Juvenile Salmonid Emigration Monitoring in the Lower American River, California

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Abstract

Operation of rotary screw traps on the lower American River in 2016 is part of 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 passage 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.

For the 2016 survey season, two 2.4 meter (8 foot) rotary screw traps (RSTs) and one 1.5 meter (5 foot) trap were operated downstream of the Watt Avenue Bridge. Sampling occurred on 69 of the 84 days between 11 January and 4 April. A total of 80,626 fall-run, 2 putative spring-run, and 1 winter-run juvenile Chinook salmon was captured. Three adult Chinook salmon, two hatchery produced and one in-river produced, were also captured and presumed by timing to be fall-run. The passage of juvenile fall-run Chinook salmon peaked between 21 February 2016 and 7 March 2016, when 47.26 percent of the total (n = 38,106) were captured. The majority of the captured juvenile fall-run Chinook salmon belonged to the fry life stage; yolk-sac fry, parr, and silvery parr were also captured. Three trap efficiency tests were conducted to assist in estimation of juvenile fall-run Chinook salmon passage. Trap efficiencies during those three tests ranged between 2.68 and 5.63 percent, with an average efficiency of 4.01 percent. The number of juvenile fall-run Chinook salmon that were estimated to have emigrated past the Watt Avenue trap site during the 2016 survey season was 2,394,719 individuals (95 percent confidence intervals = 1,803,134 – 2,907,545). A total of 332 in-river produced and nine hatchery-produced steelhead was captured. Finally, 5,869 individuals belonging to 24 different identifiable non-salmonid species were captured, as well as 491 non-salmonid individuals unable to be identified to species. Production for steelhead, the three other non-fall Chinook salmon runs, and non-salmonid fish taxa was not estimated. Sampling was terminated on 4 April 2016. Due to high flows, sampling was suspended between 7 March and 21 March, causing an unknown and potentially substantial percentage of the emigrating population to remain unobserved. Therefore, the passage estimate for juvenile fall-run Chinook salmon in 2016 is likely biased low.

This annual report also includes eight appendices. Five of those appendices describe different environmental variables and studies related to the trap site or rotary screw trap operations during the 2016 survey season.

Introduction

The American River is the southernmost major tributary to the Sacramento River in California's Central Valley. The lower portion of American flows through the highly urbanized Sacramento metropolitan area, and provides crucial spawning and rearing habitat for Chinook salmon *(Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*), the anadromous form of rainbow trout. Historically, the American River supported three runs of Chinook salmon that included fall-, spring-, and possibly late-fall-run Chinook salmon (Yoshiyama et al. 2001). During the California Gold Rush in the mid- to late 1800s, 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 Chinook salmon 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 Chinook salmon and steelhead spawning and rearing habitat, the Nimbus Fish Hatchery was built in 1958, 0.80 kilometers (km) downstream of the Nimbus Dam. The Nimbus Fish Hatchery produces a large number of fall-run Chinook salmon and steelhead. Discharges from Folsom and Nimbus dams are regulated by the U.S. Bureau of Reclamation (USBR), and provide flows that help administer flood protection, provide municipal and agricultural water supplies, generate hydroelectric power, and maintain fish and wildlife habitats.

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 and restore the natural production of juvenile Chinook salmon and steelhead. 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.

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 integral in restoring 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 (Nimbus Basin) downstream 15 river kilometers (rkm) to the River Bend Park (Allen 2016).

The CVPIA's Dedicated Project Yield Program Section (b)(2), commonly referred to as "(b)(2) water", 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, (b)(2) water can be utilized to augment base flows out of Nimbus Dam to provide improved in-stream conditions for fall-run Chinook salmon and Central Valley steelhead during critical life stage periods such as spawning, egg incubation, fry emergence, juvenile rearing, and emigration. Additionally, the (b)(2) water's flow augmentation may also contribute towards the AFRP Final Restoration Plan flow objectives for the lower American River.

Rotary screw traps (RSTs) are commonly used to monitor the abundance of emigrating juvenile salmonids and their biological response to habitat restoration activities. This report describes efforts to monitor juvenile salmonid abundance with RSTs on the lower American River in 2016 as part of a larger effort to determine if habitat restoration activities are improving Chinook salmon production. Furthermore, this report presents monitoring data assessing the temporal variability in steelhead 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 2016 survey season was the continuation of a multi-year juvenile Chinook salmon emigration study. Over the last three years, California has experienced below average precipitation, leading to a statewide drought. In 2016 however, the eastern Pacific Ocean experienced an El Niño event which finally brought the northern California region to near or above normal precipitation. With the vast differences in weather in 2016 relative to previous years, many different water years and operational procedures can be compared and contrasted to surmise which scenarios may be the most productive for juvenile Chinook salmon on the lower American River. In addition to current management practices and fish recovery projects, the RST data collected during the past four years will help better understand the drought and whether coinciding drought management and flow strategies may impact salmonids and other threatened species on the American River. From there, future severe droughts may be better anticipated and managed.

RST data will continue to be collected such that the 2013 and newer data will complement the data that were collected by the CDFW between 1992 and 2008. After five years of post-2013 data have been collected, they will then be analyzed 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 juvenile Chinook salmon and steelhead.

Based on the aforementioned goal, as identified in the previous paragraph, the primary objective of the American River trapping operations is to collect data that can be used to estimate the passage of emigrating juvenile fall-run Chinook salmon and observe abundance of steelhead 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, 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 in the vicinity of the RST trapping location.

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 range (James 1997). This river contains three major forks, including the North, Middle, and South forks that ultimately converge at 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 is to re-regulate flows downstream into the lower American River. 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 influence salmonid spawning and rearing.

Water exiting Nimbus Dam flows downstream for 36 km until it reaches the confluence with the Sacramento River. This lower stretch of the American River is now constricted and straightened by a levee system that was engineered for flood control during the urban development of Sacramento County. Currently, fall-run Chinook salmon and steelhead 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 anadromous salmonid spawning activities. The river contains gravel bar complexes and islands, flat water areas, and side-channel habitat characteristics (Merz and Vanicek 1996). Historically, flows in this lower section have ranged from 500 cubic feet per second (CFS) to upwards of 164,035 CFS. The primary salmonid spawning grounds are relegated to the uppermost portion of the lower American River between Sailor Bar (rkm 34.7) and the Lower Sunrise Recreational Area (rkm 31.1) (Phillips and Gahan 2014). CDFW (Snider and Titus 2001) 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 Chinook salmon and steelhead spawning activities in the lower American River yet far enough upstream to not be influenced by tidal and river rise from the

Sacramento River that backs up into the American River. A summary of the aforementioned points of interest on the lower American River is shown in Appendix 1.

The lower American River RST site is located just downstream of the Watt Avenue Bridge (Figure 1). During typical flow years, the American River at this location separates into two channels that pass on either side of a gravel island. The north channel carries the majority of the water volume and becomes the only channel with flowing water during flows of less than approximately 500 CFS. This north channel reach possesses a steep gradient that causes relatively high water velocities, while the south channel has a flatter gradient and lower water velocities. During flows above approximately 10,000 CFS, as were seen in 2016 between 3 March and 21 March, the gravel island separating the north and south channels becomes submerged and the American River below Watt Avenue becomes one channel. A pictorial comparison of the lower American River RST site in different flow conditions is provided in Appendix 8.

Two 2.4 meter (8 foot) diameter RSTs deployed in the north channel in 2016 were designated as Trap 8.1 and Trap 8.2 (Figure 2). Trap 8.1 was set closer to the north bank of the north channel, while Trap 8.2 was closer to south bank of the north channel. The 1.5 meter (5 foot) trap deployed in the south channel was designated as Trap SC5 (Figure 3).

Figure 1: Lower American River rotary screw trap sites in the north and south channels. Inset map illustrates the trapping location in the state of California.

Figure 2: The two north channel 8 foot traps (8.1 and 8.2) on the lower American River just downstream of the Watt Avenue overcrossing.

Figure 3: The south channel 5 foot trap (SC5) on the lower American River just downstream of the Watt Avenue overcrossing.

Methods

Trap Operations

Monitoring activities for the 2016 survey season started on 11 January and ended on 4 April. The two 8 foot (ft) RSTs were fished in a side-by-side configuration in the north channel, and a single 5 foot (ft) RST was operated in the south channel. Traps were anchored to large concrete blocks set into the cobble substrate in each river channel 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.

Trap checks were conducted at least once every 24 hours when traps were actively fishing in a cone-down configuration. During large storm events or measurable river flow increases, trap functionality could be hindered by larger sized or higher quantities of debris, creating a high potential for fish mortality. Therefore, to help prevent fish mortality, additional day time trap checks or supplementary night time checks were conducted during peak emigration weeks, or when field conditions suggested the potential for high debris load. Night checks were primarily used to clear debris and to keep the traps functioning properly; typically fish were not processed during these checks. In cases where a storm or flow increase was deemed severe enough, traps were taken out of service for an indefinite amount of time until the conditions improved. When traps were out of service, trap cones were raised, live well screens were pulled, and sampling was temporarily suspended.

In cases when large numbers of salmon could be captured and when river flow increases could result in an overwhelming amount of debris, potentially threatening fish health, a random sampling method was implemented. In those cases, two randomly selected 3-hour blocks of time, one diurnal and one nocturnal, were selected for sampling. Cones were lowered at the start of a 3-hour period, fished continuously, and then raised after three hours. Crews remained on the rotary screw traps during these sample periods to control debris within the live box and deter any large debris from entering the trap cones. Fish were then removed from the live box and processed using the methods described below.

The number of cone 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 the rotation of a trap cone to remove larger debris. For each trap visit, the extent of cone intake obstruction caused by debris was assigned a category of “none”, “partially blocked”, “completely blocked”, or “backed up into cone.”

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. For night operations, crew members were required to affix a strobe light to their personal flotation devices that turned on automatically when submerged in water. Two 12-volt, 1260 lumens, LED flood lights were affixed to each trap. On the jet-boat, navigation lights and a bow mounted 55-watt halogen driving light were also installed for safety during night operations. A coast guard approved flare kit was carried on the boat at all times.

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. As visitor use on the river increased during the warmer spring months, a large sign was mounted on the front of the traps warning boaters to pass to the south side of the north channel traps as they navigated downstream.

Environmental Parameters

During trap visits when fish were processed, the following environmental data were taken and recorded once per visit. 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). A depth rod was used to measure water depth underneath the trap to the nearest centimeter on the port and starboard sides of the two-trap array in line with the front of the trap cones or directly in front of the cone on the single 5 ft trap. Average daily river discharge for the American River was determined using data acquired from the American River at Fair Oaks monitoring station maintained by the U.S. Geological Survey (USGS) (USGS station number 11446500). Average daily temperature was measured 150 m upstream of the RSTs using data from the USGS American River below Watt Avenue Bridge station (USGS station number 11446980).

Catch and Fish Data Collection

After environmental data was collected, the process of clearing out each RST's live well and working-up the fish began. First, all debris was removed from the live well and placed into 68.14 liter (L) tubs where crew members sifted through debris and set aside or enumerated any fish, alive or dead. After all debris was removed, an assessment of debris type and volume was recorded. Next, the crew netted any remaining fish from the live well and placed them in 18.93 L buckets with lids, segregating salmonids from non-salmonids or potential predators. During periods of hot weather, fish were placed in buckets with aerators 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, if necessary, to provide shade from direct sunlight. If fish were held in buckets for a prolonged period of time, oxygen-depleted water was regularly exchanged with fresh river water.

On days when less than 100 Chinook salmon were caught per trap, the fork length of each salmon from each trap was measured to the nearest one millimeter (mm), their life stage was assessed using the smolt index rating (Table 1), the presence of marks applied during trap efficiency tests or the absence of adipose fin were noted, and fish mortality status (live vs. dead) was assessed. If Chinook salmon were ≥ 40 mm in fork length, the first 25 salmon from each trap were weighed to the nearest 0.1 gram (g).

When more than 100 Chinook salmon were caught in a trap, a random sample of 100 live salmon from each trap was collected. The fork length, life stage, mark status, and fin clip status for each of the 100 salmon was assessed. Again, if the individuals were ≥ 40 mm in fork length, the first 25 salmon from each trap were weighed to the nearest 0.1 g after they were measured and assessed for life stage. Because dead salmon are difficult to accurately measure and identify to life stage due to varying stages of decomposition that alter body size, weight, and color, live salmon were preferentially used for the random sample of 100, when possible. In those cases, mortalities were considered to be a "mort plus-count," with an unassigned life stage category.

A random sample was achieved by placing a net full of Chinook salmon from the live well into a 68.14 L tub. Debris was removed from the tub with salad tongs/probes, leaving only the subsampled salmon. Then, a random net full of salmon was taken from the tub and placed in a bucket designated for Chinook salmon subsampling. From the subsampled bucket, 100 Chinook salmon were randomly selected for analysis. Additional fall-run Chinook salmon in excess of the 100 that were present in the tub or trap live well were not measured and weighed, but each of these salmon were checked for marks, enumerated, and recorded on data sheets as a "live plus-count tally," or "mort plus-count tally." A "plus-count tally" was defined as the total number of fish that were caught in a trap on a given day, and that were not measured, weighed, or assigned a life stage. If the plus-count capture included spring-, winter-, or late-fall-run salmon that differed in size from fall-run Chinook salmon based on length-at-date criteria, individuals belonging to those three salmon runs were counted separately and up to 100 of each run were assessed for fork length, life stage, and color/fin clip mark status. Since Central Valley spring- and winter-run Chinook salmon are federally listed as threatened or endangered taxa, trapping activities attempted to identify every spring- and winter-run Chinook salmon that was captured so those data could be reported to the NMFS.

When steelhead were captured, each individual was counted, fork lengths were measured to the nearest whole mm, life stage was assessed using the smolt index rating (Table 1), and mortality status was assessed. In addition, each steelhead was checked for the presence or absence of a mark (i.e., adipose fin clipped) and the weights of each individual ≥ 40 mm in fork length were recorded.

All other individuals belonging to non-salmonid taxa were enumerated and identified to species. For each trap, fork lengths of up to 50 randomly selected individuals of each species were recorded to the nearest mm and their mortality status 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, the number of lateral circumorals in the mouth was observed. River lampreys have three lateral circumorals, while Pacific lampreys have four (Reid 2012). Because the lateral circumorals in the larval stage of ammocoetes are not well developed, they were not identifiable to species.

Table 1: Smolt index rating for assessing life stage of Chinook salmon and steelhead.

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	* $\geq$ 300mm

Prior to collecting fish fork lengths and weights, individuals were anesthetized with sodium bicarbonate tablets (Alka-Seltzer Gold) to reduce stress as they were processed. One Alka-Seltzer tablet was added to one liter of water. Approximately eight to 10 fish were placed in a solution of river water and Alka-Seltzer, then measured and weighed. The crew routinely observed the gill activity of fish immersed in the 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 additive (Poly-Aqua) to help replenish their slime coat as the fish recovered from the anesthetic. As soon as it was determined that the fish had fully recovered from anesthesia, all fish were then released well downstream of the traps to prevent recapture.

Chinook salmon were assigned a salmon run at the time of capture using length-at-date (LAD) criteria that were developed for the Sacramento River by Greene (1992). When Chinook salmon appeared to be winter- or spring-run salmon using the LAD criteria, one to two mm samples were commonly taken from the upper lobe of the caudal fin. These samples were then sent to the staff at the U.S. Fish and Wildlife Service's Abernathy Fish Technology Center to perform genetic run assignments using the panel of single-nucleotide polymorphism (SNP) markers described by Clemento et al. (2014). This panel of SNPs was developed by staff from the National Oceanic and Atmospheric Administration NOAA Fisheries, and is now used for several applications by the U.S. Fish and Wildlife Service and several partner groups (Christian Smith, USFWS, pers. comm.). Detailed methods for DNA extraction, genotyping, and run assignment are described in Abernathy Fish Technology Center Standard Operating Procedure #034. Fish captured in 2016 were assigned to one of three salmon runs: 1) winter-run, 2) spring-run, 3) fall-run.

The accuracy of genetic run assignments made using the SNP baseline was evaluated using self-assignment tests, and it was reported that winter-run were correctly assigned to run 100 percent of the time, fall-run were correctly assigned to run 85-95 percent of the time, and spring-run were correctly assigned to run 78-93 percent of the time (Clemento et al. 2014). For the purposes of this report, the SNP panel providing the "Genetic Call to three lineages" probability was used, and we employed an arbitrary 50 percent probability threshold to assign the final salmon runs as follows:

1. Individuals for which the probability of assignment was < 50 percent were not assigned based on the genetic data, i.e., assignments based on the LAD criteria were used to assign the final run.

2. Individuals for which the probability of assignment was ≥ 50 percent were assigned based on the genetic data, i.e. if LAD and genetic assignments conflicted, then final run was assigned using the genetic markers.

Eight salmon that had a LAD salmon run assignment of fall at the time of capture were genetically sampled to compare their LAD assignments with run assignments determined using the SNPs. That procedure was implemented to evaluate the similarity between LAD and SNP assignments when the LAD run assignment at time of capture was fall-run.

Trap Efficiency

Trap efficiency trials were conducted to quantify the proportion of the emigrating fall-run Chinook salmon 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 Chinook salmon migrating past 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 Chinook salmon with Bismarck Brown Y (BBY) stain when a majority of the juvenile salmon catch were < 50 mm in size. At least 500 salmon were needed to conduct trials with BBY stain. When < 500 Chinook salmon were caught on a given day, they were held overnight and salmon caught the next day were added to the previous day's catch to achieve the minimum number of Chinook salmon required for a trap efficiency trial. If the minimum number of salmon 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 in-river produced Chinook salmon 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 salmon being stained. Salmon were stained for approximately two hours, and their condition was constantly monitored during the staining process. After staining, salmon were rinsed with fresh river water and placed in a 68.14 L live cart, held overnight, and released at twilight the following evening using the technique described below.

To evaluate the potential that the size distribution of marked and released vs. recaptured in-river produced salmon used during trap efficiency trials was different, 100 fork lengths from the day the in-river produced fish were captured and marked were used as a baseline to compare to the lengths of recaptured salmon.

The trap efficiency release site was approximately 1.29 rkm upstream of the traps. To avoid schooling when Chinook salmon were released, they were scattered across the width of the river channel using small dip nets. When river flows were relatively low (e.g., < 1,250 CFS), the fish were released by wading across the river. When higher river discharges occurred, a boat was used to release the marked fish, keeping the motor upstream of the released fish. Every release of marked Chinook salmon occurred close to evening twilight to mimic natural migration patterns and to avoid predation.

