Juvenile Salmonid Emigration Monitoring in the Lower American River, California

January – June 2013

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Prepared for:

U.S. Fish and Wildlife Service, Comprehensive Assessment and Monitoring Program

and the California Department of Fish and Wildlife

by the

Pacific States Marine Fisheries Commission

The suggested citation for this report is:

Pacific States Marine Fisheries Commission. 2014. Juvenile Salmonid Emigration Monitoring in the Lower American River, California January – June 2013. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California. 54 pp.

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Abstract

Rotary screw traps were deployed 0.20 river kilometers (rkm) downstream of the Watt Avenue Bridge on the American River in Sacramento County, California, in 2013 between January 23 and June 1. The trapping operations in 2013 reflect the first year in a collaborative five-year effort by the U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program, Pacific States Marine Fisheries Commission, and the California Department of Fish and Wildlife. The primary objective of the trapping operations is to collect data that can be used to estimate the production of juvenile fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and quantify the raw catch of steelhead/rainbow trout (*Oncorhynchus mykiss*) and three other runs of Chinook salmon. Secondary objectives of the trapping operations focus on collecting fork length and weight data for juvenile salmonids and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, abundance, and production.

During the 2013 field season, three traps were deployed in the two river channels below the Watt Avenue Bridge, and staff were available to operate the traps on 120 of the 129 day field season. A total of 262,589 fall-run, 14 putative spring-run, 39 winter-run, and 35 late-fall-run juvenile Chinook salmon were captured. In addition, 2,206 in-river origin juvenile steelhead/rainbow trout were captured, and 23 adipose fin-clipped hatchery-origin steelhead were collected. The majority of the captured juvenile Chinook salmon belonged to the fry life stage; fewer numbers of the parr and silvery parr life stages were also collected. The emigration of juvenile fall-run Chinook salmon in 2013 peaked between February 12 and March 4 when 169,357 fry or 64 percent of the total seasonal salmon catch was caught. In addition, 3,979 individuals belonging to 13 different non-salmonid taxa were also caught. Eleven trap efficiency tests were conducted to collect data that were used to estimate the production of juvenile fall-run Chinook salmon. Trap efficiencies during those tests ranged between 2.70 and 11.16 percent, and the average efficiency was 6.85 percent. The number of juvenile fall-run Chinook salmon that were estimated to have emigrated past the Watt Avenue trap site on the American River during the 2013 field season was 3,195,884 individuals, and the upper and lower 95 percent confidence intervals for that estimate were 2,455,477 and 4,066,275 fish, respectively. Production estimates for steelhead/rainbow trout, the three other Chinook salmon runs, and non-salmonid fish taxa were not calculated. The 2013 trapping effort on the American River produced a high quality data set because substantial logistical or environmental issues did not interfere with the collection of field data.

Introduction

The American River is the southernmost tributary to the Sacramento River in California's Central Valley. The lower portion of that river occurs in a highly urbanized area, and it provides crucial spawning and rearing habitat for Chinook salmon (CS) *Oncorhynchus tshawytscha* and steelhead (SH) *Oncorhynchus mykiss*, the anadromous form of rainbow trout. Historically, the American River supported three races of CS that included fall-, spring-, and possibly late-fall-run CS (Yoshiyama et al. 2001). In the late 1800s during the California gold rush, hydraulic mining devastated salmon spawning habitat in the upper and lower reaches of the American River (Fisher 1994). Later, the construction of Folsom and Nimbus Dams made it impossible for spring-run CS to migrate to the cool water pools they historically used in the upper portions of the American River watershed. To mitigate the loss of fall-run CS and SH spawning and rearing habitat, the Nimbus Fish Hatchery was built 0.80 kilometers (km) downstream of the Nimbus Dam in 1958. The Nimbus Fish Hatchery is used to produce large numbers of fall-run CS and SH. Discharges from Folsom and Nimbus Dams are regulated by the U.S. Bureau of Reclamation (USBR), and they provide flows that help maintain fish and wildlife habitats, provide municipal water supplies, administer flood protection, and generate hydroelectric power.

The Central Valley Project Improvement Act (CVPIA) was authorized in 1992. One of the primary goals of that legislation is to facilitate efforts that enhance/restore the natural production of adult and juvenile CS and SH. Pursuant to that act, several programs were established to help recover salmonid populations. The CVPIA programs currently engaged in habitat restoration activities within the American River watershed include the Anadromous Fish Restoration Program (AFRP), Dedicated Project Yield Program, and Spawning Gravel Program. The Comprehensive Assessment and Monitoring Program (CAMP) was also established by the CVPIA, and that program is designed to monitor the effectiveness of ongoing habitat restoration activities and provide recommendations designed to improve the efficacy of future restoration work.

In an effort to improve salmonid spawning habitat on the lower American River, the USBR, the California Department of Fish and Wildlife (CDFW), and the CVPIA's AFRP and Spawning Gravel Program have collaborated to implement the Lower American River Gravel Augmentation and Side-Channel Habitat Enhancement Project. This project is ongoing and has in part been developed to restore adult spawning and juvenile rearing habitat that was adversely affected by the construction of the Folsom and Nimbus dams on the American River. The habitat restoration activities have occurred at seven sites from the base of Nimbus Dam downstream 2.9 river kilometers (rkm) to the Upper Sunrise Recreational Area (USDOI 2008). Within that area, approximately 57,342 cubic meters (m^3) of gravel have been added to the river between 2008 and 2012.

The CVPIA's Dedicated Project Yield Program authorizes a portion of the Central Valley Project water yield to be dedicated and managed for the benefit of fish and wildlife. As it pertains to the lower American River, that program's water can be utilized to augment base flows out of Nimbus Dam to provide improved instream conditions for fall-run CS and Central Valley SH during critical life stage periods such as spawning, egg incubation, fry emergence, juvenile rearing, and emigration. Additionally, the Dedicated Project Yield Program's flow augmentation may also contribute towards the AFRP Final Restoration Plan flow objectives for the lower American River.

Rotary screw traps (RSTs) are frequently used to monitor the abundance of juvenile salmonids and their biological response to habitat restoration activities. This report describes efforts to monitor juvenile salmonid abundance with RSTs in 2013 as part of a larger effort to determine if habitat restoration activities are improving CS production in the lower American River. Furthermore, this report presents monitoring data assessing the temporal variability in SH abundance, as well as providing data that describe the size and abundance of salmonids and other native and non-native fish species in relation to the time of year, river discharge, and environmental conditions.

The CDFW operated RSTs on the lower American River between 1992 and 2008 (Mike Healy, pers. comm.). The 2013 RST activities were the first year of a 5-year trapping project conducted on the lower America River after a 5 year hiatus. During the next four years, RST data will continue to be collected such that the new data complement the data already summarized by the CDFW. All of the RST data will then be analyzed in 2017 with the goal of understanding how ongoing habitat restoration activities affect juvenile salmonid abundance, and how future habitat restoration activities can be enhanced to increase the production of adult and juvenile CS and SH.

Based on the goal identified in the aforementioned paragraph, the primary objective of the American River trapping operations is to collect data that can be used to estimate the production of juvenile fall-run CS and quantify the catch of SH and three other runs of CS. Secondary objectives of the trapping operations focus on collecting fork length and weight data for juvenile salmonids and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, and abundance/production. An ancillary objective of the trapping operations is to collect non-salmonid fish species data that can be used to characterize the fish community in the American River.

Study Area

The American River watershed covers an area of 4,900 square kilometers (km^2), and the upper-most headwaters reach an elevation of 3,170 meters (m) on the western slopes of the Sierra Nevada mountain range (James 1997). This river contains three major forks including the North, Middle, and South that ultimately converge at the Folsom Reservoir which is impounded by the Folsom Dam 32 km northeast of the city of Sacramento (USACE 1991). The water exiting Folsom Reservoir flows immediately into Lake Natoma which is impounded by Nimbus Dam. The function of Nimbus Dam and Lake Natoma is to re-regulate flows downstream of the Folsom Dam. The area commonly called the “lower American River” refers to the portion of the American River below Nimbus Dam. Both of these two dams control water release activities including river discharge and water temperature regimes in the lower American River that relate to salmonid spawning and rearing.

Water exiting Nimbus Dam flows downstream for 36 km across an alluvial plain until it reaches the confluence with the Sacramento River mainstem. Currently, fall-run CS and SH are only able to access and occupy the lower-most 36 km of the American River, and only a small portion of the river possesses suitable substrate for salmon spawning activities. The river contains gravel bar complexes and islands, flat water areas, and side-channel habitat characteristics (Merz and Vanicek 1996). Flows in this lower section can range from 22.65 cubic meters per second (cms) (800 cubic feet per second (cfs)) to upwards of 4,644.96 cms (164,035 cfs). The primary salmonid spawning grounds are located between Sailor Bar (rkm 34.7) and the Lower Sunrise Recreational Area (rkm 31.1) according to annual escapement surveys (Phillips and Helstab 2013). CDFW selected a site 0.20 rkm downstream of the Watt Avenue Bridge (rkm 14.6) as the location to install and operate RSTs because that site is downstream of most of the CS and SH spawning activities in the lower American River (Figure 1).

The lower American River RST site is situated in an area that contains two channels that pass on either side of a gravel island downstream of the Watt Avenue Bridge (Figure 1). RSTs were deployed in both channels. The “North Channel” carries the majority of the water volume and becomes the only channel with flowing water during extreme low flows. Water velocities in the North Channel are relatively high because that reach possesses a steep channel gradient. The “South Channel” site has flatter gradient and lower water velocities.

Figure 1: 2013 lower American River rotary screw trap sites in the North and South Channels. Inset map illustrates the trapping location in the state of California.

Methods

Trap Operations

Monitoring activities were conducted using two 2.4 m and one 1.5 m RSTs. The 2013 field season started on January 23rd and ended on June 1st. From January 23rd through February 12th one 2.4 m diameter RST was deployed in the North Channel and one 2.4 m diameter RST was deployed in the South Channel. To secure the traps in a stable location, traps were anchored to large concrete blocks set into the substrate of the river bottom using 0.95 centimeter (cm) nylon coated galvanized cable and a 0.95 cm chain bridal attached to the front of each trap's pontoons. On February 13th a 1.5 m diameter RST was installed in the North Channel next to the 2.4 m diameter RST. The 2.4 m RST in the South Channel stopped fishing on March 7th due to low river flows that prevented the cone's rotation. On March 9th the position of the 1.5 m RST in the North Channel and the 2.4 m RST in the South Channel were swapped to better utilize the 1.5 m RST's ability to operate in lower water velocities in the South Channel. River discharges continued to decline through the end of March and the beginning of April, which resulted in low water velocities in the South Channel that were not suitable for normal RST operations. Plywood flow diverters were installed in front of the 1.5 m RST in the South Channel trap on

March 30th to direct a greater amount of water and increase water velocity into that RST cone (Figure 2). The flow diverters consisted of two 1.91 cm marine-grade plywood sheets measuring 2.4 m long by 0.61 m wide; they were held in place with three 1.91 cm diameter rebar stakes per board. Initially, the diverters helped keep the 1.5 m RST rotating consistently, but river flows continued to decline and it was not possible to keep the cone spinning as river discharges at Nimbus Dam declined below 42.48 cms (1,500 cfs). On April 16th the 1.5 m RST was pulled for the remainder of the trapping season due to low river discharges and velocities. The two 2.4 m RSTs in the North Channel continued to fish through the end of the field season which concluded on June 1st, 2013. Trapping activities were discontinued earlier in the field season than was planned to avoid mortality of listed fish species from river temperatures exceeding 22°C.

Figure 2: Flow diverters installed on the South Channel rotary screw trap, March 30, 2013.

Trap checks were conducted every 24 hours and sometimes twice each day when high debris loads occurred. Trap cones were raised, live well screens were pulled, and sampling was temporarily suspended during three periods of the field season when the capture of listed salmonids exceeded the American River RST project's National Marine Fisheries Service (NMFS) take permit, or when inclement weather occurred.

The number of trap rotations between trap visits was monitored using a mechanical lever actuated counter (Trumeter Company Inc.) attached to the port side pontoon on each trap; this data was used to determine how well traps functioned between trap visits. The effect of debris buildup on trap cone rotation rates was quantified by counting the number of revolutions per minute (RPM) before and after each cone was cleaned each day. Cleaning of the cones relied on the use of a scrub brush to clear off algae and other vegetation, and the field crew occasionally had to stop a trap cone to remove larger debris.

Safety Measures

All crew members were trained in RST and boat operation safety. Personal flotation devices were worn at all times when members were on the boat or the RSTs.

A variety of devices were installed to keep the public safe and away from the traps. "Keep Away" signs in English and Spanish were installed on the traps. A flashing amber construction light was attached to the top of the A-frame on the traps to alert the public at night that there was a potential navigation hazard. Orange or reflective buoys were placed on the chain bridals, and buoys were installed over concrete anchors when the water depth above an anchor was less than 30.5 cm deep. Two signs were installed approximately 106 and 244 m upstream of the RSTs in the North Channel; those signs warned and directed river users and park visitors to pass by the left side of the trap.

Trap operations were modified so traps were not deployed during the Memorial Day weekend, thereby minimizing the likelihood that the public would encounter the traps during a period when public use of the American River was high.

Environmental Parameters

Environmental data were recorded on a daily basis before fish were processed. Temperature and dissolved oxygen were measured using a YSI dissolved oxygen meter (YSI; Model 55), velocity in front of each cone was recorded using a Hach flow meter (Hach; Model FH950), and turbidity was measured using a Eutech portable turbidity meter (Eutech: Model TN-100). Average daily river discharge for the American River was determined using data from the U.S. Geological Survey's American River at Fair Oaks monitoring station (USGS station number 11446500). Average daily temperature in the vicinity of the RSTs was determined using data from the USGS's American River below Watt Avenue Bridge station (USGS station number 11446980).

Catch, and Fish Data Collection

After environmental data were collected, the process of clearing out each RST's live well and fish work-up began. First, all debris was removed from a live well and placed into 68.14

Liter (L) tubs where crew members sifted through debris and saved any fish, alive or dead. After all debris was removed, a recording of debris type and volume was taken. Next, the crew netted any remaining fish from the live well and placed them in 18.93 L buckets that segregated different fish taxa. During periods of hot weather, fish were placed in a bucket with an aerator to provide them with oxygen and an ice pack to keep the water temperature at a safe level. In addition, the crew placed buckets of fish underneath an umbrella to shade the fish from direct sunlight.

