Juvenile Salmonid Out-migration Monitoring at Caswell Memorial State Park in the Lower Stanislaus River, California

2009 Annual Data Report

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SUMMARY

We operated two rotary screw traps (RST) between 13 January and 25 June 2009 in the lower Stanislaus River, California at Caswell Memorial State Park (Caswell; N 37°42'7.533", W 121°10'44.882"); river kilometer 13.8. Since 1996, Cramer Fish Sciences has conducted annual operations at this location to monitor emigrating juvenile fall-run Chinook salmon *Oncorhynchus tshawytscha* and steelhead/rainbow trout *O. mykiss* to the San Joaquin River as part of the U.S. Fish and Wildlife Service's Anadromous Fish Restoration Program (AFRP). Low flow and changes to channel conditions at the established site made it impossible to continue operation of two tandem rotary screw traps (RSTs), as in previous years; therefore, we relocated the RSTs ~ 50 m downstream. The traps were operated separately with the primary trap positioned in the thalweg, sampling >30% of channel flow, by volume, at low flows (<250 cfs). During increased spring flows, we operated the secondary RST at the same river position, but along the opposite bank to increase catch of juvenile Chinook salmon for fish length data and calibration tests at the primary trap. Furthermore, we performed beach seining adjacent to the RST site to increase available trap calibration fish and substantiate presence/absence of salmonids when trap captures were low or zero. For the entire 2009 sampling period, we captured 767 juvenile Chinook salmon and five *O. mykiss* by RST and another 30 juvenile Chinook salmon by beach seine (797 total Chinook salmon). As in previous years, we developed abundance estimates for Chinook salmon using trap efficiency and cumulative passage; however, only the primary trap was used in the trap efficiency tests and for determining passage estimates. We determined trap efficiency with a series of mark-recapture tests by tagging and releasing salmon upstream of the primary trap that were originally captured at both traps and seining surveys. A predictive logistic regression model was then developed using efficiency data from previous years, and results of the five efficiency tests conducted in 2009. The abundance estimate of juvenile Chinook salmon passing Caswell in 2009 was 11,216 (±2,371 SE) compared to 14,016 (±3,015 SE) in 2008, and 94,448 (±15,357 SE) in 2007. This was the lowest annual estimate for juvenile Chinook salmon emigrating past Caswell in the 14 years of RST operation. This estimate follows the West Coast Chinook salmon fishery collapse and subsequent commercial fishing closures which remained in effect throughout the harvest seasons in 2008 and 2009. Subsequent low Stanislaus River adult Chinook salmon escapement in 2008, coupled with low flow conditions in the lower river over the past two years are likely issues affecting the low juvenile escapement. Overall mortality was 3.5% in 2009, with 81.5% of all mortalities occurring between 20 and 29 March. We also observed a significantly higher proportion of juvenile salmon emigrating as parr in the 2009 season than in the previous two years and a significantly earlier peak in sub-yearling smolt emigrating occurring in 2009. These observations indicate distinct differences in annual quantity, quality and migration strategies for juvenile Chinook salmon in the Stanislaus River between years, related to biotic and abiotic factors within and outside Stanislaus River management. Monitoring at Caswell continues to provide critical data on Stanislaus River salmonid life history diversity and population abundance to help AFRP track success of their California Central Valley salmon recovery program.

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INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* and steelhead trout *O. mykiss* populations in California's Central Valley are at the southernmost extent of their range in North America, and among numerous native California fish species undergoing widespread decline (Moyle et al. 2008). Chinook salmon and steelhead trout have important economic as well as cultural and ecological value, and both historically supported robust fisheries (CDFG 2001; Merz and Moyle 2006). Precipitous declines in the past century are linked to a variety of anthropogenic impacts, including mining (e.g., gold, gravel, and copper), over-harvest, logging, hydropower development, flood protection, introduced species, hatchery fish interactions, pollution, and corresponding urban and agriculture development (Nehlsen et al. 1991; Yoshiyama et al. 2001; Williams 2006; NOAA 2009). Dams and other impediments have prevented passage to important staging areas and spawning grounds with greater impacts to spring-run Chinook salmon (and *O. mykiss*) populations that historically made extensive use of higher elevation habitats (Moyle 2002; May and Brown 2002). Hatchery supplementation has only compounded the problem by compressing run timing and stock complexity (Lichatowich 1999; Augerot et al. 2005; Bottom et al. 2005), and likely has significant management implications in the Central Valley (Barnett-Johnson et al. 2007). Moyle et al. (2008) identify inadequate flows, habitat reduction and elimination, and genetic degradation from hatchery supplementation as the primary stressors affecting salmonid populations in California.

In late 2007, an Emergency Action under Magnusson-Stevens Act authority declared a commercial fishery failure for the West Coast Chinook salmon fishery due to historically low returns (National Oceanic and Atmospheric Administration (NOAA) 2008). Changing ocean conditions (i.e., shifting ocean temperatures and food sources) may be a causal factor contributing to poor juvenile salmon survival (NOAA 2008). Additional, reports state cumulative impacts to freshwater habitats have "made salmon populations more susceptible to the occasional poor ocean conditions" (NOAA 2008). Return abundance continued to decline in the fall 2008. Pacific Fishery Management Council reported 66,264 salmon adults returned to the Sacramento River in 2008—well below the 90,000 in 2007 (PFMC 2009). Commercial ocean harvest and recreational fisheries for Central Valley Chinook salmon remained closed through 2009 (CDFG 2009; PMFC 2009). New regulations also prohibited the catch and release of salmon (CDFG 2009).

The National Marine Fisheries Service (NMFS) finalized a biological and conference opinion (Opinion) in June 2009 after review of the proposed long-term operations of the Central Valley Project (CVP) and the State Water Project (SWP). The Opinion (NMFS 2009) discusses the effects the CVP/SWP operations might have on listed anadromous fishes and marine mammals in accordance with Section 7 of the Endangered Species Act of 1973 (ESA). The Opinion includes two main objectives for the Stanislaus River: (1) Provide sufficient definition of operational criteria to ensure the viability of the steelhead population on the Stanislaus River, including freshwater migration routes to and from the Delta; and, (2) halt or reverse adverse modifications of steelhead critical habitat (Available: http://swr.nmfs.noaa.gov/ocap.htm).

The 1992 Central Valley Project Improvement Act (CVPIA) granted authority to the U.S. Fish and Wildlife Service (USFWS) to develop and implement a series of restoration programs, with the goal of doubling the natural production of anadromous fish in Central Valley streams. The U.S. Bureau of Reclamation (BOR) and USFWS are responsible for implementing provisions outlined in the CVPIA (Available: http://www.usbr.gov/mp/cvpia/title_34/index.html). To support this goal, USFWS established the Anadromous Fish Restoration Program (AFRP) and the Comprehensive Assessment and Monitoring Program (CAMP). These programs set anadromous fish production targets, recommended fishery restoration actions for Central Valley streams, and formed a juvenile Chinook salmon and *O. mykiss* monitoring program to assess the relative effectiveness of fishery restoration actions. The two programs support informed feedback on population dynamics of target species that allow adjustments or improvements to adaptive management plans and approaches.

The Stanislaus River, a major tributary to the San Joaquin River, still provides valuable spawning and rearing habitat for Central Valley fall-run Chinook salmon and *O. mykiss*, both considered species of concern under the federal Endangered Species Act (NOAA 2004). Additionally, multiple habitat improvement projects have been implemented while others are currently in development. Juvenile out-migration monitoring is an important component of fisheries habitat restoration and management in the Stanislaus River. Since 1996, the USFWS has supported CFS to monitor juvenile salmonid out-migration in the Stanislaus River. The current monitoring program determines annual juvenile Chinook salmon production and *O. mykiss* presence using RSTs at Caswell Memorial State Park (Caswell; N 37°42'7.533", W 121°10'44.882") (rkm 13.8), and quantifies emigrants to the San Joaquin River. This long-term data set provides a valuable source of information for evaluating fish responses to in-river management actions. The primary objectives of this project were to:

1. Estimate annual abundance of juvenile Chinook salmon out-migrants in the lower Stanislaus River using RSTs operated near Caswell; and,
2. Determine and evaluate patterns of timing, size, and abundance of juvenile Chinook salmon and *O. mykiss* relative to time of year, flow and other environmental conditions.

This juvenile salmonid monitoring program helps AFRP and CAMP address their goals to track population dynamics, evaluate the results of past and future habitat restoration efforts, and to understand the impacts of instream flow schedules and management on the fall-run Chinook salmon and *O. mykiss* populations. This annual report details results from 2009 RST operations at Caswell in the lower Stanislaus River and addresses these objectives.

STUDY AREA

The Stanislaus River, a major tributary to the San Joaquin River, flows southwest from the western slopes of the Sierra Nevada Mountains with a drainage area of approximately 240,000 ha and approximately 40% of its basin above snowline (Kondolf et al. 2001) (Figure 1). The confluence of the Stanislaus and San Joaquin rivers is located near the southern end of the

Sacramento-San Joaquin Delta. The basin has a Mediterranean climate with dry summers and about 90% of the annual precipitation occurs between November and April (Schneider et al. 2003). More than 40 dams exist on the Stanislaus River. Collectively, these dams have the capacity to store 240% of the average annual runoff in the basin. Approximately 85% of this total storage capacity is in New Melones Reservoir (Schneider et al. 2003). Dams control the Stanislaus River for flood protection, power generation, irrigation and municipal water. The river is also used for whitewater recreation and off-channel gravel mining. Goodwin Dam (GDW), located at river kilometer (rkm) 94 of the Stanislaus River, is the upstream migration barrier to adult Chinook salmon (see Figure 1; Appendix 1). Most spawning in the Stanislaus River is by fall-run Chinook salmon and occurs in the 29 km reach below GDW; however, spawning has been observed as far downstream as rkm 53.1. Additionally, rare observations of early-migrating (i.e., May to June) adult Chinook salmon in the Stanislaus River do exist (Anderson et al. 2007); however, their origin is unclear. Little work has been gathered on *O. mykiss* migration timing, abundance or spawning parameters within the Stanislaus River to date (CFS 2009). See Appendix 2 for complete species list.

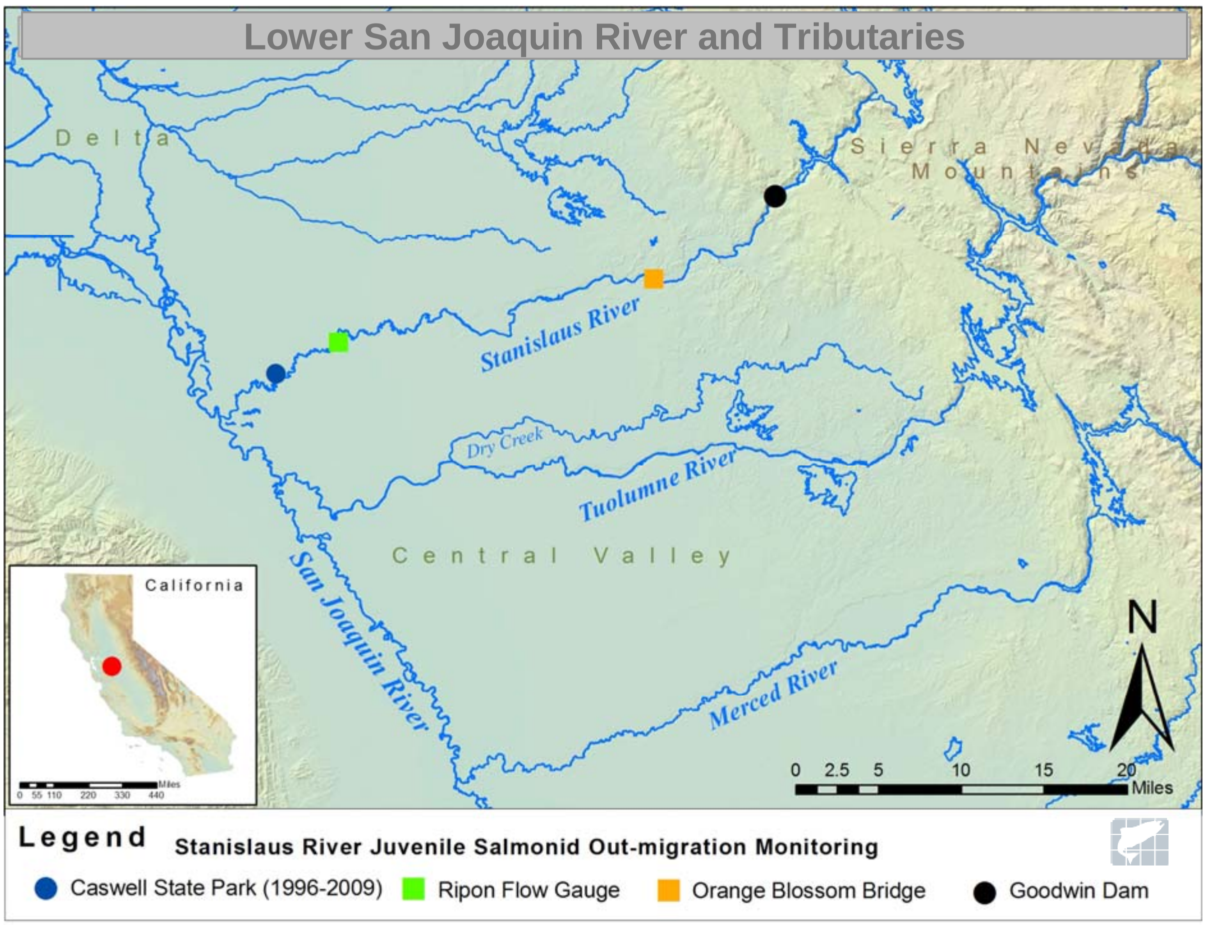

Figure 1. Map of the Stanislaus River below Goodwin Dam in relationship to other San Joaquin River tributaries and relative landmarks.

