Accurately Estimating Abundance of Juvenile Spring Chinook Salmon in Clear Creek, from October 2003 through June 2004

USFWS Report

Prepared by:

Matthew R. Brown
James T. Earley

U.S. Fish and Wildlife Service
Red Bluff Fish and Wildlife Office
10950 Tyler Road
Red Bluff, CA 96080

December 2007

Disclaimer

The suggested citation for this report is:
Brown, M.R., and J. T. Earley. 2007. Accurately Estimating Abundance of Juvenile Spring Chinook Salmon in Clear Creek, from October 2003 through June 2004. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Accurately Estimating Abundance of Juvenile Spring Chinook Salmon in Clear Creek, from October 2003 through June 2004

Matthew R. Brown, and James T. Earley
U.S. Fish and Wildlife Service
Red Bluff Fish and Wildlife Office, Red Bluff, California

Abstract.—The length-at-date criteria for designating runs of juvenile Chinook salmon *(Oncorhynchus tshawytscha)* were developed using mainstem Sacramento River fall Chinook. Tributary populations experience different spawning and emergence timing, temperature regimes and growth rates and therefore run may be mis-assigned. In Clear Creek, spring and fall Chinook salmon overlap in spawn timing and geographical distribution, making accurate run-designation of these at-risk species difficult. Since 1998, a rotary screw trap (RST) has been placed in Clear Creek downstream of most Chinook spawning habitat to estimate passage of emigrating runs of Chinook. This trap catches both spring and fall Chinook of the same length simultaneously making accurate passage estimates problematic. A temporary barrier weir was placed in Clear Creek in August of 2003 to separate fall and spring Chinook spawning areas. A second RST was operated above the weir to sample only juvenile spring Chinook. If the adult fish above the barrier were all spring Chinook then the length criteria mis-assigned 91% of the juvenile spring Chinook as fall run. Genetic analysis of tissue samples collected from Clear Creek may assist in developing better run designation criteria and passage estimates. Spawning, emergence timing and temperature data were analyzed to estimate that 1,850 daily temperature units were required for juvenile emergence (DTUE) in Clear Creek in 2003. Accurate DTUE estimates were useful in reducing potential impacts during early season RST sampling.

Table of Contents

List of Figures

List of Figures (Con't)

List of Tables

List of Appendix

Introduction

The U.S. Fish and Wildlife Service (USFWS), Red Bluff Fish and Wildlife Office (RBFWO) has been conducting a juvenile salmonid monitoring project in Clear Creek, Shasta County, California using a rotary screw trap (RST) since December 1998. This ongoing monitoring project has three primary objectives: 1) determine an annual juvenile passage index (JPI) for Chinook salmon (*Oncorhynchus tshawytscha*) and rainbow trout/steelhead (*O. mykiss*), for inter-year comparisons; 2) obtain juvenile salmonid life history information including size, condition factor, emergence, emigration timing, and potential factors limiting survival at various life stages; and 3) collect otolith and tissue samples from juvenile salmonids for future analyses. Rotary screw traps have been used as the primary means to evaluate trends in juvenile salmon abundance. Rotary screw traps have limitations, such as capturing predominately smaller sized juvenile salmon, washing out of thalweg when debris blocks normal flow or becoming miscalibrated in streams that are subject to large flow fluctuations, and misrepresenting population sizes because of low trap efficiency and high variability. Even with these limitations, RST's can be an effective monitoring tool, and can provide reliable estimates of juvenile passage when used consistently over a number of years (CAMP 2002, sec. 5-1).

Clear Creek is a tributary of the Sacramento River. Four runs of Chinook salmon from the Sacramento River watershed, including spring-run (SCS), fall-run (FCS), late-fall-run (LFCS), and winter-run (WCS), are known to inhabit Clear Creek. Spring Chinook salmon are listed as threatened (1999) and winter Chinook salmon are listed as endangered (1994) up listed from a previous 1990 listing of threatened, under the Federal Endangered Species Act (ESA). A naturally self-sustaining population of winter Chinook does not exist in Clear Creek. The *O. mykiss* population; includes both anadromous (steelhead) and resident (rainbow trout) fish. Further investigation into *O. mykiss* anadromy will be sought through otolith microchemistry analysis. *Oncorhynchus mykiss* redds are observed from snorkel and kayak surveys January through March (Giovannetti, RBFWO, USFWS, Personal Communication), with the majority occurring in January.

Spring-run Chinook salmon are a stream type-fish with a somewhat variable juvenile outmigration pattern. In some years, juveniles predominantly outmigrate as fry during winter storms, and in other years, juveniles predominantly outmigrate as yearlings during fall freshets (CDFG 1998). The distribution of spring Chinook in the Sacramento River watershed is limited to a few streams with fish passage to upper elevations. Butte, Deer, and Mill creeks are the principal streams in the Sacramento River watershed still supporting spring-run Chinook salmon (Moyle 2002). Butte Creek however has a total barrier to upstream migration of adult spring Chinook at an elevation of approximately 1000 ft. which is considerably lower than and not typical of historical SCS streams, which had adults ascending to elevations of 3,000 to 5,000 ft. Cold water transfer and flow regime manipulation through Pacific Gas and Electric hydropower operations is one of the primary reasons SCS holding and spawning is possible in lower elevations on Butte Creek (Gene Geary 2006, Pacific Gas and Electric Company, personal communication 7/27/06). Clear Creek is similar to Butte Creek in that it also has a total barrier at the base of Whiskeytown Dam at an elevation of 950 ft. The Whiskeytown reservoir has the means for providing cold water and necessary flows to Clear Creek to sustain SCS populations.

The population of SCS in Clear Creek represents a small percentage of the Sacramento River watershed population. Annual population indices of adult SCS in Clear Creek are based on August snorkel counts conducted in the SCS holding and spawning portions of the stream, similar to efforts on Butte, Deer, and Mill creeks.

Restoration of anadromous salmonid populations in Clear Creek is an important element of the Central Valley Project Improvement Act (CVPIA). The CVPIA has a specific goal to double populations of anadromous fishes in the Central Valley of California. The Clear Creek Restoration Program authorized by Section 3406 (b) 12 of CVPIA, has funded many anadromous fish restoration actions which were outlined in the CVPIA Anadromous Fisheries Restoration Program (AFRP) Working Paper (USFWS 1995), and Draft Restoration Plan (USFWS 1997; finalized in 2001).

The effects of three elements of the Clear Creek Restoration Program are being considered in this report: increased stream flow (Brown 1996), improved fish passage at McCormick-Saeltzer Dam (North State Resources, Inc. 2000), and supplementing the gravel supply which has been blocked by Whiskeytown Dam (WSRCD 2000, GMA 2006).

Beginning in 1999, Clear Creek stream flows were increased in the summer to improve water temperatures for holding spring-run Chinook. Other significant actions taken specifically for SCS have included the removal of McCormick-Saeltzer Dam in 2000, and placement of over 75,000 tons of spawning-sized gravel below Whiskeytown Dam, the Placer Road Bridge, and below the Clear Creek Road Bridge from 1995-2004.

The removal of the McCormick-Saeltzer Dam was to allow total passage of SCS to the upper reaches for holding and subsequent spawning. Prior to removal, the M-S Dam fish ladder was found to be ineffective in providing passage to upstream migratory Chinook due to poor lighting, design and lack of maintenance to the ladder entrance and exit (DWR 1986). In 2001 and 2002, with the M-S Dam no longer in place, it was observed that not only did SCS have access to the upper reaches, but FCS as well. This data is based on redd surveys conducted by USFWS staff in October and November (Newton and Brown 2004). The presence of FCS in the upper watershed can reduce the amount of available habitat for spawning spring Chinook, but also add to the potential for the superimposition of FCS and SCS redds. Superimposition can 1) lead to premature displacement of alevins from redds; 2) cause suffocation of alevins from reduced oxygen in hyporheic zone due to sediment loading, and 3) create entombment conditions where alevins can survive in the redd but are blocked from emerging by a layer of fine sediment. Overlapping spawn timing also increases the possibility of hybridization between runs, which has occurred within the mainstem Sacramento River (Brown 1996).

On September 3, 2003, a temporary picket weir was placed in upper Clear Creek at river mile (rm) 8.1, (river kilometer (rkm) 13) (Figure 1). The intent of the weir was to block the passage of FCS to SCS spawning areas upstream. At the time the weir was placed in the stream, 72% of the SCS indexed during the August snorkel survey had passed upstream of the weir site, some within a few miles of Whiskeytown Dam at rm 18.1 (rkm 29.1). The weir provided a unique opportunity to trap probable SCS juveniles with a RST and estimate their emergence timing and apparent growth rates without the presence of FCS.

The upper Clear Creek (UCC) RST was placed and operated at rm 8.3 (rkm 13.35), approximately 0.25 rm above the picket weir site. If upstream passage of FCS adults was prevented, all juveniles captured above the weir would be progeny of adults exhibiting spring-run Chinook run-timing (i.e., arriving in-stream during April-June, holding and then spawning in late summer), regardless of the length-criteria designation.

The purpose of this report is to estimate the passage of Chinook above the Clear Creek picket weir using UCC and comparing the results to estimates produced from the lower Clear

Creek RST (LCC) using length-at-date criteria. Length-at-date criteria from Greene (1992) are commonly used in the Sacramento River watershed for assigning a run designation to Chinook salmon. Greene's criteria were based upon juvenile fall Chinook salmon that were raised in the artificial channels of the Tehama-Colusa fish facility. The natural populations of spring Chinook salmon in Clear Creek and other Sacramento River tributaries would likely grow at different rates than the Tehama-Colusa facility populations. We have found these criteria don't accurately designate the fall and spring runs due to the temperature related variation in development and emergence timing (Greenwald et al 2003). We analyze spawning, RST catch and temperature data recorded from 5 locations to estimate the daily temperature units in Fahrenheit (ºF) required for emergence (DTUE) of juveniles. Daily temperature units to emergence (DTUE) are the number of degree units required for alevins to emerge from gravel redds after fertilization and subsequent deposition of eggs. A daily temperature unit (DTU) in Fahrenheit is measured by subtracting 32°F from the mean daily temperature (MDT) in ºF. Accurate DTUE estimates may be used in developing tributary-specific run-designation criteria.

This report examines the possibility that juvenile SCS in Clear Creek are mis-assigned as FCS, thereby producing erroneous juvenile passage estimates, which could compromise decisions for SCS management. The current report presents RST sampling from UCC for the period from October 15, 2003 through June 30, 2004. This reporting period is based on the date that the funding contract for the project went into effect. The focus of this report is on juvenile passage estimates for SCS. While a summary of catch totals and passage estimates for *O. mykiss* is also included, juvenile passage estimates for *O. mykiss* are provided in the annual report on the lower RST, which will include the entire watershed and outmigration period. In Broodyear 2004, more than 40% of STT redds were located downstream of the UCC (USFWS, RBFWO, unpublished data). Therefore, estimates from the UCC may exclude 40% of juvenile passage for this species.

Study Area

The Clear Creek watershed below Whiskeytown Dam covers an area of approximately 48.9 miles^2 (127 km^2), and receives supplemental water from a cross-basin transfer between Lewiston Lake in the Trinity River watershed and Whiskeytown Reservoir in the Sacramento River watershed. Separated at the Clear Creek Road Bridge, the upper and lower reaches of the creek are geomorphically distinct and support different fish communities. The upper reach flows south from Whiskeytown Reservoir almost 10 mi (16.1 rkm). The lower reach heads in an easterly direction to the Sacramento River for a distance of approximately 8.4 mi (13.68 rkm) (Figure 1). In the upper reach, the stream is more constrained by canyon walls and a bedrock channel, has a higher gradient, has less spawning gravel, and has more deep pools. In the lower reach, the stream meanders through a less constrained alluvial flood plain, has a lower gradient, has more spawning gravel, and has fewer deep pools. The lower reach supports species of the foothills fish community, is managed for fall and late-fall Chinook, while the upper reach supports coldwater species, and is managed for spring Chinook and steelhead / rainbow trout, which require cold summer water temperatures.

Acting as a sediment trap, Whiskeytown Reservoir has starved the lower portion of Clear Creek of ts sediment. Combined with years of gravel and gold mining and channel scouring by high flows, sediment starvation has limited the amount of gravel available to spawning salmonids for building redds. In some areas of the stream channel, only clay hardpan or bedrock remains, thus the need for gravel supplementation.

Ambient air temperatures range from approximately 32°F (0ºC) in winter to summer highs in excess of 115°F (46ºC). Most precipitation falls into this watershed as rainfall. The average rainfall in the Clear Creek watershed ranges from approximately 20 inches (50cm) in the lowest elevations to more than 60 in. (152 cm) in the highest elevations. Most of the watershed's rainfall occurs between November and April, with little or none occurring during the summer months (McBain and Trush et al. 2000).

The rotary screw trapping sites for this project were at the following locations: 1) UCC at rm 8.3 (rkm 13.4) above the confluence with the Sacramento River (latitude 40º 29' 30" north, longitude 122º 29' 46.8" west); and 2) LCC at rm 1.7 (2.7 rkm) above the confluence (latitude 40º 30' 22" north, longitude 122º 23' 45" west). The RSTs operate in or near the thalweg of the channel. The stream gradients at these locations range from approximately 1 - 1.5 degrees. The creek bottom substrate at these locations is primarily composed of gravel and cobble.

Methods

Sampling protocol.—Sampling for juvenile salmonids in Clear Creek was accomplished by using standardized RST sampling techniques that generally were consistent with the CVPIA Comprehensive Assessment and Monitoring Program (CAMP) standard protocol (CAMP 1997). The RST's deployed in Clear Creek, are manufactured by E.G. Solutions®, Corvallis, Oregon. This type of trap consists of a 5 ft (1.5 m) diameter cone covered with 3-mm diameter perforated stainless steel screen. This cone acts as a sieve, which separates fish from the sampled water. The cone is supported between two pontoons and its auger-type action passes water, fish, and debris to the rear of the trap, and directly into an aluminum live box. This live box retains fish and debris, and passes water through screens located in its back, sides, and bottom. We selected two trees with diameter-at-breast height measurements of approximately 12-18 in. (30 – 46 cm) on opposite banks of the creek to use as attachment points for the traps for securing the RST in the thalweg of Clear Creek. The trees were approximately 200 ft. (60 m) apart and far enough above the flood plain to avoid most flood waters. Using these trees as anchors, the RST is attached to a cable high line and positioned in stream with a system of ropes, and pulleys. The Upper Clear Creek RST was fished during the current reporting period from October 15, 2003 to June 30, 2004. An attempt was made to fish the RST 24-hours per day, seven days each week.

Fisheries crews typically accessed the RST by wading from the creek banks. However, for crew access during higher flows, the RST was pulled into shallow water for boarding. After being serviced, the RST was returned back to the thalweg as soon as possible to begin fishing again. The RST was serviced once per day unless high flows, heavy debris loads, or high fish densities required multiple trap checks to avoid mortality of captured fish or damage to equipment. At each trap servicing, crews process the collected fish, clear the RST of debris, provide maintenance, and obtain environmental and RST data.

Environmental data. —Environmental data included dates and times of RST operation, creek depth at the RST, RST cone fishing depth, number of rotations of the RST cone, amount and type of debris collected, basic weather conditions, water temperature, current velocity, and water turbidity. Water depths were measured using a graduated staff to the nearest 0.1 feet. The RST cone fishing depth was measured with a gauge that is permanently mounted to the RST frame in front of the cone. The number of rotations of the RST cone was measured with a mechanical stroke counter (Global Industrial Products, Battle Ground, WA) that was mounted to the RST railing adjacent to the cone. The amount of debris in the RST was volumetrically measured using a 10-gallon (37.9l.) plastic tub. Water temperatures were continuously obtained with an instream Onset Optic StowAway® temperature data logger. Water velocity was measured from a grab-sample using an Oceanic® Model 2030 flowmeter (General Oceanics, Inc., Miami, Florida). This velocity was measured in the time period when the live box of the RST was being cleared of debris and the fish sorted from this debris. Water turbidity was measured from a grab-sample with a Hach® Model 2100 turbidity meter (Hach Company, Ames, Iowa).

RST data.—To remove the contents of the RST live well for examination, we used dip nets to scoop debris and fish onto a sorting table. When the number of all fishes collected in the RST was less than approximately 250 individuals, we counted and measured all fishes while on the aft deck of the RST. When catch exceeded approximately 250 individuals, fishes were placed in a 5-gallon bucket, transported from the RST and, and moved to shore for subsampling and enumeration.

Counting and Measurement.—We counted and obtained length measurements (to the nearest 1.0 mm) for all fish taxa that were collected. Counts and measurements were also generated for mortalities for each fish taxa. Fish to be measured were first placed in a 1-gallon plastic tub and anesthetized with Tricaine methane sulfonate (MS-222; Argent Chemical Laboratories, Inc. Redmond, Washington) solution at a concentration of 60 - 80 mg/l. After being measured, the fish were placed in a 10-gallon plastic tub that was filled with fresh creek water to allow for recovery from the anesthetic effects before being released back into the creek. Water in the tubs was replaced as necessary with fresh creek water to maintain optimum temperature and oxygen levels.

Chinook salmon.—When less than approximately 250 salmon were collected in the RST, all were counted and measured for fork length (FL). The measured juvenile salmon were assigned a life-stage classification of yolk-sac fry, fry, parr, silvery parr, or smolt. For all Chinook salmon that were counted and measured, we also assigned a run designation, using length-at-date criteria from Greene. These designations included fall-run, late-fall-run, or spring-run. When more than approximately 250 juvenile salmon were captured, subsampling was conducted. To conduct the subsampling, a cylinder-shaped 1/8" mesh “subsampling net” with a split-bottom construction was used. The bottom of the subsampling net was constructed with a metal frame that created two equal halves. Each half of the subsampling net bottom was built with a mesh bag that was capable of being tied shut, however, just one side was tied shut and the other side was left open. This subsampling net was placed in a 25-gallon bucket that was partially filled with creek water. All collected juvenile salmon were poured into this bucket. The net was then lifted, resulting in a halving of the sample. Approximately one-half of the salmon were retained in the side of the net with the closed mesh bag, and approximately one-half of the salmon in the side with the open mesh bag were left in the bucket. We successively subsampled until approximately 150 - 250 individuals remained. The number of successive splits that we used varied with the number of salmon collected. After subsampling the salmon to the appropriate split, all fish in the subsample of approximately 150 - 250 individuals were counted and measured for FL. These salmon were also assigned a life-stage classification and run designation, using the methods previously described above.