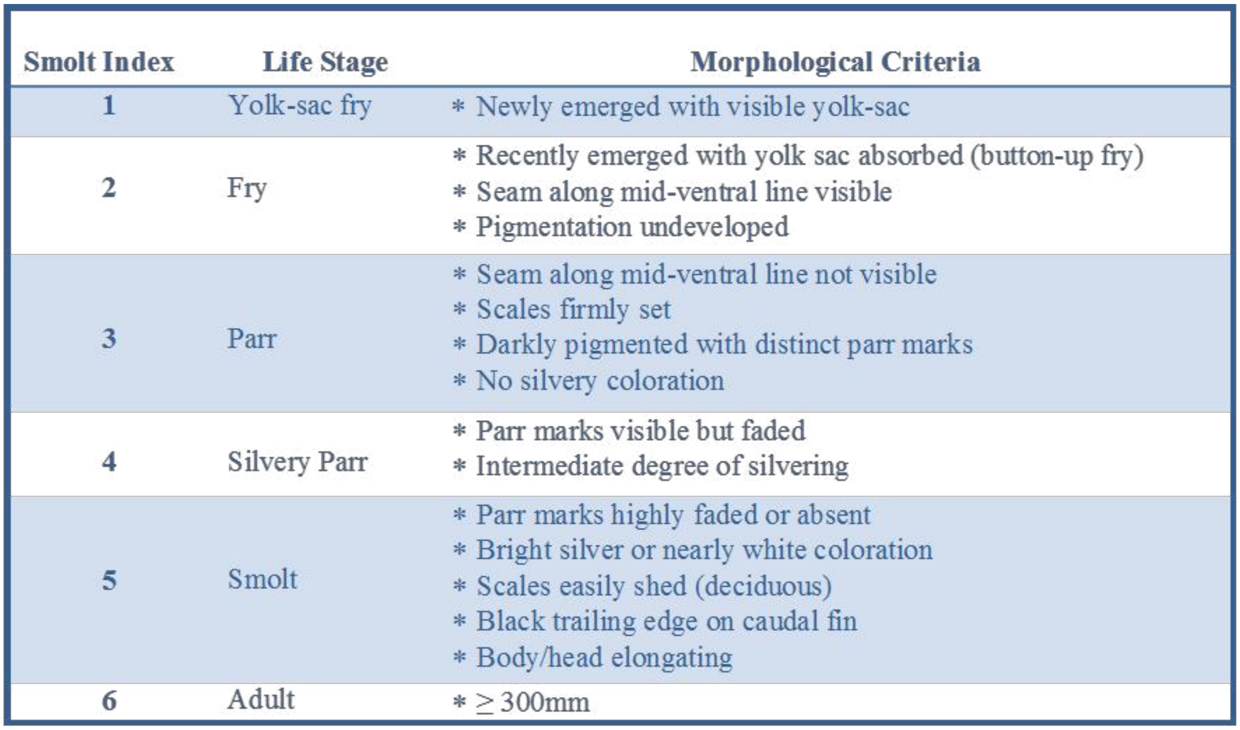
On days when less than 100 CS were caught in a trap, the fork length of each CS from each trap was measured to the nearest 1 millimeter (mm), their life stage was assessed using the smolt index rating in Table 1 below, the presence or absence of marks used during trap efficiency tests was noted, and their mortality status was assessed. If CS were ≥ 40 mm in fork length, they were weighed to the nearest 0.1 gram (g).

On days when more than 100 CS were caught in a trap, the fork lengths and life stages of a random sample of 100 CS were assessed, and fish were examined to determine if they had marks from trap efficiency tests. Again, if the individuals were ≥ 40 mm in fork length, they were weighed to the nearest 0.1 gram after they were measured and assessed for life stage. A random sample was achieved by placing an indiscriminate amount of CS from the live well into a 68.14 L tub. Debris was sorted out by hand and discarded, leaving only the subsampled fish in the tub. After separating the fish from the debris, a random net full of CS was taken from the 68.14 L tub and placed into an 18.93 L bucket designated for CS. From the subsampled bucket, 100 CS were randomly selected for analysis. Additional fall-run CS in excess of the 100 that were not measured and weighed were checked for marks, enumerated, and recorded on data sheets as a "live plus count tally," or "mort tally." A "live plus count tally" is defined as the total number of CS that were caught in a trap on a given day, and that were not measured, weighed, or assessed for life stage. A "mort tally" is similar to the "live plus count tally," except that the fish are dead instead of alive.

On days when SH were captured and river temperatures were < 21°C, each individual SH was counted, fork lengths were measured to the nearest 1 mm, their life stage was assessed using the smolt index rating in Table 1, their mortality status was assessed, they were checked for the presence or absence of a mark, and the weights of individuals ≥ 40 mm in fork length was recorded. On days when river temperatures were ≥ 21°C, SH were identified, enumerated, checked for the presence or absence of a mark, and then released downstream without being weighed or measured for fork length to minimize handling mortality brought about by higher water temperatures.

For each day and each RST, individuals belonging to non-salmonid taxa were identified to species, fork lengths of up to 50 randomly selected individuals of each species were recorded to the nearest mm, and their mortality was assessed. Because multiple entities in the Central Valley have a special interest in juvenile lamprey, an effort was made to distinguish between River lamprey and Pacific lamprey. To distinguish between the two species we observed the number of lateral circumorals in their mouths. River lampreys have three lateral circumorals, while Pacific lampreys have four (Reid 2012). Due to the larval stage of ammocoetes and their lateral circumorals not being developed, they were not identifiable to species.

Table 1: Smolt index rating for assessing life stage of Chinook salmon and steelhead on the lower American River during the 2013 field season.



Smolt Index	Life Stage	Morphological Criteria
1	Yolk-sac fry	* Newly emerged with visible yolk-sac
2	Fry	* Recently emerged with yolk sac absorbed (button-up fry) * Seam along mid-ventral line visible * Pigmentation undeveloped
3	Parr	* Seam along mid-ventral line not visible * Scales firmly set * Darkly pigmented with distinct parr marks * No silvery coloration
4	Silvery Parr	* Parr marks visible but faded * Intermediate degree of silvering
5	Smolt	* Parr marks highly faded or absent * Bright silver or nearly white coloration * Scales easily shed (deciduous) * Black trailing edge on caudal fin * Body/head elongating
6	Adult	* ≥ 300mm

Prior to collecting fish fork lengths and weights, individuals were anesthetized with MS-222 (Tricaine methanesulfonate) to reduce stress as they were processed. The MS-222 was prepared in a 1 L bottle with 10.0 g of the MS-222 powder and 1 L of deionized water. The solution was then placed in 125 milliliter (mL) bottles and stored in an ice chest with frozen water bottles to keep it cold while in the field. Approximately 8 to 10 fish were placed in a solution of river water and 5 to 8 cubic centimeters (cc) of MS-222 solution, then measured and weighed. The crew routinely observed the gill activity of fish immersed in the MS-222 solution; reduced gill activity was an indication fish were ready to be processed. After fish were measured and weighed, they were placed in an 18.93 L bucket with a mixture of fresh river water and stress coat (Poly-Aqua) that was designed to help replace their slime coat. All fish were then released well downstream of the traps to prevent recapture.

Chinook salmon run was normally assigned to an individual salmon with the length-at-date (LAD) criteria developed by Frank Fisher (1992). When CS appeared to be winter- or spring-run CS using Fisher's LAD criteria, 1 to 2 mm fin clips were taken from the upper caudal fin. The fin clips were then processed by staff at the U.S. Fish and Wildlife Service's Abernathy Fish Technology Center to develop run assignments using the standard panel of single-nucleotide polymorphism (SNP) markers used by the U.S. Fish and Wildlife Service (USFWS), University of California – Davis staff, and National Oceanic and Atmospheric Administration Fisheries agency (Christian Smith, pers. comm.). Because these SNPs are thought to be nearly 100 percent accurate for assigning winter-run CS (Clemento et al. *in press*), every CS classified as a winter-run CS using the SNPs was classified as a winter-run CS for the purposes of this report. Because the LAD criteria and SNP markers can sometimes incorrectly assign an individual salmon to the wrong run (especially in regards to fall- vs. spring-runs), a conservative pair of modified LAD criteria was used to make the final salmon run assignments for individuals that were preliminarily classified as spring-run CS using the LAD criteria. The two criteria used to make the final run assignments to the spring-run CS category were: (1) a CS was preliminarily classified as a spring-run using the LAD criteria and it was 15 mm larger in size than any other fall-run CS caught on the same day, and (2) the CS was preliminarily classified as a spring-run using the LAD and it was at least 6 mm larger in size than the fall- vs. spring-run size boundary in the LAD table used to assign CS run.

Trap Efficiency

Trap efficiency trials were conducted to quantify the proportion of the emigrating fall-run CS that were passing through the river and were collected by the RSTs; these data were then used to estimate the total number of fall-run CS migrating passed the RSTs. Trap efficiencies were assessed using two different marking methods.

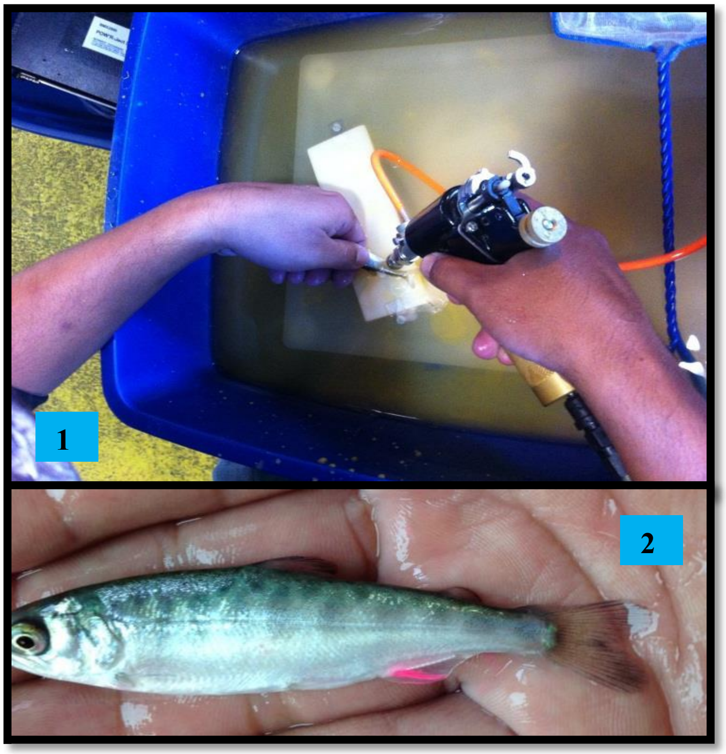
One method of marking consisted of dying the whole body of a fall-run CS that had a life stage of 2 or higher (Table 1) with Bismarck Brown Y (BBY) stain. At least 500 fish were needed to conduct trials with BBY stain; however, one trial of 215 fish was carried out to determine if the results yielded enough recaptures to conduct further tests when less fish were captured. Normally, when smaller numbers of CS were caught on a given day, they would be held overnight and the fish caught the next day would then be added to the previous days catch. If the minimum number of CS needed to conduct a trap efficiency trial were not captured within a 48-hour period, they were not used for an efficiency trial and were released downstream of the traps. Once enough CS were available to conduct a trap efficiency trial, they were placed in a 68.14 L tub and stained using a solution of 0.6 g of BBY for every 20 L of river water. The actual amount of stain used varied depending on water turbidity and the number of CS being stained. CS were stained for approximately 2 hours, and their condition was constantly monitored during the staining process. After staining, fish were rinsed with fresh river water and placed in a 68.14 L live cart, held overnight, and released at twilight the following day.

The second method of marking used a BMX2000 POW'R-JECT needleless gun to inject a photonic fluorescent dye into the anal fin of a CS (Figure 3). The color dyes used for these trials were pink, orange, and green. Since the photonic method of marking CS required the availability of CS ≥ 50 mm in size and CS in the river did not always meet this size threshold in large enough quantities for a trial, fall-run CS from the Nimbus Fish Hatchery were used when CS were photonically marked. Four trap efficiency trials, each with ~1,000 photonically marked CS, were conducted during the 2013 field season. Before we started marking, CS were anesthetized with MS-222 and the first 100 fork lengths were measured to the nearest mm. After marking, CS were held overnight at the hatchery and allowed to recover. If mortalities were discovered after being held overnight, they were counted and removed from the efficiency trial. The live CS were then transported to the release site in coolers with aerators and frozen water bottles. Upon arrival to the release site, the CS were immediately placed in live carts in the river. Marked salmon were held in the live carts in the river for two to four hours, then released at sunset using the technique described below.

The release site was approximately 1.29 rkm upstream of the traps. To avoid schooling when CS were released, they were scattered across the width of the river channel using small dip nets. When flows were relatively low, the fish were released by biologists wading across the river. When higher river discharges occurred, a boat was used as marked CS were released. Every release of marked CS occurred close to twilight to mimic CS natural migration patterns and to avoid predation.

The following days after each trap efficiency release, the crew carefully looked for any marked fish in the RST live wells. A random sample of 100 recaptured CS were measured for fork lengths, assessed for life stage, and evaluated for mortality. If more than 100 recaptures were in a RST live well, the marked CS that were not measured were enumerated and classified as a "live recap plus count tally" or "recap mort tally" per mark type and color.

Figure 3: (1) Marking a fall-run hatchery CS with a BMX2000 POW'R-JECT needleless gun using photonic fluorescent orange dye. (2) Fall-run hatchery CS with an anal fin injected with photonic fluorescent pink dye.



Passage Estimates

Fall-run CS production estimates were developed using a generalized additive model (GAM). Production estimates were not developed for the other CS runs because relatively small numbers of individuals from those runs were captured. Production estimates were not developed for SH because Central Valley fishery biologists generally believe SH fry can typically rear in river for a year before they emigrate to the ocean as smolts, at which point they become more difficult to capture due to their ability to avoid the traps.

The GAM incorporates two elements in the development of the salmon production estimates; these include the number of salmon caught by trap i on day j, and the estimated efficiency of trap i on day j.

Salmon production at trap *i* on day *j*, $\hat{N}_{ij}$, is calculated as:

$$\hat{N}_{ij} = \frac{\hat{c}_{ij}}{\hat{e}_{ij}} \text{ where}$$

$\hat{c}_{ij}$ = either the enumerated or estimated catch of unmarked salmon of a certain life stage at trapping location *i* at that location during the 24-hour period j. For example, c_{23} = estimated catch at the second trapping location during day three; and

$\hat{e}_{ij}$ = estimated trap efficiency at trapping location *i* of the site for a certain life stage during the 24-hour period *j*. For example, e_{23}= estimated efficiency at the 2nd trapping location during day three.

Estimation of $\hat{c}_{ij}$

The estimate of catch, $\hat{c}_{ij}$ is computed in one of two ways listed below. The selection of the method used is typically in the order that the methods are listed below, e.g., if a trap operated properly for an entire 24-hour period, the catch using Method #1 was used to calculate a trap's salmon production estimate. If the trap operated for less than a full day (±2 hours), Method #2 was used.

Method #1: If the interval between check *j* and check *j* – 1 was 24 ± 2 hours and the trap operated properly for the entire period, $\hat{c}_{ij}$ is the total catch of unmarked fish in the trap at check *j*.

Method #2: If the trap fished for less than 22 hours between check *j* and check *j* – 1, the fish count at time *j* is adjusted using a GAM. This model smoothes observed catch rates (fish per hour) through time much like a moving average. The prediction from this model is multiplied by the number of hours the trap was not operating during the 24 hour period to estimate catch for the day.

Estimation of $\hat{e}_{ij}$

Efficiency estimates at the *i*-th trapping location on day *j* are computed from a binomial GAM unless sufficient efficiency trials (≥ 3 per week) have been performed. Thus, if sufficient efficiency trials have been conducted (≥ 3 per week), efficiency from the most recent trial is used for $\hat{e}_{ij}$. When the most recent efficiency is not appropriate (i.e., < 3 trials per week), a binomial

GAM is fitted to past and current efficiency trials and used to compute $\hat{e}_{ij}$. The additive portion of this GAM model is:

$$\log\left(\frac{E[\hat{e}_{ij}]}{1-E[\hat{e}_{ij}]}\right) = s(j)$$

where $s(j)$ is a smooth (spline) function of the day index (i.e., smooth function of Julian date).

During sampling days during the portion of the year when trap efficiency tests were not conducted, a GAM was not used to estimate trap efficiency, and $\hat{e}_{ij}$ was the average efficiency for the trap efficiency tests that were conducted during the field season and that were included in the analyses. For example, if a field season occurred between January 1 and June 30 and trap efficiency tests were conducted between February 1 and May 30, a GAM was used to develop the estimated trap efficiencies and expand the daily trap catches between February 1 and May 30, and the average trap efficiency for the field season was used to expand the daily trap catches before February 1 and after May 30.

Estimation of $\hat{N}_{ij}$

Once $\hat{c}_{ij}$ and $\hat{e}_{ij}$ are estimated, abundance estimates for the site are computed by summing over trap locations. The total number of fish passing a particular site on day j is computed as:

$$\hat{N}_j = \sum_{t=1}^{n_{ij}} \hat{N}_{ij}$$

where n_{ij} is the number of trapping locations fishing at site i during day j. Production on day j is then summed over a week, month, or year to produce weekly, monthly, or annual estimates of abundance.

