Juvenile Salmonid Emigration Monitoring in the Lower Stanislaus River at Caswell Memorial State Park, California

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Abstract

Operation of the rotary screw traps on the lower Stanislaus River at Caswell Memorial State Park in 2018 is part of the U.S Fish and Wildlife Service's AFRP and CAMP under the NMFS RPA actions and CVPIA. 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*). Secondary objectives of the trapping operations focus on collecting fork length and weight data for juvenile salmonids and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, abundance, and production.

For the 2018 survey season, two 2.4 meter (8 foot) rotary screw traps (RSTs) were operated at Caswell Memorial State Park on the lower Stanislaus River in California. Sampling occurred on 122 of the 128 days between 12 January 2018 and 25 May 2018. A total of 3,515 fall-run juvenile Chinook salmon and one spring-run juvenile Chinook salmon was captured. The passage of juvenile fall-run Chinook salmon peaked during the weeks of 12 February and 19 February, when 47.65 percent (n = 1,675) was captured. A secondary peak in catch occurred during the weeks of 19 March and 26 March when 33.06 percent (n = 1,162) was captured. The majority of the captured juvenile Chinook salmon belonged to the button-up fry life stage; fewer numbers of the parr, silvery parr, and smolt life stages were also collected. No Chinook salmon captured were identified as yolk-sac fry life stage. Five trap efficiency trials were used to estimate the production of juvenile fall-run Chinook salmon. Trap efficiencies during those five trials ranged from 0.42 to 3.63 percent, with an average efficiency of 1.90 percent. The number of in-river produced juvenile fall-run Chinook salmon that were estimated to have emigrated past the Caswell trap site on the Stanislaus River during the 2018 survey season was 227,132 individuals (95 percent confidence intervals = 163,616 to 271,261). Finally, 432 individuals belonging to 16 different identifiable non-salmonid species were caught, 44 non-salmonid individuals were caught that were identified to family but were unable to be identified to species as well as one individual that was classified as an unidentified bony fish.

This annual report also includes seven appendices. Four of those appendices describe different environmental variables and studies related to the trap site or rotary screw trap operations during the 2018 survey season.

Introduction

The Stanislaus River is a tributary to the San Joaquin River, one of two main stem rivers of California's Central Valley watershed. This watershed once supported large populations of Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*Oncorhynchus mykiss*), the anadromous form of rainbow trout. However, over the past decade, these populations have undergone a widespread decline. The construction of impassable dams throughout the valley has reduced habitat availability for these fish populations by disrupting the natural gravel supply and distribution downstream. Additionally, hydraulic mining, over-harvesting, hydropower implementation, introduction of species, water diversions and other factors have contributed to the decline of these fish populations (Yoshiyama et al 2000, Lindley et al 2006, NMFS 2009). As a result, Chinook salmon and steelhead were listed as threatened under the Endangered Species Act (ESA) by NOAA's National Marine Fisheries Service (NMFS 2016).

In order to help protect, restore, mitigate and improve the natural production of juvenile Chinook salmon and steelhead in the Central Valley, the Central Valley Project Improvement Act (CVPIA) was established in 1992. The Fish Resource Area of the CVPIA includes all provisions under section 3406(b) to improve natural production of anadromous fish in Central Valley rivers and streams. The CVPIA Science Integration Team (SIT) was developed to use current data in decision support models (DSMs) and recommend Fish Resource Area priorities. Additionally, the CVPIA funded the San Joaquin River Restoration Program (SJRRP) to reintroduce spring-run Chinook salmon into the San Joaquin River. The success of this reintroduction as well as the continued improvement of natural production of anadromous fish is reliant upon continued monitoring throughout the watershed. Accordingly, the 2018 CVPIA annual work plan describes specific required projects, programs or monitoring activities, based on SIT recommended priorities, to be conducted which include the rotary screw trap monitoring program, Migratory Corridor Rehabilitation and Salmonid Spawning and Rearing Habitat Restoration on the Stanislaus River (CVPIA 1992, USBR 2018).

In 2009 NMFS completed their biological and conference opinion (NMFS BiOp) based on the U.S. Bureau of Reclamation's (USBR) proposed long-term operations of the Central Valley Project (CVP) and State Water Project (SWP), leading to Reasonable and Prudent Alternatives (RPA) intended to reduce the threat on ESA-listed species and negative impacts on crucial habitat. The RPA actions from the NMFS BiOp established requirements related to Stanislaus River operations which involve flow management and temperature control, restoration of freshwater migratory habitat, and adult escapement and juvenile monitoring for the Central Valley steelhead.

To meet flow management and temperature control requirements, as put forth in NMFS BiOp Appendix 2-E, the Stanislaus Operations Group (SOG) and USBR maintain a flow schedule that includes Vernalis Adaptive Management Plan (VAMP) fall and spring pulse flows. The fall pulse flows are meant to provide suitable temperatures to migrating and holding adult steelhead in October and November. After 1 March, spring pulse flows are initiated to protect incubating eggs, cue out-migrating juveniles, and signal incoming adult, potentially spring-run, Chinook salmon (NMFS 2009).

Recommended Central Valley stream restoration actions, outlined in the NMFS RPA and supported by the CVPIA's Anadromous Fish Restoration Program (AFRP), have resulted in multiple gravel restoration efforts to restore and create spawning and rearing habitat in the Stanislaus River. For example, in 2007 the Lover's Leap Restoration Project was completed where approximately 25,000 tons of gravel and cobble was placed within the 25.5 mile salmonid spawning reach (KDH 2008). Restoration also occurred at Lancaster Road where over 2 acres of floodplain and nearly 640 feet of side-channel habitat were restored (Cramer 2012). Restoration Projects still in progress include the Two Mile Bar Salmonid Habitat, creating a spawning side channel through a high floodplain, as well as other proposed projects.

Despite all efforts that have already been completed, continuous restoration, management and monitoring activities are needed to further aid the recovery of Chinook salmon and steelhead populations. To this end, NOAA Fisheries adopted a new ESA recovery plan in 2014 for Central Valley steelhead as well as Central Valley spring-run Chinook salmon and Sacramento River winter-run Chinook salmon. In 2016 a 5-year status review was completed by NMFS, determining that Chinook salmon and steelhead would remain threatened under the ESA (NMFS 2016), requiring the continuation of restoration and management activities. As the Stanislaus River is a top priority for steelhead reintroduction and a candidate for reintroduction of spring-run Chinook salmon, continued monitoring is important in determining how restoration activities and flow management affect the current salmonid populations.

There are two sites where rotary screw trap monitoring efforts occur on the lower Stanislaus River; Oakdale (river mile (RM) 40.1) and Caswell (RM 8.6). These sampling efforts, defined by the CVPIA and NMFS RPA actions, monitor juvenile salmonids to provide current and relevant data to the SIT and have been conducted since 1993 by California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), Cramer Fish Sciences (Cramer) or Pacific States Marine Fisheries Commission (PSMFC). This report describes efforts to determine the timing and abundance of emigrating juvenile salmonids using rotary screw traps (RSTs) on the lower Stanislaus River at Caswell Memorial State Park in 2018 as part of a larger effort to determine if habitat restoration activities and flow management regulations are improving

Chinook salmon production. Furthermore, this report presents data that describe the size and abundance of other native and non-native fish species in relation to the time of year, river discharge, and environmental conditions.

The primary objective of the lower Stanislaus River trapping operations is to collect data that can be used to estimate the production of juvenile fall-run Chinook salmon and observe abundance of steelhead. Secondary objectives of the trapping operations focus on collecting fork length and weight data for juvenile salmonids and gathering environmental data that will eventually be used to develop models that correlate environmental parameters with salmonid size, temporal presence, and abundance/production. An ancillary objective of the trapping operations is to collect non-salmonid fish species data that can be used to characterize the fish community in the Stanislaus River in the vicinity of the RSTs.

Study Area

The Stanislaus River headwaters begin on the western slope of the Sierra Nevada mountain range and cover an area of about 980 square miles (USBR 2017). The upper Stanislaus River consists of three forks (North, Middle and South) and tributaries which flow southwest into New Melones Reservoir. The lower Stanislaus River, located in Tuolumne, Calaveras and Stanislaus counties, is a major tributary to the San Joaquin River, which is the southern portion of California's Central Valley watershed. The San Joaquin River flows north and joins the Sacramento River in the Sacramento-San Joaquin Delta. The lower Stanislaus River is approximately 96.6 river kilometers (rkm) long from the base of Goodwin Dam to the confluence of the San Joaquin River and provides spawning and rearing habitat for fall-run Chinook salmon and Central Valley steelhead. The primary spawning habitat is relegated between Goodwin Dam (rkm 94) and Riverbank (rkm 54.7) (KDH 2008).

The lower Stanislaus River is regulated by three dams; New Melones Dam, Tulloch Dam and Goodwin Dam (Figure 1). These dams are operated by the USBR and the Tri-Dam Project to provide flood control, irrigation and agricultural use, power generation, and temperature regulation, and are also used to meet flow management requirements. Goodwin Dam is equally and jointly owned by the Oakdale (OID), South San Joaquin (SSJID), and the Stockton East Water irrigation districts (SEWID). The construction of the Melones Dam in 1926 and New Melones Dam in 1966 was believed to have been a factor in the extirpation of the spring-run Chinook salmon historically supported by the Stanislaus River.

The trapping site at Caswell Memorial State Park (rkm 13.8) was determined in 1993 to be the furthest location from the spawning area that allowed for trap deployment and access, and maintained flows consistent enough to operate rotary screw traps (Cramer 2006). Two 8 foot rotary screw traps were positioned in the thalweg of the channel near the Northern most corner of the State Park (Figure 2). The traps were designated as Trap 1 and Trap 2, with Trap 1 set closer to the southwestern bank of the river and Trap 2 set closer to the northeastern bank of the river (Figure 3). Access to the trapping site was gained through a private road.

Figure 1: Map of the Stanislaus River and rotary screw trap sites at Caswell Memorial State Park and Oakdale. Inset map illustrates the Stanislaus River in the state of California.

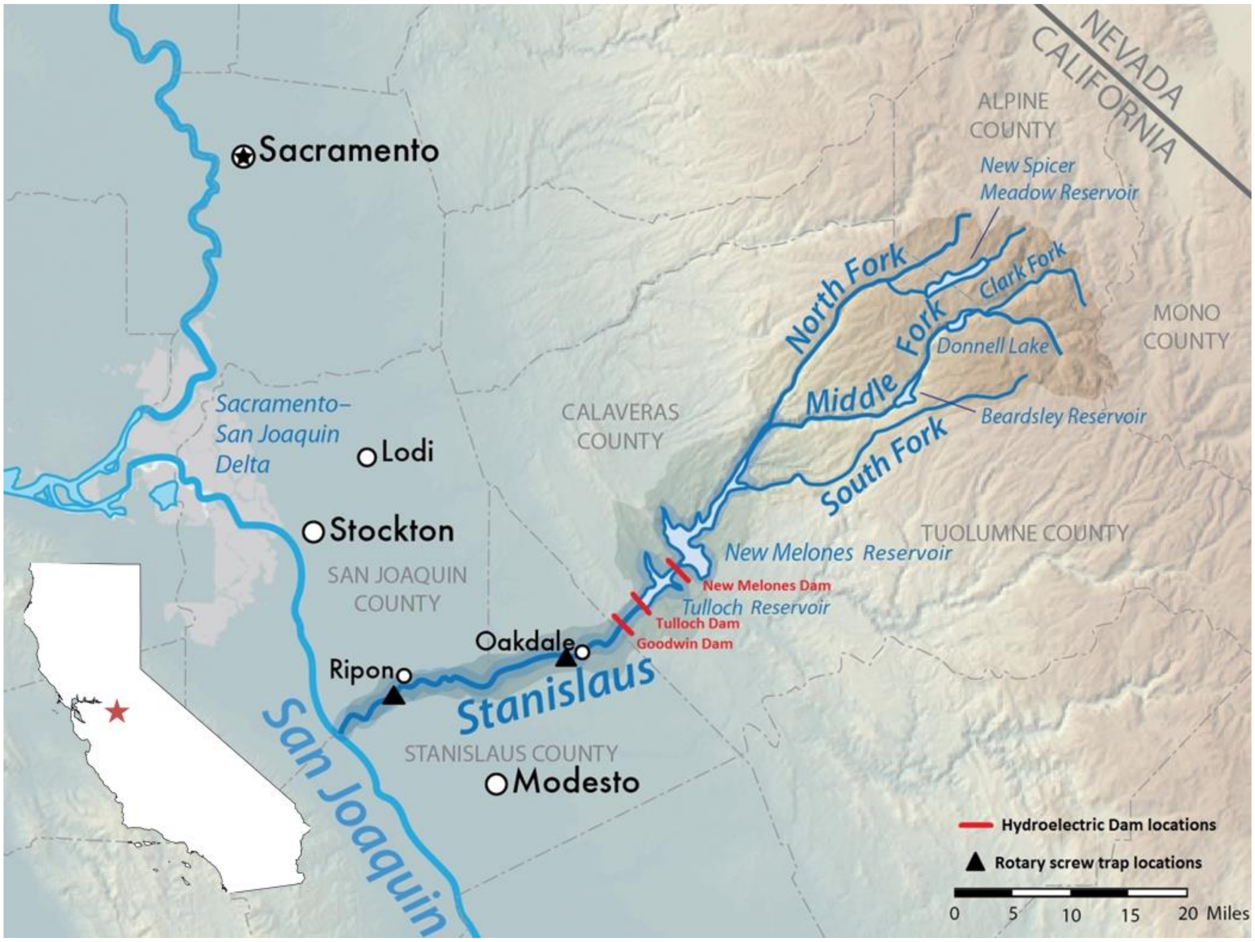
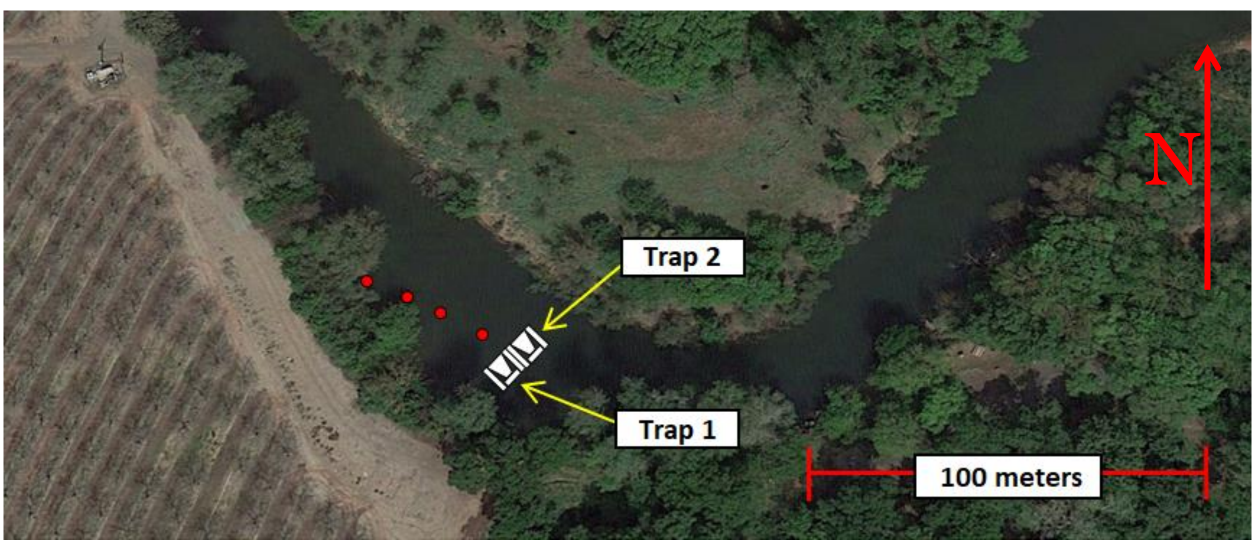


Figure 2: Operations map for the Stanislaus River Rotary Screw Trap Project.