METHODS

Trap Operations

In 2009, we continued operations in the Stanislaus River at Caswell where out-migration monitoring has been ongoing since 1996. This site was selected as the furthest downstream location with suitable channel characteristics and access to install and monitor traps. Due to low flow and changes to channel conditions at the site, we relocated the trapping operation ~ 50 m downstream (Figures 2 and 3) at Caswell. This location could only accommodate a single trap (2.5 m diameter RST, manufactured by EG Solutions, Inc., Corvallis, OR). However, positioned in the thalweg, the single trap (Trap 1) sampled >30% flow at < 250 ft^3/s. Trap 1 was operated to track juvenile salmonid out-migration and develop passage abundance estimates for Chinook salmon (Figure 3). The second RST (Trap 2) was operated during the spring increased flow period to collect additional information on the out-migrant population (i.e., size) and secure salmon for calibration of Trap 1. Traps were secured with 6.35 mm galvanized steel cable leaders fastened to large trees, and state park permits allowed CFS access to the trap by land or boat as necessary. We monitored trap operation following guidelines standard protocols (CAMP 1997; Gray et al. 2008). Trap rotations were enumerated by a mechanical counter (Redington Counters, Inc.; Model 29) secured to the pontoon adjacent to the leading edge of the cone. Similar to our primary objectives, several authors have used this methodology to monitor population dynamics and abundance for salmonid out-migrations (e.g., Thedinga et al. 1994; Fleming 1997; Roper and Scarnecchia 1998; Sparkman 2001; Workman 2002–2006; Seesholtz et al. 2004; Bottom et al. 2005; Rayton 2006; Johnson and Rayton 2007; Workman et al. 2007). Trap cones were raised and non-operational on days when sampling did not occur. We terminated sampling when at least seven consecutive days of trapping with zero catch occurred in June or July, typically the end of CV fall-run Chinook salmon emigration (Gray et al. 2009).

Figure 2. Example of low flow conditions on January 16, 2008 (left: 292 cfs) and March 6, 2008 (right: 256 cfs) at Caswell that impeded trap operation.

Figure 3. Low flow conditions on January 12, 2009 (left: 226 cfs) and February 9, 2009 (right: 226 cfs) at Caswell with Trap 1 in operation.

Safety Measures

All trap personnel were trained in RST operational safety, and safety precaution signage was posted to warn river users and park visitors of the inherent dangers of the RSTs. We placed signs in conspicuous places at the trap site and on each side of the trap, to warn people of drowning danger as well as "Keep Out" and "Private Property" signs. A warning sign strategically placed upstream of the trap stated "Danger Ahead – Stay Left" with a large arrow pointing in the direction of the best side of the river channel for boaters to pass the traps. Flashing lights and flagging were placed on the traps and along the rigging. All signs were in English and Spanish.

Seining

We sampled two locations on the Stanislaus River (upper and lower) adjacent to the RST operation site during periods of low or no RST capture of fish and when calibration fish were needed (Figure 1). A 15.25 m x 1.8 m - 0.64 cm mesh (50 ft x 6 ft -1/4 inch) beach seine with 38 mm (1.5 inch) diameter wooden support poles was used to make one to three hauls (typically three) during daylight within each sample site (Figure 4).

Figure 4. Beach seining was used to supplement catch of fish used for efficiency tests and to evaluate juvenile Chinook salmon presence/absence during periods of low RST catch.

Depth of seining was less than 1.2 m (4 ft), velocities less than 0.92 m/s (3 ft/s) and we attempted to seine areas with substrates free of large obstructions that would hinder seine movement. Two people walked the seine out into the river, deployed and the distance out was noted. One person began moving downstream to deploy the seine as the upstream member remained stationary. The seine was then pulled into shore and two markers were placed where the two ends of the seine first reached the bank. The measurement of site length multiplied by the distance out from shore provides an estimate of area seined. The two people holding the poles continued to pull the ends of the seine in while keeping the lead line down as the net was pulled on shore. When the net was completely retrieved, captured fish were removed from the net and placed in a large container of river water. Captured fish were enumerated, weighed and held for use in calibration tests of the primary RST.

Fish Handling Procedures

We generally checked traps once a day, and twice a day (or more) as conditions required (i.e., debris loads due to freshets or during scheduled flow release increases from New Melones Dam). Fish handling procedures and RST operational protocol used during trap and seine sampling followed the methods of Gray et al. (2009). We used tricaine methanesulfonate (Tricaine-S; Western Chemical, Inc.) to anesthetize fish for safe handling. To limit handling injury and stress, all captured fish were anesthetized in groups of 5 – 10 individuals immediately prior to handling using a solution of river water and Tricaine-S at a 26.4 mg/L concentration. The solution was cooled with frozen river water bottles to reduce thermal stress of captured fish. Litmus strips were used to check pH and baking soda was added to buffer the acidity of the solution. The effectiveness of Tricaine-S varies with changes in temperature and fish density; therefore, all solutions were tested with a few fish to determine potency and adjusted if necessary. StressCoat (Aquarium Pharmaceuticals, Inc.), which helps fish replace their slime coat and scales, was added to the Tricaine-S solution and recovery buckets at a rate of 2.5 ml per 9.5 L. Processed fish were returned to a bucket with fresh river water to recover prior to release. Water temperature and dissolved oxygen (DO) levels were monitored and maintained above critical levels (Gray et al. 2008). For Chinook salmon and *O. mykiss,* we recorded fork length (mm FL), weight (g), and life stage for 25 randomly-selected fish each day; any additional fish were counted. Life stage was determined by assigning a smolt index value based on morphological characteristics (Table 1). The silvery parr designation was only used for *O. mykiss*; it was not applied to juvenile Chinook salmon (CAMP 1997). All captured fish were released approximately 150 m downstream of the traps below a large, deep pool in an attempt to decrease risk of predation and prevent recapture. Night check procedures were identical to daytime checks, with the exception of only measuring the first 20 fish of each species and counting the remainder to minimize fish handling effects (CAMP 1997; Gray et al. 2009).

Table 1. Smolt index rating adapted from (CAMP 1997).

Smolt Index	Life Stage	Criteria
1	Yolk-sac Fry	-Newly emerged with visible yolk sac
2	Fry	-Recently emerged with sac absorbed; Pigment undeveloped
3	Parr	-Darkly pigmented with distinct parr marks; No silvery coloration; Scales firmly set
4*	Silvery Parr	-Parr marks visible but faded, or completely absent; Intermediate degree of silvering
5	Sub-yearling smolt	-Parr marks highly faded or absent; Bright silver or nearly white coloration; Scales easily shed; Black trailing edge of caudal fin; More slender body
	Yearling smolt	-All the same characteristics as a smolt; Generally larger than 110 mm FL

**Silvery parr life stage was only used for O. mykiss.*

Catch

We compared daily catch with flow, and summarized our weekly catch by life stage (smolt index). We developed a length histogram from our data to evaluate size classes, and compared the histogram with catch date to assess emigration timing and life history patterns.

Analysis of Trap Function and RST Catch

We improved the reliability of trap rotation data in 2008 and 2009 by standardizing data collection procedures to increase sampling consistency. To improve our assessment of trap function under low flow conditions, we assumed trap location had a significant effect on trap revolutions·min^{-1} and compared trap function in 2008 to that measured in 2009. We also assumed that there was a positive relationship between RST catch and seine catch that could be used as an indicator of juvenile Chinook salmon presence/absence when RST catch was low.

Comparison of Trap Function

To address our hypothesis about trap function under low flow conditions we first determined the Q_{50} for the period of operation in 2008 and 2009 when different trap locations were utilized; the Q_{50} value 506 ft^3/s (14.3 m^3/s) was used to parse the data into low flow and high flow conditions. The low flow trap revolution data was converted to revolutions·min^{-1} to standardize for time. We used analysis of variance (ANOVA) and a paired *t*-test to test the following null hypothesis:

> *$H1_0$: There is no difference in mean revolutions·min^{-1} under low flow conditions between trap locations utilized in 2008 and 2009.*

Assessment of RST Catch

To address our hypothesis about RST catch and seine catch we regressed RST catch with seine catch to test the following hypothesis:

> *$H2_0$: There is no linear relationship between RST catch and seine catch in 2009.*

Analysis of Life Stage Distributions and Fork Length

We assumed that water year, including temperature and flow, would have a significant effect on the development and growth of juvenile Chinook salmon produced in the Stanislaus River. To begin to address these hypotheses, we compared size (FL) and life stage distribution of captured juvenile Chinook salmon over the past three (3) years (2007-2009).

Assessment of Life Stage Distributions

To address our hypothesis about the proportion of parr:sub-yearling smolt captured among years, we compared this ratio for all parr and smolts identified in each year from 2007–2009. We performed a Chi-squared analysis to test the following null hypothesis:

> *$H3_0$: There is no difference in parr:sub-yearling smolt ratio among years (2007–2009).*

Comparison of Fork Length

To address our hypothesis about fish size among years we combined fork lengths for parr and sub-yearling smolts and compared mean FL among years (2007–2009). We used ANOVA and a paired t-test to test the following null hypothesis:

> *$H4_0$: There is no difference in combined parr and sub-yearling smolt mean FL among years (2007–2009).*

Environmental Variables

We measured physical variables daily. We used HOBO® Pendant temperature logger (Onset Computer Corporation; Part #-UA-001-08) to measure hourly water temperature both in river and inside trap live-boxes. Loggers were downloaded once a week. All temperatures reported are from the in-river logger. We recorded instantaneous water temperature and dissolved oxygen using an YSI Handheld Dissolved Oxygen Instrument (YSI; Model 550A). We measured instantaneous water velocity using a Global Flow Probe (Global Water Instrumentation, Inc.; Model FP101) in front of the trap cone to monitor local flow conditions affecting trap rotations. Instantaneous turbidity was measured in Nephelometric Turbidity Units (NTU) using a turbidity meter (LaMott Company; Model 2020). We obtained average daily flow data from three U.S. Geological Survey (USGS) gauging stations from the California Data Exchange Center (CDEC), including Goodwin Dam (GDW; rkm 94), Orange Blossom Bridge (OBB; rkm 75.5), and Ripon (RIP; rkm 25.4). We determined trap effort by measuring the rate of cone revolution during each trap check and recording revolutions between checks from counters. Our results were summarized in tables and included in our passage abundance analysis.

Trap Efficiency

We determined trap efficiency to estimate the number of natural migrants passing Trap 1 (passage). Beach seining and Trap 2 were used to augment catch for efficiency tests when flow permitted (i.e., for low and higher flows, respectively) (Figure 4). In all, 187 wild-caught, dye-marked Chinook salmon were released over five tests in groups of 17–55 fish (Table 2). Different marks were used for each release group due to the close time proximity of releases and subsequent overlapping recaptures. Fish were dye-marked using a photonic marking gun (Meda-E-Jet; A1000) with pink dye on the caudal or anal fin (Figure 5). Releases occurred approximately 430 m upstream of the traps from the north bank at a narrow (~ 20 m) and deep area of the river. Fish releases occurred approximately one hour after dark in groups of five to ten to: encourage mixing with unmarked, natural Chinook salmon in the river; prevent schooling; and mimic natural periods of nighttime migration. When water depth and flow prevented wading into the channel, marked fish were released using a long-handled (3 m) dip net to release fish across the channel at various points away from the bank. Traps were processed one hour after completing release activities. Additional recaptures were recorded with the subsequent days' catch.

Figure 5. Biologist marking fish with pink photonic dye .

Table 2. Summary of efficiency releases at Caswell, 2009.

