California Department of Fish and Wildlife
North Central Region
Lower Sacramento River Juvenile Salmonid Emigration Program

Timing, Composition and Abundance of Juvenile Salmonid Emigration in the Sacramento River near Knights Landing October 2011 – June 2012[1]

[1]Conducted by the California Department of Fish and Wildlife and funded by the Interagency Ecological Program

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LIST OF ABBREVIATIONS AND ACRONYMS

BB	Bend Bridge
BBY	Bismarck brown Y
BO	Biological Opinion
BY	Brood year
CDEC	California Data Exchange Center
cfs	Cubic feet per second
CI	Confidence interval
cm	Centimeter
CNFH	Coleman National Fish Hatchery
CPUE	Catch Per Unit Effort
CVP	Central Valley Project
%CV	Percent coefficient of variation
CWT	Coded wire tag
DCC	Delta Cross Channel
Delta	Sacramento-San Joaquin Delta
DFW	California Department of Fish and Wildlife
DOSS	Delta Operations for salmon and Sturgeon
ESU	Evolutionary Significant Unit
FL	Fork Length
km	Kilometer
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
QAQC	Quality assurance and quality control
Rkm	River kilometer
RPA	Reasonable and prudent alternatives
RPM	Revolutions per minute
RST	Rotary screw trap
SD	Standard deviation
SWP	State Water Project
YOY	Young-of-year

EXUTIVE SUMMARY

The North Central Region of the California Department of Fish and Wildlife oversees a juvenile salmonid monitoring program on the Sacramento River in California with two separate sampling locations. The downstream most sampling location is 0.8 kilometers downstream of the town of Knights Landing, at Sacramento (Rkm) 144. Two paired RSTs were used and were outfitted with 2.4-meter cones to catch juvenile emigrating fish between October 6, 2011 and June 25, 2012. Data collected during this period represents the 16th consecutive season of sampling at this location. The purpose of sampling was to gather information about native juvenile salmonids, specifically Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*).

During the sampling season, the program collected a total of 13,622 un-marked (non-adipose fin clipped) juvenile Chinook salmon in 10,780.75 hours of RST sampling, which provides an average catch rate of approximately 1.26 salmon captured per hour. Of these 13,622 Chinook salmon, 12,790 (93.89%) were fall-run, 722 (5.30%) were spring-run, 104 (0.76%) were winter-run and 6 (0.04%) were late fall-run. Fall-run Chinook salmon were captured between weeks 4 and 24, with a majority of catch occurring during weeks 4 and 20. Spring-run Chinook salmon were captured between weeks 43 and 19, with a majority of catch occurring during weeks 15 through 17. Winter-run Chinook salmon were captured between weeks 41 and 14, with the majority of catch occurring during weeks 4 and 5. Late fall-run Chinook salmon were captured between weeks 1 and 16, where during week 4 the greatest catch of late fall-run occurred.

Two hatcheries upstream from the sampling location, Livingston Stone National Fish Hatchery and Coleman National Fish Hatchery, released hatchery produced salmonids which were eventually sampled by the Knights Landing program. A total of 206 hatchery produced Chinook salmon of mixed races were captured by the Knights Landing RSTs. Hatchery produced salmon were identified by the lack of an adipose fin, which was removed by the hatcheries during the coded wire tagging (CWT) process. Of the 206 hatchery produced Chinook salmon captured by the RSTs, 138 (66.99%) were fall-run, 10 (4.85%) were winter-run and 58 (28.16%) were late fall-run. No spring-run Chinook salmon were produced by hatcheries upstream of the sampling location.

In-river produced (not reared by a hatchery) yearling steelhead trout were captured by the RSTs between week 4 and 14 of the sampling season. A total of 12 in-river produced steelhead trout were captured during this time ranging from 104 mm FL to 306 mm FL, with a mean FL of 226 mm. There were 149 hatchery produced steelhead trout captured by the RSTs during the sampling season. Hatchery produced steelhead trout were sampled between week 4 and week 16. These fish were identified as hatchery produced steelhead as they were missing their adipose fin, which was removed by the hatcheries before their release date.

Mean weekly flow varied throughout the 2011-2012 season at the sampling location near Knights Landing. To assess Sacramento River flow rates, the program used values reported by the California Department of Water Resources, California Data Exchange Center (CDEC) Wilkins Slough gauge. River flows in week 40 at the start of the sampling period had a weekly mean of

9,285 cfs, (range 8,630 to 9,570 cfs). River flows in week 26 at the end of the sampling period had a weekly mean of 6,519 cfs (range 6,140 to 6,870 cfs). However, flows varied substantially between the start and finish of the sampling season; in week 14, weekly mean flows peaked at 15,075 cfs (range 10,700 to 20,100), and in week 19 the lowest mean weekly flows were observed to be 4,849 cfs (range 4,120 to 5,940 cfs).

Environmental data collected on a per-trap-check basis included parameters such as: water temperature, water transparency, and water turbidity. During the reporting period, water temperatures at the sampling site ranged from a low of 6.7 °C in Week 52 on December 26, 2011, to a high of 22.8 °C in week 25 on June 18, 2012. Secchi disc readings at the sampling site varied between a low of 9 centimeters (cm) of water transparency during weeks 4, 15 and 16 (January 23, 2012, April 14, 2012 and April 15, 2012 respectively) to a high of 152 cm during week 43 on October 27, 2011. Turbidity at the sampling site ranged from a low of 4.5 NTU during week 44 on November 3, 2011, to a high of 246.5 NTU during week 13 on March 30, 2012.

Mark and recapture methodology was used to evaluate trap capture efficiency. Batches of a minimum of 150 non-adipose fin clipped juvenile fall-run Chinook salmon were stained with Bismarck brown Y and released 1.6 kilometers (km) upstream from the sampling site. A total of 4,701 fall-run Chinook salmon were marked and a total of 45 of these salmon were then recaptured by the RSTs. The sampling season's mean trap capture efficiency was 0.9 percent. Expanded, or uncaptured, passage estimates at the Knights Landing RSTs based on 0.9 percent capture efficiency (80 percent confidence limits in parentheses) were 1,955,243 (1,206,311 – 5,156,809) un-marked (non-adipose fin clipped) Chinook salmon. This estimate of un-marked Chinook salmon included 11,560 (7,113 – 30,409) winter-run 2010 BY, 106,541 (65,732 – 280,944) spring-run 2011 BY, 1,843,765 (1,137,536 – 4,862,794) fall-run 2011 BY, 554 (342 – 1,462) late fall-run 2010 BY, and 333 (205 - 877) late fall-run 2011 BY. An estimated 1,774 (1,094 – 4,678) in-river produced yearling steelhead trout passed the sampling site during the sampling period.