Figure 3: Stanislaus River rotary screw trap site at Caswell Memorial State Park.



Methods

Trapping Operations

Sampling for the 2018 survey season started on 12 January and ended on 25 May. The two 2.4 meter (8 feet) diameter RSTs were fished in a side-by side configuration anchored in two separate locations. A ¼ inch galvanized cable, affixed with orange buoys and was secured to a tree upstream with a cable bridle attached to the outermost pontoon of each trap. An additional anchor rope was attached to the southwestern bank, allowing for in-channel adjustments. In order for the crew to board the traps, this anchor rope was also used to pull the traps to shore. Once crew members and field sampling gear were on board, the traps were then released back out into the thalweg to continue trapping while environmental data were collected and live wells were cleared.

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

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

Safety Measures

All crew members were trained on RST safety and personal flotation devices were worn at all times when members were on the RSTs. For night operations, crew members were required to affix a strobe light to their personal flotation devices that turned on automatically when submerged in water. Two 12-volt, 1260 lumens, LED flood lights were affixed to each trap.

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 outermost railings on the traps to alert the public at night that there was a potential navigation hazard. Orange or reflective buoys were placed on the anchor cable and bridal. Signs were installed upstream and downstream of the traps, warning river users of the proximity to the trap location.

Environmental Parameters

During every trap visit when fish were processed, environmental data were recorded. Temperature and dissolved oxygen were measured using a YSI dissolved oxygen meter (YSI EcoSense DO200A), velocity in front of each cone was recorded using a Global Water flow probe, and turbidity was measured using a Eutech portable turbidity meter (Eutech; Model TN-100). When river depth was 300 cm or less, 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-trap array, in line with the front of the trap cones. Average daily river discharge and average daily temperature for the Stanislaus River was determined using data from the U.S. Geological Survey's Stanislaus River at Ripon monitoring station (USGS station number 11303000).

Catch and Fish Data Collection

After environmental data was collected, the process of clearing out each RST's live well and fish work-up began. First, debris was removed from the live well and placed into 68.14 liter (L) tubs which crew members sifted through, setting aside or enumerating any fish, alive or dead, and enumerating debris volume by gallon. After all debris was removed, an assessment of debris type and volume was recorded. Next, the crew netted any remaining fish from the live well and placed them in 18.93 L buckets with lids, segregating salmonids from non-salmonids or potential predators. During periods of hot weather, fish were placed in buckets with aerators to provide them with oxygen and an ice pack to keep the water temperature at a safe level. If fish were held in buckets for a prolonged amount of time, oxygen depleted water was regularly exchanged with fresh river water.

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 one millimeter (mm), their life stage was assessed using the smolt index rating (Table 1), the presence of marks used during trap efficiency trials or absence of adipose fin clips were noted, and their mortality status (live vs. dead) was assessed. If Chinook salmon were ≥ 40 mm in fork length, the first 25 were weighed to the nearest 0.1 gram (g).

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

The 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 in an 18.93 L bucket designated for Chinook salmon subsampling. From the subsampled bucket, 100 Chinook salmon were randomly selected for analysis. Additional fall-run Chinook salmon in excess of the 100 that were present in the tub or trap live well were not measured and weighed, but each of these salmon were checked for marks, enumerated, and recorded on data sheets as a "live plus-count tally," or "mort plus-count tally." A "plus-count tally" was defined as the total number of fish that were caught in a trap on a given day, and that were not measured, weighed, or assigned a life stage.

If steelhead were captured, 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 steelhead was checked for the presence or absence of a mark (i.e., adipose fin clipped) and the weights of each individual ≥ 40 mm in fork length were recorded.

All other individuals belonging to non-salmonid taxa were enumerated and identified to species. For each trap, fork lengths of up to 50 randomly selected individuals of each species were recorded to the nearest mm and their mortality status was assessed. Because multiple entities in the Central Valley have a special interest in juvenile lamprey, an effort was made to distinguish between river lamprey (*Lampetra ayersii*) and Pacific lamprey (*Entosphenus tridentatus*). To distinguish between the two species, the number of lateral circumorals in the mouth was observed. River lampreys have three lateral circumorals, while Pacific lampreys have four (Reid 2012). Because the lateral circumorals in the larval stage of ammocoetes are not well developed, they were not identifiable to species.

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

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

Prior to collecting fish fork lengths and weights, individuals were anesthetized with sodium bicarbonate tablets (Alka-Seltzer Gold) to reduce stress as they were processed. One Alka-Seltzer tablet was added to one liter of water. Approximately eight to 10 fish, depending on size and crew manageability, were placed in a solution of river water and Alka-Seltzer, then measured and weighed. The crew routinely observed the gill activity of fish immersed in the solution; reduced gill activity was an indication fish were ready to be processed. After fish were measured and weighed, they were placed in an 18.93 L bucket with a mixture of fresh river water and stress coat additive (Poly-Aqua) to help replenish their slime coat as the fish recovered from the anesthetic. As soon as it was determined that the fish had fully recovered from anesthesia, all fish were released well downstream of the traps to prevent recapture.

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

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 a pigment dye marking method.

Pigment dye marking consisted of dying the whole body of a fall-run Chinook salmon 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 were held overnight and salmon caught the next day were added to achieve the minimum number of Chinook salmon required for a trap efficiency trial.

Once enough in-river produced Chinook salmon were available to conduct a trap efficiency trial, they were placed in a 68.14 L tub and stained using a solution of 0.6 g of BBY for every 20 L of river water. The actual amount of stain used varied depending on water turbidity and the number of salmon being stained. Salmon were stained for approximately two hours, and their condition was monitored during the staining process. After staining, salmon were rinsed with fresh river water and placed in a 75.71 L live cart, held overnight, and released at twilight the following day using the technique described below.

To evaluate the potential for a difference in size distribution between salmon released during a trap efficiency trial and associated recaptured salmon, 100 fork lengths from the released salmon were used to produce an average release length and compared with the average length of the recaptured salmon.

The release site was approximately 0.5 rkm upstream of the traps, located at the upper of two irrigation pumps. Two methods were used depending on river flows at the time of the release. At river flows of less than approximately 1,000 CFS, a kayak was used to release salmon. Position in the river was maintained by a rope tied from shore to shore. When river flows were greater than approximately 1,000 CFS, tagged fish were taken up to the release site using a small motorized boat. To avoid schooling when Chinook salmon were released, they were scattered across the width of the river channel using small dip nets. Every release of marked Chinook salmon occurred close to twilight to mimic natural migration patterns and avoid predation.

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

After each efficiency trial, a determination was made whether to include or exclude that trial from analysis. Factors that influenced this decision included success of fishing based on trap functionality, or other factors that might have adversely affected catch and therefore biased the resultant efficiency. If excluded from analysis, the trial was not used in the development of the generalized additive model (GAM) and did not influence overall trap efficiency. The calculation of the GAM is described below.

Passage Estimates

Fall-run Chinook salmon passage estimates were developed using a generalized additive model (GAM). Passage estimates were not developed for the other Chinook salmon runs because these runs are not known to spawn in the Stanislaus River. Passage estimates were also not developed for steelhead because Central Valley steelhead fry are believed to rear in-river for one to three years before they immigrate to the ocean as smolts (Moyle et al. 2008), at which point they become more difficult to capture, as their larger size increases their ability to avoid the traps.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Retention in Analysis

For every sampling period, a determination was made whether to include or exclude that period from analysis. Factors that influenced this decision included success of fishing based on trap functionality, or other factors that might have adversely affected catch.

If fishing was unsuccessful, a calculation was conducted using the clicker total and after cleaning RPMs to determine the amount of time the trap had been functioning normally. If this calculation indicated the trap had been functioning normally for at least 70 percent of the sampling period, the sampling period was kept in analysis. If the trap was determined to have been functioning normally for less than 70 percent of the sampling period, the period was excluded from analysis. Sampling periods excluded from analysis were treated by the CAMP platform like periods not fished and a catch estimate was produced based on Method #2, as described above. This estimated catch was then compared to the actual catch encompassing that sampling period. Under the assumption that abnormal trap function adversely affects catch, the higher of the two was considered to more accurately represent what would have been caught under normal trap function. Therefore any period with abnormal trap function was only excluded from analysis if the catch estimate produced was higher than what had actually been caught. Furthermore, if an unsuccessful trapping period was the first or last of the season, or if there were seven or more consecutive days of unsuccessful trapping the CAMP platform was unable to impute catch. Therefore, the actual catch was assumed to be more accurate and the period was included in analysis.

Confidence Intervals

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

Fulton’s Condition Factor

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

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

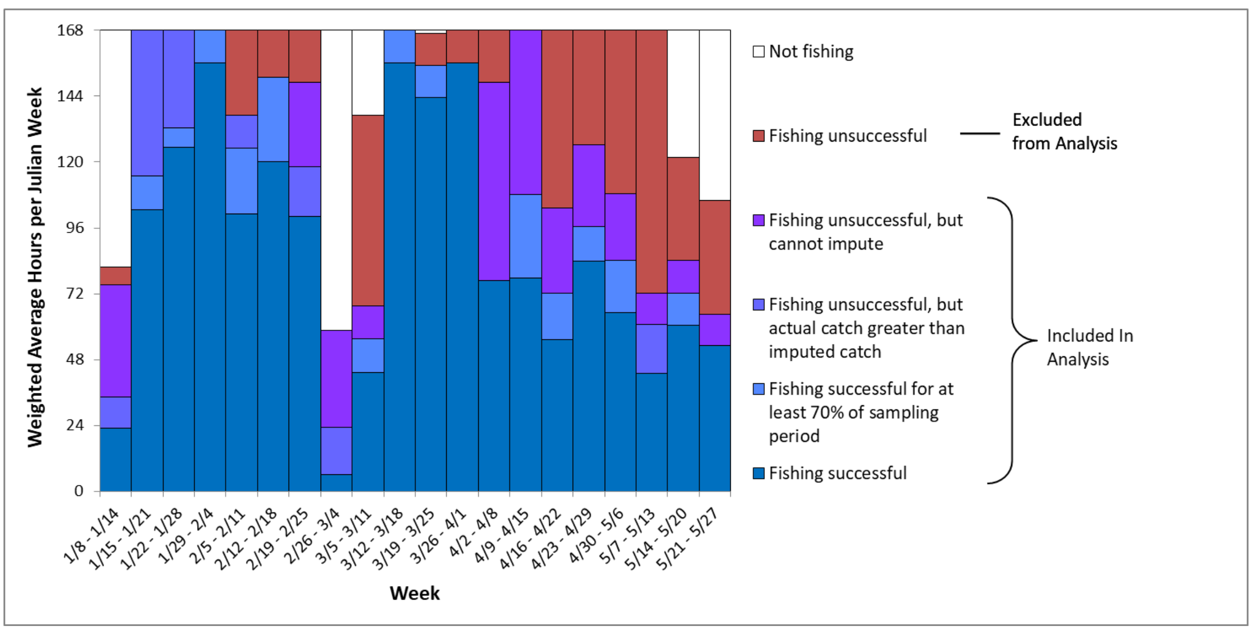
where *K* was the Fulton's condition factor, *W* was the weight in grams, and *FL* was the fork length in mm.

Results

Trap Operations

For the 2018 survey season, two 8ft RSTs were deployed in the Stanislaus River at the Caswell Memorial State Park and began sampling on 11 January 2018 at river flows of approximately 1,300 CFS. Continuous sampling occurred until 28 February when trapping was temporarily suspended to limit fish mortality. Sampling resumed on 4 March, fished continually until 18 May when cones were raised due to a personnel shortage, and then lowered on 20 May. Trap operations for the 2018 survey season ended on 25 May. As a result, sampling took place on 122 of the 128 days between 11 January and 25 May. During this time, the traps fished unsuccessfully (defined as a period of time during which the trap was fishing, but catch was determined to be adversely affected by abnormal trap function) for approximately 1,074 hours. Traps fished successfully for approximately 1,950 hours and did not fish for approximately 188 hours (Figure 4). Of the 1,074 hours of unsuccessful fishing, 548 were included in analysis despite abnormal trap function, following the process described in the Methods section of this report. As a result, a total of 2,497 hours of fishing were included in analysis and used to develop the passage estimate, and 527 hours of fishing were not included in analysis (Figure 4).

Figure 4: Weighted average hours per Julian week that both traps fished successfully, fished unsuccessfully, or did not fish during the 2018 Stanislaus River rotary screw trap survey season.

