Juvenile Salmonid Emigration Monitoring in the Lower American River, California

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Abstract

Rotary screw traps were deployed 0.20 river kilometers downstream of the Watt Avenue Bridge on the American River in Sacramento County, California in 2014. The operation of the traps in 2014 is the second year in a collaborative five-year effort by the U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program, Pacific States Marine Fisheries Commission, and the California Department of Fish and Wildlife. The primary objective of the trapping operations is to collect data that can be used to estimate the production of juvenile fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and quantify the raw catch of steelhead/rainbow trout (*Oncorhynchus mykiss*) and three other runs of Chinook salmon. Secondary objectives of the trapping operations focus on collecting fork length and weight data for juvenile salmonids and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, abundance, and production.

During the 2014 survey season, two 2.4-meter diameter rotary screw traps were operated 122 of the 137 days between January 7th and May 23rd downstream of the Watt Avenue Bridge. A total of 379,542 fall-run, 5 putative spring-run, 13 winter-run, and 2 late-fall-run juvenile Chinook salmon were captured. The majority of the captured juvenile Chinook salmon belonged to the fry life stage; fewer numbers of the yolk-sac fry, parr, silvery parr, and smolt life stages were also collected. The emigration of juvenile fall-run Chinook salmon in 2014 peaked between February 9th and March 8th when 82 percent (n = 310,229) of the total salmon was caught. Fifteen trap efficiency tests were conducted to collect data that were used to estimate the production of juvenile fall-run Chinook salmon. Trap efficiencies during those 15 tests ranged between 4.73 and 34.17 percent, and the average efficiency was 21.33 percent. Two trap efficiency tests were also conducted with juvenile steelhead from the Nimbus Fish Hatchery. Both tests were conducted minutes apart at two separate locations, one at the typical release location for Chinook salmon trials, and the second 0.5 river kilometers downstream. The tests were conducted to evaluate the trap's potential to capture juvenile steelhead. Trap efficiencies for these trials were 3.30 percent from the upstream release and 5.23 percent at the downstream release. The number of juvenile fall-run Chinook salmon that were estimated to have emigrated past the Watt Avenue trap site on the American River during the 2014 survey season was 1,734,684 individuals (95% confidence intervals = 1,639,952 - 1,977,731). In addition, 592 natural-origin *O. mykiss* were captured, and 642 adipose fin-clipped hatchery-origin *O. mykiss* were collected. Finally, 5,116 individuals belonging to 24 different non-salmonid species were also caught, a majority of which were lamprey. Production estimates for *O. mykiss*, the three other Chinook salmon runs, and non-salmonid fish taxa were not calculated. The 2014 trapping effort on the American River produced a high quality data set because substantial logistical or environmental issues did not interfere with the collection of field data.

This annual report also provides 12 appendices. Seven of the appendices provide basic data summaries of the data collected in 2014, and the five other appendices describe special studies that were conducted.

Introduction

The American River is the largest, southernmost tributary to the Sacramento River in California's Central Valley. The lower portion of that river flows through the highly urbanized Sacramento metropolitan, and it 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 races of Chinook salmon that included fall-, spring-, and possibly late-fall-run Chinook salmon (Yoshiyama et al. 2001). In the late 1800s during the California gold rush, hydraulic mining devastated salmon spawning habitat in the upper and lower reaches of the American River (Fisher 1994). Later, the construction of Folsom and Nimbus Dams made it impossible for spring-run 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 *O. mykiss* spawning and rearing habitat, the Nimbus Fish Hatchery was built 0.80 kilometers (km) downstream of the Nimbus Dam in 1958. The Nimbus Fish Hatchery is used to produce large numbers of fall-run Chinook salmon and *O. mykiss*. Discharges from Folsom and Nimbus Dams are regulated by the U.S. Bureau of Reclamation (USBR), and they provide flows that help maintain fish and wildlife habitats, provide municipal water supplies, administer flood protection, and generate hydroelectric power.

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

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

Within that area, approximately 57,342 cubic meters (m^3) of gravel have been added to the river between 2008 and 2012.

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

Rotary screw traps (RSTs) are frequently used to monitor the abundance of juvenile salmonids and their biological response to habitat restoration activities. This report describes efforts to monitor juvenile salmonid abundance with RSTs in 2014 as part of a larger effort to determine if habitat restoration activities are improving Chinook salmon production in the lower American River. Furthermore, this report presents monitoring data assessing the temporal variability in *O. mykiss* 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 2014 survey season was the second year of the rotary screw trap project. These past two years happened to coincide with back-to-back years of extreme drought, a circumstance that has not been seen in the region for decades. Since the Folsom and Nimbus dams were built, only two droughts were as severe as the current one; those occurred between 1976-1977 and 1987-1992 (CDWR 2010). Because there have only been two recorded drought events of this scale prior to the current one, very little is known about how severe droughts affect the biota in a river ecosystem, and how to properly manage water from a biological and economic standpoint. In addition to current management practices and fish recovery projects, the rotary screw trap data collected from the past two years will help to 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, we can better anticipate and manage for future severe droughts.

During the next few years, RST data will continue to be collected such that the new data complement the data that were collected by the CDFW between 1992 and 2008. All of the RST data will then be analyzed in 2017 with the goal of understanding how ongoing habitat restoration activities affect juvenile salmonid abundance, and how future habitat restoration activities can be enhanced to increase the production of adult and juvenile Chinook salmon and *O. mykiss*.

Based on the goal identified in the aforementioned paragraph, the primary objective of the American River trapping operations is to collect data that can be used to estimate the production of juvenile fall-run Chinook salmon and quantify the raw catch of *O. 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, and abundance and production. An ancillary objective of the trapping operations is to collect non-salmonid fish species data that can be used to characterize the fish community in the American River.

Study Area

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

Water exiting Nimbus Dam flows downstream for 36 rkm across an alluvial plain until it reaches the confluence with the Sacramento River main stem. Currently, fall-run Chinook salmon and *O. mykiss* are only able to access and occupy the lower-most 36 km of the American River, and only a small portion of the river possesses suitable substrate for salmon spawning activities. The river contains gravel bar complexes and islands, flat water areas, and side-channel habitat characteristics (Merz and Vanicek 1996). Flows in this lower section can range from 500 cubic feet per second (CFS) to upwards of 164,035 CFS. The primary salmonid spawning grounds are relegated to the upper most 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 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 *O. mykiss* spawning activities in the lower American River yet far enough upstream to be un-influenced by tidal and river rise from the Sacramento River that backs up into the American River.

The lower American River RST site is situated in an area that contains two channels that pass on either side of a gravel island downstream of the Watt Avenue Bridge (Figure 1). The "North Channel" carries the majority of the water volume and becomes the only channel with flowing water during extreme low flows. Water velocities in the North Channel are relatively high because that reach possesses a steep channel gradient. The "South Channel" site has flatter gradient and lower water velocities. In 2014, the two RSTs were deployed in the North Channel and no traps were deployed in the South Channel due to the minimal river discharges that year.

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.

Methods

Trap Operations

Monitoring activities for the 2014 survey season started on January 7th and ended on May 23rd. The two 2.4-meter diameter RSTs were fished in a side-by-side configuration. Traps were anchored to two large concrete blocks set into the cobble substrate of the river 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. Due to low flows, and a narrow thalweg, a rope was attached from the port side of the traps to the north cut-bank side to ensure consistent trap fishing conditions.

Trap checks were conducted at least every 24 hours or more often when the potential existed for high debris loads leading to fish mortality. Due to warm water temperatures and increasing recreational use on the weekends, twice daily trap checks were frequently performed during the months of April and May during the weekdays and when traps were in service on the weekends. On many of the weekends during those months, traps were taken out of service, i.e., trap cones were raised, live well screens were pulled, and sampling was temporarily suspended.

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 a trap cone to remove larger debris.

Safety Measures

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

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

Environmental Parameters

Environmental data were recorded on a daily basis before fish were processed. Temperature and dissolved oxygen were measured using a YSI dissolved oxygen meter (YSI; Model 55), velocity in front of each cone was recorded using a Hach flow meter (Hach; Model FH950), and turbidity was measured using a Eutech portable turbidity meter (Eutech: Model TN-100). Average daily river discharge for the American River was determined using data from the U.S. Geological Survey's American River at Fair Oaks monitoring station (USGS station number 11446500). Average daily temperature was measured 150 m upstream of the RSTs using data from the USGS's American River below Watt Avenue Bridge station (USGS station number 11446980). A depth rod was used to measure water depth underneath the trap to the nearest centimeter on the port and starboard sides of the 2-tray array, in line with the cone. A staff gauge graduated in inches was installed on the north river shoreline to monitor change in river stage.

Catch and Fish Data Collection

After environmental data were collected, the process of clearing out each RST's live well and fish work-up began. First, all debris was removed from a live well and placed into 68.14 liter (L) tubs where crew members sifted through debris and saved any fish, alive or dead. After all debris was removed, 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 that segregated salmonids from non-salmonids and from potential predation. During periods of hot weather, fish were placed in a bucket with an aerator to provide them with oxygen and an ice pack to keep the water temperature at a safe level. In addition, the crew placed buckets of fish underneath an umbrella to shade the fish from direct sunlight.

On days when less than 100 Chinook salmon were caught in a trap, the fork length of each salmon from each trap was measured to the nearest 1 millimeter (mm), their life stage was assessed using the smolt index rating in Table 1 below, the presence or absence of marks used during trap efficiency tests was noted, and their mortality status (live vs. dead) was assessed. If Chinook salmon were ≥ 40 mm in fork length, they 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. 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 in the tub. After removing the debris from the tub, a random net full of salmon was taken from the 68.14 L tub and placed into an 18.93 L bucket designated for Chinook salmon subsampling. From the subsampled bucket, 100 Chinook salmon were randomly selected for analysis. The fork length, life stage, and mark status for each of the 100 live salmon was assessed. Again, if the individuals were ≥ 40 mm in fork length, they were weighed to the nearest 0.1 gram after they were measured and assessed for life stage. 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 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. The fork length, life stage, and weight of dead salmon were not assessed because decomposition alters body size, weight, and color; dead salmon were classified so they received an "unassigned" life stage.

During the peak emigration period when fry catch totals appeared to be over 10,000 fish per day, volumetric estimates of plus count Chinook salmon were performed for each day and trap. Prior to volumetric counting, all the marked Chinook salmon and non-salmon species were separated from unmarked salmon. The following three steps were then performed. First, the unmarked salmon were netted in a small aquarium net and placed into a 100 ml cup used for volumetric measuring. Second, the cup was filled with unmarked salmon level with the top of the 100 ml cup with as much water displaced as possible. Third, the salmon were poured onto a large measuring board and each individual from that cup was counted. Those last three steps were then performed 10 times and an average Chinook salmon count per 100 ml cup was established for that particular day and trap. After the 10 volumetric measurements were completed, the crew then counted the number of 100 ml cups that were filled with salmon that remained after the 10 calibration measurements were made. The average count per cup was then multiplied by the number of cups filled and a plus count estimate for the day was formulated.

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

For each day and each RST, individuals belonging to non-salmonid taxa were enumerated and identified to species. In addition, 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 we observed the number of lateral circumorals in their mouths. 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 *O. mykiss*.

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

Prior to collecting fish fork lengths and weights, individuals were anesthetized with 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 8 to 10 fish were placed in a solution of river water and sodium bicarbonate, 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 (Poly-Aqua) that was designed to help replace their slime coat as the fish recovered from the anesthetic. As soon as it was determined that the fish have 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 (Greene 1992). When Chinook salmon appeared to be winter- or spring-run salmon using the LAD criteria, 1 to 2 mm fin clips were taken from the upper caudal fin. The fin clips were then used by staff at the U.S. Fish and Wildlife Service's Abernathy Fish Technology Center to develop 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 NOAA Fisheries, and is now used for several applications by the U.S. Fish and Wildlife Service and several partner groups (Christian Smith, pers. comm.). Detailed methods for DNA extraction, genotyping, and run assignment are described in Abernathy Fish Technology Center SOP 034. The salmon that were captured and fin clipped in 2014 were assigned to one of four salmon runs: 1) winter-run, 2) fall-run, 3) Butte Creek spring-run, and 4) spring-run with an unknown origin.

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). It was further observed that spring-run fish could be assigned back to population of origin, but with lower accuracy (e.g., Butte Creek = 68 percent, Mill/Deer Creek = 48-50 percent). For the purposes of this report, the SNP panel providing the "Genetic Call to 4 lineages" was used. In order to increase confidence in individual run assignments based on the SNP data, we employed an 80 percent probability cut-off to classify individuals that appeared to be spring-run Chinook salmon based on the LAD criteria:

1. Individuals for which the probability of assignment was < 80 percent were not assigned based on the genetic data, i.e., assignments based on the LAD criteria were used to make a final salmon run assignment.

2. Individuals for which the probability of assignment was > 80 percent were assigned based on the genetic data, i.e. if LAD and genetic assignments conflicted, then the genetic markers were used to make the final salmon run assignment.

The 80 percent threshold for assigning the final salmon run where the LAD assignment at time of capture = spring was arbitrarily chosen. Use of such a threshold has the advantage of providing greater confidence in the genetic assignments made, and the disadvantage that some salmon's run assignment will remain unchanged.

Twenty-two salmon that had a LAD assignment at the time of capture = fall were fin clipped to compare their LAD assignments with run assignments using the SNPs. That procedure was implemented to evaluate how dissimilar or not the LAD and SNP assignments were when the LAD assignment at time of capture = fall.

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 that had a life stage of 2 or higher on the smolt index scale with Bismarck Brown Y (BBY) stain.

At least 500 salmon were needed to conduct trials with BBY stain. When < 500 Chinook salmon were caught on a given day, they would be held overnight and the salmon caught the next day would then be added to the previous day's catch to achieve the minimum number of Chinook salmon required for a trap efficiency test. 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 wild 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 2 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 day.

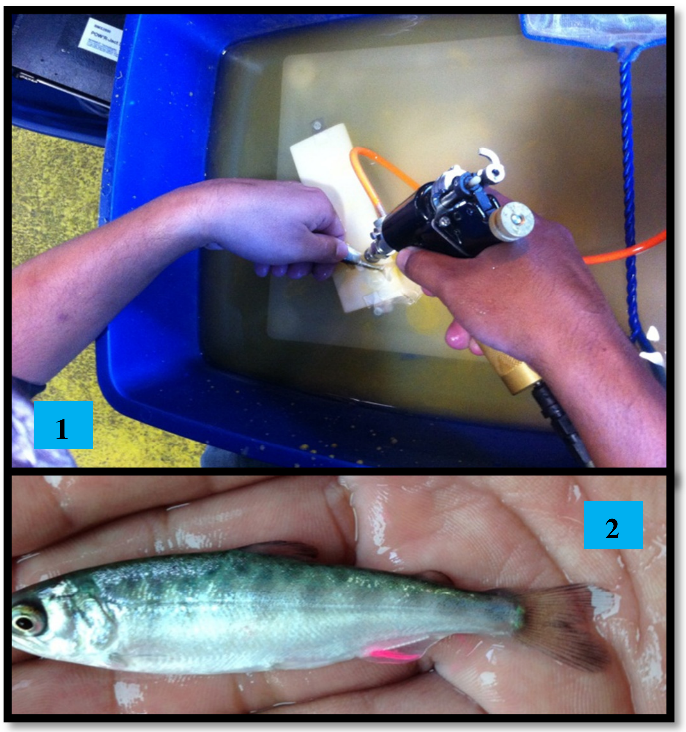
To evaluate the potential that the size distribution of recaptured wild salmon was different than the wild salmon that were released during a trap efficiency test, 100 fork lengths from the day the wild fish were captured were used as a baseline to compare with the lengths of the recapture salmon.

The second method of marking used a BMX2000 POW'R-JECT needleless gun to inject a photonic fluorescent dye into the anal fin of a Chinook salmon (Figure 2). The color dyes used during the 2014 American River trap efficiency trials were pink and green. Since the photonic method of marking Chinook salmon required the availability of individuals ≥ 50 mm in size and fish captures at the trap site did not always meet this size threshold in large enough quantities for a trial, fall-run Chinook salmon from the Nimbus Fish Hatchery were used when fish were photonicly marked. Before marking the hatchery salmon, the fish were anesthetized with alka-seltzer and the fork lengths of 100 randomly selected individuals were measured to the nearest mm. After marking, the fish were held overnight at the hatchery and allowed to recover. If mortalities were discovered after being held overnight, they were counted and removed from the efficiency trial. The live Chinook salmon were then transported to the release site in coolers with aerators and frozen water bottles. Upon arrival to the release site, the fish were immediately placed in live carts in the river. Marked fish were held in the live carts in the river for two to four hours, and then released at sunset using the technique described below.

The release site was approximately 1.1 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 biologists 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 twilight to mimic natural migration patterns and to avoid predation.

The following days after each trap efficiency release, the crew carefully looked for any marked fish in the RST live wells. A random sample of 100 recaptured 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 in a RST live well, the marked salmon in excess of the 100 other salmon were enumerated and classified as a “live recap plus count tally” or “mort recap plus count tally”.

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



Passage Estimates

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Confidence Interval Estimates

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

Fulton's Condition Factor

Fall-run Chinook salmon condition was assessed using the Fulton's condition factor. The first 25 chinook salmon 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 is the Fulton's condition factor, W is the weight in grams, and FL is the fork length in mm.

Results

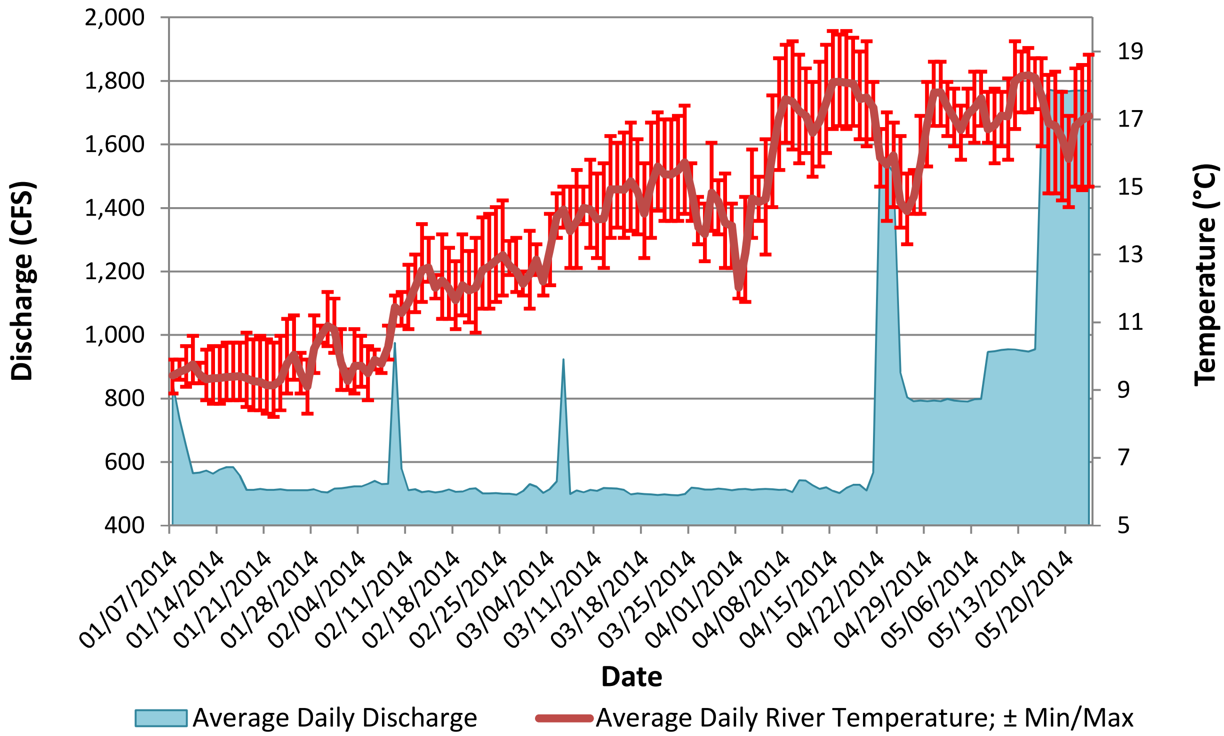
Trap Operations

During the 2014 survey season, the rotary screw traps were deployed and sampling began on January 7th. Sampling took place on 122 of the 137 days during the 2014 survey season. Starting the week of March 25th until the end of the season, sampling was performed during the weekdays only, with twice daily checks. This was in response to increasingly warming water in the LAR with the hopes of keeping salmonid mortality to a minimum. Trap operations were terminated on May 23rd, 2014, due to low fish counts and potential salmonid trapping mortality from rising river temperature.

Environmental Summary

A summary of the environmental conditions during the 2014 survey season are provided in Appendix 1. Mean daily discharge at the USGS's American River at Fair Oaks gaging station 21 rkm upstream of the RSTs ranged from a high of 1,769 CFS during the week of May 18th to a low of 498 CFS the week of March 16th (Figure 3). Mean daily temperature at the USGS's American River below Watt Avenue Bridge station 0.16 rkm upriver from the RST location ranged from 9.4° C in January to 17.8° C in April and May (Figure 3). Average turbidity was fairly consistent throughout the survey season, and was typically between 1.76 and 4.65 NTUs; during increased river flow events, turbidity reached its highest observed value at 11.99 NTUs. Mean instantaneous dissolved oxygen levels were between 9.6 and 13.2 mg/L during the survey season. Water velocities in front of the traps varied between the two traps due to a narrow thalweg at low flows. Velocities in front of trap cone 8.1 (north bank side) ranged from 0.63 meters per second (m/s) to 1.38 m/s with a mean velocity of 1.14 m/s. Velocities in front of trap cone 8.2 (south bank side) ranged from 0.43 m/s to 1.21 m/s with a mean velocity of 0.76 m/s.

Figure 3: Average daily discharge (CFS) measured at Fair Oaks, and average daily water temperature (°C) measured at Watt Avenue during the 2014 lower American River rotary screw trap survey season.



Note: Both sets of the 1/7/2014 - 5/23/2014 data were acquired from the USGS website at http://waterdata.usgs.gov/ca/nwis/uv

Catch

RST operations on the lower American River in 2014 captured a total of 380,153 fish belonging to five salmonid taxa and 28 non-salmonid taxa (Appendix 2). The salmonid taxa included *O. mykiss*, and fall-, late-fall-, winter-, and spring-run Chinook salmon.

Fall-run Chinook salmon

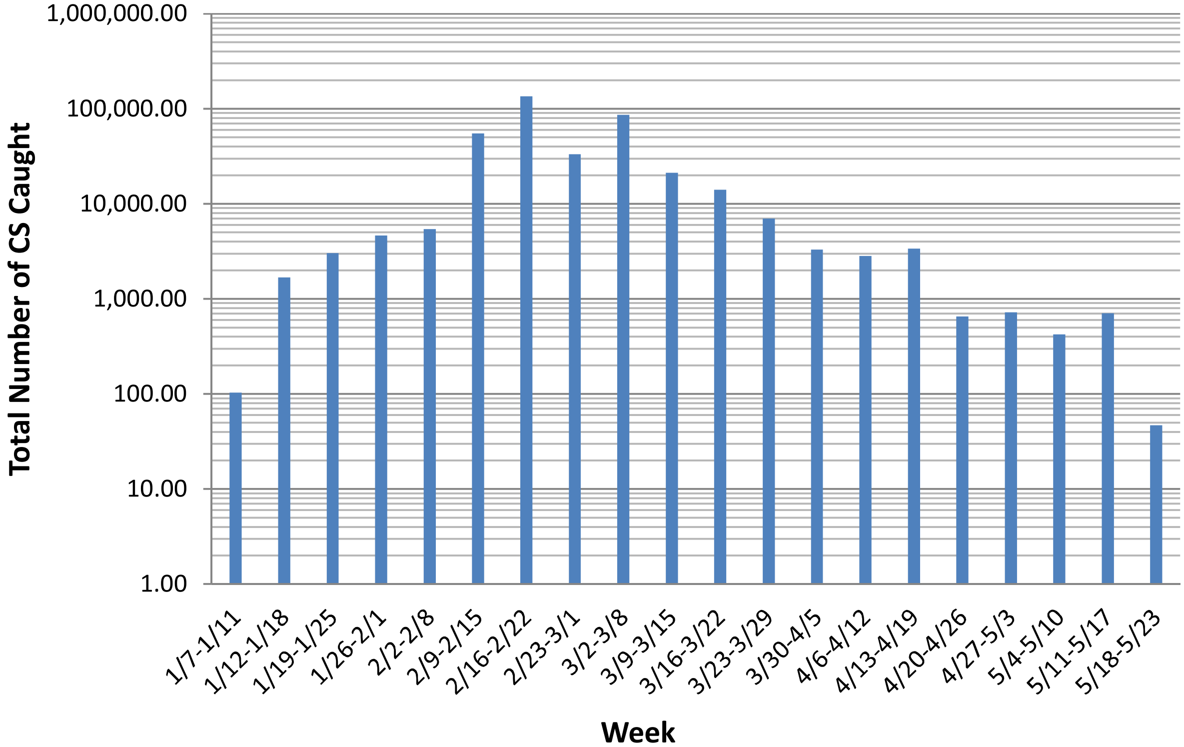
During the 2014 season, a total of 379,542 natural-origin, unmarked fall-run Chinook salmon was caught (Table 2). Weekly Chinook salmon catches peaked between February 9th and March 8th. During those weeks, 82 percent (n = 310,229) of the total Chinook salmon were caught. Thirty-six percent (n = 135,931) of that total was caught during the week of February 16-22 alone (Figure 4).

Table 2: Fall-run Chinook salmon catch totals by life stage during the 2014 lower American River rotary screw trap survey season.

Week	Yolk-sac Fry	Fry	Parr	Silvery Parr	Smolt	Unassigned Life Stage	Total
1/7-1/11	5	98	0	0	0	0	103
1/12-1/18	20	966	0	0	0	701	1,687
1/19-1/25	5	1,170	0	0	0	1,870	3,045
1/26-2/1	1	1,295	0	0	0	3,332	4,628
2/2-2/8	0	1,192	0	0	0	4,210	5,402
2/9-2/15	4	1,399	6	0	0	53,651	55,060
2/16-2/22	1	1,397	80	0	0	134,353	135,831
2/23-3/1	0	1,380	63	0	0	31,922	33,365
3/2-3/8	0	1,335	73	1	0	84,564	85,973
3/9-3/15	0	1,214	376	48	0	19,608	21,246
3/16-3/22	0	324	928	388	0	12,515	14,155
3/23-3/29	0	80	1,158	404	37	5,313	6,992
3/30-4/5	0	4	769	414	141	1,974	3,302
4/6-4/12	0	3	290	533	292	1,705	2,823
4/13-4/19	0	0	66	871	174	2,268	3,379
4/20-4/26	0	0	22	318	153	161	654
4/27-5/3	0	0	6	618	51	47	722
5/4-5/10	0	0	8	334	46	35	423
5/11-5/17	0	0	3	401	223	78	705
5/18-5/23	0	0	1	28	15	3	47
Total	36	11,857	3,849	4,358	1,132	358,310	379,542

Note: Unassigned life stage includes plus-counts and mortalities.

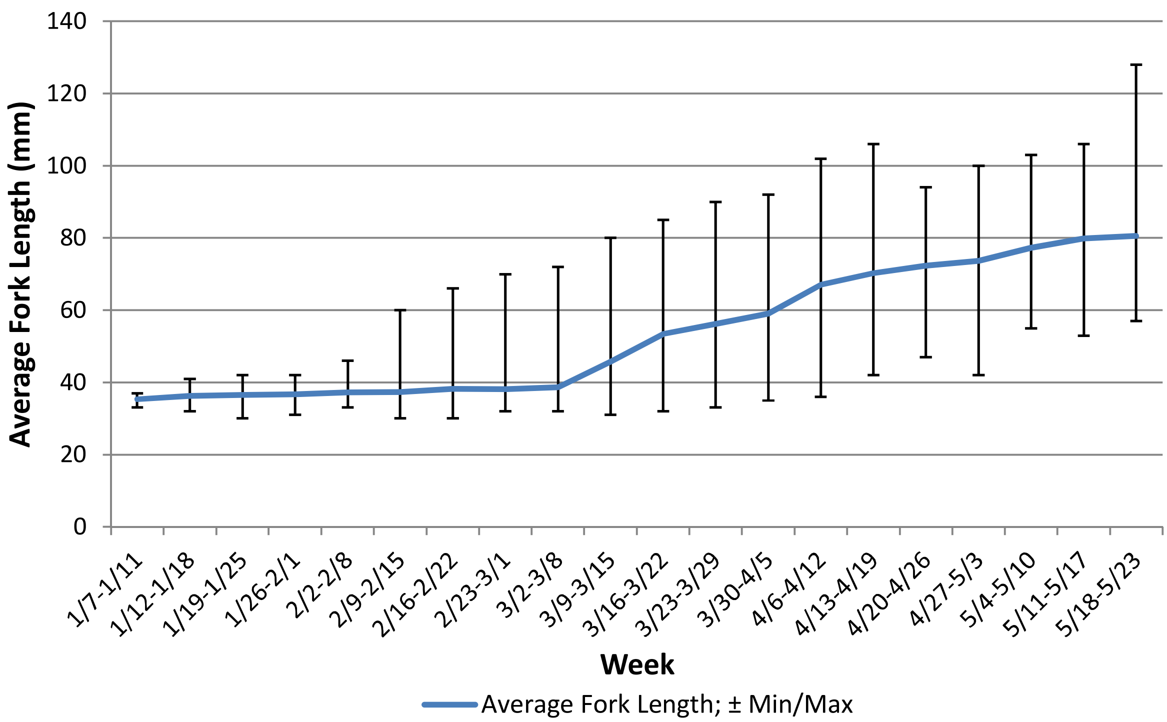
Figure 4: Weekly catch distribution of fall-run Chinook salmon during the 2014 lower American River rotary screw trap survey season.