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https://www.wildlife.ca.gov/

The Interagency Ecological Program can be found at:
http://www.water.ca.gov/ie

INTRODUCTION

The purpose of the Lower 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 Sacramento-San Joaquin Delta (Delta). The upper Sacramento River and associated tributaries provide spawning and rearing habitat for four native races of Chinook salmon; fall-run, spring-run (Federally listed threatened), late fall-run and winter-run (Federally listed endangered) as well as native Central Valley winter steelhead trout (Federally listed threatened). The Knights Landing sampling site is located just down river from the town of Knights Landing, at approximately river kilometer (Rkm) 144. All in-river produced (naturally spawned) salmonids captured by the rotary screw traps (RSTs) at Knights Landing are assumed to be produced in the upper Sacramento River and its tributaries, as the sampling site is above the confluence with lower, large tributaries, specifically the American and Feather rivers located at Sacramento River 96.7 Rkm and 128.8 Rkm, respectively.

In-river produced juvenile Chinook salmon emigrate from the upper Sacramento River and its tributaries toward the Delta in a wide range of sizes and maturity status (Healey 1991). Juvenile fall-run Chinook salmon are known to have a short residency period of one to seven months and typically migrate during the months of March through July. Juvenile spring-run Chinook salmon have a wide range 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 spring-run typically migrate between the months of March through June and between November and April as yearlings. Juvenile winter-run Chinook salmon may migrate as recently emerged fry, rear for a period and migrate as smolts or rear for longer periods and migrate as yearlings. Winter-run juveniles may have a residency period of five to ten months and will migrate as YOY or as yearlings in the months of November through May. Juvenile late fall-run Chinook salmon may also migrate as emerged fry, as smolts or as yearlings and typically migrate in the months of November through May. (Fisher 1994; Yoshiyama *et al*. 1998).

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

Two federal fish hatcheries, Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery, located upstream from the sampling location near Knights Landing produce steelhead trout and winter, fall and late-fall runs of Chinook salmon. These hatcheries tag portions of their Chinook salmon production by injecting CWTs. These hatcheries also externally mark portions of their salmon and steelhead production by removing the adipose fin prior to releasing their fish into the Sacramento River. Portions of these hatchery produced, in-river released juvenile salmonids were subsequently sampled by the RSTs.

The abundance of indigenous California Central Valley and upper Sacramento River salmonids have been severely reduced due to a variety of anthropogenic changes to the environment. Much of the historic spawning habitat for Central Valley salmonids is no longer accessible as construction of dams on many of the major salmonid bearing streams during the mid-1800's and mid-1900's has blocked access to over 72% of salmonid holding, spawning and rearing areas (Yoshiyama *et al*. 2001). Dams tend to create unsuitable habitat downstream of the impoundment by increasing in-river temperatures and river channelization while reducing natural river flows, natural cover and natural gravel recruitment necessary for successful spawning.

Juvenile salmonid rearing habitat in the Central Valley has been significantly reduced and degraded due to environmental alterations along migration corridors. Streams in the Central Valley have been altered and channelized with levees to protect city development and to aid agricultural needs. This practice has removed much rearing habitat and any loss in rearing habitat reduces juvenile survivability during emigration. In addition, water quality has been compromised by urban and agricultural runoff which may contain 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).

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 in-river 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 (State Water Project) and the Tracy Pumping Plant (Central Valley Project) (Kimmerer 2008).

Introduced, non-native fishes are widely distributed in the Sacramento River and Sacramento-San Joaquin Delta and are a recognized stressor on various early life history stages of salmonids. Introduced fishes can negatively affect native species by predation, disrupting food webs, reshaping ecosystem functions, introducing disease, or displacing native species (Mount *et al.* 2012). The introduction of highly efficient piscivores; the smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*) and striped bass (*Morone saxatilis*), imported to the Delta in 1874, 1879 and 1891 respectively (Dill 1997), have had considerable impacts to native salmon stocks. Such nonnatives 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). Nonnative piscivores occur in nearly all habitats used by emigrating and rearing juveniles including spawning grounds in the Upper Sacramento and tributaries, the entire Sacramento River migration corridor as well as the entire 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. The ability to identify emigration timing of juvenile salmonids enables water managers to adapt water transfer activities to avoid salmonid entrapment and entrainment in water diversion facilities. Various restrictions have been placed upon water diversion projects within the Delta in an effort to protect juveniles during peak emigration periods. Having a real time estimate of emigration timing and abundance of protected salmonid species as they enter the Delta improves the ability to implement and adapt protective measures, enhancing overall protection of salmonids while augmenting water management practice flexibility.

The NMFS recognized Delta water operations practices as hazardous to listed salmonid species through entrainment at the SWP and CVP pumping facilities. In response, NMFS suggested reasonable and prudent alternatives that would enable water export activities to continue in compliance with the Federal Endangered Species Act (NMFS 2009). Through the NMFS OCAP Biological Opinion, decision SWRCB 1641 (SWRCB 2000), the DCC gate operations would be modified in order to protect emigrating juvenile salmonids. The DCC gates are to be closed during peak emigration of juvenile salmonids. The DCC gates may be ordered to be closed on very short notice given advanced notice of listed juvenile salmonids migrating toward the gates.

The OCAP BO suggested the need of juvenile salmonid monitoring in the Sacramento River near Knights Landing. Data collected by the DFW Lower Sacramento River Juvenile Salmonid Emigration Monitoring Program near Knights Landing is used to identify and relate emigration trends and approximate numbers of juvenile salmonids entering the Delta. Data collected by the Program was distributed to constituents by DFW on a per-trap-check basis; when the traps were checked and data was gathered, the data was summarized in an electronic format and then distributed via email the same day. When the program reported winter-run Chinook salmon catch index of greater than three fish per day or greater, the interagency (DOSS) group has the option to suggest a closure of the DCC within 24 hours.

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 can 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.

