California Department of Fish and Wildlife
North Central Region
Middle Sacramento River Juvenile Salmon and Steelhead Monitoring Project

Timing, Composition, and Abundance of Juvenile Salmonid Emigration in the Sacramento River Near Knights Landing October 1, 2013 – June 6, 2014[1]

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List of Abbreviations and Acronyms

BBY	Bismarck brown Y
BO	Biological opinion
BY	Brood year
CDEC	California Data Exchange Center
CFS	Cubic feet per second
CDFW	California Department of Fish and Wildlife
CI	Confidence interval
cm	Centimeter
CNFH	Coleman National Fish Hatchery
CPUE	Catch per unit of effort
CVP	Central Valley Project
CWT	Coded wire tag

ESA	Endangered Species Act
DCC	Delta Cross Channel
DOSS	Delta Operations for Salmon and Sturgeon
ESU	Evolutionary significant unit
FL	Fork length
LAD	Length at date
LRP	Lake Redding Park
LSNFH	Livingston Stone National Fish Hatchery
mm	Millimeter
NMFS	National Marine Fisheries Service
NTU	Nephelometric turbidity units
OCAP	Operations criteria and procedures
rKm	River kilometer
RPA	Reasonable and prudent alternatives
RPM	Revolutions per minute
RST	Rotary screw trap
SWP	State Water Project
YOY	Young-of-the-year

Executive Summary

The North Central Region of the California Department of Fish and Wildlife operates a juvenile salmonid monitoring program on the Sacramento River in California to obtain information on the temporal distribution, relative abundance, and composition of race and species of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) emigrating from the upper Sacramento River to the Sacramento-San Joaquin Delta (Delta). These data are collected at two separate locations and use two paired rotary screw traps (RST) outfitted with 2.4m cone. The most downstream location is 0.8 kilometers (km) downstream of Knights Landing, CA at Sacramento River kilometer (Rkm) 144. Data collection is permitted under an Endangered Species Act (ESA) Section 10(a)(1)(A) Permit issued by the National Marine Fisheries Service (NMFS).

The monitoring program entered its 18th consecutive year of sampling at the Knights Landing monitoring site beginning on October 1, 2013. Sampling concluded on June 06, 2014 for a total of 249 days of sampling.

During the season, 106,466 unmarked (adipose fin intact) juvenile Chinook salmon were captured. Peak catch occurred during calendar week 9, when 49,137 unmarked juvenile Chinook were captured. Juvenile Chinook salmon were identified to run using length-at-date (LAD) criteria developed by Fisher (1992) and modified by Greene (1992). The LAD based run assignment is a widely used technique in the Central Valley for identifying juvenile Chinook

salmon when multiple runs are present (Harvey 2011). Of the 106,466 unmarked juvenile Chinook salmon captured, 142 (0.13%) were identified as winter-run, 1,509 (1.4%) identified as spring-run, and 104,815 (98.5%) identified as fall-run. No unmarked late fall-run Chinook salmon were captured. Trap efficiency data were applied to catch totals to produce run-specific passage estimates. The passage estimate for fall-run was 18,854,256; for spring-run was 171,718; and for winter-run was 13,247.

A total of 126 hatchery produced Chinook salmon was captured by the Knights Landing RSTs. These fish were identified by a missing adipose fin which is removed by hatchery staff prior to fish release. Of the 126 hatchery produced Chinook salmon captured, 86 (68.5%) were identified as winter-run, 1 (0.8%) was identified as late fall-run, 22 (17.5%) were identified as spring-run and 15 (11.9%) were identified as fall-run. It is assumed that all marked Chinook salmon observed were from the releases completed upstream of the sampling site. During the sampling period, four releases of brood year (BY) 2013 late fall-run Chinook salmon and one release of BY 2013 fall-run Chinook Salmon were completed by Coleman National Fish Hatchery (CNFH). Additionally, one release of BY 2013 winter-run Chinook salmon was completed by Livingston Stone National Fish Hatchery (LSNFH). These releases occurred upstream of the Knights Landing sampling site.

Environmental data collected at the sampling site included the following parameters: river flow volume, water temperature, water transparency, and water turbidity. Sacramento River discharge was recorded at each trap check as reported by the California Data Exchange Center (CDEC) Wilkins Slough gauge. Flows varied throughout the sampling season. Data were averaged over the calendar week for reporting. River flows at the start of the sampling season, week 40, had a weekly mean of 5,858 cubic feet per second (CFS). River flows at the end of the sampling season, week 23, had a weekly mean of 4,953 CFS. In week 51, weekly mean flows peaked at 15,173 CFS, and the lowest weekly mean flow of 3,304 CFS was observed in week 20. Weekly mean water temperature at the start of the survey period (week 40) was 16.8°C. Temperatures varied throughout the survey period with a low weekly mean temperature of 6.5°C (week 50) and a high mean temperature of 22.4°C at the end of the survey period (week 23). Mean weekly water transparency varied between a high of 199.3 centimeters (cm) during week 42 to a low of 25.4 cm during week 10. Mean weekly turbidity at the sampling site varied from a low of 1.2 nephelometric turbidity units (NTU) during week 40 to a high of 62.9 NTU during week 9.

Introduction

The purpose of the Middle Sacramento River Juvenile Salmonid Emigration Monitoring Program is to develop information on the temporal distribution, relative abundance and composition of race and species of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) emigrating from the upper Sacramento River to the Delta. The upper Sacramento River and associated tributaries provide spawning and rearing habitat for four native races of Chinook salmon: Sacramento River winter-run (Federal and State listed endangered), Central Valley spring-run (Federal and State listed threatened), Central Valley late fall-run and Central Valley fall-run, as well as native Central Valley steelhead trout (Federal listed threatened). The monitoring program consists of two sampling locations; one near the Tisdale Weir at rKm 196 and one located 0.8km downstream of Knights Landing, CA at rKm 144. Information presenting the annual timing, composition and abundance of Sacramento River salmonids observed at the Tisdale Weir sampling location is detailed in a separate document. The Knights Landing sampling site is the most downstream monitoring site on the Sacramento River above the confluence with two large salmonid bearing tributaries, the American and Feather Rivers located at rKm 96.7 and rKm 128.8, respectively. All salmonids captured by the RSTs at Knights Landing are assumed to be produced in the upper Sacramento River and its tributaries (Figure 1).

Juvenile Chinook salmon emigrate from the upper Sacramento River and its tributaries toward the Delta in a wide range of life stages (Healey 1991). Juvenile fall-run Chinook salmon have a residency period of one to seven months and typically migrate March through July. Juvenile spring-run Chinook salmon have a longer period of stream residency, between three and fifteen months, and may migrate as recently emerged fry, rear for a short period and migrate as smolts, or rear for longer periods and migrate as yearlings. Young-of-year (YOY) spring-run migrate between the months of March and June, and yearlings migrate between November and April. Winter-run juveniles have a residency period of five to ten months and may migrate as recently emerged fry, rear for a period and migrate as smolts or rear for longer periods and migrate as yearlings. Juvenile late fall-run Chinook salmon may migrate as emerged fry, as smolts or as yearlings and typically migrate during the months of November through May (Fisher 1994; Yoshiyama *et al*. 1998).

Adult Central Valley winter steelhead trout generally enter the Delta August through October and spawn December through April. Adult migration and spawning timing is highly variable and depends on river flows and water temperatures during migration periods. Juveniles may rear in their natal stream or affiliated tributary stream for 1-3 years. Juveniles may emigrate anywhere between 1-3 years of age, but generally emigrate at 2 years of age (Hallock 1989). Emigration timing is highly variable and may occur at any time of the year. However, most juveniles emigrate during spring months with a smaller emigration occurring during fall months.