On trap visits following each trap efficiency release, the crew carefully looked for any marked fish in the RST live wells. A random sample of up to 100 recaptured Chinook salmon from each trap efficiency test were measured for fork lengths, assessed for life stage, and evaluated for mortality status. If more than 100 recaptures from a trap efficiency test were found in a RST live well, the marked salmon in excess of 100 were enumerated and classified as a "live recap plus-count tally" or "mort recap plus-count tally".

Passage Estimates

Fall-run Chinook salmon passage estimates were developed using a generalized additive model (GAM). Passage estimates were not developed for the other Chinook salmon runs because relatively small numbers of individuals from those runs were captured. Passage estimates were not developed for steelhead because Central Valley fishery biologists in general believe steelhead fry typically rear in-river for one to three years before they immigrate to the ocean as smolts, at which point they become more difficult to capture, as their increased size increases their ability to avoid the traps.

The GAM incorporated two elements in the development of the salmon passage estimates; the number of salmon caught by trap *i* on day *j*, and the estimated efficiency of trap *i* on day *j*.

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

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

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

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

Estimation of ĉ ij

The estimate of catch, $\hat{c}_{ij}$, was computed in one of the following ways. The method used was typically selected in the order listed below, e.g., if a trap fished for more than 22 hours within a 24-hour period, the catch using Method #1 was used to calculate a trap's salmon production estimate. If the trap fished for less than 22 hours within a 24-hour period, Method #2 was used.

Additionally, if the 24-hour period between day *j* and day *j*-1 contained more than two hours of sampling excluded from analysis, as described in the Retention in Analysis section below, this length of time excluded from analysis was treated as a gap in sampling, and Method #2 was used.

Method #1: If the interval between day *j* and day *j* – 1 was 22 hours or more and the trap fished for the entire period, $\hat{c}_{ij}$ was the total catch of unmarked fish for day *j*.

Method #2: If the trap fished for less than 22 hours in the 24-hour period between day *j* and day *j* – 1, the fish count for day *j* was adjusted using a GAM. This model smoothed observed catch rates (fish per hour) through time much like a moving average. The prediction from this model was multiplied by the number of hours the trap was not sampling during the 24-hour period to estimate catch for the day. For example, if the trap fished for 10 hours in the 24-hour period between day j and day j-1, catch for the 14 hours not fished was calculated using the GAM, and added to the catch for the 10 hours fished to estimate $\hat{c}_{ij}$.

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

Efficiency estimates at trapping location *i* on day *j* were computed from a binomial GAM unless sufficient efficiency trials (≥ 3 per week) have been performed. Thus, if sufficient efficiency trials had been conducted (≥ 3 per week), efficiency from the most recent trial was used for $\hat{e}_{ij}$. When the most recent efficiency was not appropriate (i.e., < 3 trials per week), a binomial GAM was fitted to past and current efficiency trials and used to compute $\hat{e}_{ij}$. The additive portion of this GAM was:

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

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

On sampling days during the portion of the year when trap efficiency tests were not conducted, or if less than 10 efficiency trials were included in analysis, 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 survey season and that were included in analyses. For example, if a survey season occurred between 1 January and 30 June and trap efficiency tests were conducted between 1 February and 30 May, a GAM was used to develop the estimated trap efficiencies and expand the daily trap catches between 1 February and 30 May, and the average trap efficiency for the survey season was used to expand the daily trap catches before 1 February and after 30 May. If less than 10 efficiency trials were conducted during the survey season or less than 10 efficiency trials were included in analyses, the average trap efficiency for the survey season was used to expand the daily trap catches.

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

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

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

where n_{ij} was the number of trapping locations fishing at site *i* during day *j*. Passage on day *j* was 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).

Fulton's Condition Factor

Fall-run Chinook salmon condition was assessed using the Fulton's condition factor. The first 25 Chinook salmon larger than 40 mm captured each day were measured for weight and fork lengths. The ratio of the two was used to calculate their condition factor:

$$K = \left(\frac{W}{FL^3}\right)100{,}000$$

where *K* was the Fulton's condition factor, *W* was the weight in grams, and *FL* was the fork length in mm.

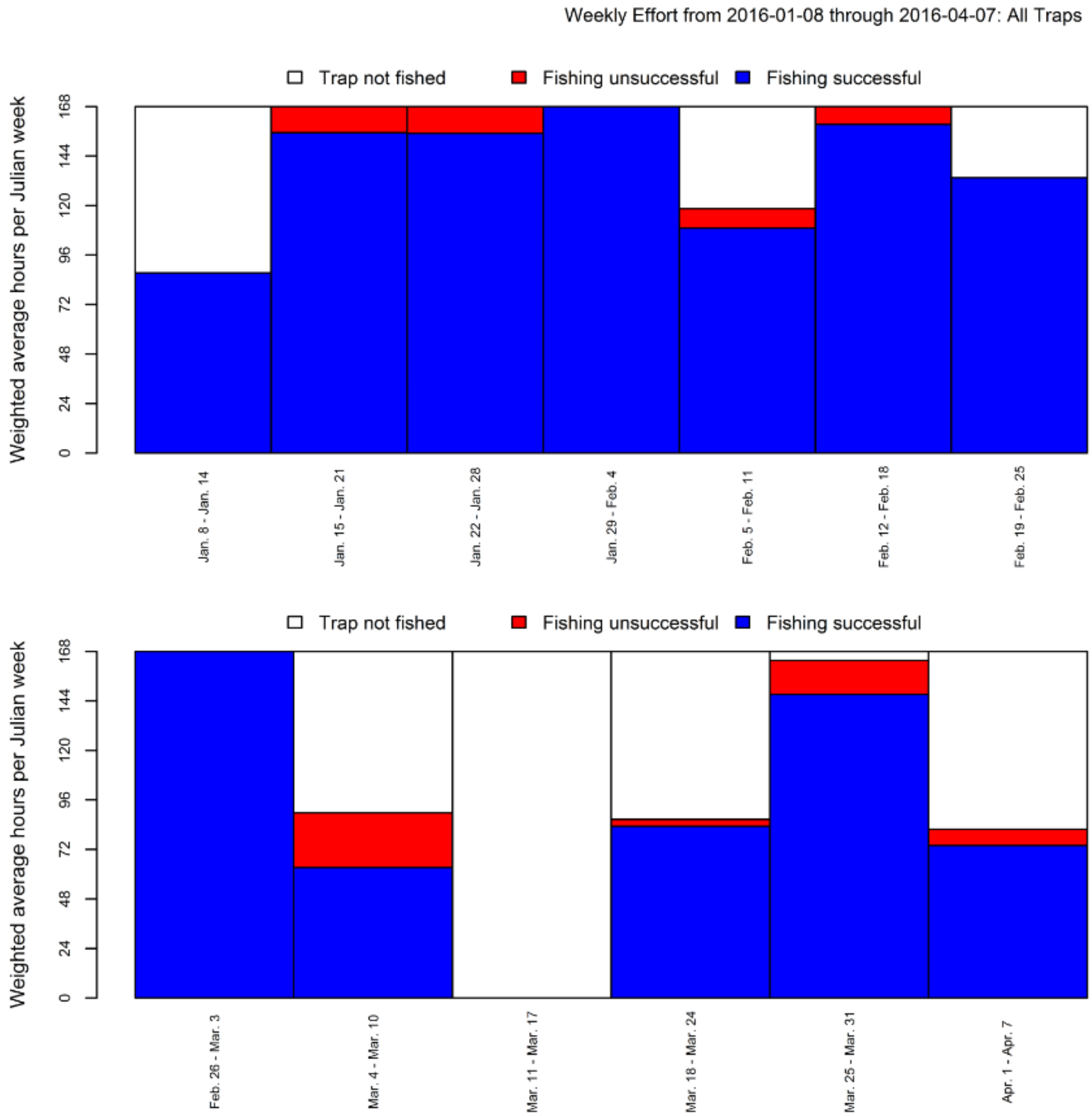
Results

Trap Operations

To start the 2016 survey season, two 8 ft RSTs were deployed in the north channel of the Watt Avenue trapping site and began sampling on 11 January at river flows of approximately 500 CFS. Trapping operations during the 2016 field season were adversely affected on multiple occasions by river discharge increases. Sampling in Trap 8.1 was suspended temporarily between 5 February and 6 February to limit potential mortality in anticipation of a river flow increase of 800 CFS (from approximately 800 CFS to approximately 1,600 CFS). Sampling for both traps ceased again on 9 February in response to river flow increasing by 1,400 CFS (from approximately 1,600 CFS to approximately 3,000 CFS). Trap 8.2 resumed sampling on 10 February and Trap 8.1 resumed sampling on 11 February. The 5 ft RST (Trap SC5) was deployed in the south channel and began sampling on 10 February. All three traps sampled continuously until 22 February, when sampling was again suspended in anticipation of an additional river flow increase of 4,000 CFS (from approximately 3,000 CFS to approximately 7,000 CFS). On 23 February, a random sampling regime was implemented, where Trap 8.1 sampled for one randomly selected 3 hour block from 8:40 AM to 11:47 AM, and Trap 8.2 sampled for two randomly selected 3 hour blocks from 8:40 AM to 11:45 AM, and from 8:00 PM to 11:00 PM. Trap SC5 resumed continuous sampling operations on 23 February, and Traps 8.1 and 8.2 resumed continuous sampling on 24 February. Sampling ceased again on 7 March in anticipation of river flow increasing by 11,000 CFS (from approximately 4,500 CFS to approximately 15,000 CFS). Continuous sampling for the 8 ft traps did not resume until 21 March when river flows declined to approximately 10,000 CFS again. Trap SC5 resumed continuous sampling operations on 29 March. Trap operations for the survey season were terminated on 4 April, because the number of live juvenile steelhead that were captured exceeded the take authorization in the National Marine Fisheries Service 10(a)(1)(A) permit relating to the American River RST project.

Throughout the 2016 survey season, sampling took place on 69 of the 84 days between 11 January and 4 April. During this time, the traps fished unsuccessfully (defined as a period of time during which the trap was fishing, but catch was determined to be adversely affected by abnormal trap function) for approximately 98 hours. Traps fished successfully for approximately 1503 hours and did not fish for approximately 583 hours (Figure 4).

Figure 4: Weighted average hours per Julian week that both traps fished successfully, fished unsuccessfully, or did not fish during the 2016 lower American River rotary screw trap survey season.

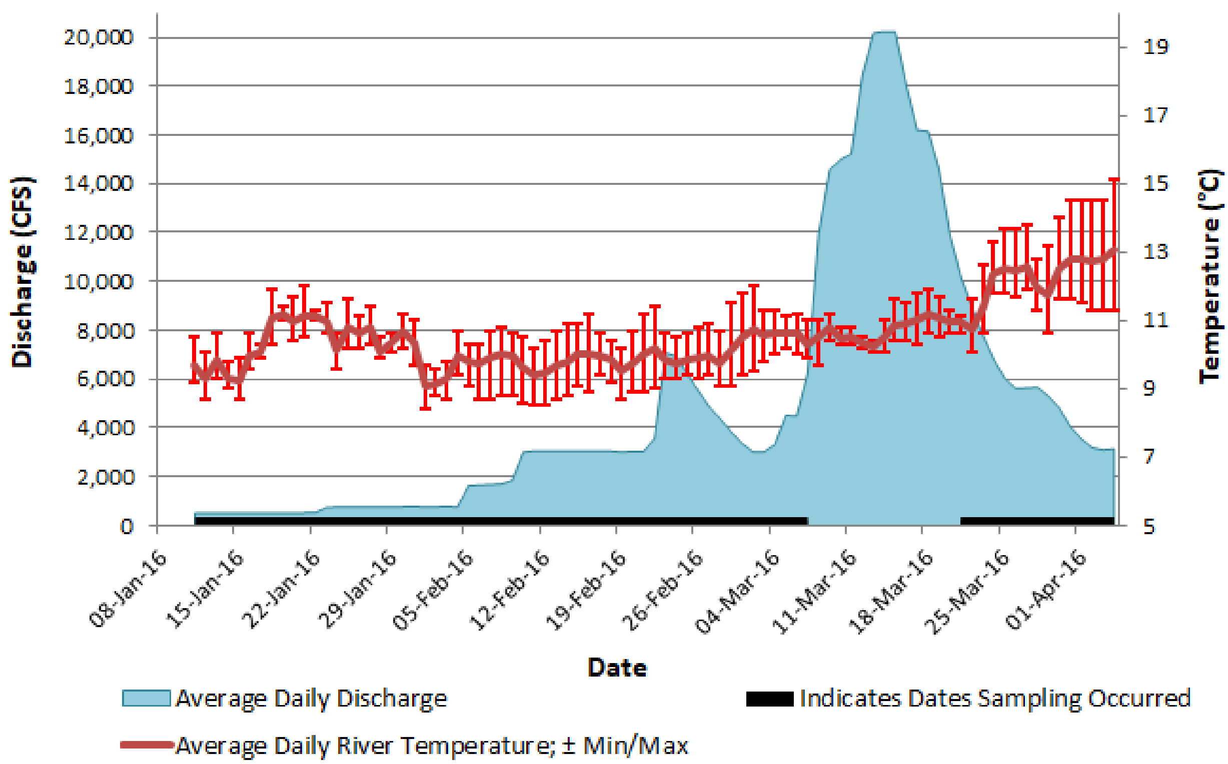


Environmental Summary

Appendix 2 provides a summary of the overall environmental conditions during the 2016 survey season.

River discharge data, recorded in 15 minute increments, was acquired from the USGS Fair Oaks gaging station on the American River, 21 rkm upstream of the RSTs. River discharge began at a low of 440 CFS on 11 January and reached a high of 20,600 CFS on 14 March and 15 March (Figure 5). River temperature, also recorded in 15 minute increments, was acquired from the USGS Watt Avenue Bridge station on the American River, 0.16 rkm upstream of the RSTs. Temperatures ranged from a low of 8.4° Celsius (C) on 1 February, to a high of 15.1° C on 4 April (Figure 5).

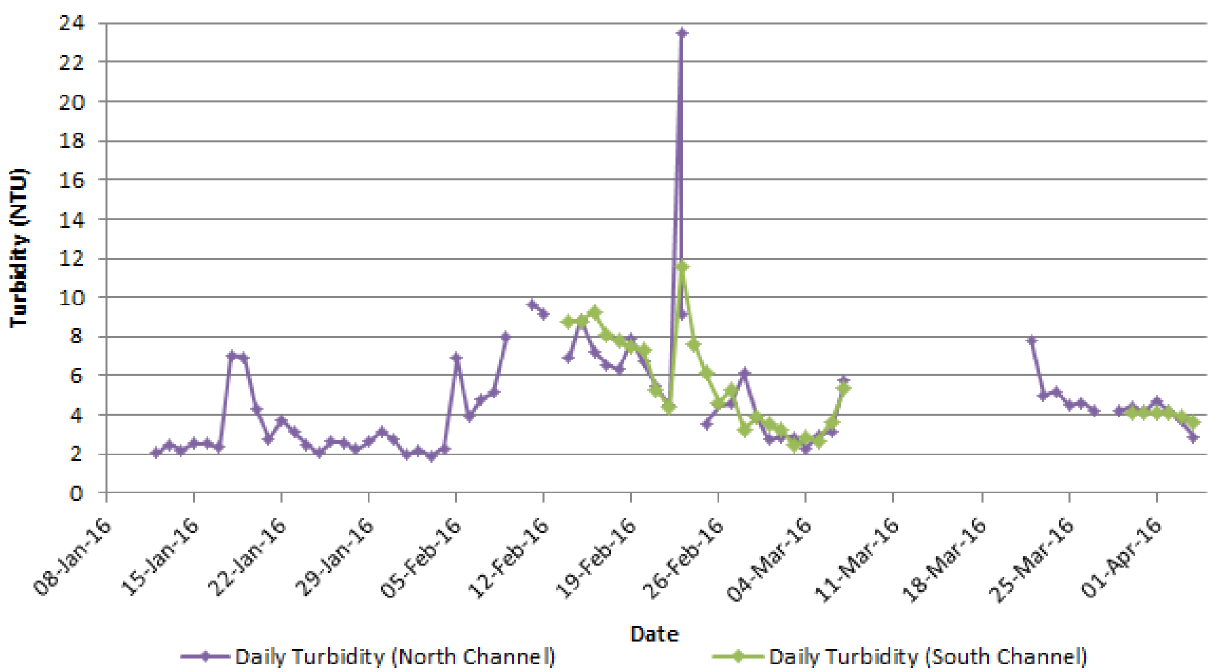
Figure 5: Average daily discharge (CFS) measured at Fair Oaks, and average daily water temperature (°C) measured at Watt Avenue during the 2016 lower American River rotary screw trap survey season.



Note: Discharge and water temperature data for the 11 January to 4 April time period were acquired from the USGS website at **http://waterdata.usgs.gov/ca/nwis/uv**

River turbidity, was measured in the field from water samples taken once per trap visit from each trap and averaged per north channel or south channel trapping location. Daily turbidity (Figure 6) at the north channel location ranged from a low of 1.9 Nephelometric Turbidity Units (NTU) on 3 February to a high of 23.5 NTU on 23 February. Daily turbidity at the south channel location ranged from a low of 2.5 NTU on 3 March to a high of 11.6 NTU on 23 February. Weekly turbidity, averaged by Julian week across both trapping locations (Appendix 2), began at a low of 2.2 NTU during the first week of trapping and increased to a high of 8.1 NTU during the week 19 February.

Figure 6: Daily turbidity at the north channel and south channel trapping locations during the 2016 lower American River rotary screw trap survey season.