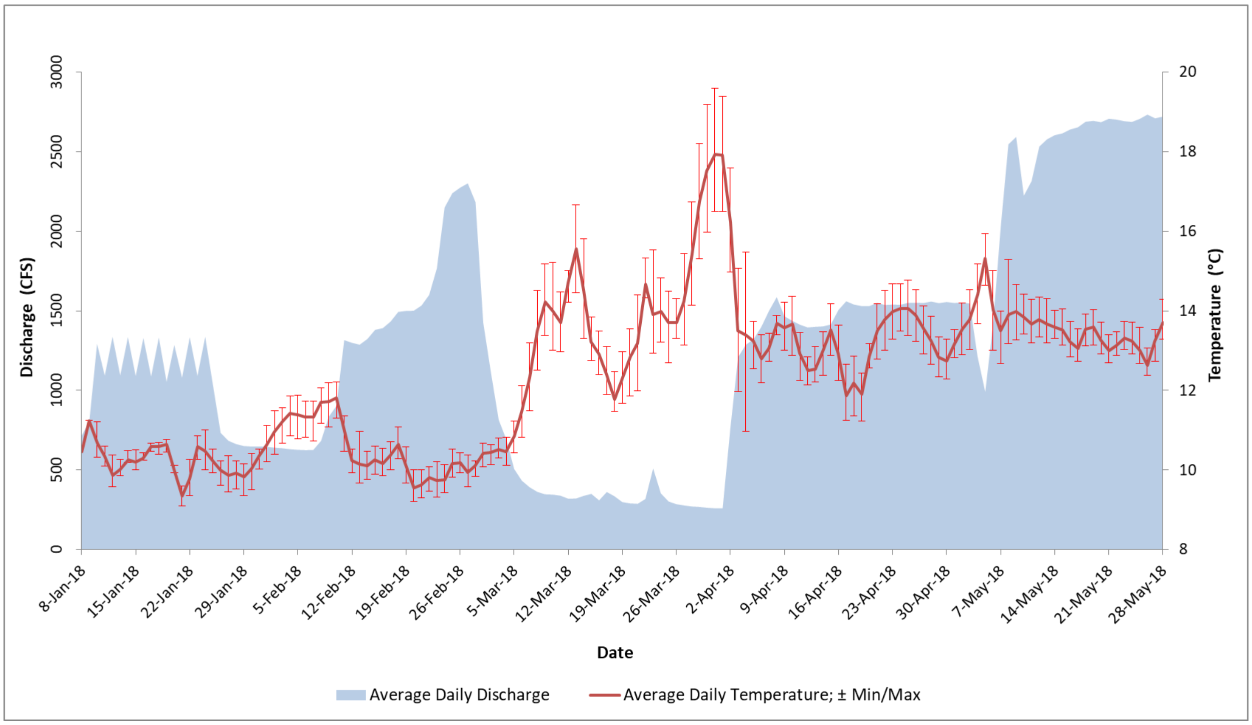


Environmental Summary

Appendix 2 provides a summary of the overall environmental conditions during the 2018 survey season, averaged by Julian week.

River discharge and temperature data, recorded in 15 minute increments, were acquired from the USGS station 11303000 on the Stanislaus River at Ripon, 12.5 rkm upstream of the RSTs. River discharge ranged from a low of 257 CFS on 31 March to a high of 2,740 CFS on 25 May (Figure 5). River temperature ranged from a low of 9.0° Celsius (C) on 21 January, to a high of 19.5° C on 1 April (Figure 5).

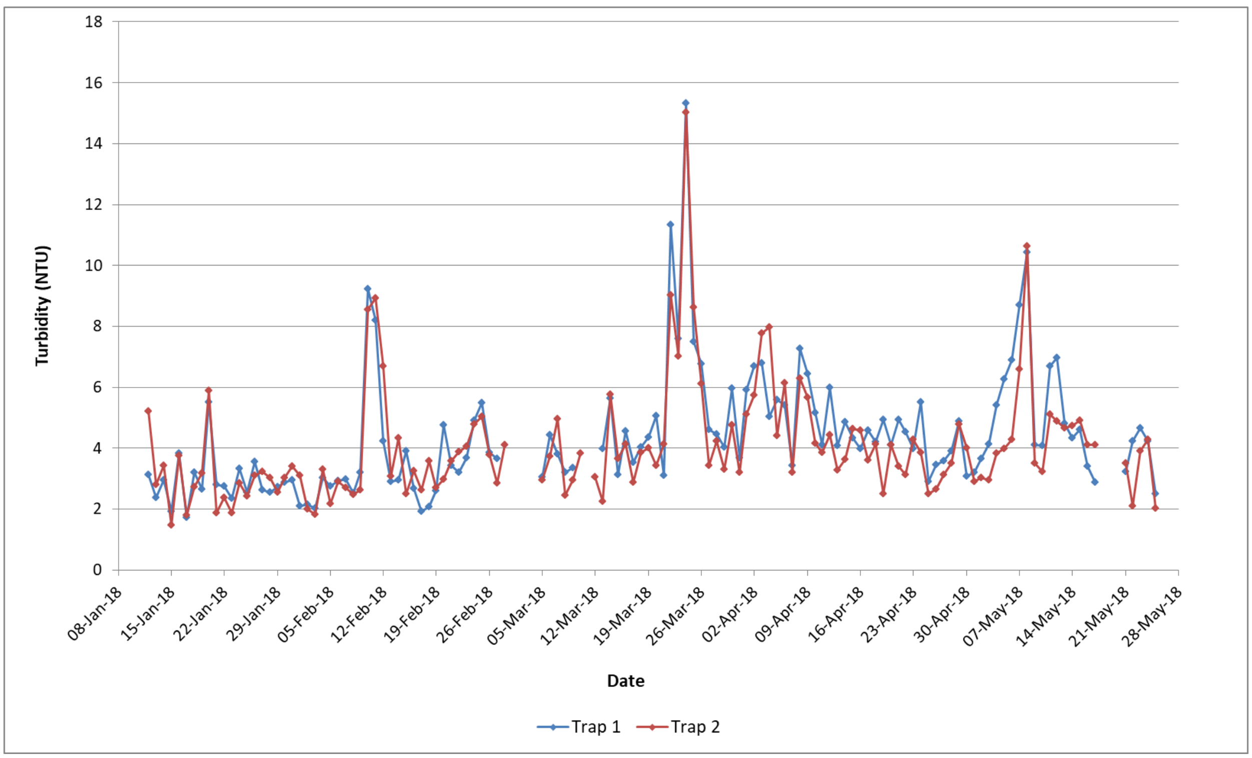
Figure 5: Average daily discharge (CFS) and average daily water temperature (°C), measured at Ripon, during the 2018 Stanislaus River rotary screw trap survey season.



Note: Discharge and water temperature data for the 8 January to 28 May time period were acquired from the USGS website at **http://waterdata.usgs.gov/ca/nwis/uv**

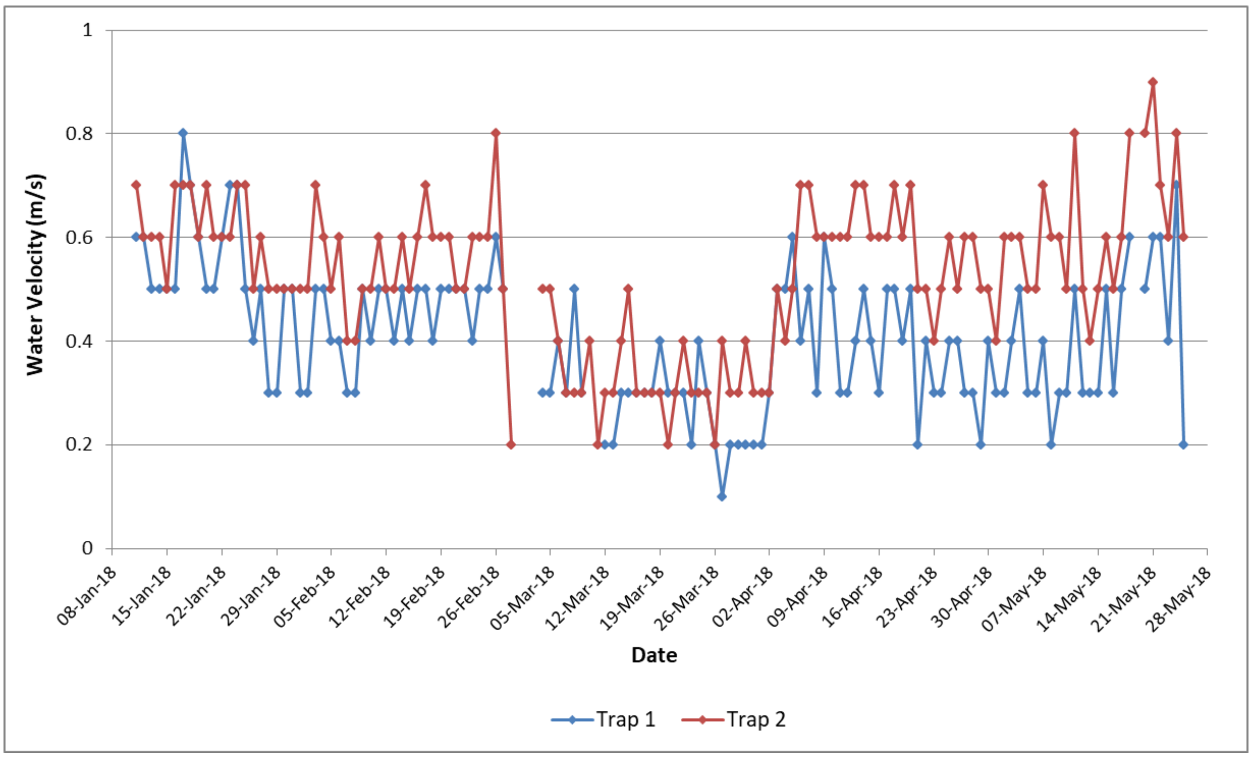
River turbidity was measured in the field, from water samples taken daily from each trap. Turbidity did not vary considerably between traps (Figure 6), but on average was slightly higher for Trap 1 (southwest side) than for Trap 2 (northeast side). Turbidity for both traps reached a season maximum on 24 March, with 15.32 Nephelometric Turbidity Units (NTU) for Trap 1 and 15.02 NTU for Trap 2. Turbidity for Trap 1 reached a season low on 17 January, with 1.71 Nephelometric Turbidity Units (NTU). The season low for Trap 2 came on 15 January with an NTU of 1.48. Weekly average turbidity across both traps, averaged by Julian week, is shown in Appendix 2. Weekly average turbidity reached a high of 7.54 NTU during the week of 19 March and had a weekly average low of 2.65 NTU during the week of 29 January.

Figure 6: Comparison of daily turbidity measured in the field during the 2018 Stanislaus River rotary screw trap survey season.



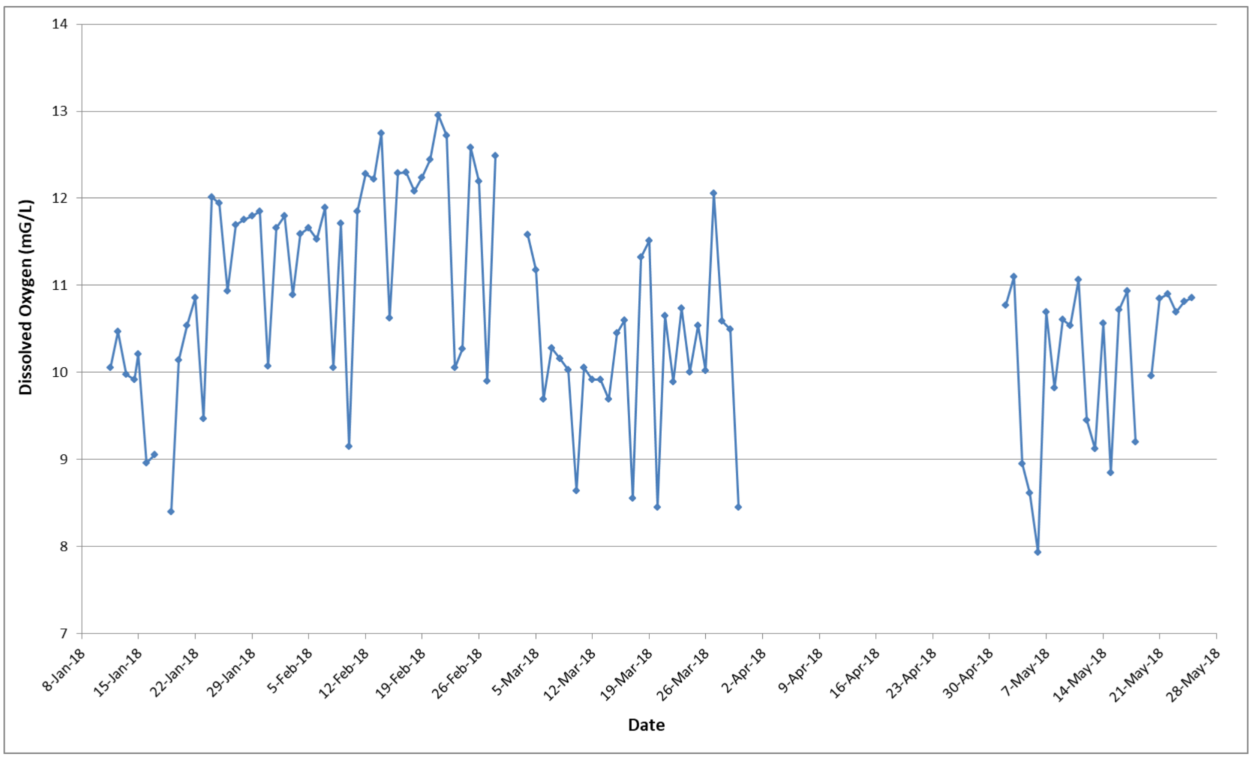
Water velocities (Figure 7) were also measured for each trap on a daily basis, and were taken from in front of each cone. Water velocities in front of Trap 2 (northeast side) were on average higher than for Trap 1 (southwest side). Water velocities in front of Trap 2 reached a low of 0.2 meters per sec (m/s) on 4 days between 28 February and 26 March, and reached a high of 0.9 m/s on 21 May. Water velocities in front of Trap 1 ranged from a low of 0.1 m/s on 27 March to a high of 0.8 m/s on 17 January. Weekly water velocity averaged across both traps by Julian week, is shown in Appendix 2. Weekly average water velocity ranged from a low of 0.26 m/s for the week of 26 March to a high of 0.63 m/s for the week of 15 January.

Figure 7: Comparison of water velocities measured daily in the field in front of each trap during the 2018 Stanislaus River rotary screw trap survey season.



Dissolved oxygen (DO) in the river water (Figure 8), taken in the field as a single daily measurement, ranged from a low of 7.93 milligrams per liter (mg/l) on 6 May to a high of 12.95 mg/l on 21 February. Weekly average DO (Appendix 2) for the 2018 survey season, averaged by Julian week, ranged from a low of 9.47 mg/l for the week of 30 April to a high of 12.08 mg/L for the week of 12 February. DO measurements were excluded from 31 March through 1 May due to a probe malfunction.