METHODS

The Knights Landing program began sampling emigrating salmonids for the 2011-2012 season on October 6, 2011 and concluded the season on June 25, 2012 for a total of 264 days of continuous sampling. The Knights Landing sampling location was chosen due to its favorable river channel structure and flow conditions as well as its position within the Sacramento River system. Rotary screw traps were used for sampling as they 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, chained them together and placed them on the east side of the Sacramento River channel (river left). Channel position of the RSTs was determined by Sacramento River flow. During baseflow conditions, the RSTs were positioned in the thalweg approximately 10-m from the east bank. During high flow events, the traps were moved to within 3.4-m of the east bank to reduce excessive debris loading.

Initially, the RSTs were checked by CDFW personnel three times per week during low flow conditions and outside of peak juvenile salmonid emigration periods. As river flows and salmonid catch rates increased, CDFW staff increased the frequency of RSTs checks, eventually moving to a schedule where the RSTs were checked on a daily basis. Two to four personnel were assigned to check the traps, depending upon expected river flows and catch. Personnel accessed the RSTs using a CDFW pontoon boat which was moored on the Sacramento River at Knights Landing. The pontoon boat was outfitted with all the equipment necessary to collect data and maintain the RSTs.

Data gathered specific to the performance of the RSTs were recorded during each RST service check. Data obtained specific to each RST included: time since last trap service recorded to the nearest quarter of an hour, average cone revolutions per minute, total cone revolutions since last RST service, total hours fished[1], 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 Humminbird® handheld electronic depth finder.

[1]RST total hours fished = ((cone revolutions/RPM)/60) *2

Environmental data collected and recorded during each RST service included: water temperature, water transparency, water turbidity, and Sacramento River flow rate. Water temperature was recorded over time 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 calculated during each trap service using a Secchi disc following standard protocols (Orth 1983). Two water samples were collected during each trap service and analyzed using a LaMotte 2020 Turbidity Meter, then averaged and reported in Nephelometric Turbidity Units (NTU). Sacramento River flow rate was obtained from the

California Data Exchange Center (CDEC 2012) gauge at Wilkins Slough, which is located 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 FL measured to the nearest mm. Steelhead trout were measured to the nearest millimeter FL, weighed to the nearest tenth of a gram, and recorded by life stage: alevin, fry, parr, silvery parr or smolt. Chinook salmon data were similarly recorded, but salmon were distinguished by race: fall-run, spring-run, winter-run and late fall-run using Chinook salmon race length-at-date identification tables (Greene 1992). Any salmonid smaller than 40mm FL was not weighed due to limitations in scale accuracy. 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[2].

[2]Catch per unit of effort = total number of fish / total RST hours fished

All data were recorded on water-proof datasheets, transported to the Region 2 CDFW office, and checked for quality assurance and quality control (QA-QC). Once all datasheets were checked for QA-QC, data were entered into an Excel spreadsheet. Data summaries were e-mailed emailed to resource agencies and various stakeholders on the same day to provide real-time reporting of trap catch data.

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. The program began sampling in week 40 of 2011, and concluded sampling in week 26 of 2012 (started October 6, 2011 and concluded June 25, 2012).

Trap efficiency was evaluated using a mark-and-recapture method (Volkhardt). When catch numbers of juvenile fall-run Chinook salmon were abundant, batches of a minimum of 150 fish were externally marked using BBY as a staining agent. In some instances when daily catch was low, two days' worth of Chinook salmon catch were combined to produce a release group of 150 fish or more. An in-river livewell 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 with 80 percent confidence intervals were calculated for all Chinook salmon ESUs and steelhead by dividing the adjusted daily catch by the mean weekly trap efficiency. In an attempt to estimate the number of salmonid individuals that passed the Knights Landing sampling site through the entire emigration period, including weeks where trapping effort was less than 100 percent, total catch of steelhead trout and each race of Chinook salmon was expanded to represent 100 percent effort (Table 14). To expand catch to reflect 100 percent effort, the mean weekly catch was divided by effort (hours) and adjusted for 336 total hours in a week:

100% effort = mean weekly catch / (trap effort hours/actual hours in a week).

Up to 20 adipose fin-clipped, hatchery produced Chinook salmon of mixed races (winter, fall and late-fall) per trap, for a maximum total of 40 adipose fin-clipped salmon per trap maintenance event, were taken to a DFW laboratory for removal of each individual's CWT. The CWTs were read by DFW and cross referenced with size-at-release and date-at-release information provided by the federal hatcheries.

Coleman National Fish Hatchery fractionally marks fall-run Chinook salmon production at a rate of approximately 25% prior to release by removing the adipose fin from fish during the coded wire tagging process (CALFED 2004). Thus, some of the hatchery fish captured by the RSTs near Knights Landing may appear to be naturally produced and recorded as such. Many of the hatchery produced fall-run Chinook salmon are a larger size at capture date compared to in-river produced juveniles of the same race due to favorable hatchery conditions and available food provided to the fish while rearing in a hatchery. Larger hatchery fall-run Chinook salmon without external markings may appear to be naturally produced spring-run using length-at-date race criteria utilized by the Knights Landing Program.

RESULTS

Environmental Conditions

Mean hourly flow during the sampling season (October 6, 2011 through June 24, 2012) was 7,592 cfs (SD = 3,721; %CV = 49.0). Maximum flow recorded was 24,500 cfs on March 29 (week 13) and minimum flow recorded during the sampling period was 4,120 on May 9 (week 19) (Table 1, Figure1).

The minimum water transparency recorded at the sampling site was 9.1 centimeters (cm) on January 23 (week 4) and again on April 14 and 15 (weeks 15 and 16). The maximum water transparency recorded was 152.4 cm at the beginning of the season on October 27 (week 43).

Mean daily water transparency for the sampling season was 62.7cm (SD = 28.9; %CV = 46.1) (Table 1, Figure1).

Turbidity at the sampling site varied from a low of 4.5 NTU during week 44 on November 3 to a high of 246.5 NTU during week 13 on March 30. Mean daily turbidity during the sampling season was 25.9 NTU (SD = 30.4 SD; %CV = 117.4) (Table 1, Figure1).

Water temperatures generally decreased from the start of sampling efforts during week 40 through week 52 then stayed fairly close to the mean until week 16 when temperatures increased steadily until the end of the sampling season (Table 1, Figure1). Mean water temperature during the sampling period was 13.3 °C (SD = 4.4 SD; % CV = 33.0). The minimum water temperature recorded during the sampling period was 6.6 °C, on December 26 (week 52), while the maximum water temperature recorded was 23.3 °C on June 17 (week 24).