Confidence Interval Estimates

Confidence intervals were computed using parametric bootstrap or Monte Carlo methods as described in the “Feasibility of Unified Analysis Methods for Rotary Screw Trap Data in the California Central Valley,” by McDonald and Banach (2010).

Results

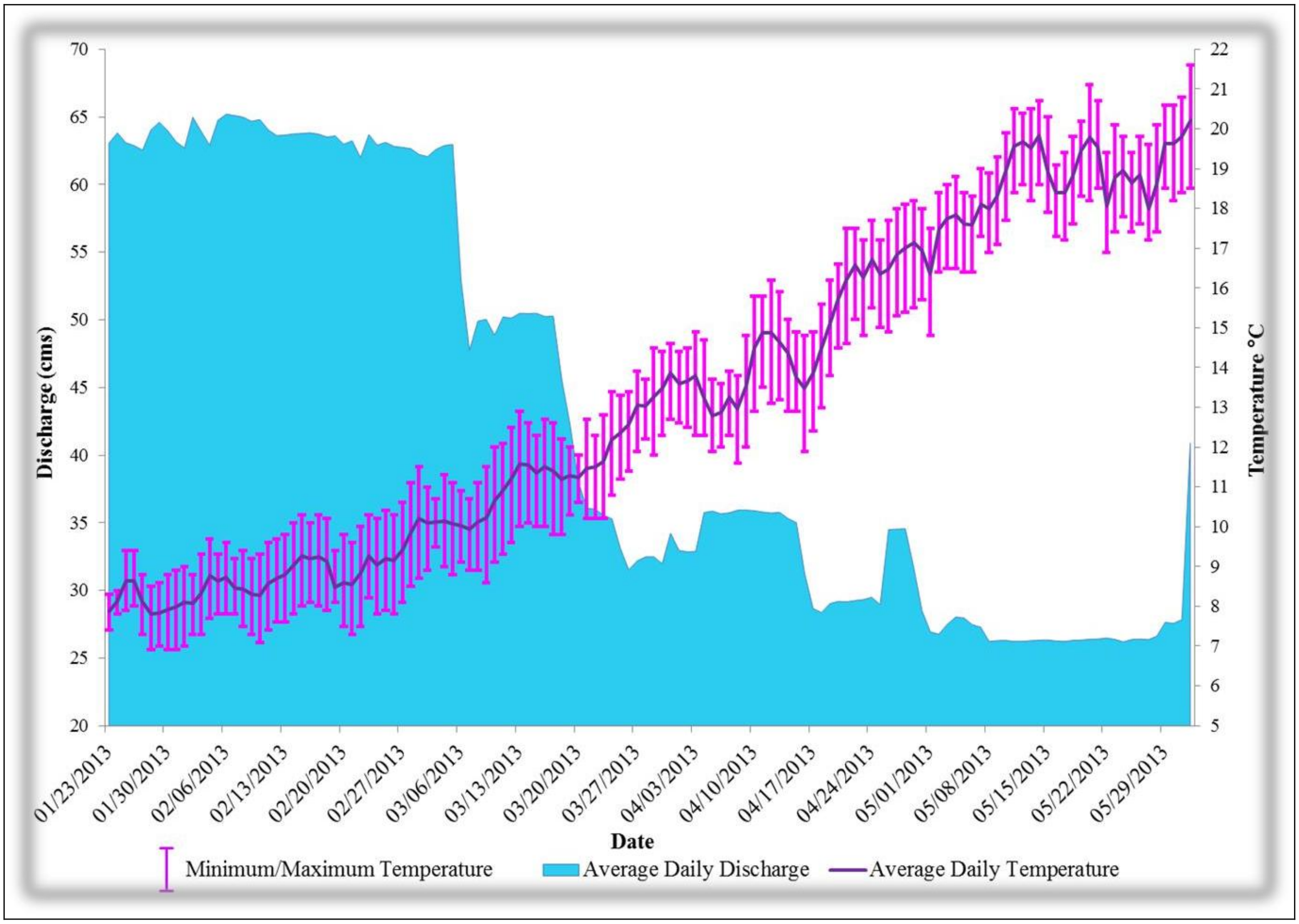
Trap Operations

Traps were deployed and sampling began on January 23rd, 2013. Trap operations were terminated on June 1st, 2013, due to elevated salmonid mortality levels in the month of May that may have been related to increasing river water temperatures. Sampling took place on 120 out of the 129 days during the 2013 field season (Appendix 1). The nine days not sampled occurred as project staff conferred with the NMFS about permitted take amounts involving SH and spring- and winter-run CS, or occurred during the Memorial Day weekend when trapping was suspended to eliminate potential issues that could arise if the public encountered rotating traps.

Environmental Variables

A summary of the environmental conditions that occurred during the 2013 field season are provided in Appendix 2. Mean daily discharge at the USGS's American River at Fair Oaks gaging station 21 rkm upstream of the RSTs ranged from a high of 68.21 cms (2,409 cfs) in February to a low of 26.19 cms (925 cfs) in May (Figure 4). Mean daily temperature at the USGS's American River below Watt Avenue Bridge station 0.16 rkm upriver from the RST location ranged from 7.8°C in January to 20.2°C in June (Figure 4). Turbidity was fairly consistent throughout the field season, and was typically between 0.57 and 1.5 NTUs except during storm events when it reached the highest observed value at 4.21 NTUs. Instantaneous dissolved oxygen levels were commonly between 10 and 11 mg/L for the majority of the field season. Water velocities in front of the trap cones were substantially different between the North and South Channels. The South Channel's water velocities reached a low of 0.18 meters per second (m/s) and a high of 0.62 m/s, whereas the North Channel's velocities stayed above 0.56 m/s and reached a maximum of 1.33 m/s (Appendix 2).

Figure 4: Average daily discharge (cms) measured at Fair Oaks, and average daily water temperature (°C) measured at Watt Avenue on the lower American River during the 2013 season.



Note: Both sets of data were taken from the USGS website from 1/23/2013-6/1/2013. http://waterdata.usgs.gov/ca/nwis/uv

Catch

RST operations on the lower American River in 2013 captured a total of 268,862 fish belonging to five salmonid taxa and 13 non-salmonid taxa (Appendix 3). The salmonid taxa included SH, and fall-, late-fall-, winter-, and spring-run CS. An overview of the catch data is provided below.

Fall-run Chinook salmon

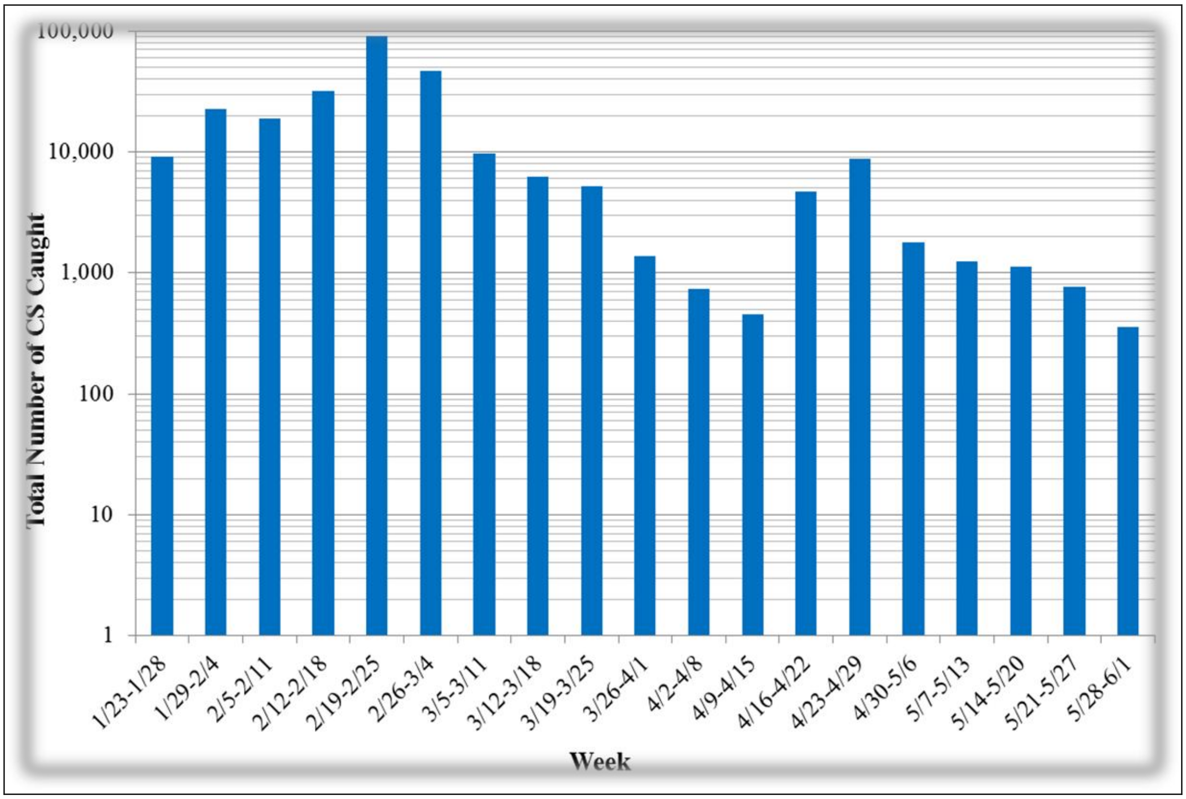
During the 2013 season, a total of 262,589 in-river origin, unmarked fall-run CS were caught (Table 2). Weekly CS catches peaked during three weeks between mid-February and early March. During those weeks, 32,157 CS were caught February 12-18; 90,188 CS were caught February 19-25; and 47,012 CS were caught February 26-March 4 (Figure 5).

Table 2: Fall-run Chinook salmon catch totals by life stage from the lower American River rotary screw traps during the 2013 field season.

Date	Yolk-sac fry	Fry	Parr	Silvery parr	Unassigned Lifestage	Total
1/23-1/28	10	1,257	0	0	7,877	9,144
1/29-2/4	12	1,788	0	0	20,939	22,739
2/5-2/11	1	1,397	0	0	17,484	18,882
2/12-2/18	2	1,898	0	0	30,257	32,157
2/19-2/25	1	1,798	1	0	88,388	90,188
2/26-3/4	0	1,889	2	0	45,121	47,012
3/5-3/11	1	1,440	11	0	8,181	9,633
3/12-3/18	2	1,629	57	0	4,580	6,268
3/19-3/25	0	1,212	190	0	3,804	5,206
3/26-4/1	1	352	650	3	374	1,380
4/2-4/8	0	122	597	17	0	736
4/9-4/15	0	11	316	123	1	451
4/16-4/22	0	3	344	1,041	3,334	4,722
4/23-4/29	0	0	149	1,273	7,360	8,782
4/30-5/6	0	0	74	1,227	489	1,790
5/7-5/13	0	0	36	1,080	138	1,254
5/14-5/20	0	0	25	1,020	71	1,116
5/21-5/27	0	0	11	678	85	774
5/28-6/1	0	0	3	349	3	355
Total	30	14,796	2,466	6,811	238,486	262,589
Percent	0.01%	5.63%	0.94%	2.59%	90.82%	100%

Note: Plus counted fall-run Chinook salmon and mortalities are included in the table.

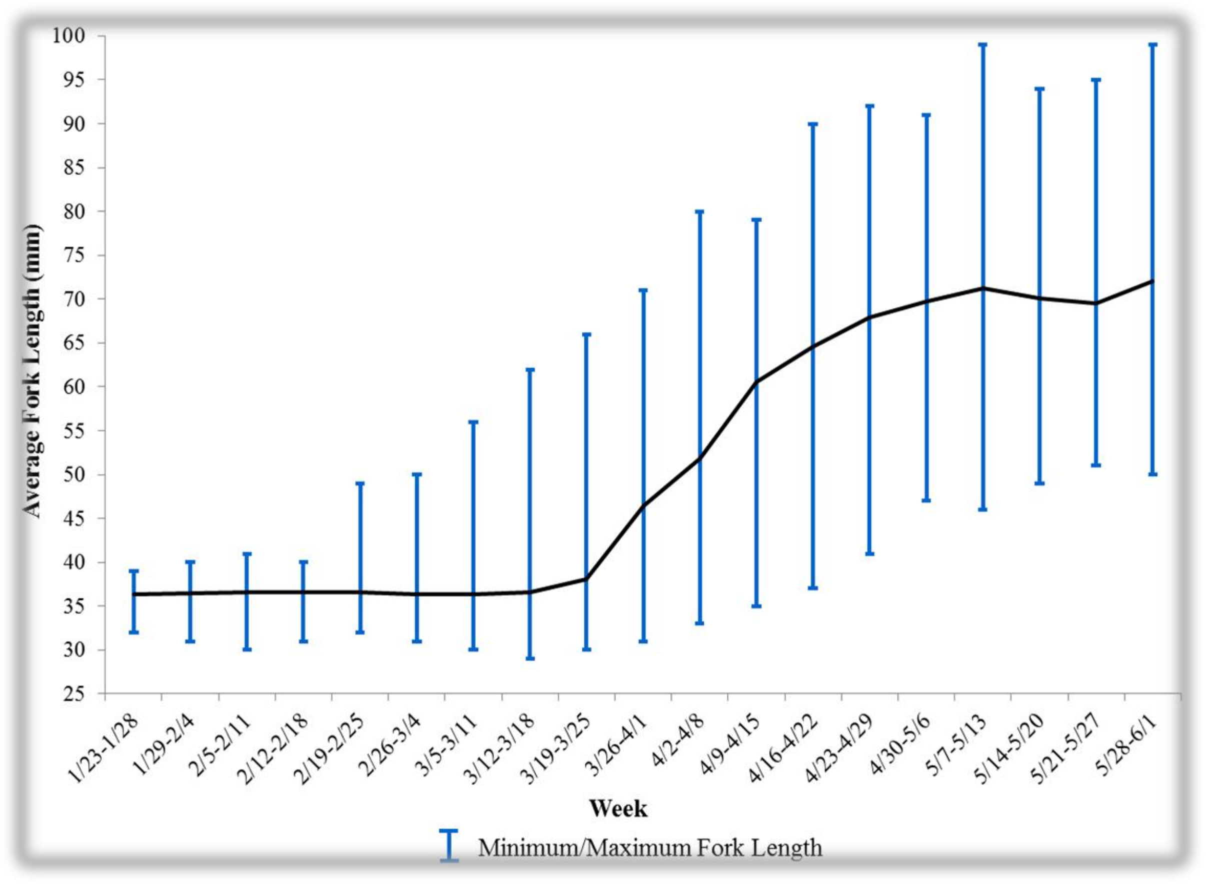
Figure 5: Weekly catch distribution of fall-run Chinook salmon captured from the lower American River rotary screw traps during the 2013 field season.



Note: Plus counted Chinook salmon and mortalities are included in the graph.

A total of 23,525 live fall-run CS were assessed for life stage and measured for fork length. Of those 23,525 fall-run CS, 0.13 percent were yolk-sac fry, 62.10 percent were fry, 9.81 percent were parr, and 27.96 percent were silvery parr. Only one CS smolt was observed and no adults were captured. The average fork length of juvenile fall-run CS during the first eight weeks of the field season was 36 mm. The lengths of measured juvenile salmon began to increase significantly after March 26th, and fall-run CS reached an average fork length of 71 mm during the week of May 7-13 (Figure 6). A total of 238,486 CS were plus count tallies that were only enumerated, i.e., those individuals were not assessed for life stage, measured, or weighed.