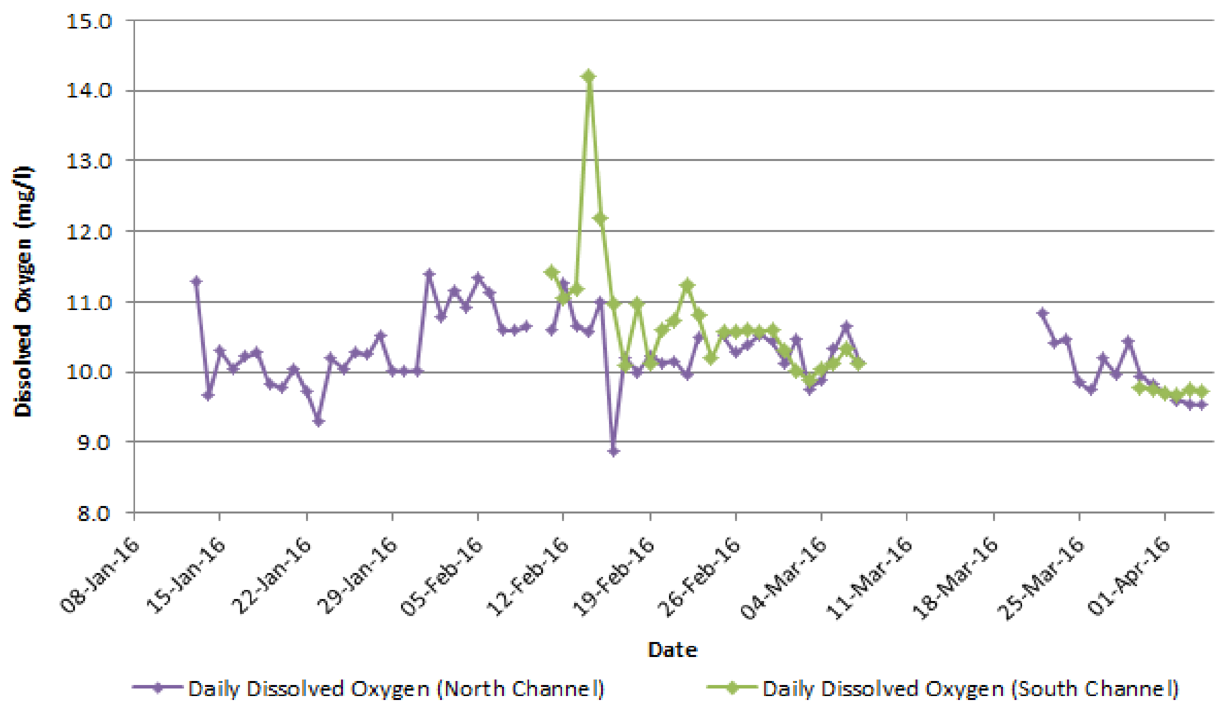


Note: Sampling did not occur between 7 March and 21 March.

Dissolved oxygen (DO) in the river water, was also measured per trap visit from both the north channel and south channel trapping locations (Figure 7). For the north channel trapping location, dissolved oxygen ranged from a high of 11.4 milligrams per liter (mg/l) on 1 February to a low of 8.9 mg/l on 16 February. At the south channel location dissolved oxygen content ranged from a high of 14.2 mg/l on 14 February to a low of 9.7 mg/l on 1 April, 2 April and 4

April. Weekly dissolved oxygen content, averaged by Julian week across both trapping locations (Appendix 2), ranged from a weekly average high of 10.9 mg/l during the week of 12 February and decreased to a weekly average low of 9.6 mg/l during the last week of the survey season.

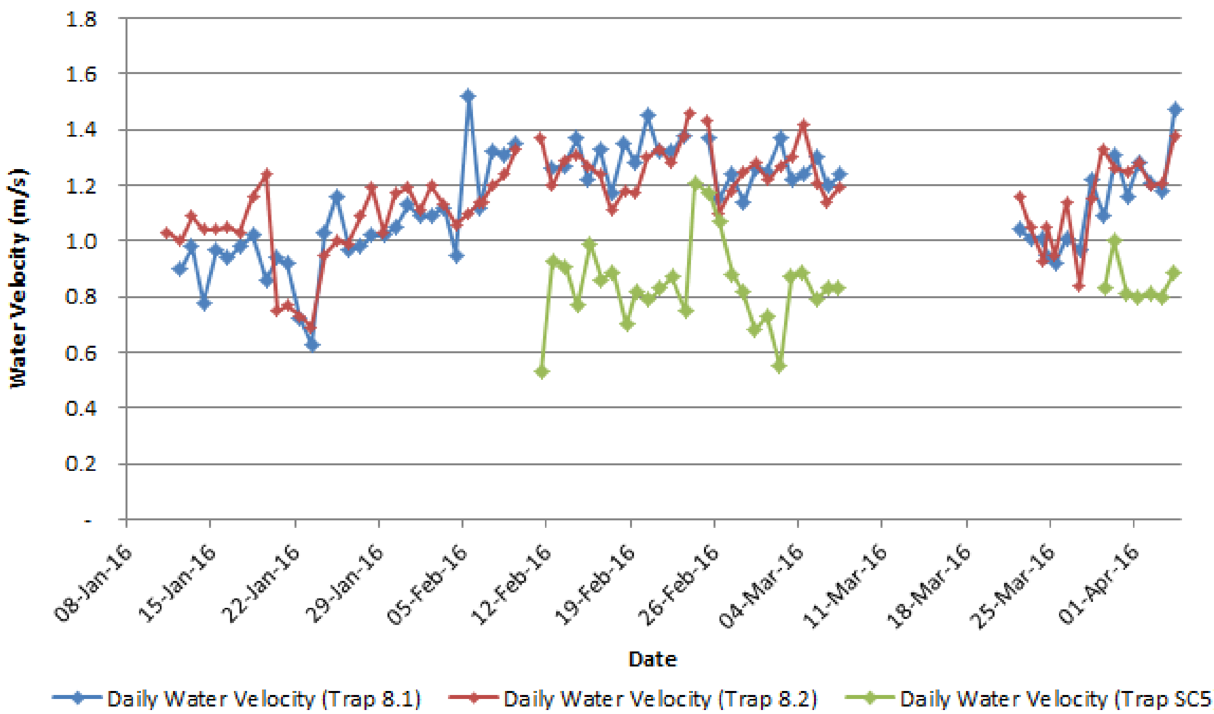
Figure 7: Daily dissolved oxygen content at the north channel and south channel trapping locations during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

Water velocities (Figure 8) were measured in the field in front of each of the three traps once per trap visit. Water velocities in the north channel traps varied little between the two traps and ranged from a low of 0.63 meters per sec (m/s) to a high of 1.52 m/s in front of Trap 8.1 (north bank side of north channel), and a low of 0.69 m/s to a high of 1.46 m/s in front of Trap 8.2 (south bank side of north channel). Water velocities in the south channel were overall lower and ranged from a low of 0.53 m/s to a high of 1.21 m/s in front of Trap SC5 (south channel).

Figure 8: Comparison of water velocities measured in front of each trap during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

Catch

The three rotary screw traps deployed during the 2016 survey season captured a total of 87,333 fish, including 11 hatchery-produced salmonids. Trap 8.1 (north bank side of north channel trapping location) captured 35.50 percent (n = 31,004) of these fish, Trap 8.2 (south bank side of north channel) captured 45.49 percent (n = 39,732), and Trap SC5 (south channel trapping location) captured 19.00 percent (n = 16,597). Salmonid species captured included steelhead and fall-, late-fall-, winter-, and spring-run Chinook salmon by length-at-date criteria. However, genetic analysis revealed that the Chinook salmon runs captured did not include late fall-run Chinook salmon (Appendix 4). Twenty four identified non-salmonid species and five unidentified non-salmonid species (Appendix 3) were also captured.

Fall-run Chinook salmon

A total of 80,626 in-river produced, unmarked fall-run Chinook salmon was captured during the 2016 survey season (Table 2 and Figure 9). Catch peaked between 21 February and 7 March, when 47.26 percent (n = 38,106) of the season's fall-run Chinook salmon was captured. A secondary peak in catch occurred between 29 March and 3 April when 19.02 percent (n = 15,265) of the season's catch occurred. The single day with the highest catch of fall-run Chinook salmon was 29 February, when 3,419 fall-run Chinook salmon were captured.

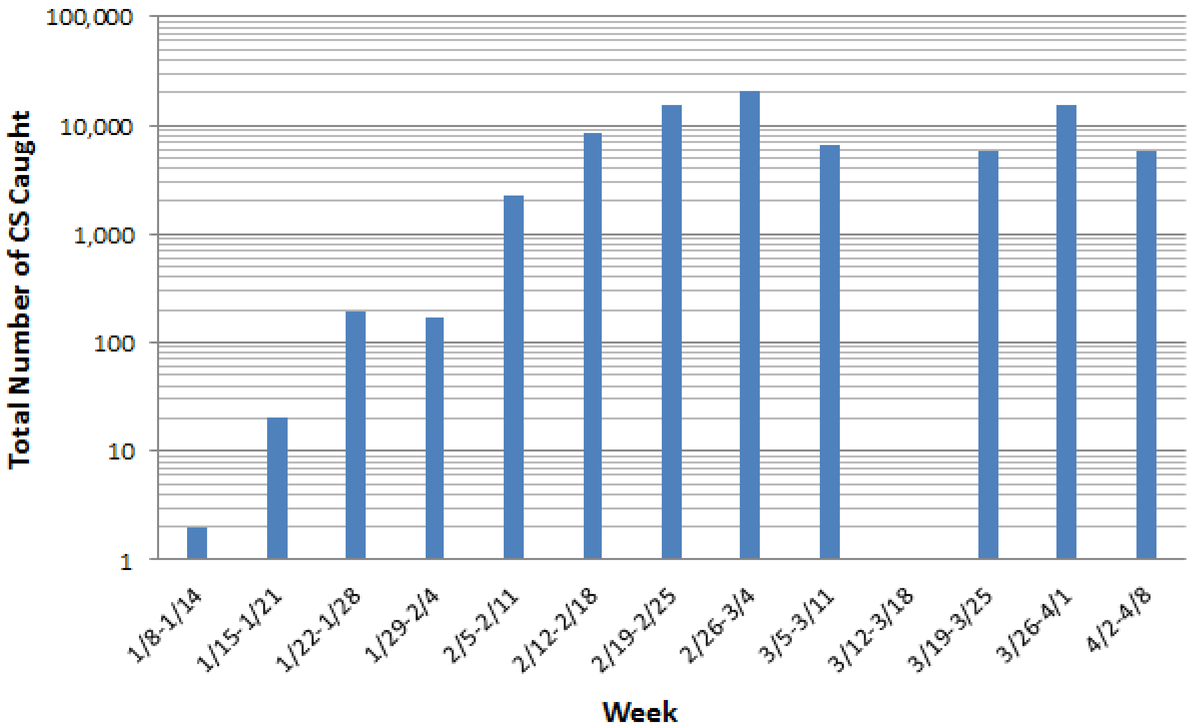
A total of 68,295 in-river produced, unmarked juvenile Chinook salmon were unmeasured plus-count tallies and may have included both LAD fall- and late fall-run Chinook salmon. By genetic analysis all LAD late fall-run Chinook salmon captured were determined to be fall-run Chinook salmon by proration of genetic analysis results, therefore all 68,295 unmeasured plus count tallies were determined to be fall-run Chinook salmon. Both the unmeasured plus-count total and the measured totals included mortalities.

Table 2: In-river produced, unmarked fall-run Chinook salmon catch totals by life stage during the 2016 lower American River rotary screw trap survey season.

Julian Week	Yolk Sac Fry	Fry	Parr	Silvery Parr	Unassigned Life Stage	Total
1/8-1/14	0	2	0	0	0	2
1/15-1/21	0	20	0	0	0	20
1/22-1/28	1	189	0	0	0	190
1/29-2/4	3	166	0	0	0	169
2/5-2/11	31	794	3	0	1,463	2,291
2/12-2/18	128	1,970	5	0	6,196	8,299
2/19-2/25	50	2,200	1	0	12,805	15,056
2/26-3/4	59	2,340	9	1	18,432	20,841
3/5-3/11	6	736	2	0	5,904	6,648
3/12-3/18						
3/19-3/25	14	748	59	11	4,972	5,804
3/26-4/1	6	1,530	160	31	13,811	15,538
4/2-4/8	4	818	201	33	4,712	5,768
Total	302	11,513	440	76	68,295	80,626

Note: Sampling did not occur between 7 March and 21 March. Catch totals for weeks encompassing dates in which no sampling or reduced sampling occurred may appear misleading. Unassigned life stage includes plus-counts.

Figure 9: Weekly catch distribution of in-river produced, unmarked fall-run Chinook salmon during the 2016 lower American River rotary screw trap survey season.

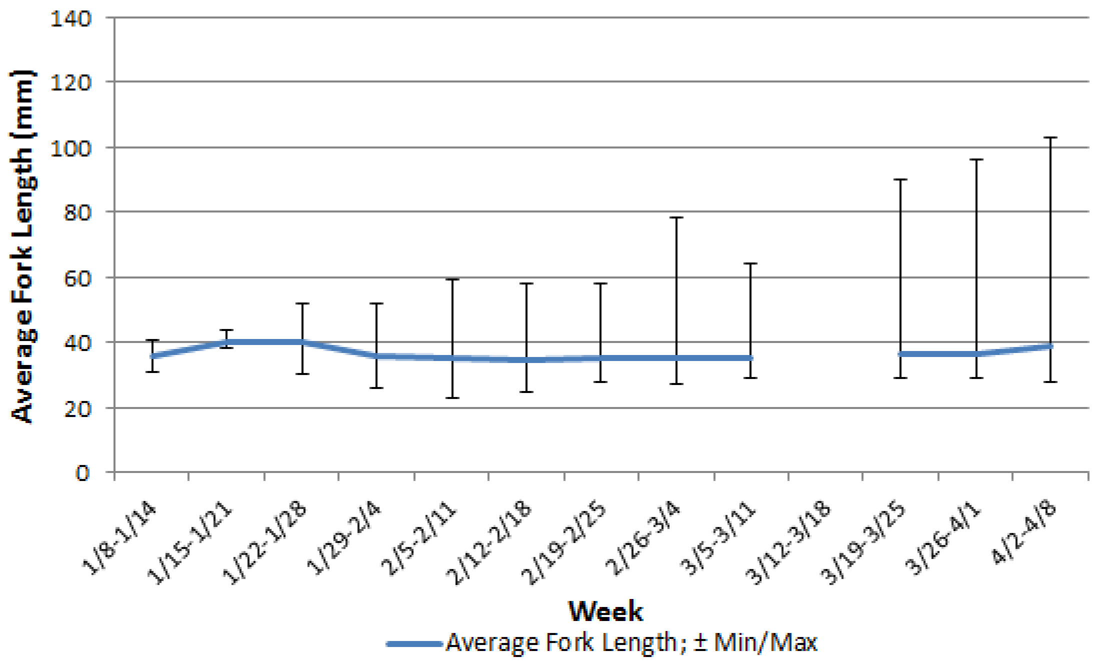


Note: Sampling did not occur between 7 March and 21 March. Catch totals for weeks encompassing dates in which no sampling or reduced sampling occurred may appear misleading. Plus-counted Chinook salmon and mortalities are included in the graph.

During the 2016 survey season, 12,331 of the 80,626 in-river produced, unmarked fall-run Chinook salmon captured were assessed for life stage and measured for fork length. The majority of this total was salmon identified as fry life stage. This life stage accounted for 93.37 percent (n = 11,513) of the measured catch. Salmon identified as yolk sac fry comprised 2.45 percent (n = 302), parr made up 3.57 percent (n = 440), and silvery parr were 0.62 percent (n = 76). No fall-run Chinook salmon identified as smolt life stage were captured during the 2016 survey season.

The average fork length began at 36 mm during the first week of sampling, increased to 40 mm between the weeks of 15 January and 28 January, then decreased to 35 mm until trapping was temporarily ceased on 7 March (Figure 10 and Table 3). When trapping resumed on 21 March average weekly fork length was at 36 mm and increased to 39 mm by the week of 2 April when trapping was terminated for the season.

Figure 10: Average weekly fork length for fall-run Chinook salmon during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March. Plus-counted fall-run Chinook salmon are not included in the graph.

Table 3: Average, minimum, maximum and standard deviations of fork lengths (mm) per week for fall-run Chinook salmon during the 2016 lower American River rotary screw trap survey season.

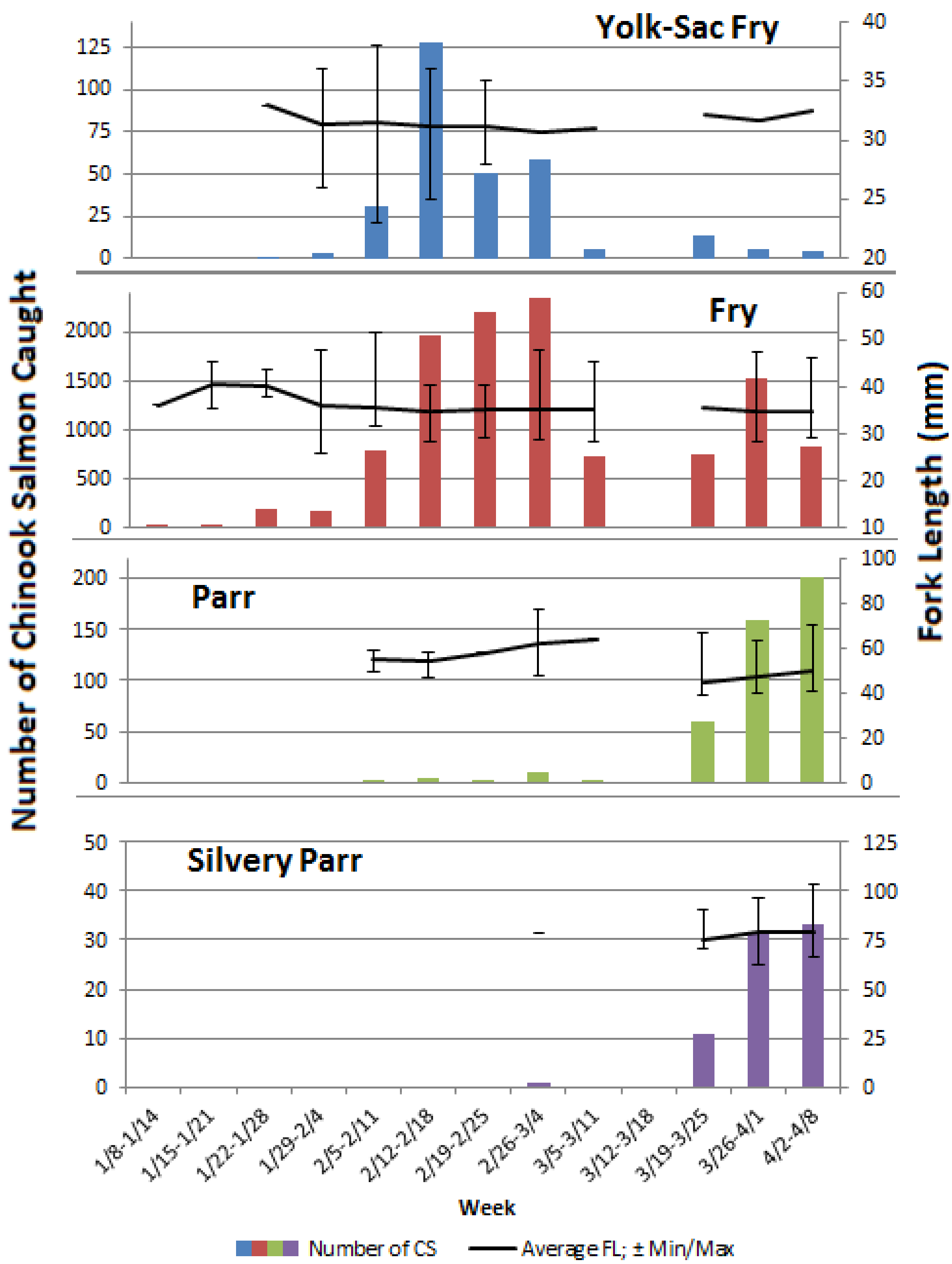
Julian Week	Fork Length			
	Average	Min	Max	St. Dev.
1/8-1/14	36	31	41	7.07
1/15-1/21	40	38	44	1.98
1/22-1/28	40	30	52	3.76
1/29-2/4	36	26	52	2.81
2/5-2/11	35	23	59	2.31
2/12-2/18	35	25	58	2.20
2/19-2/25	35	28	58	1.97
2/26-3/4	35	27	78	2.64
3/5-3/11	35	29	64	2.17
3/12-3/18				
3/19-3/25	36	29	90	5.72
3/26-4/1	37	29	96	7.33
4/2-4/8	39	28	103	10.00

Note: Sampling did not occur between 7 March and 21 March.