Date	Flow (ft^3/s)*	Release Code	Mark Code**	Avg. FL	SD	No. Released	No. Recap	% Efficiency
3/7/2009	263	C1	BCP	50.6	14.9	17	4	23.5%
3/9/2009	251	C2	ULCP	67.8	22.2	41	5	12.2%
3/10/2009	250	C3	AFP	71.7	10.7	55	4	7.3%
3/11/2009	242	C4	LCAP	62.8	9.1	33	4	12.1%
3/24/2009	343	C5	TCP	83.9	8.1	41	6	14.6%
			Total	68.7	16.6	187	23	12.3%

**Ripon flow on release date at 18:00. **BCP=bottom caudal pink; ULCP= upper and lower caudal pink; AFP= anal fin pink; LCAP= lower caudal and anal fin pink; TCP= top caudal pink*

Passage Estimates

Following methods from previous years (Watry et al. 2007, 2008), we conducted mark-recapture trials of juvenile Chinook salmon to estimate catch rate (i.e., trap efficiency). A total of 149 experimental mark-recapture release groups across years (1996–2009) were used to estimate trap efficiencies at Caswell (Appendix 3). We used logistic regression to develop a predictive model to determine daily trap efficiencies and estimate total juvenile salmonid passage as a function of multiple environmental covariates. Environmental factors that were originally considered in our analyses included the natural log of flow (denoted log(flow)), temperature, and turbidity. Fork length at release was also considered, as was the categorical variable 'year', to control for between year differences in trap efficiency (e.g., due to differences in trap placement, channel morphology, bank vegetation etc.). We used a backward stepwise regression procedure to determine the 'best fitting' model, which was then used to make predictions for daily trap efficiencies.

Logistic regression is used for predicting the probability of occurrence of an event by fitting data to a logistic curve (Zar 1999). It is essentially a generalized linear model that is applicable to binomial data (McCullach and Nelder 1989; Dobson 2002); in this case, binomial data would refer to the potential outcomes of fish collection (i.e., either the fish is caught or not). Like many forms of regression analysis, it makes use of several predictor variables that may be either numerical or categorical. Here, the binomial probability of interest is the observed trap efficiency (*q*):

(1) $$q = \frac{m}{R},$$

where *m* is number of observed recaptures (a binomial variable) of a given release group of size *R*. The logistic model with *n* explanatory variables (*x*) can be expressed in linear form as:

(2) $$y = \beta_0 + \beta_1 x_1 + ... + \beta_n x_n\ ,$$

where *y* is the "logit" transform of the observed trap efficiency (*q*):

(3) $$y = \text{logit}(q) = \log\left(\frac{q}{1-q}\right).$$

The coefficients (β), which are estimated via maximum likelihood, provide predicted values of trap efficiency via the following back-transformation of the logit function:

(4) $$\hat{q} = \frac{\exp(y)}{1+\exp(y)}.$$

We examined the following explanatory variables (x) for trap efficiency: flow, temperature, turbidity, and length (average fish length at release). We considered the natural logarithm of flow, denoted log(flow), as previous work has shown non-linear effects of flow on similar, such as migration speed and survival (Newman and Rice 2002; Newman 2003; Kjelson and Brandes 1989; Williams and Matthews 1995). We also examined the categorical variable year to account for year-to-year differences in mean trap efficiency that might arise due to annual changes (e.g., channel morphology, bank vegetation, predator abundance, trap placement, etc).

We used a forward stepwise regression procedure to determine the "best fitting" logistic regression model. In the first step, a model was fit with an intercept (β_0), and then each explanatory variable was entered one at a time. The variable with the greatest explanatory power was then included in the model, and the remaining variables were again entered one at a time. The procedure was terminated when none of the remaining variables had a statistically significant effect on survival at the $\alpha = 0.05$ significance level. An alternative approach to model selection was also examined, in which the "best fitting" model was determined using the Akaike Information Criterion (AIC), adjusted for over-dispersion (Burnham and Anderson 2002). However, the stepwise regression and AIC procedures provided the same "best" model in all analyses. The statistical significance of explanatory variables in the "best fitting" model was tested using analysis of deviance (McCullach and Nelder 1989; Venables and Ripley 1999). Under the binomial assumption, a logistic model that adequately explains variability in trap efficiencies will have a deviance roughly equal to the residual degrees of freedom. However, in our analyses, model deviances were much greater than that expected due to binomial sampling error alone. Such extra-binomial variation, which may arise from either over-dispersion or inadequate model structure (i.e., when key processes affecting trap efficiencies are missing from the model), must be accounted for when testing variables and estimating confidence intervals. Extra-binomial variation is represented by a dispersion parameter, Φ, which is a scalar of the assumed binomial variance. To conduct statistical tests and compute confidence intervals, we multiplied the variance-covariance matrix for the logistic coefficients by the dispersion parameter, which is easily estimated from the fit of a logistic regression (Venables and Ripley 1999).

The daily passage abundance (*n*) of migrating juvenile Chinook salmon was estimated as follows:

(5) $$\hat{n} = \frac{c}{\hat{q}},$$

where *c* was observed daily count and *q* was the estimated trap efficiency for that day based on the "best" logistic model. Annual passage was estimated by summing the daily abundance estimates. Standard errors (SE) and confidence intervals for measures of total annual passage were computed using the methods described in Watry et al. (2008). During some years, there were periods when traps were not fished. To estimate a missing value of daily count (c) within a sampling period, we used the weighted average of all observed counts for the five days before and five days after the missing value. The weights were equal to one through five, where values that were directly adjacent to the missing day were weighted as five, values that were two days before and after the missing day were weighted as four, and so on.

RESULTS

Trap Operations

We began our sampling effort immediately following trap installation on 13 January 2009, and operations were terminated at the end of the migration period on 25 June 2009, due to low catch and increased temperatures. We sampled seven days a week for the majority of the season, which resulted in 161 trapping days. For 46 of the 161 sampling days, two traps were operating in the river. The following results include all Chinook salmon collected; however, passage estimates are derived only using the primary trap.

Comparison of Trap Function

We proved Hypothesis 1 false despite lower flow conditions in 2009, whereby mean revolutions·min^{-1} were significantly greater for periods when RIP flow was less than Q_{50} (506 ft^3/s) in 2009 compared to 2008 (F = 102.0, df = 180, p < 0.0001) resulting in better individual trap performance (Table 3; Figure 6). Mean revolutions·min^{-1} were 2.22 (±0.07 SE) in 2009, almost twice the values recorded for 2008 under similar flow conditions.

Table 3. Summary statistics of rotary screw trap function under low flow conditions (i.e., days with RIP flow < Q_{50}) for periods of operation in 2008 and 2009 at Caswell (RIP Q_{50} = 506 ft^3/s); mean flow (i.e., days with mean daily flow < Q_{50}) with 95% confidence interval.

	2008 - N trap	2008 - S trap	2009 - 1 trap
		(revolutions · min^{-1})	
Minimum	0.01	0.44	0.52
Maximum	1.55	1.87	3.49
Mean	0.74	1.13	2.22
SE	0.09	0.09	0.07
No. stoppages	8	8	3
Days w/ flow < Q_{50}	68		94
Mean flow (ft^3/s) < Q_{50}	350 ± 19		296 ± 16

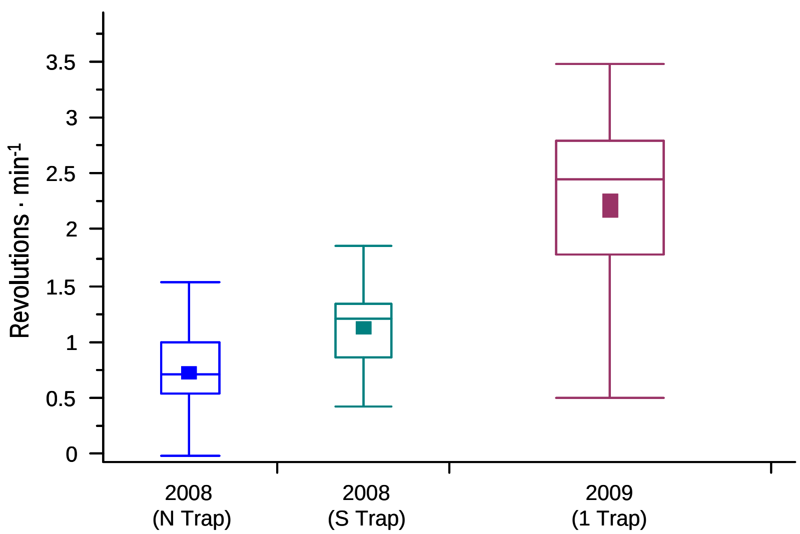

Figure 6. Comparison of daily trap rotations for individual traps in 2008 (blue and cyan) and the single trap operated in 2009 (purple) at Caswell under low flow conditions (i.e., days with mean RIP flow < Q_{50}). Solid, inner box represents the mean with 95% confidence; outer lines (whiskers) indicate 1% and 99% quantiles, while inner boxes represent 25%, median and 75% quantiles. Box width indicates relative number of days represented.

Catch

We captured a total of 767 natural, unmarked juvenile Chinook salmon and five *O. mykiss* during the 2009 trapping season (Appendix 4). Another 31 Chinook salmon were captured by seine. The first Chinook salmon catch occurred on 14 January 2009. Peak daily catches (n = 78, 44 and 16) occurred on 13 March, 25 March, and 13 May 2009, respectively. Catch did not coincide as strongly with changes in controlled flow releases for the Vernalis Adaptive Management Plan (VAMP; 17 April to 13 May 2009) as in previous years (Figure 7). The overall mortality rate was 3.5% (n = 27) of the total juvenile Chinook salmon catch, 81.5% of all mortalities occurred in a short time window in the early spring between 20 and 29 March (Figure 8).

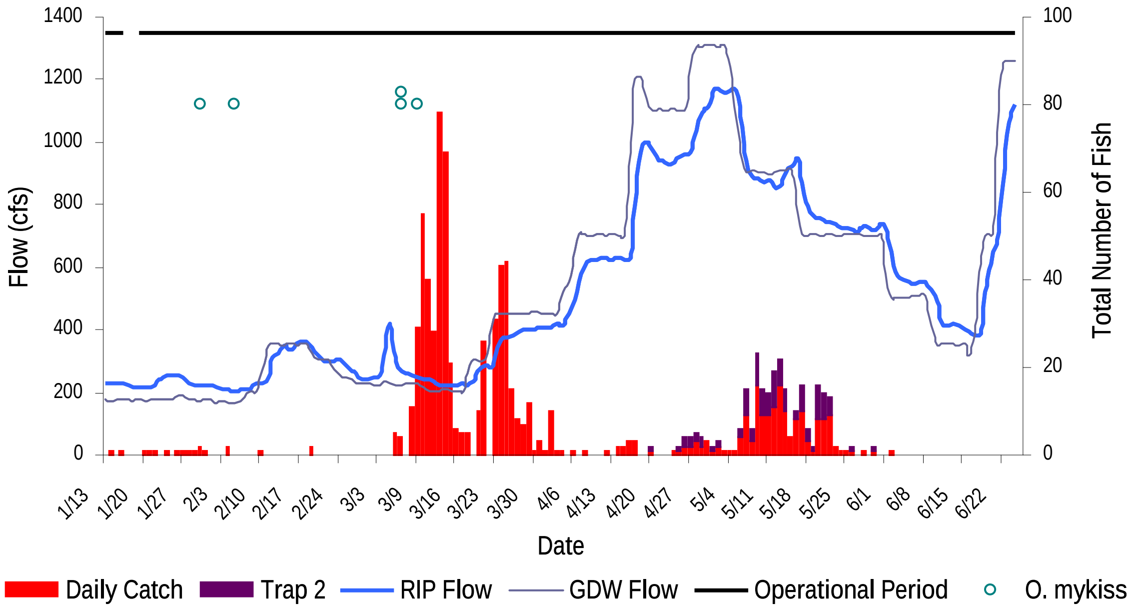

Figure 7. Daily Chinook salmon and *O. mykiss* catch and flow at Ripon (RIP), 2009.