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

A total of 21,232 live fall-run Chinook salmon were assessed for life stage and measured for fork length. Of those salmon, 0.17 percent (n = 36) were identified as yolk-sac fry, 55.84 percent (n = 11,857) were fry, 18.13 percent (n = 3,849) were parr, 20.53 percent (n = 4,358) were silvery parr, and 5.33 percent (n = 1,132) were smolts. The average fork length of juvenile fall-run Chinook salmon during the first nine weeks of the survey season was 37 mm. The lengths of measured juvenile salmon began to increase significantly after March 9th, and by the week of May 18-23rd, fall-run Chinook salmon reached an average fork length of 81 mm (Figure 5). A total of 358,310 fall-run salmon were plus count tallies and mortalities.

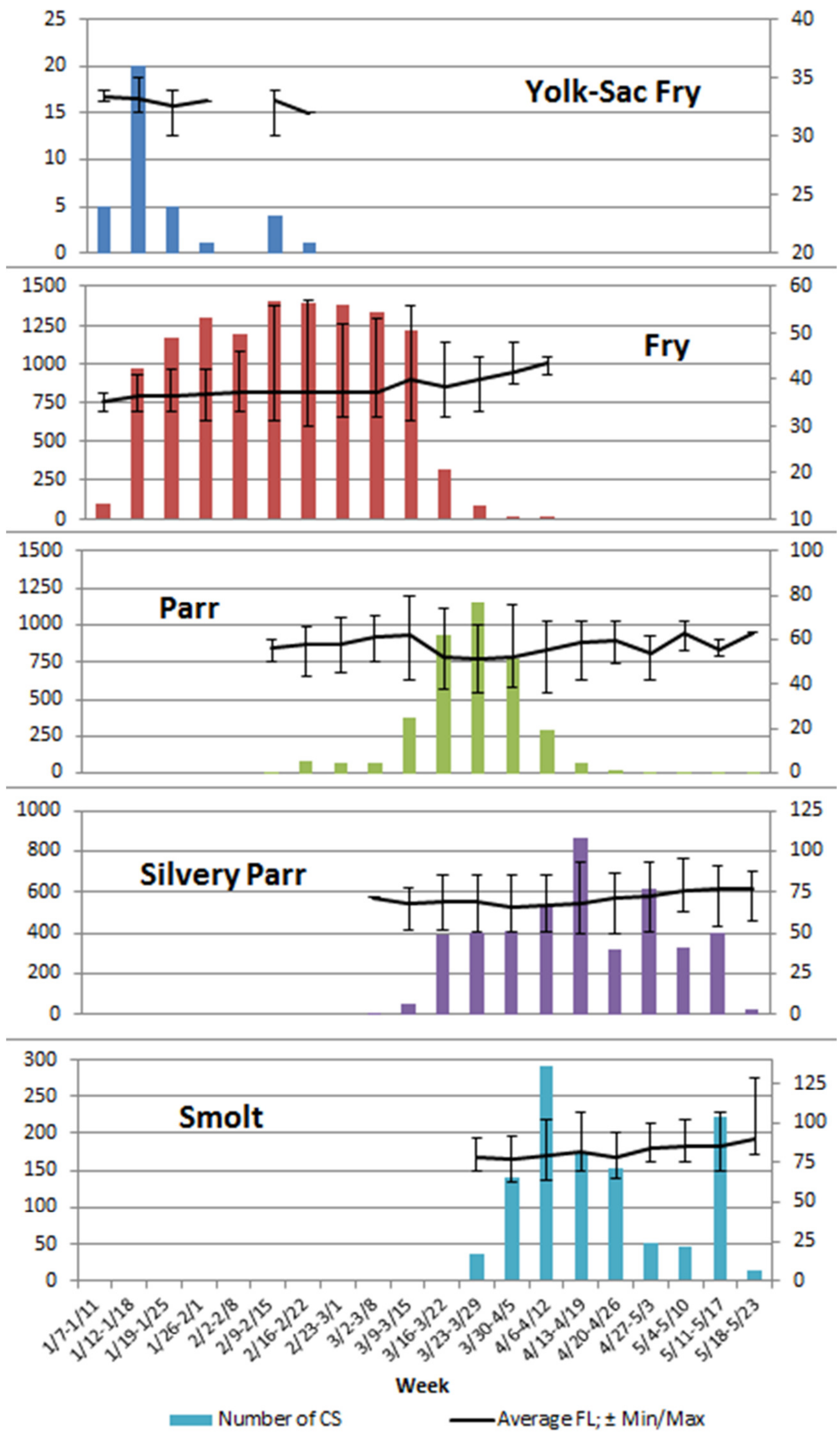
Figure 5: Average weekly fork lengths for fall-run Chinook salmon during the 2014 lower American River rotary screw trap survey season.



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

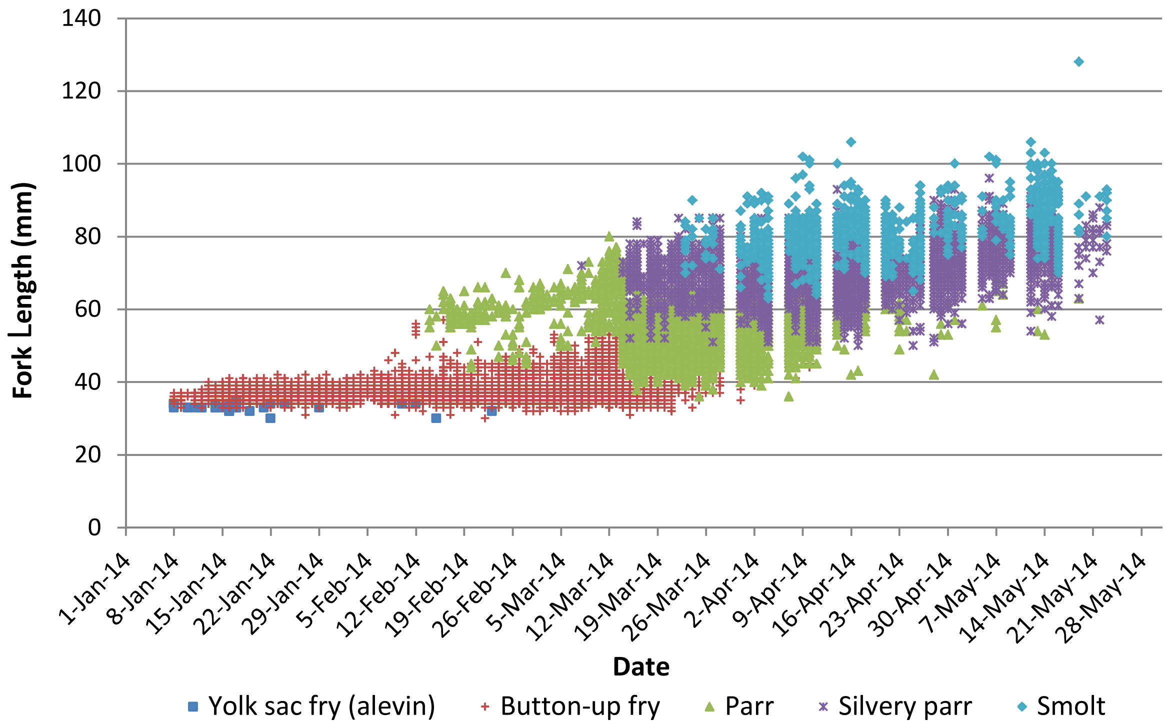
We observed the emigration of yolk-sac and fry life stages on the first sampling day of our survey season on January 7th through April 10th. The parr and silvery parr life stages of juvenile fall-run Chinook salmon were observed from February 14th through May 23rd, the end of the survey season. Smolts were observed March 23rd to the end of the survey season (Figure 6). The size distributions of the measured juvenile fall-run Chinook salmon caught varied by life stage (Figure 7). Fork length distributions for yolk-sac fry were between 30 and 35 mm, fry were between 30 and 57 mm, while parr ran from 36 to 80 mm. Silvery parr and smolt distributions contained the widest range of sizes from 50 to 96 mm for silvery parr and 63 to 128 mm for smolts (Figure 8).

Figure 6: Weekly fall-run Chinook salmon catch by life stage with average weekly fork lengths during the 2014 lower American River rotary screw trap survey season.



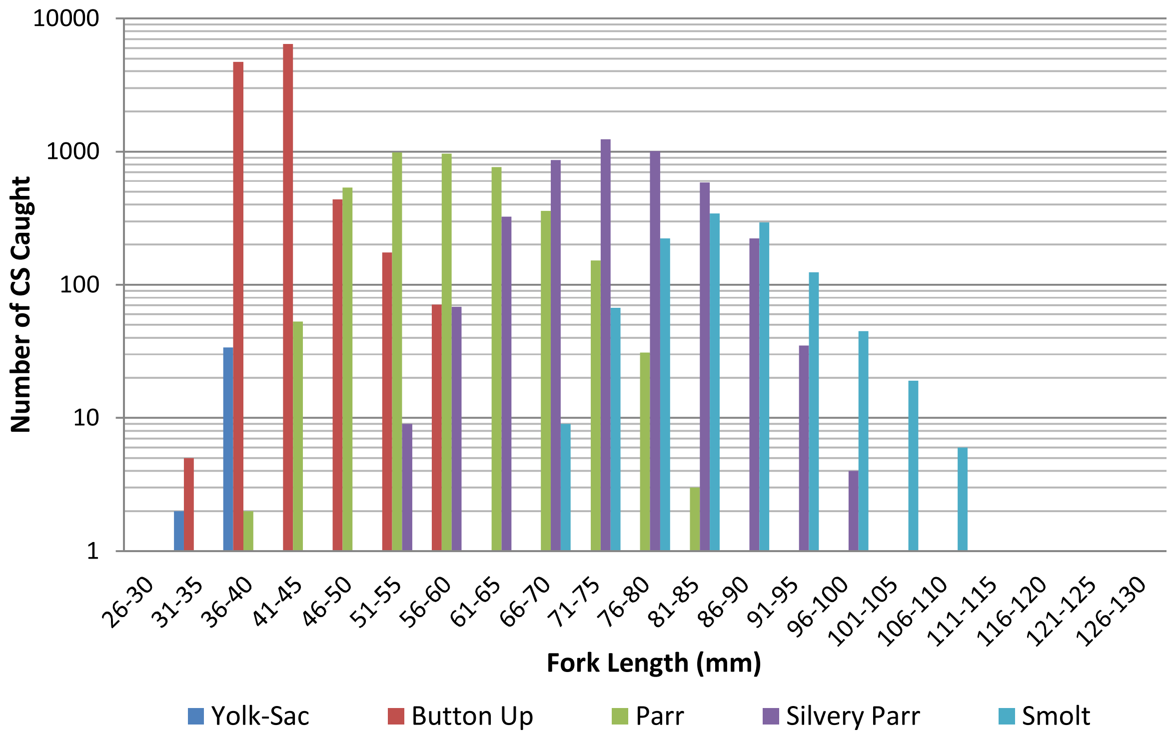
Note: Plus counted fall-run Chinook salmon and mortalities are not included in the graph.

Figure 7: Daily fall-run Chinook salmon fork lengths during the 2014 lower American River rotary screw trap survey season.



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

Figure 8: Distribution of fall-run Chinook salmon life stage and fork length during the 2014 lower American River rotary screw trap survey season.



Note: Plus counted fall-run Chinook salmon and mortalities are not included in the graph. One fall-run Chinook salmon smolt was captured at 128 mm.

Trap Efficiency

A total of 20,735 fall-run Chinook salmon was used in 15 mark-recapture trials during the 2014 survey season. Of those released, 4,873 were recaptured. A total of 17,663 Chinook salmon were stained with BBY whole body stain, and 3,072 were marked on the anal fin using a photonic marking gun. The average trap efficiency for the 15 trap efficiency tests was 21.33 percent (Table 3). Higher trap efficiencies tended to be associated with periods with lower river discharges. Generally, a vast majority of the recaptures occurred by the next trap visit after salmon were released and decreased exponentially the following days. While no statistical analysis was done to test for differences, the average size of released and recaptured salmon never varied by more than 2 mm. Trap efficiency results can potentially be affected by variables such as size of Chinook salmon, time of year, and river discharge.

Two trap efficiency tests were also conducted on May 16 near the end of the 2014 survey season with 1,000 photonicly marked hatchery-origin *O. mykiss*. This trial was a one time trial to confirm the ability of the rotary screw traps to capture *O. mykiss.* One set of 500 salmon was released at the Riviera storm drain outflow (the regular Chinook salmon trial release location) and the other 500 salmon were released under the Watt Avenue Bridge overcrossing 0.5 rkm downstream from the Riviera storm drain outflow. The Riviera trial group was marked with a pink photonic mark on the caudal fin and the Watt Avenue trial group was marked with a pink photonic mark on the anal fin. The trap efficiency for the Riviera location was 3.30 percent and the Watt Ave location was 5.28 percent. All recaptures were made by the trap check following the release.

Table 3: Trap efficiency data for mark and recapture trials during the 2014 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			
1/16/2014	Natural	Yellow	401	267	1/17/2014	5:10 PM	36	398	101	3	0	0	0	0	0	104	36	26.13%	506
1/22/2014	Natural	Yellow	868	268	1/23/2014	5:25 PM	37	856	176	10	1	1	0	0	0	188	36	21.96%	514
1/29/2014	Natural	Yellow	676	269	1/30/2014	5:25 PM	37	673	103	15	2	1	0	0	0	121	37	17.98%	497
2/5/2014	Natural	Yellow	685	270	2/6/2014	5:30 PM	37	684	94	11	1	0	0	0	0	106	38	15.50%	531
2/12/2014	Natural	Yellow	4000	271	2/13/2014	5:45 PM	37	3980	1340	10	10	0	0	0	0	1360	37	34.17%	497
2/19/2014	Natural	Yellow	4000	272	2/20/2014	5:50 PM	37	3970	939	16	2	0	1	0	0	958	37	24.13%	514
2/26/2014	Natural	Yellow	1909	273	2/27/2014	5:50 PM	38	1870	481	10	2	0	1	0	0	494	37	26.42%	489
3/5/2014	Natural	Yellow	1992	274	3/6/2014	5:50 PM	39	1910	251	9	2	2	0	0	0	264	38	13.82%	973
3/12/2014	Natural	Yellow	1975	275	3/13/2014	7:00 PM	41	1726	327	12	8	0	0	0	0	347	42	20.10%	514
3/19/2014	Natural	Yellow	1000	276	3/20/2014	7:00 PM	50	896	194	19	5	1	0	0	0	219	52	24.44%	497
4/11/2014	Hatchery	Yellow	700	278	4/14/2014	7:45 PM	63	700	136	10	0	0	0	0	0	146	65	20.86%	523
PHOTONIC MARKING				RELEASE					RECAPTURES							RECAPTURE SUMMARY			
3/19/2014	Natural	Pink	93	277	3/20/2014	7:00 PM	50	88	13	3	1	0	0	0	0	17	60	19.32%	497
4/18/2014	Hatchery	Pink	1000	279	4/22/2014	6:50 PM	68	993	47	0	0	0	0	0	0	47	73	4.73%	1,530
5/2/2014	Hatchery	Green	1000	280	5/5/2014	8:00 PM	80	992	222	0	0	0	0	0	0	222	82	22.38%	790
5/9/2014	Hatchery	Pink	1000	281	5/12/2014	8:05 PM	84	999	280	0	0	0	0	0	0	280	87	28.03%	952
STEELHEAD TRIAL				RELEASE					RECAPTURES							RECAPTURE SUMMARY			
5/16/2014	Hatchery	Pink-Caudal	500	282	5/19/2014	8:02 PM	68	455	15	0	0	0	0	0	0	15	66	3.30%	1770
5/16/2014	Hatchery	Pink-Anal	500	283	5/19/2014	7:50 PM	68	492	26	0	0	0	0	0	0	26	70	5.28%	1770

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

Natural = Lower American River (in-river produced); Hatchery = Nimbus Fish Hatchery.

BBY = Bismark brown Y whole body stain; Photonic = Bio-photonic dye mark on anal fin.

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.

O. mykiss Trial: Anal marked *O. mykiss* released under Watt Avenue overcrossing; Caudal marked *O. mykiss* released at La Riviera storm water outflow site.

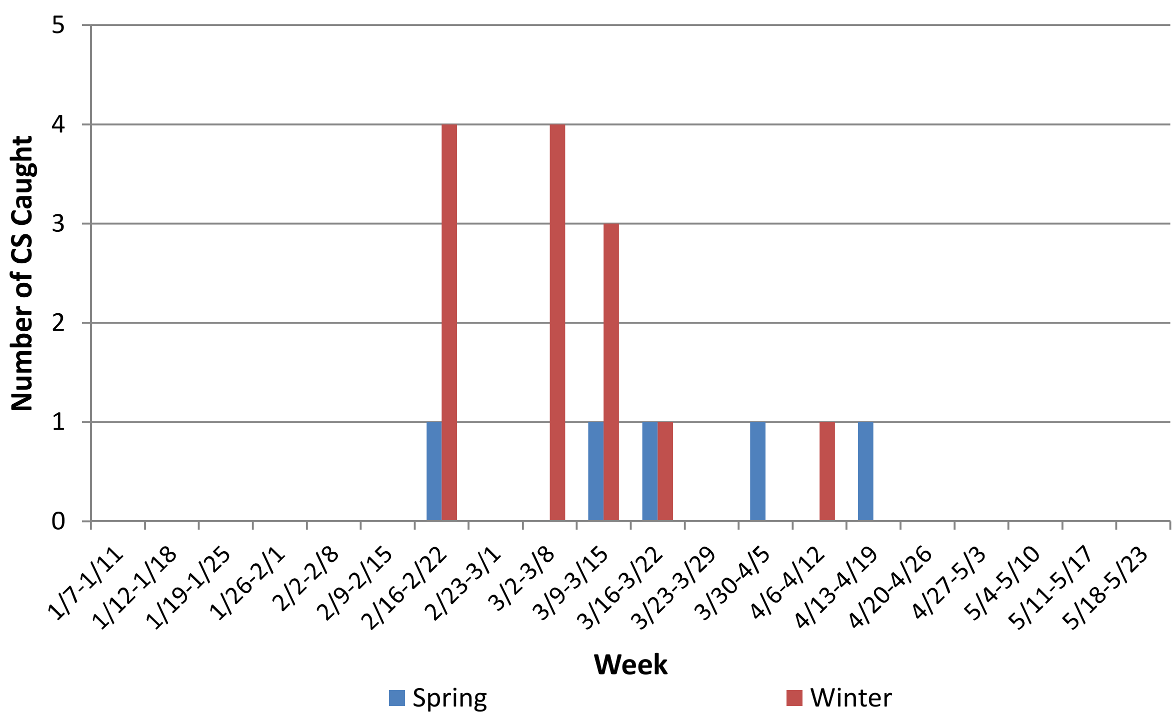
Passage Estimate for Fall-Run Chinook salmon

The estimated number of fall-run Chinook salmon to have emigrated down the lower American River during the 2014 survey season was 1,734,684 individuals (95% confidence intervals = 1,544,958 - 1,977,731). Estimated passage past the rotary screw traps by life stage was 1,476,732 fry, 239,912 parr, and 18,041 smolts.

Spring- and Winter-run Chinook salmon

Due to challenges associated with using the length-at-date criteria to conclusively determine whether individual Chinook salmon were spring- or winter-run salmon, genetic analysis was used to refine the run assignments made in the field and make final run assignments. A total of 13 winter-run and 5 putative spring-run Chinook salmon were collected by the American River RSTs during the 2014 survey season based on analyses using the SNP genetic markers (Figure 9). Winter-run life stages included 8 parr, 3 silvery parr, and 2 smolts. Two parr and 3 smolts were observed for spring-run Chinook salmon.

Figure 9: Weekly catch totals of spring- and winter-run Chinook salmon during the 2014 lower American River rotary screw trap survey season.



Ten Chinook salmon were collected and preliminarily classified as winter-run Chinook salmon according to the LAD criteria; those individuals were collected between February 17th and April 8th. Analyses using SNP genetic markers from those 10 Chinook salmon indicated 9 of those individuals were winter-run salmon, and 1 individual was a spring-run Chinook salmon that may have been from Mill or Deer Creek; for the purposes of this report, that latter individual was classified as a spring-run Chinook salmon with unknown origin (Table 4). Those creeks are located in the northern portion of the Central Valley, and are tributaries to the Sacramento River.

Table 4: Comparison of Chinook salmon run assignments using length-at-date criteria and generic markers that rely on SNP genetic markers.

	Genetic salmon run assignment based on a 80% genetic probability threshold			
LAD salmon run assignment	**Fall**	**Spring (Butte Creek)**	**Spring (unknown origin)**	**Winter**
Fall	22	0	0	0
Spring	141	3	1	4
Winter	0	0	1	9

Based on the LAD criteria, 1,855 Chinook salmon were collected between February 12th and May 19th in 2014 and classified as spring-run Chinook salmon. Of those putative spring-run salmon, 149 individuals were fin clipped. The genetic analyses and application of the aforementioned 80 percent genetic probability threshold to those 149 individuals suggest:

- One hundred forty-one individuals were likely to be fall-run salmon
- Three individuals were likely to be spring-run salmon from Butte Creek,
- One individual was likely to be a spring-run salmon of unknown origin, and
- Four individuals were winter-run salmon (Table 4).

Salmon that were classified as spring-run salmon using the LAD criteria and had a greater than 80 percent probability of being a fall-run salmon based on the SNP genetic markers were given a final run assignment = fall run. Therefore, 94.6 percent (n = 141) of the 149 salmon classified as spring-run salmon using the LAD criteria were more likely to be fall-run salmon based on the SNP genetic markers. Because there was a high likelihood that the LAD criteria were producing inaccurate spring-run assignments in 2014, all of the non-fin clipped salmon that were classified in the field as spring-run salmon received a final run designation = fall-run salmon. A complete accounting of the salmon run assignments using the LAD criteria and genetic markers is provided in Appendix 3.

Twenty-two salmon that were classified as fall-run Chinook salmon based on the LAD criteria were fin clipped during the 2014 survey season. The genetics analyses suggested all these individuals had a ≥ 97 percent genetic probability of being fall-run salmon.

Late-fall-run Chinook salmon

Only two late-fall-run Chinook salmon were captured in 2014 according to LAD criteria. One individual was caught on April 10th and the second was captured on April 21st.

Steelhead/*O. mykiss*

A total of 592 natural-origin *O. mykiss* were captured in 2014. All but four individuals were assessed for life stage, resulting in 0.3 percent (n = 2) individuals being classified as yolk-sac fry, 79.5 percent (n = 468) as fry, 13.8 percent (n = 81) as parr, 0.2 percent (n = 1) as silvery parr, 5.3 percent (n = 31) as yearling smolts, and 0.8 percent (n = 5) as adults (Table 5). Because diagnostic morphological characteristics that can be used to distinguish between the anadromous and resident forms of *O. mykiss* are not available, it is not possible to quantify how many of the 592 *O. mykiss* were steelhead or rainbow trout.

The RSTs also captured 642 fin clipped hatchery-origin *O. mykiss*; each of these fish was likely to possess anadromous parents. Of those *O. mykiss*, 633 individuals were adipose fin clipped *O. mykiss* that were part of the normal stocking activities conducted by the CDFW, and 9 individuals were *O. mykiss* that were evacuated from the Nimbus Fish Hatchery due to the potential of high water temperatures over the summer rearing season. The 9 individuals were marked by the Nimbus Fish Hatchery staff with adipose and left pelvic fin clips. This unique marking will allow future potential *O. mykiss* recaptures to be associated with the 2014 emergency released brood stock.

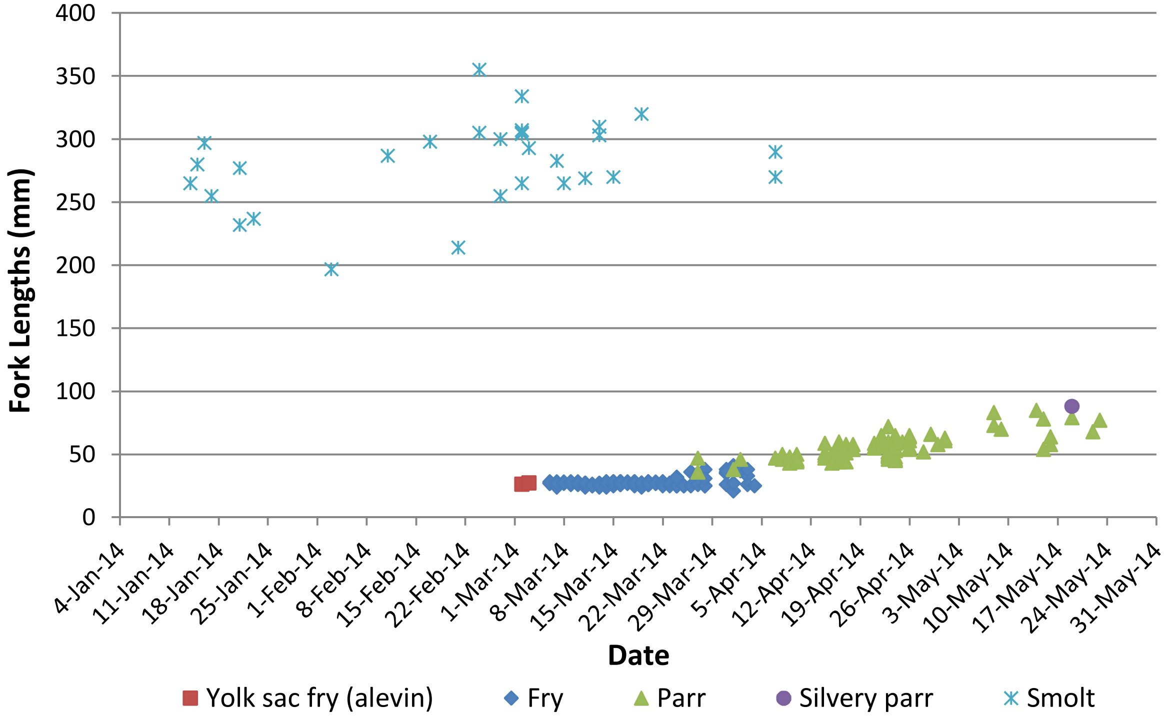
Table 5: Weekly catch totals by life stage for natural-origin *O. mykiss* during the 2014 lower American River rotary screw trap survey season.

Week	Yolk-sac	Fry	Parr	Silvery Parr	Smolt	Adult	Unassigned Life Stage	Total
1/7-1/11	0	0	0	0	0	0	0	0
1/12-1/18	0	0	0	0	4	0	0	4
1/19-1/25	0	0	0	0	3	1	0	4
1/26-2/1	0	0	0	0	0	0	0	0
2/2-2/8	0	0	0	0	1	0	0	1
2/9-2/15	0	0	0	0	1	1	0	2
2/16-2/22	0	0	0	0	2	1	0	3
2/23-3/1	0	0	0	0	4	1	0	5
3/2-3/8	2	26	0	0	8	0	0	36
3/9-3/15	0	182	0	0	4	1	1	188
3/16-3/22	0	216	0	0	1	0	0	217
3/23-3/29	0	26	2	0	0	0	0	28
3/30-4/5	0	16	2	0	0	0	0	18
4/6-4/12	0	1	11	0	2	0	1	15
4/13-4/19	0	0	19	0	1	0	1	21
4/20-4/26	0	1	31	0	0	0	1	33
4/27-5/3	0	0	5	0	0	0	0	5
5/4-5/10	0	0	3	0	0	0	0	3
5/11-5/17	0	0	5	0	0	0	0	5
5/18-5/23	0	0	3	1	0	0	0	4
Total	2	468	81	1	31	5	4	592

Note: Plus counted *O. mykiss* and mortalities are included in the totals.