In-river produced, unmarked fall-run Chinook salmon identified as fry life stage were captured throughout the survey season (Figure 11). Chinook salmon identified as yolk-sac fry and parr life stages were captured up to the end of the 2016 survey season, with the first yolk-sac fry captured on 26 January, and the first parr captured on 5 February. One juvenile Chinook salmon identified as a silvery parr life stage was caught on 3 March, but the majority were captured starting on 21 March when trapping resumed after the two week cessation. The silvery parr life stage was also captured until trapping terminated.

As in previous years, the fork length distributions of the measured juvenile fall-run Chinook salmon captured varied by life stage (Table 4 and Figure 12), and increased in width of range from life stage to life stage. Yolk-sac fry had a fork length distribution between 23 mm and 38 mm, while fry ranged from 28 mm and 52 mm. Parr and silvery parr had the most similar width of ranges with parr between 39 mm and 77 mm, and silvery parr between 63 mm and 103 mm (Figure 13 and Table 5).

Figure 11: Weekly fall-run Chinook salmon catch by life stage with average weekly fork lengths (mm) during the 2016 lower American River rotary screw trap survey season.



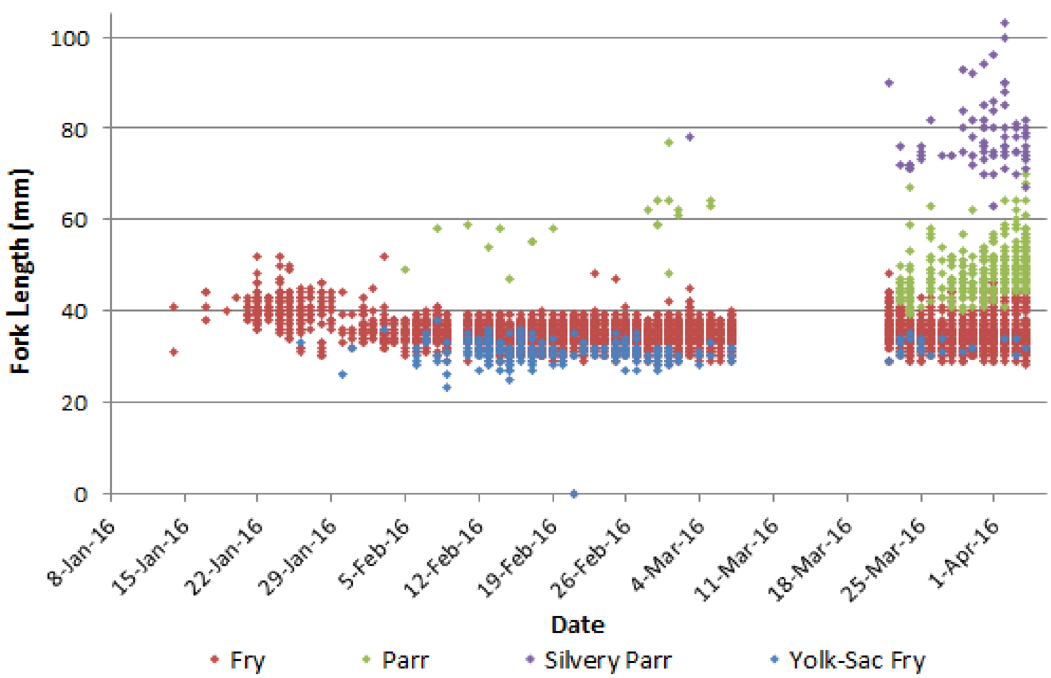
Note: Sampling did not occur between 7 March and 21 March. Plus-counted fall-run Chinook salmon are not included in the graph.

Table 4: Average, minimum and maximum fork lengths (mm) per week for each stage of fall-run Chinook salmon during the 2016 lower American River rotary screw trap survey season.

Julian Week	Yolk-Sac Fry			Fry			Parr			Silvery Parr		
	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave	Min	Max
1/8-1/14				36	31	41						
1/15-1/21				40	38	44						
1/22-1/28	33	33	33	40	30	52						
1/29-2/4	31	26	36	36	32	52						
2/5-2/11	32	23	38	36	29	41	55	49	59			
2/12-2/18	31	25	36	35	29	40	54	47	58			
2/19-2/25	31	28	35	35	29	48	58	58	58			
2/26-3/4	31	27	35	35	28	45	62	48	77	78	78	78
3/5-3/11	31	29	33	35	29	40	64	63	64			
3/12-3/18												
3/19-3/25	32	29	35	35	29	48	45	39	67	75	71	90
3/26-4/1	32	30	34	35	29	46	47	40	63	79	63	96
4/2-4/8	33	30	34	35	28	47	50	41	70	79	67	103

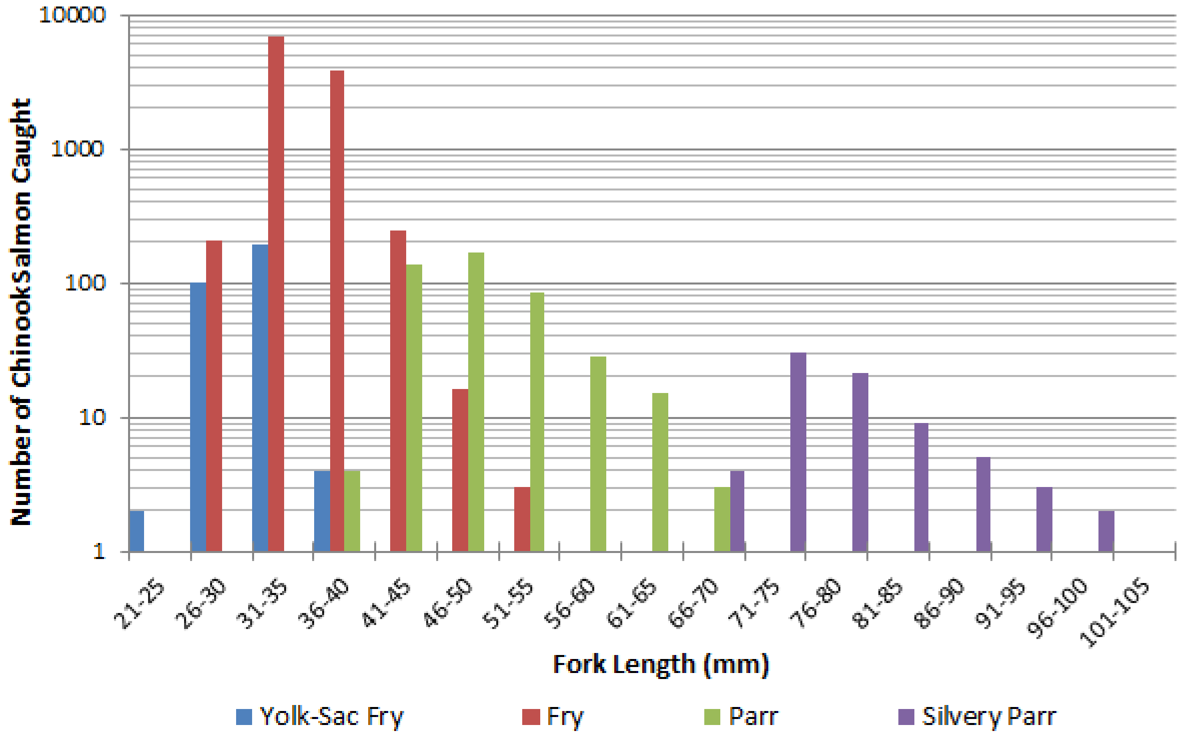
Note: Sampling did not occur between 7 March and 21 March.

Figure 12: Daily fall-run Chinook salmon fork lengths during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

Figure 13: Distribution of fall-run Chinook salmon life stage by fork length during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March. Plus-counted fall-run Chinook salmon are not included in the graph. Since the *y*-axis scale is logarithmic, fork length categories containing only one salmon are not shown in the graph. These are listed as follows: one fall-run Chinook salmon parr was captured at 77 mm, one silvery parr was captured at 63 mm, and one silvery parr was captured at 103 mm.

Table 5: Distribution of fall-run Chinook salmon life stage by fork length size class during the 2016 lower American River rotary screw trap survey season.

Fork Length Size Class	Yolk-Sac	Fry	Parr	Silvery Parr
21-25	2	0	0	0
26-30	100	207	0	0
31-35	192	6921	0	0
36-40	4	3797	4	0
41-45	0	247	136	0
46-50	0	16	169	0
51-55	0	3	84	0
56-60	0	0	28	0
61-65	0	0	15	1
66-70	0	0	3	4
71-75	0	0	0	30
76-80	0	0	1	21
81-85	0	0	0	9
86-90	0	0	0	5
91-95	0	0	0	3
96-100	0	0	0	2
101-105	0	0	0	1

Fulton’s condition factor (K) for in-river produced, unmarked fall-run Chinook salmon captured in 2016 displayed a slightly increasing trend in condition throughout the survey season (Appendix 5). The overall trend line exhibited a positive slope of 0.0025. The condition factors of each life stage had positively sloped trend lines as well; fall-run Chinook salmon identified with a life stage of parr showed the greatest increase in condition with a trend line slope of 0.0016, fry had a trend line slope of 0.0010, and silvery parr displayed the smallest increase with a trend line slope of 0.0007. Yolk-sac fry captured in 2016 were unable to be accessed for Fulton’s condition factor as every fish identified with this life stage was measured below 40 mm and weights were therefore not taken.

Trap Efficiency

Three mark-recapture trap efficiency trials were conducted during the 2016 survey season (Table 6). These trials used 4,684 fall-run Chinook salmon, all of which were in-river produced salmon that were collected with the RSTs and marked with BBY whole body stain. A total of 160 released salmon was recaptured. In the first trial, average fork length of released vs. recaptured fish decreased by approximately 1 mm, in the second and third trials it increased by approximately 1 mm. The average trap efficiency for the three trials was 4.01 percent.

Table 6: Trap efficiency data for mark and recapture trials during the 2016 lower American River rotary screw trap survey season.

Date	Fish Origin	Mark Color	Total #	Release ID Code	Date	Time	Average FL (mm)	Total Released	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total Recaptured	Average FL (mm)	Trap Efficiency	FLOW (CFS) Day of Release
BBY STAINING					RELEASE				RECAPTURES for All Traps Combined							RECAPTURE SUMMARY			
2/16/2016	In-River	Yellow	613	295	2/17/2016	5:47 PM	34.94	586	33	0	0	0	0	0	0	33	34.333	5.63%	3040
2/25/2016	In-River	Yellow	1700	296	2/26/2016	6:10 PM	34.52	1671	61	1	0	0	0	0	0	62	35.410	3.71%	5370
3/23/2016	In-River	Yellow	2465	298	3/24/2016	7:11 PM	36.87	2427	65	0	0	0	0	0	0	65	37.969	2.68%	6380

Note: Fall-run Chinook salmon were used for all trap efficiency trials.

In-River = Lower American River

BBY = Bismark brown Y whole body stain

Release ID Code: This code is associated with the CAMP RST platform used to store RST data.

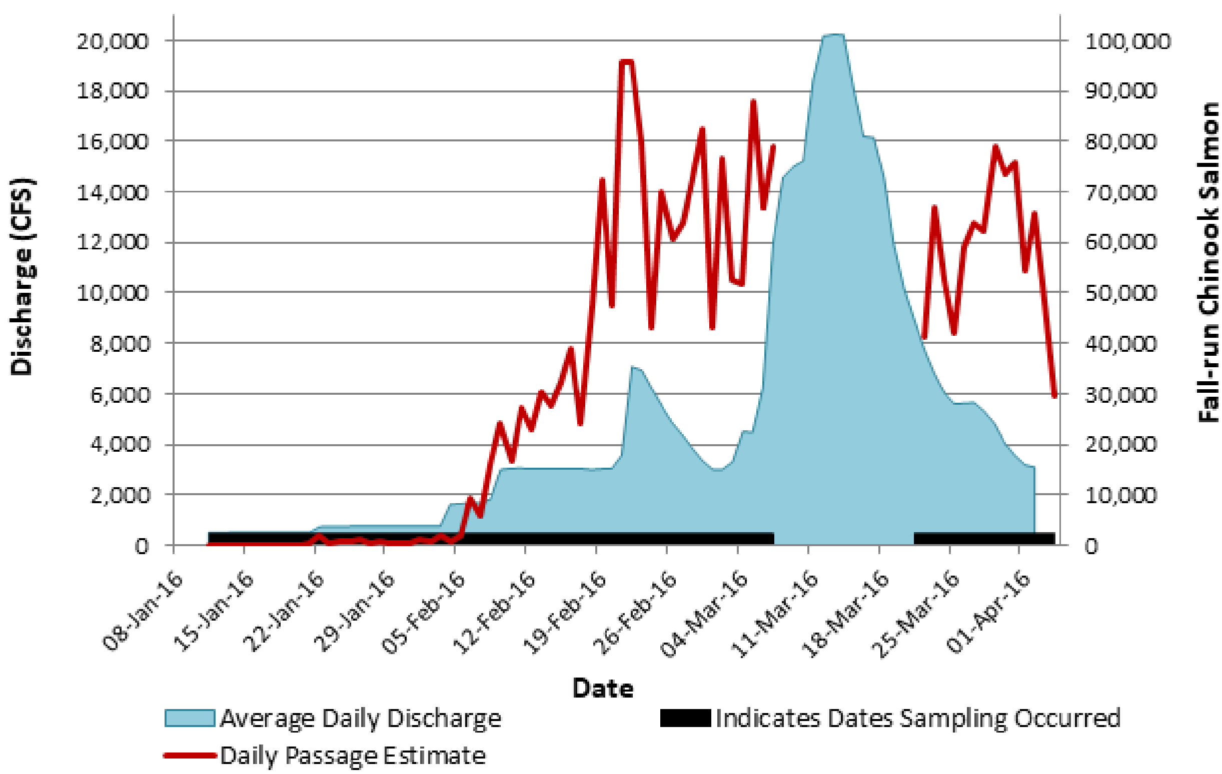
Flow (CFS) is a daily average discharge from the USGS's American River Fair Oaks monitoring station, 21 rkm upstream of the American River RSTs on the day of the trap efficiency release.

Passage Estimate for Fall-Run Chinook salmon

A total of 2,394,719 in-river produced fall-run Chinook salmon were estimated to have emigrated past the rotary screw trap location on the lower American River during the 2016 survey season. The 95 percent confidence interval for this estimate was from 1,803,134 to 2,907,545 individuals. Estimated passage down the lower American River by life stage during this time was 2,303,635 fry (including both yolk-sac fry and fry life stages), and 93,147 parr (including both parr and silvery parr life stages). It is important to note that this is only an estimate of Chinook salmon emigration during the time the traps were operating from 8 January to 7 March and from 21 March to 4 April. Potential emigration during the two weeks the traps were not sampling is not included in this estimate.

A comparison of weekly passage estimates to weekly discharge at the USGS monitoring station at Fair Oaks is displayed in Figure 14 and Table 7.

Figure 14: Daily passage estimate of fall-run Chinook salmon and daily discharge at Fair Oaks during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

Table 7: Weekly passage estimate of fall-run Chinook salmon and weekly discharge at Fair Oaks during the 2016 lower American River rotary screw trap survey season.

Date	Discharge (CFS)	Passage Estimate
1/8-1/14	502	67
1/15-1/21	511	732
1/22-1/28	722	6,165
1/29-2/4	767	5,690
2/5-2/11	2,078	101,310
2/12-2/18	3,047	224,183
2/19-2/25	4,693	504,522
2/26-3/4	3,912	503,739
3/5-3/11	10,284	233,562
3/12-3/18	18,499	
3/19-3/25	9,474	202,726
3/26-4/1	4,946	468,122
4/2-4/8	3.140	143.899

Note: Sampling did not occur between 7 March and 21 March.

Genetic Analysis

Genetic samples were taken from a total of 113 in-river produced juvenile Chinook salmon captured during the 2016 survey season. The SNP panel's "Genetic Call to three lineages" probabilities for 111 of the 113 samples exceeded a 50 percent threshold; the final salmon run assignments for those 111 salmon were therefore made based on genetic data. Fin clips from the remaining two of the 113 genetically sampled salmon did not contain enough genotypes to assign a salmon run using the genetic markers. These salmon were compared to other genetically sampled salmon of the same LAD run and were given a final run assignment respectively. A complete accounting of the salmon run assignments using LAD criteria and genetic markers is provided in Appendix 4.

Ninety-one in-river produced Chinook salmon classified as spring-run using LAD criteria were captured in 2016. Genetic samples were taken from 90 of those salmon. Analyses using SNP genetic markers from two individuals indicate they were spring-run Chinook salmon, while 87 individuals were fall-run Chinook salmon (Table 8). Not enough genotypes were identified in the sample from the remaining salmon to assign a genetic call. However, since 87 of the 89 samples (97.75 percent) that were classified as spring-run Chinook salmon using the LAD criteria were determined to be fall-run Chinook using the genetic markers (Table 8), the LAD criteria was determined to be relatively inaccurate at assigning salmon runs. The salmon that was genetically sampled, but did not contain enough genotypes to conduct successful genetic analyses was therefore given a final-run of fall to reflect the genetic run assignments given to the majority of the LAD spring-run Chinook salmon. The one LAD spring-run Chinook salmon that was captured and not genetically assessed was also compared to genetically sampled LAD spring-run given a final-run assignment of fall respectively.

Genetic analyses were conducted for all three of the in-river produced Chinook salmon that were classified as winter-run salmon using LAD criteria. Analyses using SNP genetic markers from those samples indicate one individual was a winter-run Chinook salmon, and two individuals were fall-run Chinook salmon (Table 8).