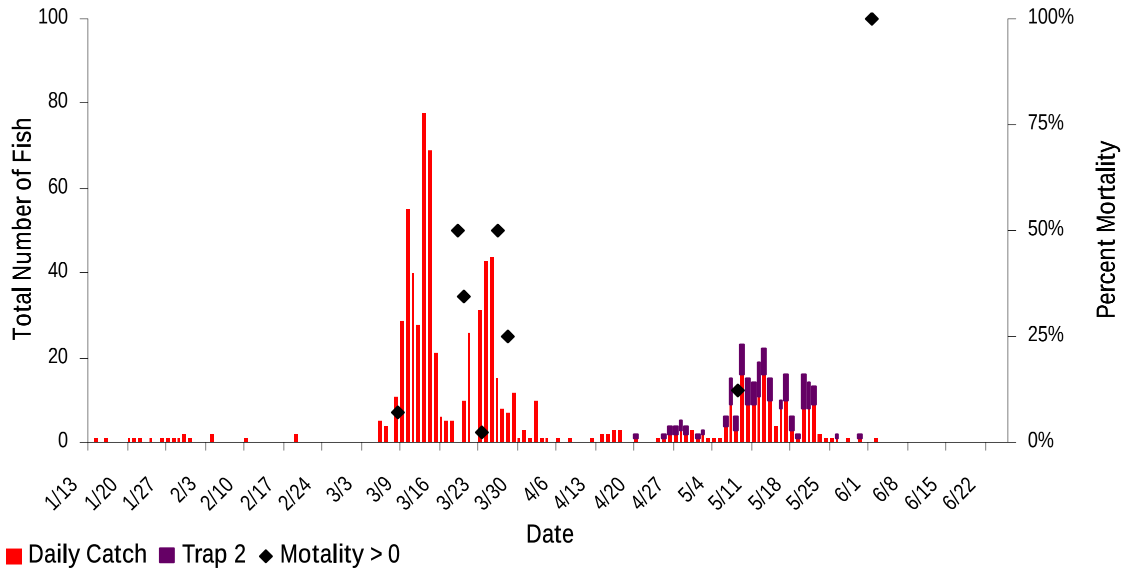

Figure 8. Daily Chinook salmon catch and percent mortality at Caswell, 2009.

Non-Target Species

We captured 1,292 incidental (non-target) fish of 20 identifiable species, including the following families: lamprey (Petromyzontidae), sunfishes and bass (Centrarchidae), western mosquitofish (Poeciliidae), Sacramento pikeminnow and other minnows (Cyprinidae), catfishes (Ictaluridae), and sculpin (Cottidae) (Figure 9). Due to difficulty in determining species of some juvenile fish in the field, we counted 260 unidentified lamprey (*Lampetra* spp.) and 23 centrarchids. A species list is also provided in Appendix 2.

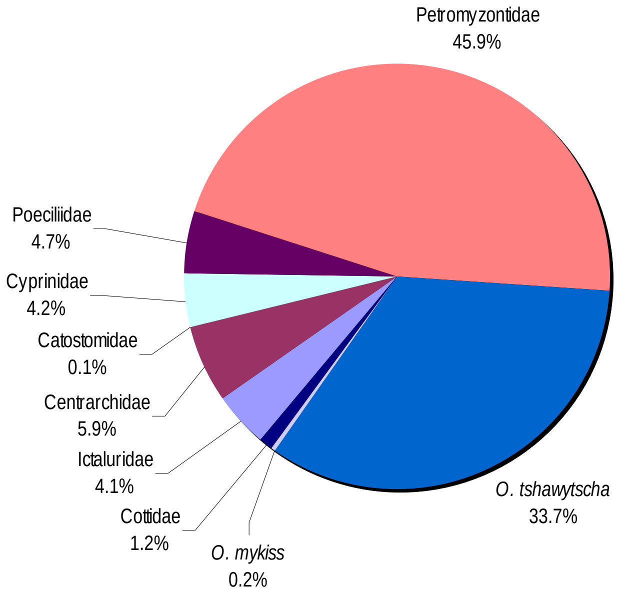

Figure 9. Relative abundance of all taxa captured at Caswell, 2009.

Seining

In all, 31 juvenile Chinook salmon were captured seining in three different sample areas (Figure 10). Sampling occurred on 11 different dates from 26 January through 27 May 2009.

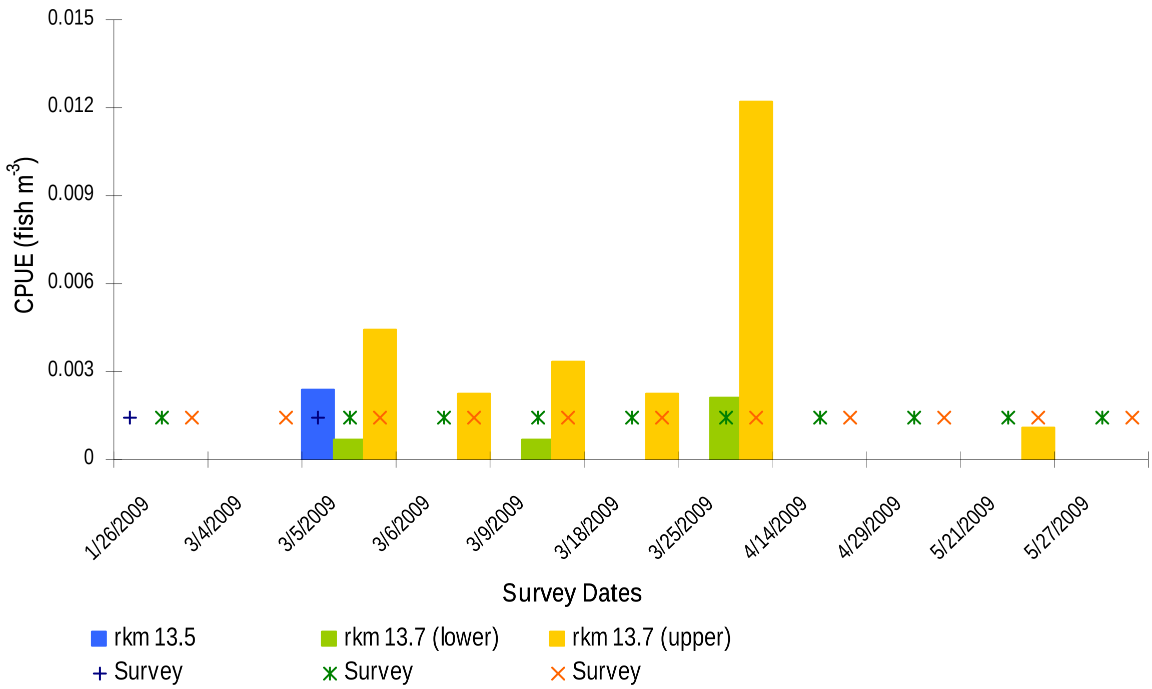

Figure 10. Seine catch per unit effort (CPUE) and survey dates for three sample areas located 100-300 m below the Caswell RST on the Stanislaus River, 2009.

Assessment of RST Catch

We proved Hypothesis 2 false as there appears to be a slightly positive linear relationship (R^2 = 0.6054) between RST catch and seine catch (Figure 11).

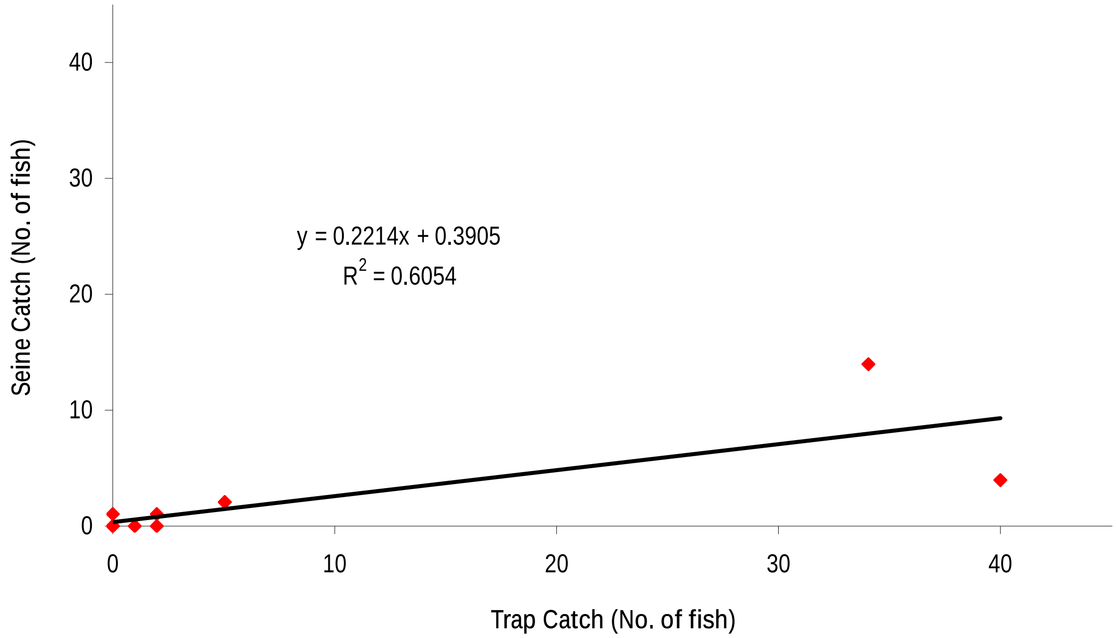

Figure 11. Regression of RST catch by seine catch 100-300 m below the Caswell RST on the Stanislaus River, 2009.

Life History Structure

We captured all four juvenile Chinook salmon life stages during the sampling season (i.e., fry, parr, sub-yearling smolt, and yearling smolt) (Table 4). Similar to other sampling years, Chinook salmon emigration occurred with a bimodal length distribution, whereby fish size progressively increased over time represented by two groups of fish in March and May (Figure 12). The majority of the out-migration catch was composed of sub-yearling smolts (58.1%), but the parr life history, nearly absent in 2007 and 2008 (Watry et al. 2007, 2008), composed 35.7% of the total catch. Each life stage has different size distributions and timing patterns (Table 4; Figure 13 and 14).

Table 4. Percent of run by life stage (according to smolt index) of Chinook salmon from Caswell, 2009. Note, totals do not include "plus counted" fish where life stage by smolt index was not recorded.

Life Stage	Number*	Percent of Run	Date Range	Median Passage	Average FL (mm)
Fry	38	5.4%	1/14 - 3/11	3/6	38.9 ± 0.5
Parr	251	35.7%	3/8 - 4/1	3/12	68.9 ± 1.2
Sub-yearling smolt	409	58.1%	3/8 - 6/2	3/28	89.5 ± 1.0
Yearling smolt	6	0.8%	3/8 - 3/25	3/9	120.2 ± 12.9
Cumulative Total	703		1/14 - 6/2/2009		

* 64 fish were plus counted and not assigned a smolt index value

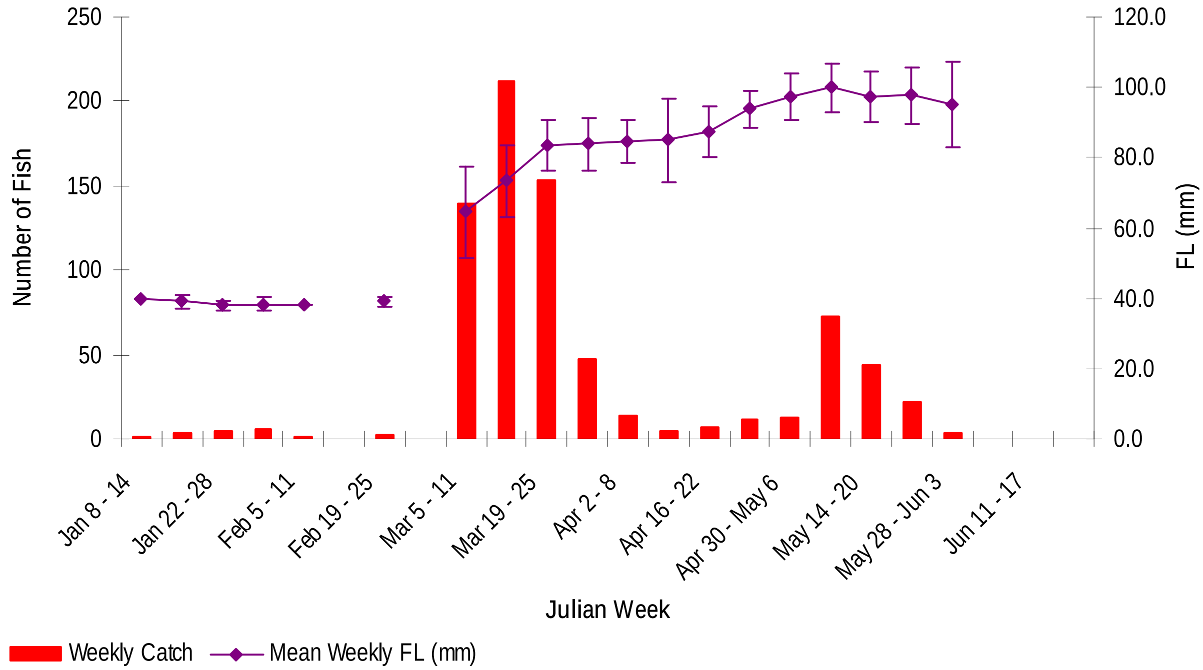

Figure 12. Weekly catch and mean weekly fork length (mm) for juvenile Chinook salmon caught at Caswell, 2009.