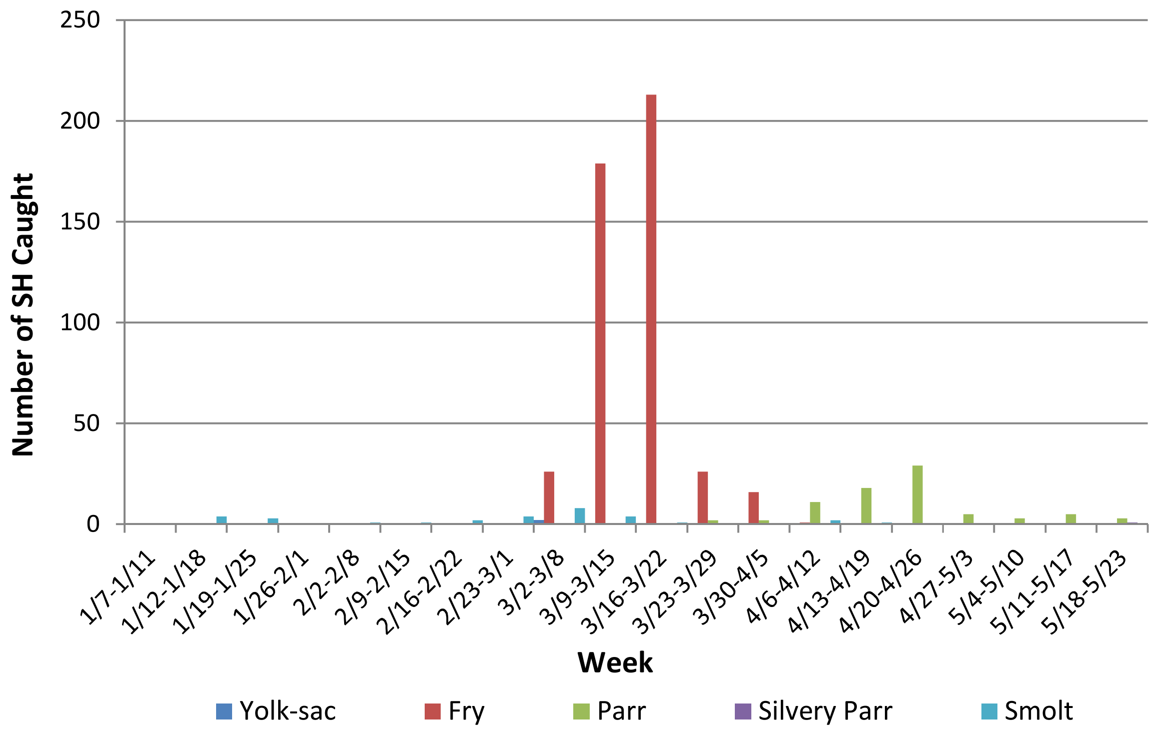
The temporal presence and abundance of natural-origin *O. mykiss* in 2014 varied by life stage. The *O. mykiss* yolk-sac fry stage was only observed twice, i.e., on March 2nd and 3^{rd,} and those individuals had fork lengths of 26 and 27 mm, respectively (Figure 10). Fry life stages were observed from March 6th until April 22nd, with their fork lengths ranging from 22 to 41 mm. The first *O. mykiss* identified as a parr life stage was observed on March 27^{th,} and they were captured through the end of the sampling season; that life stage's fork lengths ranged from 36 to 85 mm. One silvery parr life stage *O. mykiss* was observed on May 19th with an 88 mm fork length. From January 18th to April 15th, 31 yearling smolts were identified with fork lengths ranging from 197 to 355 mm. The capture of those smolts likely represents individuals that hatched in the American River in 2013, and reared in the river to become age 1 fish. Peak catch for *O. mykiss* occurred within the weeks of March 9th to March 22nd with 68.9 percent (n = 407) of the season's total natural-origin *O. mykiss* catch being collected; all of those individuals were identified as the fry life stage (Figure 11).

Figure 10: Daily fork lengths for natural-origin *O. mykiss* during the 2014 lower American River rotary screw trap survey season.



Note: Plus counted *O. mykiss* and mortalities are not included in the graph.

Figure 11: Weekly catch totals by life stage for natural-origin *O. mykiss* during the 2014 lower American River rotary screw trap survey season.



Note: Plus counted *O. mykiss* and mortalities are not included in the graph.

Non-salmonid Species

A total of 5,116 non-target fish belonging to 24 identifiable, non-salmonid species was caught during the 2014 survey season. The families of the species captured include: *Catostomidae* (sucker), *Centrarchidae* (sunfish/black bass), *Clupeidae* (shad), *Cottidae* (sculpin), *Cypinidae* (minnow), *Embiotocidae* (tule perch), *Gasterosteidae* (stickleback), *Ictaluridae* (bullhead/catfish), *Moronidae* (striped bass), *Osmeridae* (smelt), *Petromysontidae* (lamprey), and *Poeciliidae* (mosquitofish) (Figure 12). For the complete list of each non-target species captured in the 2014 survey season, see Appendix 2.

Of the 5,116 non-target individuals collected, 259 were not identifiable to the species level in the field. Those unidentified individuals belonged to one of the following families: Petromyzontidae (unidentified lamprey ammocoetes), Cyprinidae (unidentified minnows), Cottidae (unidentified sculpins), and Centrarchidae (unidentified juvenile sunfish) (Appendix 2).

Included within the non-target species collected this season were 1,525 lampreys. Of those, 63.6 percent (n = 970) were identified as Pacific lamprey, 23.7 percent (n = 361) were river lamprey, and 12.7 percent (n = 194) were lamprey ammocoetes. Lampreys were caught throughout the entire survey season, with the highest peak catches occurring during the weeks of February 9-15th and April 20-26th (Figure 13).

Figure 12: Non-salmonid catch totals for fish species collected during the 2014 lower American River rotary screw trap survey season.

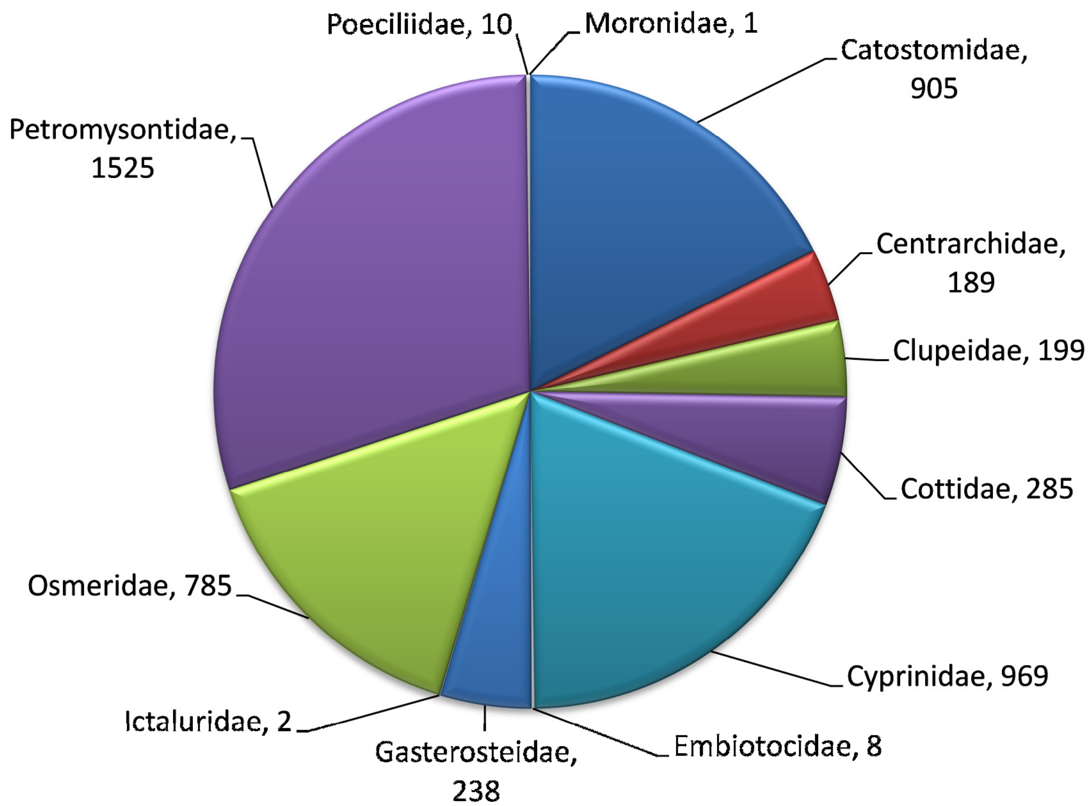
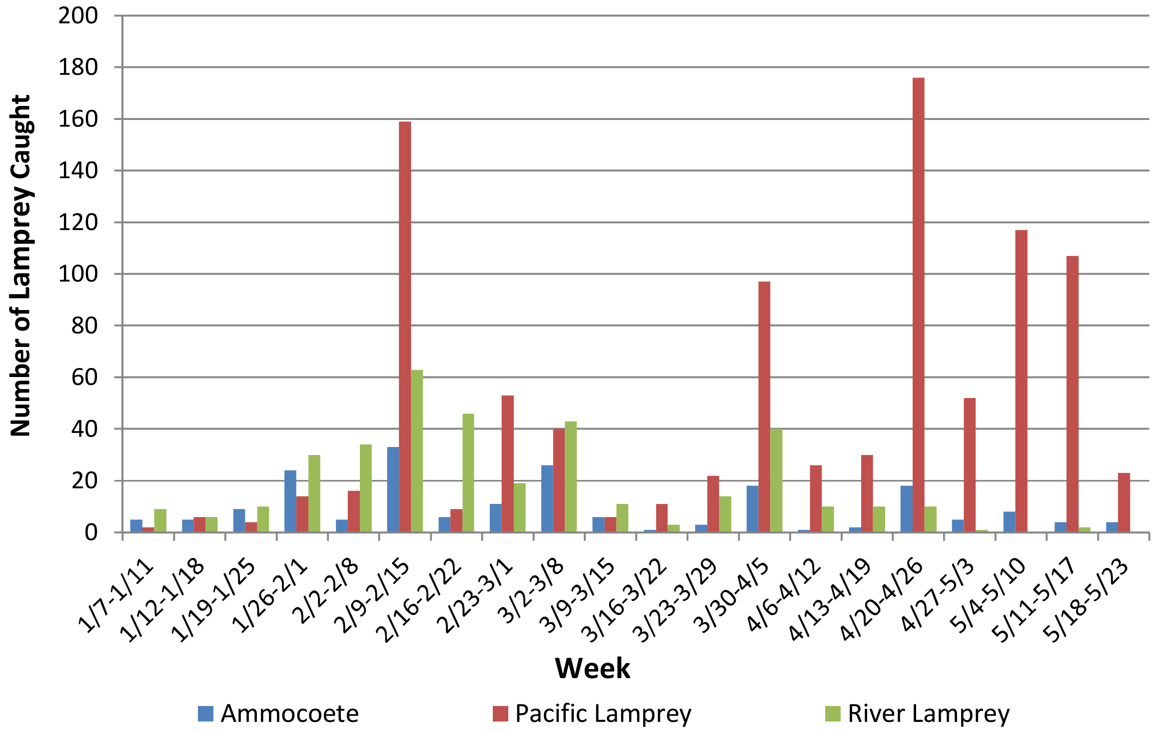


Figure 13: Total weekly lamprey catch totals during the 2014 lower American River rotary screw traps survey season.



Miscellaneous Investigations

Five of the appendices at the end of this annual report provide special studies conducted during the 2014 survey season. Those appendices address the following topics:

Appendix 8: An assessment of the juvenile *O. mykiss* response to three increases in river discharge on the American river in 2014.

Appendix 9: An evaluation of juvenile Chinook salmon life stage assignments by biologists from the American and Stanislaus Rivers.

Appendix 10: A comparison of river discharge at Nimbus Dam and Watt Avenue on the American River in 2014.

Appendix 11: Relationship between the Nimbus Dam release volume and water volume moving through the South Channel near the Watt Avenue rotary screw trap site.

Appendix 12: An Assessment of Fin Clipping and/or Bio-Photonic Marking of Salmonids.

Discussion

The 2014 lower American River survey season did not encompass an entire juvenile Chinook salmon emigration period. Chinook salmon were present on the first day and continuously through the final day of the season. However, it was assumed that only a relatively small percentage of the emigration was not surveyed due to the low numbers of catch at the beginning and end of the season. Typically, to more positively assume that the entire emigration period was captured, there must be multiple days or weeks of no catch before the first and after the last day Chinook salmon were caught. The survey season was constrained due to personnel logistics. The end of the trapping season was also affected by increasing river water temperatures. Nevertheless, during the 2014 RST survey season on the lower American River a high quality set of data was produced since no significant logistical or environmental factors hindered the accuracy of the data collected.

During the 2014 survey season, various efforts were undertaken to reduce potential adverse effects to fish captured in the RSTs. From the January 7th to March 28th, the rotary screw traps fished continuously without any scheduled downtime. With the exception of the April 21-25, 2014 pulse flow described in Appendix 8, it was decided that the traps would go offline after March 28th and be moved to the shore on weekends due to warming water temperatures. The warming temperatures created handling issues and fish stress when processing hundreds of fish at a time. In order to be proactive regarding the fish stress and mortality, we opted to do twice daily trap checks during the majority of the weekdays. This allowed for a manageable amount of fish to be processed at a time, and reduced the exposure time and organic debris accumulation in the live wells.

The 2013 American River RST annual report stated that the total number of juvenile fall-run Chinook salmon produced by the American River in 2013 was 3,195,884 individuals; that estimate was in error because the CAMP's RST Platform was not designed to account for changes in the number or position of traps that were fished during a survey season. That issue has since been addressed. The revised 2013 fall-run Chinook salmon production estimate for all juveniles in 2013 is 6,359,668.

This year's 2014 passage estimate of 1,734,685 fall-run Chinook salmon, in comparison to last year's 6,359,668 revised estimate, shows 73 percent fewer fall-run Chinook salmon passed by the RST's in 2014. Causal factors may be related to the statewide drought California has been experiencing the last couple of years. Another potential causal factor is redd dewatering as the flows from Nimbus Dam were dropped during the crucial spawning and egg development period on the lower American River. During this period, discharge dropped incrementally from 1,400 CFS on November 26th to 500 CFS by January 10th. Hydraulic simulation models developed by Chris Hammersmark of CBEC Inc. (2014) with redd data provided by the Cramer Fish Sciences company showed a scenario of a 0.2% redd dewatering at 1,250 CFS growing exponentially to 11.5% redd dewatering at 500 CFS. This dewatering scenario may be a conservative estimate since the model does not classify a redd as being dewatered as long as there is water over the top of the gravel. The model does not therefore take in account the required flow, temperature, and dissolved oxygen levels needed to sustain egg/alevin survival. Another potential adverse causal factor may relate to low water flows on the American River that could result in redd superimposition due to limited spawning habitat. If spawning Chinook salmon build new redds on top of preexisting redds, that condition could lead to eggs being destroyed, dug up, or buried further preventing the alevin/fry from emerging. Further adverse effects to juvenile salmon from low flows may include warmer water leading to increased warm water predator species, disease issues, or side channel isolation which could lead to stranding.

Many biologists assume that fall-run Chinook salmon are the only salmon run to spawn in the lower American River (Yoshiyama 2001). However, according to the LAD criteria, winter-run or putative spring-run size juvenile Chinook salmon were caught in the RSTs during the 2014 survey season. Because spring- and winter-run Chinook salmon from the Central Valley are listed taxa under the Federal Endangered Species Act; accurate taxon verification is therefore a priority in relation to the federal take permit for the American River RST project. In order to verify that the Chinook captured in the American River RSTs were indeed spring- or winter-run salmon, fin-clip samples were collected for those runs and sent to the Abernathy Fish Technology Center for genetic analysis. Additionally, as a control group, 22 fin-clip samples of salmon that had been classified as fall-run Chinook using the LAD criteria were also collected for fall-run verification. When possible, these fall-run fin-clip samples were collected twice a week throughout the survey season.

The genetic analyses with the SNPs in 2014 confirmed that 9 of the 10 individuals that were caught and classified as winter-run Chinook salmon using the LAD criteria were also found to be winter-run Chinook salmon using the genetic markers. The 2014 genetic analyses indicated the tenth individual was not a winter-run salmon, and instead was probably a spring-run salmon. During the 2013 American River RST field season, 26 salmon were classified as winter-run Chinook salmon using the LAD criteria, and SNP genetic markers indicated all 26 of those individuals were winter-run salmon. The data from the 2013 and 2014 American River RST field seasons therefore indicate that when a salmon is classified at the time of capture as a winter-run Chinook salmon using the LAD criteria, there is a high probability that the individual will be classified as a winter-run salmon using the SNP genetic markers.

Of the 149 individuals classified as spring-run salmon using the LAD criteria in 2014, 4 were winter-run salmon, 4 were likely to be spring-run salmon, and the remaining balance (141) were likely to be fall-run Chinook salmon based on the SNP genetic markers. As was noted in the 2013 American River RST annual report (PSMFC 2014), relatively small genetic differences between the Feather River's naturally spawning fall-run and hatchery produced spring-run Chinook salmon were found in a study by Garza et al. (2008), and the similarities in the genetics of salmon from the Feather River Fish Hatchery may result in spring-run salmon that have morphological features that make conclusive run assignments problematic.

Two lines of evidence suggest that changing the final salmon run assignments for 141 salmon from spring to fall in 2014 is justified. First, all of the 141 salmon have at least an 84 percent probability of being fall-run Chinook salmon based on the SNP genetic markers, and 137 of those individuals have at least a 95 percent probability of being fall-run Chinook salmon. Because the sum of the genetic assignment probabilities for each fish will always sum to 100 percent (Christian Smith, pers. comm.), there would only be a 5 - 16 percent probability that the salmon that were classified as spring-run salmon at the time of capture actually were spring- or late-fall-run salmon. And second, it is noteworthy that in most cases where the LAD criteria suggested the presence of spring-run salmon, 64 of the 141 salmon were within 6 mm of the date-specific fall-spring run LAD boundary, and 119 of the 141 salmon were within 10 mm of the date-specific fall-spring run LAD boundary. These data therefore suggest many or most of the putative spring-run salmon based on the LAD criteria were only slightly larger than the date-specific LAD boundary that separates fall- and spring-run Chinook salmon.

An abundance of food sources and/or warmer than normal water conditions during the spring of 2014 on the lower American River may have contributed to faster than normal growth of fall-run Chinook salmon. Temperatures in the river reached as high as 17 degrees Celsius by the end of March, 3 to 5 degrees higher than the prior 15-year March average (Appendix 6). Studies have shown the optimum growth rate for Central Valley fall-run Chinook salmon occurs at 15 to 18 degrees Celsius, provided that food isn't a limiting factor (Marine and Cech 2004). This suggests the application of LAD criteria on the lower American River in 2014 may have had limited utility in accurately identifying spring-run salmon because water temperatures in the American River were optimal for salmon growth and many individuals likely reached a length that exceeded a date-specific LAD boundary.

Each of the 22 Chinook salmon that were classified as fall-run Chinook salmon using the LAD criteria was confirmed to be fall-run salmon using the genetic analysis, i.e., the SNPs appear to have a relatively strong ability to accurately identify fall-run Chinook salmon. That result was interpreted as further support it was appropriate to change the at capture run designations for most of the putative spring run salmon to a final run = fall based on the genetic markers.

Winter-run Chinook salmon captured in the lower American River rotary screw traps were likely non-natal rearing winter-run from the Sacramento River. Research has shown that winter-run Chinook have a strong tendency to rear in adjoining tributaries downstream of the spawning grounds (Maslin et al. 1998). Such fish may continually rear and feed within the tributaries before they ultimately emigrate to the Sacramento – San Joaquin River Delta as smolts. The winter-run Chinook salmon caught in the lower American River rotary screw traps were either smolts or pre-smolts with fork lengths ranging from 75 to 111 mm, which is consistent with their protracted emigration characteristics (Martin 2001).

Annual *O. mykiss* catches have varied greatly by year and may be explained by many causal factor(s). These factors include: differences in trapping methods, gear size and number of traps in relation to the size of the river channel, gravel augmentation activities to enhance spawning habitats, or redds being in close proximity to the traps. Redd proximity to the RSTs may have a large correlation to young of the year (YOY) *O. mykiss* catch during each survey season. In 2013, the Bureau of Reclamation (BOR) conducted *O. mykiss* redd surveys on the lower American River and were able to locate seven redds within ~160 m upstream of the traps (Hannon 2013). In 2013, 2,206 natural-origin *O. mykiss* were captured with the RSTs; of those fish, 2,203 were YOY fry or parr, 2 were yearling smolts, and 1 was an adult. In 2014, Cramer Fish Science performed similar redd surveys along the lower American River and observed zero redds within the same ~160 m distance upstream as seen in the prior year (John Hannon, BOR, pers. comm.). Instead, the 2014 *O. mykiss* redd surveys suggested the closest redd to the RSTs was 2,150 m upstream from the Watt Avenue Bridge. Ultimately, 592 natural-origin *O. mykiss* were captured in the RST in 2014; of those fish, 556 were YOY fry or parr, 31 were yearling smolts, and 5 were adults. Overall, therefore, there was a 75 percent decrease in the catch of natural-origin fry or parr from 2013 to 2014.

In contrast to the substantial decrease in YOY *O. mykiss* catch from the previous season, natural-origin yearling *O. mykiss* catches increased markedly in 2014. In 2013, only 2 natural-origin *O. mykiss* yearlings were captured in the American River RSTs. However, 31 natural-origin yearlings were captured during the 2014 survey season. A possible cause for the increased catch of yearling *O. mykiss* in 2014 may have been due to the low river flows. The combined width of the two RSTs was roughly 60-70 percent of the river's width as a result of the discharge from Nimbus Dam being at 500 CFS for the majority of the season. During the 2013 survey season, discharge from the Nimbus Dam started at 2,500 CFS, then decreased to 1,200 CFS during the *O. mykiss* emigration period. These factors in combination created very little passage around the traps for the *O. mykiss* yearlings as they emigrated in 2014.

Another indication of the increased trap efficiency in 2014 was suggested in the capture of hatchery-origin *O. mykiss*. A total of 623 hatchery-origin ad-clipped juvenile *O. mykiss* were captured in the RSTs during the 2014 survey season in contrast to 20 hatchery-origin ad-clipped juvenile *O. mykiss* captured in 2013. This difference cannot be explained by the releases from the Nimbus Hatchery because the released stock in 2013 and 2014 were similar, i.e., 315,530 and 320,039 *O. mykiss* respectively (Gary Novak, CDFW, pers. comm.).

In addition to the release of yearling *O. mykiss* from the Nimbus Fish Hatchery into the lower American river between January 29th and February 6th, emergency releases of YOY fingerling *O. mykiss* were evacuated from the hatchery and released above Sunrise Boulevard approximately 17.5 rkm upstream of the rotary screw traps in 2014 due to concerns that water temperatures in the hatchery would rise beyond a safe level throughout the summer, a direct consequence of the drought. *O. mykiss* fingerlings were released into the lower American River on 6 days from April 29th through June 18th, 2014. The emergency releases of fingerling O. mykiss were uniquely marked with adipose and left pelvic fin clips to identify the releases in the case of recapture. Between April 29th and May 13th and after the release of 351,720 *O. mykiss* on 5 separate days, only 1 of those hatchery-origin *O. mykiss* had been captured by the rotary screw traps. On May 19th and 22nd, another 64,543 and 62,234 *O. mykiss* fingerling were released, respectively, into the lower American River. On the last day of the RST survey season on May 23rd, another 8 hatchery *O. mykiss* fingerlings were captured in the rotary screw traps. Following the end of our survey season, the remaining balances of *O. mykiss* fingerling in the Nimbus Fish Hatchery were released into the lower American River to equal a final total of 437,559 individuals released by June 18th, 2014. Biologists with the California Department of Fish and Wildlife and the lower American River Screw Trap Project expected the hatchery-origin *O. mykiss* to follow the behavioral characteristics of natural-origin *O. mykiss* which is to hold in the lower American River to rear until they emigrate as smolts the following winter (Yoshiyama 2001). However, it was expected some dispersal downstream towards the trap would happen due to the large quantity released in a relatively small area.

To evaluate how effective the American River RSTs were in regards to capturing *O. mykiss* from the hatchery releases, two efficiency trials were performed on May 16. Each trial consisted of 500 Nimbus Fish Hatchery *O. mykiss* that were given a unique photonic mark, and the locations for those releases were 0.25 rkm and 1.1 rkm upstream of the traps. The details for the trials are outlined in the Methods section of this document. Results of the trials showed a 3.30 percent recapture for the 1.1 rkm release location and 5.28 percent recapture for the 0.25 rkm release location. The two efficiency trials suggest the RSTs had an ability to capture hatchery-origin *O. mykiss,* and that few of the hatchery-origin *O. mykiss* that were released at Sunrise Boulevard were likely moving downstream past the RSTs. This may be an artifact of the natural tendency of *O. mykiss* to rear in river as fingerlings for a year and then emigrate as smolts.

In order to determine if the efforts made by AFRP and others to increase abundance of Chinook salmon and *O. mykiss* on the lower American River have been successful, additional monitoring of juvenile salmonid emigration is required. The 2014 data, coupled with prior and future season's data will provide crucial information to better understand and improve conditions for Chinook and *O. mykiss* on the lower American River. Water management modifications for the American River may need to be adjusted to become more favorable to anadromous fish in years of severe drought. Favorable options such as discharge volume and timing could be adjusted to prevent pre-spawn mortality along with redd dewatering and superimposition.

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Appendix 1: Weekly environmental conditions on the lower American River during the 2014 survey season.

Week	Water Temperature °C			Discharge (CFS)			DO (mg/L)			Turbidity (NTU)		
	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
1/7-1/11	9.6	8.9	10.6	673	424	1,020	13.09	12.66	13.41	1.76	1.27	2.39
1/12-1/18	9.4	8.5	10.7	564	440	602	13.23	12.82	13.60	1.54	1.43	1.70
1/19-1/25	9.4	8.2	11.2	512	506	523	12.86	12.32	13.22	1.75	1.30	1.99
1/26-2/1	10.1	8.3	11.9	511	497	584	12.25	11.87	12.68	1.75	1.01	3.18
2/2-2/8	9.7	8.7	10.9	529	514	557	12.31	11.42	12.76	3.16	0.98	12.36
2/9-2/15	11.9	10.8	13.9	585	392	1,510	11.02	10.52	11.68	3.66	1.70	10.11
2/16-2/22	12.1	10.7	14.1	510	497	540	11.09	10.22	11.60	2.90	2.27	3.57
2/23-3/1	12.6	11.4	14.6	506	489	531	11.18	10.72	11.67	4.65	2.46	11.99
3/2-3/8	13.5	11.8	15.5	573	416	1,070	11.00	10.68	11.41	3.78	2.96	5.59
3/9-3/15	14.5	12.6	16.6	513	472	584	10.88	10.51	11.30	2.13	1.63	2.84
3/16-3/22	15.1	12.9	17.2	498	472	523	10.92	10.53	11.65	2.12	1.56	2.79
3/23-3/29	14.7	12.8	17.4	510	481	611	11.01	10.42	11.82	2.05	1.37	2.34
3/30-4/5	13.8	11.6	16.4	514	497	531	11.14	10.49	12.13	3.81	1.57	5.98
4/6-4/12	17.0	14.4	19.3	522	416	557	11.25	9.90	12.70	1.65	1.07	2.09
4/13-4/19	17.8	15.6	19.6	517	416	549	10.59	10.23	11.00	2.06	1.80	2.60
4/20-4/26	15.9	13.3	19.3	1,051	497	1,560	11.08	10.15	12.43	3.24	1.56	5.99
4/27-5/3	16.7	14.2	18.7	793	780	810	10.91	9.88	12.07	2.41	1.96	3.65
5/4-5/10	17.1	15.7	18.4	861	780	1,000	9.97	8.97	10.64	1.85	1.22	2.84
5/11-5/17	17.8	14.8	19.3	1,178	921	1,790	9.64	8.96	10.94	2.25	1.25	3.55
5/18-5/23	16.7	14.4	18.9	1769	1740	1790	9.78	9.16	11.33	2.35	1.78	3.04

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

Appendix 2: List of fish species caught during the 2014 season using rotary screw traps on the lower American River.

Common Name	Family Name	Species Name	Total Number Caught
Chinook Salmon	Salmonidae	Oncorhynchus tshawytscha	379,562
Steelhead/Rainbow Trout	Salmonidae	Oncorhynchus mykiss	1,234
American shad	Clupeidae	Alosa sapidissima	11
Black bullhead	Ictaluridae	Ameiurus melas	1
Bluegill	Centrarchidae	Lepomis macrochirus	29
Channel catfish	Ictaluridae	Ictalurus punctatus	1
Fathead minnow	Cyprinidae	Pimephales promelas	3
Golden shiner	Cyprinidae	Notemigonus crysoleucas	68
Goldfish	Cyprinidae	Carassius auratus	3
Green sunfish	Centrarchidae	Lepomis cyanellus	5
Hardhead	Cyprinidae	Mylopharodon conocephalus	374
Largemouth bass	Centrarchidae	Micropterus salmoides	77
Mosquitofish	Poeciliidae	Gambusia Affinis	10
Pacific lamprey	Petromyzontidae	Entosphenus tridentata	970
Prickly sculpin	Cottoidea	Cottus asper subspecies	37
Redear sunfish	Centrarchidae	Lepomis microlophus	49
Riffle sculpin	Cottoidea	Cottus gulosus	226
River lamprey	Petromyzontidae	Lametra ayresii	361
Sacramento pikeminnow	Cyprinidae	Ptychocheilus grandis	506
Sacramento sucker	Catostomidae	Catostomus occidentalis occidentalis	905
Smallmouth bass	Centrarchidae	Micropterus dolomieu	1
Striped bass	Moronidae	Morone saxatilis	1
Threadfin shad	Clupeidae	Dorosoma petenense	188
Threespine stickleback	Gasterosteidae	Gasterosteus aculeatus	238
Tule perch	Embiotocidae	Hysterocarpus traskii traskii	8
Unknown/Ammocoete lamprey	Petromyzontidae	(Entosphenus or Lampetra)	194
Unknown minnow	Cyprinidae		15
Unknown sculpin	Cottoidea	(Cottus)	22
Unknown sunfish	Centrarchidae	(Lepomis)	28
Wakasagi / Japanese smelt	Osmeridae	Hypomesus nipponensis	785
		Total Cumulative	**385,912**

Note: The total number caught includes mortalities.