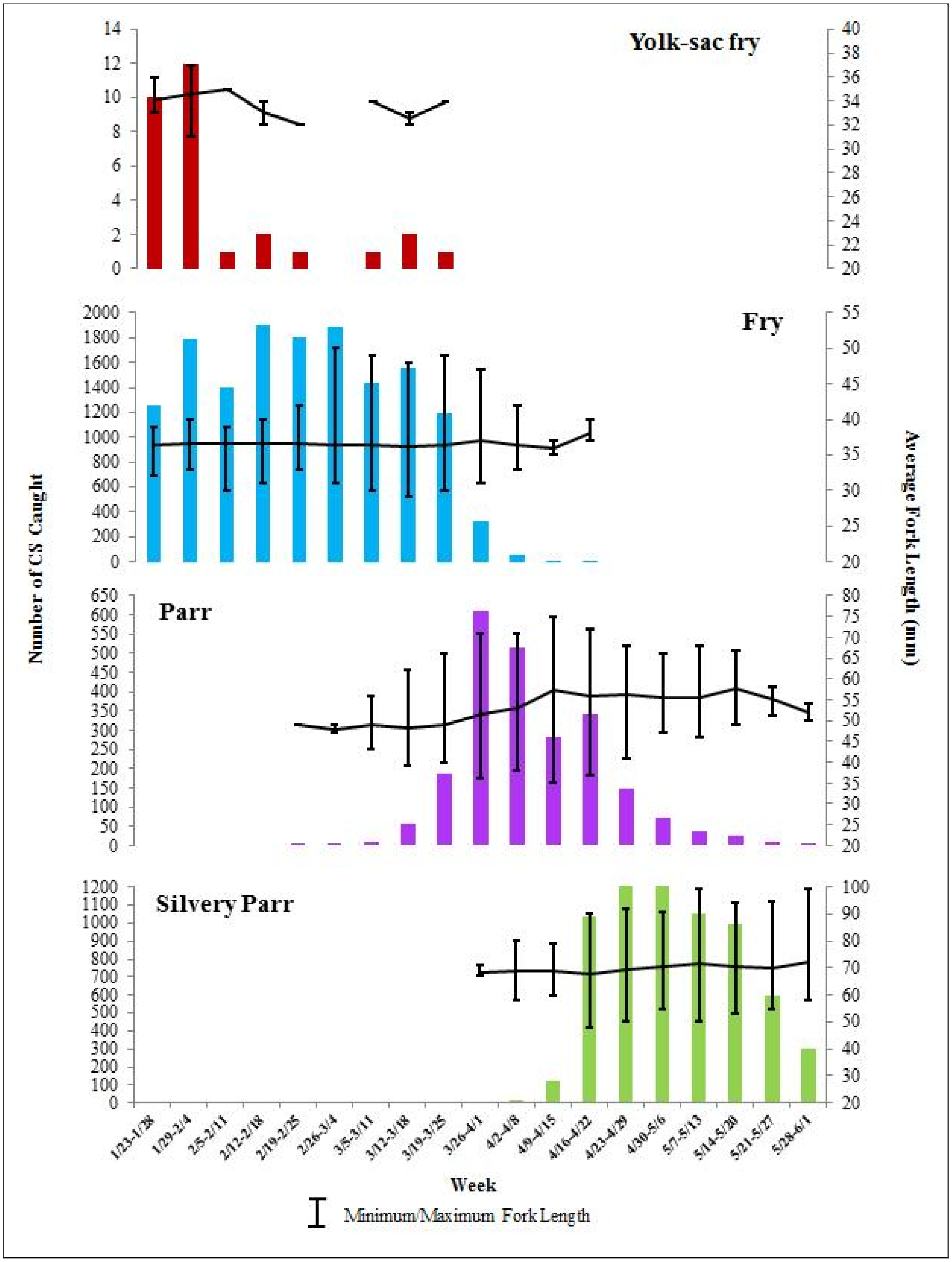
Figure 6: Average weekly fork length for fall-run Chinook salmon from the lower American River rotary screw traps during the 2013 field season.



Note: Plus counted fall-run Chinook salmon and mortalities are not included in the graph.

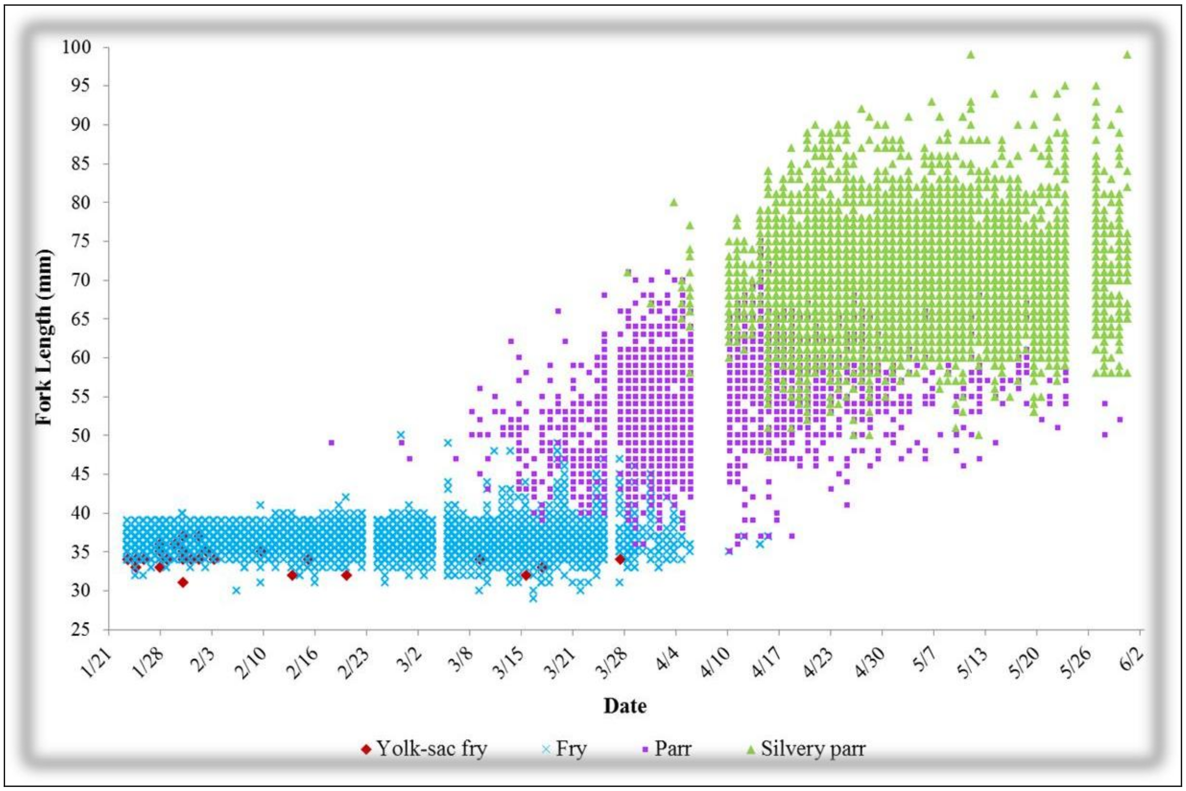
This season, we observed the emigration of yolk-sac and fry life stages from the beginning of the field season on January 24th through the end of March. The parr and silvery parr life stages of juvenile CS were observed between mid-March through the end of the field season on June 1st (Figure 7). The size distributions of the measured juvenile fall-run CS caught varied by life stage (Figure 8). Fork length distributions for fry were between 26 to 50 mm, and 76 percent of those individuals were between 36 to 40 mm. Yolk-sac fry distributions were between 31 to 40 mm, while parr size distributions ran from 36 to 75 mm with 75 percent of those fish being between 46 to 60 mm. Silvery parr distributions contained the widest range of sizes from 46 to 100 mm with 76 percent falling between 61 to 75 mm (Figure 9).

Figure 7: Total weekly fall-run Chinook salmon caught by life stage with average weekly fork lengths from the lower American River rotary screw traps during the 2013 field season.



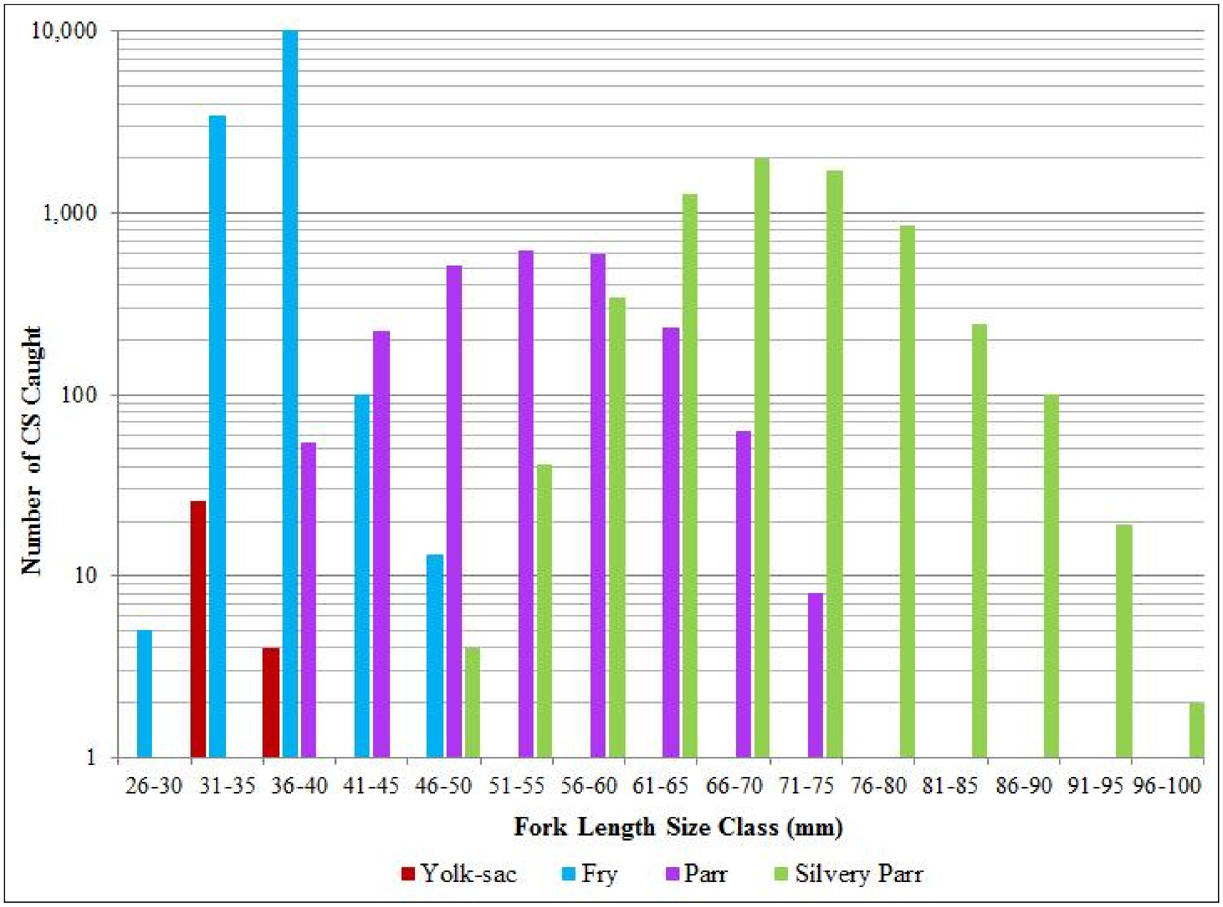
Note: Plus counted fall-run Chinook salmon and mortalities are not included in the graph.

Figure 8: Daily fall-run Chinook salmon fork length distributions collected from the lower American River rotary screw traps during the 2013 field season.



Note: Plus counted fall-run CS and mortalities are not included in the graph. No sampling occurred during the gaps between data points.

Figure 9: Total number of fall-run Chinook salmon caught in different size classes from the lower American River rotary screw traps during the 2013 field season.



Note: Plus counted fall-run Chinook salmon and mortalities are not included in the graph.

The number of juvenile fall-run CS that were estimated to have emigrated past the Watt Avenue trap site on the American River during the 2013 field season was 3,195,884 individuals, and the upper and lower 95 percent confidence intervals for that estimate were 2,455,477 and 4,066,275 fish, respectively.

Trap Efficiency

A total of 21,823 fall-run CS was used in 11 mark-recapture trials during the 2013 season. Of those released, 1,332 were recaptured. 18,659 CS were stained with BBY whole body stain, and 3,927 were marked on the anal fin using a photonic marking gun. The average combined trap efficiency for the 11 trials and the different trap combinations used during the trials was 6.85 percent (Table 3), and combined trap efficiency percentages for the 11 trials ranged between 2.70 and 11.16 percent. Higher trap efficiencies tended to be associated with periods with lower river discharges. Generally, the last recapture was observed by the 3rd day after a release. However, there were a few cases in which 1 to 4 CS were recaptured on the 4th, 5th, or 6th day after a release, and in one trial 1 CS was recaptured 13 days after a release. While there was no statistical analysis done to test for differences, the average size of released and recaptured fish never varied by more than two mm. Trap efficiency results can potentially be affected by variables such as size of CS, time of year, and river discharge.

Table 3: Combined trap efficiency data for mark and recapture trials conducted using rotary screw traps on the lower American River during the 2013 field season.

STAINING				RELEASE					RECAPTURES								Total Recaps	Average FL (mm) Recaps	Trap Efficiency	Flow[d]
Date	Origin of CS[a]	Mark Code[b]	Total Stained	Release ID Code[c]	Date	Time	Total Released	Average FL (mm) Released	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 13				
Feb-02	LAR	BBY	1,347	1	Feb-03	5:00 PM	1,334	37	31	4	1	0	0	0	0	0	36	37	2.70%	63.94
Feb-08	LAR	BBY	2,562	256	Feb-09	5:15 PM	2,481	37	63	6	4	0	0	0	0	0	73	36	2.94%	64.68
Feb-18	LAR	BBY	4,583	257	Feb-19	5:15 PM	4,441	36	308	12	3	3	0	1	0	0	327	37	7.36%	63.60
Feb-25	LAR	BBY	7,472	258	Feb-26	6:30 PM	7,237	37	364	17	2	2	1	0	0	0	386	37	5.33%	62.84
Mar-11	LAR	BBY	1,335	259	Mar-12	6:45 PM	1,177	36	69	4	2	0	0	0	0	0	75	36	6.37%	50.15
Mar-18	LAR	BBY	1,088	260	Mar-19	6:15 PM	1,020	37	47	4	0	0	0	0	0	0	51	36	5.00%	42.28
Apr-02	LAR	BBY	272	262	Apr-03	6:40 PM	215	50	11	4	2	0	0	0	0	0	17	50	7.91%	32.88
Apr-16	NFH	PO	1,000	263	Apr-17	7:15 PM	996	62	42	14	0	0	0	0	0	1	57	60	5.72%	28.66
Apr-30	NFH	PG	1,000	264	May-01	8:00 PM	998	71	64	4	0	0	1	0	0	0	69	72	6.91%	26.93
May-14	NFH	PP	1,000	265	May-15	8:15 PM	997	83	119	0	0	0	0	0	0	0	119	84	11.94%	26.33
May-28	NFH	PP	927	266	May-29	8:30 PM	927	96	122	0	0	0	0	0	0	0	122	96	13.16%	27.64

Note: All trials were achieved using fall-run Chinook salmon.

a: LAR = Lower American River (in-river produced), NFH = Nimbus Fish Hatchery.

b: BBY = Bismark brown Y, PO = Photonic orange, PG = Photonic green, PP = Photonic pink.

c: Release ID Code: This code is associated with the CAMP RST platform; a database used specifically for RST data.

d: Flow in cubic meters per second is a daily average discharge, at the USGS's American River Fair Oaks monitoring station, 21 rkm upstream of the American River RSTs on the day of the trap efficiency release.