Two federal fish hatcheries, CNFH and LSNFH (substation of CNFH), located upstream from the sampling location, collectively produce winter-, fall- and late fall-runs of Chinook salmon, as well as Central Valley steelhead trout. These fish help supplement the in-river produced populations. Prior to releasing fish into the Sacramento River, these hatcheries externally mark 100% of their steelhead production and externally marked a portion of the Chinook salmon production by removing the adipose fin. Externally marked Chinook are also given a coded wire tag (CWT). A small percentage of these hatchery fish were captured by the RST's in 2014/15.

The abundance of native, anadromous salmonids in California's Central Valley has dropped precipitously because of anthropogenic changes to the environment. Loss of spawning and rearing habitat for the Central Valley salmonids coupled with environmental alterations along migration corridors has put great strain on the natural populations. Much of the historic spawning habitat for Central Valley salmonids is no longer accessible. Construction of dams on many of the major salmonid bearing streams during the mid-1800's and mid-1900's blocked access to over 72% of salmonid holding, spawning, and rearing areas (Yoshiyama *et al*. 2001). Dams can create unsuitable habitat downstream of the impoundment by increasing in-river temperatures and increasing river channelization while reducing natural river flows, natural cover, and natural gravel recruitment necessary for successful spawning and rearing.

Streams in the Central Valley have also been altered and channelized with levees to aid in flood protection of city developments and assist in agricultural water needs. These agricultural activities may further compromise water quality with urban and agricultural runoff which often contains pollutants such as pesticides, fertilizers, and treated effluent. Increases in water turbidity from such contaminants can increase water temperatures which affect juvenile survival (Brandes and Mclain 2001, Moyle 2002). Loss of suitable rearing habitat reduces juvenile survivability during emigration which results in a reduction in the salmon population.

The demand for diverted water and associated water transfer activities in the California Central Valley alter aquatic ecosystems by creating unnatural in-river flow regimes, altering flow magnitude and reducing available habitat. These factors can have an overall negative impact on juvenile salmonid survival. Unscreened water diversions in migration corridors may directly impact juvenile salmonids through entrainment mortality. Entrainment of juvenile salmonids may occur at screened water diversions as well; two such diversions are the Harvey Banks Delta Pumping Plant (SWP) and the C.W. Bill Jones Pumping Plant (CVP) (Kimmerer 2008).

The altered aquatic environment in the Central Valley may promote the success of non-native fish species. Non-native fishes can negatively affect native species through predation, disrupting food webs, reshaping ecosystem functions, introducing disease, or displacing native species (Mount *et al.* 2012). The introduction of highly efficient piscivores such as the smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and striped bass (*Morone saxatilis*) into the Delta in the late 1800's (Dill 1997) has had considerable impacts on native salmonid stocks. These non-native fish have been observed to forage on native salmonids at greater rates than even the largest native piscivore, the Sacramento pikeminnow (*Ptychocheilus grandis*) (Nobriga and Feyer 2007). Non-native piscivores occur in nearly all habitats used by emigrating and rearing salmonid juveniles including spawning grounds in the Upper Sacramento River and tributaries, the Sacramento River migration corridor, and the Delta.

Protecting juvenile salmonids as they emigrate from their natal waters toward the Delta and onward to the Pacific Ocean is essential to maintain the existence of the remaining salmonid stocks in the Central Valley. Various restrictions have been placed upon water diversion projects within the Delta to protect juveniles during peak emigration periods. Having a near real-time estimate of abundance and emigration timing for protected salmonid species improves the ability to implement and adapt protective measures, enhancing overall protection of salmonids while augmenting water management practice flexibility.

NMFS recognized SWP and CVP Delta water operation practices to be hazardous to listed salmonid species by identifying loss at the south Delta pumping facilities or migratory delay and fish disorientation in the interior Delta. NMFS suggested Reasonable and Prudent Alternatives (RPAs) that would enable water export activities to continue in compliance with the Federal Endangered Species Act including adaptive operations of the Delta Cross Channel (DCC) gates to decrease potential entrainment into the interior Delta (NMFS 2009).

CVP/SWP operations under the 2009 NMFS Operations Criteria and Procedures (OCAP) biological opinion (BO) rely on data collected by the California Department of Fish and Wildlife (CDFW) Middle Sacramento River Juvenile Salmonid Emigration Monitoring Program (Program) near Knights Landing to inform DCC gate operations. Additionally, monitoring data from Knights Landing are used to identify and relay emigration trends and approximate numbers of juvenile salmonids entering the Delta to managers. Data collected by the Program were distributed to constituents by CDFW on a per-trap-check basis: the traps were serviced, data were gathered, data were summarized in an electronic format and then distributed via email the same day.

The primary goals of the Knights Landing program are:

1. Provide early warning of emigrating listed salmonids moving toward the Delta so the CVP and SWP projects could modify their water export activities, including DCC Gate closures for up to three days.
2. Document passage of emigrating salmonids including timing, relative abundance, and response to environmental conditions.
3. Estimate emigrating salmonid numbers in the lower Sacramento River above the Delta.
4. Develop a long-term dataset on emigration with which to compare changes over time.

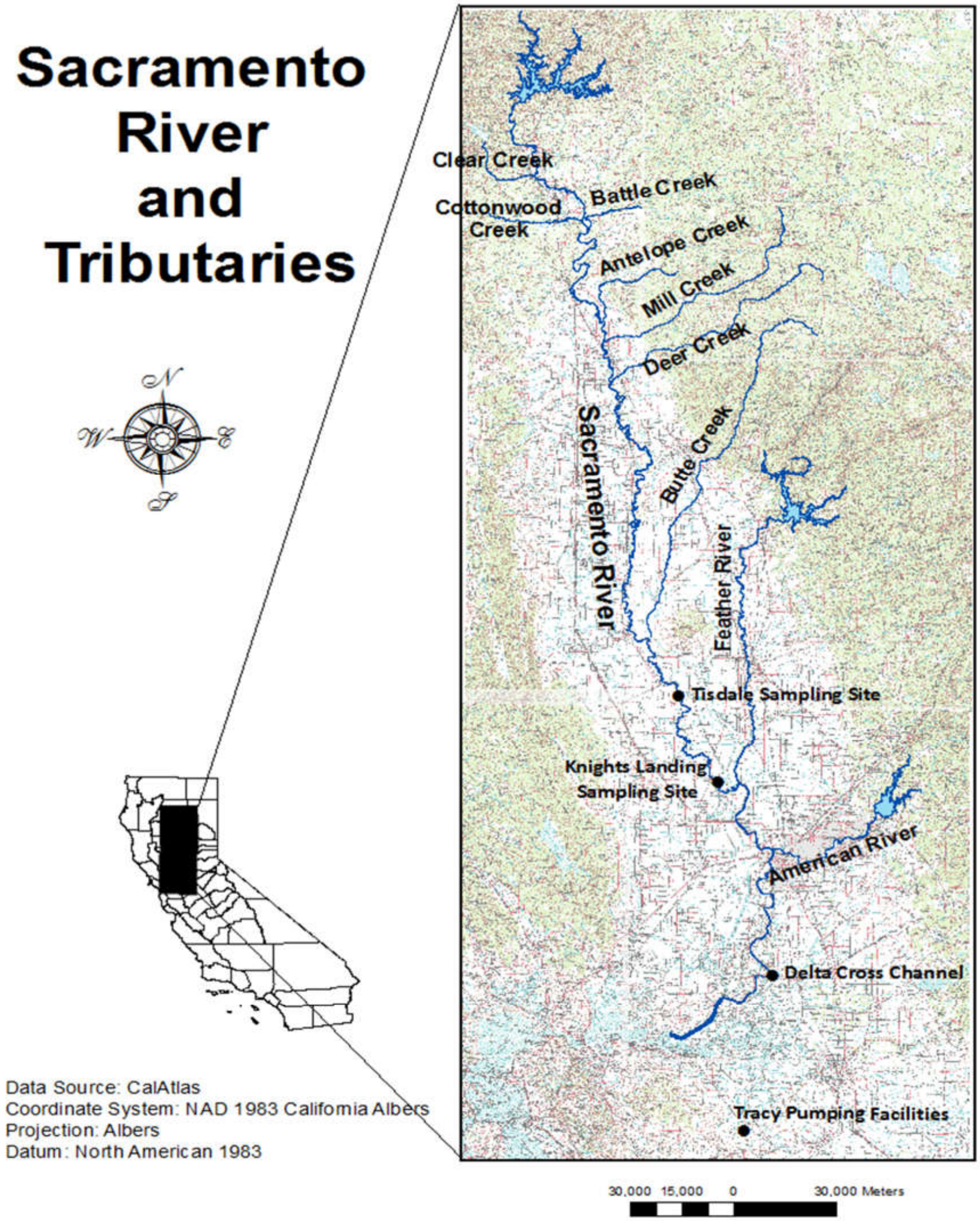

Figure 1. Map of the upper Sacramento River and tributaries depicting locations of the CDFW juvenile monitoring sites, the Delta Cross Chanel Gates and the C.W. Bill Jones (Tracy) pumping facility.