Steelhead / Rainbow Trout.—All steelhead / rainbow trout that were collected were counted and measured for FL. The measured steelhead / rainbow trout were assigned a life stage of yolk-sac fry, fry, parr, silver parr, smolt or adult. Steelhead / rainbow trout that measured over 50mm were weighed to the nearest 0.1-gram using a battery-operated Ohaus Scout® digital scale (Ohaus Corporation, Florham Park, New Jersey). Adult steelhead / rainbow trout are assigned one of the following maturation codes 1-Immature, 2-Ripe Male, 3-Ripe Female, 4-Spent Female, 5-Spent Male or 6-Maturity unknown. All juveniles were recorded as M-6 unless otherwise identified as another code.

Non-Salmonids.—All other non-salmonid species captured in the RST are measured for FL or total length (TL) up to 20 samples for each species and the remainders are tallied.

Mark and Recapture Trials.—One of the goals of our monitoring project is to develop an estimate of the number of juvenile salmonids passing downstream in a given unit of time, usually in a given week or year. We call this estimate a juvenile passage index (JPI). Since the RST only captures fish from a small portion of the creek cross section, we needed to implement a method to project the RST catch numbers to parts of the creek outside of the RST capture zone. Accordingly, we needed to determine the efficiency of the RST to catch all juvenile salmonid species moving downstream during a given time period. By determining the RST efficiency, we were able to calculate a JPI from the actual catch. To determine efficiencies of the RST, mark-recapture trials were conducted.

During periods when juvenile Chinook salmon capture was sufficient and weather permitted, mark-recapture trials were attempted twice weekly. We attempted to mark between 200 and 400 juvenile Chinook salmon for each trial, with a goal to recapture at least 7 marked individuals. In an effort to meet our goal of recapturing a minimum of 7 individuals, we generally did not conduct mark-recapture studies during periods when numbers of juvenile salmon captured were less than about 200 individuals.

Only naturally-produced (unmarked, unclipped, and untagged) juvenile salmon captured by the RST were used for mark-recapture trials. We used either a single mark or a dual mark, to mark salmon over the course of the study period. Single marking was used when our releases of marked salmon occurred more than five days apart, and when USFWS, was not actively conducting salmon mark-recapture studies at nearby locations. The USFWS conducts mark and recapture trials at the Red Bluff Diversion Dam (RBDD), for monitoring Sacramento River WCS juvenile populations. The dual mark allowed RBDD to distinguish Clear Creek marked Chinook from RBDD marked Chinook. The methods used for single marking and dual marking are described below:

Single-marking technique.—The single marking technique consisted of immersion staining of salmon with Bismarck brown-Y stain (J.T. Baker Chemical Company, Phillipsburg, New Jersey). The Bismarck brown was applied at a concentration of 8 grams / 380 liters of water (211 mg / liter), and allowed a 50-minute contact time. Due to the frequently high air temperatures in late spring and the summer months, water temperatures were measured at 15 and 30 minutes during the marking process. Temperatures never exceeded a 1°F (.56°C) change in all trials.

Dual-marking techniques.—To conduct our dual marking procedures, we first anesthetized the fish with MS-222. We then marked the fish with a single caudal fin clip. To perform the fin clips, we used small surgical scissors or scalpel, removing an area of approximately 2 mm^2. After clipping the fish we, then marked them with a Bismarck brown immersion as described above.

After the single-marking or dual-marking procedures were completed, the marked juvenile salmon were placed in a live car and allowed to recover overnight in the RST live well. This overnight detention allowed us to more reliably detect salmon with latent injuries and mortalities resulting from the marking procedure, and remove them from use in the recapture trials. On the following evening, weak, injured, and dead fish were removed. The remaining fish were counted and transported .25rm (0.8 rkm) upstream of the RST sampling site, to be released. We scheduled releases within an hour before or after sunset. The nighttime releases of marked fish were designed to 1) reduce the potential for unnaturally high predation on salmon that may be temporarily disorientated by the transportation, and 2) imitate the tendency for natural populations of outmigrating Chinook salmon to move downstream primarily at night (Healy 1998; USFWS, RBFWO, unpublished data). The stained and marked Chinook salmon that were recaptured later by the RST were counted and measured and released.

Trap efficiency.—Trap efficiencies were calculated by dividing the number of recaptured juvenile Chinook salmon by the number of released (# recaptured / # released). Efficiencies calculated from the mark-recapture trials were used to generate daily or weekly JPIs (JPI = total number of each salmonid species captured per day / daily trap efficiency or for weekly, the sum weekly catch divided by a weekly efficiency) for Chinook salmon using methods described by Thedinga et al. (1994) and Kennen et al. (1994). JPIs were calculated by two different methods for comparison purposes; 1) a daily index and 2) a weekly index based on the Bailey's estimator.

1) The daily index method assigned trap efficiency for each day the trap was run. After each mark and recapture trial, the associated trap efficiency value was assigned to the day immediately following the release and each subsequent day until a new trail was conducted. When instream flow fluctuations occurred or a trial did not recapture 7 recaptures to generate statistically sound estimates, the trial was excluded and a "season" efficiency value was used. Additionally, for the period of time preceding the first trial and proceeding a week after the last trial of the season we used the season efficiency. Season efficiency values were calculated by dividing the average of fish released from all valid mark and recapture trials and dividing it by the average of all trial recaptures.

   Daily trap efficiencies were generated by use of the equation:

$$E = R / M$$

   Where;
   E is the calculated trap efficiency,
   R is the number of marked fish recaptured,
   and M is the number of marked fish released.

Daily juvenile passage indices (JPIs) were generated by use of the equation:

$$A = C / E$$

Where;
A is the population abundance,
C is the catch for that day,
E is the calculated trap efficiency.

JPIs for salmonids were generated by summing the daily index for a weekly passage for each salmonid species and run for Chinook salmon, due to the uncertainty of run designation we calculated a combined JPI for both spring and fall-runs giving us a total passage for the upper Clear Creek watershed. The only other salmonid estimate in this report is for steelhead trout.

2) Weekly trap efficiencies were generated using a stratified Bailey's estimator, which is a modification of the standard Lincoln-Peterson estimator (Bailey 1951; Steinhorst et al. 2004). The Bailey's estimator was used as it performs better with small sample sizes and is not undefined when there are zero recaptures (Carlson et al. 1998; Steinhorst et al. 2004). In addition, Steinhorst et al. (2004) found it to be the least inaccurate of three estimators (Whitton et al., USFWS 2006).

   Weekly trap efficiencies were generated by use of the equation:

$$\hat{E}_h = \frac{(m_h + 1)}{(r_h + 1)},$$

   Where;
   E is the calculated trap efficiency,
   m_h is the number of marked fish released in week h,
   r_h is the number of marked fish recaptured in week h.

When more than one mark and recapture trial took place, the trials were pooled for that sample week to get a weekly efficiency. Similar to the daily index method, on weeks for the period of time preceding the first trial and proceeding a week after the last trial of the season, we used the season efficiency.

3) Weekly JPIs for Chinook salmon and rainbow trout/steelhead were calculated using weekly catch totals and either the weekly trap efficiency, pooled trap efficiency, or average season trap efficiency. The season was stratified by week or at times multiple strata per week because as Steinhorst et al. (2004) found, combining the data where there are likely changes in trap efficiency throughout the season leads to biased estimates. Using methods described by Carlson et al. (1998) and Steinhorst et al. (2004), the weekly JPIs were estimated by

$$\hat{N}_h = \frac{U_h}{\hat{E}_h},$$

Where;
N_h is the passage during week *h,*
U_h is the unmarked catch during week *h,*
E_h is the calculated trap efficiency during week *h.*

The variance, 90% and 95% confidence intervals (CI's) for each week (N_h) are determined by the percentile bootstrap method with 1,000 iterations (Efron and Tibshirani 1986; Buckland and Garthwaite 1991; Thedinga et al. 1994; Steinhorst et al. 2004). Using data with simulated numbers of migrants, and trap efficiencies, Steinhorst et al. (2004) determined the percentile bootstrap method for developing CI's performed the best as it had the best coverage of a 95% CI. The variance for N_h is simply the sample variance of the 1,000 iterations of N_h produced by bootstrapping U_h, E_h and m_h for each week.

As described by Steinhorst et al. (2004), and demonstrated by Whitton et al. (2006), the 90% and 95% CI's for the weekly JPIs were found by producing 1,000 iterations of N_h and locating the 25th, 50th, 950th, and 975th values of the ordered estimates. The 1000 iterations were produced by using a macro in the Systat 10 software program, which used the weekly catch, the calculated efficiency, and the number of marked fish for each trial. The macro produced 1000 variable numbers of recapture from which passage estimates were generated; these latter data were placed in a Microsoft Excel spreadsheet and subsequently ordered from low to high values. A separate spreadsheet was kept for both sets of data; ordered and unordered. The unordered and ordered data sets were used to determine the final CI and weekly CI, respectively.

This final CI was calculated by summing the stratum of each of the 1000 random unordered iterations horizontally on the spreadsheet. The final column was ordered and the 25th, 50th, 950th, and 975th values were used as the 90% and 95% CI. The final JPI CI uses unordered iterations in calculating values, as summing the ordered iterations produce a CI that is comprised of non-random values. To produce a weekly CI, each weekly stratum is ordered and the 25th, 50th, 950th, and 975th values were used as the 90% and 95% CI.

The standard deviations *(SD)* of the sample means of each stratum are also included with 90% and 95% CI's. Juvenile Chinook salmon and steelhead trout JPIs were summarized by brood year. For dates when sampling was not conducted, or when samples were lost or compromised, we used the mean catch of an equal number of days before, and an equal number of days after, the missing number of sample days to create a surrogate value. For example, if we were missing three days of sampling data, we would calculate the average of the three sampled days before and three sampled days after the missing period. This calculated average of six sampled days would then be used as the surrogate value for each of the three days of missing values. On days where more than half of the day was sampled, a proportionate value was given to the remainder of the day the trap did not fish based on the data that was collected.

Modifications to reduce mortality and improve efficiency.—During periods of high salmon emigration, we often implemented a modification in the RST to reduce potential negative impacts to juvenile salmon created by high fish densities combined with excessive debris loads. We implemented this "half-cone modification" to the RST by placing an aluminum plate over one of the two existing cone discharge ports and removing an exterior cone hatch cover. This created a condition where 50% of the collected fish and debris were not collected into the live well, but were discharged from the cone into the creek. This effectively reduced our catch of both fish and debris by 50%, and reduced crowding of fish in the live well. Results of efficiency trials during the half cone implementation period were divided by actual daily catch records since theoretically capturing only half of the efficiency fish and passing fish would result in passage equivalents to having no modification at all. To improve JPI computation, we attempted to sample high flows events when most juvenile salmonids are thought to emigrate.

Calculating daily temperature units to emergence.—A temperature unit analysis was conducted to determine when Chinook fry would be expected to emerge. An emergence timing calculator was developed using a Microsoft Excel database and an Excel macro. The calculator was designed to allow the user to input the date the redd was observed (typically through snorkel survey), the appropriate temperature monitoring station mean daily temperature (MDT), and the range of DTUE. Our calculations assumed the redds were constructed midway between the current and previous snorkel surveys, in our case, seven days prior to discovery. The program then produces the day of emergence and the calendar week of emergence for each redd found (Tables 9).

We used five temperature monitoring stations covering a distance of approximately 10 rm (16.1rkm) at the following locations progressing downstream: Whiskeytown Dam, Need Camp, Kanaka Creek, Igo and Clear Creek Road Bridge (Figure 1, 2). Temperature differences between monitoring stations generally were 1-2ºF. The emergence calculator program works by taking the day the redd was made and summing the daily temperature units of that day and all succeeding days until the user designated DTUE to emergence value is reached. DTUE's were calculated as the total number of degrees above 32ºF for the water near the redd (e.g., a redd constructed in an area where the MDT of the water was 52ºF, would accumulate 20 DTU's).

Redds were assigned temperature data from a specific temperature logger by dividing the creek into reaches bounded by the midpoint between adjacent loggers. Redds within each reach were assigned to that specific temperature logger whose MDT's were then used in the DTUE calculations. The loggers were set up to record between 48 and 96 readings per day. In instances where no data was available for a logger (i.e., dysfunctional loggers or loggers lost to high flows), interpolating the values was necessary. For short periods of time with missing data, the trend in temperatures was noted, and the difference between the last available temperature and next reliable temperature was determined and divided by the number of days data was missing. This daily increment was then applied to each succeeding missing daily value until all missing values had been interpolated. For longer periods (e.g., > 3 weeks) values were interpolated by comparing temperature loggers immediately upstream and downstream of the loggers in question. In general, the graphed water temperatures showed a linear relationship. The relative distance between known data points (e.g., 6/10 of the distance) was applied to interpolate the missing values. For example, Logger B is missing. Logger A records a temp of 60ºF (15.6°C). On the same day, logger C records a temp of 70ºF (21.1°C). Logger B is 6/10 of the distance between the two loggers, so a value of 66ºF (18.9°C) is assigned to the missing logger data set for that day.

Once emergence days and weeks were generated for various DTUE, these data sets were compared to the actual trap catch for juvenile Chinook deemed newly emergent (33-38 mm). Results were interpreted in various ways including comparing different DTUE to each other in order to determine which fit most appropriately.

Results

Sampling Effort.—We operated the UCC RST for 243 days of the 260-day report period. This represents 93% of the available sampling days. Sampling was conducted from October 15, 2003 through June 30, 2004 (Week 42 2003 – Week 26 2004) (Table 2). Due to high juvenile Chinook salmon densities that were encountered on December15, 2003 we applied the half-cone modification during the period from December 16, through March 3, 2004 to reduce capture and mortality. The UCC RST was not operated for 17 days due to high flows.

Environmental Data.—Stream discharge at the study site was approximated by using the U.S. Geological Survey Igo gauging station, located approximately 2.5 rm above the RST sampling site. Using these data, we determined that mean daily flows ranged from a minimum of 212 cubic feet per second (cfs) in October 2003 to a maximum of 2,440 cfs in February 2004 (Figure 3). The channel width of Clear Creek at the UCC RST varied from approximately 40 feet at the lowest flows to more than 200 feet at the highest flows. Water depths in Clear Creek at the base of the RST cone varied from 3.0 feet to greater than 7.0 feet, with an average depth of 4.8 ft. The lowest depths were recorded during October 2003, and the deepest depths were recorded from late November 2003 through February 2004. Turbidity levels ranged from 0.2 nephelometric turbidity units (NTU) in October 2003 to 13.3 NTU in December 2003, with a mean turbidity of 1.4 NTU. Turbidity was typically the lowest during the lower flows of summer, and tends to increase during the higher winter flows (Figure 3). Mean daily water temperatures ranged from a low of 40.1ºF on December 29, 2003 to 61.4ºF on April 30, 2004 (Figure 4).

Chinook salmon.—The only species of salmon collected was Chinook salmon. Length-at-date tables of Greene (1992) indicated that we collected individuals from three of the four Chinook salmon runs known from the Sacramento River basin (Figure 5). We collected a total of 126 samples for genetic analysis from the upper Clear Creek RST. Thirty-three of these specimens were collected from mortalities. Fork lengths for all runs of Chinook salmon ranged from 29 - 130 mm. A greater number of Chinook salmon from smaller size classes were captured, with the majority of individuals being 39 mm or less in FL (Figure 13). Chinook from all life stages were collected with 97% of them being fry (Figure 14).

Spring and Fall-run Chinook.—All BY2003 Chinook were combined to get a total passage for the UCC. A total of 5,226 Chinook were collected, representing 84.1% of the total number of fish collected of all species. When adjusted for RST efficiency values and days not fished, the total of 5,224 (5,226 minus two specimens from BY 2002) extrapolates to an 8½ month JPI by daily efficiencies of 112,643 of all BY2003 captured.

Using the weekly summed catch totals and efficiency results Chinook passage was estimated at 108,338 and when calculated using the existing Greene 1992 criteria, was 8,500. The data from LCC at river mile 1.7 generated a SCS JPI of 22,673 for the period of October 1, 2003 through June 30, 2004. The latter two estimates using the Greene criteria were calculated by dividing the catch data by trap efficiencies as previously described in the methods section above. Using the weekly estimate figures 95% confidence intervals (CI's) were calculated through the bootstrapping method described above. The upper 95% and lower 95% CI was 137,682 and 88,817 respectively (Figure 12, Table 4).

In comparing both the daily efficiency method and the Bailey's weekly estimator, we used the weekly estimator for the final passage index because it reduces some inaccuracies from the actual efficiencies used, and the CI's were generated on that data set. Both daily and weekly indices show the underestimation calculated by using the Greene (1992) length at date criteria. Using the Greene criteria, we would have underestimated the passage of SCS by approximately 91%.

Of the 53 redds observed upstream of the picket weir, 52 were located upstream of the upper RST (Table 9). The combined (FCS and SCS) data from UCC shows a 378% increase over the LCC passage index of 22, 673 SCS and an 11.75 fold increase in the passage of SCS at UCC based on Greene's data. The lower Clear Creek trap is only accounting for 21% of the SCS passage in the creek and the data from the lower trap may actually be early emigrating FCS due to warmer temperatures lower in the watershed that produce an excelled development rate. One BY2002 "Fall-run," Chinook was captured. The specimen was a 130mm fl smolt trapped on October 16, 2003. This smolt was too large to be a BY2003 progeny and not measured for the passage index. The peak emergence for these BY2003 Chinook occurred on the second week of December 2003 (Table 4).