The steelhead/Rainbow trout numbers consisted of the following categories of fish:

1. 592 natural-origin *O. mykiss*.
2. 633 hatchery-origin adipose fin clipped *O. mykiss* associated with normal hatchery planting activities by the CDFW. And,
3. 9 hatchery-origin adipose and pelvic fin clipped *O. mykiss* associated with emergency evacuations from the Nimbus Fish Hatchery.

Appendix 3: Genetic results for fin-clip samples from Chinook salmon caught in the lower American River during the 2014 survey season.

Sample #: refer to a unique number assigned by field staff, and that allowed the tracking of individual fish samples.
LAD run assignment: represents the Chinook salmon run assignment based on the length-at-date run assignment methodology developed by Greene (1992).
SNP Run Assignment: genetic run with the highest probability based on single-nucleotide polymorphism (SNP) markers.
SNP Probability: Probability of the correct SNP Chinook salmon run assignment.
Final run assignment: run assignment using a 80% 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)	Comment
11-Feb	2771-001	Spring	Fall	0.996	Fall	54		
12-Feb	2771-002	Spring	Fall	0.999	Fall	56	1.4	
12-Feb	2771-003	Spring	Fall	0.999	Fall	54	1.6	
12-Feb	2771-004	Spring	Fall	1.000	Fall	55		
12-Feb	2771-005	Fall	Fall	1.000	Fall	53		
12-Feb	2771-006	Fall	Fall	0.999	Fall	53	1.5	
12-Feb	2771-007	Spring	Fall	0.966	Fall	55	1.4	
14-Feb	2771-008	Spring	Fall	1.000	Fall	57	1.8	
14-Feb	2771-009	Spring	Fall	0.999	Fall	60	2.0	
15-Feb	2771-010	Spring						Missing Sample
15-Feb	2771-011	Spring	Fall	0.999	Fall	58	1.8	
16-Feb	2771-012	Spring	Fall	0.999	Fall	62	2.5	
16-Feb	2771-013	Spring	Fall	1.000	Fall	65	2.7	
16-Feb	2771-014	Spring	Fall	0.998	Fall	60	2.2	
16-Feb	2771-015	Spring	Fall	0.994	Fall	64	2.6	
17-Feb	2771-016	Winter	Winter	1.000	Winter	90	8.1	
17-Feb	2771-017	Spring	Fall	0.996	Fall	60	2.1	
17-Feb	2771-018	Winter	Winter	1.000	Winter	93	10.5	
17-Feb	2771-019	Spring	Fall	0.983	Fall	61	2.4	
17-Feb	2771-020	Spring	Fall	0.999	Fall	63	2.3	
17-Feb	2771-021	Spring	Fall	0.996	Fall	62	2.4	
17-Feb	2771-022	Spring	Fall	0.973	Fall	63	2.5	
17-Feb	2771-023	Spring	Fall	0.999	Fall	60	2.2	
17-Feb	2771-024	Spring	Fall	1.000	Fall	60		
18-Feb	2771-025	Winter	Winter	1.000	Winter	87	7.4	
19-Feb	2771-026	Spring	Fall	0.964	Fall	61	2.5	
19-Feb	2771-027	Spring	Fall	1.000	Fall	65	2.6	
21-Feb	2771-028	Spring	Fall	1.000	Fall	66	2.8	
21-Feb	2771-029	Spring	Winter	1.000	Winter	75	4.4	

Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)	Comment
21-Feb	2771-030	Spring	Fall	1.000	Fall	62	2.4	
22-Feb	2771-031	Spring	Fall	1.000	Fall	62	2.3	
22-Feb	2771-032	Spring	Spring	0.808	Spring	65	2.8	Butte Creek
22-Feb	2771-033	Spring	Fall	1.000	Fall	66	2.7	
25-Feb	2771-034	Spring	Fall	1.000	Fall	70	3.4	
27-Feb	2771-035	Spring	Fall	0.999	Fall	68		
27-Feb	2771-036	Spring	Fall	0.998	Fall	66	2.8	
27-Feb	2771-037	Spring	Fall	0.999	Fall	66	2.8	
1-Mar	2771-038	Spring	Fall	1.000	Fall	66		
2-Mar	2771-039	Spring	Fall	0.998	Fall	67		
2-Mar	2771-040	Spring	Fall	0.999	Fall	66		
3-Mar	2771-041	Winter	Winter	1.000	Winter	89	7.1	
5-Mar	2771-042	Winter	Winter	1.000	Winter	90	7.4	
5-Mar	2771-043	Spring	Fall	0.959	Fall	67	2.9	
6-Mar	2771-044	Spring	Fall	1.000	Fall	71	4.2	
7-Mar	2771-045	Winter	Winter	1.000	Winter	84	5.8	
8-Mar	2771-046	Spring	Fall	0.999	Fall	69	3.8	
8-Mar	2771-047	Spring	Fall	1.000	Fall	70	3.5	
8-Mar	2771-048	Spring	Winter	1.000	Winter	78	4.6	
8-Mar	2771-049	Spring	Fall	0.998	Fall	72	3.7	
8-Mar	2771-050	Spring	Fall	0.999	Fall	69	3.2	
9-Mar	2771-051	Spring	Fall	0.995	Fall	70	3.3	
9-Mar	2771-052	Spring	Fall	0.999	Fall	73	3.8	
11-Mar	2771-053	Spring	Fall	0.999	Fall	71	3.7	
11-Mar	2771-054	Spring	Fall	0.999	Fall	73	3.6	
11-Mar	2771-055	Spring						Missing Sample
11-Mar	2771-056	Spring	Fall	0.999	Fall	71	3.3	
11-Mar	2771-057	Spring	Fall	0.999	Fall	70	3.6	
11-Mar	2771-058	Spring	Fall	0.999	Fall	71	3.2	
11-Mar	2771-059	Spring	Winter	1.000	Winter	80	4.8	
11-Mar	2771-060	Spring	Spring	0.994	Spring	70	3.9	Butte Creek
11-Mar	2771-061	Winter	Winter	1.000	Winter	91	8.0	
12-Mar	2771-062	Spring	Fall	0.996	Fall	72	3.8	
12-Mar	2771-063	Spring	Fall	1.000	Fall	72	3.8	
12-Mar	2771-064	Spring	Winter	1.000	Winter	85	6.2	
12-Mar	2771-065	Spring	Fall	1.000	Fall	70	3.6	
12-Mar	2771-066	Spring	Fall	1.000	Fall	69	3.3	
12-Mar	2771-067	Spring	Fall	0.999	Fall	70	3.4	
12-Mar	2771-068	Spring	Fall	0.999	Fall	75	4.0	
12-Mar	2771-069	Spring	Fall	0.999	Fall	80	4.9	
12-Mar	2771-070	Spring	Fall	0.999	Fall	70	3.3	
12-Mar	2771-071	Spring	Fall	0.999	Fall	74	4.1	
12-Mar	2771-072	Spring	Fall	1.000	Fall	73	3.8	
12-Mar	2771-073	Spring	Fall	0.996	Fall	70	3.3	
12-Mar	2771-074	Spring	Fall	0.994	Fall	70	3.6	
12-Mar	2771-075	Spring	Fall	1.000	Fall	73	3.7	
12-Mar	2771-076	Spring	Fall	0.951	Fall	73	4.2	

Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)	Comment
12-Mar	2771-077	Spring	Fall	1.000	Fall	75	4.1	
12-Mar	2771-078	Spring	Fall	0.911	Fall	76	4.4	
12-Mar	2771-079	Spring	Fall	1.000	Fall	72	3.4	
12-Mar	2771-080	Spring	Fall	1.000	Fall	70	3.5	
12-Mar	2771-081	Spring	Fall	1.000	Fall	70	3.5	
12-Mar	2771-082	Spring	Fall	1.000	Fall	71	3.4	
16-Mar	2771-083	Winter	Winter	1.000	Winter	89	7.6	
18-Mar	2771-084	Spring	Fall	1.000	Fall	77	5.1	
18-Mar	2771-085	Spring	Fall	0.999	Fall	77	5.1	
18-Mar	2771-086	Fall	Fall	0.975	Fall	57	2.1	
18-Mar	2771-087	Fall	Fall	0.999	Fall	60	2.2	
19-Mar	2771-088	Spring	Fall	1.000	Fall	73	4.2	
19-Mar	2771-089	Spring	Fall	0.999	Fall	73	4.0	
20-Mar	2771-090	Spring	Fall	1.000	Fall	74	4.2	
20-Mar	2771-091	Spring	Fall	0.907	Fall	73	4.8	
21-Mar	2771-092	Spring	Fall	1.000	Fall	75	3.8	
21-Mar	2771-093	Spring	Fall	1.00	Fall	74	4.1	
22-Mar	2771-094	Spring	Fall	0.970	Fall	78	5.4	
22-Mar	2771-095	Spring	Fall	1.000	Fall	85	7.1	
22-Mar	2771-096	Winter	Spring	0.701	Spring	93	8.0	Possibly Mill-Deer Cr.
23-Mar	2771-097	Spring	Fall	0.999	Fall	77	5.3	
23-Mar	2771-098	Spring	Fall	1.000	Fall	84	7.0	
23-Mar	2771-099	Fall	Fall	1.000	Fall	65	3.1	
23-Mar	2771-100	Fall	Fall	0.999	Fall	53	1.5	
24-Mar	2784-001	Spring	Fall	1.000	Fall	78	4.9	
24-Mar	2784-002	Spring	Fall	0.999	Fall	75	4.7	
25-Mar	2784-003	Spring	Fall	1.000	Fall	76	4.4	
25-Mar	2784-004	Spring	Fall	0.997	Fall	85	5.8	
26-Mar	2784-005	Spring	Fall	0.999	Fall	78	5.3	
26-Mar	2784-006	Spring	Fall	1.000	Fall	76	4.2	
27-Mar	2784-007	Spring	Fall	0.844	Fall	82	5.7	
27-Mar	2784-008	Spring	Fall	0.983	Fall	81	5.8	
28-Mar	2784-009	Spring	Fall	0.999	Fall	81	5.3	
28-Mar	2784-010	Spring	Fall	0.999	Fall	82	5.4	
31-Mar	2784-011	Fall	Fall	0.999	Fall	50	1.4	
31-Mar	2784-012	Fall	Fall	1.000	Fall	50	1.5	
31-Mar	2784-013	Spring	Spring	0.497	Spring	79	5.2	Unknown origin
31-Mar	2784-014	Spring	Fall	1.000	Fall	82	6.1	
1-Apr	2784-015	Spring	Fall	0.999	Fall	91	7.6	
1-Apr	2784-016	Spring	Fall	0.996	Fall	89	7.8	
2-Apr	2784-017	Spring	Fall	1.000	Fall	90	8.5	
2-Apr	2784-018	Spring	Fall	1.000	Fall	82	5.5	
3-Apr	2784-019	Spring	Fall	1.000	Fall	85	6.5	
3-Apr	2784-020	Spring	Fall	0.996	Fall	84	6.3	
4-Apr	2784-021	Spring	Fall	0.897	Fall	91	7.6	
4-Apr	2784-022	Spring	Fall	0.999	Fall	90	8.3	
7-Apr	2784-023	Fall	Fall	1.000	Fall	72	3.8	

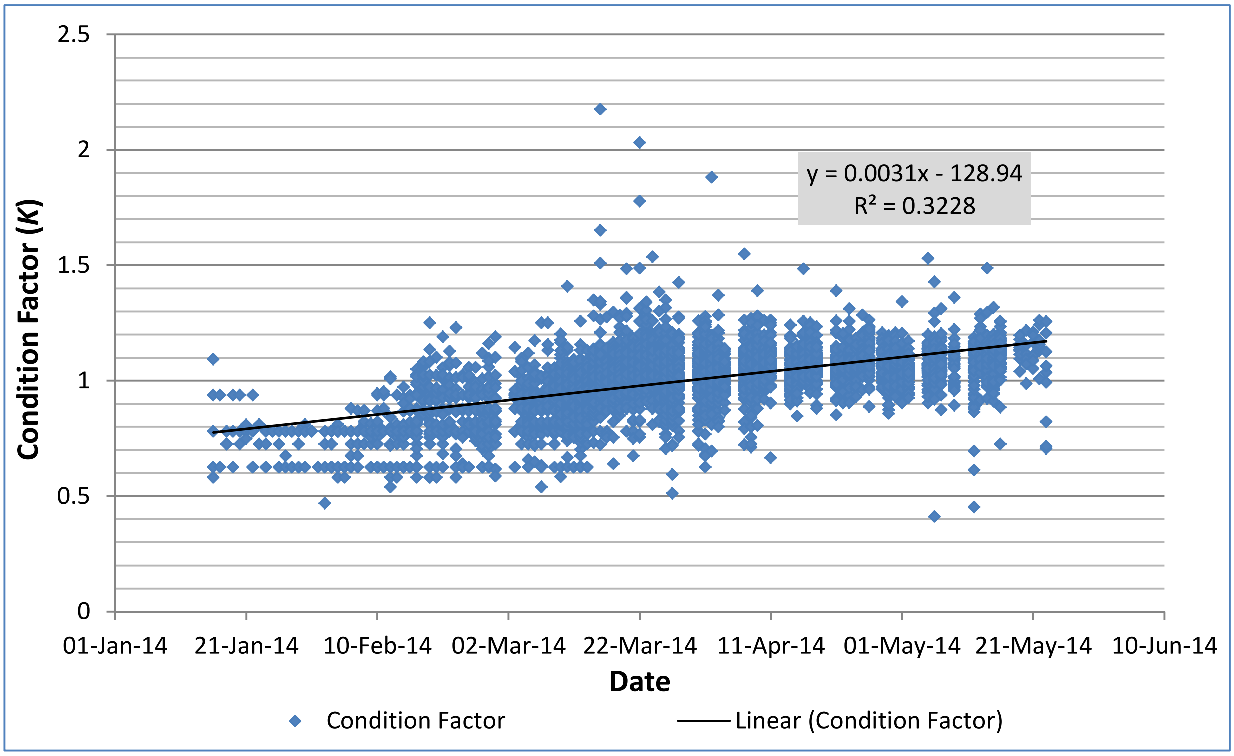
Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)	Comment
7-Apr	2784-024	Fall	Fall	0.990	Fall	74	4.1	
7-Apr	2784-025	Spring	Fall	0.998	Fall	81	5.6	
7-Apr	2784-026	Spring	Fall	1.000	Fall	81	5.9	
8-Apr	2784-027	Winter	Winter	1.000	Winter	111	15.6	
8-Apr	2784-028	Spring	Fall	1.000	Fall	82	6.1	
8-Apr	2784-029	Spring	Fall	0.999	Fall	85	6.7	
9-Apr	2784-030	Spring	Fall	0.999	Fall	83	6.3	
9-Apr	2784-031	Spring	Fall	0.999	Fall	102	12.2	
10-Apr	2784-032	Spring	Fall	0.998	Fall	93	8.6	
10-Apr	2784-033	Spring	Fall	1.000	Fall	85	6.5	
11-Apr	2784-034	Spring	Fall	0.999	Fall	85	6.7	
11-Apr	2784-035	Spring	Fall	1.000	Fall	89	7.6	
14-Apr	2784-036	Fall	Fall	0.999	Fall	73	4.1	
14-Apr	2784-037	Fall	Fall	0.996	Fall	65	2.8	
14-Apr	2784-038	Spring	Fall	1.000	Fall	89	7.4	
14-Apr	2784-039	Spring	Fall	0.998	Fall	100	10.2	
15-Apr	2784-040	Spring	Fall	1.000	Fall	87	6.8	
15-Apr	2784-041	Spring	Fall	0.999	Fall	91	8.2	
16-Apr	2784-042	Spring	Fall	0.995	Fall	106	14.2	
16-Apr	2784-043	Spring	Fall	1.000	Fall	87	7.4	
17-Apr	2784-044	Spring	Fall	1.000	Fall	92	8.4	
17-Apr	2784-045	Spring	Spring	0.996	Spring	93	9.5	Butte Creek
18-Apr	2784-046	Spring	Fall	1.000	Fall	90	8.0	
18-Apr	2784-047	Spring	Fall	0.999	Fall	88	6.7	
21-Apr	2784-048	Spring	Fall	0.999	Fall	86	6.6	
21-Apr	2784-049	Spring	Fall	1.000	Fall	85	6.5	
21-Apr	2784-050	Fall	Fall	1.000	Fall	75	4.8	
21-Apr	2784-051	Fall	Fall	0.997	Fall	66	3.1	
22-Apr	2784-052	Spring	Fall	1.000	Fall	84	6.6	
23-Apr	2784-053	Spring	Fall	0.997	Fall	88	6.6	
28-Apr	2784-054	Fall	Fall	0.999	Fall	77	4.9	
28-Apr	2784-055	Fall	Fall	0.999	Fall	72	4.2	
29-Apr	2784-056	Spring	Fall	0.997	Fall	92	8.2	
29-Apr	2784-057	Spring	Fall	1.000	Fall	92	7.3	
30-Apr	2784-058	Spring	Fall	0.999	Fall	94	8.7	
30-Apr	2784-059	Spring	Fall	1.000	Fall	90	7.6	
1-May	2784-060	Spring	Fall	1.000	Fall	90	7.8	
1-May	2784-061	Spring	Fall	0.999	Fall	89	7.2	
2-May	2784-062	Spring	Fall	1.000	Fall	91	7.9	
2-May	2784-063	Spring	Fall	0.999	Fall	90	7.4	
5-May	2784-064	Fall	Fall	0.999	Fall	79	5.0	
5-May	2784-065	Fall	Fall	1.000	Fall	83	6.0	
6-May	2784-066	Spring	Fall	0.999	Fall	102	11.4	
6-May	2784-067	Spring	Fall	0.999	Fall	96	10.3	
7-May	2784-068	Spring	Fall	0.998	Fall	101	12.4	
7-May	2784-069	Spring	Fall	0.999	Fall	100	10.4	
9-May	2784-070	Spring	Fall	1.000	Fall	95	9.4	

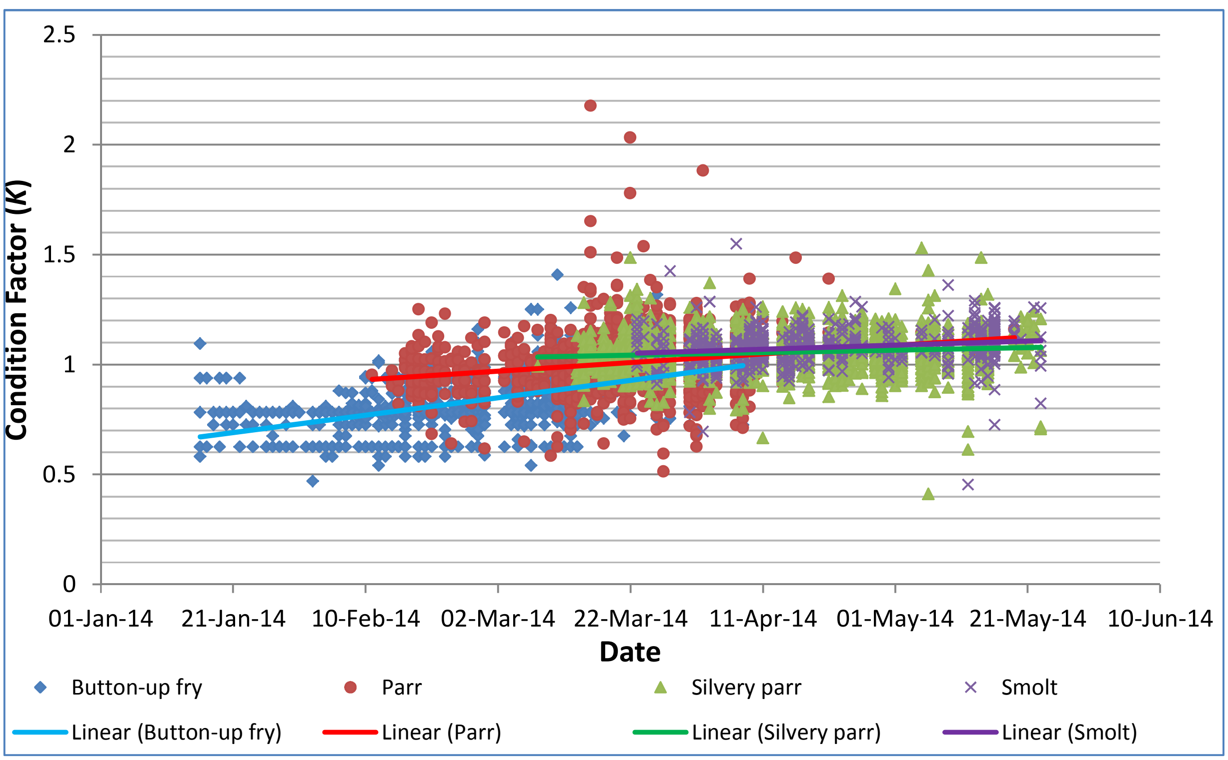
Date	Sample #	LAD Run Assignment	SNP Run Assignment	SNP Probability	Final Run Assignment	FL (mm)	W (g)	Comment
12-May	2784-071	Fall	Fall	1.000	Fall	62	2.6	
12-May	2784-072	Fall	Fall	1.000	Fall	77	4.1	
12-May	2784-073	Spring	Fall	1.000	Fall	103	11.8	
12-May	2784-074	Spring	Fall	0.999	Fall	106	13.9	
13-May	2784-075	Spring	Fall	1.000	Fall	99	11.3	
13-May	2784-076	Spring	Fall	1.000	Fall	100	12.2	
14-May	2784-077	Spring	Fall	0.999	Fall	100	11.1	
14-May	2784-078	Spring	Fall	1.000	Fall	100	12.6	
15-May	2784-079	Spring	Fall	1.000	Fall	100	12.0	
15-May	2784-080	Spring	Fall	0.999	Fall	98	11.1	
19-May	2784-081	Spring	Fall	0.999	Fall	128	25.1	
19-May	2784-082	Fall	Fall	0.999	Fall	89	8.0	
19-May	2784-083	Fall	Fall	0.998	Fall	75	4.7	

Appendix 4: Points of interest on the lower American River.

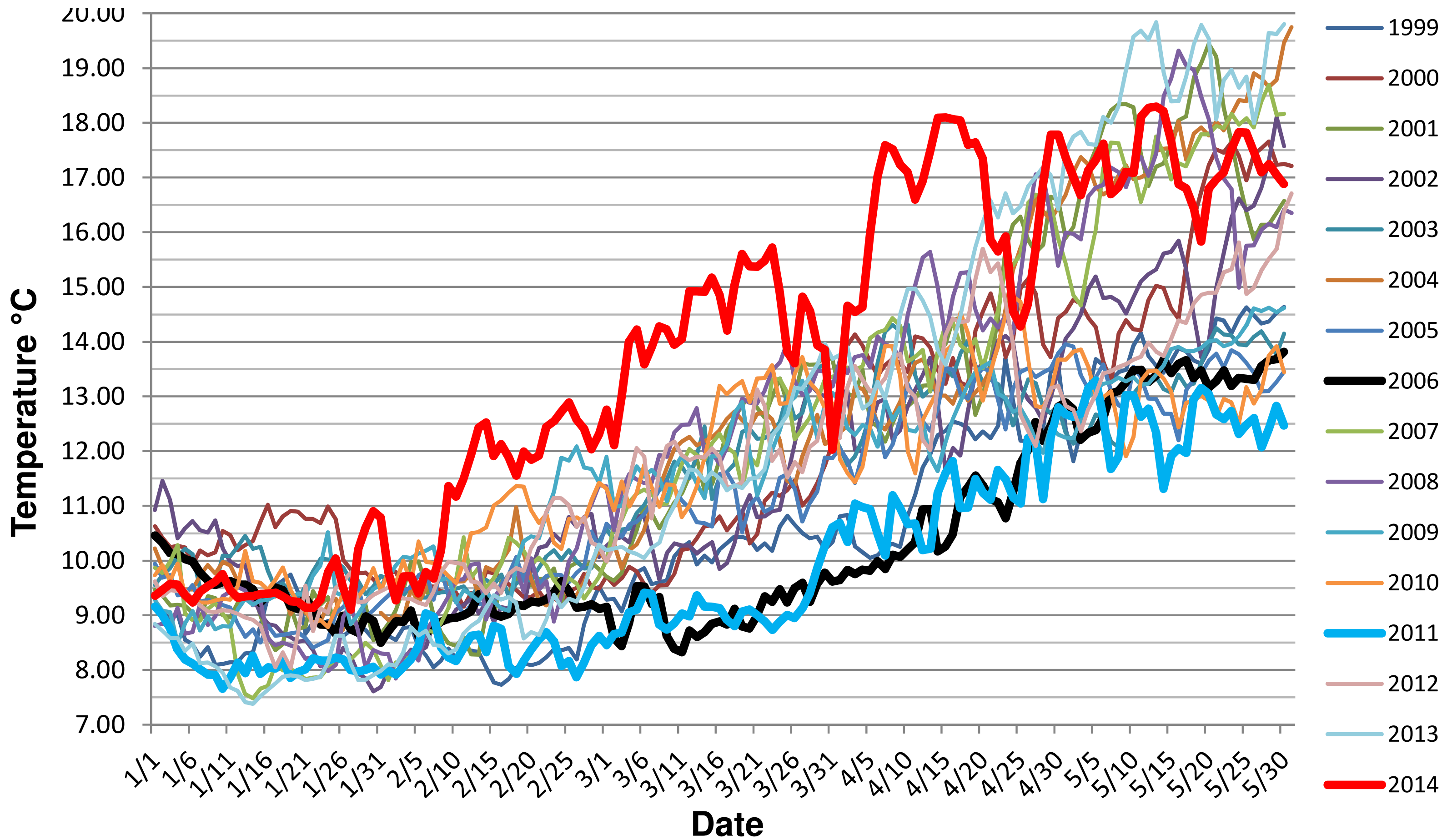
Point of Interest	Significance	Operator	River Miles (rkm)
Folsom Dam	Constructed 1956; Power Generation, flood control, water supply, recreation.	U.S. Bureau of Reclamation	29.4 (47.3)
Nimbus Dam	Constructed 1955; Power Generation, flood control, water supply, recreation.	U.S. Bureau of Reclamation	22.3 (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 5: Fulton's condition factor (*K*), overall and by life-stage, of fall-run Chinook salmon during the 2014 survey season.