A total of 12 genetic samples were taken from the 256 captured Chinook salmon classified as late fall-run Chinook salmon using LAD criteria. Analyses using SNP genetic markers from those samples indicated all 12 individuals (100.00 percent) were fall-run Chinook salmon (Table 8). Because the LAD criteria appeared to incorrectly assign this salmon run, all the LAD late fall-run Chinook salmon that were not genetically sampled were given a final-run assignment of fall to reflect the run assignments given to genetically sampled LAD late fall-run Chinook salmon. This resulted in 244 LAD late fall-run Chinook salmon that were not genetically sampled being given a final run assignment of fall.

Eight salmon classified as fall-run Chinook salmon using LAD criteria were also sampled for genetic analysis. Analyses using SNP genetic markers from these samples indicated seven of these individuals were fall-run Chinook salmon (Table 8) and not enough genotypes were identified in the remaining genetic sample to assign a genetic call. However, since 100.00 percent (n = 7) of the samples classified as fall-run Chinook salmon using the LAD criteria that were able to be genetically assessed were determined to be fall-run Chinook (Table 8), the remaining sample was also given a final-run of fall.

Table 8: Comparison of Chinook salmon run assignments using length-at-date (LAD) criteria and SNP genetic markers during the 2016 lower American River rotary screw trap survey season.

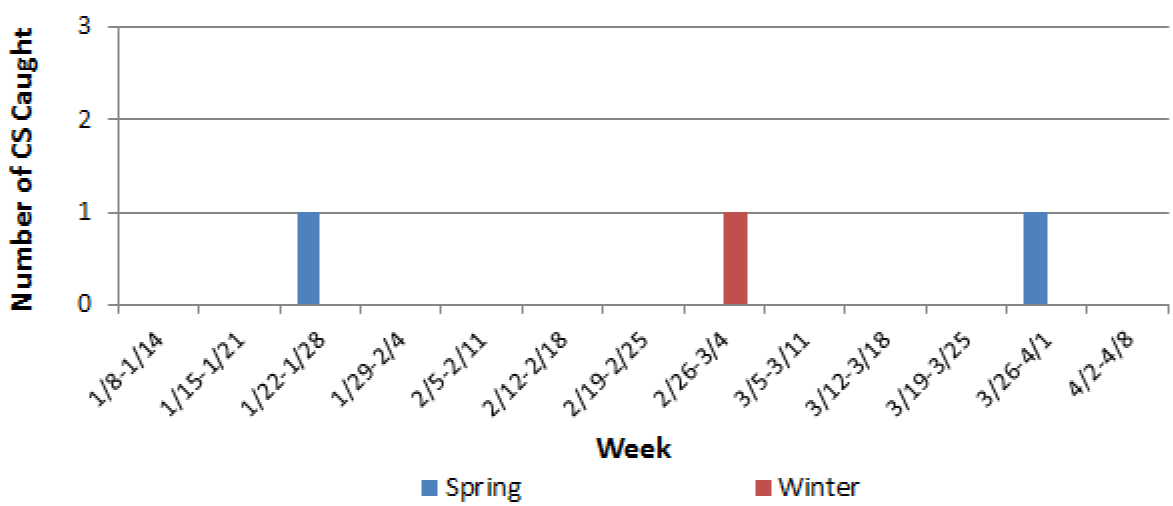
	Genetic salmon run assignment based on a >50 percent genetic probability threshold			
LAD salmon run assignment	Fall	Late Fall	Spring	Winter
Fall	7	0	0	0
Late Fall	12	0	0	0
Spring	87	0	2	0
Winter	2	0	0	1

Spring- , Winter- and Late Fall-run Chinook salmon

The genetic analyses suggest that two in-river produced spring-run Chinook salmon were captured during the 2016 survey season (Figure 15). One was identified as a button-up fry lifestage and was captured on 26 January. This individual had a fork length of 51 mm, which was 13 mm larger than the average fork length of fall-run Chinook salmon captured on that day. The second spring-run Chinook salmon was identified as a silvery parr life stage and was captured on 30 March. This individual had a fork length of 80 mm; 44 mm larger than the average fork length of fall-run Chinook salmon captured on that day.

The genetic analyses suggest that only one in-river produced winter-run Chinook salmon was captured during the 2016 survey season on 3 March (Figure 15). This individual was identified as a smolt life stage and had a fork length of 108 mm; 72 mm larger than the average fork length of fall-run Chinook salmon captured on the same day.

Figure 15: Weekly catch totals of spring- and winter-run Chinook salmon during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

The genetic analyses suggest that no late fall-run Chinook salmon was captured during the 2016 survey season.

Adult Chinook salmon

Three Chinook salmon identified as adult life stage were captured during the 2016 survey season. One of these individuals was an in-river produced Chinook salmon adult captured on 20 January, measuring 756 mm. The other two were hatchery produced adults, measuring 785 mm and 790 mm, and captured on 20 January and 19 January respectively. The individual captured on 19 January was identified as a male.

Steelhead/Rainbow Trout

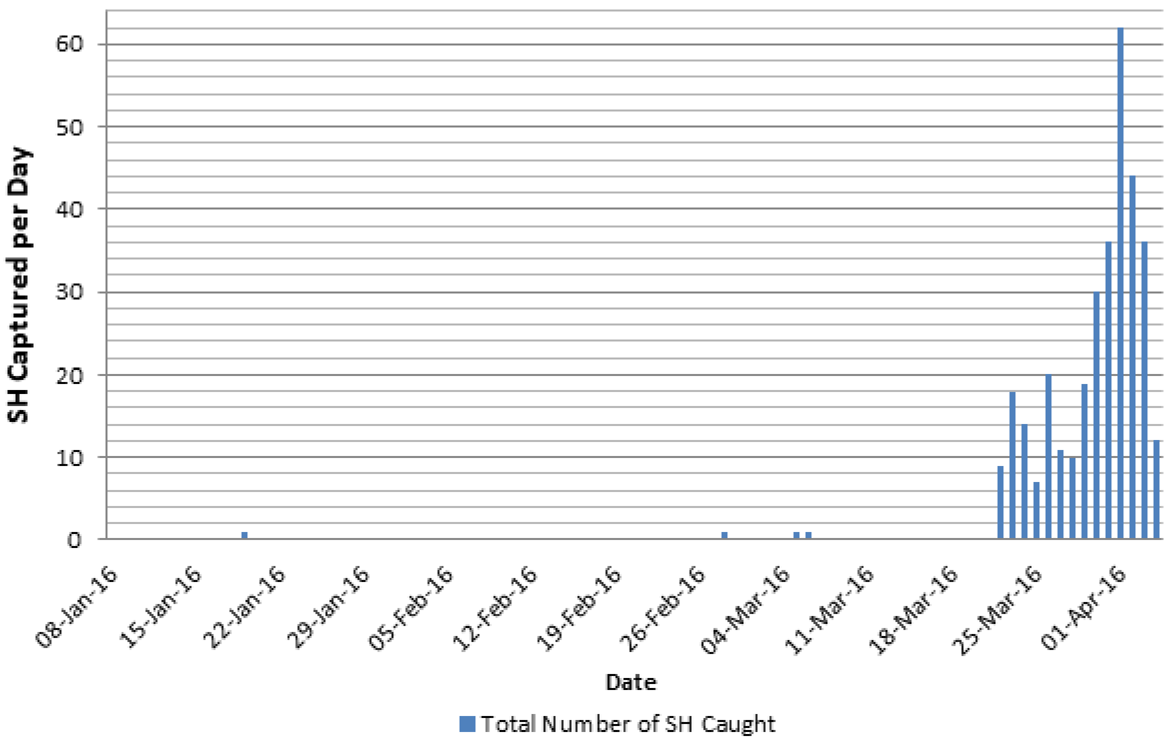
During the 2016 survey season, a total of 332 in-river produced steelhead was captured (Table 9). Of that total, 98.80 percent (n = 328) were captured in the 13 days before trapping operations were terminated, between 22 March and 4 April. In the last four days of the survey season alone, between 1 April and 4 April (Figure 16), 46.08 percent of the entire season's catch (n = 153) were captured.

Table 9: Weekly catch totals by life stage for in-river produced steelhead during the 2016 lower American River rotary screw trap survey season.

Julian Week	Yolk-Sac Fry	Fry	Parr	Silvery Parr	Smolt	Adult	Unassigned life stage	Total
1/8-1/14	0	0	0	0	0	0	0	0
1/15-1/21	0	0	0	0	1	0	0	1
1/22-1/28	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	1	0	0	0	0	0	0	1
3/5-3/11	1	1	0	0	0	0	0	2
3/12-3/18								
3/19-3/25	0	47	0	0	0	0	1	48
3/26-4/1	2	185	1	0	0	0	0	188
4/2-4/8	0	91	1	0	0	0	0	92
Total	4	324	2	0	1	0	1	332

Note: Sampling did not occur between 7 March and 21 March.

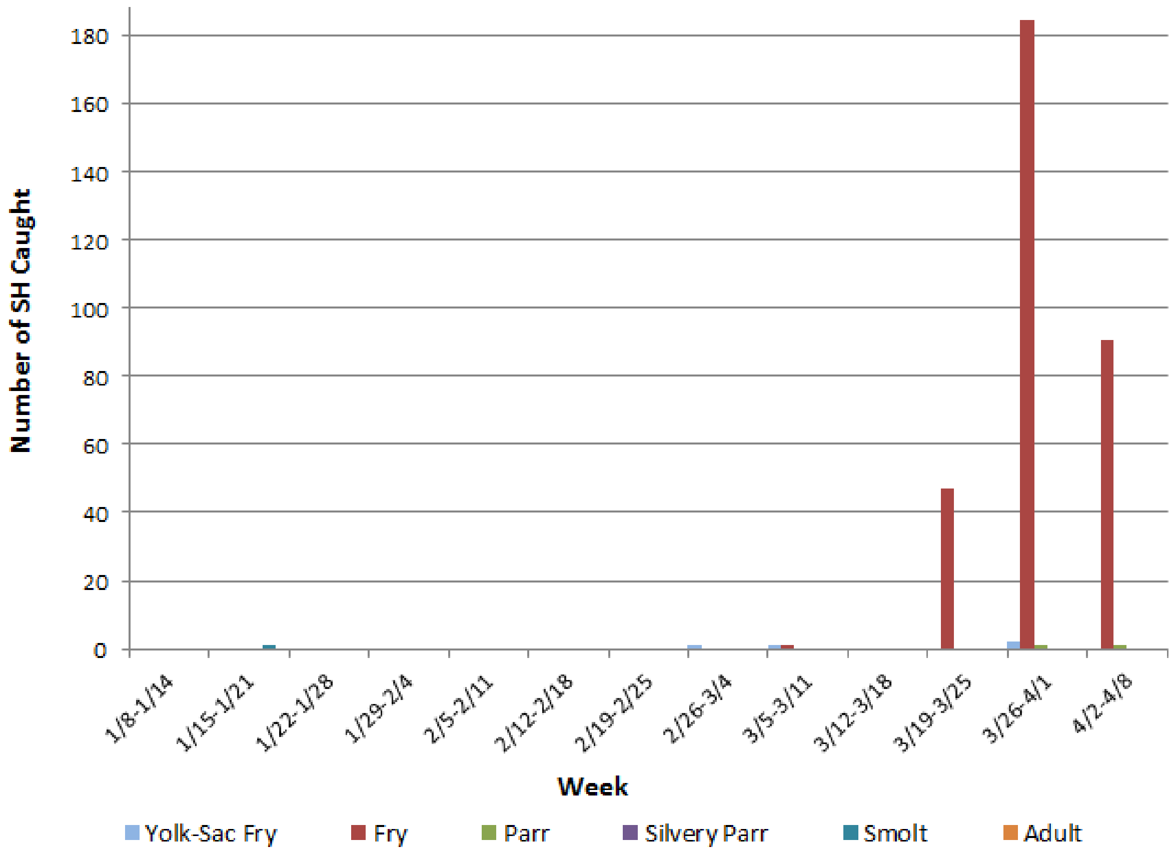
Figure 16: Daily catch totals for in-river produced steelhead during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

The life stage composition of the measured steelhead consisted of four yolk-sac fry comprising 1.21 percent of the measured total, 324 fry comprising 97.89 percent, two parr comprising 0.60 percent, and one smolt comprising 0.30 percent (Figure 17). No in-river produced steelhead was identified as silvery parr or adult life stages. Only one steelhead captured in 2016 was not assessed for a life stage.

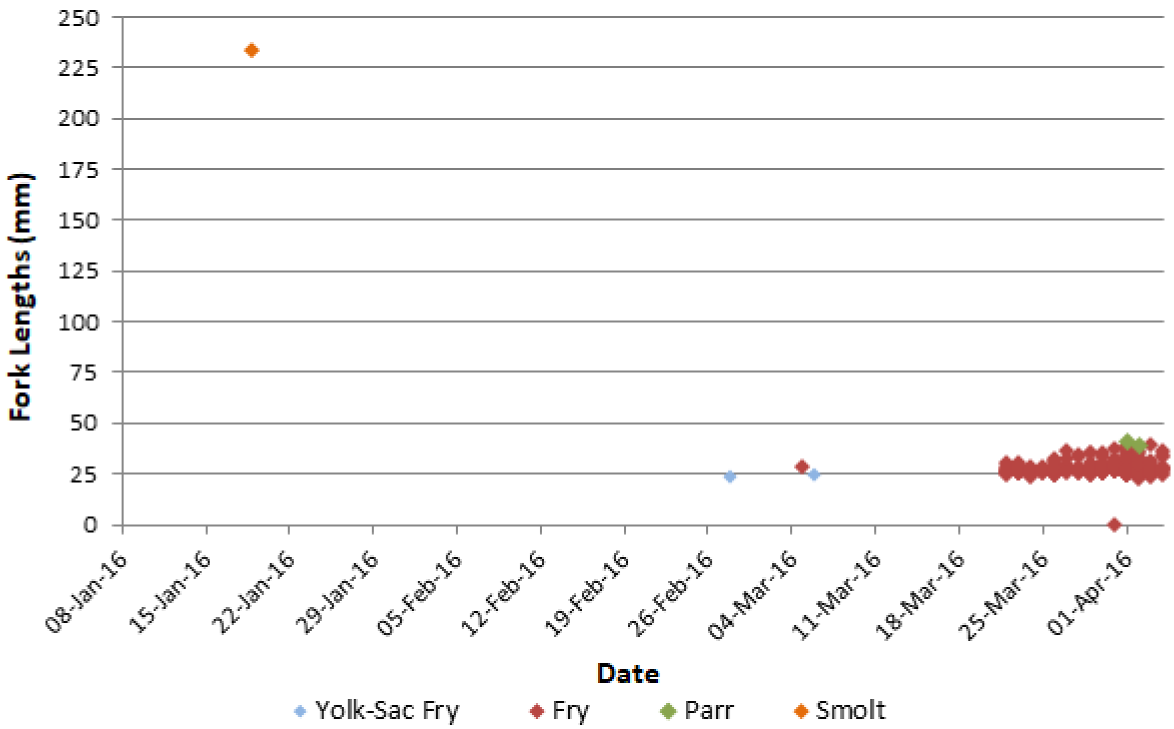
Figure 17: Weekly catch totals by life stage for in-river produced steelhead during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

The steelhead identified as a smolt life stage was captured on 19 January with a fork length of 233 mm, and the two parr were captured on 1 April and 2 April, with fork lengths of 41 mm and 39 mm, respectively. Steelhead identified as yolk-sac fry were captured between 28 February and 1 April and ranged in fork length from 23 mm to 25 mm. One fry was captured on 5 March, and the rest were captured from 22 March until trapping terminated. Steelhead identified as fry life stage ranged in fork length from 22 mm to 39 mm (Figure 18).

Figure 18: Individual fork lengths by date for in-river produced steelhead captured during the 2016 lower American River rotary screw trap survey season.



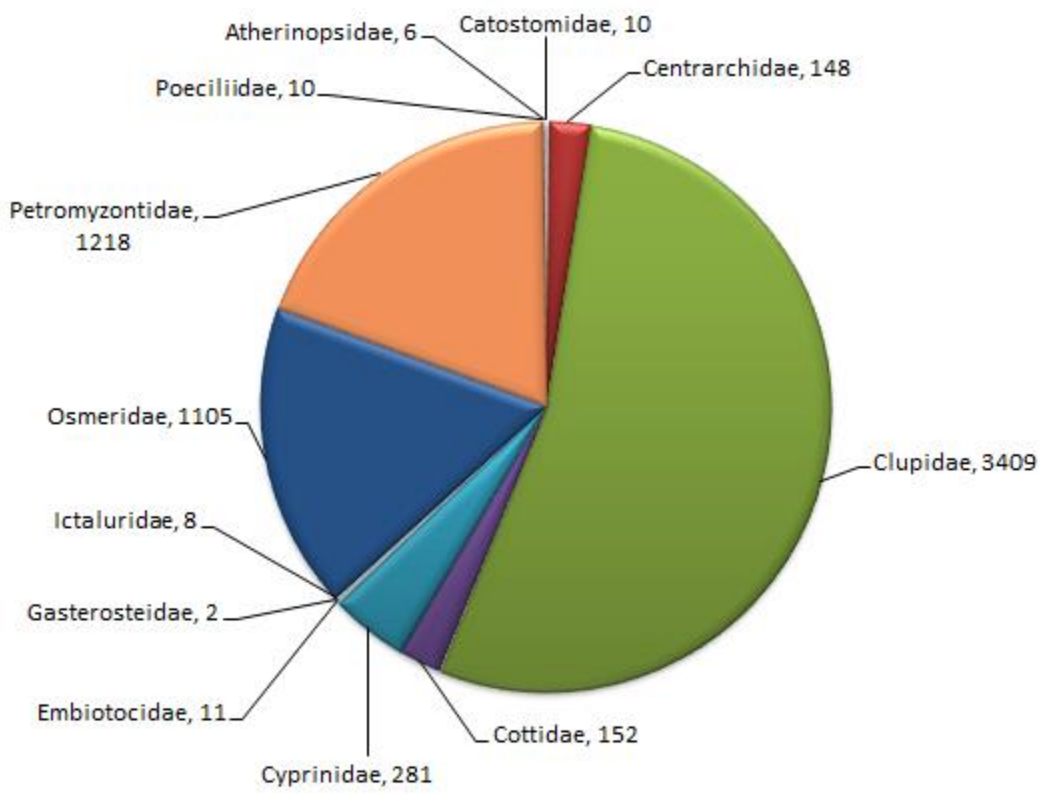
Note: Sampling did not occur between 7 March and 21 March. No plus-counted steelhead or mortalities were captured.