Late-fall-run Chinook salmon.—Only one late fall Chinook salmon was captured during the study period. The specimen was a 126mm fl smolt trapped on October 26, 2003. This fish was not included in the BY2002 passage estimate.

Winter-run Chinook salmon.—No collections of winter Chinook salmon occurred at the upper Clear Creek trap.

Steelhead / Rainbow Trout.—We captured a total of 807 steelhead / rainbow trout in the UCC. The first juvenile captures of BY2004 occurred on March 3, 2004. Fork lengths ranged from 22-289mm, with a Median FL of 44mm. The majority (440) of captures fell within the 20-29mm FL frequency (Figure 6). Steelhead / rainbow trout from all life stages described above were captured, with 91.3% being fry (462) and parr (275) (Figure 9). Steelhead trout are categorized in two groups BY2004 and BY2003 and older identified as Age 0+ (Figure 6,8,10, Table 5). The BY 2003 captures have a total passage of 1,744; the upper and lower CI's were 2,235 and 1,411 respectively. The BY2004 captures have a total passage of 7,213, the upper and lower CI's, were 9,064 and 5,834. Peak emergence occurred from March 11, 2004 through May 20, 2004, where 75% of the total catch was made. Additionally, one Brook trout *(Salvelinus fontinalis)* of unknown origin, measuring 325mm was captured.

Non-Salmonids.—A table of all scientific and common names of non- salmonid fishes is provided in Appendix A. All non-salmonid species captured are summarized in Appendix B.

Mark and Recapture Trials.—The first four trials' mark and release day was the same, due to short staff and time constraints. We conducted 26 total mark-recapture trials to test for RST efficiency from December 03, 2003 through the April 16, 2004. Seven of these were experimental groups and 19 trials were to be used to calculate total passage. A total of 6,321 Chinook salmon were marked, 73 mortalities occurred from the marking procedures. The trials used during "half-cone" periods released 2,280 fish and recaptured 180, producing an average efficiency of 8.08%, while trials using a full cone released 3,282 fish and recaptured 321, producing an average efficiency of 9.78% (Table 1, Table 8).

Three of the 19 trials where less than 7 fish were recaptured were excluded. To provide an estimate of RST efficiency for periods when mark-recapture trials were not conducted, we utilized a seasonal average or continued with the same efficiency as previous week. During March and April, we conducted experimental trials to see if larger Chinook (>40) were better at avoiding recapture than smaller brethren. Rates of recapture were 92 % higher of Chinook larger than 40 mm versus Chinook smaller than 40 mm. None of the experimental groups were used for calculating JPI due to the small size of the release groups (<81). However these data did increase the comfort in knowing Chinook of all sizes had the susceptibility to be captured.

Mortality

Marking Mortality.—A total of 73 mortalities occurred among the 6,321 marked Chinook salmon, for a total marking mortality (= total cumulative marking mortalities / total cumulative number of fish marked = 73/6321) of 1.2% (Table 1). Mortalities resulting from our marking procedures for all 26 trials resulted in five mortalities from fish captured at the UCC; all other Chinook mortalities (68) were captured at the lower Clear Creek RST. The LCC captures 98-99% fall-run Chinook salmon.

Trapping Mortality.—A total of 1,166 mortalities occurred from RST sampling (Table 3) This mortality level corresponds to 22.3% catch mortality, and 1.08% JPI mortality. The highest mortality numbers for all Chinook salmon occurred during 2003 in weeks 51-52. During this period 1,128 mortalities occurred, representing 96.7% of the total catch mortality.

Daily Temperature Units to Emergence.—Based on observations from snorkel surveys the first redd encountered in upper Clear Creek was created in, or before the week of September 9, 2003. The previous survey was conducted two weeks earlier the week of August 27, 2003 and observed no redds (Table 9). Our estimate of the DTUE's required for Chinook in Clear Creek was based on viewing graphics of several projections of DTUE's generated from redd observation ranging from 1,500 – 2,000 DTU's. The range of 1,850 was selected because it showed that peak emergence would fall around mid to late December (Figure 11).

Discussion and Recommendations

More accurate spring Chinook salmon abundance estimates

We demonstrated that using length criteria would miss-assign 91% of the juvenile SCS in UCC as FCS, thereby producing highly inaccurate juvenile passage estimates. Spring Chinook salmon management decisions would be compromised if the current run-designation criteria are used.

Recommendation 1: We recommend that the annual Clear Creek SCS passage index be derived from the UCC and should not be based on length criteria. SCS estimates made using the LCC and length criteria were only 21% of estimates derived from the UCC. While possible that genetic methods may be developed to allow more accurate estimates of SCS JPI using the LCC, the UCC would be used to collect genetic samples from which to develop these genetic methods. The passage index for SCS from the UCC of 108,305 corresponds well with the 52 SCS redds observed above the RST which produced on average, 2,083 juveniles per redd.

Snorkel surveys and daily weir inspections indicated that the picket weir was effective in blocking adult FCS and suggesting that all Chinook spawning upstream had exhibited spring Chinook adult migration timing (Newton and Brown 2007). While later spawning fall and late-fall Chinook could pass after removal of the picket weir in November, none were observed during November snorkel surveys or during kayak based surveys from December through April. It is therefore reasonable to assume that the Chinook collected in the UCC were spring-run.

Recommendation 2: We recommend that genetic analysis aid in the development of a more accurate Clear Creek-specific SCS genetic baseline. The improved baseline could aid in run-verification of fish from the RSTs and adult surveys. The improved baseline might someday allow genetic sampling at the LCC to allocate passage of SCS and FCS and eliminate the need for the UCC.

Recommendation 3: We recommend that sampling should continue year-round for at least a few years to determine the timing of SCS and STT passage and the proportion of older life stages in the population. In addition, year-round sampling would allow detection of Chinook and steelhead spawned in the lower watershed that move upstream of the UCC. Preliminary genetic analysis of Chinook collected in the UCC indicated that 92 % of fish tissue sampled before April 1 (n = 99, average FL = 40 mm) were SCS but only 26% of fish sampled after April 1 were SCS (n = 19, average FL = 78 mm). These results suggest that fall and late-Fall Chinook juveniles may have moved upstream after emergence. Alternatively, the genotypic spring Chinook may have passed downstream earlier than the later spawning fall and late-fall Chinook. Note that 99% of Chinook passage occurred before February 11.

Recommendation 4: We recommend operation of the temporary picket weir to prevent FCS from spawning in areas where the majority of SCS spawn. However, we would also like to point out that accurate estimates of juvenile SCS passage upstream of the UCC were only made possible by use of the temporary picket weir and the UCC.

Recommendation 5: We recommend that steelhead passage in Clear Creek be indexed at the lower RST, because a large and annually variable portion of spawning occurs downstream of the UCC (RBFWO, unpublished data). In BY 2004 more than 40% of *O. mykiss* redds were found downstream of the UCC.

Daily Temperature Units to Emergence

Spawning, emergence timing and temperature regime data were analyzed to estimate that 1850 daily temperature units were required for juvenile SCS emergence (DTUE). Our estimate is well within the range of 1,551 to 2,074 DTUE measured in laboratory experiments with Chinook (Heming 1982, Murray and McPhail 1988, Murray and Beacham 1987) but somewhat greater than the 1,650 TU proposed for Chinook management in Armour 1991. When compared at similar water temperature conditions, the DTUE varied between the studies. The DTUE within each lab study decreased with increasing water temperatures (Figure 15). One might expect that Clear Creek DTUE would be lower than studies conducted in more northerly latitudes, because, Clear Creek is at the southern end of the range for Chinook. However, we found the Clear Creek DTUE to be higher than some of the northerly studies. The southern populations evolved in the upper end of the optimal growth and survival temperature ranges. These populations likely have adapted to these conditions and have DTUE adjusted to optimize successful emergence timing. Beacham and Murray (1990) suggest that studies indicate, "population-specific differences in development can also exist and populations that spawn in extreme environments can probably be expected to have different rates of development and survival than populations in more moderate environments".

The first redd we observed was on September 8, 2003, assuming the redd to have been created the day after the last survey (August 28) at 1,850 DTU's we would expect to see the first emigrating fry in the RST on approximately November 27, 2003. Occurring on November 16, 2003, the first capture of a BY2003 Chinook was a yolk sac fry that may have been displaced from its redd. Following that, no captures took place for two weeks until November 29, 2003 in which a zipped up fry was captured. The following day over 80 newly emergent fry were captured.

We assumed that fry moved downstream almost immediately after emerging from redds. Mark and recapture trials conducted with SCS at UCC, found that marked fish had not only traveled the .25 rm to the trap overnight (which was expected), but to LCC as well, over 6.7 rm downstream. According to Healey 1998, Thomas et al. (1969) found that fall Chinook fry go through a period of reduced swimming ability just before the time of complete yolk absorption, and that this coincided with the time of peak downstream migration. The minimum flows in Clear Creek from mid November through the end of the emergence period were no less than 212 cfs (Figure 3). Accretions from storm events increased the flows, but flows never reduced below the baseline outflow from Whiskeytown Reservoir of 200 cfs. At these flows, the canyon bound reaches may be too swift for optimal rearing. Chinook with reduced swimming ability emerging from redds in this section may inadvertently be sent downstream and captured disrupting the natural migration timing.

The majority of the incubation period was spent under temperatures ranging from 49-56°F (9.4-13.3°C), Armour notes that (Brett et al. 1992) consider 58.6°F (14.6°C) to be optimal growth temperature under experimental conditions.

We applied the DTUE analysis to similar spring Chinook data from 4 years of Clear Creek (BY 03-06) and 4 years of Battle Creek (BY 02- 05) monitoring and came up with similar results in 7 of 8 cases (Earley and Brown, 2004; unpublished data). In Battle Creek in 2001, it appeared that 1,600 DTUE were required perhaps due to the extreme dry and warm water conditions. In recent years we have used 1,850 DTUE to accurately predict when spring Chinook would emerge and appear in our traps on Clear and Battle Creeks. This allowed us to reduce potential impacts to spring Chinook by switching to half-cone operation and increase sampling to more frequent trap checks daily when spring Chinook were predicted to emerge.

According to Armour (1991), a minimum of 1,550 DTU's were required for Chinook emergence. We estimated that Clear Creek Chinook required approximately 1,850 DTU's for emergence. Several factors may be taken into consideration to explain the additional 300 TU's including; 1) unknown rearing time; 2) actual creation of redd date; and 3) incubation under less than optimal temperatures may slow growth rates.

Recommendation 6: We recommend the use of the half cone modification before SCS are predicted to emerge based on 1,850 DTUE. The first high flow storm events combined with large amounts of debris available in the fall and the onset of emigration can result in high mortality in the RST. If not implemented all year, consideration should be made for half cone modification at least through December and January.

One of the challenges to determining an accurate DTUE in a natural setting is the time spent rearing in the stream before capture in the RST. Field studies suggest that fry emerge from redds at 31-33mm with a 0.2-0.3mm/day growth rate (Greene 1992) Given this growth rate and the length at capture (34-35mm), we made an assumption that most of the fry spend very little time rearing and head downstream immediately. Measurements made from captured Chinook revealed that >95% of them were within the FL range of 32-39mm, with 54% of them being in the 34-35mm range.

Comparison of intragravel and water temperatures may also help refine the estimates of DTUE as hyporheic water temperatures can vary considerably from stream water temperatures. A redd-capping experiment could be conducted to directly measure DTUE without the confounding element of variable amounts of rearing before capture in the RST. Redd capping involves placing a net over a redd to capture fish as they emerge from the gravel. In a parallel study, implanting a known number of eggs into artificial redds could allow calculation of percent survival to emergence. Estimating survival to emergence could assist in interpreting the relationships between the numbers of adults, redds and juvenile passage. Studies measuring survival to emergence could also be used to simultaneously evaluate the relative effectiveness of gravel improvement projects such as gravel addition, stream channel restoration, channel maintenance flows and erosion control.

Mark-recapture efficiency estimates

The current study produced mean RST efficiency values by trial of 8.08% and 9.78% for "half," and "full," cone respectively (N = 16, Table 4). A relation may exist between RST efficiency and several factors. Some of the suspected factors include variation in creek flows, fish behavior, channel width, channel depth, marking crew staffing changes, post-release mortality, water temperatures, marking methods, release methods, release locations, and predator populations. Perhaps the variations in RST efficiencies will be better understood after a few more years of efficiency data are gathered and compared.

The number of mark and recapture trials conducted during this study period appear to be adequate to determine trap efficiency. However, our estimates could still be improved by timing trials to coincide more closely with sample weeks to minimize analysis time. Conducting a second trial immediately following a trial with unusual results such as extremely high or low efficiency may help determine if the first trial was valid. Pooled trials can soften differences when calculating efficiencies weekly versus applying daily efficiencies (i.e. low efficiencies can be averaged with higher ones and misrepresent low efficiencies during peak passage) or having separate strata for each efficiency group. Trials using December fish could be conducted to verify trap efficiency for early emigrating populations. Mark and recapture trials should be more strategically centered on or around storm events to better gauge the variability of efficiency associated with variable flows.

Recommendation 7: We recommend using size-specific efficiency trials to improve the accuracy of passage estimates especially where smaller Chinook from the lower trap are used to estimate smolt passage at the upper trap. One possible approach might be to use very narrow fork lengths of Chinook that only fall within the range of what is being captured. These trial fish can be marked with visible implant elastomer tags to differentiate amongst groups if multiple trials in a week were necessary.

Recommendation 8: We recommend comparing length frequency of marked and recaptured fish to determine if parr or smolts exhibit different trap avoidance than fry.

Mortality

Marking mortality. The total marking mortality for UCC was 75 individuals, 1.9% of all marked fish. The rates of mortality for marking for the years of 2002, 2003 and 2004 at LCC were 3.0%, 2.0% and 0.6% respectively, showing a continual decrease in marking impacts to fish. The main contributor to the reduction in mortality is minimizing efficiency trials during warm spells in spring, when fish are extremely vulnerable to handling stress. Additionally when controlled water temperatures near or exceed lethal ranges, we have chosen to eliminate trials altogether.

Recommendation 9: We recommend the continued use of the temporary picket weir, operation of the upper Clear Creek rotary screw trap, annual snorkel surveys, and temperature monitoring are critical to estimating juvenile SCS passage, and improving our understanding of Clear Creek SCS life history.

Conducting more snorkel surveys during spawning would allow us to better identify the creation date of redds and better calculate DTUE or estimate potential impacts of high water temperature on redds. High temperatures can cause fertilized eggs to become unviable, and reduce the overall success of the spawning population. From 1999 to 2006, water temperatures were adequate for the Clear Creek SCS spawning population. However, warmer water temperatures associated with climate change will require more intensive management of Clear Creek flows and a better understanding of temperature impacts on juvenile passage. Therefore, continued operations of the UCC are essential for managing this population of Threatened salmon.

Trapping Mortality. We estimated 23.3% mortality in the total catch at the UCC. Estimated mortality of the total estimated passage was 1.08 %. During the current study, we used the half-cone modification 39.5% of the RST operation time, primarily during the periods of highest catches, highest flows, and high debris loads. 98.4% of the spring-run size class Chinook salmon mortalities from the current study period occurred in a two week period from December 11, 2003 to December 26, 2003 when debris loads were highest. Debris loads tend to be (Table 3) heavier in the RST during December than other months. These first winter creek flows transport previously accumulated fall-season debris down the creek channel. Together, the higher debris load and the higher creek flows tend to create stressful conditions for captured fish, especially for the smaller-sized salmon that are typically captured this time of the year. Based on our success in reducing marking mortality, we expect to be able to reduce our trapping mortality now that we know its cause.

Recommendation 10: We recommend video monitoring in the livebox of the RST to detect fish that are already dead before entering the RST. We suspect that some of the mortalities were prematurely-emerged yolk-sac fry that entered the RST already dead. Video monitoring at the mouth of the RST may also reveal differences in trap avoidance between life stages of fish, species, flows, turbidity, and marked and unmarked fish. The apparent differences in trap avoidance could be tested with paired efficiency trials to eventually result in improved efficiency estimates.

Acknowledgments

Funding for this project was provided by the CALFED Bay-Delta Program. We would also like to thank the following people for their contributions: Naseem Alston, Joe Chigbrow, Jimmy Faukner, Shea Gaither, Michael Gorman, Josh Grigg, Josh Gruber, Tricia Hoffer, Ethan Jankowski, Melissa Kleeman, Tim Loux, Ed Martin, Matt McCormack, Ryan Mertz, Phil Moeller, Kevin Niemela, Deon Pollett, Andy Popper, Bill Poytress, Adam Ray, Randy Rickert, James Smith, Laurie Stafford, Jonathan Sutliff, Brandon Thompson, Michelle Umrigar, Paul Walfoort, Charmayne Walker and Lael Will. We thank the Coleman National Fish Hatchery staff, especially Scott Hamelberg and Mike Keeler, for accommodating our program at the Coleman National Fish Hatchery. The CALFED Ecosystem Restoration Program provided California Department of Water Resources funding for this project, which was administered by the National Fish and Wildlife Foundation.

References

Armour, Carl L. 1991. Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish. U.S. Fish and Wildlife Service, *Biol. Rep.* 90(22). 13pp.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38:293-306.

Buckland, S. T., and P. H. Garwaite. Quantifying precision of mark-recapture estimates using the bootstrap and related methods. Biometrics 47: 255-268.

Beacham, T.D., and C.B. Murray. 1990. Temperature, Egg Size, and Development of Embryos and Alevins of Five Species of Pacific Salmon: A Comprehensive Analysis. Transactions of the American Fisheries Society 119:927-945.

Behnke, R.J. 2002. Trout and salmon of North America. The Free Press, New York, New York.

Brown, M. R. 1998. "Revised draft monitoring plan outline" Memo to Clear Creek Technical Work Group, dated March 2, 1998.