Figure 8: Daily dissolved oxygen content measured in the field during the 2018 Stanislaus River rotary screw trap survey season.



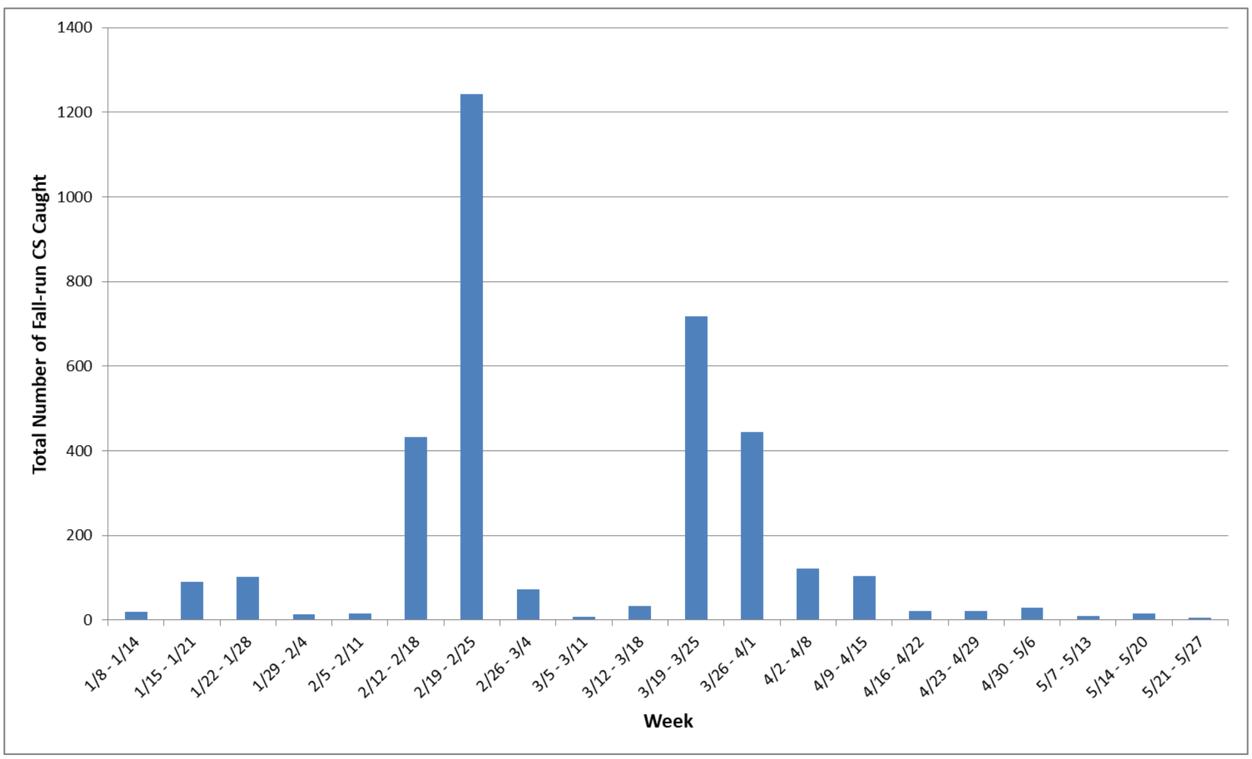
Catch

The two rotary screw traps deployed during the 2018 survey season captured a total of 3,993 fish. Trap 1 (south western side) captured 42.30 percent (n = 1,689) of these fish, and Trap 2 (north eastern side) captured 57.70 percent (n = 2304). Chinook salmon were the only salmonid species captured. Seventeen identified non-salmonid species were also captured as well as 43 individual non-salmonids that were unable to be identified to species (Appendix 3).

Fall-run Chinook salmon

Of the 3,993 fish captured during the 2018 survey season, a total of 3,515 of these were in-river produced, unmarked fall-run Chinook salmon (Figure 9). Catch of in-river produced, unmarked fall-run Chinook salmon peaked during the weeks of 12 February and 19 February, when 47.65 percent (n = 1,675) was captured. A secondary peak in catch occurred during the weeks of 19 March and 26 March when 33.06 percent (n = 1,162) was captured. The single day with the highest catch of fall-run Chinook salmon was 24 February, when 374 were captured.

Figure 9: Weekly catch distribution of in-river produced, unmarked fall-run Chinook salmon during the 2018 Stanislaus River rotary screw trap survey season.



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

A total of 2,928 of the 3,515 in-river produced, unmarked fall-run Chinook salmon captured were measured for fork length. The weekly average fork length (Figure 10 and Table 2) began at 36.55 mm during the first week of sampling, decreased to a season low of 34.36 mm the week of 29 January, then increased to a season high of 84.38 mm the week of 7 May. During the week of 21 May when trapping was terminated for the season, the weekly average fork length was 82.80 mm.

Figure 10: Average weekly fork length for fall-run Chinook salmon during the 2018 Stanislaus River rotary screw trap survey season.

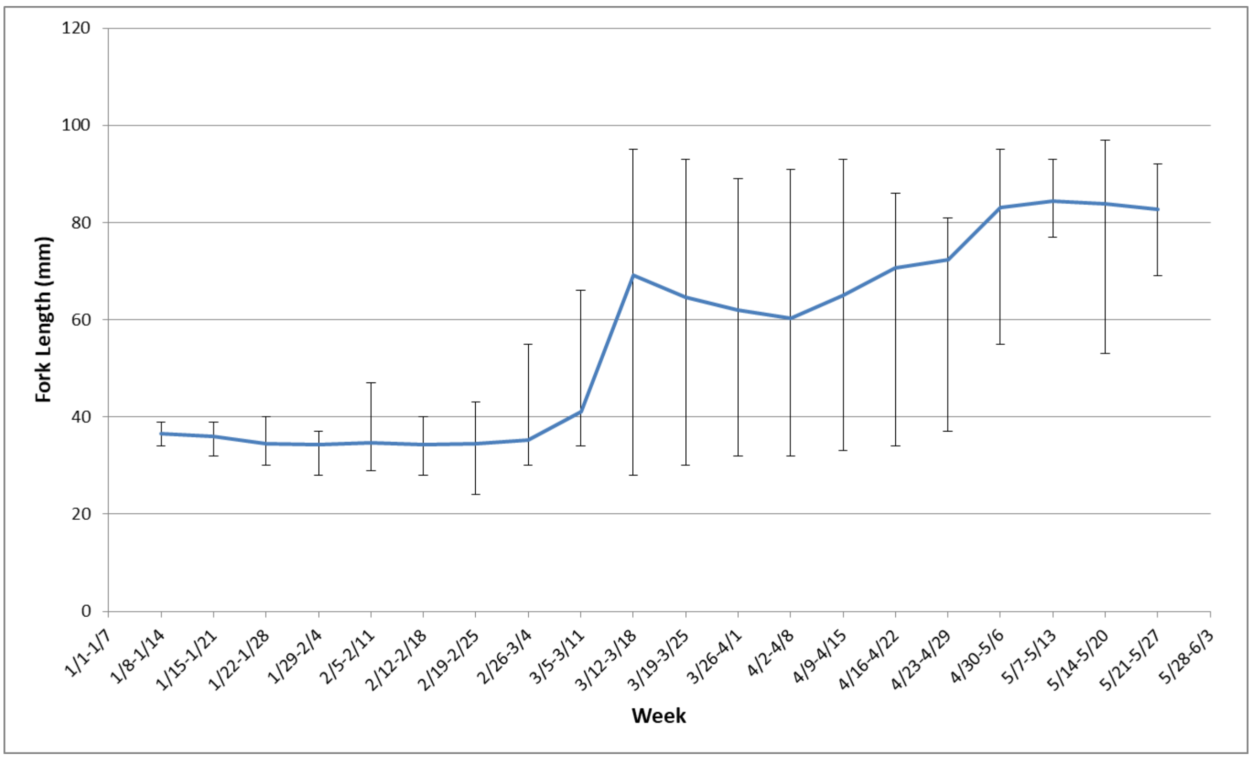
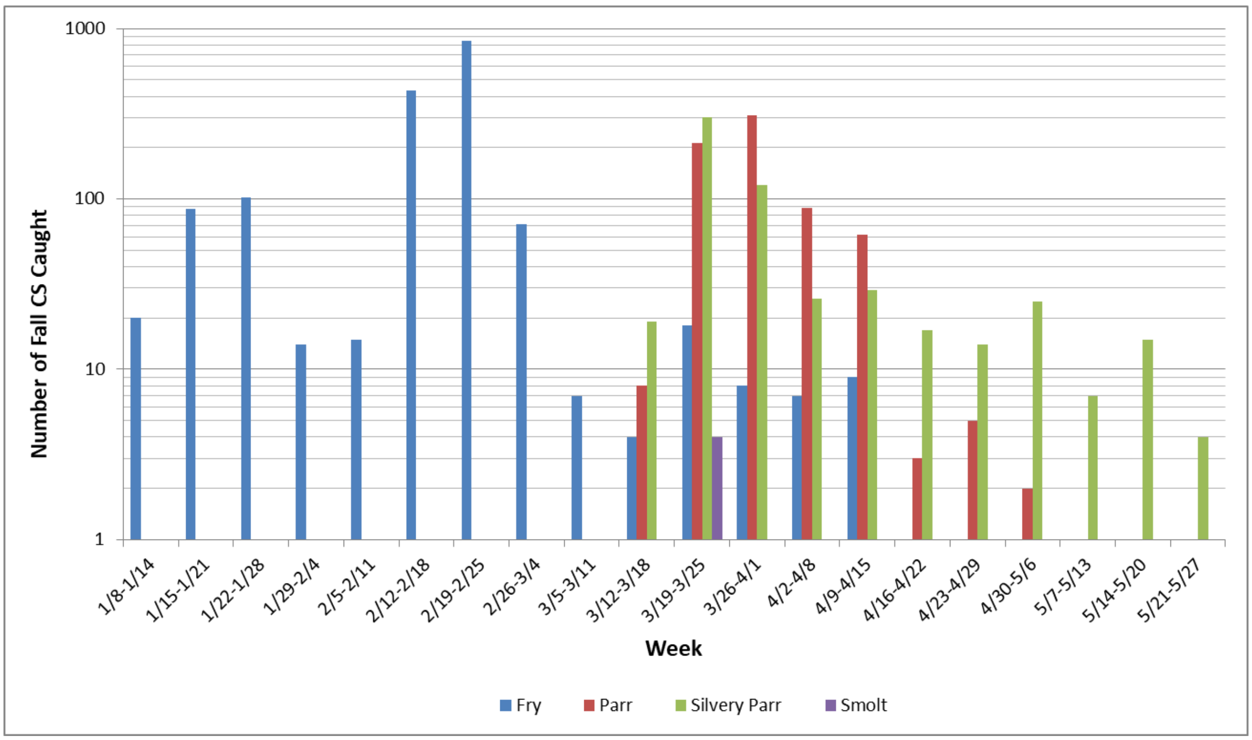


Table 2: Average, minimum, maximum and standard deviations of fork lengths (mm) per week for fall-run Chinook salmon during the 2018 Stanislaus River rotary screw trap survey season.

Julian Week	Fork Length			
	Average	Min	Max	St. Dev.
1/8-1/14	37	34	39	1.47
1/15-1/21	36	32	39	1.16
1/22-1/28	34	30	40	1.70
1/29-2/4	34	28	37	2.53
2/5-2/11	35	29	47	4.89
2/12-2/18	34	28	40	2.24
2/19-2/25	35	24	43	2.22
2/26-3/4	35	30	55	3.10
3/5-3/11	41	34	66	10.59
3/12-3/18	69	28	95	18.16
3/19-3/25	65	30	93	13.09
3/26-4/1	62	32	89	10.78
4/2-4/8	60	32	91	11.40
4/9-4/15	65	33	93	12.08
4/16-4/22	71	34	86	10.40
4/23-4/29	72	37	81	10.49
4/30-5/6	83	55	95	9.30
5/7-5/13	84	77	93	5.88
5/14-5/20	84	53	97	10.34
5/21-5/27	83	69	92	8.47

Of the in-river produced, unmarked fall-run Chinook salmon measured for fork length, a total of 2,927 were also assessed for life stage (Figure 11 and Table 3). The majority of this total was salmon identified as fry life stage, which accounted for 56.20 percent (n =1,645) of the assessed catch. Salmon identified as parr life stage comprised 23.81percent (n = 697), silvery parr were 19.78 percent (n = 579), and smolt were 0.20 percent (n = 6). No salmon identified as yolk-sac fry life stage were captured.

Figure 11: In-river produced, unmarked fall-run Chinook salmon catch by life stage during the 2018 Stanislaus River rotary screw trap survey season.



Note: Since the *y*-axis scale is logarithmic, weeks where one Chinook salmon of a given life stage was captured do not appear in the graph. See table 3 for weeks with a catch of one. Plus-counted fall-run Chinook salmon are not included in the graph.

