LCC RST) temperature logger is located at the end of the survey area at river mile 1.8.

Figure 8. High flows at the Shooting Gallery weir, October 2010.

Appendix A. Chinook salmon live adult, carcass, and redd counts on Clear Creek during snorkel surveys, 2010. Survey conditions for each reach include mean daily flow, average turbidity, and average water temperature.

Survey week	Reach	Date	Live	Redd	Carcass	Average water temperature (°F)	Average turbidity (NTU)	Mean daily flow (cfs)
1	R1	5/17/2010	0	0	0	51	2.4	233
	R2	5/18/2010	0	0	0	51	1.7	300
	R3	5/18/2010	0	0	0	53	2.6	300
	R4	5/19/2010	0	0	0	47	3.1	258
	R5abc	5/19/2010	0	0	0		*Surveyed same day as R4*	
	R6	5/21/2010	1	0	0	55	3.1	247
Survey 1 total			1	0	0	51	2.5	268
2	R1	6/1/2010	0	0	0	52	1.9	256
	R2	6/2/2010	0	0	0	53	1.5	252
	R3	6/3/2010	1	0	0	53	1.5	249
	R4	6/3/2010	0	0	0	55	2.0	249
	R5a	6/3/2010	0	0	0		*Surveyed same day as R4*	
	R5b	6/3/2010	0	0	0		"	
	R5c	6/3/2010	2	0	0		"	
	R6	6/2/2010	7	0	0	56	2.5	252
Survey 2 total			10	0	0	54	1.9	252
3	R1	6/15/2010	0	0	0	52	1.6	189
	R2	6/15/2010	0	0	0	54	1.4	189
	R3	6/16/2010	3	0	0	52	1.5	185
	R4	6/16/2010	2	0	0	55	1.4	185
	R5a	6/16/2010	2	0	0		*Surveyed same day as R4*	
	R5b	6/16/2010	0	0	0		"	
	R5c	6/16/2010	0	0	0		"	
	R6	6/17/2010	4	0	0	57	1.8	183
Survey 3 total			11	0	0	54	1.5	186
3.5	R5a	8/18/2010	1	0	0	57	1.4	95
	R5a	8/18/2010	1	0	0		*Surveyed same day as R5a*	
Survey 3.5 total			2	0	0	57	1.4	95
4	R1	8/23/2010	2	0	0	54	1.6	95
	R2	8/23/2010	9	0	0	56	1.3	94
	R3	8/24/2010	2	0	0	56	1.7	94
	R4	8/26/2010	0	0	0	61	1.5	93
	R5a	8/26/2010	1	0	0		*Surveyed same day as R4*	
	R5b	8/26/2010	3	0	0		"	
	R5c	8/26/2010	0	0	0		"	
	R6	8/26/2010	4	0	0	67	2.3	93
Survey 4 total			21	0	0	59	1.7	94
5	R1	9/8/2010	1	0	0	53	1.8	97
	R2	9/8/2010	9	0	0	55	1.1	97
	R3	9/9/2010	1	0	0	56	1.4	98
	R4	9/9/2010	0	0	0	57	1.4	98
	R5a	9/9/2010	1	0	0		*Surveyed same day as R4*	
	R5b	9/9/2010	1	0	0		"	
	R5c	9/9/2010	0	0	0		"	
	R6	9/10/2010	22	0	0	63	1.4	98
Survey 5 total			35	0	0	56	1.4	98

Survey week	Reach	Date	Live	Redd	Carcass	Average water temperature (°F)	Average turbidity (NTU)	Mean daily flow (cfs)
6	R1	9/20/2010	5	0	0	56	1.9	191
	R2	9/20/2010	4	4	0	54	1.5	191
	R3	9/21/2010	0	0	0	55	1.7	222
	R4	9/22/2010	1	1	0	57	2.0	221
	R5a	9/22/2010	0	0	0	*Surveyed same day as R4*		
	R5b	9/22/2010	1	1	0	"		
	R5c	9/22/2010	1	1	0	"		
	R6	9/23/2010	111	27	3	58	1.3	223
Survey 6 total			123	34	3	55	1.8	210
7	R1	10/5/2010	2	2	0	57	2.0	221
	R2	10/5/2010	1	0	1	57	1.5	221
	R3	10/6/2010	0	0	0	56	1.5	220
	R4	10/7/2010	1	2	1	56	2.1	220
	R5a	10/7/2010	1	0	2	57	1.4	220
	R5b	10/7/2010	12	1	0	*Surveyed same day as R5a*		
	R5c	10/7/2010	10	4	0	"		
Survey 7 total			27	9	4	56	1.7	220
8	R1	10/18/2010	0	0	3	56	1.3	220
	R2	10/19/2010	0	0	0	56	1.3	220
	R3	10/21/2010	0	0	0	58	1.8	220
	R4	10/21/2010	0	0	0	55	1.4	220
	R5a	10/21/2010	1	0	0	56	1.5	220
	R5b	10/21/2010	29	3	13	*Surveyed same day as R5a*		
	R5c	10/21/2010	15	5	2	"		
Survey 8 total			45	8	15	56	1.5	220
9	R1	11/8/2010	0	0	0	56	1.6	272
	R2	11/9/2010	0	0	0	53	1.3	248
	R3	11/9/2010	0	0	0	54	1.4	248
	R4	11/10/2010	0	0	0	55	2.0	245
	R5a	11/10/2010	0	0	0	*Surveyed same day as R4*		
	R5b	11/10/2010	1	0	0	"		
	R5c	11/10/2010	0	1	0	"		
Survey 9 total			1	1	0	54	1.6	253