Brown, M.R. 1999. "Fishery evaluation of increased water releases from Whiskeytown Reservoir into Clear Creek." Proposal to the National Marine Fisheries Service, dated April 26, 1999.

CAMP (Comprehensive Assessment and Monitoring Program). 1997. Comprehensive Assessment and Monitoring Program: standard protocol for rotary screw trap sampling. Central Valley Fish and Wildlife Restoration Program Office, Sacramento, CA.

CAMP (Comprehensive Assessment and Monitoring Program). 2002. U.S. Fish and Wildlife Service (USFWS) and U.S. Bureau of Reclamation (USBR), 2002. Comprehensive Assessment and Monitoring Program Annual Report 2000. Prepared by CH2M HILL, Sacramento, California.

California Department of Fish and Game (CDFG). 1998. Report to the Fish and Game Commission: A status review of the spring-run Chinook salmon (Oncorhynchus tshawytscha) in the Sacramento River Drainage.

DWR (California Department of Water Resources). 1988. Water Temperature Effects on Chinook Salmon (Oncorhynchus tshawytscha) with Emphasis on The Sacramento River A Literature Review

DWR (California Department of Water Resources). 1986. Clear Creek Fishery Study, dated March 1986.

Earley, J. T., and M. R. Brown. 2004. Accurately estimating abundance of juvenile spring Chinook salmon in Battle and Clear Creeks. Page 277. Getting results: integrating science and management to achieve system-level responses. 3rd biennial CALFED Bay-Delta Program science conference abstracts, Sacramento, California.

Earley J.T., D.J. Colby, and M.R. Brown. 2008. Juvenile salmonid monitoring in Clear Creek, California, from July 2002 through September 2003. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Fisher, F.W., 1992. Draft Report - Chinook Salmon, Oncoryhnchus Tshawytscha, Growth and Occurrence in the Sacramento-San Joaquin River System. California Department of Fish and Game, Inland Fisheries Division, Red Bluff, California.

Gaines, P.D, R.E. Null, and M.R. Brown. 2003. Estimating the abundance of Clear Creek juvenile Chinook salmon and steelhead trout by the use of rotary screw trap. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California. Progress Report (Vol. 1) February 2003.

PG&E Personal Communication 07/27/06 Water Transfer and Hydroelectric Production to Benefit Salmon Tour, led by Pacific Gas and Electric Co., Spring Run Chinook Watershed Symposium in Butte Creek July 27-29, 2006.

Greene, S. 1992. Estimated winter-run Chinook salmon salvage at the state water project and Central Valley Project delta pumping facilities. Memorandum dated 8 May 1992, from Sheila Greene, State of California Department of Water Resources to Randall Brown, California Department of Water Resources. 3 pp., plus 15 pp. tables.

Greenwald, G. M., J. T. Earley, and M. R. Brown. 2003. Juvenile salmonid monitoring in Clear Creek, California, from July 2001 to July 2002. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Healy, M.C. 1998. Life history of Chinook salmon. Pages 311 - 393 in Pacific salmon life histories. Edited by C. Groot and L. Margolis. UBC Press, University of British Columbia, Vancouver, B.C, Canada.

Heming, T.A., 1982. Effects of temperature on utilization of yolk by Chinook salmon (Oncorhynchus tshawytscha) eggs and alevins. Can. J. Fish Aquat. Sci. 39: 184-190

Johnson, R.R., D.C. Weigand, and F.W. Fisher 1992. Use of growth data to determine the spatial and temporal distribution of four runs of juvenile Chinook salmon in the Sacramento River, California. Report No.AFF1/FRO-92-15. U.S. Fish and Wildlife Service, Northern Central Valley Fishery Resource Office, Red Bluff, California

Kennen, J.G., S.J. Wisniewski, N.H. Ringler, and H.M. Hawkins. 1994. Application and modification of an auger trap to quantify emigrating fishes in Lake Ontario tributaries. North American Journal of Fisheries Management. 14:828-836.

Kjelson, M. A., and F.W. Fisher. 1982. Life History of Fall-Run Juvenile Chinook Salmon, Oncorhynchus Tshawytscha, in the Sacramento-San Joaquin Estuary, California

Major, R. L., and J. L. Mighell. 1969. Egg-to-migrant survival of spring chinook salmon (*Oncorhynchus tshawytscha*) in the Yakima River, Washington. Fish. Bull. 67: 347-359.

McBain and Trush, Graham Matthews, North State Resources. 2000. Lower Clear Creek floodway rehabilitation project: channel reconstruction, riparian vegetation, and wetland creation design document. Prepared by McBain and Trush, Arcata, California; Graham Matthews, Weaverville, California; and North State Resources, Redding, California, 30 August 2000.

McBain and Trush. 2001. Final report: geomorphic evaluation of lower Clear Creek downstream of Whiskeytown Dam, California. November 2001.

Moyle, P.B. 2002. Inland fishes of California. University of California Press, Berkeley, California.

Murray, C.B., and J.D. McPhail. 1988. Effect of incubation temperature on the development of five species of Pacific salmon (Oncorhynchus) embryos and alevins. Can. J. Zool. 66: 266-273.

Murray, C.B., and T.D.Beacham. 1986. The development of Chinook (Oncorhynchus tshawytscha) and Chum (Oncorhynchus keta) salmon embryos and alevins under varying temperature regimes. Can. J. Zool. 65: 2672-2681.

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.

North State Resources, Inc. 2000. *Saeltzer Dam Fish Passage and Flow Protection Project.* Joint Environmental Assessment/Initial Study Final Document

Steinhorst, K., Y. Wu, B. Dennis, and P. Kline. 2004. Confidence intervals for fish outmigration estimates using stratified trap efficiency methods. Journal of Agricultural, Biological, and Environmental Statistics 9: 284-299.

Thedinga, J.F., M.L. Murphy, S.W. Johnson, J.M. Lorenz, and K.V. Koski. 1994. Determination of salmonid smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management. 14:837-851.

Thomas, A.E., J.L. Banks, and D.C. Greenland. 1969. Effect of yolk sac absorption on the ability of fall Chinook salmon. Trans. Am. Fish. Soc. 98:406-410.

USFWS (U.S. Fish and Wildlife Service). 1995. Draft anadromous fish restoration plan - a plan to increase natural production of anadromous fish in the Central Valley of California. Prepared by the USFWS, December 1995.

USFWS (U.S. Fish and Wildlife Service). 1997. Revised Draft Restoration Plan for the Anadromous Fish and Restoration Program. A plan to increase natural production of anadromous fish in the Central Valley of California. Prepared for the U.S. Fish and Wildlife Service under the direction of the Anadromous Fish and Restoration Program Core Group. May 30, 1997.

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. Released as a revised draft on May 30, 1997 and adopted as final on January 9, 2001.

USFWS (U.S. Fish and Wildlife Service). 2001. Biological Assessment of Artificial Propagation at Coleman National Fish Hatchery and Livingston Stone national Fish Hatchery: program description and incidental take of Chinook salmon and Steelhead Trout. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

USGS (U.S. Geological Survey) 2004. Website for U.S. Geological Survey Station, Clear Creek at Igo, Real-time data for USGS 11372000 CLEAR C NR IGO CA

Whitton, K. S., J. M. Newton, D. J. Colby and M. R. Brown. 2006. Juvenile salmonid monitoring in Battle Creek, California, from September 1998 to February 2001. USFWS Data Summary Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Figures

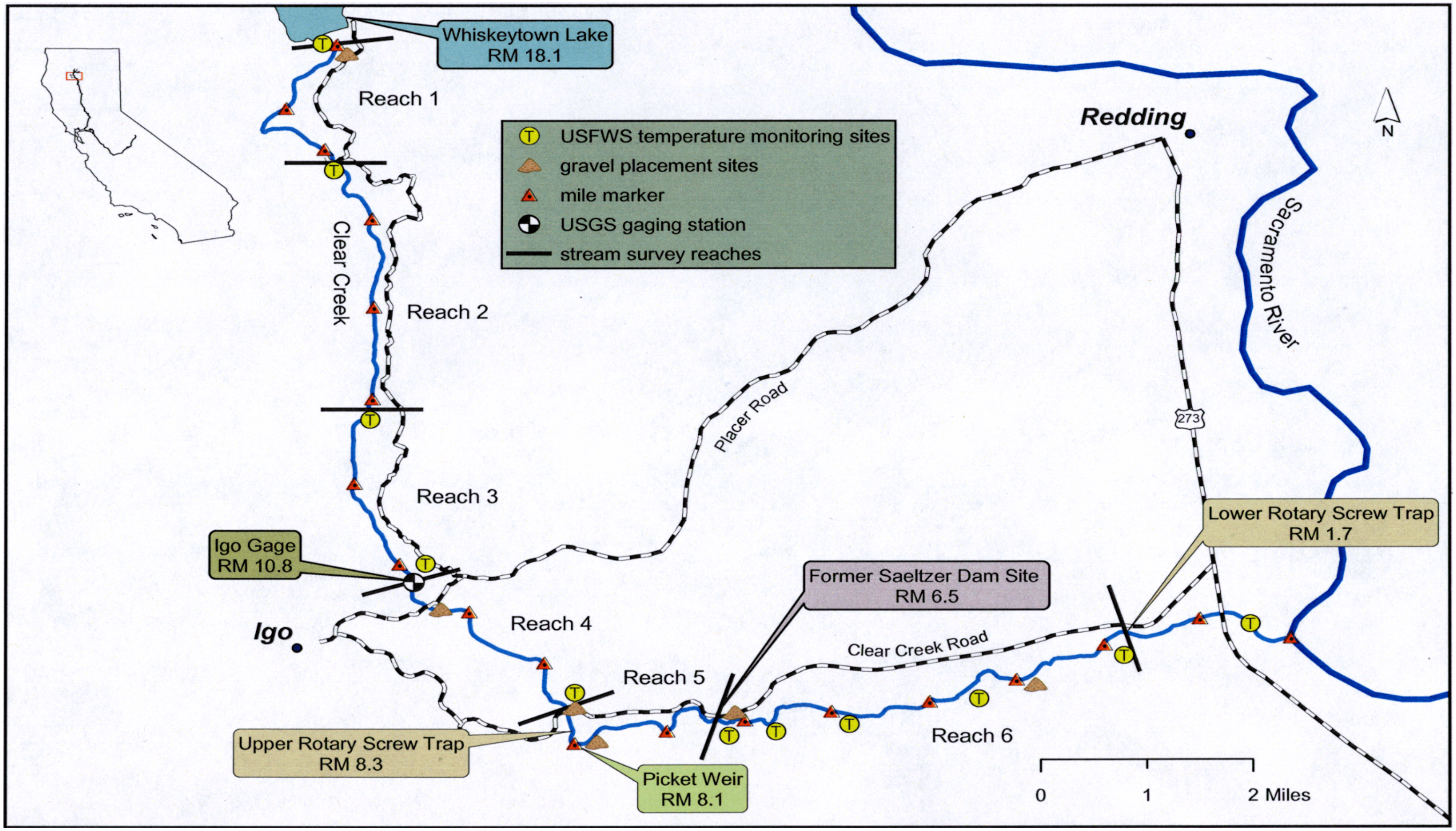

Figure 1. Locations of the upper and lower rotary screw traps (RST's) used for salmonid monitoring at river miles 1.7 and 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

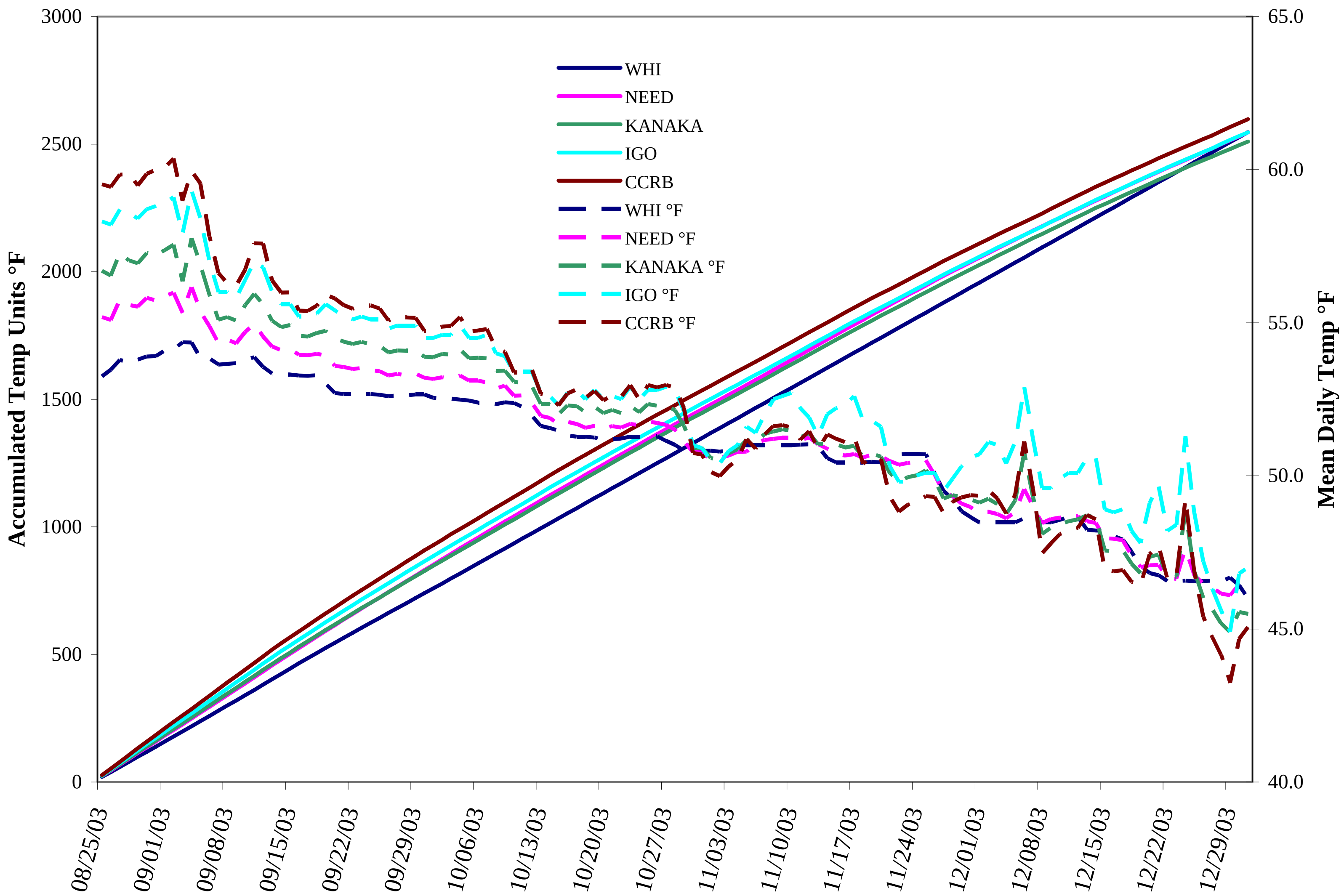

Figure 2. Mean Daily Temp (MDT) in degrees ° F and Accumulated Daily Temperature Units (DTU) ° F recorded at five temperature monitoring stations in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from September 25, 2003 through December 31, 2003.

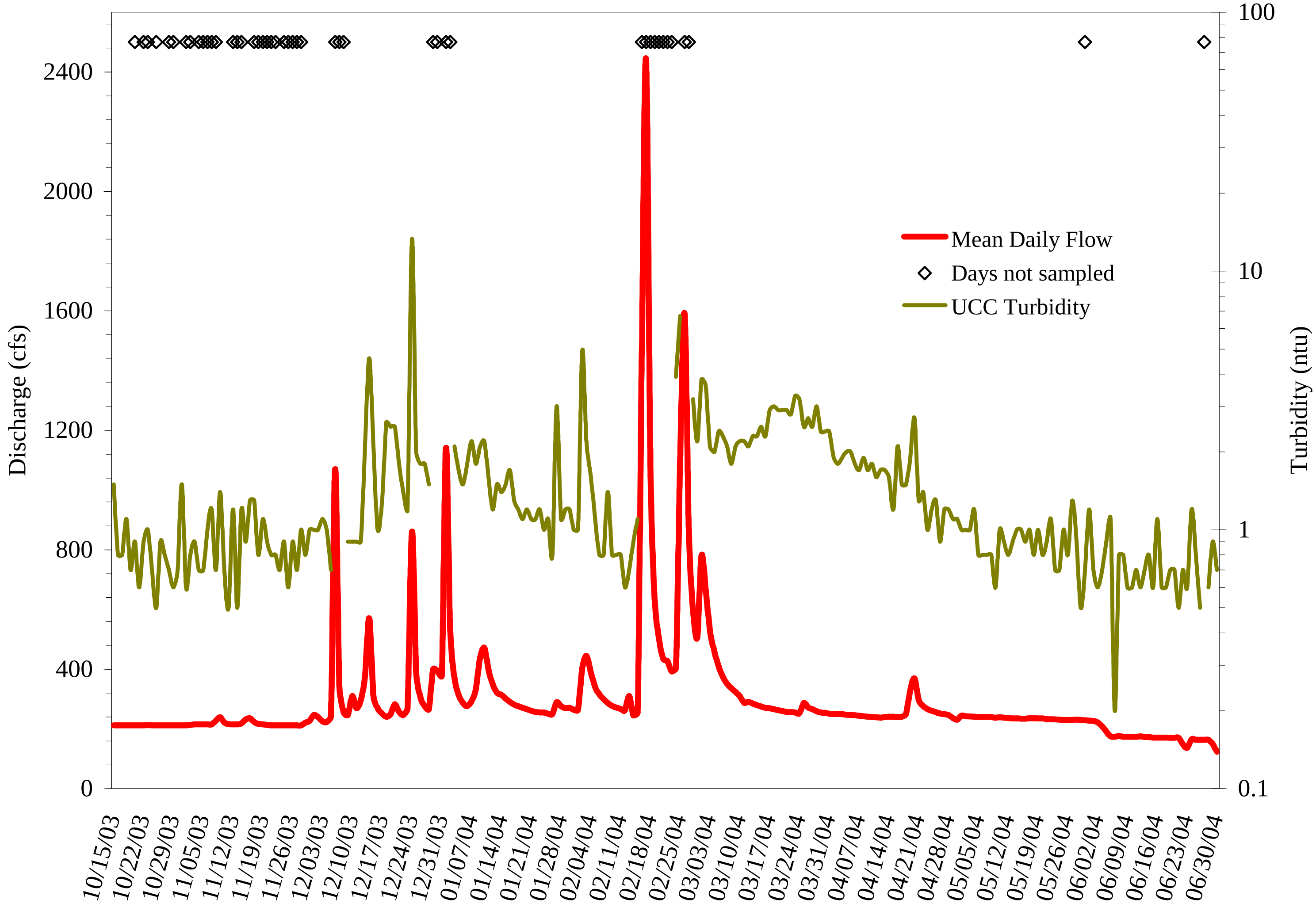

Figure 3. Mean daily flow in cubic feet per second (cfs), momentary turbidity in nephelometric turbidity units (NTU) recorded at the rotary screw trap sampling station at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