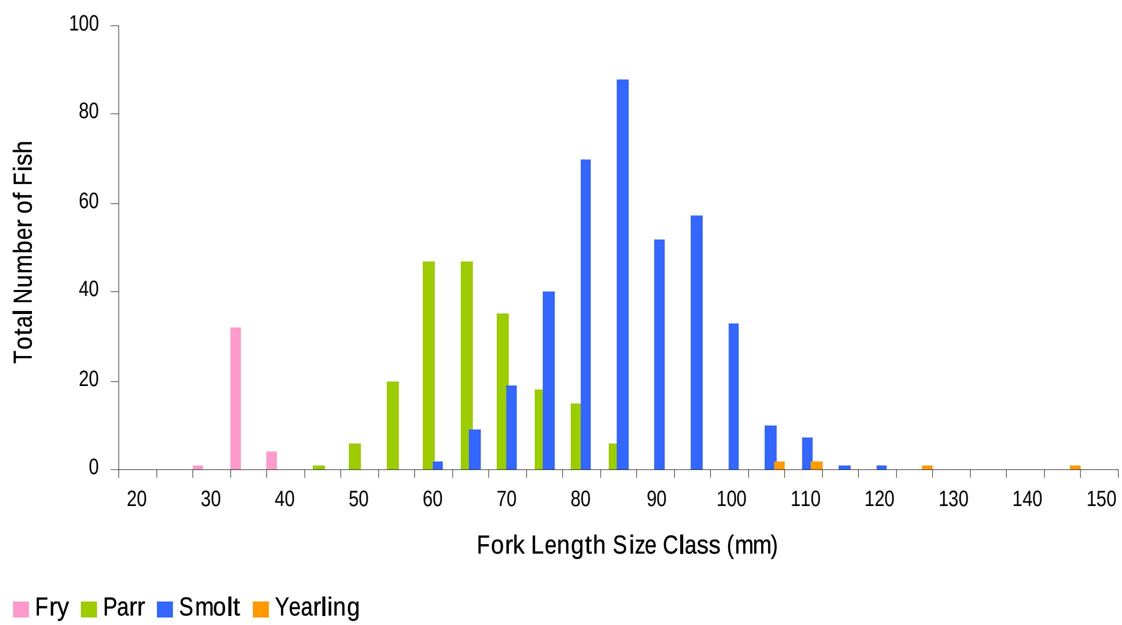

Figure 13. Fork length (mm) distributions for juvenile Chinook salmon caught at Caswell, 2009.

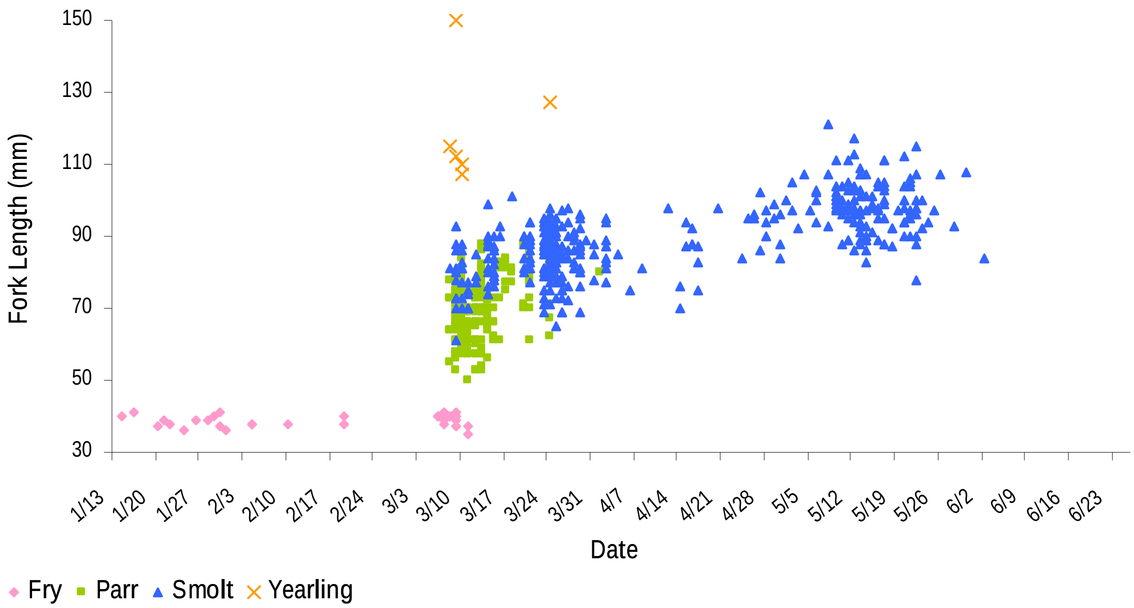

Figure 14. Fork length (mm) distributions for juvenile Chinook salmon caught at Caswell, 2009.

Comparison of Sub-yearling Smolt Fork Length

We proved Hypothesis 3 false as we detected differences in the combined mean FL of parr and sub-yearling smolts among years (2007–2009). Although the mean FL was not significantly different between 2007 and 2009 ($F = 2.1$; $df = 1327$; $p = 0.14$), mean FL was significantly larger in 2008 ($F = 128.7$; $df = 1500$; $p < 0.0001$) (Figure 15).

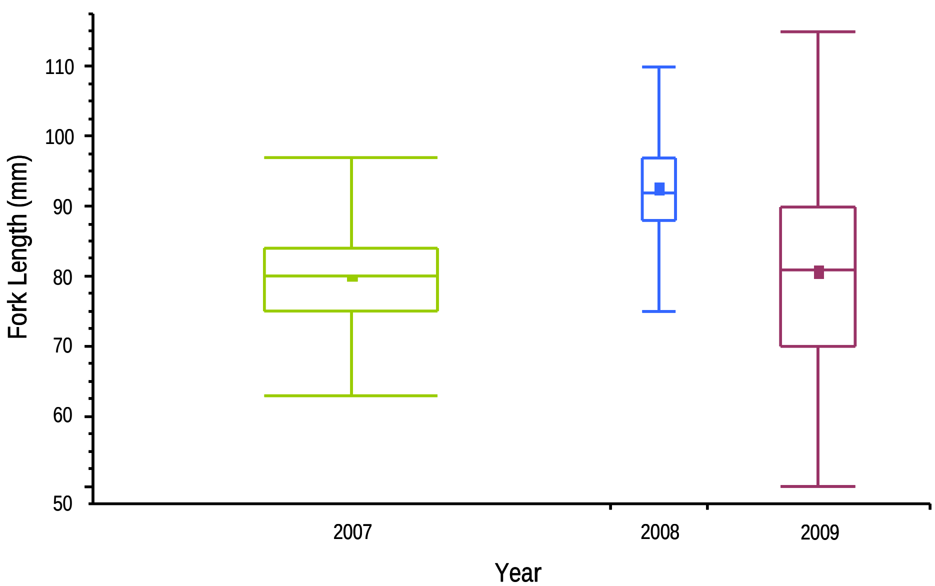

Figure 15. Comparison of mean smolt FL among years at Caswell for 2007–2009. Solid, inner box represents the mean with 95% confidence; outer lines (whiskers) indicate 1% and 99% quantiles, while inner boxes represent 25%, median and 75% quantiles. Box width indicates relative sample size.

Assessment of Life Stage Distributions

We proved Hypothesis 4 false as we detected differences in the proportion of parr and sub-yearling smolt among years from 2007 to 2009 (Table 5). In 2009, the proportion of parr was significantly higher ($X^2 = 333.7$; df = 2515, 2; $p < 0.0001$) compared to 2007 and 2008 which were relatively similar.

Table 5. Contingency table for Chi-squared analysis of parr:sub-yearling smolt ratio among years 2007–2009.

Year	Stage	No.	Freq
2007	Parr	123	0.073
2007	Smolt	1546	0.927
2008	Parr	2	0.011
2008	Smolt	172	0.989
2009	Parr	251	0.374
2009	Smolt	421	0.626

Environmental Variables

Flow at RIP during the season ranged from 206 to 1,173 ft^3/s (5.8 to 33.2 m^3/s), and was controlled by releases from New Melones Dam (Appendix 5). Daily temperature ranged from 7.8°C – 21.6°C during the sample period. Turbidity (NTU) was greatest in the early part of the out-migration season, but decreased as rain events ceased with the onset of spring and summer. Instantaneous DO never measured below 7.44 mg/L. Chinook salmon catch did not noticeably increase during controlled flow releases for the Vernalis Adaptive Management Plan (VAMP) effective from 17 April to 13 May 2009, similar to previous years (Watry et al. 2007, 2008).

Trap Efficiency

We observed a strong negative trend between trap efficiencies and flow at the Caswell site across all years of trapping (1996 to 2009) (Figure 16; Table 6). A negative trend was also apparent between trap efficiencies and average fish length (at release). However, there was no obvious trend between trap efficiencies and turbidity (see Figure 16).

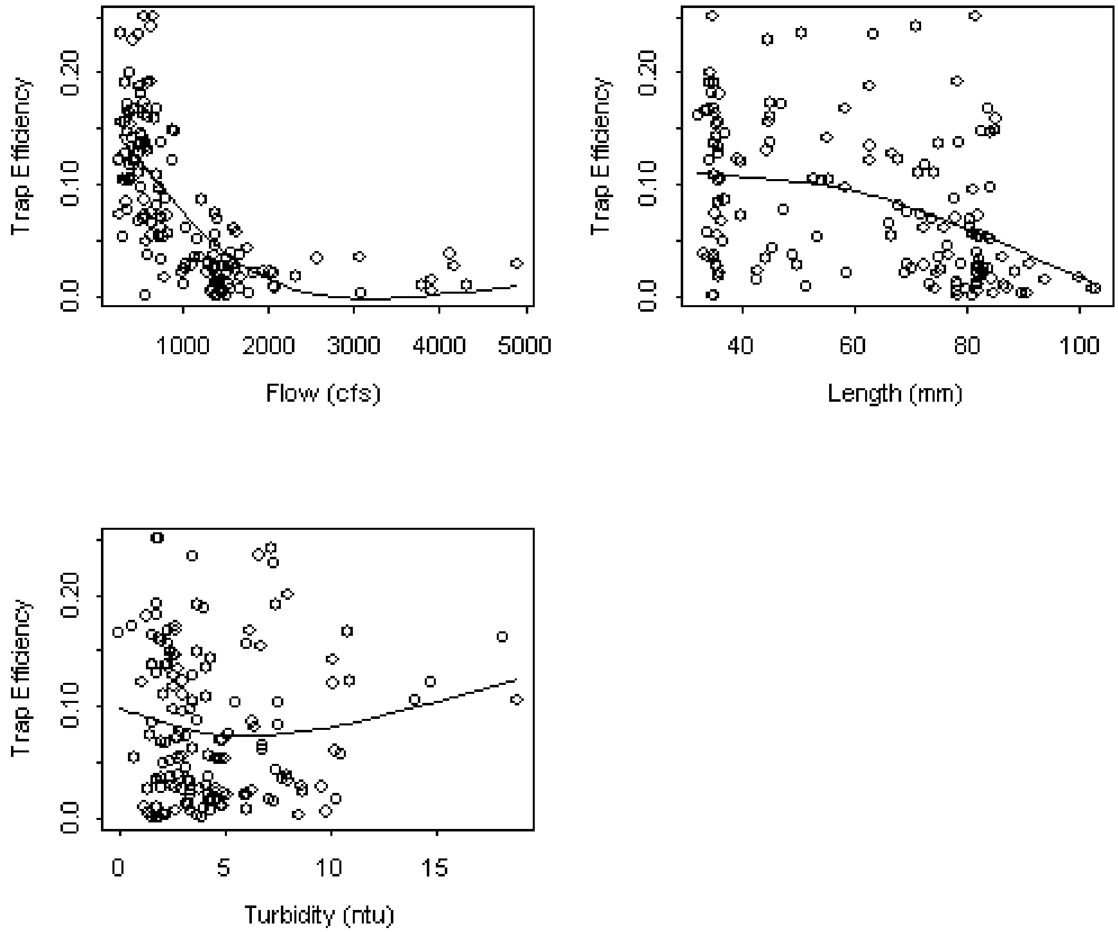

Figure 16. Trap efficiencies as a function of flow, fish length, and turbidity for the 149 mark-recapture releases at Caswell (1996–2009). Note, solid lines are exploratory fits of smoothing splines.