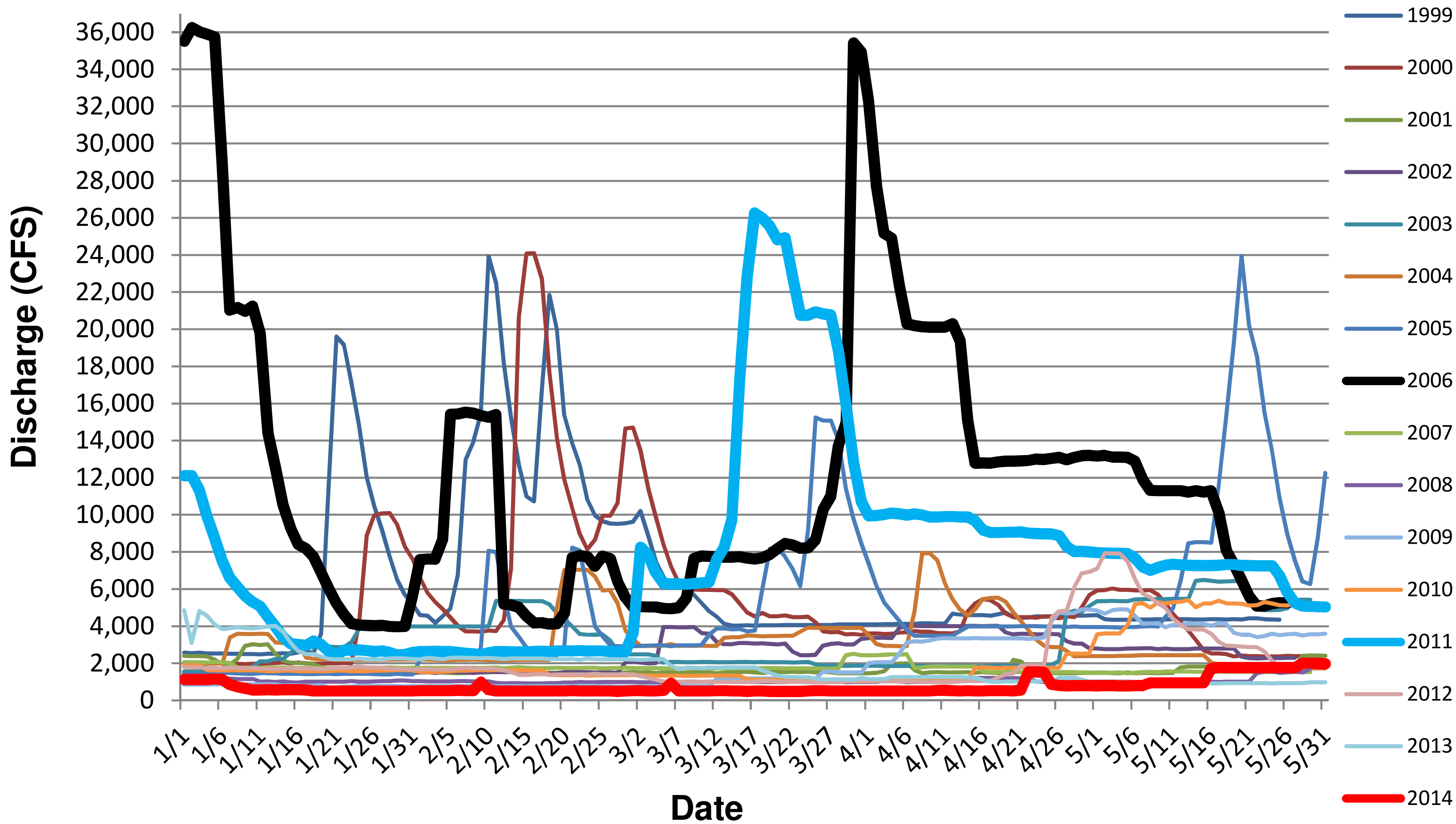




Appendix 6: Daily average water temperature (°C) in the lower American River at Watt Avenue for the 15-year period 1999 - 2014. Data from USGS station number 11446980.



Appendix 7: Daily average discharge (CFS) on the lower American River at Fair Oaks for the 15-year period 1999 - 2014. Data from USGS station number 11446500.



Appendix 8: An assessment of the juvenile fall-run Chinook salmon and *O. mykiss* response to three increases in river discharge on the American river in 2014

Abstract

An investigation was conducted to assess the juvenile fall-run Chinook salmon and steelhead/rainbow trout (*O. mykiss*) response to three pulse flows in the American River in 2014. Two of those pulse flows (i.e., salmonid pulse flows) were intended to benefit those taxa, and the third coincided with a marked rainfall event. The analysis relied on rotary screw trap data collected immediately downstream of the Watt Avenue Bridge in Sacramento County, California. The investigation suggests the salmonid pulse flows appeared to facilitate the emigration of modest numbers of juvenile *O. mykiss* from the American River, and the rainfall event had little or no effect on the number of *O. mykiss* caught in the traps. In contrast, the rainfall event appeared to stimulate the outmigration of juvenile salmon from the river, but that inference is weak because the capture of juvenile hatchery-origin *O. mykiss* before and after the rainfall event adversely affected the ability to accurately quantify the number of juvenile salmon caught in the traps. One of the salmonid pulse flows appears to have created the desired effect of encouraging the outmigration of juvenile salmon, while the other did not. To proactively facilitate the migration of large numbers of juvenile Chinook salmon and *O. mykiss* from the American River, refinements to the process of planning future pulse flows will likely be needed.

Introduction

The purpose of this document is to evaluate the relationship between the production/emigration timing of juvenile fall-run Chinook salmon and *O. mykiss* during three increases in river discharge that occurred on the American River in Sacramento County, California in 2014. Two of those increases in river discharge were actions that were intended to benefit juvenile salmonids and the third coincided with a marked rainfall event.

Rotary screw traps (RSTs) are a useful tool that can be used to assess the biological response to flow management manipulations. In 2014, two RSTs were deployed on the American River below the Watt Avenue Bridge in Sacramento County, California to quantify the production of juvenile Chinook salmon. Coincident with the collection of juvenile salmon on that river, juvenile *O. mykiss* were also collected with the RSTs. The RSTs are located 21 river kilometers downstream of Nimbus Dam, which is used to regulate river flows on the American River. Naturally-produced juvenile steelhead in the American River are classified as a Federally threatened species by the National Marine Fisheries Service. Because of the difficulty in accurately distinguishing between juvenile rainbow trout (the non-anadromous form of *O. mykiss*) and steelhead (the anadromous form of *O. mykiss*), this appendix will apply the generic term of "*O. mykiss*" to all of the juvenile steelhead or rainbow trout that were captured with the American River RSTs.

The anadromous form of *O. mykiss* that hatch in a river typically remain in their natal river for two seasons before they emigrate to the ocean. Under normal conditions, those *O. mykiss* that hatched in the American River in 2014 would remain in that river until they were one year of age, and then they would migrate to the Pacific Ocean in 2015. Juvenile fall-run Chinook salmon, in contrast, tend to emigrate to the ocean within a few months of their emergence from their natal redds.

In 2014, drought conditions in California's Central Valley adversely affected the amount and temperature of water that was present in the American River, i.e., water volumes declined and water temperatures increased. The drought conditions in the Central Valley also adversely affected the water temperature regime in the Sacramento – San Joaquin River Delta (Delta), which juvenile out-migrating salmonids must pass through on their way to the Pacific Ocean.

In the spring of 2014, fishery biologists in multiple agencies or organizations expressed concern that increasing water temperatures and decreasing river discharges in the American River posed a potential danger to juvenile salmonids. That potential danger arose from at least three sources:

1. Dewatering of redds could strand salmonid eggs or alevins within their redds, or create adverse environmental conditions within the redds as oxygen levels declined or water temperatures rose due to low flow conditions,

2. Juvenile salmonids could be exposed to lethal or sub lethal temperatures if they remained in the river over the summer months, and

3. The mortality of large numbers of juvenile *O. mykiss* could occur if the individuals that emigrated from the American River to the Pacific Ocean late in the spring or early summer of 2014 encountered lethal or sub lethal temperatures as they passed through the Delta. In that case, the Delta would in effect act as a thermal barrier or sink that prevented the successful emigration of *O. mykiss* from the American River to the Pacific Ocean.

To minimize the potential that juvenile salmonids would encounter such conditions, two salmonid pulse flows from Nimbus Dam upstream of the RSTs occurred on the American River between March 5 and 7, and between April 21 and 25.

The March salmonid pulse flow had three goals (Julie Zimmermann, USFWS, pers. comm.). The primary purpose was to reconnect the river side channels to the main channel following a period of low river discharges, thereby allowing fall-run Chinook salmon fry that had become stranded to move back into the main channel. A secondary purpose was to alleviate water quality concerns resulting from higher than normal water temperatures in the river, thereby creating a benefit for *O. mykiss* and fall-run Chinook salmon. A tertiary purpose was to encourage the outmigration of fall-run Chinook salmon from the American River so fewer salmon would be left in the river later in the season as water temperatures continued to increase. As the pulse flow in March occurred, the maximum daily discharge at the Watt Avenue Bridge trap site increased from a base flow of 520 cubic feet per second (CFS) to 1,037 CFS, and then it declined to 496 CFS after the pulse flow.

The goal of the April salmonid pulse flow was to encourage the outmigration of Chinook salmon and *O. mykiss* from the American River so fewer individuals would be left in the river during the summer when water temperatures would be especially high (Julie Zimmermann, USFWS, pers. comm.). As such, that pulse was designed to encourage the migration of salmonids from the river so they would find alternative rearing habitat downstream of the American River (if they were young-of-year) or move to the ocean (if they were age 1+). The April pulse flow also had the potential to create a benefit by reconnecting disconnected side channels to the main river channel, thereby allowing stranded salmonids to move back into the main channel. As the pulse flow in April occurred, the maximum daily discharge at the Watt Avenue trap site increased from a base flow of 502 CFS to 1,533 CFS, and then it declined to 804 CFS.

In 2014, an unusually intense storm occurred between February 8 and 10. During that storm, the Bureau of Reclamation released a large volume of water from Nimbus Dam, and the maximum daily discharge at the Watt Avenue trap site increased from 523 CFS to 1,488 CFS, then declined to 510 CFS. For comparative purposes, the juvenile fall-run Chinook salmon and *O. mykiss* response to the increase in river discharge during this storm is also evaluated in this appendix.

Methods

The river discharge data reported in this document consists of modeled discharge data at the Watt Avenue trap site. That data was produced by the CBEC, Inc. eco-engineering company.

The juvenile fall-run Chinook salmon and *O. mykiss* data in this appendix are based on data collected with two 8-foot diameter RSTs. Those traps were deployed at the Watt Avenue trap site between January 8 and May 23, 2014. The two RSTs that were deployed in 2014 consisted of Trap Number 8.1 and Trap Number 8.2.

Because changes in river discharge affect a trap's ability to collect juvenile fish moving past the trap (and therefore affects the number of fish caught), the evaluation of the fall-run Chinook salmon and *O. mykiss* response to increases in river discharge was made by evaluating changes in the daily production of those taxa, and not by evaluating changes in daily catch. Such an approach therefore compensates for changes in river discharge as changes in juvenile salmonid abundance is monitored. Most commonly, the daily production of juvenile salmonids is calculated by dividing the daily catch estimate for a salmonid taxon by the daily efficiency of the trap catching the salmonid.

Methods for quantifying changes in fall-run Chinook salmon production

The U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program maintains a rotary screw trap "Platform" that calculates the production of different runs of juvenile salmon. The Platform uses a generalized additive model (GAM) that incorporated the results from 15 trap efficiency tests that were conducted with juvenile Chinook salmon in 2014 under a range of river discharge conditions. Because the Platform automates and standardizes production estimates for juvenile salmon, that tool was used to produce the fall-run Chinook salmon production estimates provided in this report. To simplify the analysis of how juvenile salmon were affected by the three pulses flows, the salmon analyses in this report were limited to the periods when the pulse flows occurred and the 7-day period before and after each pulse flow occurred.

Methods for quantifying changes in O. mykiss production

The CAMP's RST Platform is not currently configured to automate the calculation of juvenile *O. mykiss* production estimates, and it was therefore necessary to manually calculate the juvenile *O. mykiss* production estimates presented in this appendix. To quantify changes in *O. mykiss* production, the 15 trap efficiency tests that were conducted with Chinook salmon in 2014 were used to estimate juvenile *O. mykiss* production. That approach was used because of the paucity of trap efficiency tests that were conducted with juvenile *O. mykiss* in 2014. The analysis in this appendix therefore assumes that the trap efficiency (i.e., catchability) of juvenile *O. mykiss* and Chinook salmon is essentially the same.

During the course of the 2014 RST survey season, there were infrequent occasions when the traps at Watt Avenue were either not in service or did not operate successfully. Such conditions arose because of weekends not fished, or debris-related problems that caused the traps to malfunction. In such cases and for each trap, the daily catch of *O. mykiss* was typically imputed by using a weighted average of the adjoining three days when traps did function properly. The weights assigned a value of 5, 3, and 1 to the catches on days 1, 2, and 3 before and after the day not fished. In cases with multiple consecutive days when the traps were not fished, the calculation of an imputed catch value relied on an adjoining day's imputed catch value. When the imputed catch value was less than an actual catch value for a period when the trap was partially operational, the actual catch value was used.

The daily production of natural-origin, unmarked juvenile *O. mykiss* was calculated as follows:

1. The daily catch of *O. mykiss* in each trap was quantified by deriving an actual or imputed catch value,

2. Those daily trap-specific catch values were then divided by their respective daily trap-specific efficiency values to calculate a trap-specific production estimate,

3. The two trap-specific production estimate for each day were combined to develop a total daily production estimate, and

4. The total daily production was divided by 2 to account for the fact that two traps were operated on the American River and the two traps essentially "split" the number of marked salmon released during Chinook salmon trap efficiency tests.

As such, the production estimates for *O. mykiss* in this report do not include hatchery-origin steelhead that may have been released into the river by the California Department of Fish and Wildlife.

Results

The relationship between the maximum daily discharge at Watt Avenue and the number of juvenile *O. mykiss* that were produced by/emigrated past the American River RSTs in 2014 is depicted in Figure 1 below. When viewed in the context of the entire 2014 survey season, the bulk of the *O. mykiss* production and therefore the majority of the emigration of juvenile *O. mykiss* past the RSTs did not coincide with the Nimbus Dam flood release or the two salmonid pulse flows. The two salmonid pulse flows did, however, appear to influence the number of juvenile *O. mykiss* moving past the traps because the increases in discharge during the pulses coincided with increases in the number of juvenile *O. mykiss* migrating past the RSTs.

During the February 8 – 10 flood release, there was no marked change in the daily production of natural-origin juvenile *O. mykiss* as compared to the period before and after the flood release. The average number of juvenile *O. mykiss* produced per day in the three days prior to the flood release was 2 individuals, as compared to an average production value of 1 *O. mykiss* per day during the flood release (Table 1). After the flood release, the average daily production of *O. mykiss* on February 11, 12, and 13 was also 1 fish. Each of the *O. mykiss* production values on the three days associated with this flood release represent imputed values based on a GAM, i.e., no natural origin *O. mykiss* were caught during that pulse. A total of 19 steelhead was captured during the February 8 – 10 flood release. The average fork length of those individuals was 225 mm, and their lengths ranged between 181 and 265 mm. The presence of an adipose fin clip on each of the 19 individuals suggests those fish were hatchery-origin steelhead from the Nimbus Fish Hatchery. All but one of these individuals was classified as a smolt, and the remaining individual was classified as a silvery parr.

During the three-day salmonid pulse flow between March 5 and 7, there was a 276% increase in the production of natural-origin *O. mykiss* as the average number of individuals rose to 40 fish/day, as compared to the average production of 11 fish/day in the three-day period that included March 2, 3, and 4 (Table 1). After that pulse flow subsided, *O. mykiss* production declined slightly to an average of 32 *O. mykiss* per day. A total of 24 *O. mykiss* were captured during the March 5 - 7 pulse flow. Two of the 24 individuals were smolts; one of those individuals was of natural-origin and had a fork length of 283 mm, and the other individual was an adipose clipped hatchery-origin fish with a fork length of 203 mm. The average fork length of the other 22 *O. mykiss* was 27 mm, and their lengths ranged between 24 and 28 mm. Each of those 22 *O. mykiss* were of natural-origin, and were classified as a fry life stage.

During the five-day salmonid pulse flow between April 21 and 25, there was a 30% increase in the production of natural-origin juvenile *O. mykiss* as the average number of individuals rose to 45 fish/day from the average production of 35 fish/day in the five-day period between April 16 and April 20 (Table 1). After that pulse flow subsided, *O. mykiss* production declined to an average of 15 *O. mykiss* per day, thereby suggesting that pulse flow had a somewhat depleting effect on the overall number of *O. mykiss* in the river upstream of the traps. A total of 30 *O. mykiss* were captured during the April 21 - 25 pulse flow. Two of the 30 individuals were smolts; both of those individuals were adipose clipped hatchery-origin fish with fork lengths of 290 and 305 mm. The average fork length of the other 28 *O. mykiss* was 55 mm, and their lengths ranged between 44 and 72 mm. Each of those 28 *O. mykiss* were of natural-origin. Twenty-six of the 28 individuals were classified as parr, one was classified as a fry, and one individual was not assigned to a life stage.

Figure 1. Relationship between the maximum daily discharge at Watt Avenue and the number of natural-origin juvenile *O. mykiss* emigrating past the Watt Avenue trap site on the American River in 2014.

Blue bars in the figure indicate days when both American River RSTs operated without problems in a 24-hour day and actual catch data was used to calculate *O. mykiss* production estimates. Red bars in the figure indicate days when one or both RSTs were not fished on weekends or experienced operational problems within a 24-hour day and it was necessary to impute *O. mykiss* catch as *O. mykiss* production was estimated.

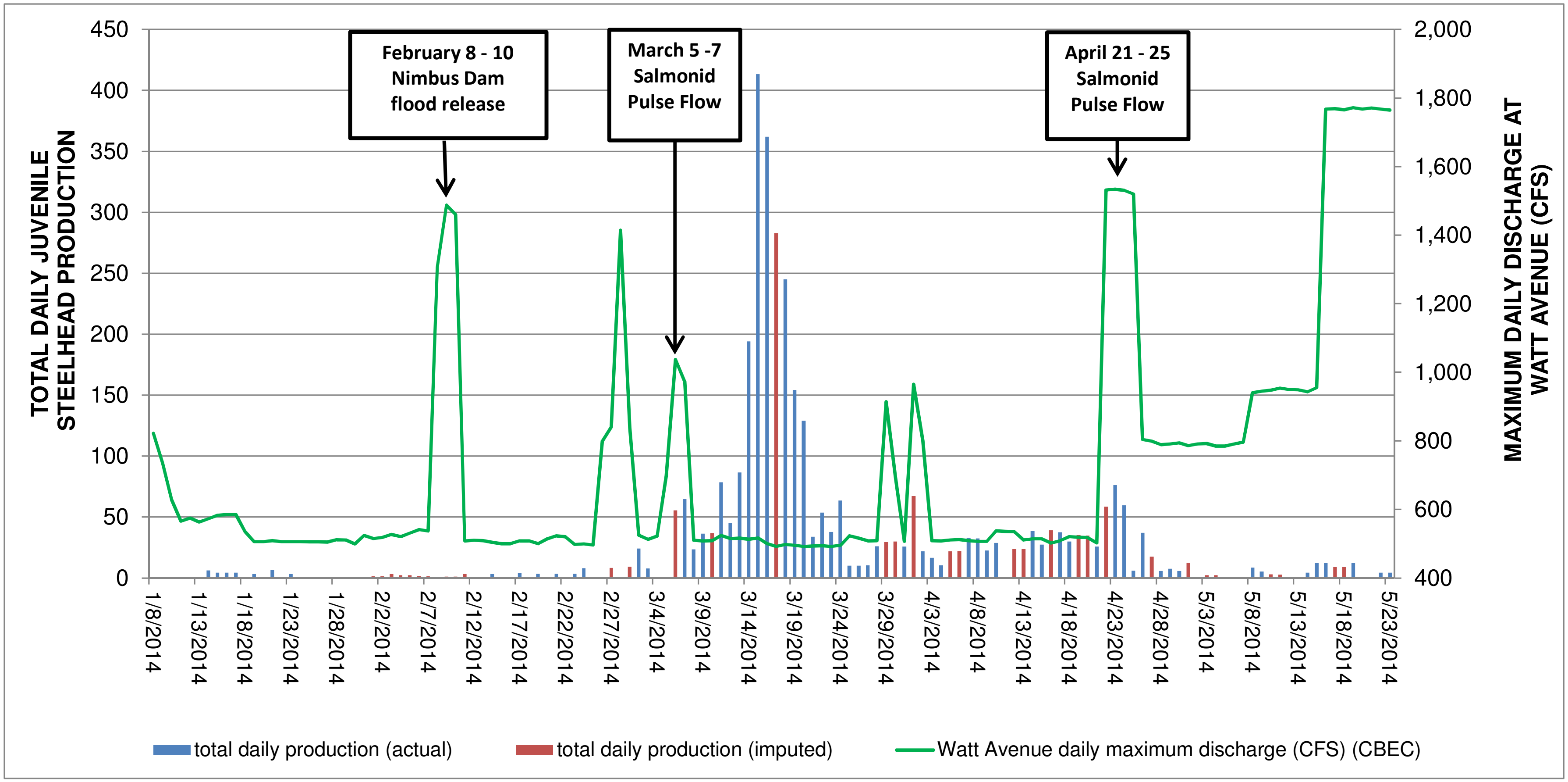


Table 1. Estimated number of natural-origin juvenile *O. mykiss* emigrating past the Watt Avenue trap site on the American River in 2014.

The production estimates only include natural-origin juvenile *O. mykiss*.

The mean and range of size *O. mykiss* fork length data included hatchery- and natural-origin *O. mykiss* captured during each event. Italicized fish length data represent data for hatchery-origin *O. mykiss*, and non-italicized fish length data represent data from natural-origin *O. mykiss*.

Event	Number of days associated with the event (N)	Mean daily *O. mykiss* production in the N days before the event	Mean daily *O. mykiss* production during the event	Mean daily *O. mykiss* production in the N days after the event	Mean and range of *O. mykiss* fork lengths (mm) during the event
February 8 -10 **Nimbus Dam flood release**	3	2	1	1	*Mean = 225 mm* *181 - 265 mm* *N = 19*
March 5 – 7 **salmonid pulse flow**	3	11	40	32	Mean = 27 mm 24 - 28 mm N = 22 Plus *1 203 mm* Plus *1* 283 mm
April 21 – 25 **salmonid pulse flow**	5	35	45	15	Mean = 55 mm 44 - 72 mm N = 28 Plus *1 290 mm* Plus *1 305 mm*

The relationship between the maximum daily discharge at Watt Avenue and the number of juvenile fall-run Chinook salmon that were produced by/emigrated past the American River RSTs during the Nimbus Dam flood release and the two salmonid pulse flows is depicted in Figure 2 A, B, and C below. In general, increases in the production of juvenile fall-run Chinook salmon during the February 8 – 10 Nimbus Dam flood release and the March 5 -7 salmonid pulse flow coincided with increases in the maximum daily discharge at Watt Avenue. In contrast, the production of juvenile fall-run Chinook salmon appeared to decrease during the elevated river discharges during the April 21 – 25 salmonid pulse flow.

The color shading in Figure 2 A, B, and C has been constructed to illustrate when the daily juvenile salmon production estimates were based on the raw catch from the RSTs vs. days when it was necessary to impute daily catch values because: (1) debris-related issues compromised the traps' ability to collect juvenile fish in an optimum manner, or (2) the capture of large numbers of hatchery-origin steelhead in the RSTs likely reduced the perceived catch numbers of out-migrating natural-origin Chinook salmon as those individuals were consumed by the larger hatchery-origin steelhead that were also present in the trap live boxes. Under optimal circumstances, the graphs would consist of bars that were dark or light green in color, thereby indicating that the juvenile salmon production estimates were based on raw catches and not imputed values.

During the three-day February 8 – 10 flood release from Nimbus Dam, there was a 114% increase in production as the average number of fall-run Chinook salmon rose to 25,004 fish/day from the average production of 11,679 fish/day in the three-day period between February 5 and 7 (Table 2). It is important to note, however, that the juvenile salmon production estimates on February 1 – 7 were based on imputed catch estimates because the capture of large numbers of hatchery-origin *O. mykiss* compromised the ability to accurately quantify how many salmonids were being captured by the RSTs. It is therefore difficult to precisely quantify how many juvenile salmon were moving past the RSTs prior to, and during the February 8 – 10 flood release. The increase in salmon production on February 9 – 12 in Figure 2 was, however, based at least in part on actual catch data, thereby suggesting that larger numbers of juvenile salmon were moving past the RSTs during and after the flood release than prior to that event.

During the three-day salmonid pulse flow between March 5 and 7, the average production of juvenile salmon appeared to decrease to 30,924 individuals from the 83,486 individuals that were present in the three-day period before pulse flow (Table 2). That inference is biased, however, by the unusually large number of salmon that were captured on March 2nd. If the catch on March 2nd is ignored, the production of salmon on March 6 and 7 was notably greater than what existed on March 4, 5, and 6, thereby suggesting the pulse flow did elicit a response in terms of the number of emigrating juvenile salmon.

During the five-day salmonid pulse flow between April 21 and 25, there was a 37% decrease in juvenile Chinook salmon production as the average number of individuals declined from 1,163 fish/day in the five day period before the pulse to an average production of 732 fish/day between April 21 and April 25 (Table 2). After the pulse flow concluded, the average production of juvenile salmon in the period between April 26 and 30 increased to 2,449 fish/day. It is noteworthy this pulse flow occurred well after the majority of the juvenile fall-run Chinook salmon had emigrated from the river in 2014.

Figure 2 A, B, and C. Relationship between the maximum daily discharge released from Nimbus Dam and the number of juvenile fall-run Chinook salmon emigrating past the Watt Avenue trap site on the American River in 2014.

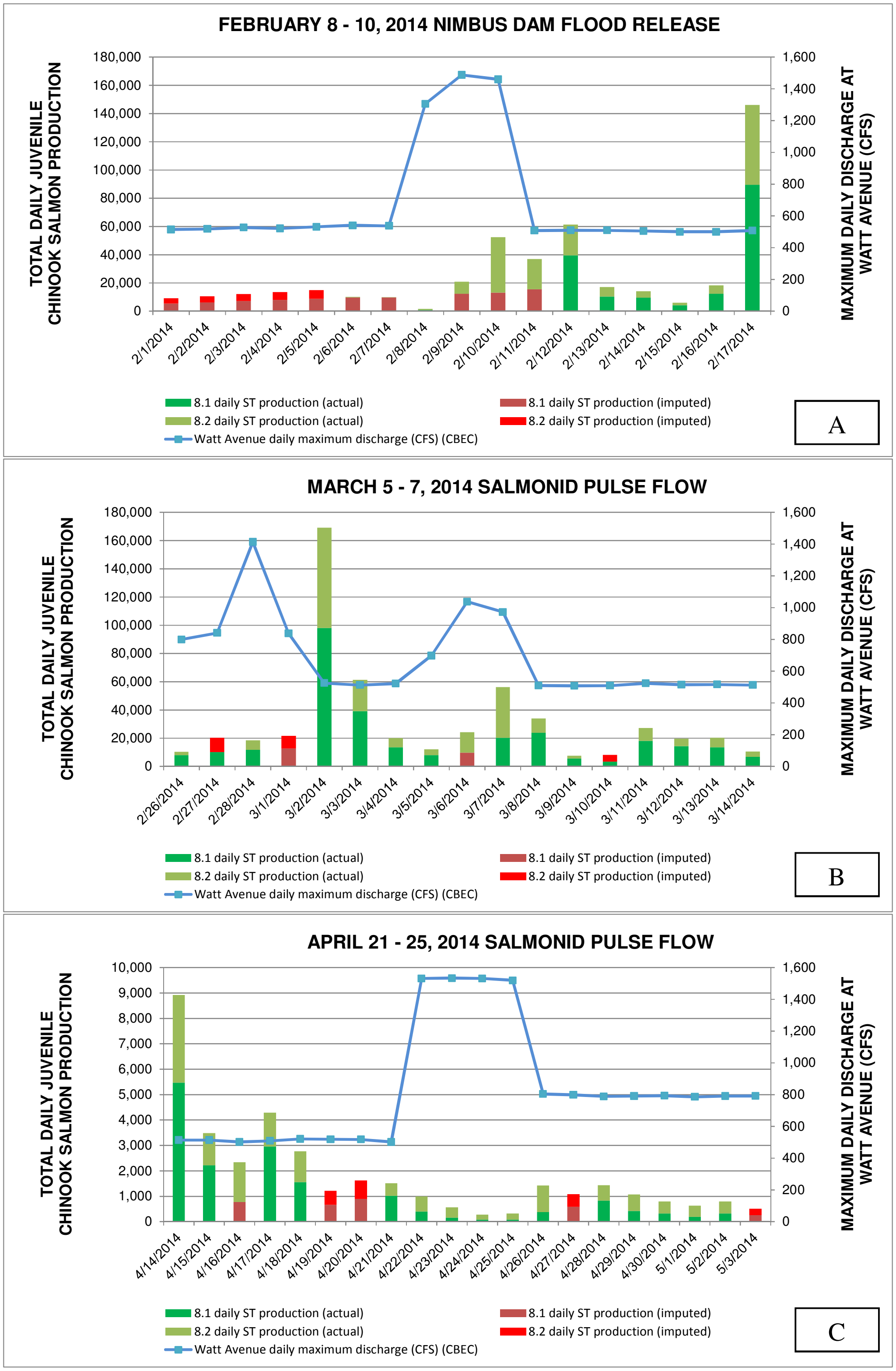


Table 2. Estimated number of juvenile fall-run Chinook salmon (FRCS) emigrating past the Watt Avenue trap site on the American River during three pulse flows in 2014.

Event	Number of days associated with the event (N)	Mean daily FRCS production in the N days before the event	Mean daily FRCS production during the event	Mean daily FRCS production in the N days after the event
February 8 -10 **Nimbus Dam flood release**	3	11,679	25,004	38,403
March 5 – 7 **salmonid pulse flow**	3	83,486	30,924	16,612
April 21 – 25 **salmonid pulse flow**	5	1,163	732	2,449

Discussion

The February 8 – 10 Nimbus Dam flood release was correlated with an increase in the production of juvenile fall-run Chinook salmon, but did not appear to coincide with an increase in the production of juvenile natural-origin *O. mykiss*. The increase in the production of juvenile Chinook salmon was not surprising, given that modest numbers of mobile juvenile salmon were present in that river during that period. In contrast, very few natural-origin *O. mykiss* had been caught in the RSTs to that point in the field season, and it was likely that most juvenile *O. mykiss* had not yet emerged from in their redds and therefore were not subject to flushing flows that would result in their capture in the RSTs.