Nine hatchery-produced steelhead, marked with clipped adipose fins, were also captured. Three of these, captured between 26 January and 5 February, were identified as adult life stage, and ranged in fork length from 705 mm to 730 mm. Two hatchery-produced steelhead were identified as smolts, and measured 213 mm and 254 mm. These were captured on 9 February and 3 April, respectively. Four hatchery-produced steelhead, captured between 12 February and 22 February were identified as silvery parr life stage, and ranged in fork length from 182 mm to 201 mm.

Non-salmonid Species

In addition to the salmonids, 6,360 non-salmonid fish were captured during the 2016 survey season. The majority (n = 5,869, or 92.28 percent) of these fish belonged to 24 identified species in the following families: *Atherinopsidae* (silverside), *Catostomidae* (sucker), *Centrarchidae* (sunfish/black bass), *Clupeidae* (shad), *Cottidae* (sculpin), *Cypinidae* (minnow), *Embiotocidae* (Tule perch), *Gasterosteidae* (stickleback), *Ictaluridae* (bullhead/catfish), *Osmeridae* (smelt), *Petromysontidae* (lamprey), and *Poeciliidae* (mosquitofish) (Figure 19). The remaining 7.72 percent (n = 491) were not able to be identified to species level, but belonged to the following families: *Petromyzontidae*, *Cyprinidae*, *Cottidae*, and *Centrarchidae*. A total of 1,655 (26.02 percent) of the non-salmonid fish captured in 2016 are of species native to Central Valley watersheds, and a total of 4,697 (73.85 percent) are of non-native species. A complete list of non-salmonid species captured in the 2016 survey season is presented in Appendix 3.

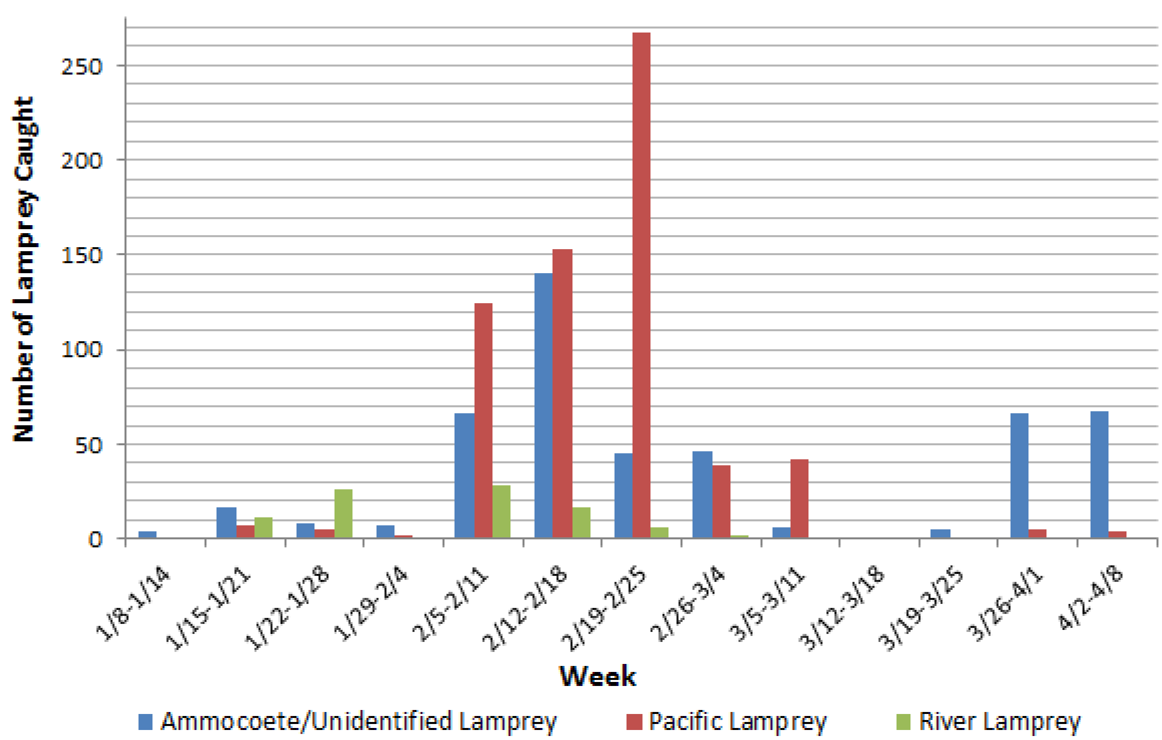
Figure 19: Non-salmonid catch totals for families of fish species collected during the 2016 lower American River rotary screw trap survey season.



Of the 6,360 non-salmonid fish, 1,218 (19.15 percent) were lamprey species. Individuals identified as Pacific lamprey made up 53.36 percent (n = 650) of captured lampreys and included six individuals identified as adult life stage and 644 individuals identified as juvenile life stage. River lamprey comprised 7.47 percent (n = 91) of the lamprey captured and were all identified as juvenile life stage. The remaining 39.16 percent (n = 477) were unidentifiable to the species level, with 476 identified as ammocoete life stage, and one individual identified as a juvenile life stage. Pacific lamprey and ammocoetes were captured throughout the season, while river lamprey were captured only from 18 January to 26 February (Figure 20.)

Catch of river lamprey peaked on 11 February when 19.78 percent (n= 18) of the season's river lamprey total was captured. Catch of Pacific lamprey peaked between 11 February and 25 February. At this time, 82.77 percent (n= 538) of the season's Pacific lamprey total was captured, with 22.46 percent (n = 146) captured on 24 February alone. Of the lamprey identified as ammocoete life stage or otherwise unidentified to species level, 36.06 percent (n=172) were captured between 11 February and 16 February, with 10.48 percent (n=50) captured on 11 February alone.

Figure 20: Total weekly lamprey catch during the 2016 lower American River rotary screw trap survey season.



Note: Sampling did not occur between 7 March and 21 March.

Discussion

When interpreting the data collected during the 2016 survey season and the juvenile Chinook salmon passage estimate produced from that data, several influential factors must be considered. One of the most significant of these may be environmental factors, which likely hindered the ability to collect consistent and high quality data.

Similar to the conditions seen in 1997 and 1998, 2016 was one of the strongest El Niño events on record for the eastern Pacific Ocean and resulted in a modest relief of the multi-year drought in northern California (NOAA 2016, DWR 2016). According to the Department of Water Resources (DWR), the water level in Folsom Lake was increased to a capacity that exceeded the historical average capacity in February and March due to rainfall and snowmelt (DWR 2016). Since Folsom Lake is a reservoir primarily used for flood control, USBR is required to keep Folsom Lake at a mandated percentage of maximum capacity in an effort to control for flood events and maintain storage for rain and snowmelt throughout the winter months. USBR was therefore required to release significant amounts of water from Folsom Lake into the American River in 2016 to comply with the mandate. Subsequently, four significant increases to the outflow of Nimbus Dam were scheduled, resulting in river flow that ranged from 440 CFS to 20,600 CFS throughout the 3-month sampling period.

Unlike in the previous two years where river flows reached a maximum of approximately 2,000 CFS during the survey season, the heightened river flows resulting from the 2016 El Niño event increased the velocity and depth of the river sufficiently to support a 5 ft trap in the south channel in addition to the two 8 ft traps typically deployed in the north channel. This 5 ft trap was installed on 10 February when river discharges reached approximately 3,000 CFS, removed on 7 March when discharges reached 15,000 CFS, and redeployed on 29 March when flows reached approximately 5,300 CFS.

In addition to increasing the depth and velocity of the river channels, the high river flows increased the amount of debris in the water column, subsequently increasing the amount of debris that got captured in the RSTs. Higher amounts of debris can cause mortality by crushing fish within the debris or by stopping the rotation of the cone, which can cause fish trapped there to become pummeled by incoming water. Increased debris loads also increase the potential for damage to traps and sampling equipment. In order to mitigate the potential for fish mortality associated with increased debris loads or high debris loads and increased fish passage, various methods were employed throughout the 2016 survey season. Trap checks were performed at night when increased debris loads could be managed by twice daily trap checks, a random sampling regime was implemented when debris loads could only be controlled for a short period of time, and when debris loads were judged to be too high to be reasonably managed, the RST cones were raised and pulled out of the thalweg until river flows were sustained at a constant discharge or debris load reduced to a manageable level. As data cannot be collected when the cones are raised, the CAMP platform was used to estimate potential catch during gaps in sampling less than seven days in duration, based on the catch from trap visits before and after the gap in sampling. With the understanding that the smaller the gap in sampling, the more confidence can be had in the accuracy of the estimated catch, when it was necessary to cease sampling entirely, an effort was made to raise the RST cones for a maximum of approximately 48 hours. Gaps in sampling that were under 48 hours in duration occurred following the flow increase to 1,600 CFS on 5 February, to 3,000 CFS on 9 February and to 7,000 CFS on 22 February.

During the 2016 trapping season, night checks in addition to daily trap visits were implemented on three occasions. After sampling resumed following the river flow increase to 3,000 CFS, night checks were performed on 11 February and 12 February to ensure debris load could be managed and fish health would not be adversely affected. Night checks were also implemented between 17 February and 22 February in response to the full moon, which in previous survey seasons had been associated with an increase in passage. When continuous sampling resumed on 24 February after the river flow increase to 7,000 CFS, night checks were again implemented, and occurred between 24 February and 26 February.

On 22 February 2016, the timing of the full moon corresponded with a scheduled outflow increase from Nimbus Dam. Since debris levels were judged to be too high to be reasonably managed, a random sampling regime for the north channel RSTs was implemented in an effort to collect data while simultaneously reducing potential fish mortality. Subsamples were three hours in duration and occurred at randomly selected times in an attempt to gain an unbiased estimate of salmon catch that could be expanded by the CAMP program to more accurately estimate the previous and subsequent gaps in sampling. During the first randomly selected 3-hour subsample block, which occurred on 23 February from 8:00 AM to 11:00 AM, the debris intake for Trap 8.1 was unable to be controlled even with constant monitoring. The second subsample block, therefore, only included Trap 8.2, and occurred on 23 February from 8:00 PM to 11:00 PM. Trap SC5 was able to sample continuously with no debris complications, thus no random sampling regime was implemented for this trap.

On 7 March 2016, due to flood control regulations, water was released from the Folsom Dam spillway for the first time in four years (USBR 2016). Discharges from Nimbus Dam were consequently heightened as well, increasing American River flows from approximately 4,500 CFS to approximately 20,000 CFS during the week following 7 March. During this flow increase, cones were raised and pulled out of the thalweg and were unable to be redeployed within 48 hours. When river flows were sustained at 15,000 CFS, an attempt was made to redeploy the 8 ft RSTs. However, at this discharge, the high velocity of the RST cone rotation significantly increased safety hazards and potential for damage to the sampling equipment, and the traps were determined to be inoperable. Sampling did not occur again until 21 March when flows declined to approximately 10,000 CFS and safety concerns were reduced. This resulted in a two-week gap in sampling between 7 March and 21 March.

Since the gap in sampling between 7 March and 21 March exceeded the seven day maximum threshold for the CAMP platform to accurately estimate catch, the passage estimate produced for the 2016 survey season excludes this period of time and is likely biased low. Furthermore, although catch during these two weeks is unknown, its proximity to the apparent peak of the season coupled with the continuation of elevated catch when trapping resumed, implies that the peak of catch may actually have occurred during this two week gap in sampling, further biasing the production estimate for the 2016 survey season.

In addition, the 2016 survey season likely did not encompass the entire juvenile fall-run emigration period. To be certain that the entire emigration period is sampled, there should be multiple weeks of zero catch before the first and after the last Chinook salmon are captured in a given season, which was not the case in 2016. Despite this, only six juvenile fall-run Chinook salmon were caught during the first seven days of the survey, out of a total of 80,626 captured throughout 2016 sampling operations, indicating that only 0.0074 percent of the entire season's catch was captured during the first full week of sampling. Additionally, while trapping began on 11 January, the first juvenile Chinook salmon was not captured until 14 January. Sampling operations during 2016 may therefore be safely assumed to have encompassed the majority of the emigration period start. Unfortunately, sampling efforts did not encompass the end of the emigration period, as monitoring efforts were not able to continue through the typical duration of a survey season. Trapping operations had to cease nearly two months earlier than historical American River RST survey seasons, which typically continued through May as temperature and river conditions permitted. On 4 April, the 2016 survey season was terminated due to exceeding authorized capture of live juvenile steelhead trout. During the last seven days of the survey season 16,335 juvenile fall-run Chinook salmon were captured, accounting for 20.26 percent of the entire season's catch. It is likely, therefore, that the survey season was terminated before the end of the emigration period, further biasing the 2016 passage estimates. Since it is unknown how many juveniles emigrated after sampling operations were terminated, it is not even possible to determine if the majority of the emigrating population is included in the passage estimate.

Despite its low bias, the 2016 passage estimate reflects a 61.16 percent increase from 2015. A total of 2,394,719 in-river produced fall-run Chinook salmon were estimated to have emigrated past the rotary screw trap location on the lower American River during the 2016 survey season, compared to 1,464,697 fall-run Chinook during the 2015 survey season. However, the confidence intervals for the 2016 survey season are 23.15 percent larger than in 2015, and range from 1,803,134 to 2,907,545 individuals, compared to a range of 1,412,787 to 1,668,506 individuals in the 2015 estimate. This difference in confidence interval width is likely due to the greater distribution of daily catch totals throughout the 2016 survey season, compared to 2015. Despite its increased width, however, even the lower boundary of the 2016 passage estimate confidence interval exceeds the upper boundary of the 2015 confidence interval by 134,628 fish, at minimum reflecting an 8.07 percent increase in estimated passage from 2015 to 2016.

However, passage estimates are also greatly influenced by trap efficiencies. The trap efficiency trials conducted in the 2016 survey season may have less accurately represented actual trap efficiencies than the trials conducted in previous seasons. For higher accuracy, multiple trap efficiency trials should be completed throughout a trapping season. Since trap efficiencies are inversely affected by the river discharge, trap efficiency trials rely heavily on a consistent river discharge throughout the entire trial period in order to provide accurate trap efficiencies. During the 2016 survey season, an attempt was made to conduct trap efficiency trials when each river flow increase stabilized, but with flow increases frequently occurring throughout the 3-month period, relatively few trap efficiency trials were able to be conducted.

The frequent river flow increases that occurred during the 2016 survey season helped maintain lower water temperatures compared to previous survey seasons where river flows were lower overall. River temperatures in 2016 ranged from a low of 8.4° C to a high of 15.1° C, compared to a low of 9.6° C and a high of 20.8° C during the 2015 survey season. According to a study performed on hatchery American River Chinook salmon, river temperatures inversely affect the growth rate throughout each life stage. The study found that optimal alevin fry length is achieved at 5° C, while higher water temperatures during the embryo incubation stage result in the production of smaller alevins (McCullough 1999). When comparing the average fork lengths of captured Chinook salmon throughout the 2015 and 2016 trapping seasons, the average fork length in January 2016 appeared to be greater than the average fork length in January 2015 (40 mm in January 2016 compared to 37 mm in January 2015). Alternatively, this observation may have been an artifact of low catch numbers in the first few weeks of the survey season, and the resultant higher percentage of fish with fork lengths of 40 mm and greater. Furthermore, instead of displaying an upward trend in average fork lengths as seen in previous years, the 2016 survey season displayed an initial decrease in average fork length. Due to the premature termination of the 2016 sampling season, however, it is unknown whether an increased number of large fish would have been captured in April and May 2016 resulting in the overall upward trend in average fork length as seen in previous years.

Despite differences in average fork lengths and fork length trends between the two survey seasons, LAD criteria in 2016 proved similarly inaccurate at determining the run of captured LAD spring-run Chinook salmon compared to 2015. Of the 89 samples taken in 2016 that were able to be genetically assessed and were classified as spring-run Chinook salmon using the LAD criteria, 2.24 percent (n = 2) were determined to be spring-run Chinook, compared to 12.62 percent (n = 13 of 103) determined by genetic analysis to be spring-run in 2015. Contrary to previous survey seasons, however, LAD criteria proved relatively inaccurate at determining the run of LAD winter-run Chinook salmon as well. In 2016, three LAD winter run were captured, and 33.33 percent (n = 1) was determined by genetic analysis to be a winter-run, compared to 78.57 percent (n = 22) determined by genetic analysis to be winter-run from 28 LAD winter-run samples taken in 2015.

Overall, fewer genetically determined winter- and spring-run Chinook salmon were captured in the American River RSTs during the 2016 survey season compared to the 2015 survey season. In 2016, only one non-natal winter-run Chinook salmon and two putative spring-run Chinook salmon were captured, versus 28 winter-run and 19 spring-run captured in 2015.

Since winter- and spring-run Chinook salmon do not spawn in the American river, it was historically hypothesized that the capture of these juveniles was correlated with high flow events on the Sacramento River causing a water level differential between the Sacramento and American River and resulting in a reversal of flow (backflow) into the American River. This backflow theoretically caused recently emerged winter- and spring-run juvenile Chinook emigrating down the Sacramento River to move up into the American River and rear above the rotary screw trap locations. In 2016, although flows were high on the Sacramento River during typical winter- and spring-run juvenile emigration times, the high discharge on the American River may have counteracted the backflow of the Sacramento River and resulted in the capture of fewer winter- or spring-run Chinook salmon.

Likewise, no hatchery produced juvenile Chinook salmon were captured in 2016, compared to 16 captured in 2015. Since hatchery produced juvenile Chinook salmon typically also stray into the American River when emigrating down the Sacramento River, the lack of hatchery produced juveniles observed in 2016 may follow the same premise theorized for the decreased catch of in-river produced winter- and spring-run Chinook salmon. In other words, although hatchery produced late fall-run juvenile Chinook salmon were released from Coleman National Fish Hatchery (NFH) on 12 January 2016, and winter-run juvenile Chinook salmon were released from Livingston Stone NFH on 17 and 18 February 2016, high discharge on the American River may have hindered the ability of these fish to rear in the American River in 2016.

During the 2016 season, a total of 332 in-river produced steelhead were captured in the American River RSTs with 97.89 percent of that total recorded as a fry life stage. Of the steelhead fry captured in the RSTs, 98.80 percent were caught in the last two weeks of the survey which is likely a result of our proximity to one or more steelhead redds. In 2016, redd surveys were conducted by Cramer Fish Sciences (Cramer) on the lower American River from 8 January to 14 April and found, using discriminant function analysis (DFA), that there were 53 steelhead redds throughout the survey section (RM 9 to RM 23)(Cramer 2016). During a survey conducted by Cramer on 3 February, two steelhead redds were found upstream of our rotary screw traps. One was at river mile nine and the other near river mile 10 (Figure 21).