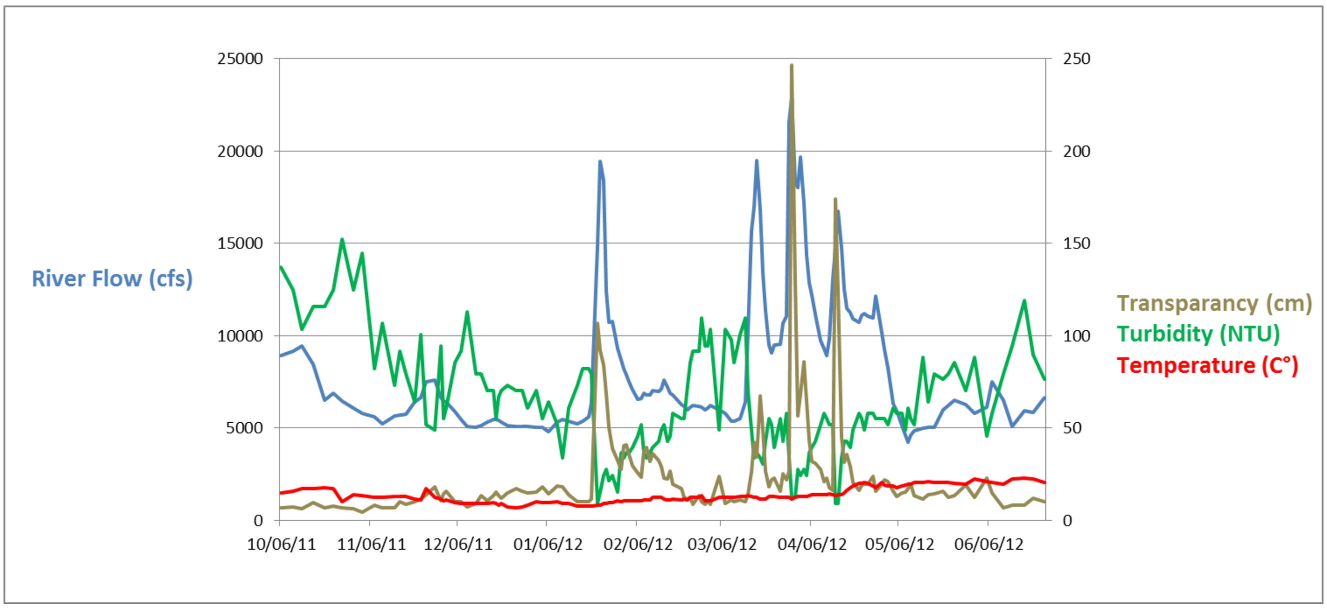

Figure 1. Daily water transparency (cm), turbidity (NTU) and temperature (C°) values collected at the sampling site during the 2011/2012 sampling season. Water flow rate was reported by CDEC, Wilkins Sough gauge and reported in cubic feet per second (cfs).

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 6, 2011 through June 25, 2012.

Week	Beginning Date	Mean Water Temperature (C°)	Mean River Flow (cfs)	Mean Secchi Depth (cm)	Mean Water Turbidity (NTU)
40	10/2/2011	13.2	9,285	137.2	6.8
41	10/9/2011	15.5	9,257	115.8	6.7
42	10/16/2011	16.6	7,398	115.8	8.1
43	10/23/2011	14.9	6,613	140.2	7.1
44	10/30/2011	12.8	5,859	134.1	5.4

Week	Beginning Date	Mean Water Temperature (C°)	Mean River Flow (cfs)	Mean Secchi Depth (cm)	Mean Water Turbidity (NTU)
45	11/6/2011	10.8	5,403	94.5	7.5
46	11/13/2011	11.7	5663	82.3	8.3
47	11/20/2011	10.6	6,876	73.2	11.7
48	11/27/2011	10.5	6,878	64.0	14.5
49	12/4/2011	8.5	5,488	97.5	8.9
50	12/11/2011	8.2	5,162	76.2	11
51	12/18/2011	8.1	5,300	67.1	13.7
52	12/25/2011	7.7	5,073	67.1	15.8
1	1/1/2012	9.3	4,939	64.0	16
2	1/8/2012	8.8	5,319	48.8	16.9
3	1/15/2012	7.7	5,527	79.2	10.3
4	1/22/2012	8.5	14,408	21.3	73.4
5	1/29/2012	9.8	8,413	33.5	34.5
6	2/5/2012	10.7	6,771	39.6	32.3
7	2/12/2012	11.0	7,089	48.8	25.5
8	2/19/2012	11.1	6,249	73.2	12.5
9	2/26/2012	10.6	6,169	97.5	10.3
10	3/4/2012	11.7	5,739	85.3	13.5
11	3/11/2012	12.1	9,436	73.2	20.6
12	3/18/2012	11.5	12,743	42.7	34.3
13	3/25/2012	11.3	14,836	36.6	77.8
14	4/1/2012	12.6	15,075	30.5	45.3
15	4/8/2012	13.4	10,849	45.7	46.4
16	4/15/2012	15.4	12,624	36.6	47.6
17	4/22/2012	19.0	11,156	54.9	19.1
18	4/29/2012	17.6	8,336	54.9	18.2
19	5/6/2012	19.0	4,849	54.9	15.9
20	5/13/2012	20.3	5,070	76.2	13.1
21	5/20/2012	20.0	6,156	79.2	13.7
22	5/27/2012	20.1	5,954	79.2	15.7
23	6/3/2012	20.2	6,645	51.8	23
24	6/10/2012	20.7	5,745	88.4	7.3
25	6/17/2012	21.5	5,877	103.6	10
26	6/24/2012	18.2	6,519	76.2	9.8

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 13,828 juvenile salmon were captured, of which 13,622 unmarked (adipose intact) salmon accounted for 98.5% of total catch. Unmarked Chinook salmon include naturally-spawned winter-run and spring-run Chinook salmon; and both naturally-spawned and hatchery-produced fall run Chinook salmon. The 206 hatchery-produced (adipose clipped) salmon captured accounted for 1.5% of total catch.

The first juvenile Chinook salmon was captured during week 41 and the last salmon was captured during week 24. However, the peak catch and catch rates did not occur until week 4 when 6,947 salmon of mixed races were captured with a CPUE of 28.2 fish per hour. Catch of salmon declined over the next six weeks, and then increased again in week 11. Mean weekly catch numbers of salmon remained consistent (> 20) until week 22 when catch dropped to less than five salmon a week and continually dwindled to week 24. No salmon were captured in the last two weeks of the sampling period.