Table 6. Analysis of deviance for the logistic model fit to trap efficiencies of 149 mark-recapture releases at the Caswell trap site. Note, Df = degrees of freedom.

Variable	Df	Deviance	Residual Df	Residual Deviance	F Value	Pr (F)
Intercept			142	4579.6		
log(flow)	1	1950.1	140	1270.3	256.6	< 0.001
Length	1	1359.2	141	3220.4	178.9	< 0.001
Year	12	338.1	128	932.2	3.71	< 0.001
Total	14	3647.4	409	5422.9		

Passage Estimates

The logistic regression analysis indicated that trap efficiencies were significantly related to the variables log(flow), length, and year (Table 7). The dominant explanatory variable was log(flow), accounting for 53% of the total deviance. Fish length at release, which accounted for 37% of the deviance, had a moderate negative effect on trap efficiencies. The categorical variable 'year' accounted for 9.2% of the deviance, and indicated that trap efficiencies from 2006 to 2009 were lower on average than during the previous five years 2001–2005.

Estimates of the total abundance of juvenile Chinook salmon passing the Caswell trap site from 1996 to 2009 are presented in Table 7. Total annual passage estimates for all sample years ranged from 11,216 to 2,141,260 (mean = 467,734) with the highest abundance occurring in 2000, and the lowest in 2009. The estimated precision (an indicator of reliability) and confidence interval for the total passage estimate for 2009 suggests that the estimate is reasonably precise (95% CI: 7,384 to 17,038; CV = 21.1%), although the coefficient of variation for 2009 was the second highest among all available years (Table 7; this is likely the results of a small sample size). The majority of fish migrated past the Caswell trap site between 9 March and 20 May 2009 (Figure 17).

*Table 7. Estimated total number of juvenile Chinook salmon passing the Caswell trap site, 1996-2009. SE = standard error of the estimate. CV = coefficient of variation of the estimate, where % CV = (SE / Total Passage) * 100. 95% confidence intervals are reported for both normal and lognormal error distributions.*

Year	Passage Estimate	SE	CV	Lower 95% CI	Upper 95% CI
1996*	70,824	7,848	11.1%	56,785	88,334
1997*	95,997	11,175	11.6%	76,117	121,068
1998	1,244,438	193,712	15.6%	913,219	1,695,788
1999	1,556,576	243,144	15.6%	1,141,064	2,123,394
2000	2,141,260	244,269	11.4%	1,705,703	2,688,039
2001	164,474	17,150	10.4%	133,589	202,499
2002	104,088	12,239	11.8%	82,343	131,577
2003	170,470	22,457	13.2%	131,133	221,606
2004	418,831	70,297	16.8%	300,099	584,539
2005	262,082	37,837	14.4%	196,646	349,293
2006	199,561	30,923	15.5%	146,651	271,562
2007	94,448	15,357	16.3%	68,373	130,467
2008	14,016	3,015	21.5%	9,159	21,446
2009	11,216	2,371	21.1%	7,384	17,038

**Trap only operated during part of the out-migration due to high water conditions, estimates are not comparable.*

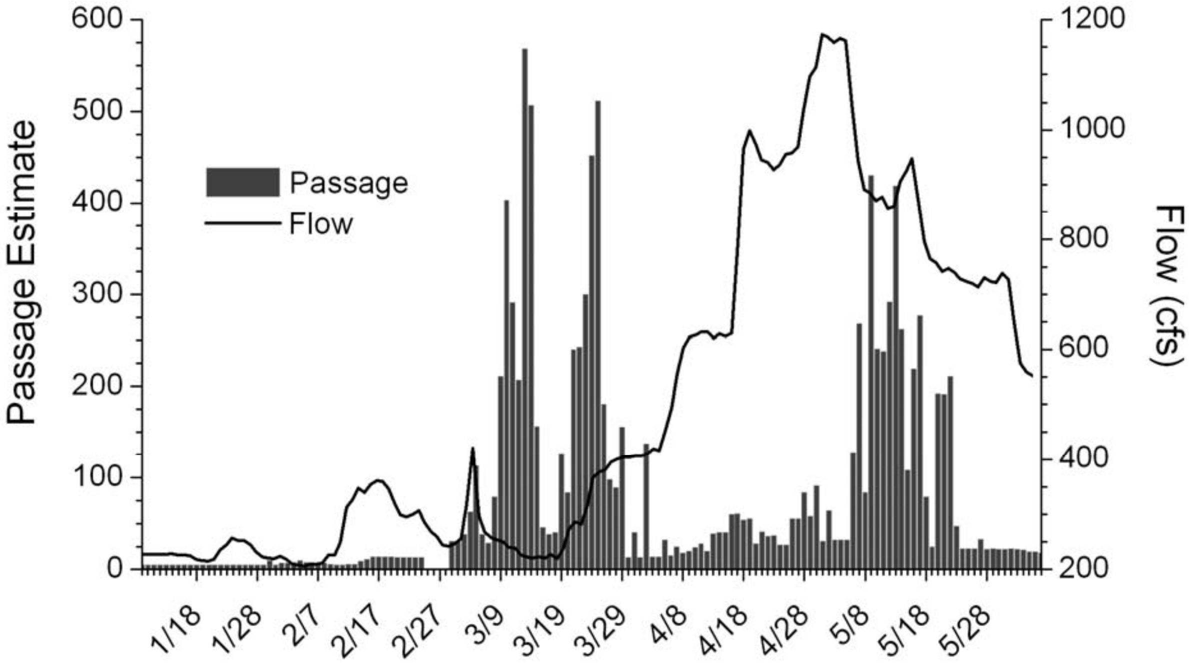

Figure 17. Daily passage of juvenile Chinook salmon and flow at Ripon in the Stanislaus River at Caswell, 2009.

DISCUSSION

Catch for the 2009 out-migration season was very low. We caught 767 juvenile Chinook salmon and five *O. mykiss*, and estimated juvenile Chinook salmon migrant passage as 11,216 (±2,371 SE). This was the lowest estimated abundance since we began monitoring in 1996. Record low juvenile abundances in 2009 also correspond to the second lowest adult escapement on record for 2008.

In 2009, low flow conditions warranted relocating the trap site 50 m downstream to a site with more suitable flow dynamics; however, this location could only accommodate a single trap. To address concerns regarding trap function at the new site in 2009 and to assess periods of low catch, we performed additional analyses to evaluate RST effectiveness. A measure of trap function (i.e., revolutions·min^{-1}) was used to compare operations between years, and we demonstrated significant improvements to trap function at the new site in 2009. This validated our decision to relocate the traps within the Caswell site. In an attempt to evaluate RST effectiveness during periods of extreme low catch we compared seine catch to RST catch. We found that a positive relationship exists between seine catch and RST catch, whereby seine catch increases as RST catch increases indicating that juvenile Chinook salmon abundances are likely low when catch is low. We believe periods of extreme low RST catch resulted from the relative absence of migrating juvenile Chinook salmon in the lower river near Caswell.

The new location and single trap operation in 2009 is superior to operating two traps in tandem at the previous site as evidenced by higher mean trap efficiency results in 2009 compared to the last three years (i.e., 2006-2008). In fact, the 2009 estimate has a lower associated SE compared to 2008, resulting in a more precise confidence interval. Surprisingly, this was accomplished by only conducting five calibration trials with 17 to 52 fish per trial in 2009. Conducting more trials with larger release group sizes will provide additional data to further improve future years' estimates.

Different from recent years, a large proportion (35.7%) of out-migrants exhibited the parr life history type; meanwhile, 5.4% of fish emigrated as fry, 58.1% as sub-yearling smolts, and 0.8% as yearling smolts (based on catch abundance only). Diversity in salmon early life history is an important factor affecting the adaptability (Thorpe 1989; Mangel 1994a, b) and fitness (Healey and Prince 1995) of salmonid populations. Understanding the relationship of life history diversity to flow, temperature, and other environmental variables is important to properly evaluate effects on the success and condition of salmonid populations in the Stanislaus River.

In 2009, the sub-yearling smolt median passage date of 28 March 2009 was approximately one month earlier than the two previous years (i.e., 29 April 2007 and 30 April 2008). It is difficult to determine the reason for this difference, but we speculate it could be related to the earlier pulse attraction flow in fall 2008. Attraction flows are used to aid adult salmon migration and correspond to increased adult abundances in the spawning reach. An earlier adult spawning migration related to an earlier than usual attraction flow release could be responsible for an earlier onset of spawning. Gestation in salmonids is controlled by temperature-days (i.e., the number of days eggs experience a specific temperature regime) making length of gestation variable and dependent on environmental conditions (Groot and Margolis 1991). Earlier immigration by adults could have numerous affects on growth and developmental rates for young-of-the-year juveniles, likely related to increased exposure to slightly warmer water temperatures (Hanson 1997), among other influences.

Despite the earlier out-migration timing in 2009, overall fish size for parr and sub-yearling smolts combined was slightly larger yet similar to 2007; however, both of these years had significantly smaller fish than 2008. These data demonstrate the ability to detect differences in overall population trends, including development and size of salmon emigrating from the Stanislaus River. While this project is not designed to identify factors to creating these trends, further analyses of the influence of environmental variables and biological factors, such as density dependence on annual growth, are necessary to explain these trends. For example, a detailed look at the relationship of spawning period outflow conditions and body size may yield important information for fisheries managers seeking to improve condition in out-migrating juvenile salmonids. Results from the 2009 monitoring season provide critical information to AFRP and CAMP. These data coupled with previous years' datasets should be used to better understand and improve conditions for Chinook salmon and *O. mykiss* within the lower Stanislaus River.

Fish Health Update

We continued our qualitative fish health assessments in 2009 to monitor and document episodes of observed poor fish health. A majority (81.5%) of all mortalities observed in 2009 (n = 27) occurred between 20 and 29 March when episodes of poor fish health were encountered. Although gill rating observations indicated healthy appearing gills (gill rating of 4 or 5), some fish were clearly in poor condition; and a few affected individuals expired while being held in sampling buckets. We collected six affected specimens during this period and submitted these samples to Scott Foott (USFWS CA-NV Fish Health Center, Anderson, CA) for histological analysis. Although results indicated no definitive cause for morbidity, signs of increased urine flow (i.e., diuresis) were detected; this condition can occur with exposure to elevated ammonia concentrations (Appendix 6). It is not known if this condition affected fish survival or if these conditions resulted from abnormal exposure to causative agents. In 2007, episodes of poor fish health were also encountered, though columnaris (infection by *Flavobacterium columnare*) was suspected as the cause (Watry et al. 2007); no disease or fish health out-breaks were observed in 2008 (Watry et al. 2008). More information is required in future years to determine the origin of fish health out-breaks in the Stanislaus River.

RECOMMENDATIONS

We continue to work closely with AFRP, CAMP and the Juvenile Monitoring Project Work Team to make recommendations and adapt our operational protocols to be consistent with program objectives. In addition to the previously implemented protocol changes (Gray et al. 2009), we suggest the following:

1) Continue operation of a single trap at the 2009 trapping location. Trap efficiencies with a single trap in 2009 were greatly improved results compared to the previous three years (2006–2008) at the upstream trap location using the tandem trap configuration. These results indicate that a single trap can be effectively operated at this site. Since site conditions drastically changed at the upstream site, utilizing the 2009 trap location with a single trap is the preferred alternative.
2) Continue to evaluate fish health and water quality standards at Caswell; and,
3) With AFRP support and CDFG approval, acoustically tag out-migrating *O. mykiss* smolts to improve our understanding of *O. mykiss* population dynamics and the resulting migratory tendencies of tagged individuals. This information will inform management actions as they relate to requirements for the Stanislaus River and San Joaquin Delta listed in NMFS' Biological and Conference Opinion (NMFS 2009).

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- Joanne Karlton of State Parks for granting access through their Caswell Memorial State Park;
- Oakdale Wastewater Treatment Plant staff for providing space to store RST equipment; and,
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REFERENCES

Anderson, J. T., C. B. Watry, and A. Gray. 2007. Adult Chinook salmon counts using a portable resistance board weir in the Stanislaus River, California, 2007. Annual Report of Cramer Fish Sciences to U.S. Fish and Wildlife Service, Anadromous Fish Restoration Program, Grant No. 813326G004, Stockton, California.

Augerot, X., D. N. Foley, C. Steinback, A. Fuller, N. Fobes, and K. Spencer. 2005. Atlas of Pacific salmon: the first map-based status assessment of salmon in the north Pacific. University of California Press, Berkeley and Los Angeles, CA. 150 pp.

Barnett-Johnson, R., C. B. Grimes, C. F. Royer, and C. J. Donohoe. 2007. Identifying the contribution of wild and hatchery Chinook salmon (*Oncorhynchus tshawytscha*) to the ocean fishery using otolith microstructure as natural tags. Canadian Journal of Fisheries and Aquatic Sciences 64:1683-92.