Figure 21: Steelhead redd locations on the lower American River, depicted by the red markers, found on 3 February 2016 during the survey conducted by Cramer Fish Sciences.

A total of nine hatchery-produced steelhead, marked with clipped adipose fins, were caught during the 2016 lower American River RST survey. Of these nine, three were recorded as adults ranging from 705 mm to 730 mm. The other six were recorded as silvery parr (four ranging from 182 to 201 mm) and smolt (two at 213 and 254 mm) life stages. Coleman Fish Hatchery released a total of 591,362 BY 2015 steelhead with an average FL of 216 mm into the Sacramento River at Bend Bridge between 4 January and 9 January. Additionally, Nimbus Fish Hatchery released a total of 227,855 BY 2015 hatchery steelhead with an average FL of 152 mm into the American River at Howe Avenue between 10 February and 25 February. Based on the timing and size at capture, the steelhead captured on 9 February was likely from the CFH release and the steelhead captured between 12 February and 22 February were likely from the NFH release. Furthermore, the steelhead captured on 3 April may have been from either the CFH or NFH release.

Management Implications

In order to determine if efforts made by AFRP and others to increase abundance of Chinook salmon and steelhead on the lower American River have been successful, additional monitoring of juvenile salmonid emigration is required. There should also be continued water temperature and flow management to make the river conditions more favorable to anadromous fish. The 2016 data will be coupled with prior and future data to provide crucial information to better understand and improve conditions for Chinook salmon and steelhead on the lower American River. The 2016 data is of particular interest as it was considered an El Niño year, and can be contrasted with the drought years directly prior. This data can be used to influence water management modifications for the American River to make the river environment more favorable to anadromous fishes in future drought conditions. Management options such as modifications to discharge volume and timing could be adjusted to reduce pre-spawn mortality and minimize redd dewatering and superimposition which have likely had a negative influence on spawning in previous drought years, and may not have had as great an influence on spawning in 2016 due to the higher volumes of water.

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References

Allen, L. 2016. Gravel Augmentation Update Recreation and Park Commission for the Sacramento Water Forum. 25 May 2016. PowerPoint file.

California Department of Water Resources (DWR). 2010. California's drought of 2007-2009, an overview.

California Department of Water Resources (DWR). 2016. State Water Project Allocation Increased. 21 April 2016. http://www.water.ca.gov/news/newsreleases/2016/042116.pdf

California Water Science Center: California Drought. USGS. 31 Oct. 2015. https://ca.water.usgs.gov/data/drought/

Clemento A.J., E.D. Crandall, J.C. Garza, E.C. Anderson. 2014. Evaluation of a SNP baseline for genetic stock identification of Chinook salmon (Oncorhynchus tshawytscha) in the California Current large marine ecosystem. Fishery Bulletin 112:112-130.

Cramer Fish Sciences (Cramer). 2016. Lower American River Monitoring. 2016 Steelhead (Oncorhynchus mykiss) Spawning and Stranding Surveys Central Valley Project, American River, California Mid-Pacific Region. 46 pp plus appendix.

Demko, D.B., C. Gemperle, S.P. Cramer, and A. Philips. 1998. Evaluation of juvenile Chinook behavior, migration rate and location of mortality in the Stanislaus River through the use of radio tracking. Prepared by Cramer Fish Sciences for Tri-dam Project. December 1998.

Fisher, F.W. 1994. Past and present status of Central Valley Chinook salmon. Conservation Biology 8:870-873.

Greene, S. 1992. Estimated winter-run Chinook salmon salvage at the State Water Project and Central Valley Project Delta Pumping Facilities. 8 May 1992. California Department of Water Resources. Memorandum to Randall Brown, California Department of Water Resources. 3 pp. plus 15 pp. tables.

Hammersmark, C. 2014. 2013 Chinook Salmon Potential Redd Dewatering Estimate. Technical Memorandum. CBEC Inc.

Hannon, J. 2013. American River Steelhead (*Oncorhynchus mykiss*) Spawning – 2013, with comparisons to prior years. Unpublished report prepared by the U.S. Department of the Interior, Bureau of Reclamation, Central Valley Project, Mid-Pacific Region. 32 pp.

Healey, T.P. 1977. The Effects of High Temperature on the Survival of Sacramento River Chinook Salmon (Oncorhynchus tshawytcha) Eggs and Fry. California Department of Fish and Game, Anadromous Fisheries Branch. Admin. Rpt. No. 79-10.

Hicks, M. 2000. Evaluating standards for protecting aquatic life in Washington's surface water quality standards. Draft Discussion Paper and Literature Summary. Washington State Department of Ecology, Olympia, Washington.

James, L.A. 1997. Channel incision on the lower American River, California, from stream flow gage records. Water Resources Research 33:485-490.

Kohlhorst, D. W. 1976. Sturgeon spawning in the Sacramento River in 1973, as determined by distribution of larvae. California Fish and Game 62:32-40.

Marine, K. R., and J. J. Cech. 2004. Effects of high water temperatures on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. North American Journal of Fisheries Management 24: 198-210.

Martin, C.D., P. D. Gaines, and R.R. Johnson. 2001. Estimating the abundance of Sacramento River juvenile winter chinook salmon with comparisons to adult escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. U. S. Fish and Wildlife Service, Red Bluff, CA.

Maslin, P.E., W.R. McKinnev, and T.L. Moore. 1998. Intermittent streams as rearing habitat for Sacramento River Chinook salmon. Unpublished report prepared for the U. S. Fish and Wildlife Service under the authority of the Federal Grant and Cooperative Agreement Act of 1977 and the Central Valley Improvement Act.

McCullough, D. A. 1999. A Review and Synthesis of Effects of Alterations to the Water Temperature Regime on Freshwater Life Stages of Salmonids, With Special Reference to Chinook Salmon. Report No. EPA 910-R-99-010. Seattle, WA: EPA, Region 10.

McCullough, D., S. Spalding, D. Sturdevant, M. Hicks. 2001. Issue Paper 5. Summary of technical literature examining the physiological effects of temperature on salmonids. Prepared as part of U.S. EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. EPA-910-D-01-005.

McDonald, T., and M. Banach. 2010. Feasibility of unified analysis methods for rotary screw trap data in the California Central Valley. U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program, Cooperative Agreement No. 81420-8-J163. 18 pp.

Merz, J.E., and D.C. Vanicek. 1996. Comparative feeding habits of juvenile Chinook salmon, steelhead, and Sacramento squawfish in the Lower American River, California. California Fish and Game 82(4):149-159.

Merz, J.E., K. Sellheim, M. Saiki, C. Watry, D. Richards. 2013. Evaluation of gravel placement on habitat conditions for juvenile and adult anadromous salmonids in the lower American River, California. Prepared by Cramer Fish Sciences for the Sacramento Water Forum, U.S. Bureau of Reclamation, and the U.S. Fish and Wildlife Service CVPIA Gravel Program. June 2014.

Moyle, P. 2002. Inland Fishes of California. University of California Press, Berkeley and Los Angeles, California, USA.

Myrick, C.A., J.J. Cech. 2001. Temperature effects on Chinook salmon and steelhead: a review focusing on California's Central Valley populations. Bay-Delta Modeling Forum Technical Publication 01-1.

National Oceanic and Atmospheric Administration (NOAA). 2016. Leftover Warm Water in Pacific Ocean Fueled Massive El Niño. Web. Nov 2016. https://news.agu.org/press-release/leftover-warm-water-in-pacific-ocean-fueled-massive-el-nino/

Pacific States Marine Fisheries Commission (PSMFC). 2013. 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.

Pacific States Marine Fisheries Commission (PSMFC). 2014. Juvenile salmonid emigration monitoring in the lower American River, California January – May 2014. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California.

Pacific States Marine Fisheries Commission (PSMFC). 2015. Juvenile salmonid emigration monitoring in the lower American River, California January – May 2015. Unpublished report prepared for the U.S. Fish and Wildlife Service and California Department of Fish and Wildlife, Sacramento, California.

Phillips, J., and J.M. Helstab. 2013. Lower American River fall-run Chinook salmon escapement survey October 2012 – January 2013. U.S. Bureau of Reclamation. 22 pp. plus figures and appendix.

Phillips, J., and K.M. Gahan. 2014. Lower American River fall-run Chinook salmon escapement survey October 2013 – January 2014. California Department of Fish and Wildlife. 25 pp. plus figures and appendix.

Phillips, J., and H.S. Kubo. 2015. Lower American River fall-run Chinook salmon escapement survey October 2014 – January 2015. California Department of Fish and Wildlife. 27 pp.

Poole, G. J. Dunham, M. Hicks, D. Keenan, J. Lockwood, E. Materna, D. McCullough, C. Mebane, J. Risley, S. Sauter, S. Spalding, D. Sturdevant. 2001. Scientific issues relating to temperature criteria for salmon, trout, and char native to the Pacific Northwest. Prepared as part of U.S. EPA Region 10 Temperature Water Quality Criteria Guidance Development Project. EPA-910-R-01-007.

Reid, S. 2012. Lampreys of Central California field ID key (a living document). U.S. Fish & Wildlife Pacific Lamprey Conservation Initiative.

Rich, A.A. 1987. Report on studies conducted by Sacramento County to determine the temperatures which optimized growth and survival in juvenile Chinook salmon (*Oncorhynchus tshawytscha*). Prepared for the County of Sacramento.

Sellheim, K., J. Merz, P. Haverkamp, and J. Sweeney. 2015. Lower American River monitoring 2015 steelhead (*Oncorhyncus mykiss*) spawning and stranding survey. Prepared by Cramer Fish Sciences for the Sacramento Water Forum, U.S. Bureau of Reclamation. July 2015.

Snider, B., and R. G. Titus. 2001. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing October 1997 – September 1998. Conducted by the Department of Fish and Game. Funded partially by the California Department of Water Resources through the Interagency Ecological Program. Stream Evaluation Program Technical Report No. 00-5. July 2001.

Sogard, S. M.; J. E. Merz, W. H. Satterthwaite, M. P. Beakes, D. R. Swank, E. M. Collins, R. G. Titus and M. Mangel. 2012. Contrasts in Habitat Characteristics and Life History Patterns of Oncorhynchus mykiss in California's Central Coast and Central Valley. Series: Transactions of the American Fisheries Society, Vol. 141, Page(s): 747-760

US Army Corps of Engineers (USACE). 1991. American River watershed investigation, California Lower American River area. United States Department of Interior, Fish and Wildlife Service. Appendix S Part 2, Vol 7:1-460.

United States Department of the Interior (USDOI). 2008. Lower American River salmonid spawning gravel augmentation and side-channel habitat establishment program. Bureau of Reclamation, Mid-Pacific Region Rpt. 27 pp.

Williams, John. 2001. Chinook salmon in the Lower American River, California's largest urban stream. Contributions to the Biology of Central Valley Salmonids, Vol Two. Fish Bulletin 179: 1-38.

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. Contributions to the Biology of Central Valley Salmonids, Vol 1. Fish Bulletin 179:71-176.

Appendix 1: Points of interest on the lower American River.

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	River 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 (Chinook and Steelhead Trial)		9.7 (15.6)
Above Watt Avenue Bridge	Release site for trap efficiency mark-recapture trials (Steelhead Trial Only)		9.4 (15.1)
Watt Avenue bridge	River temperature 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 (Site not used in low water years)		8.8 (14.2)
Howe Avenue boat launch	Nimbus Fish Hatchery release site for Chinook salmon and steelhead		7.8 (12.6)
Jabboom St. bridge	Nimbus Fish Hatchery release site for Chinook salmon and steelhead		0.2 (0.3)
Mouth of American River	American-Sacramento River Confluence		0

Appendix 2: Weekly environmental conditions on the lower American River during the 2016 survey season.

Julian	Water Temperature °C			Discharge (CFS)			DO (mg/L)			Turbidity (NTU)		
Week	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
1/8-1/14	9.5	8.7	10.6	502	440	549	10.5	9.7	11.3	2.2	2.0	2.5
1/15-1/21	10.5	8.7	12.0	511	489	531	10.1	9.8	10.3	4.1	2.3	7.1
1/22-1/28	10.6	9.6	11.6	722	497	870	10.0	9.3	10.5	2.7	2.1	3.7
1/29-2/4	9.8	8.4	11.2	767	713	870	10.6	10.0	11.4	2.4	1.9	3.2
2/5-2/11	9.8	8.5	10.8	2,078	761	3,090	10.9	10.6	11.9	6.3	3.9	9.6
2/12-2/18	9.8	8.5	11.2	3,047	2,880	3,250	10.8	8.9	14.2	7.8	6.3	9.3
2/19-2/25	9.8	8.7	11.4	4,693	2,980	7,230	10.4	10.0	11.2	8.1	3.5	23.5
2/26-3/4	10.3	9.1	12.0	3,912	2,710	5,730	10.3	9.8	10.6	3.9	2.5	6.1
3/5-3/11	10.5	9.7	11.2	10,284	4,000	16,100	10.2	9.9	10.6	3.6	2.3	5.7
3/12-3/18	10.7	10.1	11.9	18,499	14,300	20,600						
3/19-3/25	11.4	10.1	13.7	9,474	5,650	16,200	10.5	10.3	10.8	5.8	4.8	7.8
3/26-4/1	12.4	10.6	14.5	4,946	3,090	5,930	10.0	9.8	10.4	4.3	4.1	4.6
4/2-4/8	12.9	11.3	15.1	3,140	3,060	3,520	9.6	9.5	9.8	3.9	2.9	4.7

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 Julian 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 by weekly averages from daily values gathered from crew members in the field across both north and south channel trapping locations. Dissolved oxygen and turbidity min and max values are reflective of the minimum and maximum daily value gathered during the Julian week defined by the "Week" column in the table above across both the north and south channel trapping locations.

Appendix 3: List of fish species caught during the 2016 season using rotary screw traps on the lower American River.

Common Name	Family Name	Species Name	Total Number Caught
Chinook salmon	Salmonidae	*Oncorhynchus tshawytscha*	80,632
Steelhead/Rainbow Trout	Salmonidae	*Oncorhynchus mykiss*	341
Black Crappie	Centrarchidae	*Pomoxis nigromaculatus*	1
Bluegill	Centrarchidae	*Lepomis macrochirus*	126
Brown Bullhead	Ictaluridae	*Ameiurus nebulosus*	1
Channel catfish	Ictaluridae	*Ictalurus punctatus*	4
Golden shiner	Cyprinidae	*Notemigonus crysoleucas*	15
Green sunfish	Centrarchidae	*Lepomis cyanellus*	4
Hardhead	Cyprinidae	*Mylopharodon conocephalus*	108
Hitch	Cyprinidae	*Lavinia exilicauda*	1
Inland silverside	Atherinopsidae	*Menidia beryllina*	6
Largemouth bass	Centrarchidae	*Micropterus salmoides*	9
Mosquitofish	Poeciliidae	*Gambusia affinis*	10
Pacific lamprey	Petromyzontidae	*Entosphenus tridentatus*	650
Prickly sculpin	Cottidae	*Cottus asper*	114
Redear sunfish	Centrarchidae	*Lepomis microlophus*	3
Riffle sculpin	Cottidae	*Cottus gulosus*	34
River lamprey	Petromyzontidae	*Lampetra ayresii*	91
Sacramento pikeminnow	Cyprinidae	*Ptychocheilus granelis*	153
Sacramento sucker	Catostomidae	*Catostomus occidentalis*	10
Smallmouth bass	Centrarchidae	*Micropterus dolomieu*	1
Threadfin shad	Clupidae	*Dorosoma petenense*	3,409
Threespine stickleback	Gasterosteidae	*Gasterosteus aculeatus*	2
Tule perch	Embiotocidae	*Hysterocarpus traskii*	11
Wakasagi	Osmeridae	*Hypomesus nipponensis*	1,105
White catfish	Ictaluridae	*Ameiurus catus*	1
Unidentified Lamprey ammocoetes	Petromyzontidae		477
Unidentified Minnows	Cyprinidae		4
Unidentified Sculpins	Cottidae		4
Unidentified Sunfish	Centrarchidae		4
Unknown catfish or bullhead	Ictaluridae		2
		Total Cumulative	**87,333**

Appendix 4: Genetic results for fin-clip samples from Chinook salmon caught in the lower American River during the 2016 survey season.

Sample #: refer to a unique number assigned by field staff, and that allowed the tracking of individual fish samples.
LAD run assignment: Chinook salmon run assignment based on the length-at-date run assignment methodology developed by Greene (1992).
SNP Run Assignment: Chinook salmon run assignment using "Genetic Call to three lineages" single-nucleotide polymorphism (SNP) markers.
SNP Probability: Probability of the correct SNP Chinook salmon run assignment.
Final run assignment: run assignment using a 50 percent threshold based on the SNP probability.
FL: fork length in millimeters.
W: weight in grams.