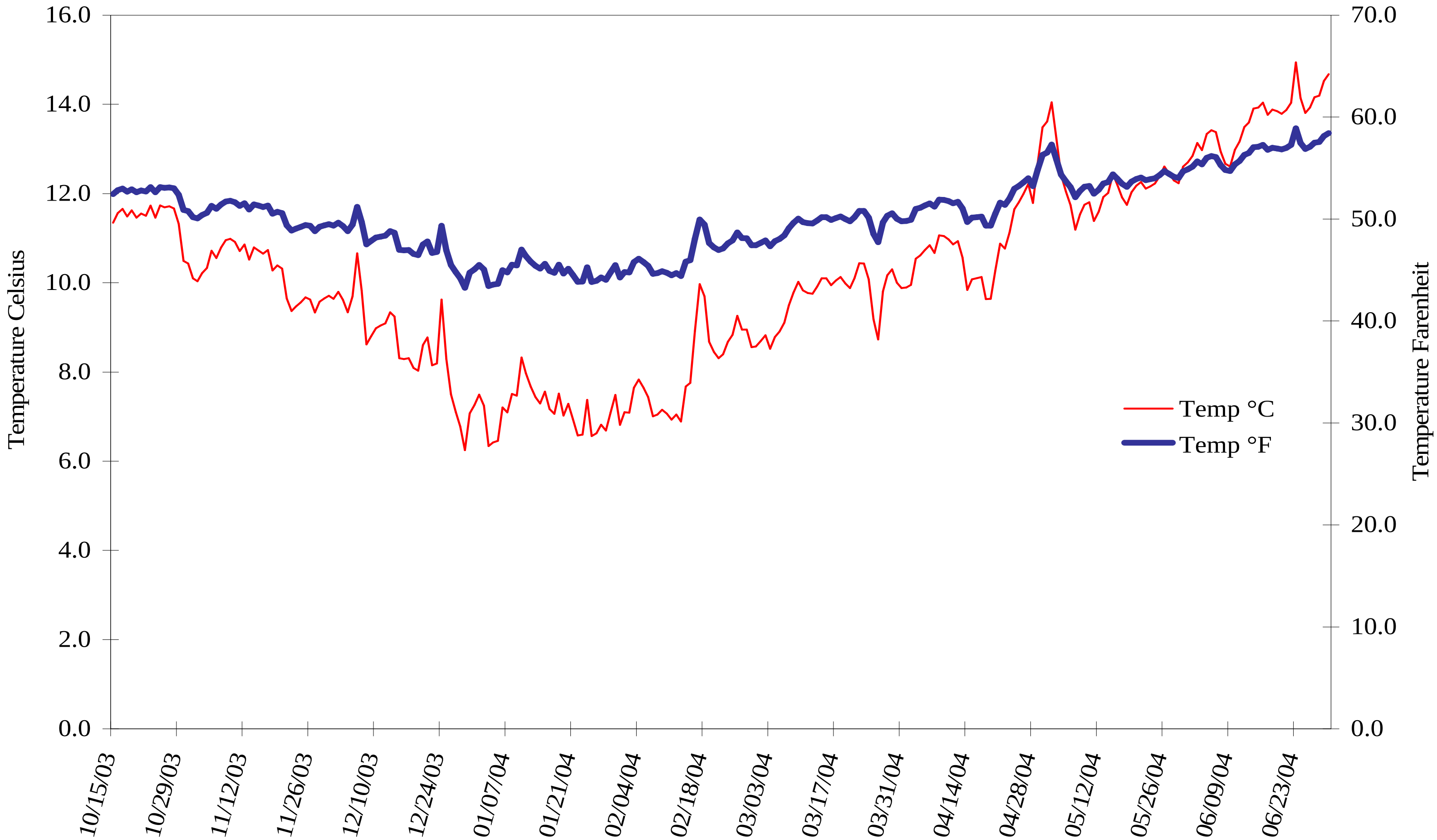

Figure 4. Mean daily water temperatures (°F and °C) recorded at the rotary screw trap sampling station at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

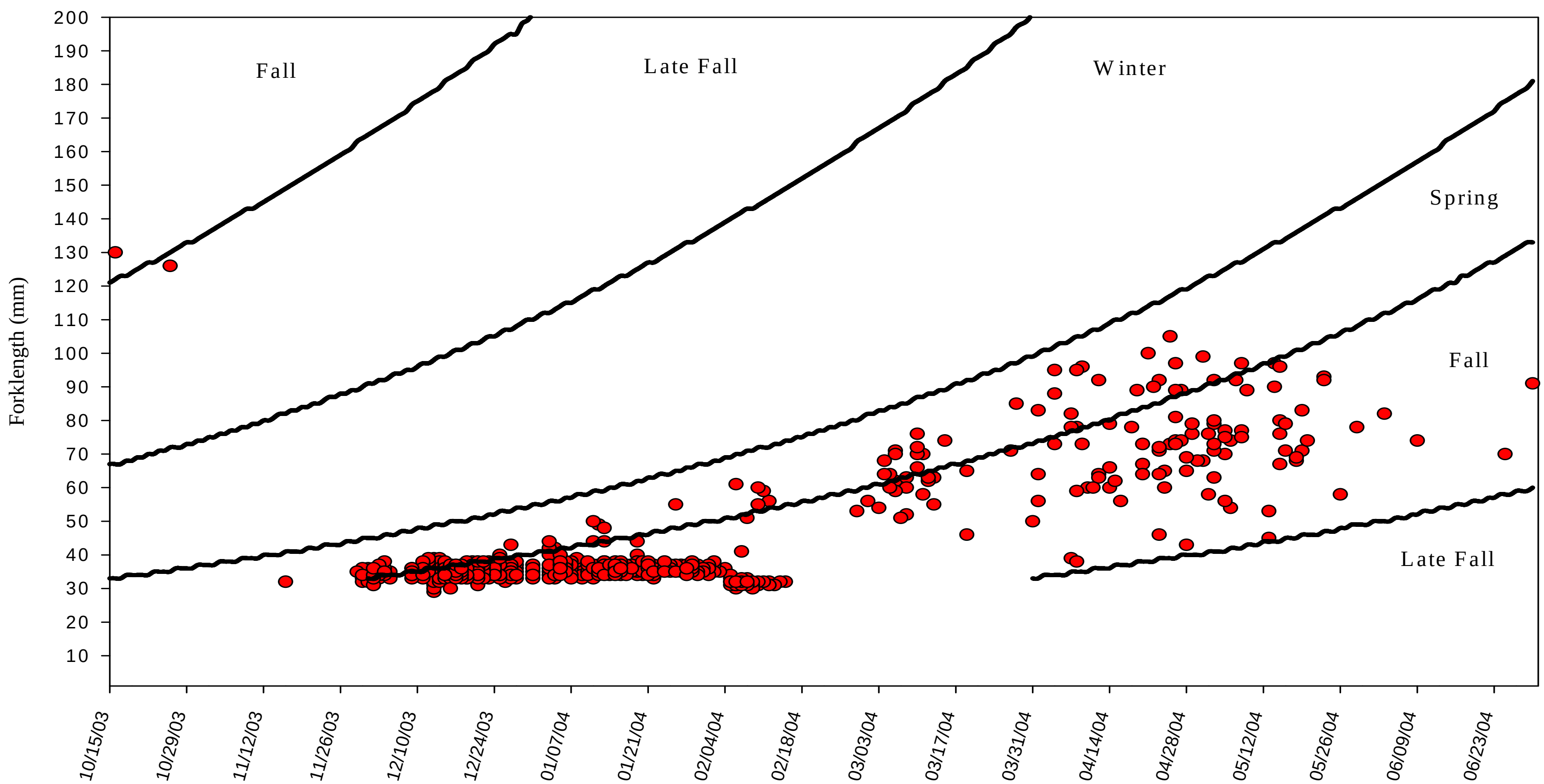

Figure 5. Fork length (mm) distribution by date and run for Chinook salmon captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004. Spline curves represent the maximum fork lengths expected for each run by date, based upon criteria developed by the California Department of Water Resources (Greene 1992).

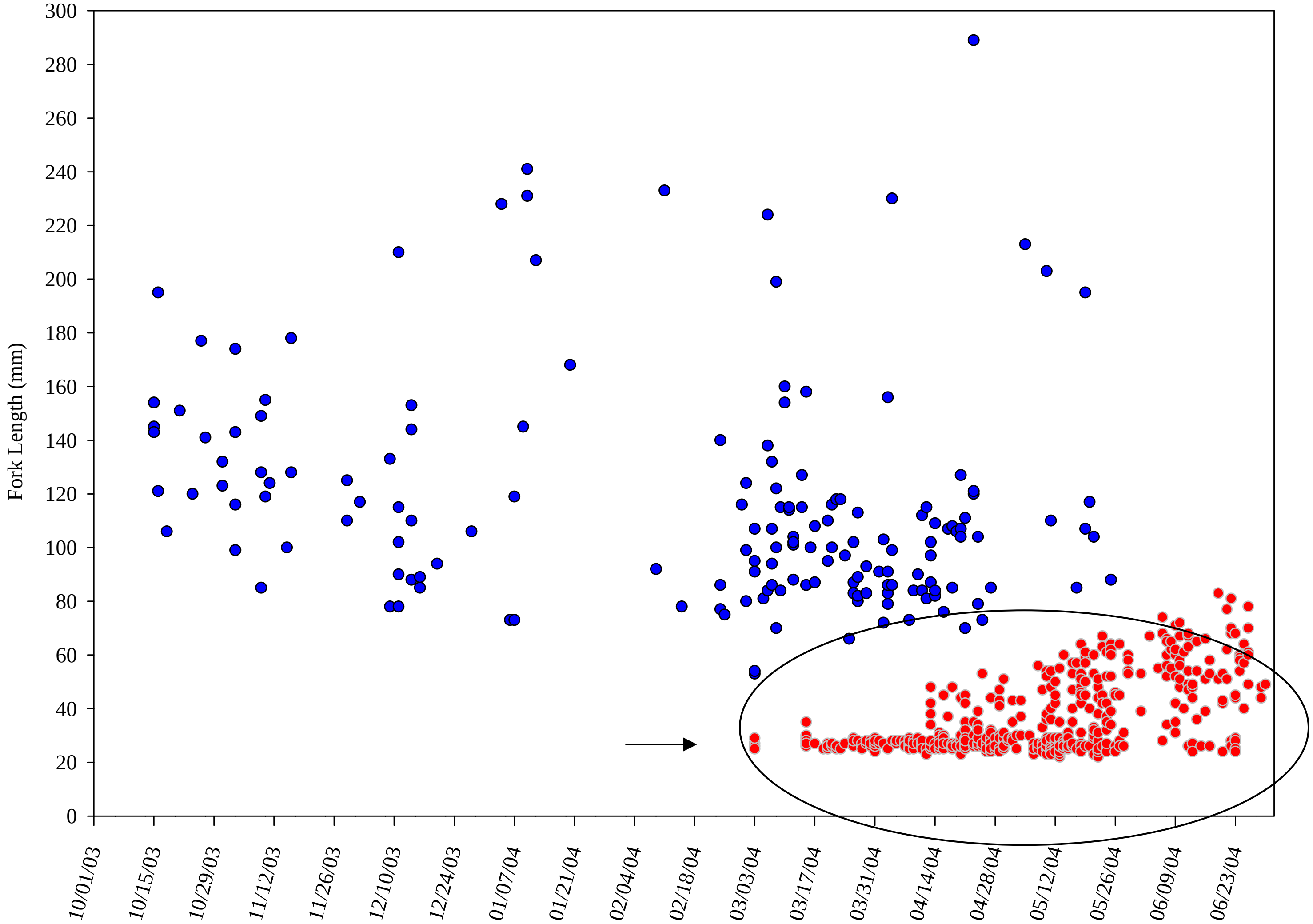

Figure 6. Fork length (mm) distribution by date for steelhead / rainbow trout captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004. Blue dots represent age 0 + steelhead trout that most likely are of BY 2003 or earlier, while the red dots represent passage from BY 2004.

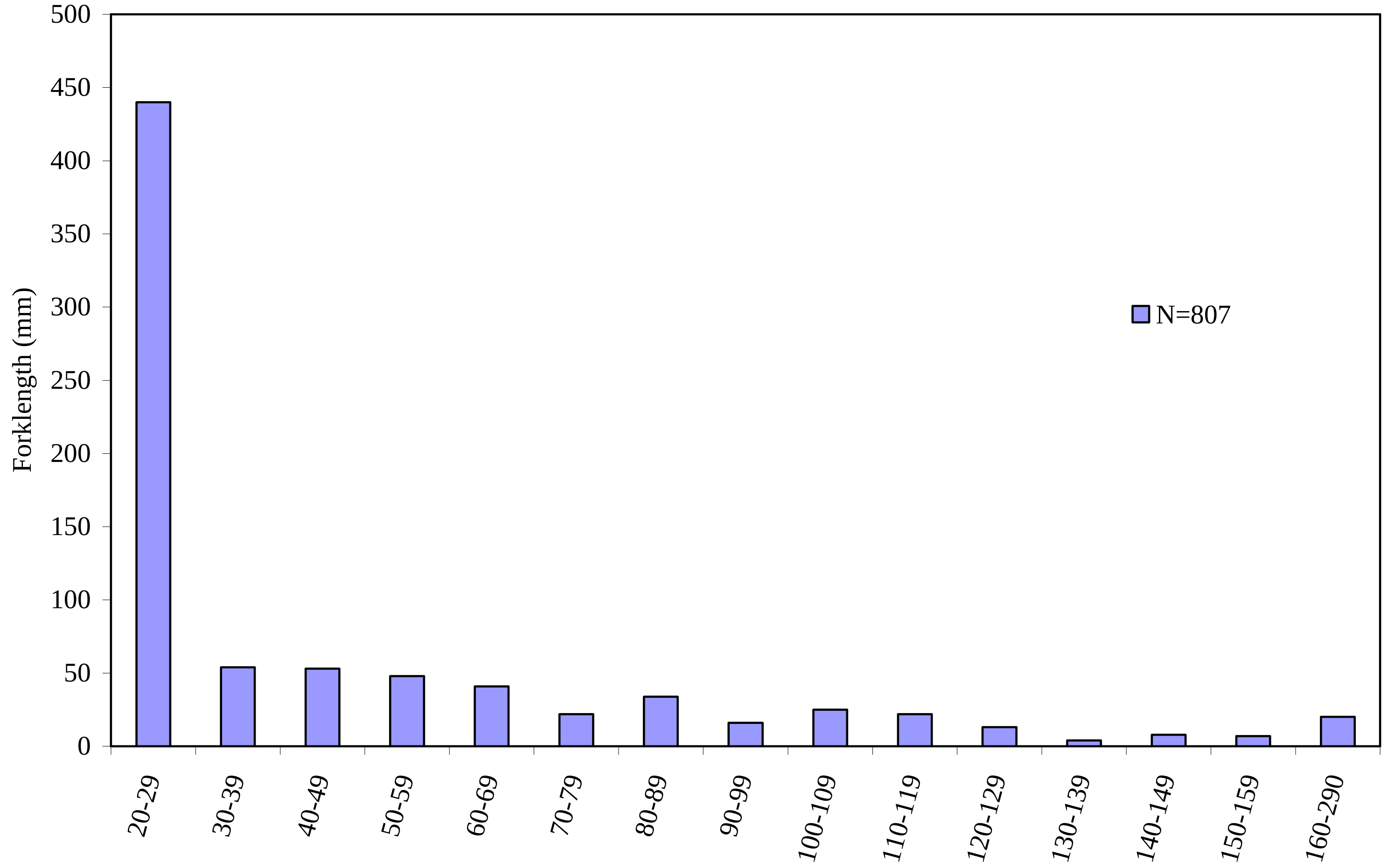

Figure 7. Fork length (mm) distribution by date for steelhead / rainbow trout captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