Spring- and Winter-run Chinook salmon

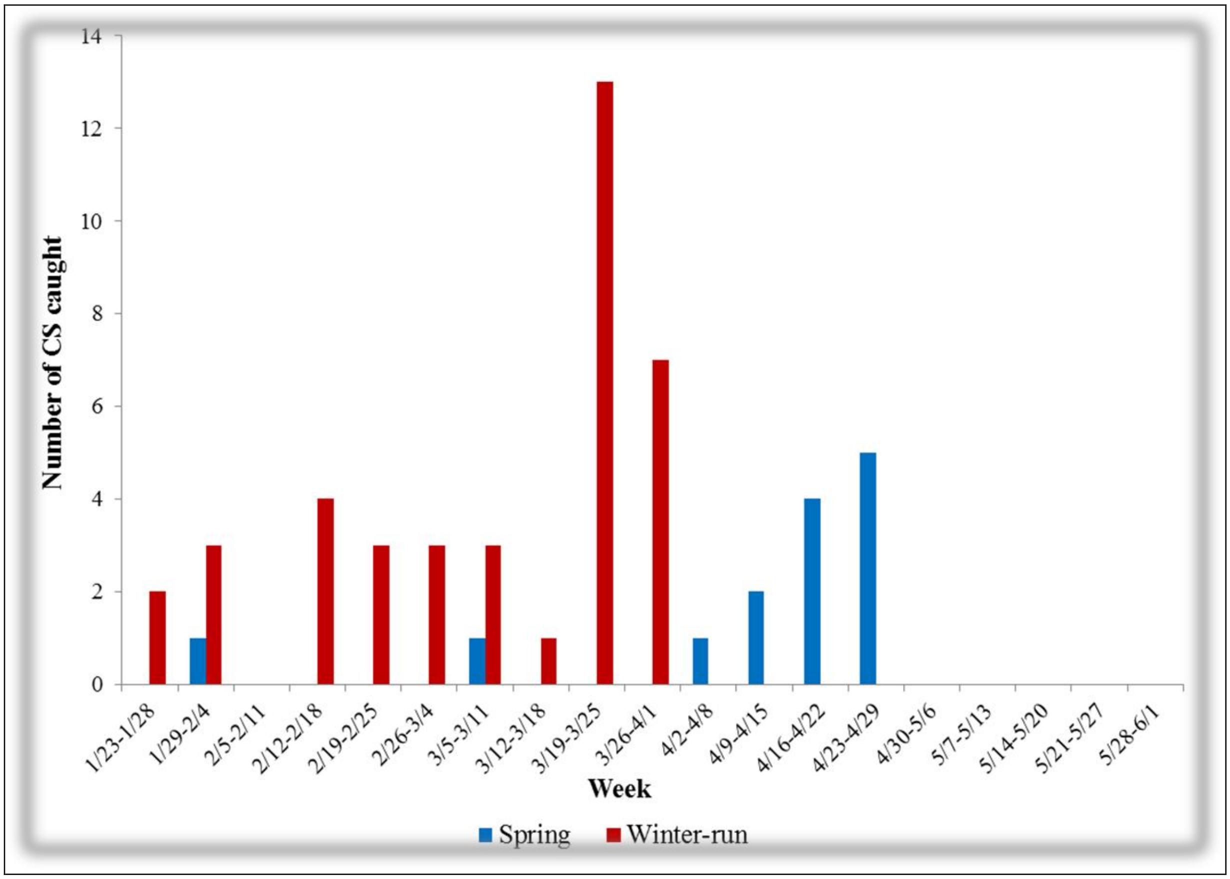
Thirty-nine winter-run, and 14 putative spring-run CS were also captured in 2013. The tentative assignment of 14 individuals to the spring-run category occurred because of challenges associated with conclusively determining those individuals were in fact spring-run CS.

Based on LAD criteria, 26 CS were collected and classified as winter-run CS from January 26th through March 30th. Analyses using fin clips and SNP genetic markers from those 26 CS also suggested those individuals were winter-run CS.

Ninety-three spring-run CS based on the LAD criteria were collected from February 3rd through May 12th. Of those 93, 13 turned out to be winter-run CS and 66 appeared to be fall-run CS according to the SNP genetic markers. Based on the modified LAD criteria described in the Methods section of this report, it appears that only 14 putative spring-run CS were caught during the 2013 season (Appendix 4).

In summary, a total of 39 winter-run CS were collected by the American River RSTs during the 2013 field season based on analyses using the SNP genetic markers, and 14 putative spring-run CS were caught based on the use of modified LAD criteria (Figure 10). Winter-run life stages included four parr, 34 silvery parr, and one smolt. Thirteen silvery parr life stages, and one parr life stage were observed for spring-run CS.

Figure 10: Spring- and winter-run Chinook salmon caught from the lower American River rotary screw traps during the 2013 field season.



Late-fall-run Chinook salmon

The first late-fall-run CS was caught on April 2nd and the last juvenile for this taxon was collected on May 7th. Altogether, 35 late-fall-run CS were caught during the 2013 field season. Ninety-four percent of the late-fall-run catch occurred in the month of April, and only two were observed in May. The fork length distribution for the 35 late-fall-run CS was between 27 to 37 mm.

Steelhead

A total of 2,206 in-river produced SH were captured in 2013 of which 1,840 were observed and assigned a life stage. Of those 1,840 SH, 0.71 percent were yolk-sac fry, 56.85 percent were fry, 42.12 percent were parr, 0.16 percent were silvery parr, 0.11 percent were smolts, and 0.05 percent were adults (Table 4). In addition, we captured 23 ad-clipped hatchery produced SH, three of which were adults and the other 20 were smolts.

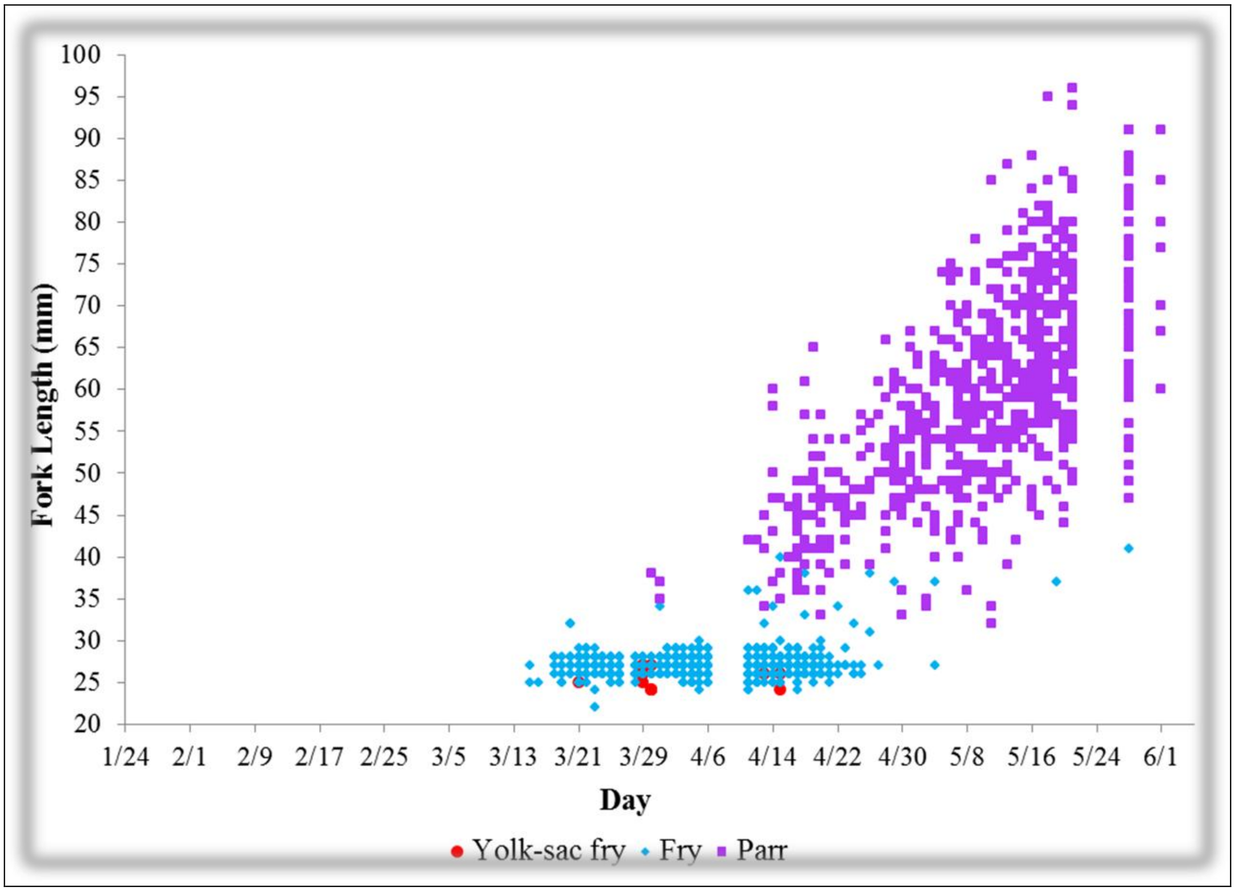
Table 4: Steelhead catch totals by life stage from the lower American River rotary screw traps during the 2013 field season.

Date	Yolk-sac fry	Fry	Parr	Silvery parr	Smolt	Adult	Unassigned Lifestage	Total
1/23-1/28	0	0	0	0	0	0	0	0
1/29-2/4	0	0	0	0	0	0	0	0
2/5-2/11	0	0	0	0	0	0	0	0
2/12-2/18	0	0	0	0	0	0	0	0
2/19-2/25	0	0	0	0	0	0	0	0
2/26-3/4	0	0	0	0	0	0	0	0
3/5-3/11	0	0	0	0	0	0	0	0
3/12-3/18	0	7	0	0	2	0	0	9
3/19-3/25	1	148	0	0	0	0	1	150
3/26-4/1	9	161	3	0	0	0	0	173
4/2-4/8	0	222	0	0	0	0	1	223
4/9-4/15	3	242	15	0	0	0	5	265
4/16-4/22	0	246	65	0	0	0	0	311
4/23-4/29	0	15	53	0	0	1	0	69
4/30-5/6	0	3	107	0	0	0	1	111
5/7-5/13	0	0	180	1	0	0	0	181
5/14-5/20	0	1	253	0	0	0	2	256
5/21-5/27	0	0	43	0	0	0	151	194
5/28-6/1	0	1	56	2	0	0	205	264
Total	13	1,046	775	3	2	1	366	2,206
Percent	0.59%	47.42%	35.13%	0.14%	0.09%	0.05%	16.59%	100%

Note: Plus counted steelhead and mortalities are included. The 23 ad-clipped (hatchery produced) SH are not included in the table.

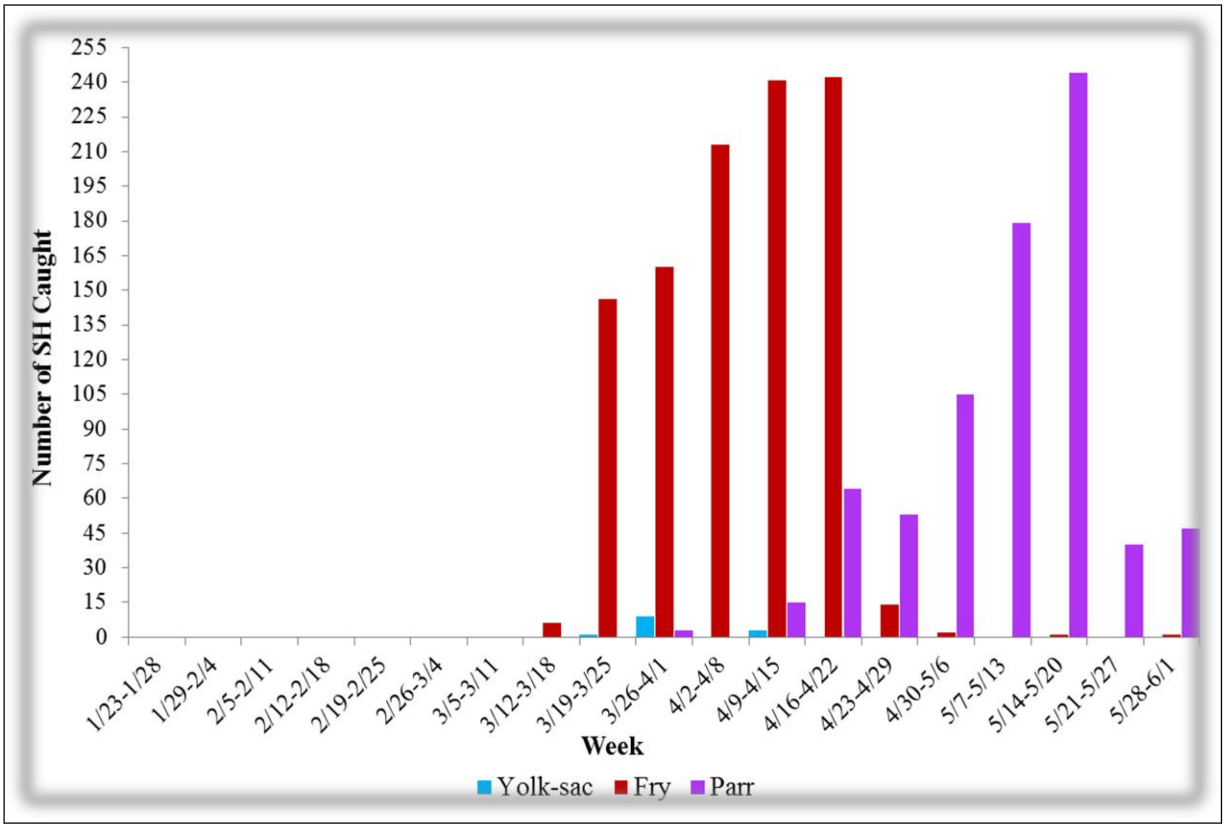
The majority of the SH captured were fry and parr. The fry life stage was first observed on March 15th, and throughout the field season their fork lengths ranged from 22 to 41 mm. The yolk-sac fry life stage was observed a little later on March 21st, and fork lengths for those fish ranged from 24 to 27 mm during the 2013 season. The first SH with a parr life stage was observed on March 30th, and their fork length distributions ranged from 32 to 112 mm (Figure 11) throughout the season. Ninety-eight percent (1,019) of the fry were caught between March 19th and April 22nd. Seventy percent (540) of the SH with a parr life stage were caught between April 30th and May 20th (Figure 12). Towards the end of the field season, water temperatures in the river began to reach 20°C. These temperatures, and the stress associated with handling, appeared to lead to increased levels of juvenile salmonid mortality. In order to reduce the stress from handling, the weighing and measuring of SH was terminated on May 22nd, and data collection for that species was limited to enumerating the catch.

Figure 11: Daily steelhead fork length distributions collected from the lower American River rotary screw traps during the 2013 field season.



Note: Plus counted steelhead and mortalities are not included in the graph. No sampling occurred during the gaps between data points.

Figure 12: Total weekly steelhead caught by life stage from the lower American River rotary screw traps during the 2013 field season.



Note: Plus counted steelhead and mortalities are not included in the graph.