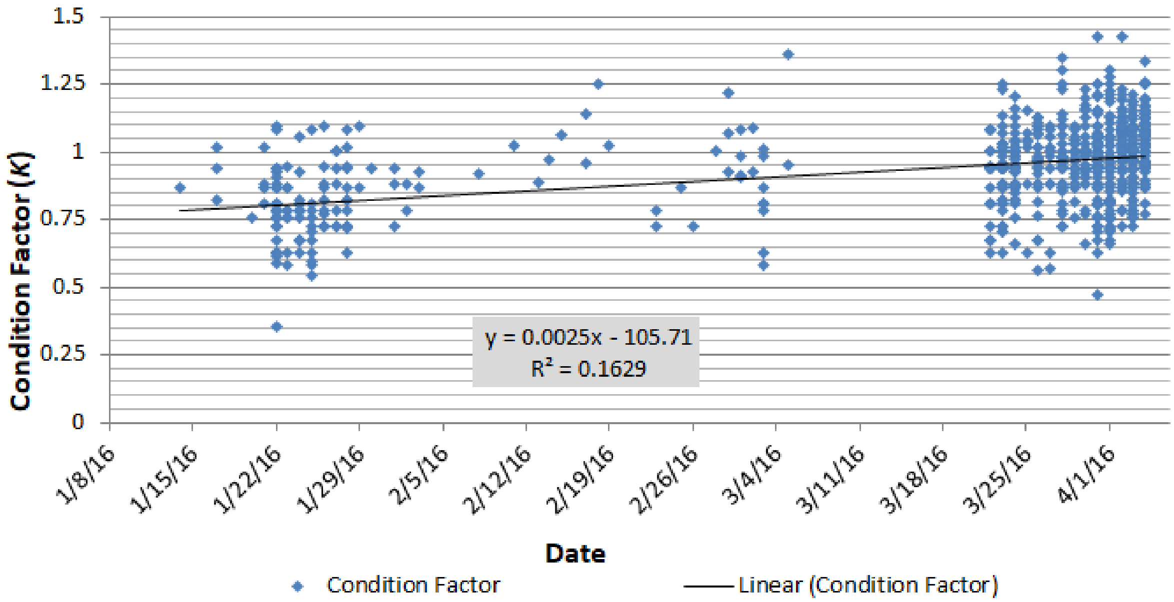
Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)
17-Jan	3156-001	Fall	No Assignment	-	Fall	44	0.7
17-Jan	3156-002	Fall	Fall	0.997	Fall	44	0.8
17-Jan	3156-003	Fall	Fall	1.000	Fall	41	0.7
20-Jan	3156-004	Fall	Fall	1.000	Fall	43	0.6
22-Jan	3156-005	Fall	Fall	1.000	Fall	46	0.9
22-Jan	3156-006	Spring	Fall	1.000	Fall	48	1
22-Jan	3156-007	Fall	Fall	0.996	Fall	46	0.6
22-Jan	3156-008	Spring	Fall	0.988	Fall	52	0.5
24-Jan	3156-009	Spring	Fall	0.997	Fall	50	-
24-Jan	3156-010	Spring	Fall	1.000	Fall	52	1.1
25-Jan	3156-011	Spring	Fall	1.000	Fall	49	0.7
25-Jan	3156-012	Spring	Fall	0.732	Fall	50	-
26-Jan	3156-013	Spring	Spring	0.957	Spring	51	1.1
3-Feb	3156-014	Spring	Fall	0.942	Fall	52	1.3
8-Feb	3156-015	Spring	Fall	0.998	Fall	58	1.8
11-Feb	3156-016	Spring	Fall	0.997	Fall	59	2.1
13-Feb	3156-017	Spring	Fall	0.993	Fall	54	1.4
14-Feb	3156-018	Spring	Fall	1.000	Fall	58	1.9
17-Feb	3156-019	Spring	Fall	1.000	Fall	55	1.9
17-Feb	3156-020	Spring	Fall	0.940	Fall	55	1.6
19-Feb	3156-021	Spring	Fall	1.000	Fall	58	2
28-Feb	3156-022	Spring	Fall	0.999	Fall	62	2.4
29-Feb	3156-023	Spring	Fall	0.999	Fall	64	3.2
29-Feb	3156-024	Spring	Fall	0.997	Fall	59	2.2
29-Feb	3156-025	Spring	Fall	0.999	Fall	59	1.9
1-Mar	3156-026	Spring	Fall	0.888	Fall	77	4.5
1-Mar	3156-027	Spring	Fall	0.977	Fall	64	2.4

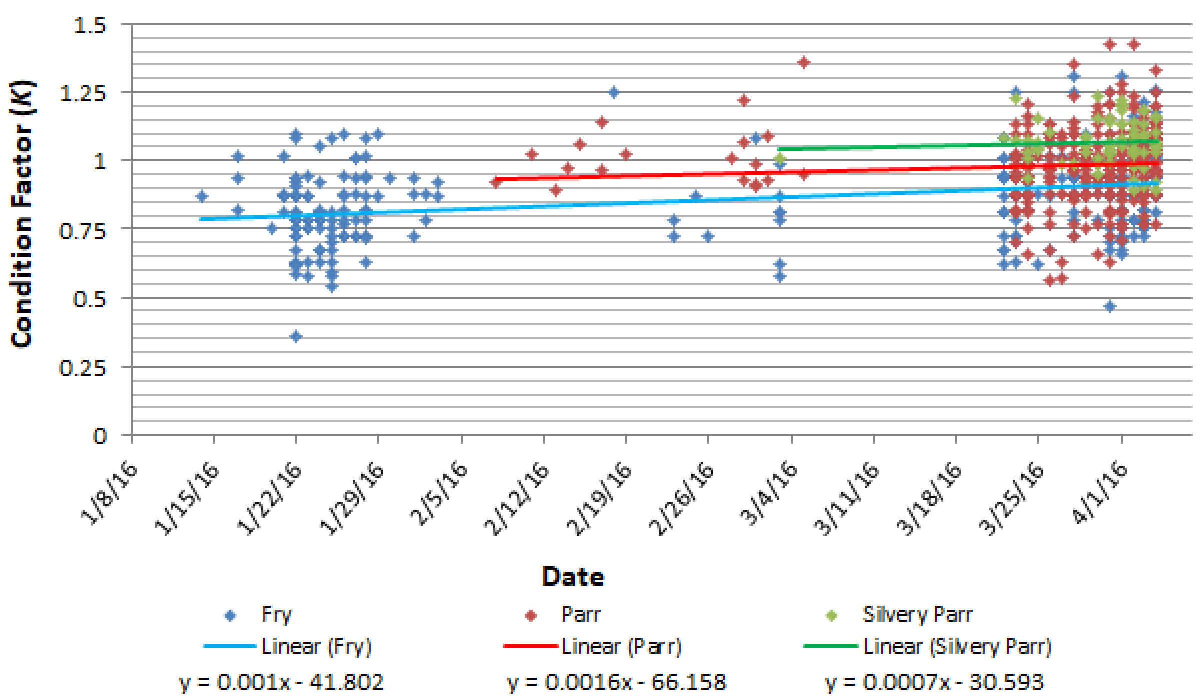
Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)
2-Mar	3156-028	Spring	Fall	0.991	Fall	62	2.6
2-Mar	3156-029	Spring	Fall	1.000	Fall	61	2.1
3-Mar	3156-030	Winter	Winter	1.000	Winter	108	13.1
3-Mar	3156-031	Spring	Fall	0.999	Fall	78	4.8
5-Mar	3156-032	Spring	Fall	0.996	Fall	63	3.4
5-Mar	3156-033	Spring	Fall	0.998	Fall	64	2.5
22-Mar	3156-034	Spring	Fall	0.999	Fall	90	7.9
23-Mar	3156-035	Spring	Fall	1.000	Fall	72	4
23-Mar	3156-036	Spring	Fall	1.000	Fall	76	5.4
24-Mar	3156-037	Spring	No Assignment	-	Fall	71	3.6
24-Mar	3156-038	Spring	Fall	1.000	Fall	72	3.5
24-Mar	3156-039	Spring	Fall	0.980	Fall	72	4
24-Mar	3156-040	Spring	Fall	1.000	Fall	71	3.7
25-Mar	3156-041	Spring	Fall	1.000	Fall	75	4.4
25-Mar	3156-042	Spring	Fall	0.999	Fall	73	4.5
25-Mar	3156-043	Spring	Fall	0.991	Fall	76	4.7
25-Mar	3156-044	Spring	Fall	0.998	Fall	74	4.2
26-Mar	3156-045	Spring	Fall	0.998	Fall	82	6.1
26-Mar	3156-046	Fall	Fall	1.000	Fall	36	-
26-Mar	3156-047	Fall	Fall	1.000	Fall	45	0.9
27-Mar	3156-048	Spring	Fall	1.000	Fall	74	4
28-Mar	3156-049	Spring	Fall	0.999	Fall	74	4
28-Mar	3156-050	Spring	Fall	0.999	Fall	74	4
29-Mar	3156-051	Spring	Fall	0.996	Fall	93	8.3
29-Mar	3156-052	Spring	Fall	0.990	Fall	84	6.4
29-Mar	3156-053	Spring	Fall	0.926	Fall	80	5.4
29-Mar	3156-054	Spring	Fall	0.999	Fall	75	4.6
30-Mar	3156-055	Spring	Spring	0.582	Spring	80	5.1
30-Mar	3156-056	Spring	Fall	0.973	Fall	72	4.3
30-Mar	3156-057	Spring	Fall	0.995	Fall	92	7.4
30-Mar	3156-058	Spring	Fall	0.998	Fall	82	6.8
30-Mar	3156-059	Spring	Fall	0.830	Fall	78	4.7
30-Mar	3156-060	Spring	Fall	0.993	Fall	74	4.1
31-Mar	3156-061	Spring	Fall	0.999	Fall	85	6.1
31-Mar	3156-062	Spring	Fall	0.989	Fall	94	8.6
31-Mar	3156-063	Spring	Fall	1.000	Fall	80	5.4
31-Mar	3156-064	Spring	Fall	0.997	Fall	77	4.7
31-Mar	3156-065	Spring	Fall	0.998	Fall	82	6.3
31-Mar	3156-066	Spring	Fall	0.973	Fall	76	4.5
31-Mar	3156-067	Spring	Fall	0.990	Fall	75	4.5
31-Mar	3156-078	Spring	Fall	1.000	Fall	80	5.4

Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)
31-Mar	3156-069	Spring	Fall	1.000	Fall	73	4.5
1-Apr	3156-070	Late Fall	Fall	1.000	Fall	31	-
1-Apr	3156-071	Late Fall	Fall	1.000	Fall	32	-
1-Apr	3156-072	Late Fall	Fall	1.000	Fall	31	-
1-Apr	3156-073	Late Fall	Fall	1.000	Fall	29	-
1-Apr	3156-074	Late Fall	Fall	1.000	Fall	30	-
1-Apr	3156-075	Late Fall	Fall	1.000	Fall	31	-
1-Apr	3156-076	Late Fall	Fall	1.000	Fall	29	-
1-Apr	3156-077	Late Fall	Fall	1.000	Fall	30	-
1-Apr	3156-068	Spring	Fall	1.000	Fall	84	6.4
1-Apr	3156-079	Spring	Fall	1.000	Fall	75	5.1
1-Apr	3156-080	Spring	Fall	0.970	Fall	96	10
1-Apr	3156-081	Spring	Fall	1.000	Fall	80	5.4
1-Apr	3156-082	Spring	Fall	0.995	Fall	86	7.2
1-Apr	3156-083	Spring	Fall	1.000	Fall	74	4.8
2-Apr	3156-084	Winter	Fall	1.000	Fall	103	12.5
2-Apr	3156-085	Spring	Fall	0.991	Fall	75	4.7
2-Apr	3156-086	Spring	Fall	0.999	Fall	90	7.6
2-Apr	3156-087	Winter	Fall	0.992	Fall	100	10.4
2-Apr	3156-088	Spring	Fall	0.982	Fall	85	5.7
2-Apr	3156-089	Spring	Fall	1.000	Fall	74	4.4
2-Apr	3156-090	Spring	Fall	0.997	Fall	76	4.8
2-Apr	3156-091	Spring	Fall	1.000	Fall	90	6.5
2-Apr	3156-092	Spring	Fall	0.998	Fall	80	5
2-Apr	3156-093	Spring	Fall	0.993	Fall	76	4.5
2-Apr	3156-094	Spring	Fall	1.000	Fall	88	7.3
2-Apr	3156-095	Spring	Fall	1.000	Fall	78	4.9
3-Apr	3156-096	Spring	Fall	0.999	Fall	80	5.6
3-Apr	3156-097	Spring	Fall	0.907	Fall	81	6.3
3-Apr	3156-098	Spring	Fall	1.000	Fall	75	4.6
3-Apr	3156-099	Spring	Fall	0.562	Fall	75	5
3-Apr	3156-100	Spring	Fall	1.000	Fall	75	4.1
3-Apr	3157-001	Spring	Fall	1.000	Fall	75	4.6
3-Apr	3157-002	Spring	Fall	0.962	Fall	80	5.8
3-Apr	3157-003	Spring	Fall	0.970	Fall	78	4.9
4-Apr	3157-004	Spring	Fall	0.999	Fall	79	5.7
4-Apr	3157-005	Spring	Fall	0.987	Fall	82	5.1
4-Apr	3157-006	Spring	Fall	0.987	Fall	75	4.4
4-Apr	3157-007	Spring	Fall	1.000	Fall	80	5.4
4-Apr	3157-008	Late Fall	Fall	1.000	Fall	32	-
4-Apr	3157-009	Late Fall	Fall	1.000	Fall	33	-

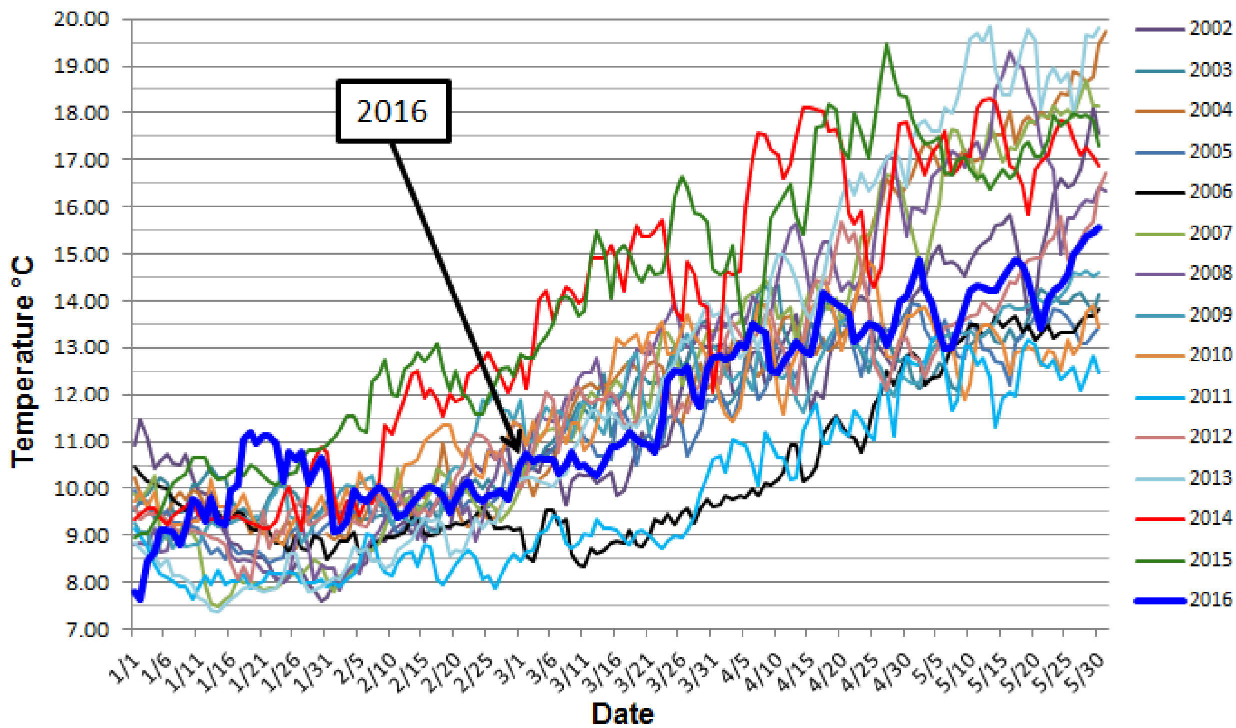
Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)
4-Apr	3157-010	Late Fall	Fall	1.000	Fall	31	-
4-Apr	3157-011	Late Fall	Fall	1.000	Fall	33	-
4-Apr	3157-012	Spring	Fall	1.000	Fall	76	4.7
4-Apr	3157-013	Spring	Fall	0.939	Fall	78	-

Appendix 5: Fulton's condition factor (*K*), overall, and by life-stage, of fall-run Chinook salmon during the 2016 survey season.

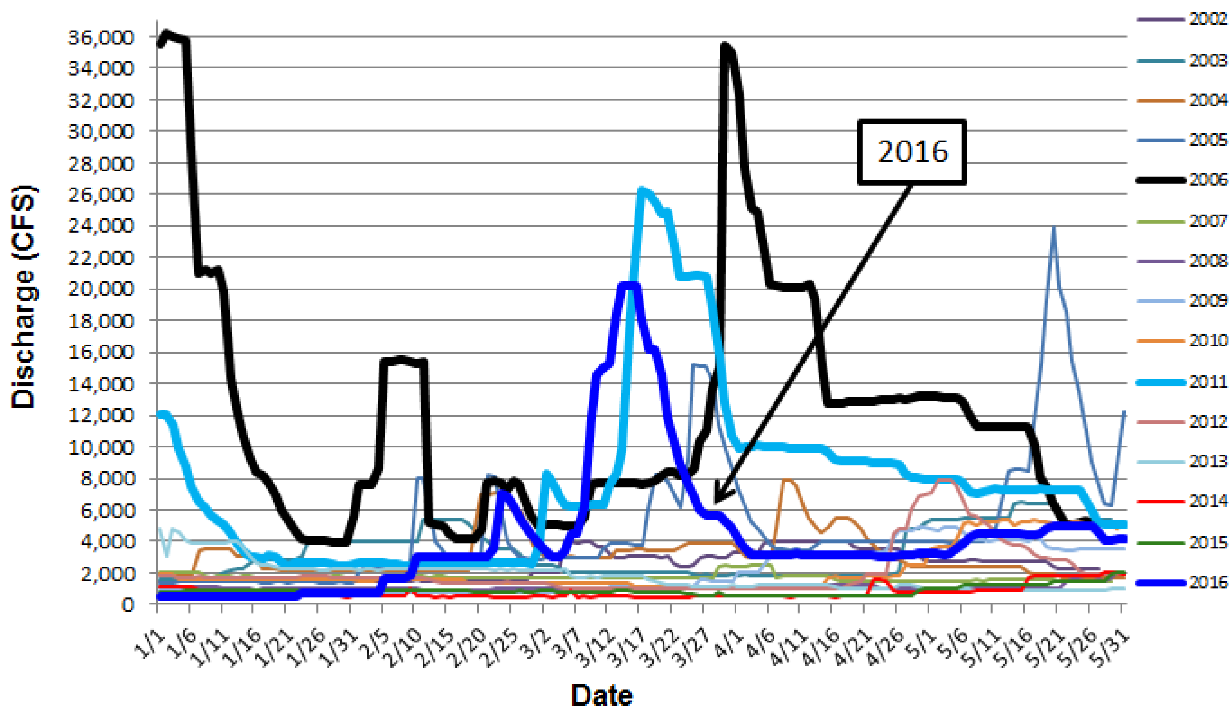




Appendix 6: Daily average water temperature (°C) in the lower American River at Watt Avenue for the 15-year period 2002 – 2016. Data from USGS station number 11446980.



Appendix 7: Daily average discharge (CFS) on the lower American River at Fair Oaks for the 15-year period 2002 – 2016. Data from USGS station number 11446500.



Appendix 8: A view of American River at the Watt Ave sampling location under different flow conditions.

500 CFS 3/20/2014

1,500 CFS 4/24/2014

7,000 CFS 2/23/2016

20,000 CFS 3/14/2016

Note: These photos were taken from the Watt Ave Bridge outlook, at UTM Northing NAD83 4269922, and UTM Easting NAD83 640864