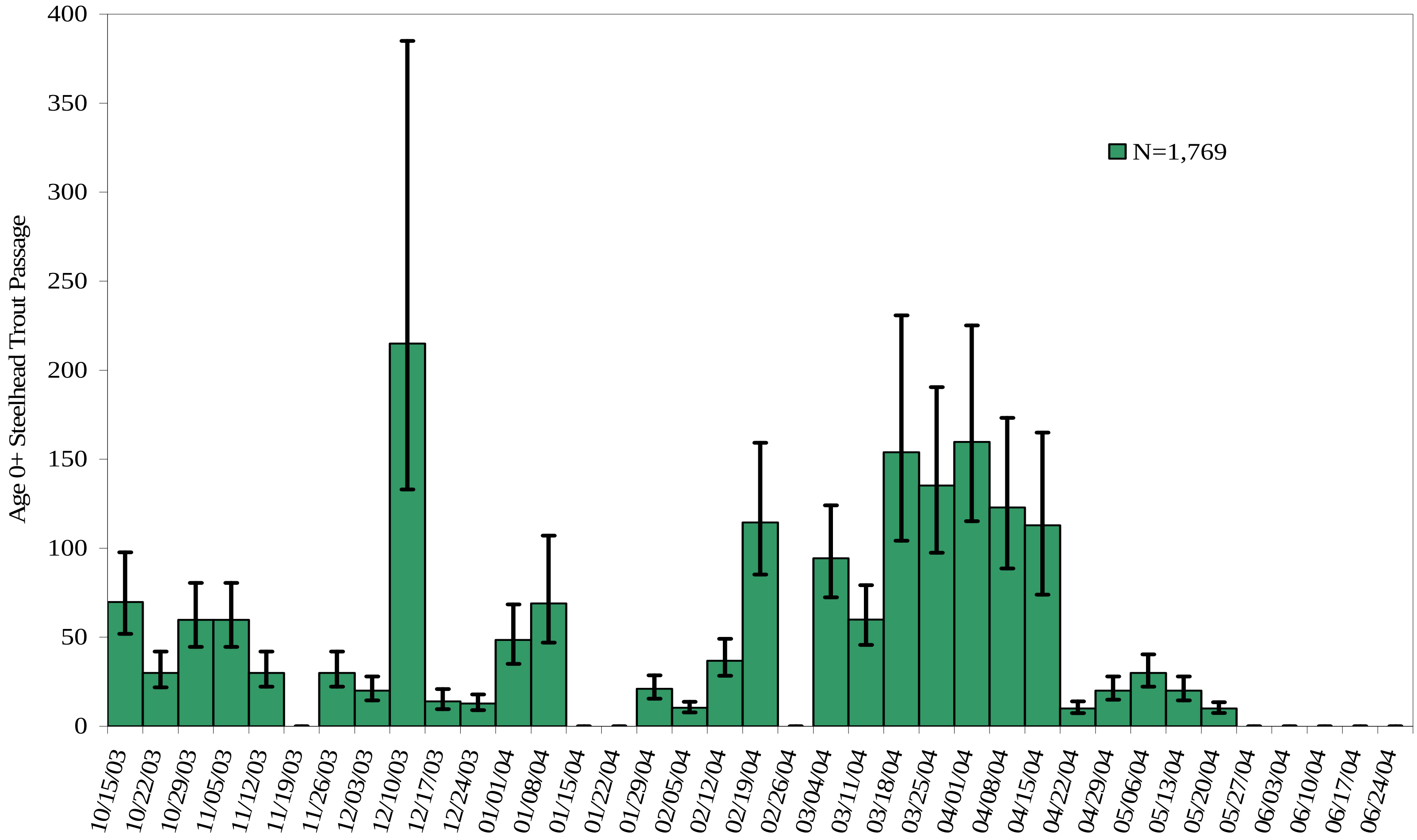

Figure 8. Passage index with 95% confidence intervals for steelhead / rainbow trout BY 2003 captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

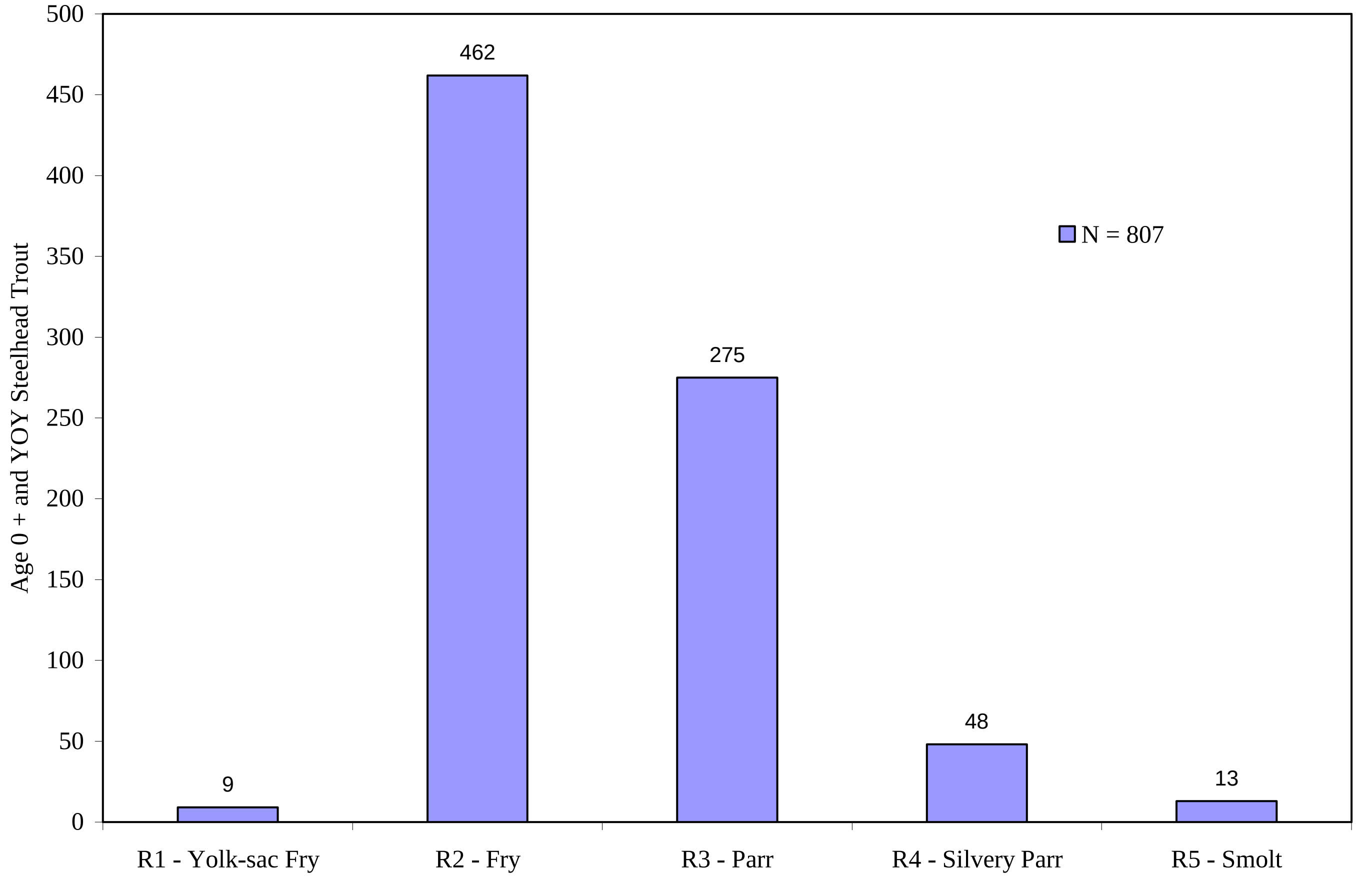

Figure 9. Life stage ratings for juvenile steelhead / rainbow trout salmon captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

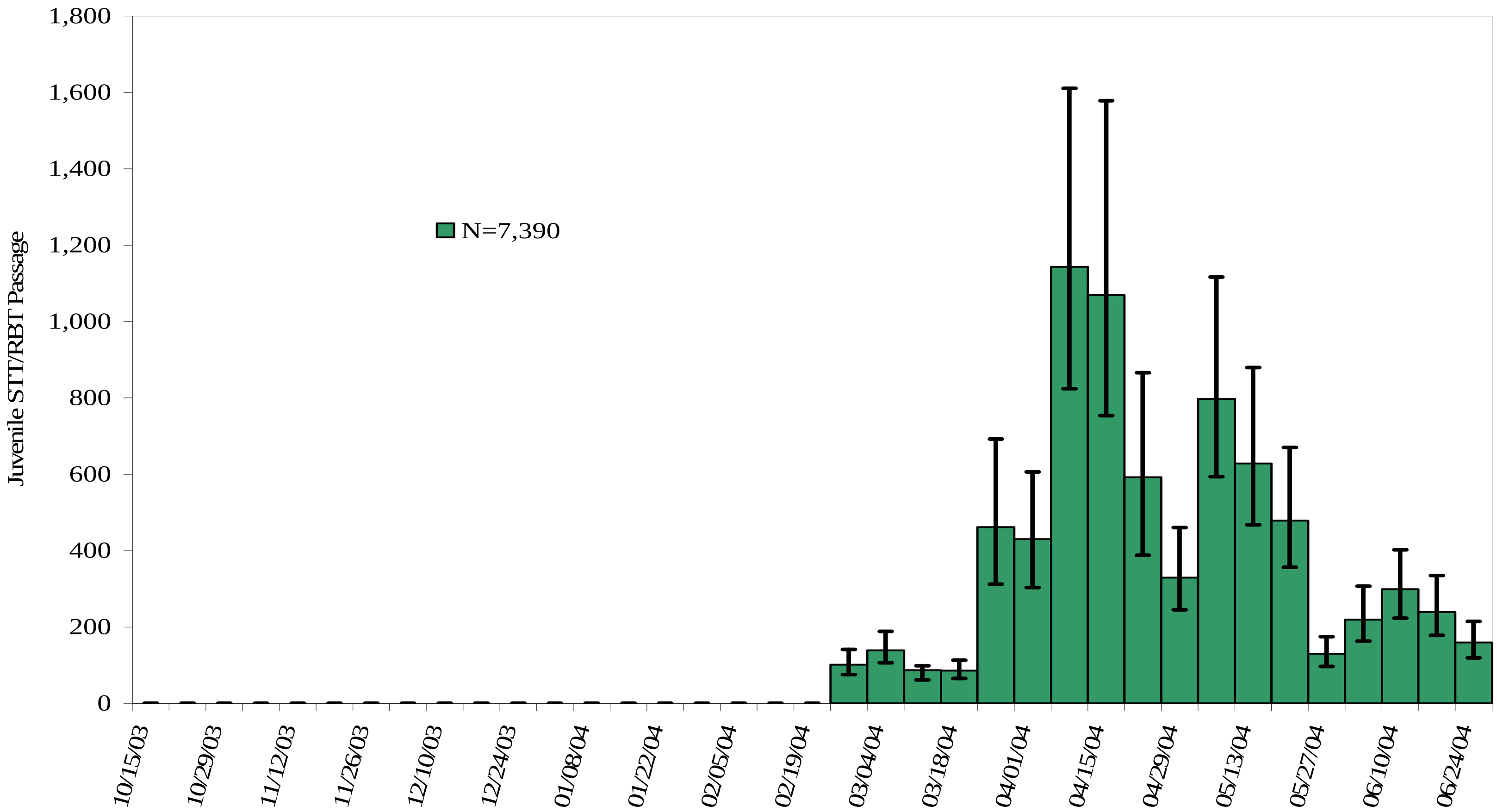

Figure 10. Passage index with 95% confidence intervals for steelhead / rainbow trout BY 2004 captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

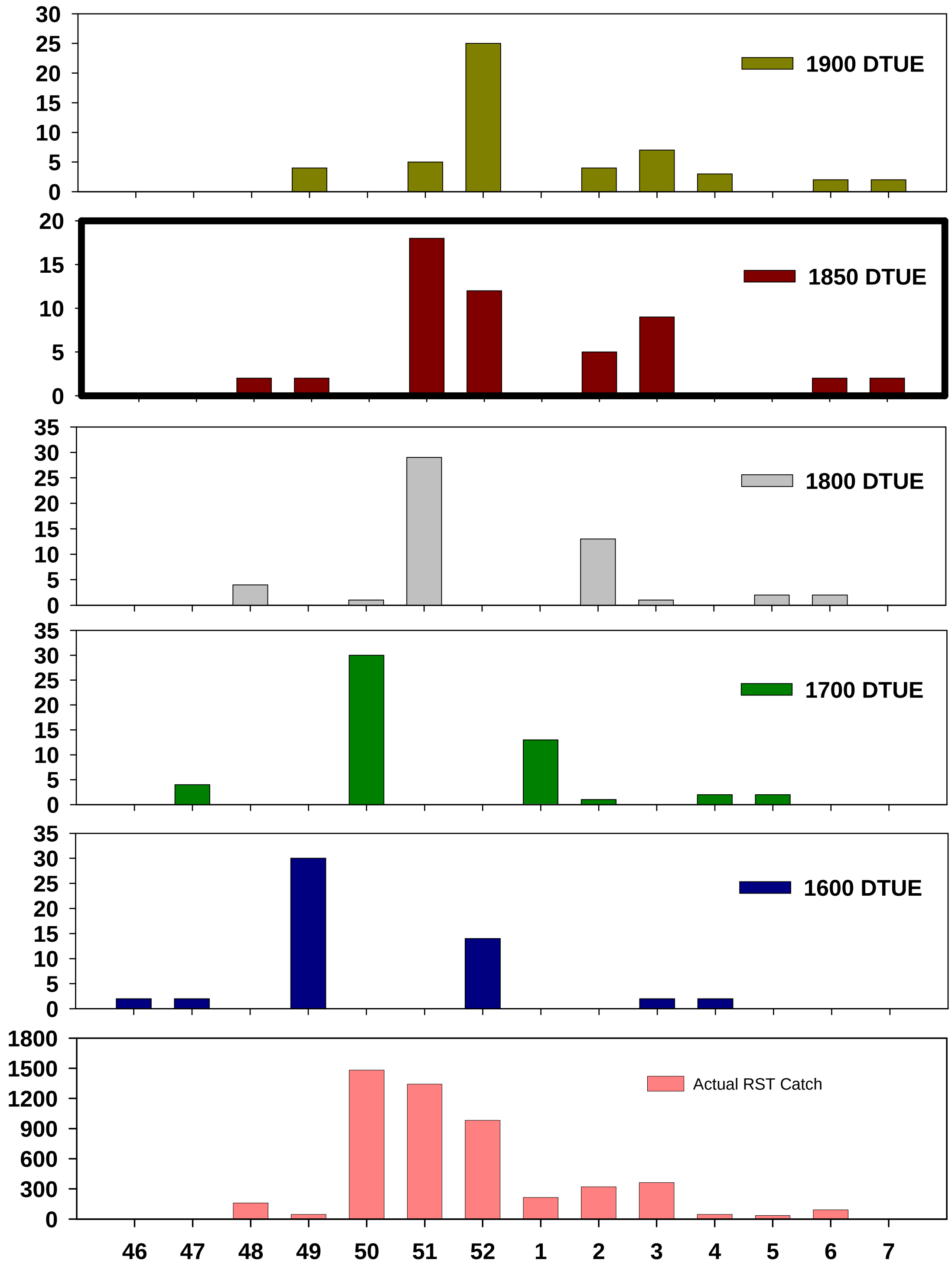

Figure 11. Daily Temperature Unit (DTU's) distributions and expected juvenile Chinook emergence dates of ranges between 1,600 and 1,900 based on redd observations; the bottom graph is actual RST catch of juvenile Chinook captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 15 to February 18, 2004.

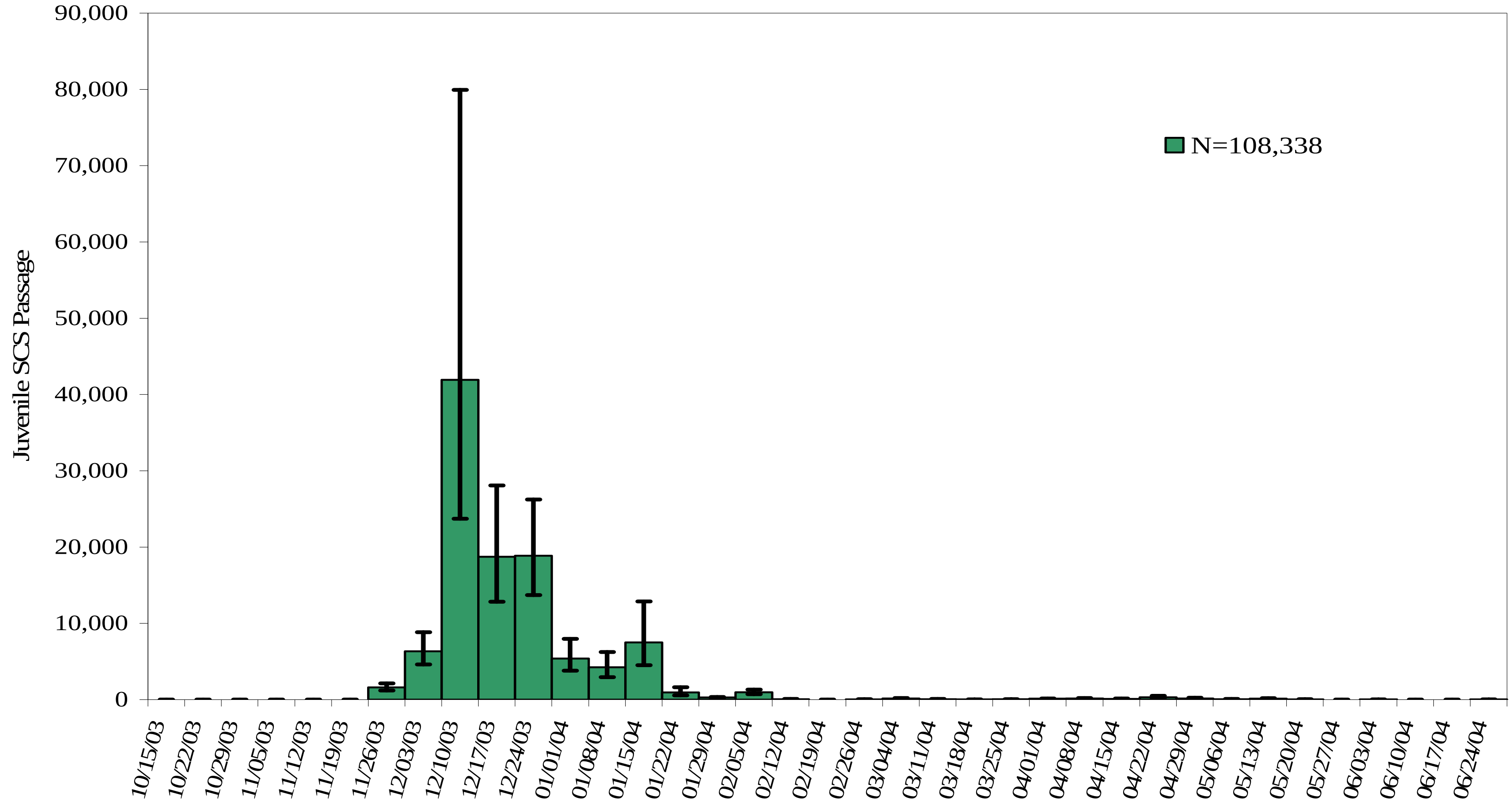

Figure 12. Passage index with 95% confidence intervals of juvenile spring-run Chinook BY 2003 captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