Methods

Juvenile salmonid emigration monitoring at the Knights Landing sampling site began on October 1, 2013 and concluded on June 06, 2015, for a total of 249 days of continuous sampling. Rotary screw traps allow for data to be collected on juvenile salmonid presence and passage over time, age and size at emigration, emigration timing, and species and race composition. A detailed description of RST use and operation is described in Kennen *et al*. (1994) and Volkhardt *et al*. (2007).

The Knights Landing Program outfitted two RSTs with 2.4-m diameter cones which were secured to one another and anchored in place on the east side of the Sacramento River channel (river left). The channel position of the RSTs fluctuated slightly based on Sacramento River flow. During baseflow conditions, the RSTs were positioned in the thalweg approximately 10 m from the east bank. During high flow conditions the RSTs were within approximately 3.4 m of the east bank.

Servicing of the RSTs was completed in accordance to a condition dependent sampling schedule which is an approach where environmental conditions dictate trap operation. Daily trap checks were the baseline approach to sampling under normal conditions where river flows were stable (less than 10,000 CFS) and in-river debris was minimal. As river conditions changed or an increase in catch was observed, various trap servicing and configuration methods were employed, such as half-cone sampling. (Appendix A)

Personnel accessed the RSTs using CDFW vessels which were moored on the Sacramento River at Knights Landing. These vessels included a 30' pontoon work boat and a 19' Design Concepts Delta Angler. Both were outfitted with the equipment necessary to collect data and maintain the RSTs.

During each trap servicing, crews collected data specific to the performance of each RST including time since last RST service, average cone revolutions per minute (RPM), total cone revolutions since last RST service, total hours sampled as seen in (3), water velocity entering each RST cone, and depth of water where the RSTs were positioned. Water velocity was evaluated using a Global Water flow probe (model FP111) and water depth at each trap was estimated using a handheld electronic depth finder.

$$Total\ hours\ sampled\ = \frac{Total\ cone\ revolutions}{Ave\ RPM*60} \quad (3)$$

Environmental data collected and recorded during each RST service included water temperature, water transparency, water turbidity, and river discharge volume. Water temperature was recorded every fifteen minutes using an electronic Onset HOBO temperature logger and during each trap service with a handheld H-B USA standard liquid thermometer. Water transparency at the sampling location was recorded during each trap service using a Secchi disc following standard protocols (Orth 1983). Water turbidity was measured by collecting two water samples during each trap service and analyzed using an HF Scientific DRT-

15CE turbidimeter, then averaged and reported in Nephelometric Turbidity Units (NTU). River discharge volume, measured in in cubic feet per second (CFS), was obtained from the California Data Exchange Center (CDEC 2015) gauge at Wilkins Slough, which is located 30 river miles upstream from the town of Knights Landing. River flow was an important factor for the program to consider as river flows are known to influence juvenile emigration patterns and may create hazardous working conditions for personnel working on the traps.

All fishes captured in the RSTs were identified to species and measured to the nearest millimeter (mm). Salmonids greater than 40 mm fork length (FL) were weighed to the nearest tenth of a gram. Race was assigned to juvenile Chinook based on FL using the LAD race identification tables (Greene 1992). Life stages were assigned based on visual appearance and recorded as alevin, fry, parr, silvery parr, or smolt. Steelhead life stage was estimated based on FL measurements. Fish measuring < 100 mm were assigned to the young-of-the-year (YOY) age class, fish measuring 100mm to 300mm were yearlings, and fish over 300mm were adults. Catch per unit of effort (CPUE) for each race of Chinook salmon and steelhead trout was evaluated by calculating total number of fish captured divided by the total hours of sampling. Non-salmonids were measured to total length (TL), no weights were recorded. For reporting purposes, all salmonids possessing an intact adipose fin (unmarked) were considered to be of natural origin. It is recognized that portions of hatchery production releases contain unmarked and untagged juvenile Chinook, however, identifying them against their natural origin counterparts is not possible without genetic data.

Up to 20 adipose fin-clipped, hatchery produced Chinook salmon of each race per trap maintenance event were collected. The absence of the adipose fin indicates the presence of a coded wire tag (CWT) identifying the hatchery of origin, release date, release location, and release group size. These fish were taken to a CDFW laboratory for removal of the CWT. The CWTs were read by DFW staff and cross referenced with release information provided by the federal hatcheries.

All data were recorded on water-proof datasheets, transported to the CDFW Region 2 Headquarters office, and checked for quality assurance and quality control (QAQC). Data summaries were e-mailed to resource agencies and various stakeholders on the same day to provide real-time reporting of trap catch data. Following the initial data quality check, data were entered into the Comprehensive Assessment & Monitoring Program (CAMP) database platform developed by the United States Fish and Wildlife Service (USFWS) for analysis and reporting. Following database entry, data were again verified for QAQC using standardized protocols.

In this report, Chinook salmon and steelhead trout data were combined into weekly sums to evaluate trends in salmonid emigration timing and abundance, and to help in normalizing variation in effort and trap efficiency trials. Sample weeks began on a Sunday and ended on a Saturday, and each week of the year was assigned a number in accordance with the Julian calendar.

Trap efficiency was evaluated using mark-and-recapture methods (Volkhardt 2007). Groups of 150 or more juvenile Chinook were marked externally using Bismarck Brown (BBY), a biological stain. In some instances when daily catch was low, Chinook salmon catch was retained for two days and combined to produce a release group of 150 fish or more. An in-river live-well near the sampling location was used to hold fish overnight.

To externally mark salmon, batches of 150 or more juvenile fall-run Chinook salmon were placed in a mixture of 0.6 grams BBY per 20 liters of river water for approximately one hour. Ceramic air diffusers were used throughout the process to aerate the mixture and provide adequate dissolved oxygen levels. Water temperature was monitored using a standard liquid thermometer and maintained using frozen water bottles. Stained salmon were then held overnight and checked the following day for mortality associated with the staining process. Mortalities were censored from the mark and recapture trials while healthy stained fish were counted and then transported 1.6 kilometers upstream from the RSTs and released evenly distributed across the river, perpendicular to the river banks. The upstream release site was selected as it was assumed that marked fish would evenly distribute and have an equally likely chance of being captured again by the RSTs, but not too far upstream as to where predation on marked fish would be substantial.