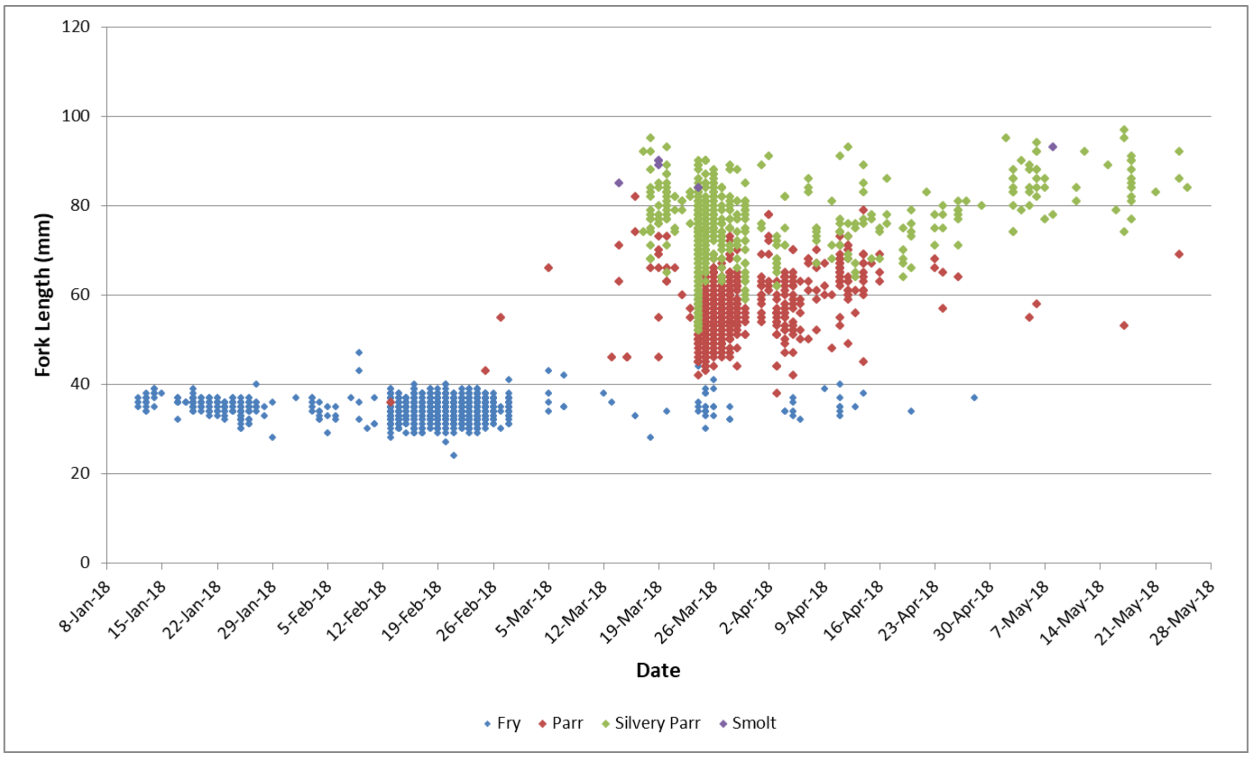
Table 3: Total of in-river produced, unmarked fall-run Chinook salmon by life stage or unassigned life stage during the 2018 Stanislaus River rotary screw trap survey season.

Julian Week	Fry	Parr	Silvery parr	Smolt	Unassigned Life Stage	Total
1/8 - 1/14	20	0	0	0	0	20
1/15 - 1/21	87	0	0	0	3	90
1/22 - 1/28	102	0	0	0	0	102
1/29 - 2/4	14	0	0	0	0	14
2/5 - 2/11	15	0	0	0	0	15
2/12 - 2/18	431	1	0	0	0	432
2/19 - 2/25	850	1	0	0	392	1,243
2/26 - 3/4	71	1	0	0	0	72
3/5 - 3/11	7	1	0	0	0	8
3/12 - 3/18	4	8	19	1	0	32
3/19 - 3/25	18	213	303	4	179	717
3/26 - 4/1	8	309	120	0	8	445
4/2 - 4/8	7	89	26	0	0	122
4/9 - 4/15	9	62	29	0	3	103
4/16 - 4/22	1	3	17	0	0	21
4/23 - 4/29	1	5	14	0	1	21
4/30 - 5/6	0	2	25	0	1	28
5/7 - 5/13	0	0	7	1	1	9
5/14 - 5/20	0	1	15	0	0	16
5/21 - 5/27	0	1	4	0	0	5
Total	**1,645**	**697**	**579**	**6**	**588**	**3,515**

Note: Unassigned life stage includes plus-counts.

As shown in Figure 12, Chinook salmon identified as fry life stage were captured between 12 January and 28 April, and salmon identified as parr life stage were caught between 13 February and 24 May. Chinook salmon identified as silvery parr life stage were captured starting 18 March to the last day of the survey season on 25 May, and salmon identified as smolt life stage were caught between 14 March and 8 May.

Figure 12: Daily fall-run Chinook salmon fork lengths during the 2018 Stanislaus River rotary screw trap survey season.



For each identified life stage of measured fall-run Chinook salmon, fork length distributions varied (Table 4). Salmon identified as fry life stage ranged from 28 mm to 46 mm. Parr life stage ranged from 36 mm to 82 mm, and silvery parr ranged between 52 mm and 97 mm. Smolt life stage ranged from 84 mm to 93 mm.

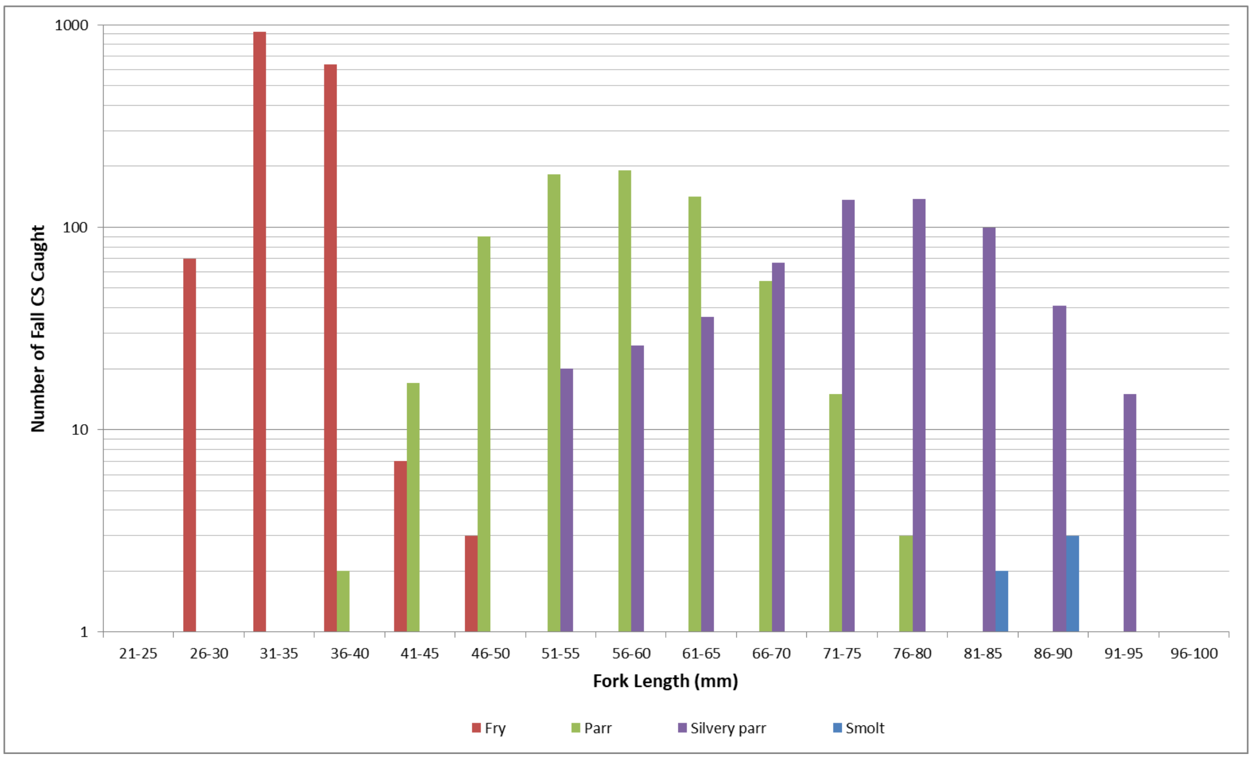
Weekly average fork lengths increased by life stage progression with fry life stage having the lowest weekly average fork lengths, and smolt life stage having the largest weekly average fork lengths (Figure 13). Overall average fork length for each life stage also increased according to life stage progression. Salmon identified as fry life stage had an average folk length of 35 mm. Salmon identified as parr life stage had an average of 57 mm, silvery parr had an average of 79 mm and smolt had an average of 89 mm.

Table 4: Average, minimum and maximum fork lengths (mm) per week for each stage of fall-run Chinook salmon during the 2018 Stanislaus River rotary screw trap survey season.

Julian	Fry			Parr			Silvery Parr			Smolt		
Week	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
1/8 - 1/14	37	34	39									
1/15 - 1/21	36	32	39									
1/22 - 1/28	34	30	40									
1/29 - 2/4	34	28	37									
2/5 - 2/11	35	29	47									
2/12 - 2/18	34	28	40	36	36	36						
2/19 - 2/25	35	24	40	43	43	43						
2/26 - 3/4	35	30	41	55	55	55						
3/5 - 3/11	38	34	43	66	66	66						
3/12 - 3/18	34	28	38	62	46	82	79	68	95	85	85	85
3/19 - 3/25	37	30	46	54	42	73	73	52	93	88	84	90
3/26 - 4/1	35	32	41	57	44	75	76	59	89			
4/2 - 4/8	34	32	37	59	38	78	73	62	91			
4/9 - 4/15	36	33	40	64	45	79	75	64	93			
4/16 - 4/22	34	34	34	66	63	69	74	64	86			
4/23 - 4/29	37	37	37	64	57	68	77	71	81			
4/30 - 5/6				57	55	58	85	74	95			
5/7 - 5/13							83	77	92	93	93	93
5/14 - 5/20				53	53	53	86	74	97			
5/21 - 5/27				69	69	69	86	83	92			

Catch totals distributed by 5 mm fork length size classes are shown in Figure 13 and Table 5. Chinook salmon measured to be between 31 mm and 40 mm were captured most frequently. The size class between 31 mm and 35 mm, consisting of only fry life stage, comprised 31.67 percent (n = 927) of the 2018 survey season's total catch, and the size class between 36 mm and 40 mm, consisting of fry and parr life stages, comprised 21.83 percent (n =639).

Figure 13: Distribution of fall-run Chinook salmon life stage by fork length during the 2018 Stanislaus River rotary screw trap survey season.



Note: Plus-counted fall-run Chinook salmon are not included in the graph. Since the *y*-axis scale is logarithmic, fork length categories containing only one salmon are not shown in the graph. See table 5 for categories represented by only one individual.

Table 5: Distribution of fall-run Chinook salmon life stage by fork length size class during the 2018 Stanislaus River rotary screw trap survey season.

Fork Length Size Class	Fry	Parr	Silvery Parr	Smolt	Total
21-25	1	0	0	0	1
26-30	70	0	0	0	70
31-35	927	0	0	0	927
36-40	637	2	0	0	639
41-45	7	17	0	0	24
46-50	3	90	0	0	93
51-55	0	183	20	0	203
56-60	0	191	26	0	217
61-65	0	141	36	0	177
66-70	0	54	67	0	121
71-75	0	15	136	0	151
76-80	0	3	138	0	141
81-85	0	1	99	2	102
86-90	0	0	41	3	44
91-95	0	0	15	1	16
96-100	0	0	1	0	1

Fulton's Condition Factor

Fulton's condition factor (K) for in-river produced, unmarked fall-run Chinook salmon captured in 2018 displayed a slightly increasing trend in condition throughout the survey season (Appendix 5). The overall trend line exhibited a positive slope of 0.0012. The trend line slopes were positive for parr (0.0022), silvery parr (0.0006) and smolt (0.0013) life stages; however the fry life stage had a slightly negative slope of -0.0005. Yolk-sac fry captured in 2018 were unable to be assessed for Fulton's condition factor as every fish identified with this life stage was measured below 40 mm and was therefore not weighed.

Trap Efficiency

Five mark-recapture trap efficiency trials were conducted throughout the 2018 survey season, all of which were included in analysis and used by the CAMP platform to determine passage estimates (Table 6). These trials used a total of 3,391 hatchery produced fall-run Chinook salmon from Merced Fish Hatchery; no in-river produced salmon were used for these trials. A total of 66 released salmon was recaptured. For the five trials in which fish were recaptured, the average fork length of recaptured fish was approximately 2 mm smaller than the average fork length of released fish, and per trial ranged from a difference of approximately 2 mm larger to 1 mm smaller. The average trap efficiency of the five trials kept in analysis and used to determine passage estimates was 1.90 percent.

Table 6: Trap efficiency data for mark and recapture trials during the 2018 Stanislaus River rotary screw trap survey season.

Date	Fish Origin	Mark Color	Location	Release ID Code	Included in Analysis	Date	Time	Average FL (mm)	Total Released	Trial Day 1	2	3	4	5	6	7	Total Recaptured	Average FL (mm)	Trap Efficiency	Flow (CFS) Time of Release
BBY Staining						Release				Recaptures for all Traps Combined							Recapture Summary			
2/20/2018	Hatchery	Brown	Whole Body	310	Yes	2/20/2018	17:25	43	700	12	1	0	0	0	0	0	13	45	1.86%	1,510
3/13/2018	Hatchery	Brown	Whole Body	311	Yes	3/13/2018	17:35	55	729	11	5	0	0	0	0	0	16	54	2.19%	328
Fin Clip						Release				Recaptures for all Traps Combined							Recapture Summary			
3/27/2018	Hatchery	N/A	Upper Caudal	312	Yes	3/27/2018	18:53	62	744	27	0	0	0	0	0	0	27	63	3.63%	275
Photonic Marking						Release				Recaptures for all Traps Combined							Recapture Summary			
4/11/2018	Hatchery	Green	Anal Fin	313	Yes	4/11/2018	19:09	71	720	3	0	0	0	0	0	0	3	73	0.42%	1,390
4/25/2018	Hatchery	Green	Anal Fin	314	Yes	4/25/2018	19:20	82	498	7	0	0	0	0	0	0	7	83	1.41%	1,540

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

Hatchery = Merced Fish Hatchery.

BBY = Bismark brown Y whole body stain.

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

Included in Analysis: indicates if the trial was used by the CAMP RST platform to determine passage estimates.

Flow (CFS) is the discharge acquired from the USGS station 11303000 on the Stanislaus River at Ripon, 12.5 rkm upstream of the RSTs at the day and time of the trap efficiency release.

Passage Estimate for Fall-run Chinook salmon

According to the CAMP platform "run_passage" report, a total of 222,000 in-river produced fall-run Chinook salmon were estimated to have emigrated past the Caswell Memorial State Park rotary screw trap location on the Stanislaus River during the 2018 survey season. The 95 percent confidence interval for this estimate was from 162,000 to 293,500 individuals. The CAMP platform "lifestage_passage" report, which subdivides a passage estimate by life stage, estimated a total of 138,800 fry (including both yolk-sac fry and fry life stages), 79,750 parr (including both parr and silvery parr life stages), and 455 smolts emigrated past the trap location during the 2018 survey season.

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

Figure 14: Daily passage estimate of fall-run Chinook salmon and daily discharge at Ripon during the 2018 Stanislaus River rotary screw trap survey season.