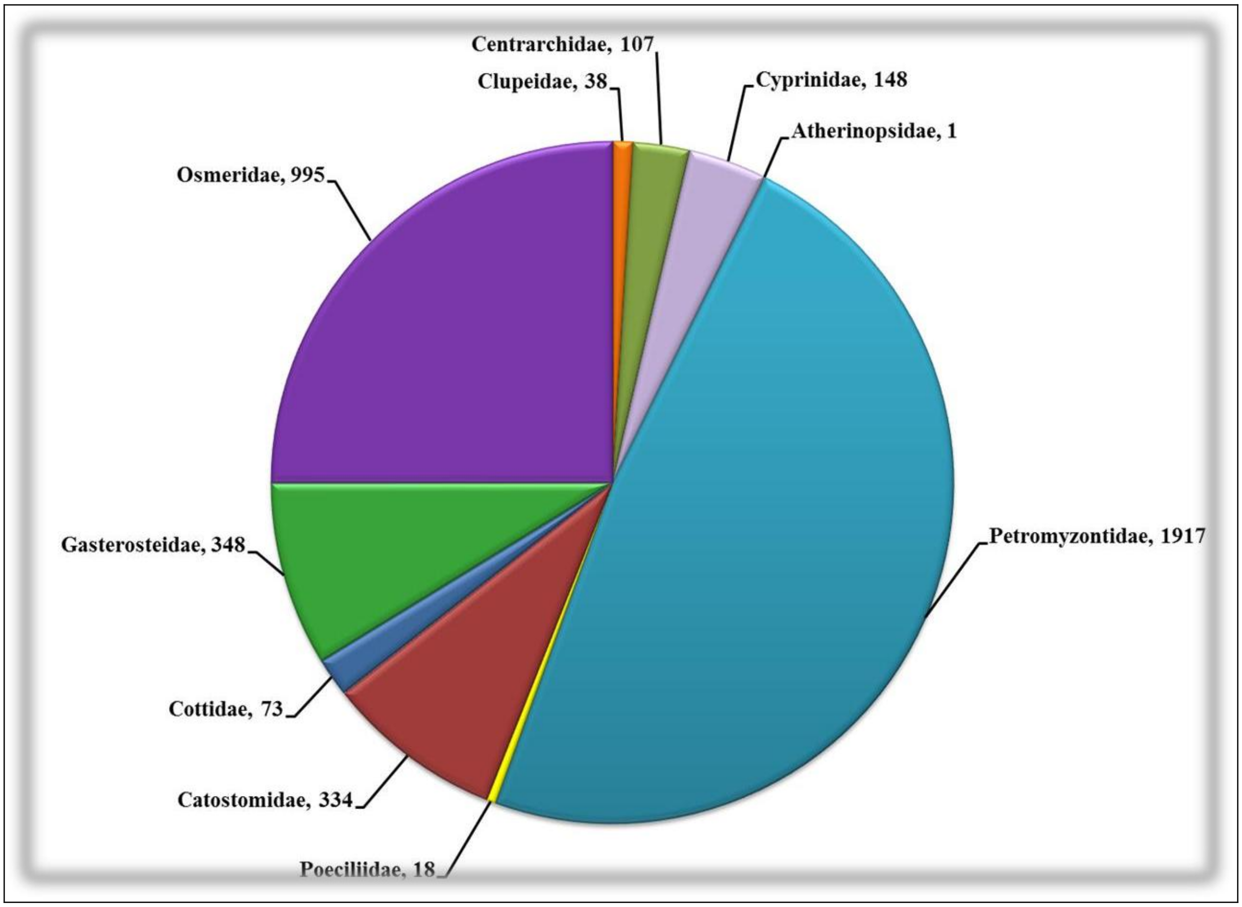
Non-salmonid Bi-catch

A total of 3,979 individuals belonging to 13 non-salmonid taxa were collected during the 2013 field season. Those taxa were: *Alosa sapidissima* (American Shad), *Lepomis macrochirus* (Bluegill), *Notemigonus crysoleucas* (Golden Shiner), *Carassius auratus* (Goldfish), *Menidia beryllina* (Inland Silverside), *Gambusia affinis* (Mosquitofish), *Entosphenus tridentatus* (Pacific Lamprey), *Lepomis microlophus* (Redear Sunfish), *Lampetra ayresii* (River Lamprey), *Catostomus occidentalis* (Sacramento Sucker), *Dorosoma petenense* (Threadfin Shad), *Gasterosteus aculeatus* (Threespine Stickleback), and *Hypomesus nipponensis* (Wakasagi or Japanese Smelt) (Figure 13). To view the family names of the above mentioned taxa please see Appendix 3 of this report.

Of those 3,979 total individuals caught, 447 of them were not identifiable to the species level. Therefore, those individuals were classified according to the following family names: Centrarchidae (unidentified juvenile bass), Petromyzontidae (unidentified lamprey ammocoetes), Cyprinidae (unidentified minnows), Cottidae (unidentified Sculpins), and Centrarchidae (unidentified juvenile sunfish) (Appendix 3). In addition, around mid-April the crew observed translucent juvenile fish that were < 20 mm in length that could not be identified to a family taxonomic level.

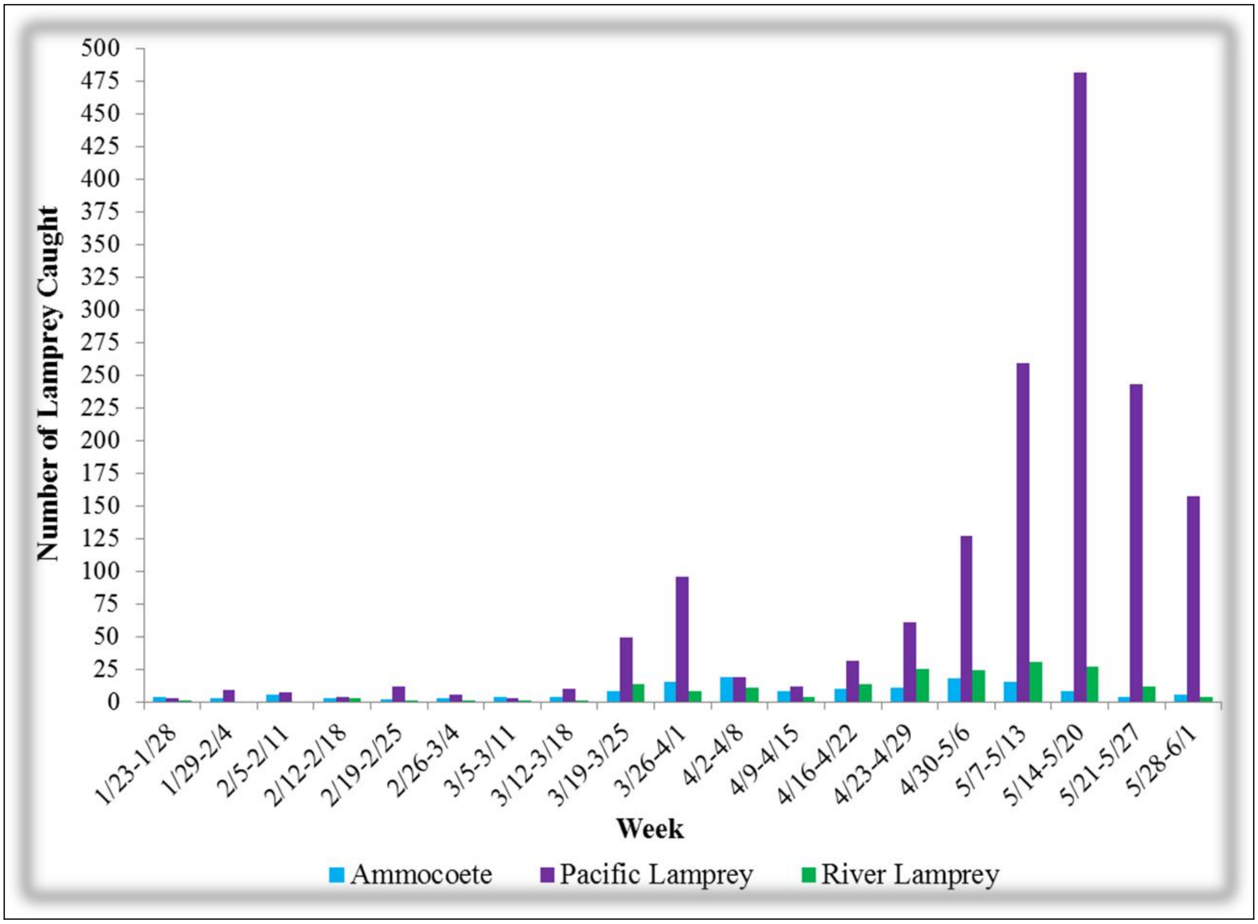
Of the 3,979 non-salmonids caught, 1,917 (i.e., 48 percent of all the non-salmonids) were lamprey. Of those individuals, 1,589 (83 percent) were Pacific lamprey, 179 (9 percent) were River lamprey, and 149 (8 percent) were lamprey ammocoetes. Lampreys were caught throughout the field season, and the peak catch occurred during the week of May 14-20 when 27 percent of the season's lamprey were captured (Figure 14).

Figure 13: Total non-salmonid bi-catch collected from rotary screw traps in the lower American River during the 2013 field season.



Note: The total number of Chinook salmon caught (262,677) and the total number of in-river produced steelhead caught (2,206) are not included in the pie chart above.

Figure 14: Total lamprey caught by week from the lower American River rotary screw traps during the 2013 field season.



Discussion

The 2013 American River trapping season did not encompass the start or end of the juvenile CS migration period because juvenile salmon were present in the river when the field season began and when trapping efforts were terminated. The period of emigration when trapping did not occur is believed to be a small percentage of the overall juvenile CS passage because relatively small numbers of salmon were caught at the beginning and end of the trapping season. The peak of CS migration was observed and RST efforts would have continued through the end of June had it not been for increasing water temperatures that could elevate stress levels in captured threatened and endangered salmonids.

Out of the 129 day field season, staff were available to operate the traps without problems for 120 days. For a short period of nine intermittent days, trapping efforts were discontinued as endangered species take issues were addressed. Nevertheless, the 2013 RST season on the lower

American River produced a high quality set of data because significant logistical or environmental issues did not hinder the accuracy of the data collected.

In previous years when sampling occurred on the lower American River under the CDFW, that agency's findings suggest that the proportion of juvenile CS life stages emigrating down the American River was variable from year to year (Snider et al. 1997). This is contrary to what Hoar (1976) speculated in his paper "Smolt Transformation: Evolution, Behavior, and Physiology." Hoar hypothesized that characteristics of juvenile salmon transitioning from life stages, such as turning silvery, were strongly dependent on size. When comparing fork length distributions to life stage characteristics they can vary from river to river, and from year to year when comparing RST sampling across the Central Valley. Our parr and silvery parr life stages varied over a wide range of fork length sizes (silvery parr were as small as 48 mm while parr were as big as 75 mm). In spite of this, life stage classification based on morphological features may be perceived in different ways by different crew members and may be influenced by surrounding light conditions.

An egg production estimate for fall-run CS was developed using data from an adult salmon carcass survey on the American River between October 2012 and January 2013. Based on that survey, 34,900 in-river adult fall-run CS were estimated to occur in that river (Phillips and Helstab 2013). Using the data from that survey, an estimate was developed of the projected number of eggs laid in the lower American River during the 2012-2013 spawning season. Appendix 6 displays the total number of female carcasses collected and the estimated expanded number of females present during the 2012-2013 spawning season; an expanded adjusted number of females was developed to account for the fact that subsampling of salmon occurred during some, but not all, of the escapement surveys and this creates minor differences in the percent values presented in this report and the Phillips and Helstab (2013) report. Appendix 7 illustrates the number of females (grilses and adults combined) that spawned or partially spawned, and also provides the percentage of total females that are assumed to have contributed to egg production in the American River. Appendix 8 displays values that were used to estimate the total number of eggs produced in the American River during the 2012-2013 spawning season. Using these values, it is estimated that 93,537,512 fall-run CS eggs were laid in the American River during the 2012-2013 spawning season. Integrating these data with the juvenile salmon production estimates described in this report suggests that 5,472 fall-run CS eggs were produced per female (93,537,512 eggs / 17,095 spawned or partially spawned females), and that the survival between the fry/parr/silvery parr and egg life stages was 3.42 percent (3,195,884 fry/parr/silvery parr produced / 93,537,512 eggs); a survival value that included the smolt life stage was not calculated because no smolt CS were captured during the 2013 field season.

CDFW annual reports provide juvenile SH catch data for seven years between 1994 and 2001 when the agency operated the RSTs below the Watt Avenue Bridge. During that time frame, CDFW staff captured 23 - 145 juvenile SH each year, averaging about 78 juvenile SH a year. In contrast, trapping efforts with RSTs at the same location in 2013 resulted in the capture of 2,206 juvenile SH (not including the 23 ad-clipped SH). The causal factor(s) for the markedly greater catch of juvenile SH in 2013 is unknown, but might be explained by differences in trapping methods, gear size and trap number, gravel augmentation activities that have enhanced the production of juvenile SH in the American River, or the unusual presence of SH redds that produced large numbers of fry in close proximity to the RSTs in 2013. In regard to the presence of SH redds near the RSTs, Bureau of Reclamation (BOR) staff conducted an aerial redd survey on February 13, 2013 and they noted five SH redds 24 - 44 meters upstream of the Watt Avenue Bridge (Hannon 2013). On February 21, 2013, BOR staff conducted an on the ground SH redd survey and they observed seven SH redds ~160 meters upstream of the South Channel trap location (Hannon 2013). Four of those redds were classified as test redds, one was classified as having multiple test redds, one was classified as having an adult SH on it, and one was classified as a new, still clear redd.

Spring- and winter-run CS are threatened and endangered species, respectively, under the Federal and California Endangered Species acts. We collected fin-clip samples to send to a geneticist to analyze the DNA of CS that keyed out to be spring- or winter-run CS according to the LAD criteria. In so doing, we discovered that all the CS that were classified as winter-run CS according to the LAD criteria were also assigned as winter-run salmon using the genetic markers. We also discovered that of the 62 putative spring-run that were fin clipped and classified as such using the LAD criteria in 2013, 37 (60 percent) were likely to be fall-run CS based on the SNP genetic markers or the modified LAD criteria, 13 (21 percent) were winter-run CS according to the SNP genetic markers, and 12 (19 percent) were likely to be spring-run CS based on the SNP genetic markers or the modified LAD criteria. These data collectively suggest that the application of the LAD on the American River in 2013 were of limited value in correctly identifying spring-run CS.

One theory why the LAD and genetic-based salmon run assignments for spring-run salmon did not align in all cases may relate to the Feather River Fish Hatchery's production of fall- and spring-run CS (Cavallo et al. 2009). In the past, fish originating in this watershed may have experienced some level of hybridization that is now reflected in the morphology or genetics of Central Valley CS. Additionally, we note that relatively small genetic differences between the Feather River's naturally spawning fall-run and hatchery produced spring-run CS were found in a study by et al. (2008), and the similarities in the genetics of salmon from the Feather River Fish Hatchery may result in salmon that have morphological features that make conclusive run assignments problematic. Furthermore, in November and December of 2012 flows increased substantially on the Sacramento River to the point that the main river system backed up the natural outflow of the American River. As this happened, CS fall- and spring-run hybrid juveniles that originated in other rivers (e.g., Feather River) may have received an environmental cue to swim up the American River instead of migrating out to the Sacramento-San Joaquin Delta. Additionally, according to the 2012-2013 escapement survey conducted on the lower American River, only fall-run CS carcasses were retrieved, however, no genetic testing was done and the CWTs retrieved from the hatchery fish collected have yet to be read and documented for results (Phillips and Helstab 2013). This information leads to the preliminary indication that spring-run CS did not spawn in the American River during the 2013 season, and we did not therefore develop passage estimates for spring-run CS. We also did not develop production estimates for juvenile winter-run CS that were caught in the American River RSTs in 2013 because we believe those individuals originated in the Sacramento River mainstem. That inference is based on data in a report by Maslin et al. (1998) which demonstrates that winter-run CS from the Sacramento River mainstem will occasionally stray into adjoining tributaries.