The March 5 - 7 salmonid pulse flow designed to reconnect side channels in the river with the main channel and encourage the outmigration of juvenile Chinook salmon into the main channel appeared to achieve its management objective, although that inference is somewhat confounded by an usually large catch of juvenile salmon a few days before the pulse flow. It is noteworthy the production of salmon on March 6 and 7 was notably greater than what existed on March 4 and 5, thereby suggesting that salmon were responding to the pulse flow.

The April 21 – 25 salmonid pulse flow designed to encourage the movement of juvenile *O. mykiss* and Chinook salmon from the American River in 2014 appeared to elicit a modest biological response from *O. mykiss* as the number of juvenile *O. mykiss* emigrating past the RSTs increased relative to the period before the pulse flow began. In contrast, the number of juvenile fall-run Chinook salmon emigrating past the traps declined slightly during the April 21 – 25 salmonid pulse, but then doubled to the pre-pulse amount after the pulse flow was complete.

The majority of the juvenile *O. mykiss* emigrating past the RSTs in 2014 did so during a period when salmonid pulse flows and the Nimbus Dam flood release did not occur. During the period between March 8 and April 20 when management-related pulse flows did not occur, it is estimated that approximately 2,984 juvenile *O. mykiss* migrated past the RSTs; this is in contrast to the approximately 3,633 juvenile *O. mykiss* that migrated past the RSTs throughout the January 8 - May 23 RST survey season. The estimated number of *O. mykiss* emigrating past the traps during the March 5 - 7 and April 21 - 25 pulse flows was 120 and 226 juvenile *O. mykiss*, respectively. The April 21 - 25 pulse flow therefore appears to have occurred too late in the season to have a marked affect because it appears the majority of juvenile *O. mykiss* that were going to emigrate from the river had already departed.

It is important to note the fish response to the Nimbus Dam flood release and the two salmonid pulse flows in 2014 is based on RST data that was only collected in one of the two river channels below the Watt Avenue Bridge. Because low river discharge conditions occurred in the American River in 2014, a RST was not deployed in the South Channel, i.e., a river channel south of an island downstream of the Watt Avenue Bridge. Fieldwork described in Appendix 11 of this report demonstrates that at ~1,500 CFS, i.e., the maximum discharge during the February 8 – 10 Nimbus Dam flood release and the April 21 – 25 salmonid pulse flow, approximately 15% of the river discharge below the Watt Avenue bridge would have passed through the South Channel. The salmonid production estimates presented in this appendix and the inferences (and biological responses) therefore drawn are likely biased in a slightly conservative manner because some emigrating salmonids would not have been subject to possible capture. The amount of water passing through the South Channel during the March 5 – 7 salmonid pulse flow was probably only on the order of 5% of the total river discharge. In all three events where the river discharge increased, the RSTs should provide a relatively robust ability to infer how fish were being affected by the increased river discharge because the two deployed RSTs were fishing in the North Channel where most of the fish had to pass.

To increase the accuracy of the Chinook salmon production estimates that occurred during the two salmonid pulse flows, one trap efficiency test with Chinook salmon was conducted during each of those events. As such, the trap efficiency releases, and most of the recaptures of released salmon during each pulse flow, overlapped the period when the pulse flows occurred.

As stated above, this document assumes the trap efficiency of Chinook salmon and *O. mykiss* is similar. To test this assumption, the results from three trap efficiency tests in 2014 were compared. On April 22, 2014, a trap efficiency test with Chinook salmon was conducted. Those salmon had an average fork length of 68 millimeters (mm), the river discharge at the time of release was 1,530 CFS, and the trap efficiency for that test was 4.73%. On May 19, 2014, two trap efficiency tests with *O. mykiss* were conducted. Those *O. mykiss* groups had an average fork length of 67 mm or 70 mm, the river discharge at the time of release was 1,770 CFS, and the trap efficiencies for the tests were 3.30% and 5.28%. These data collectively suggest that for at least three tests with similar size fish and similar river discharges, the trap efficiencies of Chinook salmon and *O. mykiss* appeared to be similar in 2014 (4.73% vs. 3.30 or 5.28%), and it might be appropriate to use Chinook salmon trap efficiencies to expand *O. mykiss* catch values and thereby develop *O. mykiss* production estimates. It is also noteworthy that the Chinook salmon that were used during trap efficiency trials in 2014 ranged in size between 36 and 87 mm, and the range in size of non-smolt natural-origin *O. mykiss* that were captured in 2014 was between 21 and 88 mm. This similarity may suggest Chinook salmon trap efficiencies could be used to expand raw non-smolt *O. mykiss* catches because the size of individuals from the two taxa was similar. In contrast, the use Chinook salmon trap efficiencies to expand raw *O. mykiss* smolt catches would probably not be appropriate because the average size of the *O. mykiss* smolts that were caught in 2014, i.e., 279 mm. That number is markedly larger than any of the Chinook salmon that were used for trap efficiency tests in 2013 or 2014, and the larger size of the *O. mykiss* smolts would make it more likely they would avoid the RSTs.

The blue bars in Figure 1 depict the occurrence of periods during the 2014 trapping season when actual *O. mykiss* catch was used to develop production estimates, and the red bars indicate when operational issues at the traps or when weekends not fished necessitated the use of imputed *O. mykiss* catch values. The predominance of blue bars in the figure suggests the natural-origin *O. mykiss* production estimates during the 2014 survey season are relatively robust, particularly during the period when the bulk of those fish moved past the RSTs between March 8 and April 20.

The use of a weighted average to impute catch during periods when RSTs do not function properly is a common technique for estimating catch when operational issues arise. The technique does, however, have the potential to mask when and how many salmonids would have been captured had the RSTs functioned in an optimal manner. During the February 8 – 10 pulse flow, there was not a need to impute catch for one of the two RSTs, i.e., Trap 8.2. The other trap (Trap 8.1) did experience issues where the trap cone was filled with debris on February 9 and 10, thereby necessitating the need to impute catch for that trap on those days. During the March 5 – 7 pulse flow, the debris load in trap 8.2 was heavy on 2 of the 3 days of the pulse flow, but the trap was not compromised to the extent that it was necessary to impute the catch of salmonids. Upon arrival at Trap 8.1 on March 6, that trap was found to be not rotating and it was necessary to impute catch for that day. It was not necessary to impute catch for that trap on March 5 or 7. During the April 21 - 25 pulse flow, the field crew serviced the trap twice each day to increase the likelihood that the traps would operate in an optimal manner. While both traps intermittently experienced debris-related issues, there was only one event where it was necessary to impute catch during the April 21 - 25 pulse flow and that occurred on April 22 for Trap 8.1 when the trap stopped rotating and the cone intakes were filled with debris. A review of trap function during the three pulses suggests that while there were intermittent operational issues during the pulse flows, the numbers in Tables 1 and 2 should represent reasonably accurate approximations of the trends in the number of salmonids emigrating past the traps during those pulses.

It is important to note that portions of each of salmonid pulse flows in 2014 coincided with periods of rainfall. For example, 15 mm of rain occurred during the March 5 - 7 pulse flow, and 21 mm of rain fell during the April 21 - 25 pulse flow. Because the factors that cause juvenile Chinook salmon and *O. mykiss* to emigrate are not well understood, there may be some potential that salmon and *O. mykiss* movements from the river are caused by one or more factors that are not solely due to increases in river discharge. This suggests that several years of data collection activities are likely needed to successfully understand which factors managers can control to promote the emigration of juvenile salmon and *O. mykiss* from the American River.

Management Implications:

1. The deployment of rotary screw traps on the American River in 2014 provided data that could be used to evaluate the biological response to pulse flows that were designed to benefit juvenile fall-run Chinook salmon and Federally listed steelhead.

2. Two pulse flows from the Nimbus Dam in 2014 that were designed to benefit juvenile salmonids appeared to facilitate the emigration of modest numbers of juvenile Chinook salmon and *O. mykiss* from the American River.

3. A procedure should be developed to determine how previously collected RST data during a given survey season can be used to schedule pulse flows during that survey season so they produce the biggest effect in terms of encouraging the emigration of juvenile fall-run Chinook salmon or *O. mykiss*.

4. Each use of a pulse flow to encourage the emigration of juvenile salmonids should be viewed as an experiment, and the data collected during each experiment should be used in an iterative manner to improve the ability to adaptively manage future pulse flows so they achieve the desired result.

5. The management purpose of each pulse flow should be precisely described prior to the pulse flow so there is a clear and permanent record that can be used to evaluate if the management purpose was achieved.

6. A more accurate assessment of *O. mykiss* production patterns will likely require that at least 10 - 20 additional trap efficiency tests will need to be conducted with juvenile *O. mykiss* under a diverse range of river discharge and life stage conditions, and that in the longer-term, trap efficiency tests with Chinook salmon are not used as a proxy for *O. mykiss*.

7. Several years of additional rotary screw trap data from the American River, in conjunction with monitoring of environmental variables, will likely be needed to fully identify and understand the factors and triggers that affect juvenile salmon or *O. mykiss* emigration from the American River.

Appendix 9: An evaluation of juvenile Chinook salmon life stage assignments by biologists from the American and Stanislaus Rivers

Abstract

An experiment was performed on May 7, 2014 to quantify differences in how biologists from the American River and Stanislaus River in California's Central Valley assign juvenile Chinook salmon to different life stages. The experiment results suggest there are substantial differences in the way biologists assign juvenile Chinook salmon to different life stages. Some of these differences appear to relate to watershed-specific life stage classification systems used by the biologists from the two watersheds, while other differences are more likely caused by biologist-specific differences in the way salmon are assigned a life stage.

Introduction

The U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program (CAMP) has a responsibility to monitor fish and wildlife resources in the Central Valley of California and assess the biological results and effectiveness of actions implemented pursuant to subsection 3406 of the Central Valley Project Improvement Act (CVPIA). In 1997, the CAMP and various partners developed a CAMP implementation plan which provides a framework for developing standardized fishery data sets that could be used to assess temporal changes in the abundance of adult and juvenile salmon. With the acquisition of standardized data sets, the CAMP could pool data across watersheds to make more robust, complete assessments of changes in the abundance of salmon across the entire Central Valley.

An effort to pool fisheries data across a broader geographic area, i.e., across watershed boundaries, requires that data are collected in a comparable manner. In the absence of a standardized approach, it would difficult to know if differences in the production of juvenile Chinook salmon were due to: (1) actual biological differences across watersheds or (2) differences in the way biologists collected data.

A potential confounding error that could adversely affect the CAMP's ability to pool juvenile salmon data across watershed boundaries relates to the use of different life stage classification systems by different biologists. For example, the biologists that operate the RSTs at the Red Bluff Diversion Dam in the northern portion of the Central Valley use the fry and presmolt/smolt life stages to classify salmon, and biologists that operate the RSTs on the Feather River in the central portion of that valley use the yolk sac fry, fry, parr, intermediate, and smolt life stages to classify salmon.

CAMP staff have ranked the importance of different RST data sets in the Central Valley by watershed, and the American River and Stanislaus River are classified as high priority watersheds. That priority is based in part on the fact that both watersheds are part of the Central Valley Project that was authorized prior to the authorization of the CVPIA. The RSTs on the American River are operated by staff from the Pacific States Marine Fisheries Commission (PSMFC), and the RSTs on the Stanislaus River are operated by staff from Cramer Fish Science (CFS) company.

To successfully aggregate the RST data from the American River and Stanislaus River, biologists in each watershed would need to use a life stage classification system that did not produce major differences in the tallies of the number of fish in each life stage. At the present time, the PSMFC biologists on the American River assign individual salmon to the yolk sac fry, button up fry, parr, silvery parr, and smolt life stages. The CFS biologists from the Stanislaus River, in contrast, have rarely used the silvery parr life stage. Therefore, the PSMFC biologists use a life stage classification system that has one additional life stage (i.e., silvery parr) in addition to those used by the CFS biologists.

To determine if there were substantial differences in the way the biologists from the two watersheds make their life stage assignments, an experiment was conducted on May 7, 2014.

Methods

As data were collected to determine if there were substantial differences in the way the PSMFC and CFS biologists assign juvenile salmon life stage, an effort was undertaken to avoid the potential that one biologist's life stage assignment would bias another biologist's assignment.

One PSMFC biologist from the American River (AR) traveled to the Stanislaus River (SR) and was paired with a CFS biologist from the Stanislaus River, and CFS biologist from the SR traveled to the AR and was paired with a PSMFC biologist from the AR. Therefore, a total of four biologists in two teams participated in the experiment, and one team handled salmon for the AR, while the team handled salmon for the SR. A fifth person in each watershed served as a third party facilitator in the experiment; that individual was responsible for recording data, and passing the individual salmon that one biologist had already assigned to a life stage to the next biologist so the second biologist could assign the same fish to a life stage. As the experiment occurred, the biologists used morphological characteristics, e.g., parr mark presence/absence, prevalence of scale shedding, etc., to assign a particular salmon to a life stage.
The process for conducting the experiment was as follows:

1. PSMFC and CFS biologists were situated so they were sitting in a back-to-back configuration and were positioned so they were at least 10 feet apart. As such, they could not see each other.

2. At least 22 juvenile salmon were classified according to life stage by the two teams of biologists. Because the experiment was conducted toward the end of the 2014 RST field season, all of the salmon used in the experiment belonged to a parr, silvery parr, or smolt life stage.

3. Live juvenile Chinook salmon from that day's RST catch were placed in a bucket.

4. The bucket of salmon was given to a PSMFC biologist (i.e., Biologist #1), they randomly selected a single salmon, and they classified that salmon according to the AR life stage classification system.

5. The PSMFC biologist used a hand signal to indicate to the facilitator which life stage assignment they thought applied to that salmon, e.g., three fingers indicated a parr salmon, four fingers meant a silvery parr salmon, and five fingers meant a smolt. Because the paired biologists were seated in a manner where they could not see each other, it was assumed that the SR biologist (i.e., Biologist #2) was unaware of the life stage assignments being made by Biologist #1.

6. The facilitator recorded the life stage assignment made by Biologist #1, took the salmon from that biologist, and then handed Biologist #2 the salmon.

7. The SR biologist (i.e., Biologist #2) assigned a life stage to the salmon using the SR life stage classification system, indicated that assignment to the facilitator using a hand signal, and then assigned a life stage to the salmon using the AR life stage classification system.

8. The facilitator took the salmon from Biologist #2 and returned the salmon to the river.

9. The process was then replicated again using several additional juvenile salmon.

Results

The results from the life stage experiment are presented in Tables 1 and 2. Tables 1A, 1B, 2A, and 2B reflect the results when CFS biologists used their typical life stage classification system, i.e., one that did not include a silvery parr life stage. Tables 1C, 1D, 2C, and 2D reflect results when CFS biologists used the life stage classification used by the PSMFC staff from the American River, i.e., one that included a silvery parr life stage. Tables 1A, 1B, 2A, and 2B provide raw counts of the number of salmon assigned to each life stage, while Tables 1C, 1D, 2C, and 2D present the numbers in percent form. A total of 30 salmon from the American River were used during the experiment, and 22 salmon from the Stanislaus River were used because that was the number of salmon caught by the Stanislaus River RSTs on the day of the experiment. The yellow shading in the tables highlights the differences in the life stage assignments for the same salmon that were made by the CFS and PSMFC staffs.

In the case where salmon from the American River were used and where CFS staff did not adopt a silvery parr life stage, the CFS and PSMFC staffs assigned 26 (7 + 19) of the 30 salmon to different life stages (Table 1A). In percentage terms the two staffs assigned 86.66% (23.33 + 63.33) of the 30 salmon to different life stages (Table 1B). In the case where salmon from the American River were used and where CFS staff adopted a silvery parr life stage, the CFS and PSMFC staffs assigned 15 (1 + 14) of the 30 salmon to different life stages (Table 1C). In that case, the two staffs assigned 50% (3.33 + 46.67) of the 30 salmon to different life stages (Table 1D).

In the case where salmon from the Stanislaus River were used and where CFS staff did not adopt a silvery parr life stage, the CFS and PSMFC staffs assigned 14 (3 + 11) of the 22 salmon to different life stages (Table 2A). In percentage terms the two staffs assigned 63.64% (13.64 + 50.00) of the 22 salmon to different life stages (Table 2B). In the case where salmon from the Stanislaus River were used and where CFS staff adopted a silvery parr life stage, the CFS and PSMFC staffs assigned 5 (1 + 4) of the 22 salmon to different life stages (Table 2C). In that case, the two staffs assigned 22.73% (4.55 + 18.18) of the 22 salmon to different life stages (Table 2D).

Tables 1 A, B, C, and D. Experiment results from trials conducted with juvenile Chinook salmon from the American River.

Yellow shaded cells represent differences in the way PSMFC and CFS biologists assign a particular salmon to a different salmon life stage.

Table 1A		CFS life stage, historical life classification scheme, no silvery parr	
		# parr	# smolts
PSMFC life stage	# parr	1	0
	# silvery parr	7	19
	# smolts	0	3

Table 1B		CFS life stage, historical life classification scheme, no silvery parr	
		% parr	% smolt
PSMFC life stage	% parr	3.33%	0.00%
	% silvery parr	23.33%	63.33%
	% smolt	0.00%	10.00%

Table 1C		CFS life stage, non-historical life classification scheme, adopt silvery parr		
		# parr	# silvery parr	# smolts
PSMFC life stage	# parr	0	1	0
	# silvery parr	0	12	14
	# smolts	0	0	3

Table 1D		CFS life stage, non-historical life classification scheme, adopt silvery parr		
		% parr	% silvery parr	% smolt
PSMFC life stage	% parr	0.00%	3.33%	0.00%
	% silvery parr	0.00%	40.00%	46.67%
	% smolts	0.00%	0.00%	10.00%

Tables 2 A, B, C, and D. Experiment results from trials conducted with juvenile Chinook salmon from the Stanislaus River.

Yellow shaded cells represent differences in the way PSMFC and CFS biologists assign a particular salmon to a different salmon life stage.

Table 2A		CFS life stage, historical life classification scheme, no silvery parr	
		# parr	# smolts
PSMFC life stage	# parr	0	0
	# silvery parr	3	11
	# smolts	0	8

Table 2B		CFS life stage, historical life classification scheme, no silvery parr	
		% parr	% smolt
PSMFC life stage	% parr	0.00%	0.00%
	% silvery parr	13.64%	50.00%
	% smolt	0.00%	36.36%

Table 2C		CFS life stage, non-historical life classification scheme, adopt silvery parr		
		# parr	# silvery parr	# smolts
PSMFC life stage	# parr	0	0	0
	# silvery parr	0	10	4
	# smolts	0	1	7

Table 2D		CFS life stage, non-historical life classification scheme, adopt silvery parr		
		% parr	% silvery parr	% smolt
PSMFC life stage	% parr	0.00%	0.00%	0.00%
	% silvery parr	0.00%	45.45%	18.18%
	% smolts	0.00%	4.55%	31.82%

Discussion

The life stage classification experiment suggests there are substantial differences in the way biologists from the Cramer Fish Science company and Pacific States Marine Fisheries Commission assign juvenile Chinook salmon to different life stages. Some of these differences appear to relate to the fact that CFS biologists use four life stages to classify salmon, and PSMFC biologists use five life stages. There also appear to be some biologist-specific differences in the way individuals from the two organizations assign a life stage to a particular salmon, even when the biologists use a classification system that possesses five life stages.

Modifying the life stage classification system used by CFS biologists so it includes the silvery parr life stage reduced the overall differences in how the two sets of biologists assigned an individual salmon to a life stage regardless of whether the salmon were from the American River or Stanislaus River. Evidence to that effect for the American River is found by comparing the percentages in Tables 1B and 1D, i.e., the total percentage difference in salmon that were not assigned to the same life stage by biologists fell from 86.66% to 50.00%. Using Stanislaus River salmon, the total percentage difference in salmon that were not assigned to the same life stage declined from 63.64% to 22.73% (Tables 2B and 2D).

Adopting a common life stage classification system on the American River and Stanislaus River would not likely resolve all the major issues that cause differences in how individual salmon are assigned to a particular life stage. Evidence for that statement is found in Table 1D, where even with the same classification system, the PSMFC and CFS biologists still had different life stage assignments for 50% of the salmon they handled. This circumstance may have several explanations, but is most likely caused by different biologists using different morphological factors as they make their life stage assignments, or placing greater emphasis on particular factors when a salmon is in a borderline situation in regards to a life stage category.

The life stage experiment results suggest there are likely to be considerable obstacles that confound the ability to successfully compare juvenile life-stage specific salmon production estimates among watersheds. That conclusion however, is based on an analysis using biologists from two watersheds. How the inclusion of experimental results from other biologists in a third or fourth watersheds would affect the overall ability to aggregate life-stage specific salmon production estimates across watersheds is not discernable at the present time.

Every RST program in the Central Valley assigns all or some of their juvenile salmon to a watershed-specific life stage classification system. If comparable life-stage specific production estimates are to be made across watersheds, there will need to be greater standardization of how biologists classify salmon. To meet that goal, the CAMP should consider leading an effort that provides tools and training that allow biologists to make more similar, comparable life stage assignments.

Appendix 10: A comparison of river discharge at Nimbus Dam and Watt Avenue on the American River in 2014

Abstract

An investigation was conducted in 2014 that compared the discharge in the American River at the Watt Avenue Bridge at river kilometer 14.8 and at the Nimbus Dam at river kilometer 35.8. The latter location has the potential to experience greater river discharges because of run off into the river during substantial precipitation events. The investigation suggests discharge at the two locations was similar between January and late May except for periods when substantial precipitation occurred, i.e., when total daily rainfall exceeded 2.54 mm (0.10 inches).

Introduction

The purpose of this document is to evaluate the differences in river discharge at two locations on the American River in Sacramento County, California in 2014. Those locations are located at the Watt Avenue Bridge at river kilometer 14.8 and at the Nimbus Dam at river kilometer 35.8.

Fishery biologists that collect juvenile salmonid data with rotary screw traps (RSTs) at the Watt Avenue trap site in the American River in Sacramento County, California frequently rely on river discharge data to plan their field activities. Historically, the only discharge data they could readily acquire were from the U.S. Geological Survey's American River at Fair Oaks gaging station located 21 river kilometers upstream of the Watt Avenue trap site. The U.S. Geological Survey (USGS) station number for that gaging station is 11446500, and the California Data Exchange Center's station code for that gaging station is AFO. For the purposes of this document, that station will be referred to as the "AFO Station".

The AFO Station is located 0.5 kilometers river downstream of Nimbus Dam. Management of that dam results in large-scale increases or decreases in American River discharge, which in turn affects the amount of water that moves past the RSTs 21 river kilometers below the dam. The amount of river discharge passing the RSTs is also likely influenced by precipitation events that create runoff into the river between the dam and the Watt Avenue trap site.

Water releases from Nimbus Dam are managed by the Bureau of Reclamation (BOR). Those releases occur on an intermittent basis for variety of purposes. These include: (1) unscheduled releases to avoid unsafe water levels in the Lake Natoma Reservoir behind Nimbus Dam that result from unusual storm events, (2) short-term pulses that are meant to encourage the migration of juvenile salmonids in the American River so those fish are not exposed to elevated water temperatures in the American River or Sacramento – San Joaquin River Delta (Delta), and (3) releases that are designed to meet regulatory water quality requirements in the Delta.

To date, there has been little or no ability to quantify the difference in discharge at the AFO Station and Watt Avenue trap site that may be due to local or regional rainfall events. The primary purpose of this document is to compare the river discharge at these two locations during the 2014 RST survey season so the influence of local rainfall events can be ascertained, and the limitations in the utility of the AFO Station data can be assessed in the context of RST operations at the Watt Avenue trap site. A secondary purpose of this document is to compile "change orders" that were transmitted from the BOR to interested stakeholders via emails during the 2014 RST survey season; those change orders quantify changes in the amount of water released from Nimbus Dam between January 7 and June 17, 2014.

Methods

This document synthesizes: (1) discharge data from the USGS's American River at Fair Oaks gaging station, (2) modeled river discharge data at the Watt Avenue trap site that were produced by the CBEC, Inc. eco-engineering company, (3) precipitation data that were collected in Fair Oaks, California, and are available on the California Irrigation Management Information System's website (http://www.cimis.water.ca.gov/), and (4) BOR change orders quantifying the amount of water released from Nimbus Dam between January 1 and June 17, 2014.

The modeled river discharge data produced by the CBEC company were generously provided to the Comprehensive Assessment and Monitoring Program by Chris Hammersmark. CBEC's ability to produce the modeled river discharge data was made possible through funding provided by The Water Forum. The forum facilitates the collaborative management of water resources in Sacramento, El Dorado, and Placer counties, California.

CBEC staff used a 1-dimensional HEC-RAS model to estimate the amount of discharge moving past the Watt Avenue trap site between January 1 and May 22, 2014. To estimate river discharge between February 1 to April 30, river stage data were collected with an in-river pressure transducer located XX meters upstream of Watt Avenue, and those data were incorporated into the HEC-RAS model used to predict discharge at the Watt Avenue trap site. The predicted discharge at Watt Avenue prior to February 1 and after April 30 did not utilize in-river pressure transducer data, and the predicted discharge instead relied solely on the HEC-RAS model. The lack of in-river pressure transducer data to forecast flows during part of the 2014 RST survey season should have minimal effect on the accuracy of the predicted amount of river discharge moving past Watt Avenue because there were only four days when pressure transducer data were unavailable and the total daily rainfall exceeded 2.54 millimeters (mm) (0.10 inches).

The precipitation data presented in this report were collected at the California Irrigation Management Information System's Fair Oaks station (station number 131). That station is located 17.4 kilometers (rkm) northeast of the Watt Avenue trap site and 1.7 rkm north northeast of Nimbus Dam. As such, that station collects precipitation that falls upstream of the RSTs and downstream of the Nimbus Dam.

The influence that precipitation events had on river discharge was assessed by developing three graphs depicting the relationship between discharges at Watt Avenue and the AFO Station. Days when dam management activities affected the amount of water being released from the dam were excluded from analysis. That approach was used because the relationship between the discharges at the two locations can be markedly distorted due to the ~ 5 - 10 hour delay between the time water is released at the dam and when water flows past the Watt Avenue trap site.

The three graphs present data in the following three scenarios:

1. All of the discharge data were used, regardless of the total daily precipitation.

2. The discharge data were limited to days when the total daily precipitation was less than 2.54 millimeters (0.1 inches). And,

3. The discharge data were limited to days when the total daily precipitation was greater than 2.54 millimeters (0.1 inches).

For the purpose of this document, an "event" is defined to be a period when the discharge at the Watt Avenue trap site rose from a relatively constant level to some increased level, then declined to a value similar to the pre-increase level.

Results

The relationship between daily average and daily maximum discharge at the AFO Station and Watt Avenue trap site is depicted in Figures 1 and 2. The figures suggest discharge at the two locations was usually the same except for periods when substantial precipitation occurred. For the purpose of this document, "substantial precipitation" is defined to have occurred when the total daily rainfall in Fair Oaks was greater than 25.4 millimeters (1 inch). The three events when the discharge at the two locations were dissimilar and substantial precipitation occurred were on February 26 – March 1 (Event #2), March 29 – 30 (Event #4), and April 1 – 2 (Event #5). There was also one event when substantial precipitation occurred, i.e., February 8 - 10 (Event #1), but when river discharges at the AFO station and Watt Avenue were similar. There were also two events during the 2014 RST survey season, i.e., March 5 - 7 (Event #3), and April 21 – 25 (Event #6), when the discharge at the two locations were similar and substantial precipitation did not occur.

Figure 1. Comparison of the daily maximum discharge at Watt Avenue and the U.S. Geological Survey's American River at Fair Oaks gaging station, 2014.