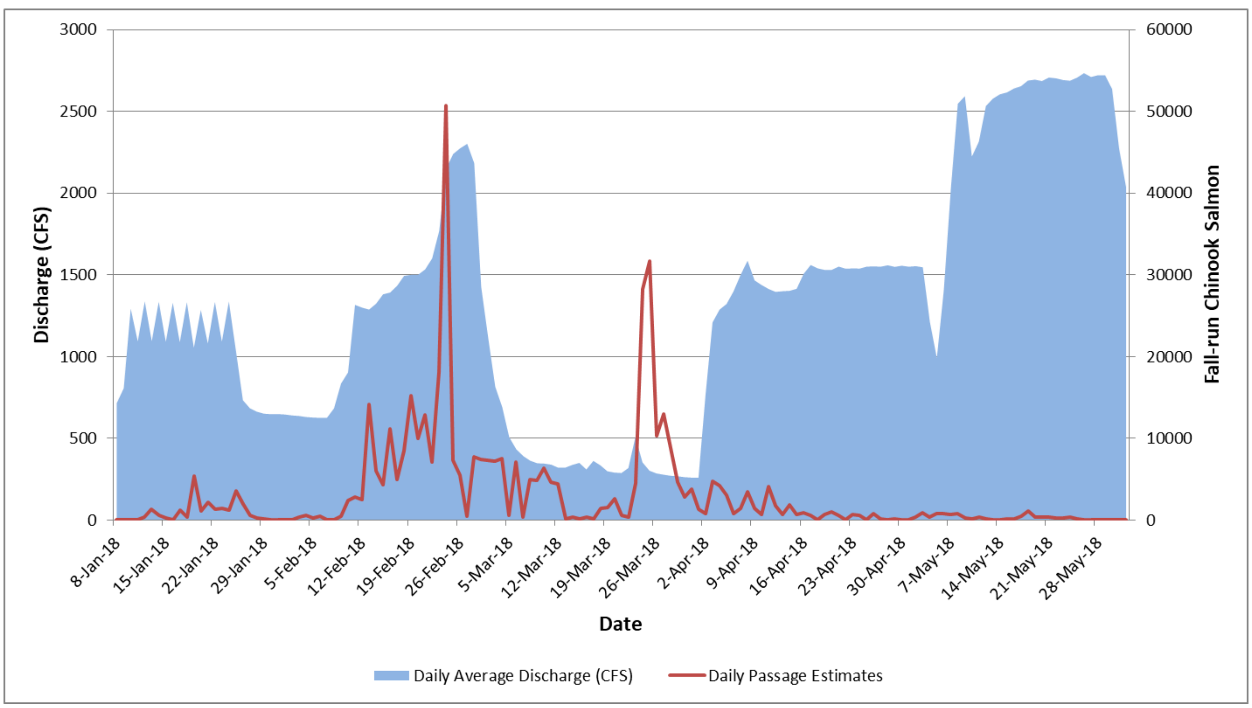


Table 7: Weekly passage estimate of fall-run Chinook salmon and weekly discharge at Ripon during the 2018 Stanislaus River rotary screw trap survey season.

Date	Discharge (CFS)	Passage Estimate
1/8 - 1/14	1,096	2,337
1/15 - 1/21	1,180	10,484
1/22 - 1/28	983	10,312
1/29 - 2/4	643	1,189
2/5 - 2/11	802	6,472
2/12 - 2/18	1,373	51,781
2/19 - 2/25	1,756	121,351
2/26 - 3/4	1,543	43,144
3/5 - 3/11	389	28,601
3/12 - 3/18	334	6,954
3/19 - 3/25	337	69,651
3/26 - 4/1	269	44,713
4/2 - 4/8	1,295	18,579
4/9 - 4/15	1,419	11,264
4/16 - 4/22	1,536	3,842
4/23 - 4/29	1,548	2,452
4/30 - 5/6	1,403	3,163
5/7 - 5/13	2,402	2,481
5/14 - 5/20	2,655	2,634
5/21 - 5/27	2,706	1,365

Genetic Analysis

During the 2018 survey season genetic analysis using SNP genetic markers was conducted on a total of 52 samples taken from in-river produced juvenile Chinook salmon captured in the RSTs. The SNP panel's "Genetic Call to four lineages" probabilities for each of the 52 samples exceeded a 50 percent threshold; the final salmon run assignments for those salmon were therefore made based on genetic data. A complete accounting of the final salmon run assignments made using genetic markers is provided in Appendix 4.

A total of 377 in-river produced Chinook salmon captured in 2018 were classified as spring-run Chinook salmon using LAD criteria. Genetic samples taken from 45 of these salmon were analyzed to determine run assignments. The analyses indicated 97.78 percent (n=44) of those individuals were fall-run Chinook salmon, and one was a spring-run Chinook salmon that likely originated from Mill-Deer Creek (Table 8). Since the LAD criteria appeared to incorrectly assign salmon runs at a high frequency, the 332 LAD spring-run Chinook salmon that were not analyzed using genetic markers were given a final run assignment of fall-run.

A total of four Chinook salmon classified as winter-run Chinook salmon using LAD criteria were captured during the 2018 survey season. Genetic samples were taken from two fish and were analyzed to determine run assignments. Analyses using SNP genetic markers from those samples indicated both individuals (100.00 percent) were fall-run Chinook salmon (Table 8). Because the LAD criteria appeared to incorrectly assign this salmon run, the two LAD winter-run Chinook salmon that were not analyzed using genetic markers were given a final run assignment of fall-run.

A total of seven Chinook salmon classified as late fall-run Chinook salmon using LAD criteria were also captured in 2018. Genetic samples were taken from five of these and were analyzed to determine run assignments. Analyses using SNP genetic markers from those samples indicated both individuals (100.00 percent) were fall-run Chinook salmon (Table 8). Because the LAD criteria appeared to incorrectly assign this salmon run, the two LAD late fall-run Chinook salmon that were not analyzed using genetic markers were given a final run assignment of fall-run.

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

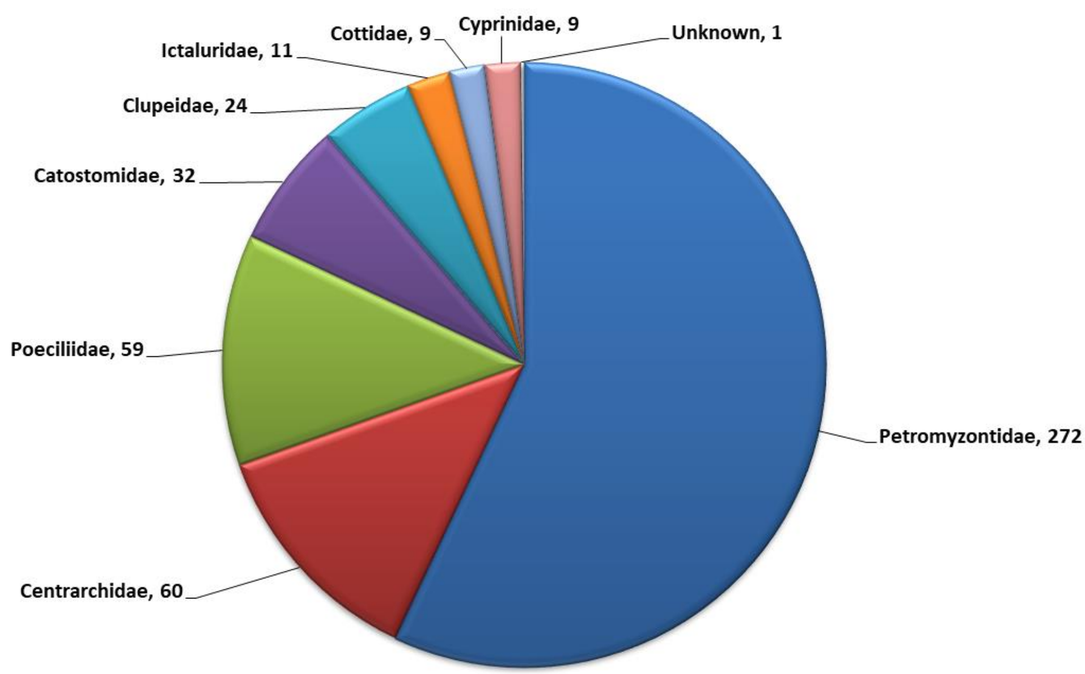
The genetic analysis results suggest that one in-river produced spring-run Chinook salmon was captured during the 2018 survey season. This was captured on 24 March and was identified as a silvery parr life stage. This individual had a fork length of 76 mm, which was 19 mm larger than the average fork length of fall-run Chinook salmon captured on that day.

Genetic analysis suggests that no winter-run Chinook salmon were captured during the 2018 survey season. The genetic analysis also suggests that no late fall-run Chinook salmon were captured.

Non-salmonid Species

In addition to the salmon, 477 non-salmonid fish were captured during the 2018 survey season. The majority (n = 432, or 90.57 percent) of these fish belonged to 16 identified species in the following families: *Catostomidae* (sucker), *Centrarchidae* (sunfish/black bass), *Clupeidae* (shad), *Cottidae* (sculpin), *Cyprinidae* (minnow), *Ictaluridae* (bullhead/catfish), *Petromyzontidae* (lamprey), and *Poeciliidae* (mosquitofish) (Figure 15). A total of 44 (9.22 percent) were not able to be identified to species level, but belonged to the following families: *Centrarchidae, Cottidae*, *Cyprinidae*, and *Ictaluridae*. The remaining individual was not able to be identified to family level. Of the non-salmonid fish captured in 2018, a total of 316 (66.25 percent) are of species native to Central Valley watersheds, and a total of 161 (33.75 percent) are of non-native species. A complete list of non-salmonid species captured in the 2018 survey season is presented in Appendix 3.

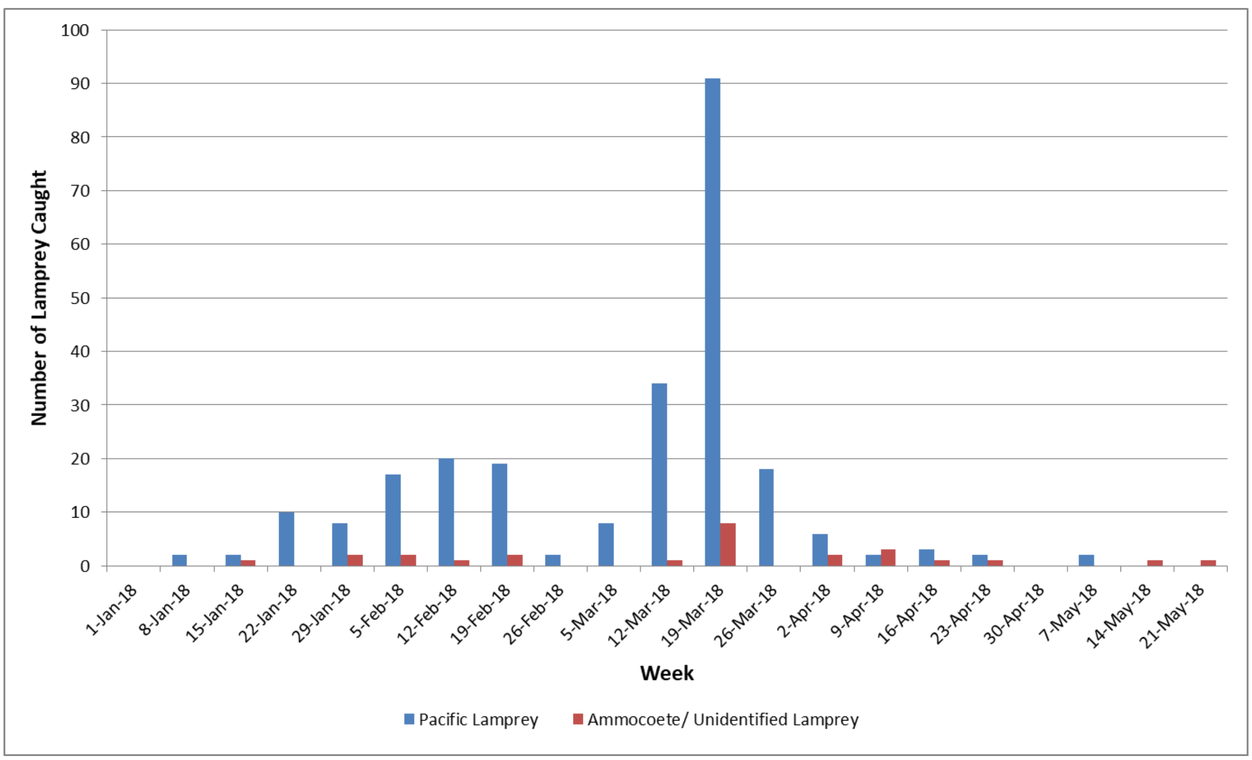
Figure 15: Non-salmonid catch totals for families of fish species collected during the 2018 Stanislaus River rotary screw trap survey season.



Of the 477 non-salmonid fish captured in 2018, 57.02 percent (n = 272) were lamprey species. Five of these were identified as adult Pacific Lamprey, and were captured on 13 March, 26 March, 31 March, and 18 April. The individuals identified as adult life stage ranged in total length from 380 and 485 mm. Of the remaining 267 lamprey, 90.26 percent (n = 241) individuals were identified as juvenile life stage and were captured between 13 January and 7 May. Those identified as juveniles ranged in total length from 111 to 172 mm. The remaining 9.74 percent (n = 26) were identified as ammocoetes, unidentifiable to the species level. No lamprey individuals captured in 2018 were identified as river lamprey.

Both Pacific lamprey and ammocoetes were captured through the survey season. Catch of Pacific lamprey and ammocoete life stage peaked on 24 March. At this time, 28.86 percent (n = 71) of the season's Pacific lamprey total was captured. Additionally, 30.77 percent (n = 8) of the lamprey identified as ammocoete life stage or otherwise unidentifiable to species level was captured on this date.

Figure 16: Total weekly lamprey catch during the 2018 Stanislaus River rotary screw trap survey season.



Discussion

When interpreting the data collected during the 2018 survey season and the juvenile Chinook salmon passage estimate produced from that data, several influential factors must be considered. One of the most significant of these may have been environmental factors, especially fluctuating river flow levels. During the 2018 survey season, both high and low flows were experienced, both of which may have hindered the ability to collect consistent and high quality data by reducing the successful operation of the traps, or by limiting the number of trap efficiency tests that could be performed.