Each of the factors described in the paragraph above create difficulty in successfully identifying spring-run CS on a real time basis as RST operations occur on the American River. That difficulty can exaggerate the perceived numbers of spring-run CS caught, create the perception that the permitted take limits for that taxon have been exceeded when they probably weren't, and cause trap operations to be suspended as field crews consult with NMFS staff. The data collected during the 2013 RST field season on the American River suggest that for that watershed, an accurate accounting of the number of spring-run CS caught during a field season may not be feasible until that field season is complete and genetics results and growth analyses for the putative spring-run CS become available. This statement is based on the observation that of the 91 putative spring-run CS that were classified with the LAD criteria during the 2013 field season, only 14 were determined to likely be spring-run salmon based on genetics and juvenile salmon growth analyses after the field season.

In order to determine if the efforts made by AFRP and others to increase the abundance of CS and SH on the lower American River have been successful, additional monitoring of juvenile salmonid emigration is required. The 2013 data coupled with future season's data will provide crucial information to better understand and improve conditions for CS and SH on the lower American River.

Acknowledgements

The funding for this project was provided by the USFWS CAMP. A special thanks goes to the staff at USFWS CAMP including Doug Threloff for technical support, assistance in the field, and for all the help he gave for data analysis and training. We would also like to thank the Pacific States Marine Fisheries Commission staff Stan Allen for management support and Amy Roberts for purchasing and other administrative support. Connie Shannon for creating Access queries that made analyzing RST data simpler. Special recognition goes to our crew members

Nathan Cullen and Wes Hartman for their hard work and assistance in collecting the data for this report. We would also like to thank the staff at the CDFW and their collaborative effort this season. A special thank you goes to Rob Titus and Mike Brown for their technical support, Jeanine Phillips for her willingness to collaborate and share data regarding the fall-run CS escapement survey, as well as George Edwards for allowing us to use his warehouse for storage, and the staff in the Region 2 office for providing us with an additional RST to operate for our field season. Furthermore, we would like to thank Dan Kratville, Lea Koerber, and the scientific aides in the CDFW's Tissue Archive Lab for the MOU to collect our CS fin-clip samples, in addition to their guidance in retrieving our fin-clip samples for further genetic analyses. Our gratitude is extended to the staff at the Abernathy Fish Technology Center, Christian Smith and Jennifer Von Bargen for their assistance with genetic analyses of our spring- and winter-run CS fin-clips. We would also like to say thank you to the Nimbus Fish Hatchery staff Paula Hoover and Gary Novak for setting aside 4,000 fall-run CS for our project to use in our efficiency trials to produce passage estimates. We would like to extend our appreciation to Amanda Cranford from the National Marine Fisheries Service for assisting with our Federal take permit (Permit Number 17428), and her willingness to quickly respond to our unpredictable field season and extending our take on listed species. Lastly, we would like to say thank you to the staff at the Stockton USFWS office for storing our RSTs and equipment.

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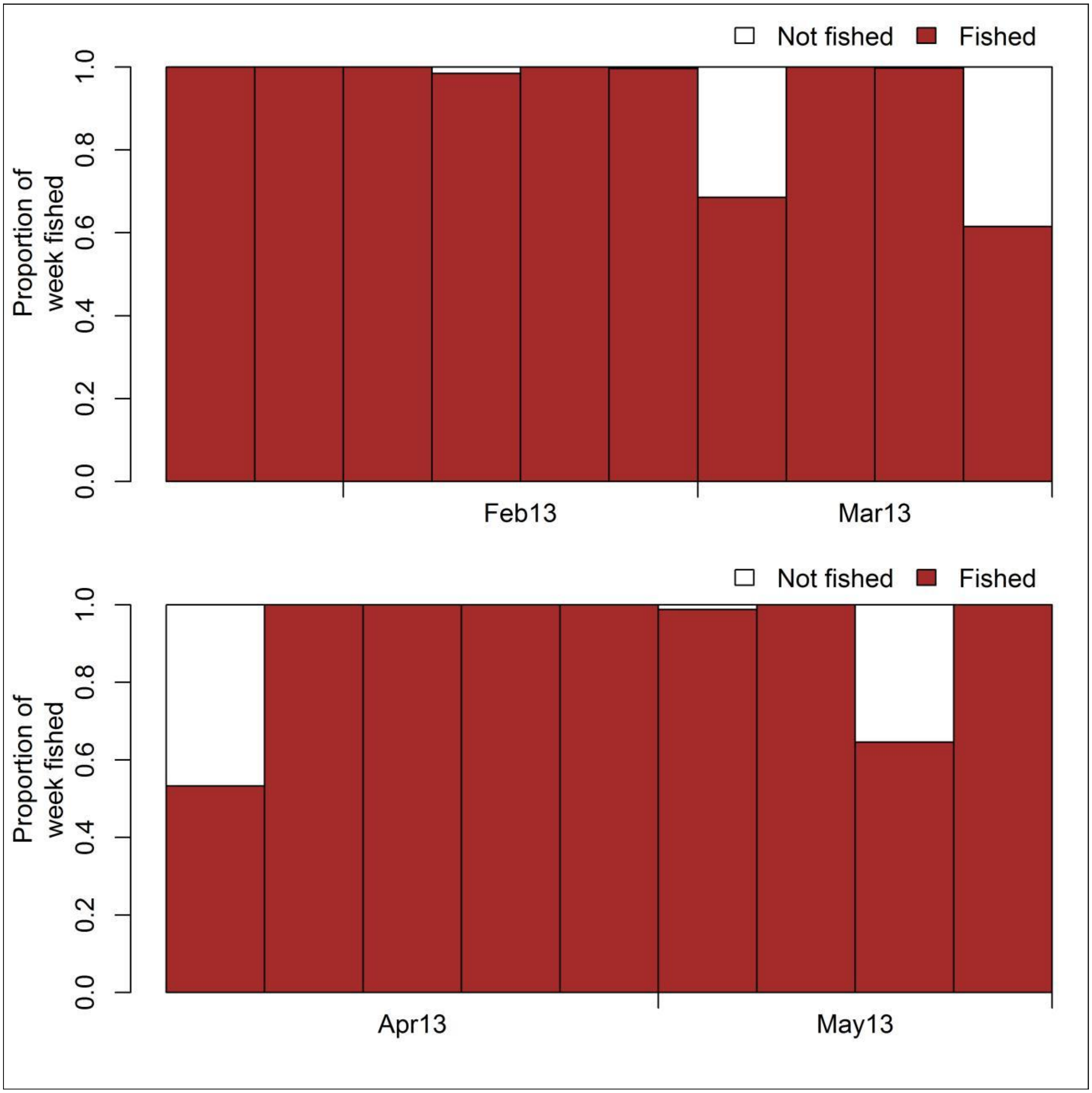
Appendix 1: Rotary screw trap weekly sampling effort from both the North and South Channels during the 2013 field season on the lower American River.



Appendix 2: Weekly environmental conditions on the lower American River during the 2013 field season.

Week	Water Temperature °C			Discharge (CFS)			DO (mg/L)			Turbidity (NTU)		
	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
1/23-1/28	8.2	6.9	9.4	2,234	2,080	2,530	14.44	12.30	18.85	1.54	1.31	1.91
1/29-2/4	8.1	6.9	9.7	2,252	1,940	2,320	12.42	10.46	14.80	1.44	0.88	2.04
2/5-2/11	8.5	7.1	9.6	2,288	2,210	2,320	10.55	9.70	11.80	1.28	1.11	1.68
2/12-2/18	9.1	7.6	10.3	2,249	2,180	2,290	10.98	10.32	12.11	1.08	0.80	1.48
2/19-2/25	8.9	7.3	10.4	2,228	1,420	2,820	10.97	10.25	11.65	1.06	0.69	1.38
2/26-3/4	9.9	7.8	11.5	2,210	2,090	2,440	11.12	10.18	12.84	0.91	0.71	1.37
3/5-3/11	10.3	8.6	12.1	1,830	1,640	2,280	11.70	11.00	12.55	1.00	0.68	1.42
3/12-3/18	11.4	9.6	12.9	1,754	1,430	1,900	11.96	10.74	13.08	0.85	0.66	1.43
3/19-3/25	11.7	10.2	13.4	1,293	1,100	1,740	11.26	10.24	12.34	0.87	0.57	1.41
3/26-4/1	13.3	11.4	14.6	1,150	1,030	1,300	10.46	9.61	11.15	1.57	0.74	4.21
4/2-4/8	13.2	11.6	14.9	1,234	1,130	1,810	10.10	9.62	10.57	1.38	1.01	2.18
4/9-4/15	14.4	12.0	16.2	1,258	1,220	1,300	10.02	9.50	10.29	1.62	0.84	2.13
4/16-4/22	15.1	11.9	17.5	1,034	942	1,260	9.54	7.78	10.67	1.32	0.80	1.67
4/23-4/29	16.7	14.8	18.2	1,125	942	1,230	9.71	8.76	10.24	1.70	1.13	2.08
4/30-5/6	17.4	14.8	18.8	974	942	1,120	8.60*	6.87	9.85	1.67	1.14	2.48
5/7-5/13	18.9	16.9	20.5	933	921	1,000	10.11	8.46	11.12	1.18	0.72	1.62
5/14-5/20	19.1	17.2	21.1	929	921	952	10.79	10.53	11.07	1.31	0.75	1.62
5/21-5/27	18.7	16.9	20.7	931	911	952	10.81	10.44	11.24	1.51	1.28	1.68
5/28-6/1	19.6	17.4	21.6	1,063	911	1,500	10.72	10.42	10.96	1.68	1.24	2.39

Note: The USGS website provides the discharge and temperature data by day in 15 minute intervals. To calculate the averages by week, the 15 minute intervals were first averaged by day, and then the days were averaged by the seven day week indicated by the "Week" column in the table above. The min and max values for the discharge and temperature data are the highest and lowest values recorded for the week. Dissolved oxygen and turbidity were calculated weekly averages from daily values gathered from crew members in the field. Dissolved oxygen and turbidity min and max values are reflective of the minimum and maximum daily value gathered during the week defined by the "Week" column in the table above.

*Technical issues with the DO meter gave lower than normal readings and skewed the average for the week of 4/30/2013 – 5/6/2013.

Appendix 3: Complete list of species caught during the 2013 season using rotary screw traps on the lower American River.

Common Name	Family Name	Species Name	Total Number Caught
American Shad	Clupeidae	*Alosa sapidissima*	34
Bluegill	Centrarchidae	*Lepomis macrochirus*	12
Chinook Salmon	Salmonidae	*Oncorhynchus tshawytscha*	262,677
Golden Shiner	Cyprinidae	*Notemigonus crysoleucas*	16
Goldfish	Cyprinidae	*Carassius auratus*	1
Inland Silverside	Atherinopsidae	*Menidia beryllina*	1
Mosquitofish	Poeciliidae	*Gambusia affinis*	18
Pacific Lamprey	Petromyzontidae	*Entosphenus tridentatus*	1,589
Redear Sunfish	Centrarchidae	*Lepomis microlophus*	1
River Lamprey	Petromyzontidae	*Lampetra ayresii*	179
Sacramento Sucker	Catostomidae	*Catostomus occidentalis*	334
Steelhead	Salmonidae	*Oncorhynchus mykiss*	2,206
Threadfin Shad	Clupeidae	*Dorosoma petenense*	4
Threespine Stickleback	Gasterosteidae	*Gasterosteus aculeatus*	348
Wakasagi	Osmeridae	*Hypomesus nipponensis*	995
Unidentified Bass	Centrarchidae		92
Unidentified Lamprey Ammocoetes	Petromyzontidae		149
Unidentified Minnows	Cyprinidae		131
Unidentified Sculpins	Cottidae		73
Unidentified Sunfish	Centrarchidae		2
	Total Cumulative Fish Caught for the 2013 Season:		268,862

Note: The total number caught includes mortalities. The total number of SH does not include the 23 ad-clipped, hatchery produced caught.

Appendix 4: Spring- and winter-run Chinook salmon caught during the 2013 season on the lower American River using rotary screw traps.

Capture Date	Sample #	FL (mm)	LAD Run Assignment	SNP Run Assignment	SNP Probability	Genetic Run Assignment	Final Run Assignment	Rational For Final Run Assignment
Jan-26	2709-001	100	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Jan-28	2709-002	75	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Jan-29	2709-003	67	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Jan-30	2709-004	84	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-01	2709-005	89	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-12	2709-006	78	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-12	2709-007	78	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-12	2709-008	94	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-16	2709-009	85	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-19	2709-078	60	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-22	2709-010	84	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-23	2709-073	71	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-26	2709-011	83	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-26	2709-012	88	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-26	2709-071	77	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-07	2709-013	95	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-09	2709-064	81	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-11	2709-063	82	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-13	2709-062	83	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-21	2709-014	103	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-21	2709-061	84	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-22	2709-015	103	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-22	2709-016	111	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-22	2709-027	87	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-24	2709-017	101	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics

Capture Date	Sample #	FL (mm)	LAD Run Assignment	SNP Run Assignment	SNP Probability	Genetic Run Assignment	Final Run Assignment	Rational For Final Run Assignment
Mar-24	2709-018	128	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-24	2709-019	100	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-24	2709-020	94	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-24	2709-028	90	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-24	2709-029	90	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-25	2709-021	120	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-25	2709-060	84	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-26	2709-022	108	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-26	2709-023	123	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-28	2709-024	115	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-28	2709-025	110	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-28	2709-030	94	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-29	2709-031	94	Spring-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Mar-30	2709-026	110	Winter-run	Winter-run	1.000	Winter-run	Winter-run	genetics
Feb-03	2709-079	59	Spring-run	Spring-run	0.899	No Call	Spring-run	genetics, >6 mm LAD boundary ▲
Mar-07	2709-065	63	Spring-run	Fall-run	0.879	No Call	Spring-run	difference from fall-run fork lengths
Apr-05	2709-032	92	Spring-run	Fall-run	0.991	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-15	2709-033	88	Spring-run	Fall-run	0.977	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-15	2709-034	94	Spring-run	Fall-run	1.000	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-17	2709-035	90	Spring-run	Fall-run	0.988	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-18	2709-036	90	Spring-run	Fall-run	1.000	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-19	None*	89	Spring-run	None	None	None	Spring-run	>6 mm LAD boundary ▲
Apr-21	None*	93	Spring-run	None	None	None	Spring-run	>6 mm LAD boundary ▲
Apr-23	2709-098	92	Spring-run	Fall-run	1.000	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-24	2709-082	98	Spring-run	Fall-run	1.000	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-24	2709-084	92	Spring-run	Fall-run	0.997	Fall-run	Spring-run	>6 mm LAD boundary ▲
Apr-24	2709-085	94	Spring-run	Fall-run	1.000	Fall-run	Spring-run	>6 mm LAD boundary ▲

Capture Date	Sample #	FL (mm)	LAD Run Assignment	SNP Run Assignment	SNP Probability	Genetic Run Assignment	Final Run Assignment	Rational For Final Run Assignment
Apr-24	2709-087	94	Spring-run	Fall-run	0.995	Fall-run	Spring-run	>6 mm LAD boundary ▲

Sample #: refer to a unique number assigned by field staff, and that allowed the tracking of individual fish samples.
FL (mm): represents the fork length in millimeters of the sampled salmon.
LAD run assignment: represents the CS run assignment based on the length-at-date run assignment methodology developed by Greene (1992).
SNP Run Assignment: genetic run with the highest probability based on single-nucleotide polymorphism (SNP) markers.
SNP Probability: probability associated with the SNP CS run assignment.
Genetic Run Assignment: if the SNP Probability is ≥ 0.900, then the Genetic Run Assignment is the same as the SNP Run Assignment. If the SNP Probability is < 0.900, then the Genetic Run Assignment is the classified as a “No Call” because the SNP markers yield equivocal results.
Final Run Assignment: the final run given to CS for the purposes of this report. Because the SNP markers cannot always conclusively identify a spring-run CS, modified LAD criteria were sometimes used to assign some CS to the spring-run category.
Rational For Final Run Assignment: provides the basis for making the Final Run Assignment.