Passage estimates were generated for Chinook salmon using the functions embedded in the RST data management and access platform developed by the USFWS CAMP. The CAMP RST platform estimates daily passage by dividing daily catch by a daily estimate of efficiency derived from efficiency trials conducted during the season. Daily catch is expanded during times where no sampling was conducted or where the half cone sampling configuration was utilized. To estimate passage during times where no sampling was conducted, the platform smooths observed catch per unit effort (CPUE) through time, similar to a moving average. The CPUE is then multiplied by the number of hours the trap was not operational during the 24-hour period to estimate catch for that day. To expand catch during times where the half cone sampling configuration was utilized, daily catch was doubled as it is assumed that modifying the trap to half cone fishing reduces effort by half. To estimate efficiency every day of the season, the Platform utilizes a b-spline smoothing method to model daily efficiency. Steelhead trout life history creates uncertainty when applying trap capture efficiencies to estimate passage, thus, passages estimates were not produced for steelhead trout.

Results

Environmental Conditions

Mean daily flow reported at the CDEC Wilkins Slough gauge during the sampling season (October 1, 2013 through June 6, 2014) was 5,418 CFS (2,693 CFS standard deviation (SD)).

Maximum flow volume recorded was 20,200 CFS during week 10 on March 5, and minimum flow volume recorded was 3,090 CFS during week 20 on May 17 (Figure 2, Table 1).

Water temperatures generally decreased from the start of sampling efforts during week 40 through week 50, then generally increased through the end of the sampling season. Mean water temperature during the sampling period was 14.2 °C (4.5°C SD). The minimum water temperature was 5.6 °C recorded during week 50 on December 10, and the maximum water temperature was 23.3 °C recorded during week 21 on May 25 (Figure 2, Table 1).

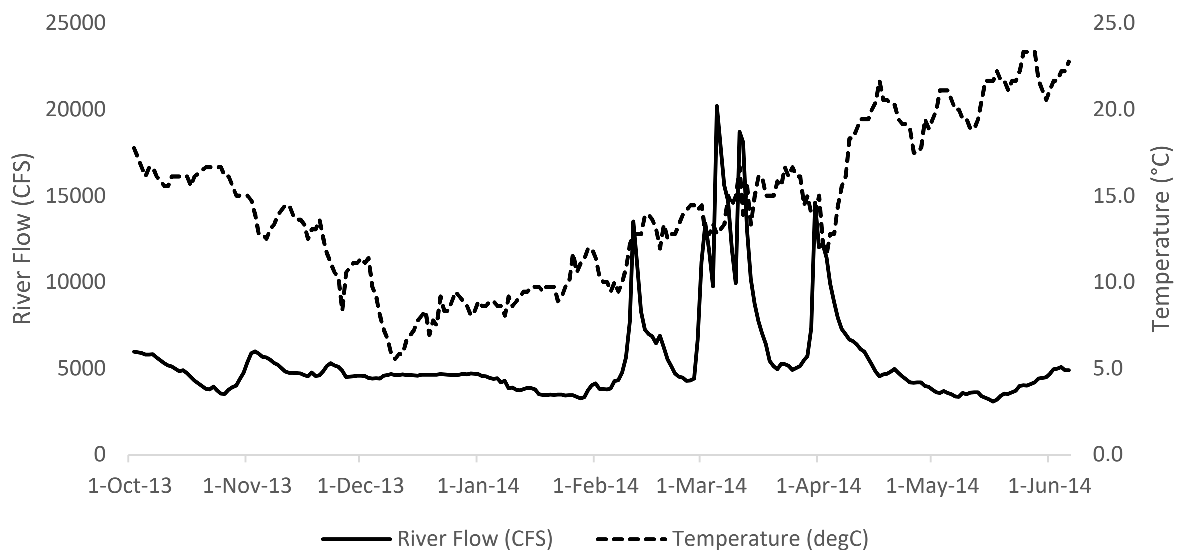

Figure 2. Daily water temperature (C°) values collected at the sampling site between October 1, 2013 and June 6, 2014. Water flow rate was reported by CDEC, Wilkins Sough gauge and reported in cubic feet per second (cfs).

Mean water transparency for the sampling season was 111.5 cm (52.4 cm SD). Maximum water transparency was 228.6 cm recorded during week 41 on October 14. Minimum water transparency was 9.1 cm recorded during week 9 on March 3 (Figure 3, Table 1).

Mean turbidity for the sampling season was 12.1 NTU (20.9 NTU SD). Maximum turbidity was 192.0 NTU recorded during week 9 on March 3. Minimum turbidity was 0.42 NTU recorded during week 40 on October 4 (Figure 3, Table 1).

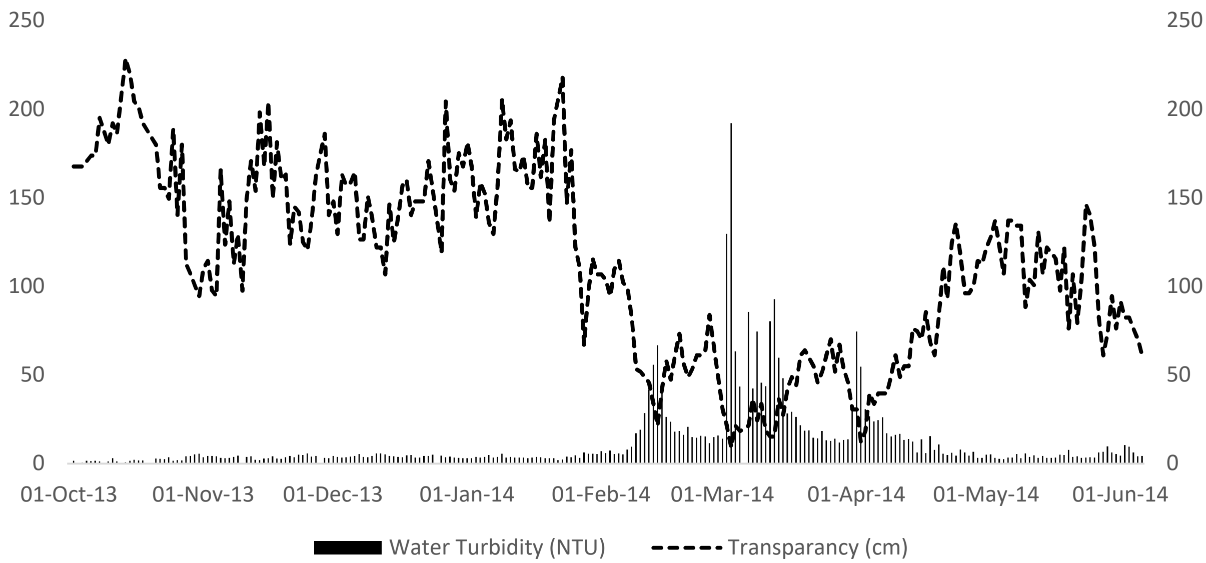

Figure 3. Daily water transparency (cm) and turbidity (NTU) values collected at the sampling site between October 1, 2013 and June 5, 2014.

Table 1. Weekly summaries of environmental conditions recorded at the rotary screw traps located on the Sacramento River near Knights Landing, California during the period of October 1, 2013 through June 6, 2014