Increased flows, like those seen during the 2018 survey season, increase the amount of debris in the water column, which can affect the successful operation of the rotary screw traps by stopping the rotation of the cone or can increase the potential for damage to traps and sampling equipment. Increased debris associated with high flows can also cause fish mortality by crushing fish within the debris or by causing fish trapped within a stopped cone to become pummeled by incoming water. When debris loads were judged too high to be managed even by performing night checks in addition to day checks, or if weather conditions are deemed too dangerous to perform daily routine checks, the RST cones were raised and pulled out of the thalweg until the debris load was reduced to a manageable level. This occurred once during the 2018 survey season where cones were raised on 28 February and lowered on 4 March once high debris levels subsided and safety concerns associated with weather conditions decreased. As data cannot be collected when the cones are raised, the CAMP platform was used to estimate potential catch during gaps in sampling less than seven days in duration, as described in the Methods section of this report. With the understanding that the smaller the gap in sampling, the more confidence can be had in the accuracy of the estimated catch, and when it was necessary to cease sampling entirely, an effort was made to lower the RST cones and resume trapping as soon as possible.

Lower flows were also experienced during the 2018 survey season for the majority of March when Stanislaus River flows were reduced and averaged approximately 390 CFS, resulting in a lowered river velocity that also hindered the ability of the rotary screw traps to rotate normally. Despite the reduced functionality, two trap efficiency trials were conducted during this week which resulted in recaptures and demonstrated that the traps were still able to capture Chinook salmon and served to quantify trap efficiency during these lower flows.

Furthermore, river flow effects trap efficiency trials. Since trap efficiencies are inversely related to river discharge, trap efficiency trials rely heavily on a consistent river discharge throughout the entire trial period in order to accurately determine efficiencies. However, efforts to maintain successful trap operation during trial periods proved difficult due to fluctuating discharge throughout the survey season. As a result, at least one trap was stopped or not functioning normally at some point during every trial. Because this was consistent with day to day operation of the traps, the trials were deemed to be an accurate representation of the daily catch numbers and thus all five trials were included for analysis.

Given that the five trials used in analysis contained periods of unsuccessful trap operation, the trap efficiencies for the 2018 survey season were likely an underestimate of what the traps would have recaptured under normal function, and the 2018 trap efficiencies were therefore likely biased low. Since trap efficiencies are used to develop passage estimates for the in-river produced fall-run Chinook salmon, a low bias in the trap efficiencies may have resulted in a high bias for the passage estimate.

The total number of in-river produced fall-run Chinook salmon estimated to have emigrated past the rotary screw trap location on the Stanislaus River at Caswell Memorial State Park was 222,000 individuals, with 95 percent confidence intervals ranging from 162,000 to 293,500 individuals. This relatively small confidence interval width is likely due to the lower distribution of daily catch totals throughout the 2018 survey season.

It is important to note that this passage estimate was not calculated entirely from actual catch. The 2018 passage estimate includes multiple days of estimated catch which may reduce the accuracy of the passage estimate. Days for which catch was estimated include gaps in sampling that were less than seven days and days that were excluded from analysis due to unsuccessful fishing, as described in the Methods section of this report. It is also important to note that this passage estimate only includes the salmon estimated to have emigrated past the rotary screw trap location between 12 January and 25 May. The 2018 survey season likely encompassed the majority of the juvenile fall-run Chinook salmon emigration period. Out of the 3,515 fall-run Chinook salmon captured in the 2018 survey season, only 34 were captured during the first seven days of sampling, comprising only 0.97 percent of the total season catch of Chinook salmon, and comprising 0.93 percent (n = 2,060) of the total passage estimate. During the last seven days of sampling, 19 salmon were captured, consisting of 0.54 percent of the total catch and 0.52 percent (n = 1146) of the total passage estimate.

A bi-modal peak was observed in unmarked juvenile fall-run Chinook salmon catch during the 2018 survey where the primary peak was seen during the seventh week of sampling and the secondary peak in catch occurred during the eleventh and twelfth week of sampling. The timing of these peaks may have also been influenced by the fluctuating river flows seen in the 2018 survey season. The lower Stanislaus River flows were increased to meet Vernalis Flow Objectives, and scheduled outflow changes from Goodwin Dam beginning on 10 February increased river flows from approximately 600 CFS to 2,300 CFS on 22 February. This flow increase coincided with the first peak of catch seen between 13 February and 25 February where 1,675 salmon were captured (47.65 percent of the total captured) and 85,294 Chinook salmon were estimated to have out-migrated past the rotary screw trap location (38.42 percent of the total passage estimate). The second peak occurred despite any significant scheduled increase in river flow; however it did coincide with a storm event that began on 20 March. During this second peak which occurred between 24 March and 29 March, 1,056 salmon were captured (30.04 percent of the total captured) and 48,346 Chinook salmon were estimated to have out-migrated past the rotary screw trap location (21.78 percent of the total passage estimate).

In 2018, one spring-run Chinook salmon was genetically proven to have been captured at the Caswell RST location on the Stanislaus River. This may have been a result of the spring-run releases into the upper San Joaquin River which began in 2014 as an experimental study to support reintroduction by the SJRRP (NOAA 2014). These fish were sourced from the Feather River Hatchery and is not unlikely that Mill/Deer Creek spring-run Chinook salmon strayed into this river system during the time frame in which the brood stock was obtained. It is important to consider the possibility that a small number of spring-run Chinook salmon strayed into this non-natal stream and successfully spawned, however, less likely. Genetic analyses should be conducted on both juvenile and adult Chinook salmon to determine how many spring-run Chinook salmon may be currently utilizing the Stanislaus River for spawning or rearing habitat and to further assess the success of the reintroduction of spring-run Chinook salmon.

Furthermore, no steelhead were captured during the 2018 survey season at Caswell Memorial State Park, unlike in previous survey seasons, during which small numbers of steelhead smolt were caught at the Caswell and Oakdale rotary screw trap locations (NMFS 2017). The relatively low steelhead population numbers in combination with the reduced trap efficiencies seen during 2018 survey season are likely factors contributing to the absence of steelhead in the 2018 Caswell RSTs catch.

Management Implications

In order to determine if efforts made by AFRP and others to increase the abundance of Chinook salmon and steelhead on the lower Stanislaus River have been successful, additional monitoring of juvenile salmonid emigration is required. There should also be continued management of river flows and water temperature to maintain favorable river conditions for the anadromous fish populations in the Stanislaus River. The 2018 data is of particular interest as it can be used to further understand the impact of the prior five year drought on anadromous species. Additionally, it is a required monitoring program as stated in the NMFS BiOp and can be used to help determine the success of habitat rehabilitation and species reintroduction. This data can then also be used to guide water management modifications including timing of pulse flows which may influence juvenile Chinook salmon emigration.

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Appendix 1: Points of interest on the Stanislaus River.

Point of Interest	Significance	Operator	River Mile (rkm)
New Melones Dam	Constructed 1978; Flood control, power generation, water supply, recreation.	U.S. Bureau of Reclamation	60 (96.6)
Tulloch Dam	Constructed 1957; Flood control, power generation, water supply, recreation.	Tri-Dam Project	55 (88.5)
Goodwin Dam	Constructed 1913; Flood control, water supply.	U.S. Bureau of Reclamation	58.4 (94)
Lover's Leap	Habitat improvement; Gravel augmentation		53.4-51.8 (85.9-83.4)
Lancaster Road	Habitat improvement; side channel restoration project		~41 (65.9)
Oakdale	RST site for monitoring juvenile salmonid abundance and outmigration	FishBio Consulting	40.1(64.5)
Stanislaus River at Ripon (Hwy 99 Bridge)	River discharge and temperature monitoring station	U.S. Geological Survey	15.8 (25.4)
Upper Irrigation Pump at Caswell	Release site for trap efficiency mark-recapture trials		8.9 (14.3)
Caswell Memorial State Park	RST site for monitoring juvenile salmonid abundance and outmigration		8.6 (13.8)
Mouth of Stanislaus River	Stanislaus-San Joaquin Confluence		0

Appendix 2: Weekly environmental conditions during the 2018 Stanislaus River rotary screw trap survey season.

Julian Week	Water Temperature (C°)			Discharge			Dissolved Oxygen (mg/L)			Turbidity (NTU)			Velocity (m/s)		
	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max
1/8-1/14	10.41	9.9	11.2	1096	715	1338	10.09	9.92	10.47	3.31	2.37	5.21	0.60	0.5	0.7
1/15-1/21	10.24	9.3	10.6	1180	1054	1333	9.48	8.40	10.54	2.86	1.48	5.89	0.63	0.5	0.8
1/22-1/28	10.12	9.8	10.6	983	663	1337	11.24	9.47	12.01	2.75	1.87	3.56	0.56	0.3	0.7
1/29-2/4	10.63	9.8	11.4	643	631	651	11.44	10.07	11.85	2.65	1.82	3.41	0.48	0.3	0.7
2/5-2/11	11.47	11.0	11.8	802	625	1316	11.12	9.15	11.89	4.44	2.17	9.22	0.45	0.3	0.6
2/12-2/18	10.27	10.1	10.6	1373	1288	1494	12.08	10.62	12.75	3.33	1.92	6.68	0.51	0.4	0.7
2/19-2/25	9.83	9.5	10.2	1756	1500	2239	11.89	10.05	12.95	3.94	2.61	5.48	0.53	0.4	0.6
2/26-3/4	10.29	9.9	10.5	1543	691	2301	11.40	9.90	12.49	3.65	2.84	4.11	0.49	0.2	0.8
3/5-3/11	12.86	10.8	14.2	389	339	507	10.11	8.64	11.18	3.52	2.45	4.96	0.35	0.2	0.5
3/12-3/18	13.59	11.8	15.6	334	309	362	10.06	8.55	11.32	3.88	2.26	5.77	0.31	0.2	0.5
3/19-3/25	13.51	12.3	14.7	337	288	509	10.25	8.45	11.51	7.54	3.09	15.32	0.31	0.2	0.4
3/26-4/1	16.21	13.7	17.9	269	260	286	10.32	8.45	12.06	4.68	3.21	6.76	0.25	0.1	0.4
4/2-4/8	13.70	12.8	16.2	1295	762	1586				5.84	3.20	7.98	0.49	0.3	0.7
4/9-4/15	13.10	12.5	13.7	1419	1396	1466				4.61	3.28	6.45	0.53	0.3	0.7
4/16-4/22	12.72	11.9	13.8	1536	1506	1560				4.05	2.50	4.93	0.50	0.2	0.7
4/23-4/29	13.66	12.8	14.1	1548	1538	1559				3.78	2.49	5.50	0.42	0.2	0.6
4/30-5/6	13.85	12.7	15.3	1403	991	1556	9.47	7.93	11.10	4.12	2.90	6.90	0.44	0.3	0.6
5/7-5/13	13.77	13.5	14.0	2402	2025	2593	10.18	9.12	11.06	6.03	3.23	10.62	0.46	0.2	0.8
5/14-5/20	13.40	13.1	13.6	2655	2604	2694	10.04	8.85	10.93	4.14	2.88	4.90	0.54	0.3	0.8
5/21-5/27	13.08	12.6	13.3	2706	2688	2734	10.82	10.69	10.90	3.46	2.02	4.65	0.61	0.2	0.9

Note: The USGS website provides the discharge and temperature data by day in 15 minute intervals. To calculate the averages by week, the 15 minute intervals were first averaged by day, and then the days were averaged by the seven day Julian week indicated by the "Week" column in the table above. The min and max values for the discharge and temperature data are the highest and lowest values recorded for the week. Dissolved oxygen was calculated by weekly averages from daily values gathered by crew members in the field. Dissolved oxygen min and max values are reflective of the minimum and maximum daily value gathered during the Julian week defined by the "Julian Week" column in the table above. Dissolved oxygen values from 31 March through 1 May were excluded due to a probe malfunction. Turbidity and velocity reflect a weekly average of values, gathered per trap by crew members in the field and averaged into a single daily value. Turbidity and velocity min and max values are reflective of the minimum and maximum daily value gathered for each trap during the Julian week defined by the "Julian Week" column in the table above.

Appendix 3: List of fish species caught during the 2018 Stanislaus River rotary screw trap survey season.

Common Name	Family Name	Species Name	Total Number Caught
Chinook salmon	Salmonidae	*Oncorhynchus tshawytscha*	3,516
Bluegill	Centrarchidae	*Lepomis macrochirus*	15
Brown Bullhead	Ictaluridae	*Ameiurus nebulosus*	1
Channel catfish	Ictaluridae	*Ictalurus punctatus*	5
Golden shiner	Cyprinidae	*Notemigonus crysoleucas*	3
Green sunfish	Centrarchidae	*Lepomis cyanellus*	2
Pacific lamprey	Petromyzontidae	*Entosphenus tridentatus*	246
Prickly sculpin	Cottidae	*Cottus asper*	8
Redear sunfish	Centrarchidae	*Lepomis microlophus*	1
Riffle sculpin	Cottidae	*Cottus gulosus*	1
Sacramento pikeminnow	Cyprinidae	*Ptychocheilus grandis*	3
Sacramento sucker	Catostomidae	*Catostomus occidentalis*	32
Smallmouth bass	Centrarchidae	*Micropterus dolomieu*	6
Spotted bass	Centrarchidae	*Micropterus punctulatus*	21
Threadfin shad	Clupeidae	*Dorosoma petenense*	24
Western mosquitofish	Poeciliidae	*Gambusia affinis*	59
White catfish	Ictaluridae	*Ameiurus catus*	5
Unidentified bass (Micropterus)	Centrarchidae	*Micropterus sp.*	2
Unidentified Centrarchid	Centrarchidae		11
Unidentified lamprey	Petromyzontidae		26
Unidentified Minnows	Cyprinidae		3
Unidentified Sunfish	Centrarchidae		2
Unidentified bony fish			1
		Total	**3,993**

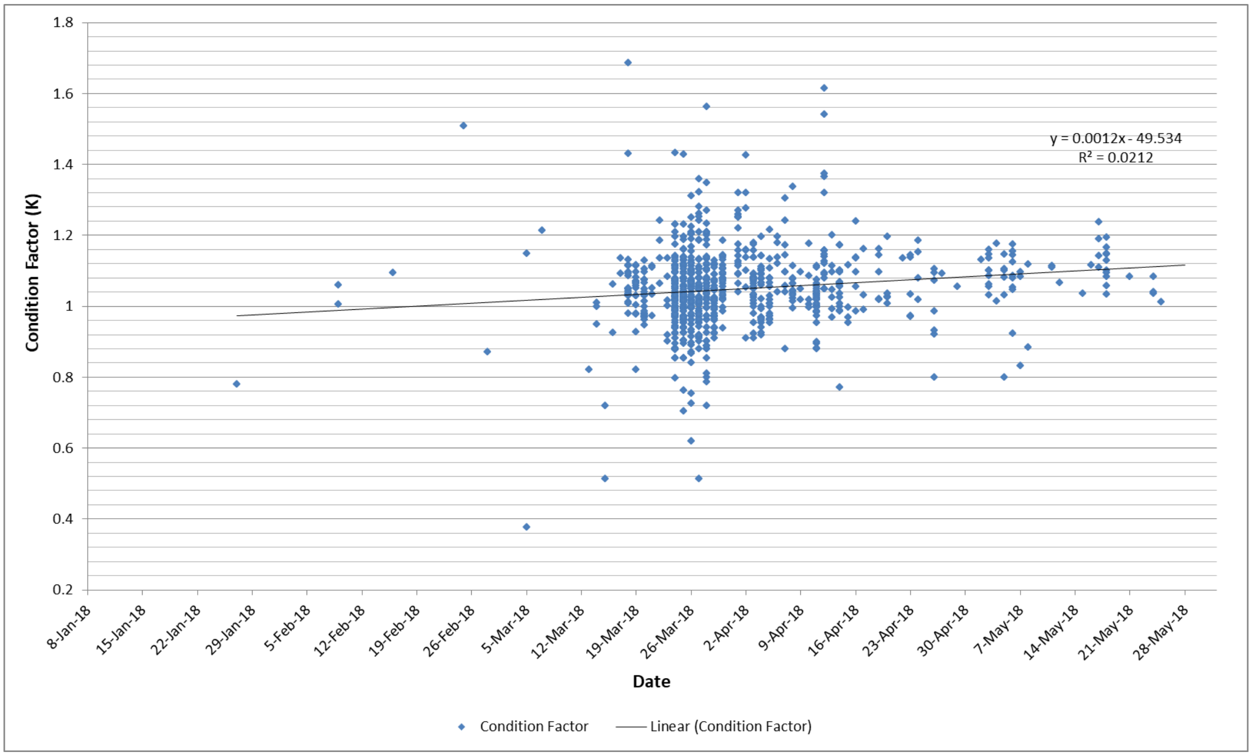
Appendix 4: Genetic results for fin-clip samples from Chinook salmon caught during the 2018 Stanislaus River rotary screw trap survey season.