Note: Fin clip samples were not taken for the 2 fish without sample numbers; therefore genetic information for those fish is unavailable. For the purposes of this report they were assigned race designations using the reason stated in the Rational For Final Run Assignment column.

Appendix 5: Points of interest on the lower American River during the 2013 field season.

Point of Interest	Significance	Operator	River Miles (rkm)
Folsom Dam	Constructed 1956; Power Generation, flood control, water supply, recreation.	U.S. Bureau of Reclamation	29.4 (47.3)
Nimbus Dam	Constructed 1955; Power Generation, flood control, water supply, recreation.	U.S. Bureau of Reclamation	22.3 (35.8)
Nimbus Fish Hatchery	Chinook salmon and Steelhead Hatchery; Fish ladder, weir.	California Department of Fish and Wildlife	22.2 (35.7)
American River at Fair Oaks	Discharge gauging station	U.S. Geological Survey	22.1 (35.6)
Sailor Bar	Habitat improvement; Gravel augmentation		~22 (35.4)
Lower Sunrise	Habitat improvement; Gravel augmentation		~19 (30.6)
Sacramento Bar	Habitat improvement; Gravel augmentation		~18 (29)
La Riviera storm water outflow	Release site for trap efficiency mark-recapture trials		9.7 (15.6)
Watt Avenue bridge	Temperatuer monitoring station	U.S. Geological Survey	9.2 (14.8)
North channel RST below Watt Avenue	RST site for monitoring juvenile salmonid abundance and outmigration		9 (14.5)
South channel RST below Watt Avenue	RST site for monitoring juvenile salmonid abundance and outmigration		8.8 (14.2)
Howe Avenue boat launch	Hatchery release site for Chinook salmon and steelhead		7.8 (12.6)
Jabboom St. bridge	Hatchery release site for Chinook salmon and steelhead		0.2 (0.3)
Mouth of American River	American-Sacramento River Confluence		0

Appendix 6: Total number of fall-run Chinook salmon carcasses by age class and sex from the lower American River during the 2012-2013 escapement survey.

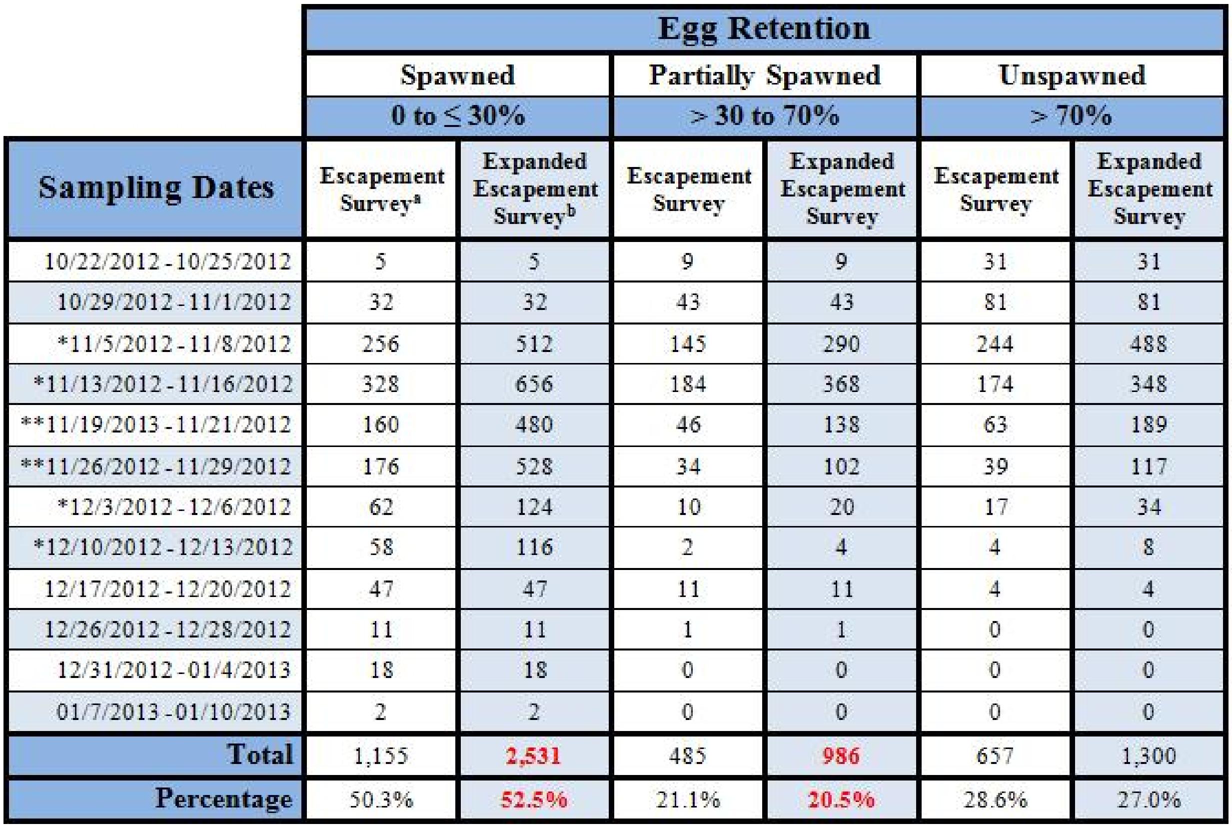
		Escapement Survey[a]		Expanded Escapement Survey[b]		Escapement Survey		Expanded Escapement Survey		Expanded Escapement Survey	Escapement Survey	Expanded Escapement Survey
Survey Period	**Sampling Proportion**	**Female Grilse**	**Male Grilse**	**Female Grilse**	**Male Grilse**	**Female Adult**	**Male Adult**	**Female Adult**	**Male Adult**	**Total Females[c]**	**Total Salmon**	**Total Salmon**
10/22/2012 -10/25/2012	Every Carcass	0	3	0	3	51	12	51	12	51	66	66
10/29/2012 - 11/1/2012	Every Carcass	4	10	4	10	164	53	164	53	168	231	231
11/5/2012 - 11/8/2012	Every 2nd Carcass	3	45	6	90	657	197	1,314	394	1,320	902	1,804
11/13/2012 - 11/16/2012	Every 2nd Carcass	2	27	4	54	686	168	1,372	336	1,376	883	1,766
11/19/2013 - 11/21/2012	Every 3rd Carcass	2	25	6	75	272	94	816	282	822	393	1,179
11/26/2012 - 11/29/2012	Every 3rd Carcass	2	33	6	99	251	131	753	393	759	417	1,251
12/3/2012 - 12/6/2012	Every 2nd Carcass	2	24	4	48	90	87	180	174	184	203	406
12/10/2012 - 12/13/2012	Every 2nd Carcass	3	18	6	36	63	95	126	190	132	179	358
12/17/2012 - 12/20/2012	Every Carcass	3	19	3	19	64	110	64	110	67	196	196
12/26/2012 - 12/28/2012	Every Carcass	0	3	0	3	12	21	12	21	12	36	36
12/31/2012 - 01/4/2013	Every Carcass	1	1	1	1	17	2	17	2	18	21	21
01/7/2013 - 01/10/2013	Every Carcass	0	1	0	1	2	3	2	3	2	6	6
	Total	22	209	40	439	2,329	973	4,871	1,970	4,911	3,533	**7,320**
	Percent of Total Population	0.6%	5.9%	0.5%	6.0%	65.9%	27.5%	66.5%	26.9%	**67.1%**		

a) Escapement survey: The numbers were pulled directly from the "Lower American River Fall-Run Chinook Salmon Escapement Survey October 2012 – January 2013" report.

b) Expanded Escapement Survey: The numbers were expanded to reflect the sampling proportion for the week. If every 2nd salmon was sampled the number of carcasses processed was multiplied by 2. If every 3rd salmon was sampled the number of carcasses processed was multiplied by 3.

c) Total Females: Particular interest was focused on the total number of female carcasses processed in order to derive an estimate of eggs laid in the American River.

Appendix 7: Egg retention for fall-run Chinook salmon carcasses on the lower American River during the 2012-2013 escapement survey.



	Egg Retention					
	Spawned		Partially Spawned		Unspawned	
	0 to ≤ 30%		> 30 to 70%		> 70%	
Sampling Dates	Escapement Survey[a]	Expanded Escapement Survey[b]	Escapement Survey	Expanded Escapement Survey	Escapement Survey	Expanded Escapement Survey
10/22/2012 - 10/25/2012	5	5	9	9	31	31
10/29/2012 - 11/1/2012	32	32	43	43	81	81
*11/5/2012 - 11/8/2012	256	512	145	290	244	488
*11/13/2012 - 11/16/2012	328	656	184	368	174	348
**11/19/2013 - 11/21/2012	160	480	46	138	63	189
**11/26/2012 - 11/29/2012	176	528	34	102	39	117
*12/3/2012 - 12/6/2012	62	124	10	20	17	34
*12/10/2012 - 12/13/2012	58	116	2	4	4	8
12/17/2012 - 12/20/2012	47	47	11	11	4	4
12/26/2012 - 12/28/2012	11	11	1	1	0	0
12/31/2012 - 01/4/2013	18	18	0	0	0	0
01/7/2013 - 01/10/2013	2	2	0	0	0	0
Total	1,155	**2,531**	485	**986**	657	1,300
Percentage	50.3%	**52.5%**	21.1%	**20.5%**	28.6%	27.0%

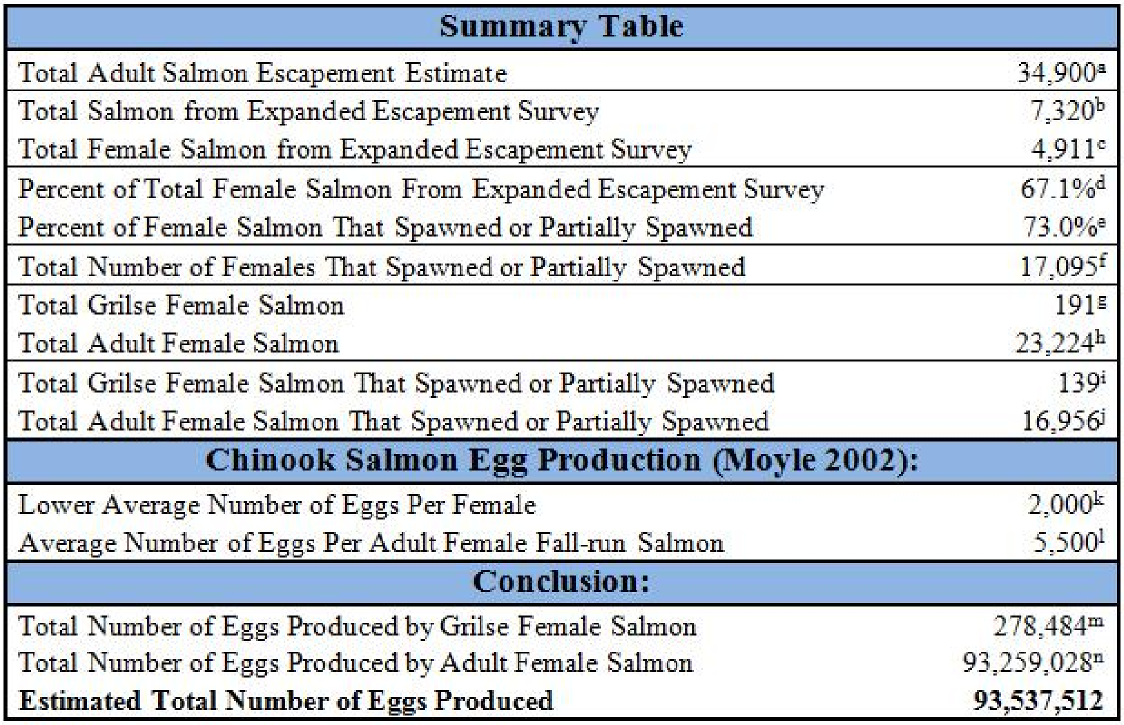
a) Escapement survey: The numbers were pulled directly from the "Lower American River Fall-Run Chinook Salmon Escapement Survey October 2012 – January 2013" report.

b) Expanded Escapement Survey: The numbers were expanded to reflect the sampling proportion for the week. If every 2nd salmon was sampled the number of carcasses processed was multiplied by 2. If every 3rd salmon was sampled the number of carcasses processed was multiplied by 3.

* Every 2nd salmon carcass was processed.

** Every 3rd salmon carcass was processed.

Appendix 8: Summary of values calculated to estimate the total number of eggs produced during the 2012-2013 spawning season.



Summary Table	
Total Adult Salmon Escapement Estimate	34,900[a]
Total Salmon from Expanded Escapement Survey	7,320[b]
Total Female Salmon from Expanded Escapement Survey	4,911[c]
Percent of Total Female Salmon From Expanded Escapement Survey	67.1%[d]
Percent of Female Salmon That Spawned or Partially Spawned	73.0%[e]
Total Number of Females That Spawned or Partially Spawned	17,095[f]
Total Grilse Female Salmon	191[g]
Total Adult Female Salmon	23,224[h]
Total Grilse Female Salmon That Spawned or Partially Spawned	139[i]
Total Adult Female Salmon That Spawned or Partially Spawned	16,956[j]
Chinook Salmon Egg Production (Moyle 2002):	
Lower Average Number of Eggs Per Female	2,000[k]
Average Number of Eggs Per Adult Female Fall-run Salmon	5,500[l]
Conclusion:	
Total Number of Eggs Produced by Grilse Female Salmon	278,484[m]
Total Number of Eggs Produced by Adult Female Salmon	93,259,028[n]
Estimated Total Number of Eggs Produced	**93,537,512**

a) The fall-run Chinook salmon in-river escapement estimate derived from the Cormack-Jolly-Seber mark and recapture model (Phillips and Helstab 2013).

b-d) Numbers derived from Appendix X.

e) Total percentage of expanded escapement for the spawned plus the partially spawned females (Appendix Y).

f) The estimated total number of females that spawned or partially spawned; (a*d*e) derived by taking the total adult salmon escapement estimate multiplied by the percent of total female Chinook salmon surveyed multiplied by the percentage of the total number of grilse and adult female salmon that spawned or partially spawned.

g) The estimated total number of grilse female salmon; derived by multiplying the total adult salmon escapement estimate by the percentage of grilse females surveyed (0.5%; taken from Appendix X).

h) The estimated total number of adult female salmon; derived by multiplying the total adult salmon escapement estimate by the percentage of adult females surveyed (66.5%; taken from Appendix X).

i) The estimated total number of grilse female salmon that spawned or partially spawned; (g*e) derived by multiplying the estimated total number of grilses by the percentage of the total number of grilse and adult female salmon that spawned or partially spawned.

j) The estimated total number of adult female salmon that spawned or partially spawned; (h*e) derived by multiplying the estimated total number of adults by the percentage of the total number of grilse and adult female salmon that spawned or partially spawned.

k) The lowest average of eggs produced per female (Moyle 2002).

l) The average number of eggs produced per female fall-run Chinook salmon (Moyle 2002).

m) Total estimated number of eggs produced by grilse female fall-run Chinook salmon during the 2012-2013 spawning season; (i*k) derived by multiplying the estimated total number of grilse female salmon that spawned or partially spawned by the lowest average number of eggs known to be produced by a female Chinook salmon.

n) Total estimated number of eggs produced by adult female fall-run Chinook salmon during the 2012-2013 spawning season; (j*l) derived by multiplying the estimated total number of adult female salmon that spawned or partially spawned by the average number of eggs known to be produced by a female fall-run Chinook salmon.