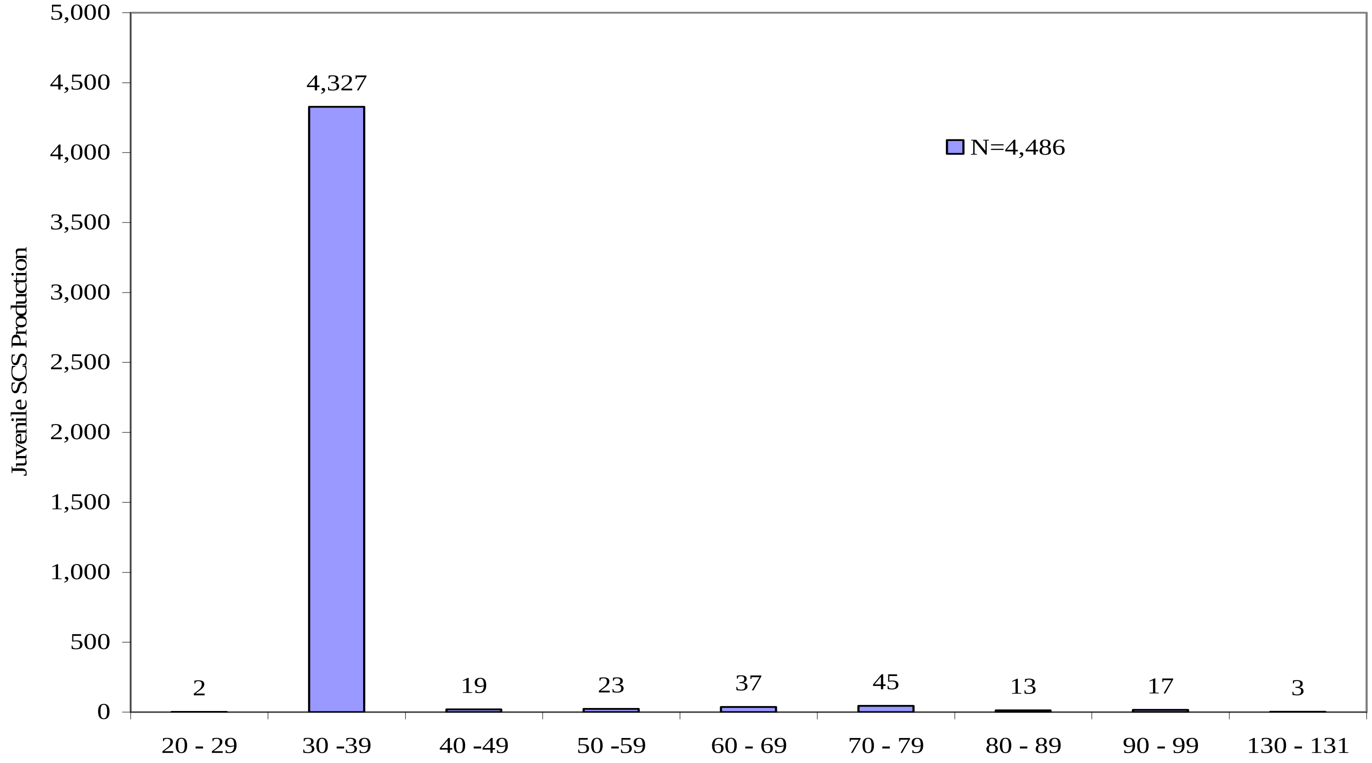

Figure 13. Fork length (mm) frequency distribution of juvenile spring-run Chinook salmon captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004. Fork length frequencies were assigned based on the proportional frequency of occurrence, in 10 mm increments.

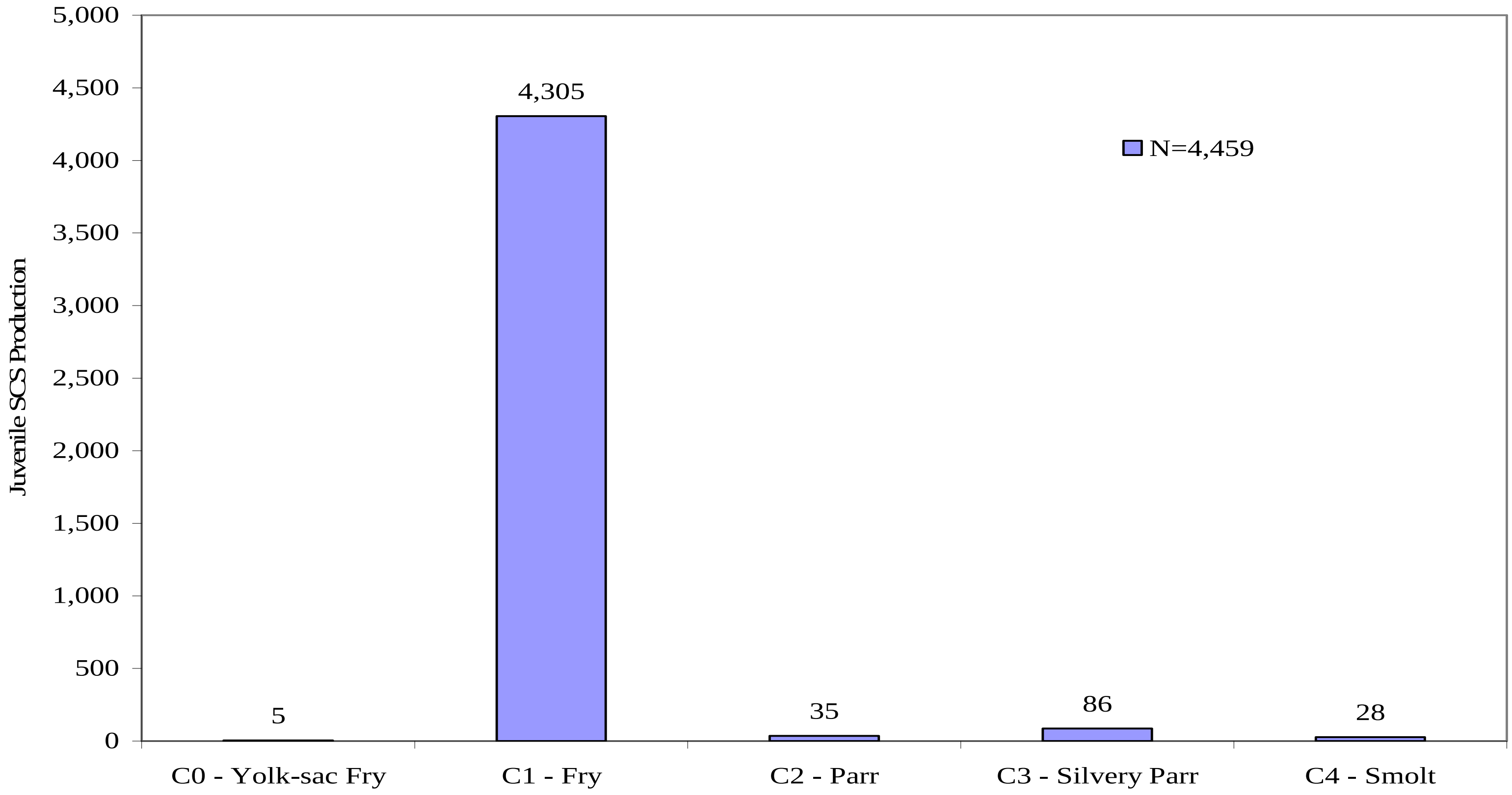

Figure 14. Life stage ratings for juvenile spring-run Chinook salmon captured by the rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 2003 through June 2004.

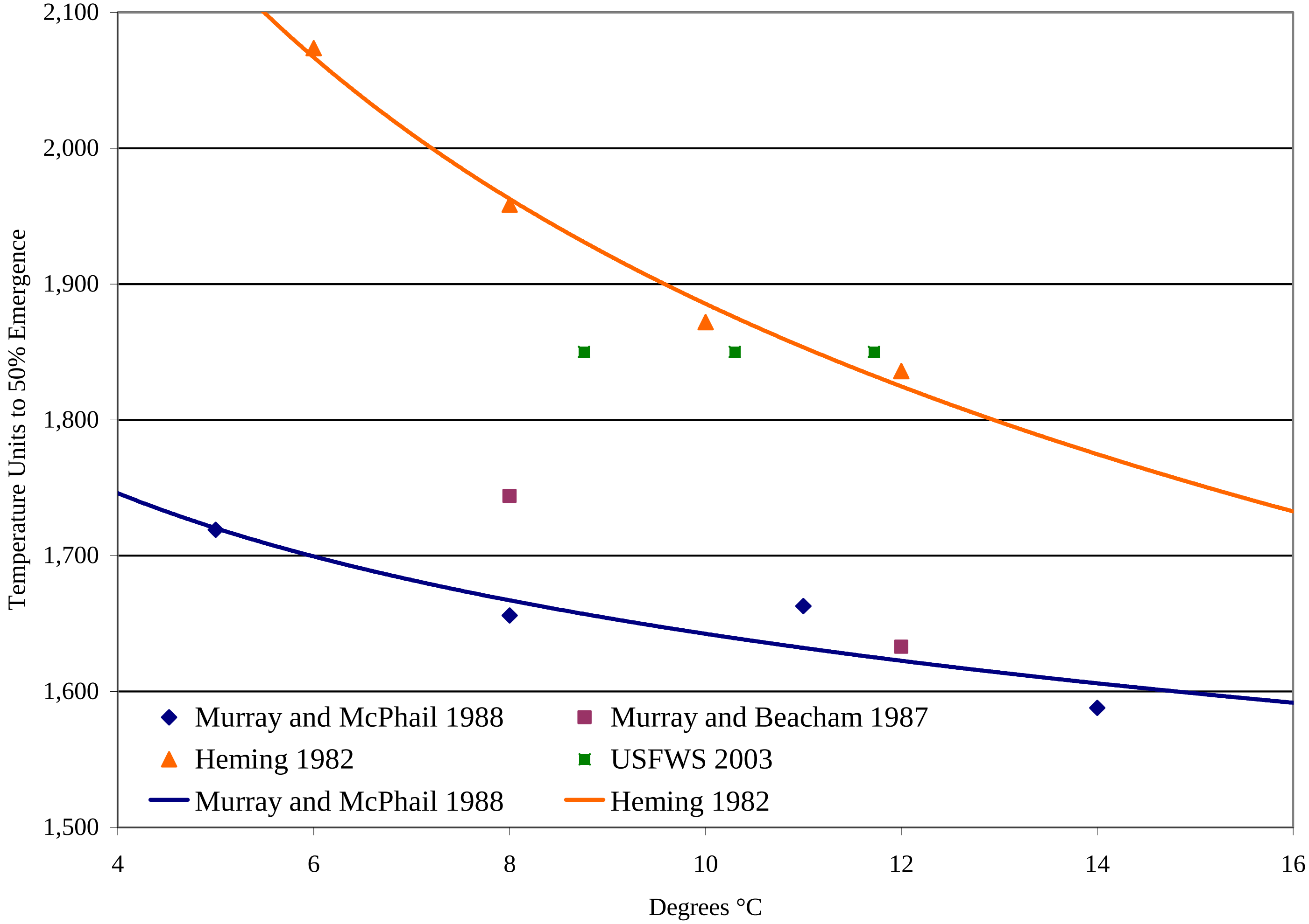

Figure 15. U.S. Fish and Wildlife Service 2003 study on Clear Creek of estimated daily temperature units to emergence (DTUE) compared to studies by Murray and McPhail 1988, Murray and Beacham 1987 and Heming 1982.

Tables

Table 1. Summary of rotary screw trap efficiency test data gathered by using mark-recapture trials with juvenile Chinook salmon at river mile 8.3 in Clear Creek, Shasta County, California by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

Trial Date	Mark Date	Release Date	# Marked/Trial	Fish Released/Trial	Mortality/Trial	% Mortality/Trial	Actual Trap Catch/Trial	% Efficiency
1[a]	3-Dec-03	3-Dec-03	21	20	1	4.76%	6	30.00%
2[a]	13-Dec-03	13-Dec-03	262	259	3	1.15%	7	2.70%
3[a]	17-Dec-03	17-Dec-03	61	60	0	0.00%	1	1.67%
4[a]	19-Dec-03	19-Dec-03	409	409	0	0.00%	31	7.58%
1	12-Jan-04	13-Jan-04	249	248	1	0.40%	11	4.44%
2	29-Jan-04	30-Jan-04	401	400	0	0.00%	50	12.50%
3	5-Feb-04	6-Feb-04	400	400	0	0.00%	27	6.75%
4	9-Feb-04	10-Feb-04	399	397	2	0.50%	32	8.06%
5	12-Feb-04	13-Feb-04	370	367	3	0.81%	39	10.63%
6	23-Feb-04	24-Feb-04	409	406	3	0.73%	21	5.17%
7	1-Mar-04	2-Mar-04	406	405	1	0.25%	40	9.88%
8	4-Mar-04	5-Mar-04	389	389	0	0.00%	50	12.85%
9	8-Mar-04	9-Mar-04	300	298	2	0.67%	33	11.07%
10	11-Mar-04	12-Mar-04	373	368	5	1.34%	57	15.49%
11	15-Mar-04	16-Mar-04	390	384	6	1.54%	44	11.46%
12	25-Mar-04	26-Mar-04	364	358	6	1.65%	20	5.59%
13	1-Apr-04	2-Apr-04	406	401	5	1.23%	39	9.73%
14	8-Apr-04	9-Apr-04	171	153	18	10.53%	6	3.92%
15	15-Apr-04	16-Apr-04	283	267	16	5.65%	18	6.74%
	Totals		6063	5989	72		532	

[a] Fall 2003 trials.

Table 2. Dates with corresponding week numbers for rotary screw trapping operations at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

Dates	Corresponding Week	Dates	Corresponding Week
10/15/03-10/21	42	02/26-03/03	9
10/22-10/28	43	03/04-03/10	10
10/29-11/04	44	03/11-03/17	11
11/05-11/11	45	03/18-03/24	12
11/12-11/18	46	03/25-03/31	13
11/19-11/25	47	04/01-04/07	14
11/26-12/02	48	04/08-04/14	15
12/03-12/09	49	04/15-04/21	16
12/10-12/16	50	04/22-04/28	17
12/17-12/23	51	04/29-05/05	18
12/24-12/31	52[a]	05/06-05/12	19
01/01-01/07/04	1	05/13-05/19	20
01/08-01/14	2	05/20-05/26	21
01/15-01/21	3	05/27-06/02	22
01/22-01/28	4	06/03-06/09	23
01/29-02/04	5	06/10-06/16	24
02/05-02/11	6	06/17-06/23	25
02/12-02/18	7	06/24-06/30	26
02/19-02/25	8		

[a] Week 52 contains 8 days for keeping Jan. 1 as Julian calendar day 1.