Winter-run

All unmarked winter-run Chinook salmon caught by the RSTs were assumed to be in-river produced as LSNFH marked 100% of their production of this race prior to release. A total of 104 in-river produced winter-run were captured, and the first fish of this run were captured during week 41. Winter-run were inconsistently captured during weeks: 42, 48, 49, 1 and 3 where only one or two were captured per week (Table 2). During week 4, the first spike in Sacramento River flows related to the first large precipitation event of the winter occurred and 78 winter-run were captured. This was the greatest CPUE for winter-run during the sampling season where an average of 0.32 fish was captured per hour. Another increase in winter-run catch occurred and coincided with a second large precipitation event and related increase in river flows during weeks 12, 13 and 14. No other individuals of this race were captured after week 14. All winter-run captured during the sampling period were 2010 BY.

Table 2. Summary of weekly catch of in-river produced juvenile winter-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race was captured during week 41 and the last fish were captured during week 14.

Week	Beginning date	Effort (h)	Winter-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
41	10/9/2011	261.3	4	0.015	41	39	43	1.4
42	10/16/2011	325.3	1	0.003	36	36	36	n/a
48	11/27/2011	184.8	1	0.005	55	55	55	n/a
49	12/4/2011	362.5	1	0.003	81	81	81	n/a
1	1/1/2012	348.5	2	0.006	82	81	83	1
3	1/15/2012	362.1	1	0.003	96	96	96	n/a
4	1/22/2012	246.0	78	0.317	88	68	116	10.2
5	1/29/2012	252.9	5	0.020	97	81	122	13.8
6	2/5/2012	212.6	1	0.005	90	90	90	n/a
7	2/12/2012	334.6	1	0.003	105	105	105	n/a
8	2/19/2012	337.6	1	0.003	62	62	62	n/a
12	3/18/2012	267.6	2	0.007	98	96	99	1.5

13	3/25/2012	263.6	2	0.008	100	99	100	0.5
14	4/1/2012	236.9	4	0.017	109	104	115	4.8

Spring-run

A total of 722 unmarked spring-run Chinook salmon were captured during weeks 43, 4 and 5 and again between 9 and 19 (Table 3). However, the majority of spring-run Chinook salmon catch occurred in weeks 11 through 17, accounting for 97% of the total catch of this race. Mean catch rate during this period was approximately 0.4 fish per hour of RST sampling. All juvenile spring-run Chinook salmon sampled by the RSTs were 2011 BY.

The use of length-at-date criteria to distinguish salmon ESUs may have resulted in some hatchery fall-run Chinook salmon being classified as in-river produced spring-run Chinook salmon due to hatchery produced fall-run being larger at date than their natural origin counterparts. Approximately 68% of hatchery fall-run fish were not marked by the removal of adipose fins and may have been large enough to code as spring-run using length-at-date criteria used to distinguish salmon races. The first capture of a marked hatchery produced fall-run salmon (n = 4) occurred on April 24, 2012 during week 17 from a release by CNFH which occurred five days earlier on April 19. All spring-run captured prior to this date were considered in-river produced; while salmon captured after April 24 with a spring-run size range length-at-date value were recorded as spring-run but could have been unmarked fall-run hatchery-produced fish. Thirty salmon captured after April 24th were recorded as spring-run Chinook salmon by the program.

Table 3. Summary of weekly catch of in-river produced juvenile spring-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race was captured during week 43 and the last fish were captured during week 19.

Week	Beginning date	Effort (h)	Spring-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
43	10/23/2011	248.9	1	0.004	34	34	34	n/a
4	1/22/2012	246.0	6	0.024	50	53	45	2.9
5	1/29/2012	252.9	3	0.012	50	52	49	1.3
9	2/26/2012	313.6	1	0.003	68	68	68	n/a
10	3/4/2012	390.9	1	0.003	64	64	64	n/a
11	3/11/2012	298.9	15	0.050	68	70	67	1.3
12	3/18/2012	267.6	73	0.273	71	86	67	3.9
13	3/25/2012	263.6	160	0.607	79	97	72	5.1
14	4/1/2012	236.9	267	1.127	79	100	71	4.6
15	4/8/2012	231.1	38	0.164	86	99	80	4.4
16	4/15/2012	252.9	122	0.482	85	101	80	3.8
17	4/22/2012	312.2	28	0.090	87	95	85	2.3

18	4/29/2012	244.3	3	0.012	91	94	89	2.1
19	5/6/2012	336.1	4	0.012	96	98	94	1.4

Fall-run

A total of 12,790 unmarked fall-run Chinook salmon were captured by the RSTs. Weekly captures of salmon occurred during weeks 4 through 22 (Table 4). In week 4 during the first high flow event of the season, 54 percent of the total catch of fall-run occurred with a mean weekly CPUE of 27.9 fish per hour of RST sampling. Additional spikes in fall-run catch coinciding with high flow events occurred in subsequent weeks, but capture rates were not as abundant as the catch during week 4. After week 16, catch of fall-run declined to zero in week 23, and only one juvenile fall-run Chinook salmon was captured in week 24.

Distinction of in-river produced fall-run Chinook salmon and unmarked hatchery produced fall-run was impossible after the first catch of marked fall-run which occurred on April 24, 2012 during week 17. CNFH released over nine million unmarked fall-run fish upstream from the sampling location near Knights Landing. As such, all unmarked fall-run captured prior to week to 17 were known to be in-river-produced and any unmarked fall-run captured after this time were of unknown origin. Therefore, it was determined that of the 12,970 unmarked fall-run Chinook salmon captured, 12,454 were in-river produced and 336 were of undetermined origin.

Table 4. Summary of weekly catch of un-marked juvenile fall-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race were captured during week 4 and the last fish was captured during week 24.