Boles, G. L. 1988. Water temperature effects on Chinook salmon (*Oncorhynchus tshawytscha*) with emphasis on the Sacramento River. Prepared for the California Resources Agency, Department of Water Resources, Northern District, Sacramento, CA.

Bottom, D. L., K. K. Jones, T. J. Cornwell, A. Gray, and C. A. Simenstad. 2005. Patterns of Chinook salmon migration and residency in the Salmon River estuary (Oregon). Estuarine Coast and Shelf Science 64:79-93.

Brett, J. R. 1971. Energetic responses of salmon to temperature. A study of some thermal relations in the physiology and freshwater ecology of sockeye salmon (*Oncorhynchus nerka*). American Zoology 11:99-113.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: A practical information-theoretic approach. Second Edition. Springer, New York, NY.

California Department of Fish and Game (CDFG). 2001. California's living marine resources: a status report. Leet, W. S., C. M. Dewees, R. Klingbeil, and E. J. Larson. Editors. California Department of Fish and Game Resource Agency. Sacramento, 592 pp.

California Department of Fish and Game (CDFG). 2009. Salmon Fishery Changes, News and Frequently Asked Questions. (Available: http://www.dfg.ca.gov/news/issues/salmon/).

Comprehensive Assessment and Monitoring Program (CAMP). 1997. Standard protocol for rotary screw trap sampling of out-migrating juvenile salmonids. U.S. Fish and Wildlife Service, Sacramento, CA.

Cezilly, F. 1992. Turbidity as an ecological solution to reduce the impact of fish-eating colonial waterbirds on fish farms. Colonial Waterbirds 15:249-252.

Cramer Fish Sciences (CFS). 2009. A plan to restore anadromous salmonid habitat in the lower Stanislaus River. Prepared for USFWS' Anadromous Fish Restoration Program and the Stanislaus River Fish Group, 148 pp.

Dobson, A. J. 2002. An Introduction to Generalized Linear Models (2nd Ed.). Chapman and Hall.

Fleming, C. 1997. 1995 Stanislaus River Emigration Survey. U.S. Fish and Wildlife Service, Stockton, CA.

Giannico, G. R., and M. C. Healey. 1998. Effects of flow and food on winter movements of juvenile coho salmon. Transactions of the American Fisheries Society 127:645-651.

Gradall, K. S., and W. A. Swenson. 1982. Responses of brook trout and creek chubs to turbidity. Transactions of the American Fisheries Society 111:391-395.

Gray, A., C. B. Watry, J. D. Montgomery, and B. Cavallo. 2008. Rotary screw trapping protocol: A detailed protocol for rotary screw trapping operations for the Stanislaus and Merced rivers. Cramer Fish Sciences, 32 pp.

Gregory, R. S. 1993. Effect of turbidity on the predator avoidance behaviour of juvenile Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 50:241-246.

Gregory, R. S., and C. D. Levings. 1998. Turbidity reduces predation on migrating juvenile pacific salmon. Transactions of the American Fisheries Society 127:275-285.

Hanson, C. 1997. Impacts on Mokelumne River fishery. Testimony before the State Water Resources Control Board, Bay-Delta Flow Allocation Hearing. November 1997.

Healey, M. C. and A. Prince. 1995. Scales of variation in life history tactics of Pacific salmon and the conservation of phenotype and genotype. American Fisheries Society Symposium 17:176-184.

Holt, R. A., J. E. Sanders, J. L. Zinn, J. L. Fryer, and K. S. Pilcher. 1975. Relation of water temperature to *Flexibacter columnaris* infection in steelhead trout (*Salmo gairdneri*), coho (*Oncorhynchus kisutch*), and Chinook (*O. tshawytscha*) salmon. Journal of Fisheries Research Board of Canada 32:1553-1559.

Holtby, L. B., T. E. McMahon, and J. C. Scrivener. 1989. Stream temperatures and inter-annual variability in the emigration timing of coho salmon (*Oncorhynchus kisutch*) smolts and fry and chum salmon (*O. keta*) fry from Carnation Creek, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences 46:1396-1405.

Johnson, P. N. and M. D. Rayton. 2007. Enumeration of juvenile salmonids in the Okanogan Basin using rotary screw traps. Report of LGL Limited Environmental Research Associates and Colville Tribes Fish and Wildlife to U.S. Department of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR.

Kjelson, M. A., P. F. Raquel, and F. W. Fisher. 1981. Life history of fall-run juvenile Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. Pages 393-411 *in* V.S. Kennedy (editor), Estuarine Comparisons. Academic Press, New York, NY.

Kjelson, M. A. and P. L. Brandes. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin Rivers, California. Canadian Journal of Fisheries and Aquatic Sciences 105:100-115.

Kondolf, G. M., A. Falzone, and K. S. Schneider. 2001. Reconnaissance-level assessment of channel change and spawning habitat on the Stanislaus River below Goodwin Dam. Report of G. M. Kondolf to U.S. Fish and Wildlife Service, Sacramento, CA.

Lichatowich, J. A. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, DC.

Mangel, M. 1994a. Climate change and salmonid life history variation. Deep-Sea Research II 41:75-106.

Mangel, M. 1994b. Life history variation and salmonid conservation. Conservation Biology 8:879-880.

Marine, J. 1997. Effects of elevated water temperature on some aspects of the physiological performance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*): implications for management of California's Central Valley salmon stocks. Master's thesis. University of California, Davis.

May, J. T., and L. R. Brown. 2002. Fish communities in the Sacramento River basin: implications for conservation of native fishes in the Central Valley, California. Environmental Biology of Fishes 63:373-388.

Merz, J. E. and P. B. Moyle. 2006. Salmon, wildlife, and wine: Marine-derived nutrients in human-dominated ecosystems of Central California. Ecological Applications 16(3):999-1009.

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. Salmon, steelhead, and trout in California: status of an emblematic fauna. University of California, Davis, CA. Center for Watershed Sciences. 316 pp. (Available: http://www.Caltrout.org).

Moyle, P. B. 2002. Inland fishes of California. Revised and expanded. University of California Press, Berkeley and Los Angeles, CA. 502 pp.

National Marine Fisheries Service (NMFS). 2009. Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project. Endangered Species Act Section 7 Consultation with U.S. Bureau of Reclamation, Central Valley Office. (Available: http://swr.nmfs.noaa.gov/ocap.htm).

National Oceanic and Atmospheric Administration (NOAA). 2004. Endangered and threatened species, establishment of species of concern list, addition of species to species of concern list, description of factors for identifying species of concern, and revision of candidate species list under the Endangered Species Act. Federal Register 69:19975-19979.

National Oceanic and Atmospheric Administration (NOAA). 2008. Fisheries of West Coast states and in the western Pacific; West Coast salmon fisheries; 2008 management measures and a temporary rule. Federal Register 73:23971-23982. Available: http://www.nwr.noaa.gov/Publications/FR-Notices/2008/upload/73FR23971.pdf.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. Fisheries 16:4-21.

Newman, K. B. and J. Rice. 2002. Modeling the survival of Chinook salmon smolts outmigrating through the lower Sacramento River system. University of Idaho and University of California- Berkeley. Journal of the American Statistical Association 97: 983-93.

Newman, K. B. 2003. Modeling paired release-recovery data in the presence of survival and capture heterogeneity with application to mark juvenile salmon. Statistical Modelling 3:157-177.

Pacific Marine Fisheries Council (PMFC). 2009. Fisheries off West Coast states, West Coast Salmon Fisheries, 2009 Management Measures. Federal Register 74: 20610-20620. May 5, 2009. (Available: http://www.pcouncil.org/fr/2009/E9-10308.pdf).

Rayton, M. D. 2006. Field Manual: Okanogan Basin monitoring and evaluation program rotary screw trap protocols. The Colville Confederated Tribes. Omak, WA.

Rich, A. A. 1997. Testimony of Alice A. Rich, Ph.D., submitted to the State Water Resources Control Board regarding water rights applications for the Delta Wetlands, Bouldin Island, and Holland Tract in Contra Costa and San Joaquin Counties.

Roper, B. B., and D. L. Scarnecchia. 1998. Emigration of age-0 Chinook salmon (*Oncorhynchus tshawytscha*) smolts from the upper South Umpqua River basin, Oregon, USA. Canadian Journal of Fisheries and Aquatic Sciences 56:939-946.

Schachte, J. H. 1983. Columnaris Disease. Pages 199-203 *in* F. P. Meyer, J. W. Warren, and T. G. Carey, editors. A guide to integrated fish health management in the Great Lakes basin. Great Lakes Fishery Commission, Special Publication No. 83-2, Ann Arbor, Michigan. Available: http://www.glfc.org/pubs/SpecialPubs/sp83_2/pdf/chap23.pdf (July 2007).

Schneider, K. S., G. M. Kondolf, and A. Falzone. 2003. Channel-floodplain disconnection on the Stanislaus River: a hydrologic and geomorphic perspective. Pp. 163-168 *in* P. M. Faber, (Ed.). California riparian systems: Processes and floodplain management, ecology, and restoration. Riparian habitat and floodplains conference proceedings, Riparian habitat joint venture, Sacramento, CA.

Schreck, C. B. 1982. Parr-smolt transformation and behavior. Pages 164-172 *in* E.L. Brannon and E.O. Salo (editors), Salmon and trout migratory behavior symposium. Oregon State University Department of Fisheries and Wildlife, Oregon Cooperative Fishery Research Unit, Corvallis, OR.

Seesholtz, A., B. J. Cavallo, J. Kindopp, and R. Kurth. 2004. Juvenile fishes of the lower Feather River: distribution, emigration patterns, and associations with environmental variables. American Fisheries Society Symposium 39:141-166.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Sparkman, M. 2001. Redwood Creek rotary screw trap downstream migration study Redwood Valley, Humboldt County, CA. Report of Michael Sparkman to Redwood Creek Landowners Association, Humboldt County, CA.

State Water Resources Control Board. 1991. Water Quality Control Plan for Salinity-San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Sacramento, CA.

State Water Resources Control Board. 1995. Water Quality Control Plan for Salinity-San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Sacramento, CA.

Sullivan, K., D. J. Martin, R. D. Cardwell, J. E. Toll, and S. Duke. 2000. An analysis of the effects of temperature on salmonids of the Pacific Northwest with implications for selecting temperature criteria. Sustainable Ecosystems Institute, Portland, OR.

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, AK, to predict effects of glacial flooding. North American Journal of Fisheries Management 14:837-851.

Thorpe, J. E. 1989. Developmental variation in salmonid populations. Journal of Fish Biology 35 Supplement A:295-303.

U.S. Environmental Protection Agency (EPA). 1994. Water Quality Standards for Surface Waters of the Sacramento River, San Joaquin River, and San Francisco Bay and Delta of the State of California. Federal Register 59:810-852. January 6, 1994.

U. S. Fish and Wildlife Service (USFWS). 1992. Shaded Riverine Aquatic cover of the Sacramento River system: Classification as resource category 1 under the FWS mitigation policy. U.S. Fish and Wildlife Service, Fish and Wildlife Enhancement, Sacramento, CA.

U.S. Fish and Wildlife Service (USFWS). 1995. Working paper on restoration needs – Habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Sacramento, CA.

U.S. Fish and Wildlife Service (USFWS). 2003. Abundance and survival of juvenile Chinook salmon in the Sacramento-San Joaquin estuary. 1999 Annual Progress Report, Sacramento-San Joaquin Estuary Fishery Resource Office, U.S. Fish and Wildlife Service, Stockton, California.

U.S. National Oceanic Atmospheric Administration (NOAA). 2004. Endangered and threatened species, establishment of species of concern list, addition of species to species of concern list, description of factors for identifying species of concern, and revision of candidate species list under the Endangered Species Act. Federal Register 69:19975-19979.

Venables, W. N., and B. D. Ripley. 1999. Modern Applied Statistics with S-PLUS. Springer-Verlag, New York, NY.

Watry, C. B., A. Gray, J. Montgomery, C. Justice, and J. E. Merz. 2008. Juvenile Salmonid Out-migration Monitoring at Caswell Memorial State Park in the Lower Stanislaus River, California. Report prepared for U.S. Fish and Wildlife Service, Anadromous Fish Restoration Program, Grant No. 813326G008. Cramer Fish Sciences, Oakdale, CA.

Watry, C. B., A. Gray, R. Cuthbert, B. Pyper, and K. Arendt. 2007. Out-migrant abundance estimates and coded wire tagging pilot study for juvenile Chinook Salmon at Caswell Memorial State Park in the Lower Stanislaus River, California. Report prepared for U.S. Fish and Wildlife Service, Anadromous Fish Restoration Program, Grant No. 813326G008. Cramer Fish Sciences, Oakdale, CA.