Week	Beginning Date	Mean Water Temperature (C°)	Mean River Flow (CFS)	Mean Secchi Depth (cm)	Mean Water Turbidity (NTU)
40	10/1/13	16.8	5,858	170.7	1.2
41	10/8/13	15.9	5,216	196.3	1.3
42	10/15/13	16.1	4,450	199.3	1.9
43	10/22/13	16.3	3,743	154.6	2.4
44	10/29/13	14.5	5,171	102.5	4.4
45	11/5/13	13.3	5,308	132.4	3.5
46	11/12/13	13.5	4,690	175.0	2.9
47	11/19/13	11.8	4,957	139.8	4.1
48	11/26/13	10.6	4,604	150.6	3.6
49	12/3/13	8.3	4,511	149.6	3.8
50	12/10/13	6.5	4,611	128.5	4.6
51	12/17/13	8.0	4,642	153.1	3.9
52	12/24/13	8.8	4,657	161.0	3.8
53	12/31/13	8.3	4,695	167.6	2.9
1	1/1/14	8.7	4,459	152.0	3.4
2	1/8/14	9.0	3,884	177.7	3.7
3	1/15/14	9.7	3,571	167.2	3.1
4	1/22/14	10.2	3,416	149.4	3.6
5	1/29/14	11.0	3,805	104.9	5.9
6	2/5/14	10.7	6,286	78.8	13.2
7	2/12/14	13.1	7,676	44.2	38.8
8	2/19/14	13.3	4,979	59.7	16.4
9	2/26/14	13.8	8,779	40.1	62.9
10	3/5/14	14.5	15,173	25.4	55.8
11	3/12/14	15.0	10,191	32.9	52.0
12	3/19/14	15.8	5,158	56.8	16.9
13	3/26/14	14.9	7,894	49.9	24.5
14	4/2/14	13.7	9,229	31.8	28.9
15	4/9/14	19.1	6,076	60.1	13.3
16	4/16/14	20.5	4,749	81.6	9.0
17	4/23/14	18.5	4,234	112.1	5.4
18	4/30/14	20.3	3,664	123.7	3.4
19	5/7/14	19.4	3,517	118.4	4.0
20	5/14/14	21.6	3,304	108.4	4.4
21	5/21/14	22.4	3,849	111.5	3.9
22	5/28/14	21.6	4,589	80.1	7.4
23	6/4/14	22.4	4,953	69.1	4.7

Summary of Chinook Salmon Emigration

All races and juvenile life stages of Chinook salmon were represented in the RST catch during the sampling season. A total of 106,613 juvenile salmon was captured, of which 106,466 unmarked (adipose intact) Chinook salmon accounted for 99.9% of total catch. Unmarked Chinook salmon include naturally spawned winter-run, spring-run, fall-run and late fall-run. One-hundred-twenty-six marked Chinook salmon were caught, or 0.1% of total catch. Historically, upstream hatcheries produced and released into the Sacramento River above Red Bluff late fall-run, winter-run, and fall-run Chinook salmon. This year, due to unfavorable river conditions at the time of release, portions of the hatchery produced fall-run Chinook salmon were trucked to and released in the Delta. On April 4, one river release of over 3 million hatchery produced fall-run Chinook occurred. Winter-run and late-fall run Chinook were released in accordance to historic hatchery practices. Due to differential growth rates of hatchery produced fish some marked Chinook salmon captured by the RSTs were incorrectly identified using LAD methodology confirmed through CWT analysis.

The first and last capture of juvenile Chinook salmon occurred during week 40, on October 2, and week 23, on June 6, respectively. Peak catch occurred during week 9 where 49,137 Chinook salmon, or 46.1% of the season's total catch, were captured over 208.9 hours of monitoring.

In-river Produced Chinook Salmon

Winter-run

All unmarked winter-run Chinook salmon were assumed to be in-river produced as all upstream releases of hatchery origin Chinook were externally marked by the removal of the adipose fin prior to release. A total of 142 naturally produced winter-run Chinook salmon were caught by the RSTs. The first fish of this run was caught during week 40 on October 5. Winter-run were present in the RSTs during week 40 through week 14. Catch peaked during week 9 and 10 with 93 winter-run sized fish accounting for approximately 65% of the season total catch of this race and a CPUE of 0.31. All winter-run captured during the sampling period were BY 2013 based on their size at capture (Table 2).

Table 2 Summary of the weekly catch of in-river produced juvenile winter-run Chinook salmon sampled from October 1, 2013 through June 6, 2014. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
40	10/5/2013	215.5	2	0.009	38	36	39	2.1
41	10/10/2013	302.9	2	0.007	41	41	41	n/a
4	1/25/2014	258.1	1	0.004	100	100	100	n/a
7	2/12/2014	166.3	23	0.138	95	77	140	15.9
8	2/19/2014	339.4	3	0.009	95	78	105	14.6
9	3/1/2014	208.9	63	0.302	99	82	146	14.4
10	3/7/2014	92.6	30	0.324	97	84	135	12.5
11	3/12/2014	179.3	17	0.095	102	87	145	14.3
14	4/2/2014	145.4	1	0.007	110	110	110	n/a

Spring-run

Unmarked spring-run Chinook salmon catch can include unmarked portions of hatchery origin fall-run Chinook from CNFH. Often hatchery origin fish display different growth rates compared to fish rearing in-river. Unmarked portions of hatchery release groups are often misidentified in both race and origin at monitoring locations downstream of release sites.

A total of 1,509 unmarked spring-run Chinook salmon was caught by the RSTs. The first spring-run sized fish was caught during week 43 on February 12. Spring-run emigration timing was bimodal with two peaks in catch occurring during the monitoring year. The first peak occurred during weeks 9 through 11 with a catch total of 1,047 and a CPUE of 2.18. The second peak occurred during weeks 13 and 14 with a catch total of 211 and a CPUE of 0.63. All juvenile spring-run Chinook salmon sampled by the RSTs were BY 2013 based on size at capture (Table 3).

Table 3. Summary of the weekly catch of in-river produced juvenile spring-run Chinook salmon sampled between October 1, 2013 through June 6, 2014. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
7	2/12/2014	166.3	34	0.204	60	54	73	4.6
8	2/19/2014	339.4	13	0.038	61	57	66	2.8
9	2/28/2014	208.9	494	2.365	67	59	81	4.9
10	3/5/2014	92.6	289	3.121	69	61	84	5.0
11	3/12/2014	179.3	264	1.472	71	64	87	5.1
12	3/19/2014	183.2	43	0.235	72	68	87	4.1
13	3/26/2014	187.2	109	0.582	78	73	90	4.1
14	4/2/2014	145.4	102	0.702	79	74	97	4.4
15	4/9/2014	178.3	90	0.505	82	77	89	2.7
16	4/16/2014	304.9	69	0.226	88	81	97	4.5
17	4/23/2014	209.3	2	0.010	89	86	92	4.2

Fall-run

All unmarked fall-run Chinook salmon catch can include unmarked portions of hatchery origin fall-run Chinook from CNFH. Often hatchery origin fish display differential growth rates compared to fish rearing in-river. Unmarked portions of hatchery release groups are often misidentified in both race and origin at monitoring locations downstream of release sites.

A total of 104,815 unmarked fall-run Chinook salmon was caught by the RSTs. The first fall-run were caught during week 2 on January 11 and were present throughout the remainder of the survey period with few exceptions. Catch peaked on week 9 with a total of 48,505 fall-run captured, representing 46.3% of total in-river produced fall-run Chinook catch and a CPUE of 232.2. All juvenile fall-run Chinook salmon sampled by the RSTs were BY 2013 based on size at capture (Table 4).

Table 4. Summary of the weekly catch of in-river produced juvenile fall-run Chinook salmon sampled between October 1, 2013 and June 6, 2014. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
2	1/11/2014	327.5	2	0.006	38	37	39	1.4
3	1/17/2014	335.1	2	0.006	39	37	40	2.1
5	2/4/2014	322.9	1	0.003	37	37	37	n/a
7	2/12/2014	166.3	22,579	135.773	39	32	53	2.7
8	2/19/2014	339.4	3,485	10.268	41	31	57	3.6
9	2/26/2014	208.9	48,505	232.192	43	30	59	4.7
10	3/5/2014	92.6	16,792	181.339	42	33	62	5.6
11	3/12/2014	179.3	11,667	65.07	43	31	66	7.3
12	3/19/2014	183.2	402	2.194	49	35	68	7.2
13	3/26/2014	187.2	337	1.8	53	35	72	9.4
14	4/2/2014	145.4	689	4.739	58	33	75	10.1
15	4/9/2014	178.3	227	1.273	64	46	78	8.2
16	4/16/2014	304.9	87	0.285	68	41	83	10.9
17	4/23/2014	209.3	20	0.096	74	45	86	12.2
18	5/1/2014	312.7	6	0.019	78	71	84	5.6
19	5/8/2014	305.7	6	0.02	84	74	93	7.1
20	5/14/2014	342.7	7	0.02	79	50	90	14
22	5/29/2014	285.9	1	0.003	68	68	68	n/a

Late fall-run

There were no in-river produced late fall-run Chinook salmon captured during the sampling season.