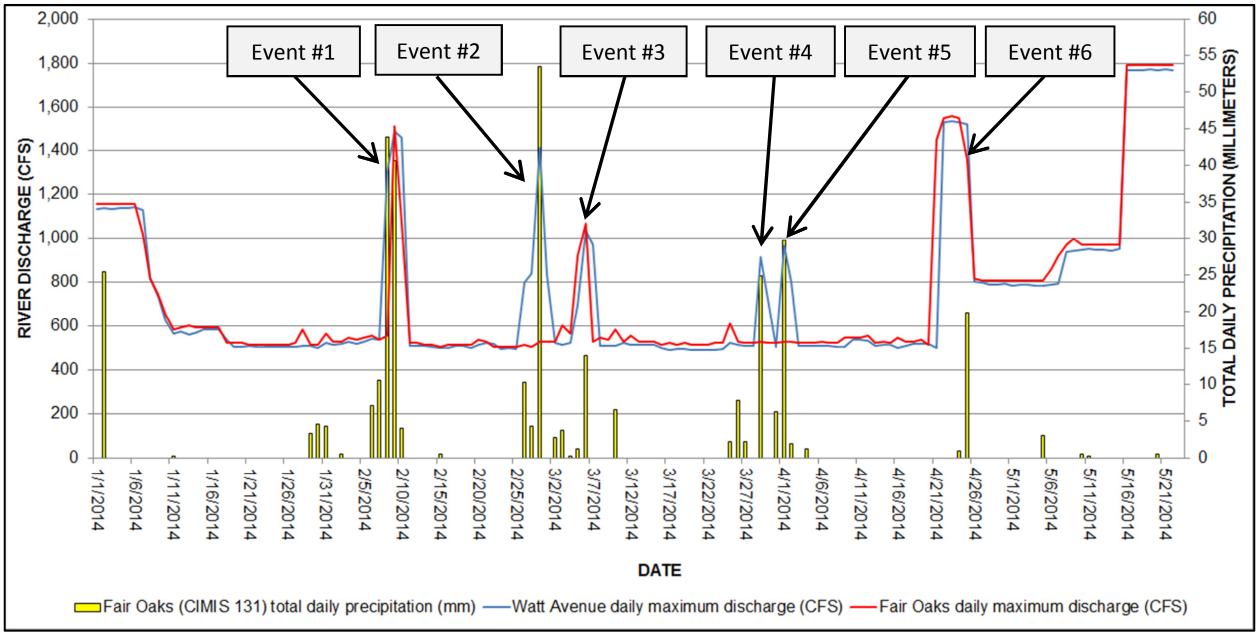
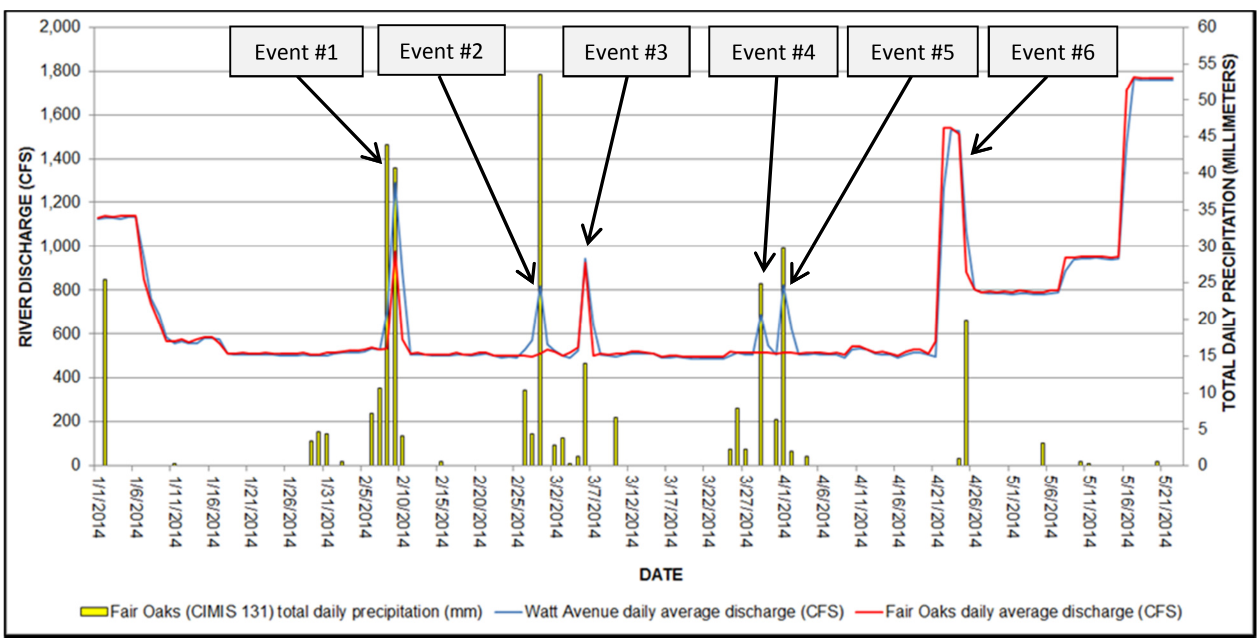


Figure 2. Comparison of the daily average discharge at Watt Avenue and the U.S. Geological Survey's American River at Fair Oaks gaging station, 2014.



The pattern of change in the maximum daily discharge during an event coincided with the pattern of change in the average daily discharge, i.e., as a spike in the maximum daily discharge occurred, the average daily discharge also increased.

Figures 1 and 2 also illustrate when the American River discharge increased on May 8 and May 16. The increase in discharge on these dates are not classified as an "event" in this document because the river discharge did not increase and then decline to some prior level. The increase in discharge on these dates is notable, however, because they represent situations that have the ability to affect the operation of the RSTs at the Watt Avenue trap site and the behavior and movement of salmonids in the river.

Table 1 quantifies the total amount of rainfall and the magnitude of the maximum fluctuation in discharge at the AFO Station and Watt Avenue during each of the six aforementioned events in 2014. During Event numbers 2, 4, and 5, the discharge at the two locations were dissimilar. For example, during Event #2 between February 28 and March 1, discharge at Nimbus Dam was stable with discharge at the beginning of the event being 506 cubic feet per second (CFS) and ending at 531 CFS. In contrast, the discharge at Watt Avenue began in the morning at 486 CFS on February 28, rose to 1,414 CFS late in the day on February 28, and then declined to 525 on March 1. The total precipitation during Event #2 was 54 mm (2.1 inches), and it can be inferred the heavy precipitation caused the sharp increase in the discharge at Watt Avenue. During the three events when there were differences in the discharge at the two locations, the estimated discharge at Watt Avenue was 62 – 173% greater than what was recorded at the AFO Station.

During three other events (Events 1, 3, and 6), the discharge at the two locations were similar. For example, during Event #1 between February 8 and 10, a substantial amount of rain (89 mm, 3.5 inches) fell at Fair Oaks and an unscheduled release of water from Nimbus Dam took place to avoid an unsafe rise in the water level of the reservoir behind the dam. The magnitude of the change in discharge at Nimbus Dam and Watt Avenue were similar, however, and the discharge at both locations rose from 523 - 531 CFS to 1,488 - 1,510 CFS, then declined to 510 - 514 CFS.

To facilitate the outmigration of juvenile salmon and *O. mykiss* from the American River, the discharge from Nimbus Dam was increased between March 5 and 6 (Event #3) and again between April 21 and 25 (Event #6). The releases were scheduled to encourage the outmigration of salmonids so those fish would not be subject to high water temperatures in the American River or the Sacramento – San Joaquin River Delta later in the year. Both of those pulse flows resulted in similar patterns in the increase and decrease of river discharge at the AFO Station and Watt Avenue. It is important to note that 15 – 20 mm (0.6 – 0.8 inches) of rain fell during each of these events, thereby confounding the ability to determine if an increase in fish emigration was due to higher river discharges or chemical cues that might be associated with runoff into the river as rain fell.

Table 1. Precipitation and river discharge characteristics during six events that caused temporary increases in river discharge in the American River in 2014.

Black font indicates events when the magnitude of change in discharge at Nimbus Dam and Watt Avenue was similar, and red font indicates events when the magnitude of change in discharge at the two locations was dissimilar.

Event Number/ Date Range	Amount of rainfall in Fair Oaks in millimeters (inches)	Magnitude of maximum change in the discharge at Nimbus Dam (CFS)	Magnitude of maximum change in the discharge at Watt Avenue (CFS)	Notes
Event #1: **February 8 - 10**	89 (3.5)	531→1,510→514	523→1,488→510	Significant rainfall event Nimbus Dam flood release
Event #2: **February 28 – March 1**	54 (2.1)	506→531	493→1,414→525	Significant rainfall event
Event #3: **March 5 - 7**	15 (0.60)	549→1,020→497	520→1,037→496	Salmonid pulse flow Nimbus release
Event #4: **March 29 - 30**	25 (1.0)	514→514	508→914→507	Significant rainfall event
Event #5: **April 1 - 2**	32 (1.3)	514→523	506→965→509	Significant rainfall event
Event #6: **April 21 - 25**	20.8 (0.8)	506→1,560→810	502→1,533→804	Salmonid pulse flow Nimbus release

Figures 3, 4, and 5 provide graphs and regression lines plotting the relationship between the American River discharge at the AFO Station and Watt Avenue trap site. The figures do not include days when a pulse of water was released from Nimbus Dam and therefore only includes data when dam release volumes were relatively constant.

The slope of a regression line (0.9707) plotting the relationship in river discharge at the AFO Station and Watt Avenue trap site on all days with or without precipitation in 2014 (Figure 4) suggests there is a relatively close relationship between the discharge at the two locations. If days when total daily rainfall in excess of 2.54 mm (0.10 inches) are removed from the analysis, the slope of a regression line becomes 0.9955 (Figure 3), which indicates that under those precipitation conditions there is a nearly 1:1 relationship in the river discharge at the AFO Station and Watt Avenue trap site and the discharge data from the AFO Station can be used to accurately predict the discharge at Watt Avenue. If the analysis is limited to days when the total daily rainfall was in excess of 2.54 mm (0.10 inches), the slope of a regression line becomes 0.2208 and the correlation coefficient declines to 0.184 (Figure 5), which indicates the AFO Station discharge data cannot be used to accurately predict the discharge at the Watt Avenue trap site under those precipitation conditions. In 2014, there were only 21 days when the total daily precipitation in Fair Oaks was greater 2.54 mm (0.10 inches), i.e., during the majority of the trapping season when RSTs were operated on the American River, the AFO Station discharge data could be used to accurately predict the discharge at the Watt Avenue trap site.

Discussion

The data presented in this document provide a basis for making inferences about the relationship between the discharge at the AFO Station and the Watt Avenue trap site. Those inferences are specific to conditions in 2014, and additional data in future years will be needed to determine if the inferences are applicable across a broad range of precipitation conditions.

1. The amount of discharge passing the Watt Avenue trap site on the American River was markedly influenced by three rainfall events in 2014, i.e., the river discharge at that location was influenced by a combination of rainfall and the amount of water released from Nimbus Dam.

2. Discharge data from the U.S. Geological Survey's American River at Fair Oaks gaging station can be used to predict the discharge at the Watt Avenue trap site when the total daily rainfall is less than 2.54 mm (0.10 inches). Conversely, when total daily rainfall exceeds this amount, the amount of discharge at the Watt Avenue trap site can be 62 – 173% greater than that at the American River at Fair Oaks gaging station.

3. Data from 2014 suggests that when a relatively large amount of water is released from Nimbus Dam (e.g., 1,500 CFS) and that release coincides with a substantial amount of rainfall, the American River discharge at the AFO Station and Watt Avenue trap site can be similar. This may suggest that a release of water from the dam has a greater influence on river discharge than precipitation events.

4. The development of the HEC-RAS model and collection of in-river pressure transducer data at Watt Avenue by the CBEC staff provides two benefits for the fishery biologists operating the rotary screw traps on the American River. First, that data provides a more accurate understanding of the actual discharge at the location where the biologists operate the RSTs. And second, if the collection of the in-river pressure transducer data is maintained in the long-term, it will facilitate the development of a trap efficiency model that will lead to more accurate estimates of the number of Chinook salmon produced by the American River.

Figure 3. Comparison of 2014 river discharge at Fair Oaks vs. Watt Avenue, with no Nimbus Dam flow management and no daily precipitation > 2.54 mm (0.10 inches).

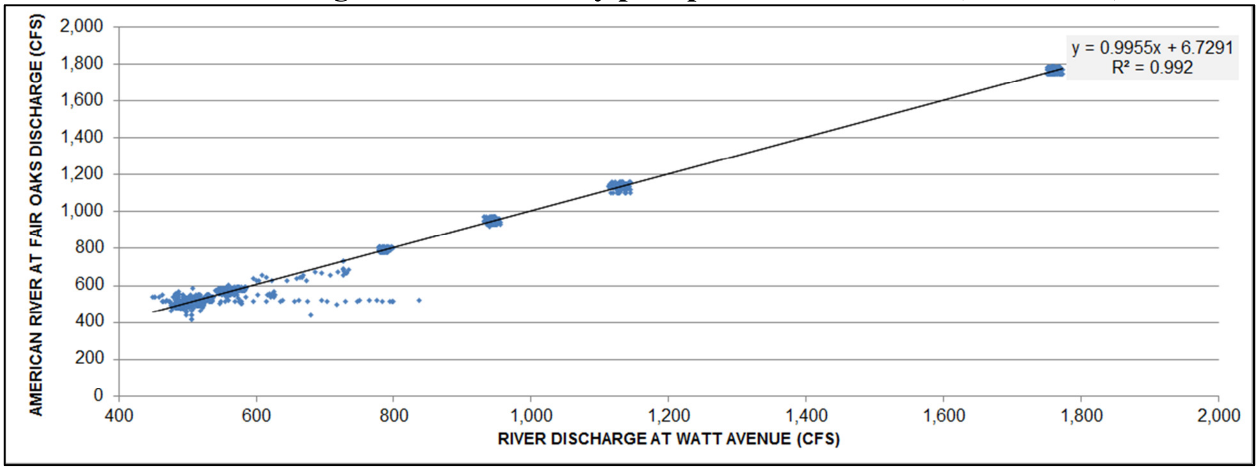


Figure 4. Comparison of 2014 river discharge at Fair Oaks vs. Watt Avenue, with no Nimbus Dam flow management and includes all days with or without precipitation.

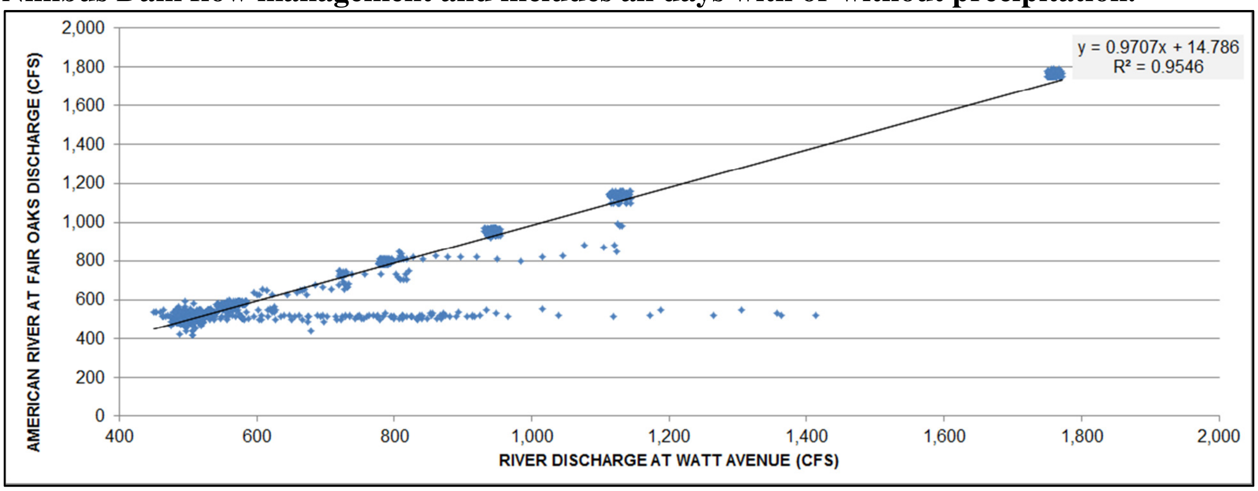


Figure 5. Comparison of 2014 river discharge at Fair Oaks vs. Watt Avenue, with no Nimbus Dam flow management and daily precipitation > 2.54 mm (0.10 inches).

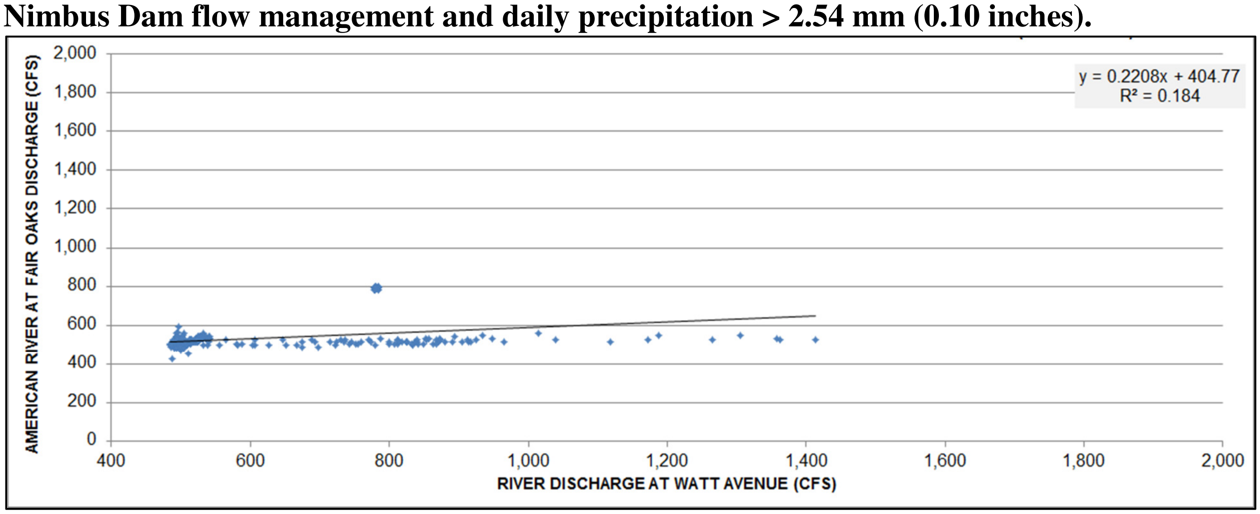


Table 2. Consolidated sequence of Nimbus Dam change orders issued by Bureau of Reclamation staff between January 7 and June 17, 2014.

The shading illustrates distinct events that occurred as the volume of water released from the dam was changed.

Date	Time	From (CFS)	To (CFS)	comment
January 7, 2014	1:00 AM	1,100	1,000	Storage conservation
January 7, 2014	4:00 AM	1,000	900	Storage conservation
January 7, 2014	7:00 AM	900	800	Storage conservation
January 8, 2014	1:00 AM	800	700	Storage conservation
January 9, 2014	1:00 AM	700	600	Storage conservation
January 10, 2014	1:00 AM	600	500	Storage conservation
February 9, 2014	9:00 AM	500	750	Nimbus flood control
February 9, 2014	10:00 AM	750	1,000	Nimbus flood control
February 9, 2014	1:00 PM	1,000	1,250	Lake Natoma flood control
February 9, 2014	3:00 PM	1,250	1,500	Lake Natoma flood control
February 9, 2014	8:00 PM	1,500	1,400	Ramping down from Lake Natoma flood control
February 9, 2014	9:00 PM	1,400	1,300	Ramping down from Lake Natoma flood control
February 9, 2014	10:00 PM	1,300	1,200	Ramping down from Lake Natoma flood control
February 9, 2014	11:00 PM	1,200	1,100	Ramping down from Lake Natoma flood control
February 10, 2014	12:01 AM	1,100	1,000	Ramping down from Lake Natoma flood control
February 10, 2014	1:00 AM	1,000	900	Ramping down from Lake Natoma flood control
February 10, 2014	2:00 AM	900	800	Ramping down from Lake Natoma flood control
February 10, 2014	3:00 AM	800	700	Ramping down from Lake Natoma flood control

Date	Time	From (CFS)	To (CFS)	comment
February 10, 2014	4:00 AM	700	600	Ramping down from Lake Natoma flood control
February 10, 2014	5:00 AM	600	500	Ramping down from Lake Natoma flood control
March 5, 2014	8:00 PM	500	750	Fish pulse flow
March 5, 2014	10:00 PM	750	1,000	Fish pulse flow
March 6, 2014	8:00 PM	1,000	900	Fish pulse flow
March 6, 2014	9:00 PM	900	800	Fish pulse flow
March 6, 2014	10:00 PM	800	700	Fish pulse flow
March 6, 2014	11:00 PM	700	600	Fish pulse flow
March 6, 2014	12:00 AM	600	500	Fish pulse flow
April 21, 2014	9:00 PM	500	1,000	Fish pulse per request of Fishery Agencies
April 21, 2014	11:00 PM	1,000	1,500	Fish pulse per request of Fishery Agencies
April 24, 2014	9:00 PM	1,500	1,400	Fish pulse per request of Fishery Agencies
April 24, 2014	11:00 PM	1,400	1,300	Fish pulse per request of Fishery Agencies
April 25, 2014	1:00 AM	1,300	1,200	Fish pulse per request of Fishery Agencies
April 25, 2014	2:00 AM	1,200	1,100	Fish pulse per request of Fishery Agencies
April 25, 2014	3:00 AM	1,100	1,000	Fish pulse per request of Fishery Agencies
April 25, 2014	4:00 AM	1,000	900	Fish pulse per request of Fishery Agencies
April 25, 2014	5:00 AM	900	800	Fish pulse per request of Fishery Agencies
May 8, 2014	1:00 AM	800	950	Delta Requirements
May 16, 2014	1:00 AM	950	1,350	Delta Requirements
May 16, 2014	2:00 AM	1,350	1,750	Delta Requirements
May 28, 2014	1:00 AM	1,750	2,000	Delta Requirements
June 17, 2014	1:00 AM	2,000	2,500	Delta Water Quality Requirements

Appendix 11: Relationship between the Nimbus Dam release volume and water volume moving through the South Channel near the Watt Avenue rotary screw trap site

Abstract

An investigation was conducted in 2014 that compared the amount of river discharge that moved through two channels of the American River near the Watt Avenue Bridge in Sacramento County, California. That investigation was conducted under a variety of river discharge scenarios. Fishery biologists operate rotary screw traps below the bridge each year as juvenile Chinook salmon are monitored. The study results demonstrate that when total river discharge is limited to 500 – 1,000 cubic feet per second, a relatively small fraction of the total river discharge moves through the more southerly of the two river channels. As total river discharge exceeds 1,000 cubic feet per second, flows in the more southerly channel increase in a non-linear fashion, and a progressively greater percentage of the total river flow begins to move through that channel. That pattern affects fishery biologist's ability to successfully operate a rotary screw trap in the more southerly channel during periods when river discharge is relatively low.

Introduction

The Watt Avenue trap site where the American River rotary screw traps (RSTs) are deployed in Sacramento County, California is bisected by the presence of a small island that splits the American River into two channels, i.e., the North Channel and the South Channel. The relative proportion of river water moving through the channels varies depending on river discharge, and when discharges are low, the South Channel possesses very little discharge relative to the North Channel.

In 2013, RSTs were deployed in the North Channel and South Channel. In 2014, traps were only deployed in the North Channel because river discharges were abnormally low during that trapping season. The low river discharges in 2014 were an artifact of drought conditions. The drought in turn resulted in drastic reductions in the release of water from Nimbus Dam upstream of the location where RSTs are typically deployed.

Because the volume of water moving through the North and South channels can affect the operation and efficiencies of the RSTs in a marked way, an investigation was conducted to better understand how much water moves through each channel under different river discharge scenarios. Developing trap-specific trap efficiency models that account for the volume moving past the traps in each channel may ultimately improve the ability to develop more accurate salmon production estimates if it is determined that the volume of river discharge in each channel is correlated with trap efficiency.

To quantify the amount of water passing through the South Channel, the total combined amount of water moving through the river in both of the channels at the Watt Avenue trap site was assumed to equal the amount of water passing the U.S. Geological Survey (USGS) American River at Fair Oaks gaging station (USGS station number 11446500) upstream of the traps. This assumption was made because the period when the river discharge in the South Channel was measured between March 5 and May 28, 2014 did not experience any storms that would have contributed additional water to the river over and above the amount passing by the USGS gage. Because the USGS gage is located 470 meters below Nimbus Dam, it can be assumed that the discharge measured by the USGS gage is equal to the amount of water being released by Nimbus Dam. It is also assumed that between March 5 and May 28, 2014, no water entered the river from storm drains and ephemeral creeks that are present between Nimbus Dam and the Watt Avenue trap site. This assumption was made because little or no precipitation fell during that period.

Methods

The process of measuring the discharge in the South Channel is as follows:

1. Rebar stakes were driven into the ground and used to establish the end points of a transect across the South Channel. These stakes thereby provided a standardized mechanism for collecting discharge data along the same transect during multiple iterations of measuring the stream discharge in the South Channel.

2. Discharge in the South Channel was quantified on eight different occasions between March 5 and May 28, 2014 under a variety of river discharges.

3. The USGS's methodology and processes for collecting stream discharge data were adopted and used. That methodology and process is described in the USGS's 1976 *Techniques of Water-Resources Investigations of the United States Geological Survey* document.

4. A Hach portable water velocity meter (model FH9500), standard wading rod, and measuring tape were used to collect water depth and water velocity data, and data were recorded on a standardized data sheet. The analytical process for analyzing the raw data and calculating stream discharge estimates is based on the formulas used in the USGS's 1976 manual.

5. Data on the water depth, water velocity, and distance along the measuring tape in the South Channel were collected at 14 to 36 locations along the measuring tape during each event when stream discharge was measured.

6. The stream width during the different stream gaging events was determined by comparing the locations on the measuring tape where water began and ended as the tape was laid across the river channel.

7. Because the aforementioned rebar stakes were used to establish the beginning and ending points of the gaging transect and water depth measurements were made at several locations along the same transect each time field work was conducted, it was possible to develop a two dimensional model illustrating how water depths along the transect in the South Channel varies under a variety of river discharge conditions.

8. An effort to quantify the discharge in the North Channel was not made because the faster water velocities in that channel made stream gaging activities problematic.

The estimated amount of discharge in the North Channel was calculated as:
Discharge at the USGS's American River at Fair Oaks gaging station – the measured discharge in the South Channel.

Results

The discharges at American River at Fair Oaks gaging station when the stream gaging activities were undertaken were between 500 and 2,020 cubic feet per second (CFS). During those flow regimes, the amount of water passing through the South Channel varied between 2.2 and 412.3 CFS (Table 1). When the total combined river discharge moving through the North and South channels past the trap site was assumed to be 500 – 550 CFS, the amount of discharge moving through the South Channel was estimated to be 1.2 – 2.2 CFS, i.e., 0.2 – 0.4% of the total river discharge. When the total combined river discharge moving through the channels was 2,020 CFS, the amount of discharge moving through the South Channel was estimated to be 412 CFS, i.e., 20.4% of the total river discharge.

A regression line plotting the relationship comparing the total combined river discharge with the South Channel discharge has a high R^2 value of 0.9913 when the relationship is modeled as a polynomial relationship (Figure 1). In general, very little water moves through the South Channel when the flows at Nimbus Dam are less than 1,000 CFS. As flows as Nimbus Dam exceed 1,000 CFS, flows in the South Channel increase in a non-linear fashion and a progressively great percentage of the total river flow begins to move through the South Channel.

The width of the wetted stream within the South Channel at 500 – 550 CFS was only 11.5 – 16.1 meters. As the discharge at Nimbus Dam increased to 2,020 CFS, the width of aquatic habitat in the South Channel also increased until the stream was 80.4 meters wide (Table 1). At a discharge of 2,020 CFS, the southern edge of the South Channel abutted a vertical bank, and increased discharges above that level would not be expected to extend the southern extent of the wetted channel. On the north edge of the South Channel, the bank is more gradual in slope, and discharges above 2,020 CFS would be expected to cause the wetted channel to move north at least another 10-20 meters before a steeper incline on that bank would cause the river water to become channelized.

At 500 - 550 CFS, the width of the aquatic habitat in the South Channel occupies a relatively small proportion of that channel's total width (Figure 2). In contrast, the width of the aquatic habitat in the South Channel at 2,020 CFS occupied almost the entire channel between the south bank abutment and the island separating the North and South channel.

Figure 3 provides an illustration of the bathymetry along the transect in the South Channel under different river discharge conditions. At 500 – 550 CFS, the water depth in that channel is limited almost entirely to depths less than 0.1 meters. As river discharges increase, the water depth in the South Channel becomes progressively deeper. Figure 3 suggests that when the discharge exceeds 973 CFS, the stream width begins to become markedly larger than what occurs with lower river discharges, and water depths become substantially deeper. When Nimbus Dam river discharges are 1,500 to 2,020 CFS, the water along the transect was 0.5 – 0.5 meters deep.

Table 1. Tabular data quantifying the volume of water moving through the North and South Channels in the vicinity of Watt Avenue trap site where rotary screw traps were deployed in 2014.

Nimbus release discharge (CFS)	Amount of water moving through the South Channel (CFS) based on stream gaging data	Percent of Nimbus Dam discharge passing through the South Channel	Estimated amount of water moving through the North Channel (CFS)	Percent of Nimbus Dam discharge passing through the North Channel	Stream width (meters)
550	2.2	0.4%	547.8	99.6%	11.5
973	51.8	5.3%	921.2	94.7%	26.7
500	1.2	0.2%	498.8	99.8%	16.1
1,500	235.6	15.7%	1,264.4	84.3%	70.2
800	26.3	3.3%	773.7	96.7%	27.5
950	51.7	5.4%	898.3	94.6%	24.3
1,770	287.3	16.2%	1,482.7	83.8%	77.1
2,020	412.3	20.4%	1,607.7	79.6%	80.4

Figure 1. Relationship between Nimbus Dam release volume and water volume moving through the South Channel near the Watt Avenue rotary screw trap site, 2014.