Table 3. Weekly catch, passage indices and mortality of all BY 2003 Chinook captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

Week	Date	Weekly Estimate	Catch	Mortality	% Passage	% Catch
Week 42	10/15/03	0	1	0	0.00%	0.00%
Week 43	10/22/03	0	1	0	0.00%	0.00%
Week 44	10/29/03	0	0	0	0.00%	0.00%
Week 45	11/05/03	0	0	0	0.00%	0.00%
Week 46	11/12/03	10	1	0	0.00%	0.00%
Week 47	11/19/03	0	0	0	0.00%	0.00%
Week 48	11/26/03	1,585	159	2	0.13%	1.26%
Week 49	12/03/03	6,332	46	1	0.02%	2.17%
Week 50	12/10/03	41,923	1,482	800	1.91%	53.98%
Week 51	12/17/03	18,732	1,342	19	0.10%	1.42%
Week 52*	12/24/03	18,847	983	328	1.74%	33.37%
Week 1	01/01/04	5,410	214	1	0.02%	0.47%
Week 2	01/08/04	4,247	321	6	0.14%	1.87%
Week 3	01/15/04	7,512	362	4	0.05%	1.10%
Week 4	01/22/04	955	46	1	0.10%	2.17%
Week 5	01/29/04	267	34	1	0.37%	2.94%
Week 6	02/05/04	968	92	1	0.10%	1.09%
Week 7	02/12/04	62	6	0	0.00%	0.00%
Week 8	02/19/04	0	0	0	0.00%	0.00%
Week 9	02/26/04	38	3	0	0.00%	0.00%
Week 10	03/04/04	156	18	0	0.00%	0.00%
Week 11	03/11/04	65	9	0	0.00%	0.00%
Week 12	03/18/04	17	2	0	0.00%	0.00%
Week 13	03/25/04	51	3	0	0.00%	0.00%
Week 14	04/01/04	111	9	1	0.90%	11.11%
Week 15	04/08/04	172	14	0	0.00%	0.00%
Week 16	04/15/04	98	8	0	0.00%	0.00%
Week 17	04/22/04	310	22	0	0.00%	0.00%
Week 18	04/29/04	170	17	0	0.00%	0.00%
Week 19	05/06/04	70	7	0	0.00%	0.00%
Week 20	05/13/04	140	14	1	0.72%	7.14%
Week 21	05/20/04	40	4	0	0.00%	0.00%
Week 22	05/27/04	10	1	0	0.00%	0.00%
Week 23	06/03/04	20	2	0	0.00%	0.00%
Week 24	06/10/04	0	0	0	0.00%	0.00%
Week 25	06/17/04	0	0	0	0.00%	0.00%
Week 26	06/24/04	20	2	0	0.00%	0.00%

Table 4. Weekly passage indices with 90% and 95% confidence intervals, standard deviation (SD) of the weekly strata and summed daily efficiencies for comparison of all Chinook captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

Days Sampled	Week	Date	95% CI Lower	90% CI Lower	Weekly Estimate	90% CI Upper	95% CI Upper	S.D.
7 of 7	Week 42	10/15/03	0	0	0	0	0	0
7 of 7	Week 43	10/22/03	0	0	0	0	0	0
7 of 7	Week 44	10/29/03	0	0	0	0	0	0
7 of 7	Week 45	11/05/03	0	0	0	0	0	0
7 of 7	Week 46	11/12/03	7	8	10	13	14	2
7 of 7	Week 47	11/19/03	0	0	0	0	0	0
7 of 7	Week 48	11/26/03	1,181	1,233	1,585	2,055	2,134	259
4 of 7	Week 49	12/03/03	4,617	4,818	6,332	8,208	8,865	1,074
7 of 7	Week 50	12/10/03	4,047	4,227	5,434	7,045	7,608	885
7 of 7	Week 50 Pt II	12/10/03	18,425	19,741	34,548	55,276	69,095	14,212
7 of 7	Week 50 Pt III	12/10/03	1,266	1,266	1,941	2,912	3,236	522
7 of 7	Week 51	12/17/03	12,845	13,623	18,732	24,976	28,098	3,823
6 of 7	Week 52*	12/24/03	13,707	14,360	18,847	25,130	26,222	3,360
5 of 7	Week 1	01/01/04	3,811	4,090	5,410	7,291	7,986	1,003
7 of 7	Week 2	01/08/04	2,448	2,568	3,396	4,387	4,785	617
7 of 7	Week 2 Pt II	01/08/04	510	567	851	1,276	1,458	256
7 of 7	Week 3	01/15/04	4,507	4,744	7,512	11,267	12,877	2,388
7 of 7	Week 4	01/22/04	573	603	955	1,432	1,636	292
7 of 7	Week 5	01/29/04	210	216	267	333	350	36
7 of 7	Week 6	02/05/04	736	751	968	1,269	1,314	158
4 of 7	Week 7	02/12/04	47	49	62	79	85	10
2 of 7	Week 8	02/19/04	0	0	0	0	0	0

Days Sampled	Week	Date	95% CI Lower	90% CI Lower	Weekly Estimate	90% CI Upper	95% CI Upper	S.D.
5 of 7	Week 9	02/26/04	28	29	38	51	53	7
7 of 7	Week 10	03/04/04	117	124	156	205	219	24
7 of 7	Week 11	03/11/04	51	52	65	81	86	9
7 of 7	Week 12	03/18/04	13	14	17	21	23	2
7 of 7	Week 13	03/25/04	35	37	51	72	77	12
7 of 7	Week 14	04/01/04	78	83	111	149	157	20
7 of 7	Week 15	04/08/04	122	129	172	221	232	33
7 of 7	Week 16	04/15/04	70	74	98	132	147	20
7 of 7	Week 17	04/22/04	210	218	310	435	508	81
7 of 7	Week 18	04/29/04	124	129	170	220	237	30
7 of 7	Week 19	05/06/04	52	54	70	90	98	11
7 of 7	Week 20	05/13/04	102	106	140	181	188	23
7 of 7	Week 21	05/20/04	30	31	40	52	54	6
7 of 7	Week 22	05/27/04	7	8	10	13	14	2
7 of 7	Week 23	06/03/04	15	16	20	26	28	3
7 of 7	Week 24	06/10/04	0	0	0	0	0	0
7 of 7	Week 25	06/17/04	0	0	0	0	0	0
6 of 7	Week 26	06/24/04	15	16	20	26	28	3
242 of 259		Total	88,817	90,113	108,338	130,960	137,672	

* Week 52 (12/24/03-12/31/03) contains 8 days for the purpose of keeping Jan. 1 as Julian calendar day 1.

Table 5. Weekly passage indices with 90% and 95% confidence intervals, standard deviation (SD) of the weekly strata for BY 2003 and BY 2004 steelhead / rainbow trout captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

Days Sampled	Week	BY03	95% CI Lower	90% CI Lower	Weekly Estimate	90% CI Upper	95% CI Upper	S.D.
7 of 7	Week 42	10/15/03	52	54	70	94	98	12
7 of 7	Week 43	10/22/03	22	23	30	39	42	5
7 of 7	Week 44	10/29/03	45	47	60	78	81	10
7 of 7	Week 45	11/05/03	45	46	60	75	81	10
7 of 7	Week 46	11/12/03	22	23	30	39	42	5
7 of 7	Week 47	11/19/03	0	0	0	0	0	0
7 of 7	Week 48	11/26/03	22	23	30	39	42	5
4 of 7	Week 49	12/03/03	15	15	20	26	28	4
7 of 7	Week 50	12/10/03	36	38	50	65	67	8
7 of 7	Week 50 Pt II	12/10/03	74	74	130	208	260	47
7 of 7	Week 50 Pt III	12/10/03	23	24	35	52	58	9
7 of 7	Week 51	12/17/03	10	10	14	20	21	3
6 of 7	Week 52*	12/24/03	9	10	13	17	18	2
5 of 7	Week 1	01/01/04	35	37	49	63	68	9
7 of 7	Week 2	01/08/04	34	37	49	65	72	9
7 of 7	Week 2 Pt II	01/08/04	12	14	21	31	36	6
7 of 7	Week 3	01/15/04	0	0	0	0	0	0
7 of 7	Week 4	01/22/04	0	0	0	0	0	0
7 of 7	Week 5	01/29/04	15	16	21	28	29	3
7 of 7	Week 6	02/05/04	8	8	10	13	14	2
4 of 7	Week 7	02/12/04	28	29	37	46	49	5
2 of 7	Week 8	02/19/04	85	89	114	153	159	21
5 of 7	Week 9	02/26/04	0	0	0	0	0	0
7 of 7	Week 10	03/04/04	72	76	94	117	124	13
7 of 7	Week 11	03/11/04	46	47	60	75	79	9

Days Sampled	Week	BY03	95% CI Lower	90% CI Lower	Weekly Estimate	90% CI Upper	95% CI Upper	S.D.
7 of 7	Week 12	03/18/04	104	108	154	215	231	35
7 of 7	Week 13	03/25/04	97	102	135	175	191	23
7 of 7	Week 14	04/01/04	115	121	160	206	225	28
7 of 7	Week 15	04/08/04	89	93	123	159	173	21
7 of 7	Week 16	04/15/04	74	79	113	153	165	26
7 of 7	Week 17	04/22/04	7	8	10	13	14	2
7 of 7	Week 18	04/29/04	15	16	20	26	28	3
7 of 7	Week 19	05/06/04	22	23	30	39	40	5
7 of 7	Week 20	05/13/04	15	16	20	26	28	3
7 of 7	Week 21	05/20/04	7	8	10	13	13	2
7 of 7	Week 22	05/27/04	0	0	0	0	0	0
7 of 7	Week 23	06/03/04	0	0	0	0	0	0
7 of 7	Week 24	06/10/04	0	0	0	0	0	0
7 of 7	Week 25	06/17/04	0	0	0	0	0	0
6 of 7	Week 26	06/24/04	0	0	0	0	0	0
242 of 259		Total	1,619	1,642	1,769	1,916	1,952	

Days Sampled	Week	BY04	95% CI Lower	90% CI Lower	Weekly Estimate	90% CI Upper	95% CI Upper	S.D.
7 of 7	Week 42	10/15/03	0	0	0	0	0	0
7 of 7	Week 43	10/22/03	0	0	0	0	0	0
7 of 7	Week 44	10/29/03	0	0	0	0	0	0
7 of 7	Week 45	11/05/03	0	0	0	0	0	0
7 of 7	Week 46	11/12/03	0	0	0	0	0	0
7 of 7	Week 47	11/19/03	0	0	0	0	0	0
7 of 7	Week 48	11/26/03	0	0	0	0	0	0
4 of 7	Week 49	12/03/03	0	0	0	0	0	0
7 of 7	Week 50	12/10/03	0	0	0	0	0	0
7 of 7	Week 51	12/17/03	0	0	0	0	0	0
6 of 7	Week 52*	12/24/03	0	0	0	0	0	0

Days Sampled	Week	BY04	95% CI Lower	90% CI Lower	Weekly Estimate	90% CI Upper	95% CI Upper	S.D.
5 of 7	Week 1	01/01/04	0	0	0	0	0	0
7 of 7	Week 2	01/08/04	0	0	0	0	0	0
7 of 7	Week 3	01/15/04	0	0	0	0	0	0
7 of 7	Week 4	01/22/04	0	0	0	0	0	0
7 of 7	Week 5	01/29/04	0	0	0	0	0	0
7 of 7	Week 6	02/05/04	0	0	0	0	0	0
4 of 7	Week 7	02/12/04	0	0	0	0	0	0
2 of 7	Week 8	02/19/04	0	0	0	0	0	0
5 of 7	Week 9	02/26/04	76	78	102	136	142	17
7 of 7	Week 10	03/04/04	106	110	139	177	188	20
7 of 7	Week 11	03/11/04	62	62	87	94	98	10
7 of 7	Week 12	03/18/04	65	68	86	107	113	12
7 of 7	Week 13	03/25/04	313	334	462	646	692	102
7 of 7	Week 14	04/01/04	303	325	430	580	606	78
7 of 7	Week 15	04/08/04	824	864	1,143	1,476	1,611	206
7 of 7	Week 16	04/15/04	753	808	1,069	1,441	1,578	198
7 of 7	Week 17	04/22/04	388	417	592	866	866	142
7 of 7	Week 18	04/29/04	245	256	329	427	461	53
7 of 7	Week 19	05/06/04	594	607	798	1,034	1,117	136
7 of 7	Week 20	05/13/04	468	489	628	814	879	102
7 of 7	Week 21	05/20/04	356	372	479	620	670	78
7 of 7	Week 22	05/27/04	97	101	130	162	175	20
7 of 7	Week 23	06/03/04	163	167	219	284	307	36
7 of 7	Week 24	06/10/04	223	233	299	388	403	48
7 of 7	Week 25	06/17/04	178	186	239	322	335	40
6 of 7	Week 26	06/24/04	119	124	160	207	215	25
242 of 259			6,655	6,756	7,390	8,118	8,264	

* Week 52 (12/24/03-12/31/03) contains 8 days for the purpose of keeping Jan. 1 as Julian calendar day 1.

Table 6. Reach numbers and locations with associated river miles for 2003 Clear Creek snorkel surveys.

Reach	River Mile	Location
1	18.1 - 15.9	Whiskeytown Dam to Need Camp Bridge
2	15.9 - 13.0	Need Camp Bridge to Kanaka Creek
3	13.0 - 10.9	Kanaka Creek to Igo Gauge
4	10.9 - 8.5	Igo Gauge to Clear Creek Road Bridge
5	8.5 - 6.5	Clear Creek Road Bridge to McCormick Saeltzer Dam Site
6	6.5 - 1.7	McCormick Saeltzer Dam Site to USFWS Lower Rotary Screw Trap

Table 7. Mark and recapture efficiency values used for weekly passage indices of Chinook captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004. Shaded rows indicate pooled values where more than one trial was used to determine efficiency.

Week	Marks	Recaptures	Efficiency
42-48**	348	34	.1003
49**	348	34	.1003
50 Pt. I**	348	340	.1003
50 Pt. II	259	7	.0308
50 Pt. III	259	14	.0577
51	334	23	.0716
52	409	31	.0780
1*	375	30	.0824
2*	375	30	.0824
2 Pt. II	248	11	.0482
3	248	11	.0482
4	248	11	.0482
5	400	50	.1272
6	399	37	.0950
7	382	36	.0966
8	367	39	.1087
9	406	31	.0786
10	364	41	.1151
11	333	45	.1377
12	384	44	.1169
13-17	342	26	.0787
18-26**	348	34	.1003
*Half Cone Average	375	30	.0824
**Full Cone Average	348	34	.1003

Table 8. Mark and recapture efficiency values used for weekly passage indices of Steelhead trout captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004. Shaded rows indicate pooled values where more than one trial was used to determine efficiency.

Week	Marks	Recaptures	Efficiency
42-49**	348	34	.1003
50 Pt. I**	348	340	.1003
50 Pt. II	259	7	.0308
50 Pt. III	259	14	.0577
51-3	344	24	.0725
6-8	389	37	.0974
9	406	31	.0786
10	364	41	.1151
11	333	45	.1377
12	384	44	.1169
13-17	342	26	.0787
18-26**	348	34	.1003
*Half Cone Average	375	30	.0824
**Full Cone Average	348	34	.1003

Table 9. Chinook redds observed during the 2003 Clear Creek snorkel surveys in Clear Creek from April through November of 2003 and expected date for Chinook emergence.

Reach	Date	Redds	Date of emergence
1	04/21/2003	0	
1[a]	05/09/2003	0	
1	05/19/2003	0	
1	06/16/2003	0	
1	07/14/2003	0	
1	08/25/2003	0	
1[a]	08/26/2003	0	
1	09/08/2003	2	11/30/2003
1	09/22/2003	4	12/21/2003
1	10/06/2003	3	1/12/2004
1	10/20/2003	2	2/4/2004
1	11/04/2003	0	
2	04/22/2003	0	
2	05/20/2003	0	
2	06/17/2003	0	
2	07/15/2003	0	
2	08/27/2003	0	
2	09/09/2003	0	
2	09/23/2003	15	12/21/2003
2	10/07/2003	4	1/12/2004
2	10/21/2003	0	
2	11/05/2003	0	
3	04/23/2003	0	
3	05/21/2003	0	
3	06/18/2003	0	
3	07/16/2003	0	
3	08/27/2003	0	
3	09/10/2003	1	11/27/2003
3	09/24/2003	4	12/16/2003
3	10/08/2003	0	
3	10/22/2003	0	
3	11/06/2003	0	
4	04/24/2003	N/S	
4	05/22/2003	0	
4	06/19/2003	0	
4	07/17/2003	0	
4	08/28/2003	0	
4	09/11/2003	1	11/28/2003
4	09/25/2003	7	12/17/2003
4	10/09/2003	6	1/7/2004
4	10/23/2003	2	2/7/2004

Reach	Date	Redds	Date of emergence
4	11/07/2003	0	
5	04/24/2003	N/S	
5	05/22/2003	0	
5	06/19/2003	0	
5	07/17/2003	0	
5	08/28/2003	0	
5a[b]	09/11/2003	0	
5b[b]	09/11/2003	0	
5a	09/25/2003	2	12/17/2003
5b	09/25/2003	1	
5a	10/10/2003	0	
5b	10/10/2003	9	
5a	10/24/2003	0	
5b	10/24/2003	8	
5a	11/07/2003	0	
5b	11/07/2003	1	
6	04/25/2003	N/S	
6	05/23/2003	0	
6	06/20/2003	0	
6	07/18/2003	0	
6	08/29/2003	0	
6	09/12/2003	0	
6	09/26/2003	98	

[a] Supplemental survey.
[b] A picket weir was installed in Clear Creek Reach 5 on 09/02/2003 and removed on 11/03/2003. Reach 5 was divided into 5a and 5b during this time period in order to separate fish and redds above and below the barrier weir. Although the picket weir was removed before Reach 5 was surveyed on 11/07, the fish and redd counts were divided at the previous weir location.

Appendix

Appendix A. Name key of non salmonid fish taxa captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

Abbreviation	Common name	Scientific Name
BGS	Blue Gill Sunfish	*Lepomis macrochirus*
BLB	Black Bullhead	*Ameiurus melas*
CAR	California Roach	*Hesperoleucus symmetricus*
COTFRY	Sculpin Fry	*Cottus spp.*
CYPFRY	Minnow Fry	*Cyprinidae spp.*
DACE	Speckled Dace	*Rhinichthys osculus*
GSF	Green Sunfish	*Lepomis cyanellus*
HH	Hardhead	*Mylopharodon conocephalus*
PL	Pacific Lamprey	*Lampetra tridentata*
PRS	Prickly sculpin	*Cottus asper*
RFS	Riffle sculpin	*Cottus gulosus*
SASQ	Sacramento Pikeminnow	*Ptychocheilus grandis*
SASU	Sacramento Sucker	*Catostomus occidentalis*
TP	Tule Perch	*Hysterocarpus traski*

Appendix B. Summary of non salmonid fish taxa captured by rotary screw trap at river mile 8.3 in Clear Creek, Shasta County, California, by the U.S. Fish and Wildlife Service from October 15, 2003 through June 30, 2004.

	Oct	Nov	Dec	Jan	Mar	Apr	May	Jun	Jul	Species Totals
BGS	0	0	1	0	0	0	0	0	0	1
BLB	0	1	0	0	0	0	0	0	0	1
CAR	3	2	1	0	13	36	62	25	0	142
COTFRY	0	0	0	0	0	0	0	557	69	626
CYPFRY	1	0	1	0	2	7	2	0	0	13
DACE	0	0	0	1	0	0	1	0	0	2
GSF	1	3	2	0	0	0	0	0	0	6
HH	1	0	0	0	1	0	0	0	0	2
PL	0	0	11	2	0	0	0	0	0	13
PRS	0	1	0	0	0	0	0	0	0	1
RFS	0	0	5	0	38	93	71	15	4	226
SASQ	1	1	1	0	3	4	3	0	0	13
SASU	12	1	1	0	2	0	1	3	1	21
TP	0	1	0	0	0	0	0	0	0	1
									Total	1,068