Week	Beginning date	Effort (h)	Fall-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
4	1/22/2012	246.0	6860	27.886	37	28	45	1.8
5	1/29/2012	252.9	777	3.072	38	28	71	2.2
6	2/5/2012	212.6	123	0.579	41	36	50	2.6
7	2/12/2012	334.6	96	0.287	44	36	52	4.3
8	2/19/2012	337.6	39	0.116	46	36	55	6.2
9	2/26/2012	313.6	9	0.029	51	40	57	5.9
10	3/4/2012	390.9	6	0.015	50	37	59	7.5
11	3/11/2012	298.9	186	0.622	43	30	74	11.4
12	3/18/2012	267.6	891	3.330	41	31	68	8.6
13	3/25/2012	263.6	1160	4.401	42	31	73	8.2
14	4/1/2012	236.9	1595	6.733	47	33	75	10.3
15	4/8/2012	231.1	66	0.286	62	35	79	11.4
16	4/15/2012	252.9	386	1.526	61	36	81	11.1
17	4/22/2012	312.2	260	0.833	70	40	87	11.0
18	4/29/2012	244.3	58	0.237	76	55	91	9.0
19	5/6/2012	336.1	245	0.729	79	49	93	6.7
20	5/13/2012	367.8	22	0.060	80	61	95	7.1

Week	Beginning date	Effort (h)	Fall-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
21	5/20/2012	286.7	5	0.017	83	74	95	7.8
22	5/27/2012	262.6	5	0.019	84	78	89	3.6
24	6/10/2012	328.4	1	0.003	71	71	71	n/a

Late fall-run

All unmarked late fall-run Chinook salmon caught by the RSTs were assumed to be in-river produced as CNFH marked their production of this race at rate of 100 percent. A total of six in-river produced juvenile late fall-run were captured by the RSTs during weeks 1, 4 and 16 (Table 5). The four-late fall-run captured during weeks 1 and 4 were 2010 BY, while the two fish of this race captured during week 16 were 2011 BY.

Table 5. Summary of weekly catch of in-river produced juvenile late fall-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race was captured during week 1 and the last fish were captured during week 16.

Week	Beginning date	Effort (h)	Late Fall-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
1	1/1/2012	348.5	1	0.003	154	154	154	n/a
4	1/22/2012	246.0	3	0.012	147	133	161	11.4
16	4/15/2012	252.9	2	0.008	35	33	37	2

Hatchery Produced Chinook Salmon

CNFH fall-run Chinook salmon production was 3,018,088 marked and tagged with a CWT and another 9,390,063 unmarked (32% mark rate) and without tags. CNFH late fall-run Chinook salmon production was 1,040,932 marked and tagged with a CWT and another 12,350 marked but not tagged with a CWT. CNFH produced 665,941 steelhead trout which were all externally marked but not tagged with a CWT. LSNFH produced 186,045 winter-run Chinook salmon which were all externally marked and tagged with CWTs, with another 8,219 with external marks only (Table 6).

Table 6. Summary of hatchery production of juvenile Chinook salmon and steelhead trout by Coleman and Livingston Stone national fish hatcheries, released upstream from the Knights Landing sampling site during the sampling period of October 6, 2011 through June 25, 2012.

Species & Race (for Chinook)	Week	Release dates	Number marked with CWT	Number marked without CWT	Number unmarked	Release location[1]
Chinook						
Winter	5	2/2/2012	186,045	8,219		LRP
Late fall	50	12/16/2011	393,243	1,651		CNFH
Late fall	50	12/23/2011	61,486	936		CNFH

Species & Race (for Chinook)	Week	Release dates	Number marked with CWT	Number marked without CWT	Number unmarked	Release location[1]
Late fall	1	1/3/2012	445,150	8,338		CNFH
Late fall	2	1/13/2020	80,042	809		CNFH
Late fall	3	1/20/2012	61,011	616		CNFH
Fall	16	4/19/2012	1,468,302		4,724,270	CNFH
Fall	16	4/20/2012	200,236		605,058	CNFH
Fall	18	5/1/2012	1,349,550		4,060,735	CNFH
steelhead	1 & 2	1/4/2012-1/9/2012		665,941		BB

[1]LRP = Lake Redding Park; CNFH = Coleman National Fish Hatchery; BB = Bend Bridge.

Winter-run

The RSTs near Knights Landing caught a total of 10 hatchery produced juvenile winter-run Chinook salmon released by LSNFH at Rkm 480. This hatchery marks 100 percent of their winter-run by removing the adipose fin and injecting a CWT into each fish prior to release. Hatchery produced winter-run were captured in weeks 4 and 5 (Table 7) and were from the 2010 BY. No hatchery produced winter-run Chinook salmon of the 2011 BY were captured by the RSTs during the sampling period.

Table 7. Summary of weekly catch of hatchery produced juvenile winter-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race were captured during week 4 and the last fish was captured during week 5.

Week	Beginning date	Effort (h)	Hatchery Winter-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
4	1/22/2012	246.0	9	0.037	117	97	131	11.7
5	1/29/2012	252.9	1	0.004	98	98	98	n/a

Fall-run

The first in-river release of fall-run Chinook salmon produced by CNFH occurred on April 19, 2012, 203 Rkm upstream from the sampling location at Rkm 437. The first hatchery produced fall-run was caught on April 24, 2012; five days after the first in-river release. There were 138 hatchery produced, externally marked fall-run captured by the RSTs occurring during weeks 17 through 20 (Table 8).

As mentioned earlier, CNFH reported their fall-run Chinook salmon 2012 BY production was fractionally marked at a rate of approximately 32%. Expansion of the adjusted catch (Table 14) (138 adjusted to 146) of marked fall-run Chinook salmon by a factor of 0.68 (68 %) to account for unmarked hatchery produced salmon, suggests that approximately 215 hatchery produced fall-run were recorded as in-river produced fall-run or spring-run depending on length-at-date criteria for in-river produced juveniles by cohort.

Table 8. Summary of weekly catch of hatchery produced juvenile fall-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race were captured during week 17 and the last fish were captured during week 20.

Week	Beginning date	Effort (h)	Hatchery Fall-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
17	4/22/2012	312.2	29	0.093	80	66	86	4.3
18	4/29/2012	244.3	16	0.065	83	66	86	3.9
19	5/6/2012	336.1	89	0.265	79	63	89	6.1
20	5/13/2012	367.8	4	0.011	81	74	88	8.5

Late fall-run

The first hatchery produced Chinook salmon caught by the RSTs during the 2011-2012 sampling season was in week 1 and was a late fall-run juvenile released from CNFH (Table 9). All late fall-run Chinook salmon released by CNFH were marked externally by the removal of the adipose fin and injected with a CWT. All of the fish of this race captured by the RSTs were 2011 BY. CNFH released their late fall-run Chinook salmon 2011 BY at a greater individual fish size than in previous years as surrogates for spring-run Chinook salmon in an effort to provide insight into the migratory behavior and fate of yearling spring-run Chinook salmon produced (in-river) and emigrating from the upper Sacramento River (DOSS 2012). Hatchery produced late fall-run Chinook salmon were caught by the RSTs near Knights Landing between weeks 1 and 5, where 93 percent (n = 54) of the total catch of 58 fish were caught during week 4, which coincided with the first seasonal peak flows of the Sacramento River.