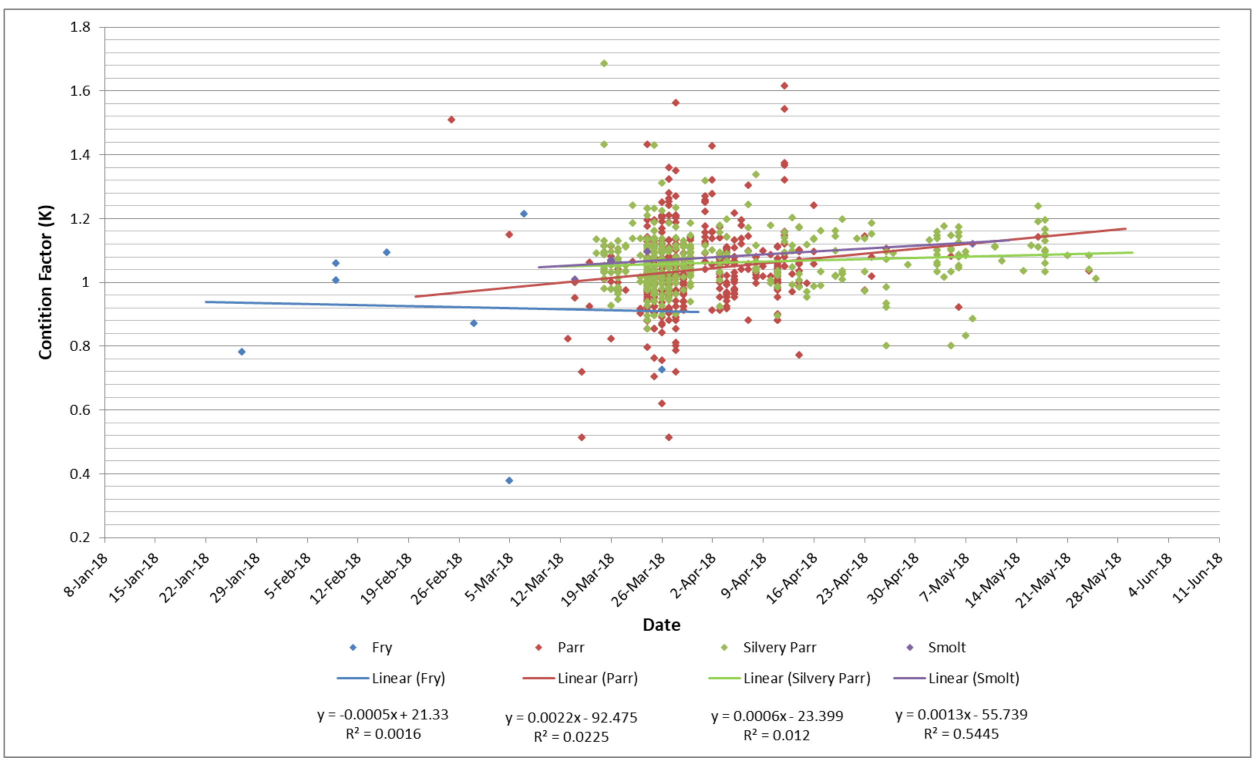
Sample #: refer to a unique number assigned by field staff, and that allowed the tracking of individual fish samples.
At Capture run assignment: Chinook salmon run assignment based on the historically held assumption that the Stanislaus River only supports fall-run Chinook salmon.
SNP Run Assignment: Chinook salmon run assignment using “Genetic Call to four lineages” single-nucleotide polymorphism (SNP) markers.
SNP Probability: Probability of the correct SNP Chinook salmon run assignment.
Final run assignment: run assignment using a 50 percent threshold based on the SNP probability.
FL: fork length in millimeters.
W: weight in grams.

Date	Sample #	At Capture Run Assignment	SNP Run Assignment	SNP Probablity	Final Run Assignment	FL (mm)	W (g)
5-Mar	3432-001	Spring	Fall	1.00	Fall	66	3.3
14-Mar	3432-002	Spring	Fall	1.00	Fall	85	6.2
14-Mar	3432-003	Spring	Fall	1.00	Fall	71	3.4
16-Mar	3432-004	Spring	Fall	1.00	Fall	74	4.3
16-Mar	3432-005	Spring	Fall	0.99	Fall	82	5.1
17-Mar	3432-006	Winter	Fall	0.98	Fall	92	8.5
17-Mar	3432-007	Spring	Fall	1.00	Fall	74	4.6
18-Mar	3432-008	Spring	Fall	1.00	Fall	71	3.7
18-Mar	3432-009	Winter	Fall	1.00	Fall	95	9
19-Mar	3432-010	Spring	Fall	1.00	Fall	84	6.5
19-Mar	3432-011	Spring	Fall	1.00	Fall	90	7.8
20-Mar	3432-012	Spring	Fall	1.00	Fall	77	4.7
20-Mar	3432-013	Spring	Fall	1.00	Fall	80	5.5
21-Mar	3432-014	Spring	Fall	1.00	Fall	79	5.1
21-Mar	3432-015	Spring	Fall	1.00	Fall	82	5.7
22-Mar	3432-016	Spring	Fall	1.00	Fall	81	6.3
23-Mar	3432-017	Spring	Fall	1.00	Fall	83	6.2
23-Mar	3432-018	Spring	Fall	1.00	Fall	82	5.6
24-Mar	3432-019	Spring	Fall	0.98	Fall	84	6.5
24-Mar	3432-020	Spring	SpringMD	0.65	Spring	76	4.7
24-Mar	3432-021	Spring	Fall	1.00	Fall	74	4
24-Mar	3432-022	Spring	Fall	1.00	Fall	75	4.4
25-Mar	3432-023	Spring	Fall	1.00	Fall	77	5.1
25-Mar	3432-024	Spring	Fall	1.00	Fall	79	5.1
26-Mar	3432-025	Spring	Fall	1.00	Fall	85	6.5
26-Mar	3432-026	Spring	Fall	1.00	Fall	76	4.4

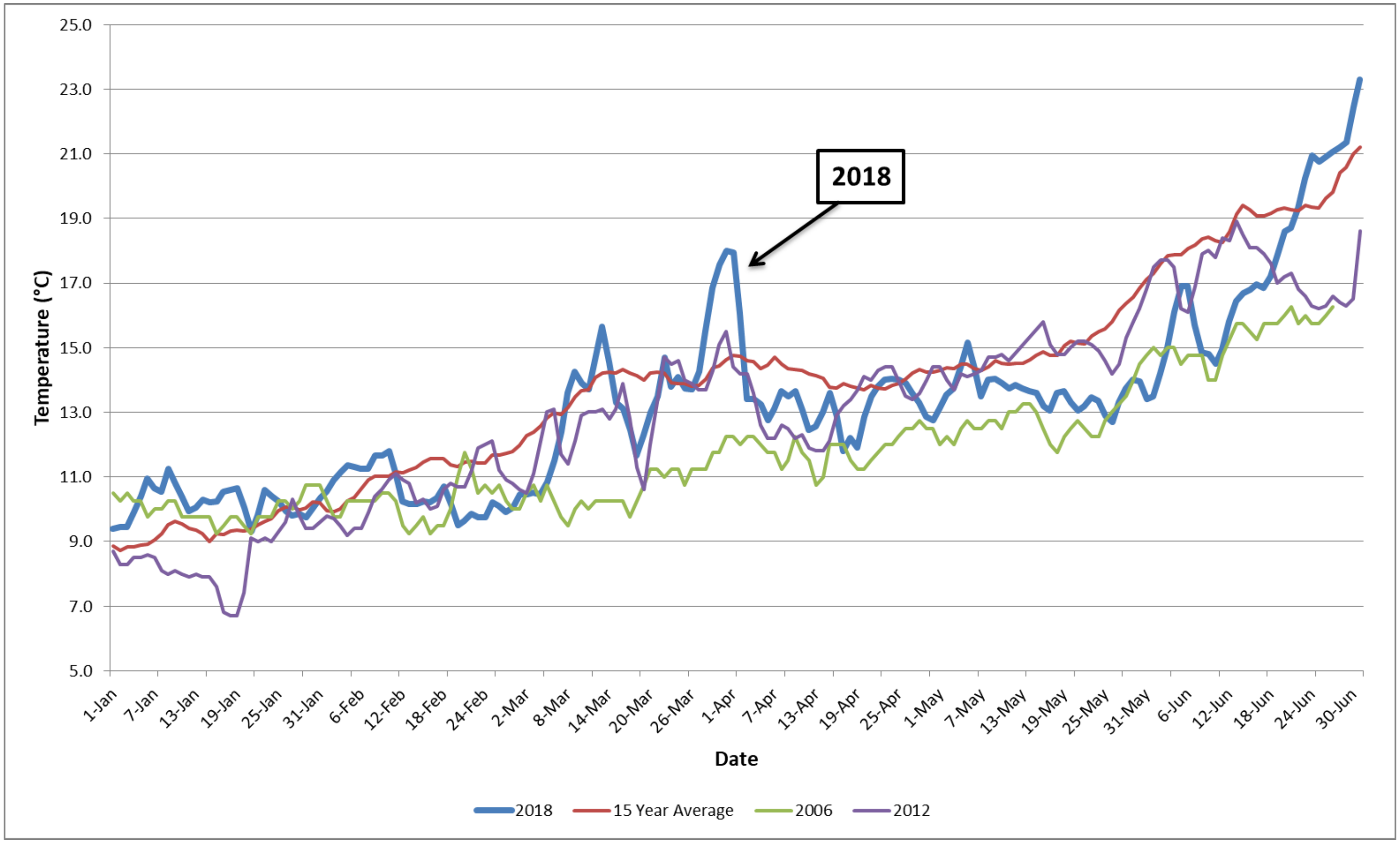
27-Mar	3432-027	Spring	Fall	1.00	Fall	84	6
27-Mar	3432-028	Spring	Fall	1.00	Fall	74	4
28-Mar	3432-029	Spring	Fall	1.00	Fall	80	5.3
28-Mar	3432-030	Spring	Fall	1.00	Fall	89	7.6
29-Mar	3432-031	Spring	Fall	0.99	Fall	72	3.9
29-Mar	3432-032	Spring	Fall	1.00	Fall	88	7.7
30-Mar	3432-033	Spring	Fall	1.00	Fall	85	6.8
30-Mar	3432-034	Spring	Fall	1.00	Fall	72	3.9
1-Apr	3432-035	Spring	Fall	1.00	Fall	89	9.3
2-Apr	3432-036	Spring	Fall	1.00	Fall	91	8.3
4-Apr	3432-037	Spring	Fall	1.00	Fall	75	4.5
5-Apr	3432-038	Late fall	Fall	1.00	Fall	33	
6-Apr	3432-039	Late fall	Fall	1.00	Fall	32	
7-Apr	3432-040	Spring	Fall	1.00	Fall	84	6.5
10-Apr	3432-041	Spring	Fall	0.99	Fall	81	5.3
11-Apr	3432-042	Spring	Fall	1.00	Fall	91	7.7
12-Apr	3432-043	Spring	Fall	1.00	Fall	93	8.8
14-Apr	3432-044	Spring	Fall	1.00	Fall	83	6.7
14-Apr	3432-045	Spring	Fall	1.00	Fall	89	7.1
13-Apr	3432-046	Late fall	Fall	1.00	Fall	35	
17-Apr	3432-047	Spring	Fall	1.00	Fall	86	6.3
20-Apr	3432-048	Late fall	Fall	1.00	Fall	34	
28-Apr	3432-049	Late fall	Fall	1.00	Fall	37	
2-May	3432-050	Spring	Fall	1.00	Fall	95	9.7
6-May	3432-051	Spring	Fall	0.99	Fall	92	8.4
6-May	3432-052	Spring	Fall	1.00	Fall	94	9.5

Appendix 5: Fulton's condition factor (*K*), overall, and by life-stage, of fall-run Chinook salmon during the 2018 survey season.





Appendix 6: Daily average water temperature (°C) in the Stanislaus River at Ripon for the 15 year period 2004-2018, the highest temperature year, the lowest temperature year, the 15 year average and the current year (2018). Data from USGS station number 11303000.



Appendix 7: Daily average discharge (CFS) on the Stanislaus River at Ripon for the 15-year period 2004 – 2018, the highest water year, the lowest water year, 15 year average and the current year (2018). Data from USGS station number 11303000.