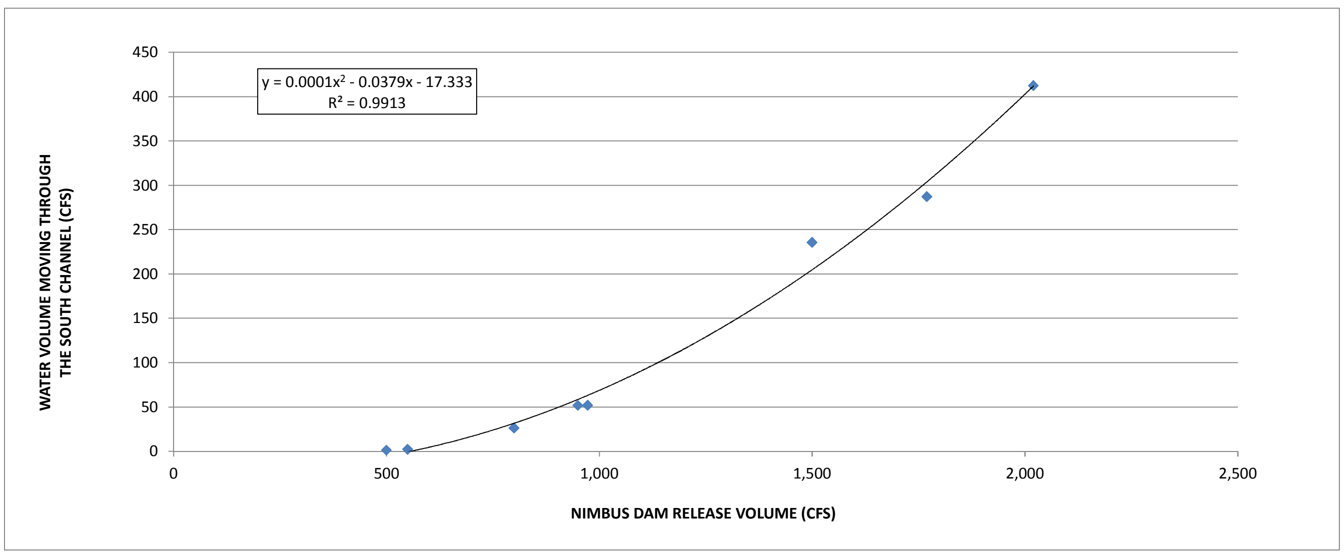


Figure 2. Photograph illustrating the stream width in the South Channel under four river discharge conditions in 2014.

Each set of color lines represent the wetted channel with different river discharges from Nimbus Dam. Red lines represent 500 CFS discharges. Yellow lines represent 800 CFS discharges. Green lines represent 1,500 CFS discharges. White lines represent 2,020 CFS discharges. Water in the river flows from right to left.

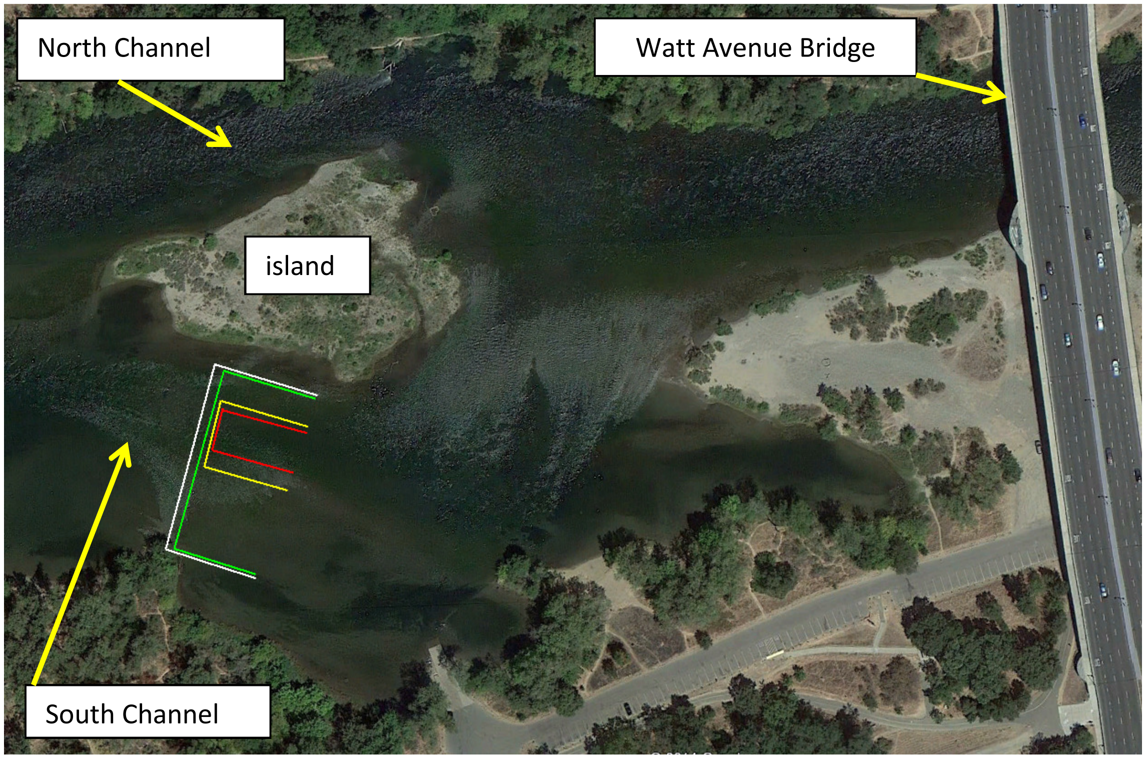
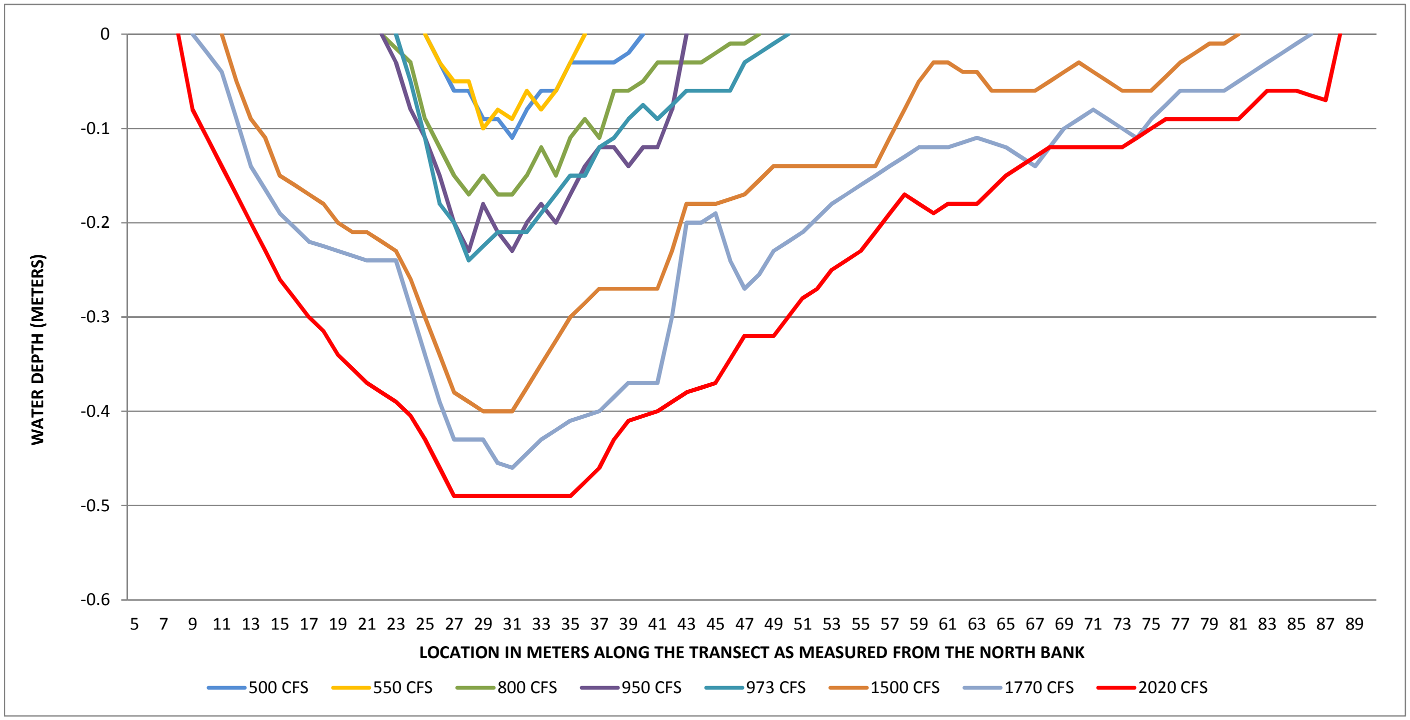


Figure 3. Bathymetry profile in the South Channel under variable river flow conditions, 2014.



The results from the stream gaging activities in 2014 explain why the ability to successfully deploy RSTs in the South Channel is affected by the volume of water released from Nimbus Dam. When releases from the dam are less than 1,000 CFS, relatively little water moves through the South Channel, and most of the water moving past the Watt Avenue trap site instead moves through the North Channel. As dam releases increase over 1,000 CFS, a progressively greater amount of water begins to move through the South Channel, thereby allowing the trap in that channel to have a sufficient water volume and velocity to rotate in a satisfactory manner.

Discussion

A RST's ability to successfully collect emigrating fish is substantially affected by the water velocities in the vicinity of the trap; in the absence of adequate water velocities, emigrating fish are unlikely to be directed through the trap cone and into the trap live well by flowing water. Staff from the E.G. Solutions® company that manufacture the RSTs used on the American River recommend that water velocities at a trap site where an 2.4 meter diameter RST is operated should not be less than 0.6 meters/second (2.2 feet/second) at the lowest discharge that is sampled (Mark Wade, pers. comm.). Under optimal conditions, the water velocities at a trap site with a 2.4-meter trap should be 1.5 meters/second (4.9 feet/second). The ability to successfully operate a RST is also dependent on having a sufficient water depth that the trap cone can spin without coming in contact with the bottom substrate underneath the trap.

In 2014, the amount of water moving through the South Channel was not sufficient to deploy a trap. That condition arose because exceptionally low river discharges created a water column that was not deep enough to deploy a trap until the end of the 2014 RST survey season.

In 2013, a RST with a 2.4-meter diameter cone was deployed in the south channel. That trap was able to spin with water velocities greater than 1.25 feet/second and collect data that could reliably be included in data analyses. On March 6, the amount of water released from Nimbus Dam upstream of the traps was decreased from 1,869 CFS to 1,686 CFS (Figure 4). On March 7, the resulting water velocity in front of the 2.4-meter diameter trap declined from ~ 1.6 to 0.6 feet/second, thereby stopping the rotation of the trap and creating a situation where fish data could no longer reliably be included in data analyses. On March 9th, the 2.4-meter diameter trap was removed and a 1.5-meter diameter trap was installed at the same location. The 1.5-meter diameter trap was able rotate if the amount of water released from Nimbus Dam was in excess of 1,500 CFS (Figure 5). On March 19, the water release from Nimbus Dam declined below 1,500 CFS, and the 1.5-meter diameter trap ceased to function on a reliable basis due to low water velocities in front of the trap. On March 30, plywood flow diverters were placed on either side of the trap to increase the river discharge and water velocities in front of the trap. That effort had mixed results, however, and the 1.5-meter trap was finally removed from the river when the mean daily discharge declined from 1,235 CFS on April 15 to 1,103 CFS on April 16.

In summary, a 2.4-meter diameter trap in the American River's South Channel appears to need a Nimbus Dam release of at least 1,869 CFS to spin and a 1.5-meter diameter trap needs at least 1,500 CFS. It is important to note, however, that these lower river discharge conditions do not create the optimal water velocities recommended by the E.G. Solutions® company.

Figure 4. Relationship between water velocity, river discharge, and function of 2.4-meter diameter rotary screw trap in the South Channel of the American River below the Watt Avenue Bridge, 2013.

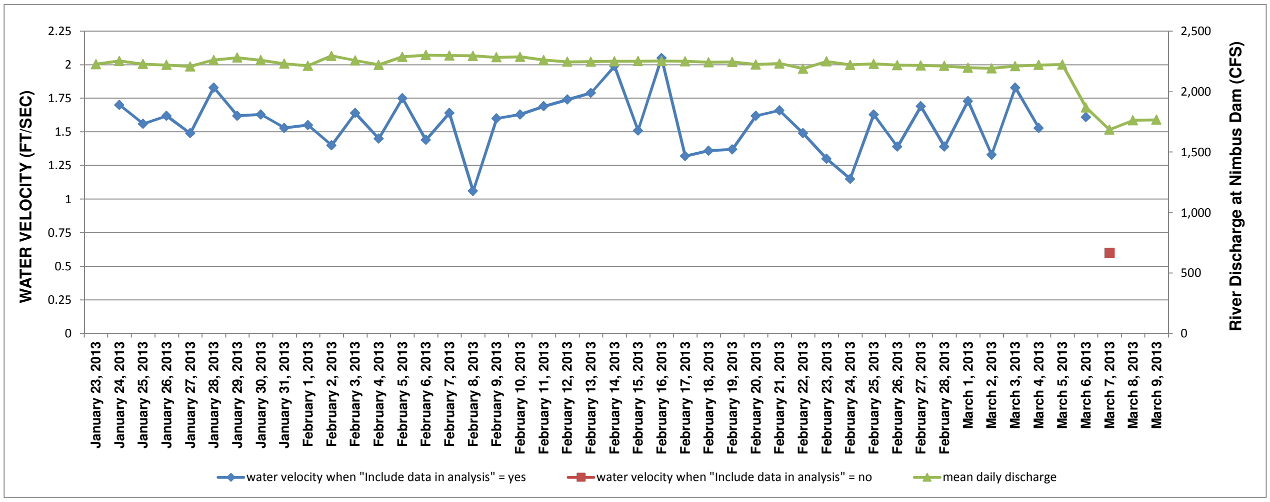
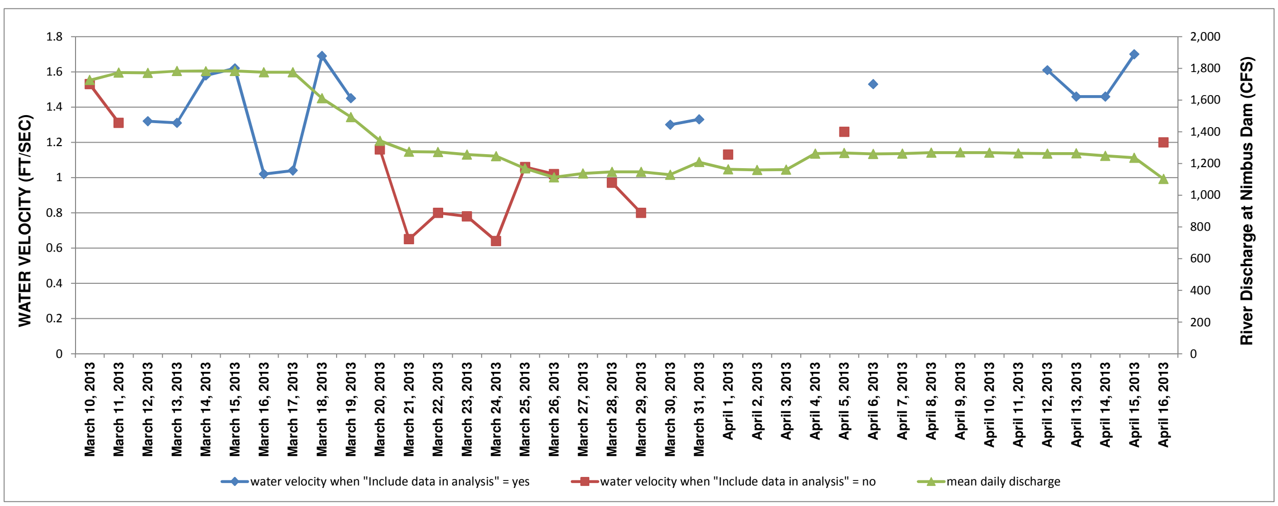


Figure 4. Relationship between water velocity, river discharge, and function of 1.5-meter diameter rotary screw trap in the South Channel of the American River below the Watt Avenue Bridge, 2013.



Appendix 12: An assessment of fin clipping and/or bio-photonic marking of salmonids

Abstract

An investigation was conducted to assess the juvenile *O. mykiss* response two types of marking techniques. These two techniques were bio-photonic pigment marking and fin clipping. Four groups of 30 steelhead from the Nimbus Fish Hatchery were used and each group had their own separate fish raceway inside the Nimbus hatchery building. One group had no clips or marks, the second had an adipose clip, left pelvic fin clip, but no photonic marks. The third group had only a photonic mark on the anal fin and the fourth group had an adipose fin clip, left pelvic fin clip, and a photonic marking on the anal fin. The analysis required three separate visits to asses' fish condition and mark retention. The analyses suggest that after one *O. mykiss* mortality on initial marking, no further mortality occurred in the following days. The results suggest both bio-photonic marking and fin clipping as a viable and safe option for marking fish.

Introduction

Marking fish is a widely used technique to identify and separate a certain group of fish from the rest of the fish population. There are many different techniques to mark fish, but for the purpose of this assessment, the focus will be on fin clipping and photonic marking; these are the most commonly used techniques for marking juvenile salmonids.
Bio-photonic marking is a tagging technique that injects a highly visible mark into the translucent flesh of the animal. In the case of the lower American River screw trap project, bio-photonic marking is used to mark salmonids for the purpose of running a simple mark-recapture trial to estimate trap efficiency. One or combinations of fins are injected with a bio-photonic tag formulation of fluorescent microspheres to give a distinguishing mark separating the trial fish from the non-trial fish. The proportion of trial fish to non-trial fish captured in the rotary screw traps in a given trial duration will produce a trap efficiency. The injection is performed by an injection marking gun that forces the fluorescent microspheres in by way of high-pressure CO_2 depressing a piston and forcing the dye into the fin. Only a small amount of dye is actually injected into the fin, often only marking a few rays of a juvenile salmonid. While the marking is temporary, it is said that this dye can last for months or years at a time depending on the adhesive formulation. The purpose of this assessment is to verify the longevity and accuracy of bio-photonic dye for the purposes of marking juvenile salmonids for rotary screw trap mark and recapture trials.

As a secondary trial, the California Department of Fish and Wildlife was performing adipose fin and pelvic fin clips by hand to hundreds of thousands of *O. mykiss* fingerlings. Typically, the *O. mykiss* would only have an adipose fin clipped as the identifying mark for hatchery origin fish which would be performed by an automated tagging machine. In 2014, the Nimbus Fish Hatchery was concerned about increasing water temperatures in the hatchery from their water source at Lake Natoma. With concern that they may lose their entire brood stock of *O. mykiss* over the summer, hatchery managers decided to release the entire stock of fish as young of the year fry/parr into the lower American River in hopes that they would naturally find a way to survive. In normal years, the *O. mykiss* would be released as yearling smolts. To identify these fish in the case of future recaptures, the entire brood stock had an additional clip of the left pelvic fin. This had to be done by hand as there was no automated machine to perform this clip. This assessment takes into account these clipped fish and whether there may be any adverse effects to the *O. mykiss* being handled and clipped by hand.

Methods

For the bio-photonic marking assessment trial, hatchery *O. mykiss* parr/smolts were used from the Nimbus Fish Hatchery, on the American River. Four groups of 30 steelhead were used and each group had their own separate fish raceway inside the Nimbus hatchery building. One group had no clips or marks, the second had an adipose clip, left pelvic fin clip, but no photonic marks. The third group had only a photonic mark on the anal fin and the fourth group had an adipose fin clip, left pelvic fin clip, and a photonic marking on the anal fin. Both photonicly marked *O. mykiss* groups were marked on the anal fin with pink tagging formula. The *O. mykiss* were held for 21 days and marks were assessed three times during the trial, starting May 21st, June 5th, and June 17th.

For the photonic marking, a BMX2000 POW'R-JECT (New West Technologies) CO2 powered gun is used to inject a pink bio-photonic fluorescent tagging formulation (BioPhotonic Tags; New West Technologies) into the anal fin of a *O. mykiss* (Figure 1). Before marking, the *O. mykiss* was anesthetized with a solution of alka-seltzer (one tablet) and a liter of water, to allow the fish to be safely handled for marking. Once the gill movement slowed and the O. mykiss started to turn over, they were then removed from the anesthetic solution and placed in a marking tub for tagging. The marking tub consists of a shallow plastic bin with a nylon board with a ceramic tile segment affixed to it. Fresh water is then filled to about ¼ inch above the tile. The water is used to help keep the fish moist and also to minimize the splatter of the tagging formulation when injected. The fin of *the O. mykiss* that is going to be marked is placed against the ceramic tile. To tag the fin, the marking gun is set to inject 0.05-.010 ml of tagging formulation, depending on the size of fish. Then the nozzle of the gun is placed at base of the anal fin and angled at 45 degrees and the trigger is depressed. Once tagged, they were immediately placed into fresh water of each raceway to recover.

O. mykiss that received fin clips were first clipped by hand with small surgical scissors by the California Department of Fish and Wildlife employees after being submerged in a bath of fresh water and anesthesia. Fish that were fin clipped and photonicly marked were first clipped and immediately handed off for photonic marking before the anesthesia dosage wore off.

Results

Mortality: There was only one *O. mykiss* mortality throughout the entirety of the marking trial. It was a part of the group with ad-clip, left-pelvic clip, and photonic mark. It occurred immediately after being marked by all three marks. The mort *O. mykiss* had gill movement immediately after being marked but was never able to recover later after marking. All others recovered quickly after anesthesia and survived throughout the 21 day duration of the trial.

Photonic mark retention: In figures 1 through 3, retention through the 21 day trial showed very little fade of mark from beginning to the end.

Figure 1: Initial photonic marking of O. mykiss on May 21, 2014.

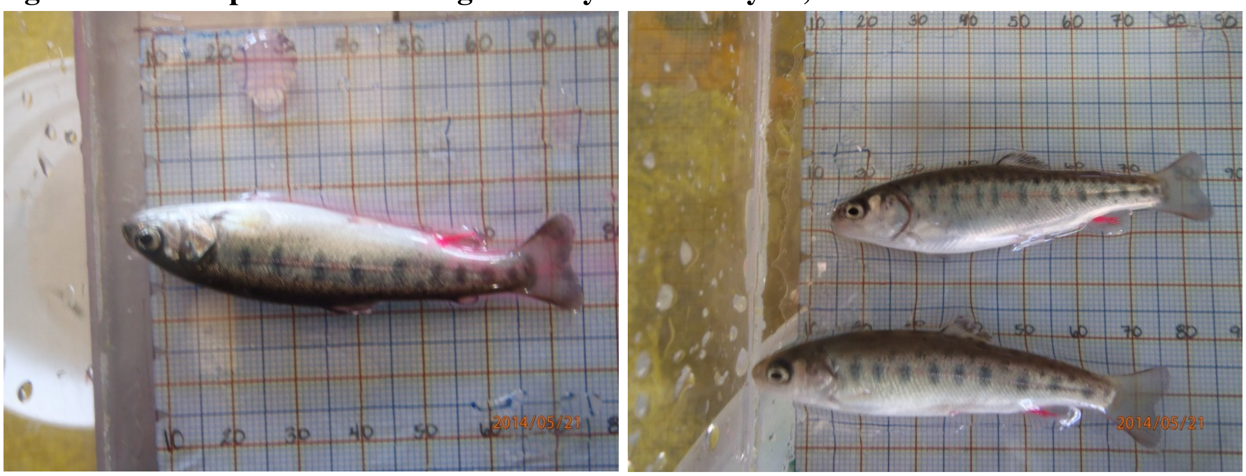


Figure 2: Photonic marks on June 5, 2014.

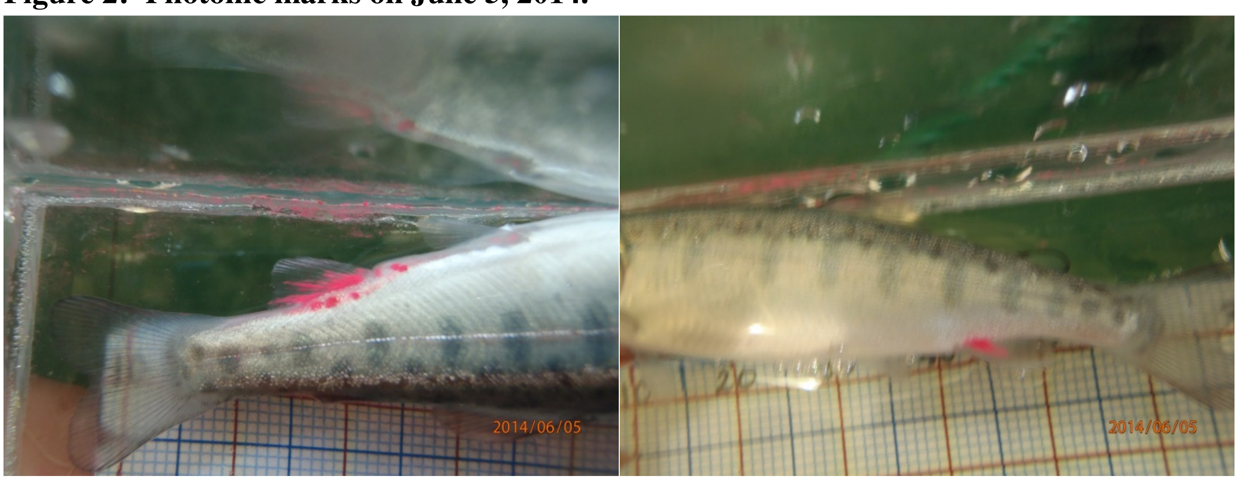
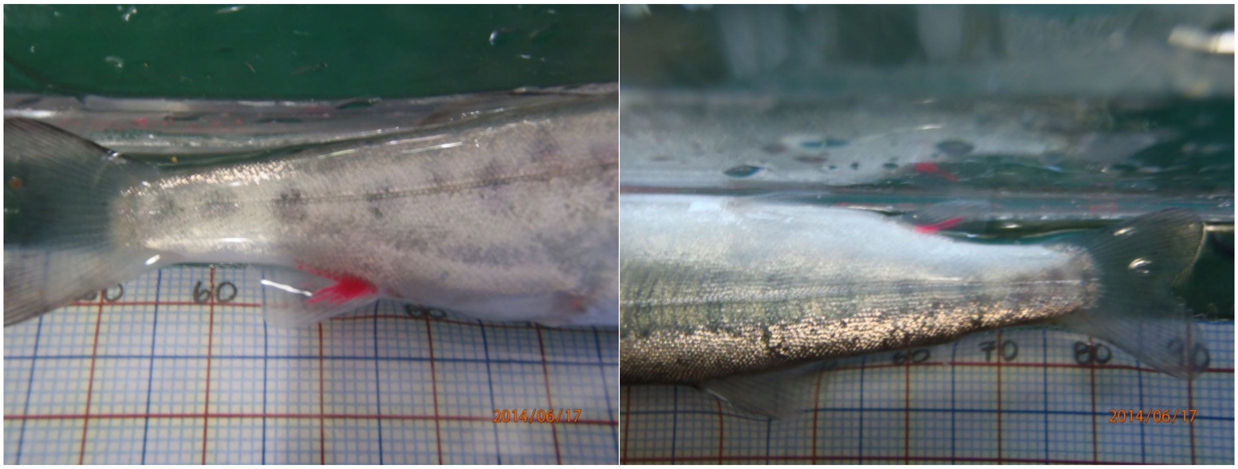


Figure 3: Photonic marks on June 17, 2014.



Discussion

The analysis results suggest both bio-photonic marking and fin clipping as a viable and safe option for marking fish.

1. The bio-photonic marking is a good long term, yet still temporary way to mark salmonids with multiple colors. Many combinations can be used to identify the trial group of fish including multiple color and fin locations. After 21 days, the color was still very visible and vibrant. After the 21 days, it seems like the mark will be identifiable for at least another week or more.

2. Bio-photonic marking may be a better option over whole body staining (i.e. Bismarck Brown y), another commonly used marking technique for juvenile salmonids. Whole body stain adds color pigment to the entire body which can enhance the visibility of the salmonids to predators. It also requires the fish to be submerged in a mixture of stain and water for nearly two hours which can create stress to the fish. There is commonly a small percentage of mortality for this marking technique. The whole body stain's color, in most cases, only lasts a little over a week on the flesh of the fish. As the mark fades away, the color may become difficult to identify positively. Bio-photonic marking only takes a matter of seconds to perform, and other than being submerged in the anesthesia for a few minutes, the fish are always held in fresh water. If protocol is followed correctly, bio-photonic marking.

3. If protocol is followed correctly, fin clipping the adipose and pelvic fins can be done safely and quickly. However, when clipping many thousands of fish, a large amount of staff may be needed. Small fish 50 mm or under may pose some inaccuracy issues when clipping due to the small size of fin. Adipose fin clips may only receive a partial fin clip or may receive trauma to the body when attempting to clip the entire

fin. The pelvic fin is often hard to see due to its size and transparent color in smaller salmonids. This can pose a problem attempting to clip the pelvic fin or verifying the complete clipping of it.