Table 9. Summary of weekly catch of hatchery produced juvenile late fall-run Chinook salmon sampled during the 2011/2012 sampling season. The first fish of this race was captured during week 1 and the last fish was captured during week 5.

Week	Beginning date	Effort (h)	Hatchery Late Fall-run Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
1	1/1/2012	348.5	1	0.003	161	161	161	n/a
2	1/8/2012	266.0	1	0.004	162	162	162	n/a
3	1/15/2012	362.1	1	0.003	144	144	144	n/a
4	1/22/2012	246.0	54	0.220	152	144	199	16.1
5	1/29/2012	252.9	1	0.004	131	131	131	n/a

Summary of Steelhead Trout Emigration

All hatchery produced steelhead trout released above the sampling location were externally marked (100% mark rate); therefore, all unmarked steelhead captured by the RSTs were assumed to be in-river produced. A total of 12 in-river produced steelhead were captured by the RSTs during the sampling period. One steelhead was captured in week 4, one in week 12, two in week 13 and eight were caught in week 14 (Table 10). All captured steelhead were yearlings (>70 mm), except one adult sized fish (> 300 mm) captured during week 14. The minimum and maximum fork lengths of steelhead were 104 mm and 306 mm respectively. The increase in steelhead catch in week 14 seems to have been related to the third peak in seasonal flows in the Sacramento River which occurred during the same week.

Table 10. Summary of weekly catch of in-river produced juvenile steelhead trout sampled during the 2011/2012 sampling season. The first in-river produced steelhead trout was captured during week 4 and the last fish was captured during week 14.

Week	Beginning date	Effort (h)	Steelhead Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
4	1/22/2012	246.0	1	0.004	250	250	250	n/a
12	3/18/2012	267.6	1	0.004	275	275	275	n/a
13	3/25/2012	263.6	2	0.008	149	104	194	63.6
14	4/1/2012	236.9	8	0.034	238	199	306	38.4

Hatchery Produced Steelhead Trout

A total of 149 hatchery produced steelhead trout were captured by the RSTs during weeks 4 through 16 (Table 11). CNFH externally marks all their juvenile steelhead production by removing the adipose fin (100% mark rate), but does not implant their steelhead with CWTs. Hatchery steelhead were released into the Sacramento River near the Bend Bridge (Rkm 414) area during weeks 1 and 2. The largest catch of hatchery produced steelhead occurred during week 4, when 121 (81% of total catch) were captured. This catch coincided with the first high flow event in the Sacramento River.

Table 11. Summary of weekly catch of hatchery produced juvenile steelhead trout sampled during the 2011/2012 sampling season. The first hatchery produced steelhead trout were captured during week 4 and the last fish was captured during week 16.

Week	Beginning date	Effort (h)	Hatchery steelhead Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
4	1/22/2012	246.0	121	0.492	223	122	298	21.2
5	1/29/2012	252.9	7	0.028	217	181	243	19.2
7	2/12/2012	334.6	1	0.003	233	233	233	n/a
8	2/19/2012	337.6	1	0.003	228	228	228	n/a
11	3/11/2012	298.9	1	0.003	233	233	233	n/a
13	3/25/2012	263.6	4	0.015	257	235	269	13.7

Week	Beginning date	Effort (h)	Hatchery steelhead Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
14	4/1/2012	236.9	12	0.051	240	117	290	42.1
15	4/8/2012	231.1	1	0.004	245	245	245	n/a
16	4/15/2012	252.9	1	0.004	277	277	277	n/a

Other Fish Species Captured

A total of 3,223 non-target fishes, representing 11 families and 30 species were captured by the RSTs during the sampling period (Table 12). All non-target fish species were enumerated and measured to fork length. Of these 30 fish species, 10 are native to the Sacramento River and its tributaries, while 20 of the non-target fish species encountered were introduced to the Sacramento River. Native fishes comprised 49% of the catch and non-native fishes comprised 51% of the catch.

Due to similar morphological features during juvenile development, some related genera catch totals were combined. Pacific and river lamprey (*Lampetra spp*.) ammocetes were collectively tallied together and totaled 369. Juvenile black and white crappie (*Pomoxis spp.*) were enumerated together for a total of 128. Juvenile minnows (*Cyprinidae spp*.) were also collectively inventoried due to ambiguity of identifying characteristics at larval stages and totaled 118.

Table 12. Summary of non-target fish species captured during the 2011/2012 sampling season.

Common Name	Scientific Name	Number Captured	Mean Size FL (mm)	Min Size FL (mm)	Max Size FL (mm)	Standard Deviation
Sacramento splittail	*Pogonichthys macrolepidotus*	532	36	25	234	31.8
Inland silverside	*Menidia beryllina*	529	55	25	103	10.7
Sacramento pikeminnow	*Ptychocheilus grandis*	375	73	19	390	32.4
Lamprey ammocete[1]	*Lampetra spp.*	369	117	41	176	19.8
Common carp	*Cyprinus carpio*	317	19	13	163	25.2
Mosquitofish	*Gambusia affinis*	142	31	21	55	5.4
Crappie[2]	*Pomoxis spp.*	128	73	13	215	26.1
Juvenile cyprinids	*Cyprinidae*[3]	118	30	18	79	10.2
Golden shiner	*Notemigonus crysoleucas*	115	76	28	145	20.8
River lamprey	*Lampetra ayresi*	104	135	75	168	17.1
Sacramento sucker	*Catostomus occidentalis*	86	28	16	70	7.5
Juvenile Pacific lamprey	*Lampetra tridentata*	84	125	107	168	12.4
Threadfin shad	*Dorosoma petenense*	73	74	15	125	20.6
Largemouth bass	*Micropterus salmoides*	55	43	16	273	44.8
Fathead minnow	*Pimephales promelas*	38	51	32	65	9.5
Goldfish	*Carassius auratus*	36	57	25	140	37.2