Hatchery Produced Chinook Salmon

Upstream production releases from CNFH and LSNFH consisted of winter-run, fall-run and late fall-run Chinook and totaled 5,667,379. In prior years, CNFH would release all hatchery produced fall-run Chinook salmon into the Sacramento River above Red Bluff. However, this year, due to unfavorable river conditions, a portion of the hatchery produced fall-run Chinook salmon were trucked to and released in the Delta. One release of 4,506,160 fall-run occurred upstream of Red Bluff at CNFH. An additional 7,273,847 were trucked to Delta release sites near Rio Vista, Mare Island, and San Pablo Bay.

It is the intention of both hatcheries to mark, by the removal of the adipose fin, and tag, with a CWT, at least 25% of hatchery produced fish under the guidelines of the Constant Fractional Marking Program (Palmer-Zwahlen *et al*. 2019). Hatchery produced winter-run and late fall-run

Chinook Salmon are 100% marked. However, due to error associated with the marking and tagging equipment utilized in this process, portions of each release were not marked and/or tagged. A total of 193,155 BY2013 winter-run Chinook Salmon were released by LSNFH. Within this release, 2,047 (1.1%) were marked but not tagged, 30 (<0.1%) were tagged but not marked, and 173 (0.1%) were neither marked nor tagged. A total of 968,064 BY 2013 late fall-run Chinook salmon were released by CNFH. Within this release, 8,554 (0.9%) were marked but not tagged, 15,608 (1.6%) were tagged but not marked, and 740 (0.1%) were neither marked nor tagged (Table 6).

Following the releases, 126 adipose fin-clipped Chinook salmon were captured by the RSTs consisting of all 4 races using the LAD criteria for race determination: 88 winter-run (69.8%), 22 spring-run (17.5%), 15 fall-run (11.9%), and 1 late fall-run (0.8%).

Table 5. Summary of hatchery production of juvenile Chinook salmon and steelhead trout by CNFH and LSNFH, released upstream from the Knights Landing sampling site during the sampling period of October 1, 2013 through June 6, 2014.

BY & Race	Week	Release Date	Number Marked with CWT	Number Marked without CWT	Number Unmarked with CWT	Number Unmarked without CWT	Release Location
BY2013 Late-fall	49	12/10/13	267,301	0	7,834	401	CNFH
BY2013 Late-fall	1	1/7/14	68,516	361	3,245	0	CNFH
BY2013 Late-fall	2	1/13/14-1/14/14	534,488	7,457	4,529	339	CNFH
BY2013 Late-fall	3	1/23/14	72,857	763	0	0	CNFH
BY2013 Winter	6	2/10/14	190,905	2,047	30	173	LRP
BY2013 Fall	14	4/4/14	1,125,706	0	0	3,380,454	CNFH

LRP = Lake Redding Park; CNFH = Coleman National Fish Hatchery

Winter-run

A total of 86 hatchery produced juvenile winter-run Chinook salmon was captured by the RSTs between weeks 9 and 11. All hatchery produced winter-run Chinook were BY 2014 (Table 7).

Table 6. Summary of weekly catch of hatchery produced juvenile winter-run Chinook salmon sampled from October 1, 2013 through June 5, 2014. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
9	3/1/2014	208.9	70	0.335	96	83	120	7.6
10	3/5/2014	92.6	12	0.130	94	88	108	5.2
11	3/12/2014	179.3	6	0.033	97	89	108	6.3

Spring-run

A total of 22 hatchery origin juvenile Chinook was identified as spring-run using LAD methodology. These fish were captured during weeks 9, 15, and 16. Hatcheries upstream of the sampling site do not produce spring-run. To correctly identify the run and hatchery of origin for spring-run sized fish, CWTs were removed and read. CWT analysis confirmed that the LAD spring-run sized hatchery origin Chinook captured during week 9 were winter-run Chinook released by LSNFH and those captured during weeks 15 and 16 were fall-run Chinook released by CNFH (Table 7).

Table 7. Summary of weekly catch of hatchery produced juvenile spring-run Chinook salmon sampled between October 1, 2013 through June 6, 2016. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
9	3/4/2014	208.9	5	0.024	71	62	80	7.5
15	4/11/2014	178.3	10	0.056	83	79	90	4.1
16	4/16/2014	304.9	7	0.023	84	82	89	2.3

Fall-run

In years prior, all releases of fall-run Chinook salmon produced by CNFH occurred in the Sacramento River above Red Bluff. This strategy promoted the imprinting of juvenile Chinook on their natal waters, the use of riverine rearing habitat, and a more natural Delta entry timing following diel and hydrological cues. Only one release of over 3 million fall-run Chinook from CNFH occurred in-river. The remaining 7.2 million fall-run Chinook raised at CNFH were trucked to various release sites in the Delta and San Pablo Bay because drought and river conditions were expected to have deleterious effects on groups released in-river (Jones 2015). A total of 15 hatchery origin late-fall Chinook salmon was captured during weeks 15 and 16 following a release during week 14 (Table 9).

Table 8. Summary of weekly catch of hatchery produced juvenile fall-run Chinook salmon sampled between October 1, 2014 through June 5, 2015. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	Mean FL (mm)	Min FL (mm)	Max FL (mm)	Standard Deviation
15	4/11/2014	178.3	11	0.062	76	73	79	1.8
16	4/16/2014	304.9	4	0.013	79	77	80	1.4

Late-Fall run

Only one hatchery produced late fall-run Chinook was captured. This occurred during week 5 on February 1 (Table 9).

Table 9.. Summary of weekly catch of hatchery produced juvenile late fall-run Chinook salmon sampled between October 1, 2013 through June 6, 2014. Weeks during the monitoring season not presented here resulted in zero catch of this race.

Week	Beginning Date	Effort (h)	Total Catch	CPUE	FL (mm)
5	2/1/2014	322.9	1	0.003	182

Summary of Steelhead Trout Emigration

No catch of in-river or hatchery produced steelhead trout occurred during this monitoring season.

Trap Efficiency Trials

Four efficiency trials were conducted during weeks 8 through 11 using fall-run Chinook salmon externally marked with BBY stain. The highest efficiency was observed during trials conducted during week 11 with a value of 1.53%. Overall, a total of 1,363 fall-run fish was used in efficiency trials, and 17 of these fish were recaptured. The mean trap efficiency for the season was 1.16% (Table 10).

Table 10. Summary of capture efficiency trials initiated between October 1, 2013 through June 6, 2014.

Week	Week Dates	Stained Released	Stained Recaptured	Efficiency Rating (%)
8	2/16/2014-2/22/14	136	1	0.74
9	02/23/14-03/01/14	149	2	1.34
10	03/02/14-03/08/14	488	5	1.02
11	03/09/14-03/15/14	590	9	1.53

Passage Estimates

Annual passage for each run was estimated from the beginning of the week where the first catch of that run was observed to the end of the week where the last catch of that run was observed. It is estimated that a total of 18,854,246 fall-run, 275,939 spring-run, and 19,907 winter-run Chinook salmon passed the monitoring site between October 10, 2014 and June 05, 2015 (Table 11).

Table 11. Estimates of in-river produced Chinook salmon that passed the Knights Landing sampling location between October 1, 2013 through June 6, 2014 and associated 95% confidence interval (CI).

Race	Passage	Lower 95% CI	Upper 95% CI
Fall	18,854,246	12,199,145	28,960,378
Spring	275,939	171,718	428,550
Winter	19,907	13,247	30,508

Other Fish Species Captured

A total of 2,775 non-target fishes were captured during the 2013/2014 sampling season, representing 38 different species both native and non-native. Unknown individuals were identified to closest familial or genus taxonomic groups. Juvenile *L. tridentate* and *L. ayresi* were collectively grouped as *Lampetra* spp. (Table 12).