Williams, J. and G. Matthews. 1995. A review of flow and survival relationships for spring and summer Chinook salmon, *Oncorhynchus tshawytscha*, from the Snake River Basin. U.S. National Marine Fisheries Service Fishery Bulletin 93: 732-740.

Williams, J. G. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4(3): Article 2. Available: http://repositories.cdlib.org/jmie/sfews/vol4/iss3/art2/. (July 2007).

Workman, M. E. 2002 – 2006. Downstream Migration Monitoring at Woodbridge Dam on the Lower Mokelumne River, Ca. December 2000 through July 2006. Series of Annual Reports for East Bay Municipal Utility District, 25-39 pp.

Workman, M. E., C. E. Hunter, M. S. Saldate, and J. L. Shillam. 2007. Downstream Fish Migration Monitoring at Woodbridge Irrigation District Dam Lower Mokelumne River, December 2006 through July 2007. Report for East Bay Municipal Utility District, 33 pp.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Pages 71–176 *in* R. L. Brown (Ed.). Contributions to the Biology of Central Valley Salmonids, Fish Bulletin 179. California Department of Fish and Game, Sacramento, CA.

Zar, J. H. 1999. Biostatistical Analysis. Fourth Edition. Upper Saddle River, NJ: Prentice Hall.

APPENDIX 1: STANISLAUS RIVER POINTS OF INTEREST

Point	Purpose/Significance	Operator	rkm (RM)
New Melones Dam	Constructed in 1978; Flood control, water supply, power generation, recreation	BOR	96.6 (60)
Tulloch Dam	Constructed in 1957; Flood control, water supply, recreation	TriDam	88.5 (55)
Goodwin Dam	Constructed in 1913; Irrigation water diversion canals	BOR	93.9 (58.4)
Knights Ferry Covered Bridge	Historic feature	ACOE	87.4 (54.3)
Knights Ferry Gravel Augmentation	Habitat improvement	CDFG	87.4 – 86.6 (54.3 – 53.8)
Orange Blossom Bridge	Temperature gauging station	DWR	75.5 (46.9)
Oakdale Rotary Screw Traps	Juvenile salmonid abundance and out-migration timing	Oakdale Irrigation District (OID)	64.5 (40.1)
Stanislaus River Weir	Adult passage and timing	AFRP/TriDam	49.9 (31)
Hwy 99 Bridge (Ripon)	Temperature, discharge and DO	USGS	25.4 (15.8)
Caswell Memorial State Park	Juvenile salmonid abundance and out-migration timing	AFRP	13.8 (8.6)
Two Rivers Trailer Park	San Joaquin-Stanislaus confluence	—	0 (0)

APPENDIX 2: STANISLAUS RIVER FISH SPECIES LIST

Common names, species names, native fish and predator designation, and number of fish captured at Caswell, 2009.

Common Name	Species Name	Native* (Yes or No)	Predator* (Yes or No)	Number Captured
Black Crappie	*Pomoxis nigromaculatus*	No	Yes	2
Bluegill Sunfish	*Lepomis macrochirus*	No	Yes	80
Chinook Salmon	*Oncorhynchus tshawytscha*	Yes	Yes	788
Common Carp	*Cyprinus carpio*	No	No	4
Golden Shiner	*Notemigonus crysoleucas*	No	No	5
Goldfish	*Carassius auratus*	No	No	64
Green Sunfish	*Lepomis cyanellus*	No	Yes	5
Hardhead	*Mylopharodon conocephalus*	Yes	No	10
Largemouth Bass	*Micropterus salmoides*	No	Yes	6
Prickly Sculpin	*Cottus asper*	Yes	Yes	29
Rainbow Trout/Steelhead	*Oncorhynchus mykiss*	Yes	Yes	5
Redeye Bass	*Micropterus coosae*	No	Yes	2
Red Shiner	*Cyprinella lutrensis*	No	No	1
Sacramento Pikeminnow	*Ptychochelius grandis*	Yes	Yes	79
Sacramento Sucker	*Catostomus occidentalis*	Yes	No	2
Smallmouth Bass	*Micropterus dolomieu*	No	Yes	8
Spotted bass	*Micropterus punctulatus*	No	Yes	1
Tule Perch	*Hysterocarpus traski*	No	No	7
Western Mosquitofish	*Gambusia affinis*	No	No	110
White Catfish	*Ictalurus catus*	No	Yes	96
White Crappie	*Pomoxis annularis*	No	Yes	3
Unidentified Lamprey	*Lampetra spp.*	Yes	No	1,074

**Native and predator designations developed from Moyle (2002).*

APPENDIX 3: ANNUAL MARK-RECAPTURE RESULTS

Results of annual release group sizes, number of fish released per group, and total number of fish released and recaptured at Caswell, 1996-2009.

Year	Release Groups	Average Number Released / Group	Total Released	Total Recaptures
1996	8	2,720	21,757	1,000
1997	2	3,391	6,781	187
1998	7	2,714	18,996	463
1999	8	1,964	15,713	407
2000	15	1,011	15,166	456
2001	12	1,085	13,014	1,330
2002	11	800	8,804	973
2003	35	109	3,823	495
2004	8	255	2,039	263
2005	16	238	3,802	489
2006	6	1,017	6,102	58
2007	9	77	697	28
2008	7	626	4,383	59
2009	5	37	187	23
Total	149	1,146	121,264	6,231

APPENDIX 4: WEEKLY CATCH SUMMARY

Summary of weekly number of days of trap operation, catch-totals (by trap), catch by life history type (i.e., fry, parr, sub-yearling smolt and yearling smolt), number of total plus counted individuals and O. mykiss catch at Caswell, 2009.

Week	Number of Days		Weekly Catch		Catch by Life History Type					Plus Count	*O. mykiss*
	Trap 1	Trap 2	Total	Trap 1 (Trap 2)	Fry	Parr	Sub-yearling smolt	Yearling-smolt	Not assigned		
1/12-1/18	3	-	2	2	2	0	0	0	0	0	0
1/19-1/25	7	-	4	4	4	0	0	0	0	0	0
1/26-2/1	7	-	7	7	7	0	0	0	0	1	1
2/2-2/8	7	-	2	2	2	0	0	0	0	0	1
2/9-2/15	7	-	1	1	1	0	0	0	0	0	0
2/16-2/22	7	-	2	2	2	0	0	0	0	0	0
2/23-3/1	7	-	0	0	0	0	0	0	0	0	0
3/2-3/8	7	-	20	20	12	6	1	1	0	0	2
3/9-3/15	7	-	320	320	8	156	52	4	47	100	1
3/16-3/22	7	-	52	52	0	28	22	0	2	2	0
3/23-3/29	7	-	160	160	0	4	134	1	1	21	0
3/30-4/5	7	-	17	17	0	1	15	0	1	1	0
4/6-4/12	7	-	3	3	0	0	3	0	0	0	0
4/13-4/19	7	2	10	10 (0)	0	0	10	0	0	0	0
4/20-4/26	7	7	5	1 (4)	0	0	5	0	0	0	0
4/27-5/3	7	7	14	6 (8)	0	0	14	0	0	0	0
5/4-5/10	7	7	43	19 (24)	0	0	30	0	11	13	0
5/11-5/17	7	7	68	36 (32)	0	0	67	0	0	1	0
5/18-5/24	7	7	32	10 (22)	0	0	32	0	0	0	0
5/25-5/31	7	7	4	2 (2)	0	0	4	0	0	0	0
6/1-6/7	7	2	1	1 (0)	0	0	1	0	1	0	0
6/8-6/14	7	-	0	0	0	0	0	0	0	0	0
6/15-6/21	7	-	0	0	0	0	0	0	0	0	0
6/22-6/25	4	-	0	0	0	0	0	0	0	0	0
1/12 – 6/25	161	46	767	675 (92)	38	195	390	6	63	139	5

APPENDIX 5: WEEKLY ENVIRONMENTAL CONDITIONS SUMMARY

Summary of weekly environmental conditions, including: minimum and maximum mean daily flow at Ripon (RIP); minimum, maximum and mean daily temperatures (°C); minimum and mean daily dissolved oxygen (DO) concentrations (mg/L); and maximum and mean turbidity (NTU) recorded at Caswell, 2009.

Date	Daily Flow		Daily Temperature (°C)			DO (mg/L)		Turbidity (NTU)	
	Min	Max	Min	Max	Mean	Min	Mean	Max	Mean
1/8 - 1/14	228	229	7.8	7.8	7.8	11.19	11.19	1.92	1.92
1/15 - 1/21	215	226	8.1	8.9	8.3	10.84	11.18	1.66	1.26
1/22 - 1/28	232	257	8.0	11.8	10.0	9.89	10.30	5.96	3.01
1/29 - 2/4	208	224	8.1	9.9	9.0	11.07	11.30	2.12	1.52
2/5 - 2/11	206	249	9.5	16.7	11.6	10.03	10.62	2.47	1.59
2/12 - 2/18	312	361	9.5	10.4	10.1	10.42	10.85	3.55	2.71
2/19 - 2/25	285	346	10.2	12.9	11.4	9.95	10.49	2.88	2.20
2/26 - 3/4	242	318	12.1	13.0	12.6	9.42	9.70	3.64	2.18
3/5 - 3/11	240	420	10.8	11.9	11.5	9.25	9.51	10.97	5.06
3/12 - 3/18	221	239	11.4	14.8	13.2	8.21	8.90	2.17	1.67
3/19 - 3/25	220	367	12.6	15.8	14.2	8.01	8.74	5.21	3.75
3/26 - 4/1	377	406	13.4	15.5	14.3	8.93	9.28	5.24	3.84
4/2 - 4/8	407	556	13.4	16.1	14.4	9.10	9.37	4.68	3.77
4/9 - 4/15	603	632	12.5	14.6	13.4	9.41	9.69	3.90	2.91
4/16 - 4/22	624	999	12.6	15.2	14.3	9.35	9.69	4.84	2.91
4/23 - 4/29	927	1036	12.9	15.2	13.6	9.57	10.01	2.95	2.12
4/30 - 5/6	1096	1173	12.9	14.7	13.6	9.87	10.10	3.44	2.40
5/7 - 5/13	857	1047	15.0	16.3	15.7	9.21	8.04	3.90	1.84
5/14 - 5/20	765	948	15.6	18.4	17.2	7.44	8.88	3.25	2.51
5/21 - 5/27	720	758	16.8	18	17.3	8.10	8.89	3.24	2.64
5/28 - 6/3	649	738	17.3	18.8	18.0	8.81	8.92	3.01	2.11
6/4 - 6/10	531	575	17.2	18.3	17.8	8.76	9.02	3.55	2.76
6/11 - 6/17	396	487	18.3	19.7	19.0	8.42	8.58	7.32	4.40
6/18 - 6/24	382	1060	17.3	21.6	19.4	7.85	8.53	6.24	4.22

APPENDIX 6: FISH HEALTH PATHOLOGY REPORT

PATHOLOGY REPORT

US Fish & Wildlife Service
CA-NV Fish Health Center
24411 Coleman Hatchery Rd
Anderson, CA 96007

phone 530-365-4271
fax 530-365-7150

FHC Case No. : 09-047 **Submittal date: 3/30/2009**
Sample Collector: Cramer assoc.
209-847-7786 phone
Sample Site(s): Stanislaus R, Caswell RST
Histological specimen examiner: J. Scott Foott
Species: Fall-run Chinook smolts **Age: 0-1+**

Tissues:
Six whole fish in sample group. Gill, liver, acinar/pyloric cecae, kidney, lower intestine removed and sectioned

Fixative: Davidson (X), PREFER-ETOH (), 10%BF ( ), ZFIX ( ), Bouins ( )

Stains: Hematoxylin & eosin (X), PAS ( ), Iron ( )
Block No. 6105 - 6110 **Block / slide deposition: FHC**

Blood Smear (Number): ND **Bloodsmear Stain: Lieshman-Giemsa ( ), DiffQuick( )**
Clinical chemistry: ND

Summary
One fish was dead prior to fixation (6107) with necrotic tissues and another had post-morteum changes suggestive of death prior to fixation (6110) – no results on tissue lesions but no macroparasites observed.

Tissue from the other 4 specimens were similar.
Gills – normal , no parasites or significant lesion
Liver – low glycogen level in hepatocytes but no lesions
Heart (2) – normal
Lower/small intestine, pyloric ceca, acinar cell – normal
Kidney - varying degrees of particulate matter (protein?) observed in the glomerulus and tubules. No inflammation or necrosis. No parasites observed.

No definitive diagnosis for morbidity. Nephron precipitate could be related to increased urine flow (diuresis). This condition can occur in elevated ammonia conditions. Was water quality tested at collection site?