Table 12. Summary of non-target fish species captured between October 1, 2013 and June 6, 2014

Common Name	Scientific Name	Total Catch	Mean TL (mm)	Min TL (mm)	Max TL (mm)	Standard Deviation
Sacramento splittail	*Pogonichthys macrolepidotus*	757	53	19	300	198.7
Inland silverside	*Menidia beryllina*	354	66	20	102	58.0
Black crappie	*Pomoxis nigromaculatus*	223	84	19	260	170.4
Fathead minnow	*Pimephales promelas*	213	31	17	101	59.4
Sacramento Pikeminnow	*Ptychocheilus grandis*	168	82	20	317	210.0
Brown bullhead	*Ameiurus nebulosus*	158	68	50	135	60.1
Sacramento sucker	*Catostomus occidentalis*	107	83	17	451	306.9
River lamprey	*Lampetra ayresi*	97	143	115	195	56.6
Tule perch	*Hysterocarpus traskii*	86	53	20	147	89.8
Wakasagi	*Hypomesus nipponensis*	86	39	7	102	67.2
Golden shiner	*Notemigonus crysoleucas*	78	69	21	131	77.8
Lamprey ammocete	*Lampetra* spp.	64	113	11	143	93.3
Unknown minnow	Family Cyprinidae	56	31	19	41	15.6
Mosquitofish	*Gabusia affinis*	49	35	22	72	35.4
Bluegill	*Lepomis macrochirus*	40	40	18	220	142.8
Unknown sunfish	Family Centrarchidae	33	23	14	37	16.3
Common carp	*Cyprinus carpio*	28	55	21	150	91.2
Threadfin shad	*Dorosoma petenense*	28	90	40	116	53.7
Channel catfish	*Ictalurus punctatus*	20	96	50	310	183.8
Pacific lamprey	*Lampetra tridentata*	18	119	102	167	46.0
White crappie	*Pomoxis annularis*	17	105	22	300	196.6
Goldfish	*Carassius auratus*	14	73	27	392	258.1
White catfish	*Ameiurus catus*	14	129	47	255	147.1
Hardhead	*Mylopharodon conocephalus*	11	99	32	223	135.1
Largemouth bass	*Micropterus salmoides*	9	83	30	260	162.6
Green sunfish	*Lepomis cyanellus*	8	78	28	220	135.8
Striped bass	*Morone saxatilis*	6	258	31	565	377.6
American shad	*Alosa sapidissima*	4	195	57	520	327.4
Black bullhead	*Ameiurus melas*	4	143	128	160	22.6
California roach	*Hesperoleucus symmetricus*	4	68	32	135	72.8

Common Name	Scientific Name	Total Catch	Mean TL (mm)	Min TL (mm)	Max TL (mm)	Standard Deviation
Red shiner	*Cyprinella lutrensis*	4	57	43	85	29.7
Hitch	*Lavinia exilicauda*	3	63	61	65	2.8
Threespine stickleback	*Gasterosteus aculeatus*	3	33	33	35	1.4
Riffle sculpin	*Cottus gulosus*	2	60	60	60	n/a
Smallmouth bass	*Micropterus dolomieu*	2	107	84	130	32.5
Spotted bass	*Micropterus punctulatus*	2	95	94	96	1.4
Unknown catfish	Ictaluridae	2	34	18	49	21.9
Redear sunfish	*Lepomis microlophus*	1	180	180	180	n/a
Warmouth	*Lepomis gulosus*	1	78	78	78	n/a

DISCUSSION

The 2014 water year (October 1, 2013 to September 30, 2014) is the second year of what would become a historic five-year drought in California. Flows experienced during monitoring were atypical of historic trends. In prior years, strong winter storms producing heavy rain and snow accumulation fed Sacramento River flows through tributary accretions. During the 2014 water year flow generating storms were not observed until February (Figure 6). Often, flows observed during strong winter storms would overtake the flood relief structures along the banks of the Sacramento River, including the Moulton (RM158), Colusa (RM146), Tisdale (RM119) and Fremont (RM83) weirs (Figure 5).

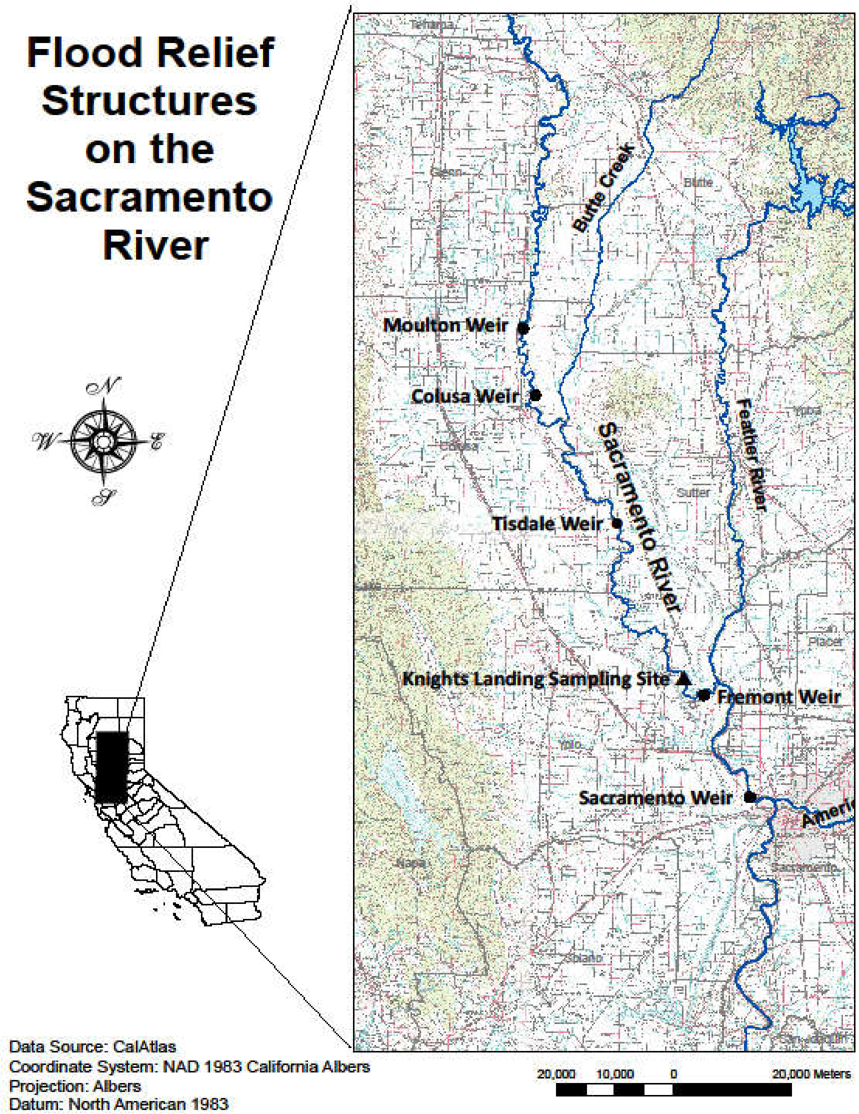

Figure 4. Map of the upper Sacramento River and tributaries depicting locations of the CDFW juvenile monitoring site in relation to flood relief structures

The over topping of the Moulton, Colusa and Tisdale weirs inundates the Sutter Bypass, and the Fremont Weir inundates the Yolo Bypass, providing emigrating juvenile salmonids access to thousands of acres of natural flood plain rearing habitat and routing them around key monitoring stations such as that at Knights Landing. Flooding flows inundating the bypasses were not observed this year and juvenile emigration corridors were constrained to the mainstem of the Sacramento River. This allowed the Knights Landing to sample the population of juveniles produced in the upper Sacramento River as they entered the Delta providing a better picture of the timing of emigration and allowing more accurate abundance estimates to be calculated.

Increased flow, reduced water temperatures, and increases in water turbidity promote the downstream migration of juvenile salmonids (Michel *et al.* 2013, Kemp *et al.* 2005, Giorgi *et al.* 1997). During the 2013/2014 monitoring year, there were three distinct flow events where late winter and spring storms elevated river flows. While catch data resolution, trap capture efficiency, and uncertainty in the geographic distance fish travel prior to capture makes correlating emigration cues with catch data difficult, increases in juvenile salmonid presence were observed with each increase in flow (Figure 5), a trend that is similar to those observed in previous years. Combined catch during these flow events (n=104,953) made up 98% of the total juvenile Chinook salmon catch. Increased flows have also been suggested to increase survival for emigrating salmonids (Perry 2010, Rosario *et al* 2013, Notch *et al* 2020) High river flows and volume of emigrating juvenile Chinook observed during this water year likely contributed to high survival to the Delta.

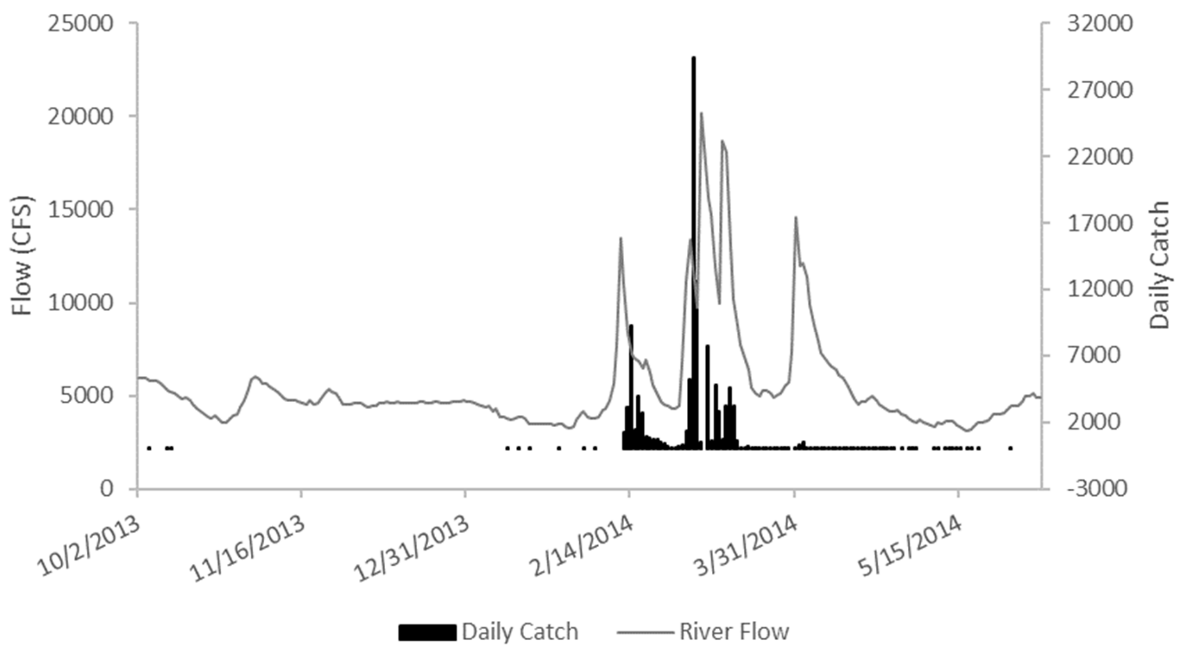

Figure 5. Daily flow measured at the CDEC Wilkins Slough Gauge and total daily catch of in-river produced Chinook salmon between October 1, 2013 and June 6, 2014.

Catch and flow data suggest that very few fish passed the sampling site during periods when river flow was low and were largely driven by releases from Lake Shasta through Keswick Reservoir. However, it is likely migrating juvenile salmonids passed the sampling site during these periods at levels below that which can be observed by sampling equipment. The performance of trapping equipment during varying environmental conditions and trap configurations which reduce effort can be evaluated through extensive trap capture efficiency testing. Currently, these assessments rely on successful trapping, limiting the range of environmental conditions to those periods where trap catch is high. There were four trap efficiency tests performed during the 2013/2014 monitoring year resulting in an average efficiency of 1.16%. These tests occurred during periods of high flow and turbidity, conditions suggested to decease trap avoidance and increase catchability of passing salmonids. Expanding trap efficiency analysis to include time periods where flows are low and effort is reduced can increase the confidence of passage estimations and further define emigration timing response to environmental conditions.

Passage estimations and measures of emigrations timing also rely on correctly identifying the run of juveniles observed in the RSTs. CWT data collected throughout the season demonstrates error associated with length at date run assignment methodology. Twenty of the 124 juvenile hatchery origin Chinook (16%) sampled for CWT analysis were assigned the incorrect run using length at date methods. Misidentification using the LAD methods has also been observed in natural origin juveniles Chinook (Johnson *et al.* 2012, Merz *et al.* 2014). These errors also have implications in accurate and complete reporting of catch numbers for delta water operation triggers, as well as ESA Section 10 permit compliance for project activities. Currently, run assignment errors are only tracked through CWT verification of hatchery origin Chinook salmon. Future monitoring efforts should include the collection and evaluation of tissue samples from natural origin Chinook salmon in assessments of run confirmation.

Data collected during the 2013/2014 Lower Sacramento River Juvenile Salmonid Emigration Program provided a complete measure of emigration timing and facilitated an estimation of run specific abundance upon entry into the Sacramento-San Joaquin Delta. Further, data collection efforts fulfilled the program's goals of:

1. Providing early warning of emigrating listed salmonids moving into the Delta so the CVP and SWP projects could modify their water export activities, including DCC Gate closures for a period sufficient to minimize entrainment of juveniles into the south Delta;
2. Documenting passage of emigrating salmonids including timing, relative abundance, and response to environmental conditions;
3. Estimating emigrating salmon numbers in the lower Sacramento River above the Delta; and
4. Contributing to the long-term dataset on emigration with which to compare changes over time.

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Sampling Options

Conditions						Additional Options During High Flow Periods***		
		Daily Trap Check	Twice Daily Trap Checks	Continuous Monitoring During Daylight Hours	Half Cone Sampling (cones modified to reduce fishing effort)	Sub-sample (Random sampling within 12hr. periods)	Fishing One Trap (with half cone)****	Shore Sampling (traps secured to shore to avoid debris)****
Conditions	0-10,000 CFS: Stable Flows							
	0-10,000 CFS: Unstable Flows (> 3,500 CFS change in 12 hrs. at respective gages*)							
	10,000-20,000 CFS: Stable Flows							
	10,000-20,000 CFS: Unstable Flows (> 3,500 CFS change in 12 hrs. at respective gages*)							
	> 20,000 CFS: Stable Flows							
	> 20,000 CFS: Unstable Flows ** (> 3,500 CFS change in 12 hrs. at respective gages*)							

*CDEC gages: Sac. River below Wilkins Slough (WKL) for Knights Landing and Sac. River at Colusa (COL) for Tisdale Weir

**Sampling during high flows will be conducted depending on equipment, personnel safety, and logistical concerns. Sampling will be evaluate in real-time and may be discontinued for any of these reasons as well as if lethal take risk for listed species is high.

***High Flow period operations will be evaluated in real-time and may very with data needs, take risk, and equipment and personnel safety .

**** May have implications on trap capture efficiency and data comparability between sampling periods. Sampling will be conducted in a manner to allow for calculation of 24 hr. catch indices if possible.

Condition Dependent Sampling Schedule used to guide RST operations during varying environmental conditions.