Common Name	Scientific Name	Number Captured	Mean Size FL (mm)	Min Size FL (mm)	Max Size FL (mm)	Standard Deviation
Brown bullhead	*Ameiurus nebulosus*	29	104	36	300	56.8
Channel catfish	*Ictalurus punctatus*	21	93	19	392	98.0
Tule perch	*Hysterocarpus traski*	14	61	30	90	19.8
White catfish	*Ameiurus catus*	12	174	56	240	64.2
Wakasagi	*Hypomesus nipponensis*	8	63	25	92	25.1
Warmouth	*Lepomis gulosus*	7	60	27	164	46.9
Green sunfish	*Lepomis cyanellus*	6	67	44	88	18.9
Hardhead	*Mylopharodon conocephalus*	5	63	24	158	53.9
Sacramento perch	*Archoplites interruptus*	5	74	42	90	18.6
Threespine stickleback	*Gasterosteus aculeatus*	4	33	25	40	6.2
Bluegill	*Lepomis macrochirus*	4	64	22	157	62.6
Smallmouth bass	*Micropterus dolomieu*	3	253	158	340	91.3
Hitch	*Lavinia exilicauda*	1	119	119	119	n/a
Adult Pacific lamprey	*Lampetra tridentata*	1	154	154	154	n/a
Redear sunfish	*Lepomis microlophus*	1	131	131	131	n/a
Red shiner	*Cyprinella lutrensis*	1	41	41	41	n/a

[1]Ammocetes were grouped by genus (*Lampetra tridentata* and *L. ayresi*)
[2]Black and white crappie were grouped together (*Pomoxis nigromaculatus* and *P. annularis*)
[3]Juvenile cyprinids were grouped together (*Cyprinidae spp.*)

Trap Efficiency Trials

A total of five efficiency trials were conducted during weeks 5, 6, 12, 14 and 16 using fall-run Chinook salmon externally marked with BBY (Table 13). The lowest and highest recapture rates were 0% during week 16 and 2.3% during week 14, respectively. Overall, a total of 4,701 fall-run were used in efficiency trials, and 45 of these fish were recaptured. The mean trap efficiency for the season was 0.9%.

Table 13. Summary of capture efficiency trials initiated during the 2011/2012 sampling season.

Week	Week Dates	Stained Released	Stained Recaptured	Efficiency Rating (%)
5	1/29/2012-2/4/2012	2,291	13	0.57
6	2/5/2012-2/11/2012	196	3	1.5
12	3/18/2012-3/24/2012	696	1	0.14
14	4/1/2012-4/7/2012	1,234	28	2.3
16	4/15/2012-04/21/2012	284	0	0

Passage Estimates

The mean weekly trap efficiency of 0.9 percent and associated 80 percent confidence intervals (0.34 – 1.46) was used to calculate passage estimates for each Chinook salmon race and steelhead trout (in-river and hatchery produced for both species). Passage estimates were calculated using the adjusted catch to normalize for 100 percent sampling effort (Table 14).

Table 14. Estimates of salmonid catch adjusted for total effort (100%) during the 2011/2012 sampling season.

	Late fall-run BY 2010		Late fall-run BY 2011		Winter-run		Spring-run[1]		Fall-run		Steelhead	
	No Clip	Clip	No Clip	Clip	No Clip	Clip	No Clip	Clip	No Clip	Clip	No Clip	Clip
Original Catch	4	58	2	0	104	10	722	n/a	12,790	138	12	149
Adjusted Catch	5	78	3	0	104	13	961	n/a	17,085	146	16	203

[1]No hatchery produced spring-run Chinook salmon are released upstream from the sampling site near Knights Landing.

An estimated 84,114 hatchery produced Chinook salmon (80% CI, 51,897 – 221,846) emigrated past the Knights Landing sampling site into the lower Sacramento River and Delta. An estimated 22,505 hatchery produced yearling steelhead trout (80% CI, 13,885 – 59,357) emigrated past Knights Landing during the sampling period. Survival rates were calculated by dividing actual production numbers provided by CNFH and LSNFH with the passage estimates. The estimated survival rate of hatchery produced salmon ranged from 0.5 percent and 0.8 percent depending on race. The estimated survival rate for hatchery produced steelhead was 3.4 percent (Table 15).

Table 15. Estimates of hatchery produced Chinook salmon and yearling steelhead trout that passed the Knights Landing sampling location for the period of October 6, 2011 through June 25, 2012. Mean weekly efficiency of 0.009 with associated 80% confidence interval of (0.003 – 0.014) was used to calculate values.

	A	B	C	D	E	F	G
Cohort	**Marked Catch (adjusted)**	**Marked Estimate (A/efficiency)**	**Number Released Marked**	**Survival (B/C)**	**Number released unmarked**	**Unmarked estimate (D*E)**	**Hatchery Produced Estimate (B+F)**
Late fall-run	78	8,647 (5,335-22,807)	1,053,282	0.08 (0.005-0.022)	0	0	8,647 (5,335-22,807)
Winter-run	13	1,441 (889-3,801)	194,264	0.007 (0.005-0.020)	0	0	1,441 (889-3,801)
Fall-run[1]	146	16,186 (9,986-42,690)	3,018,088	0.005 (0.003-0.014)	9,390,063	50,359 (31,069-132,820)	66,545 (41,055-175,510)
Total Chinook	237	26,275 (16,211-69,298)	4,265,634	0.006 (0.004-0.016)	9,390,063	57,839 (35,686-152,548)	84,114 (51,897-221,846)
Steelhead	203	22,505 (13,885-59,357)	665,941	0.034 (0.021-0.089)	0	0	22,505 (13,885-59,357)

[1]Includes spring-run-sized fall-run Chinook salmon.

Unmarked Chinook salmon passage was estimated by removing the estimated hatchery component for each cohort from the estimated total of unmarked fish per cohort moving past the sampling site. An estimated 1,955,243 unmarked Chinook salmon (80% CI, 1,206,311 –

5,156,809) emigrated past the sampling site near Knights Landing into the lower Sacramento River and Delta (Table 16). An estimated 1,774 in-river produced yearling steelhead (80% CI, 1,094 – 4,678) emigrated past Knights Landing during the sampling period.

Table 16. Estimates of in-river produced Chinook salmon and yearling steelhead trout that passed the Knights Landing sampling location for the period of October 6, 2011 through June 25, 2012 Mean weekly efficiency of 0.009 with associated 80% confidence interval of (0.003 – 0.014) was used to calculate values.

Cohort	A Total Effort-adjusted Unmarked	B Unmarked Estimate (A/efficiency)	C Unmarked Hatchery Estimate (from table 15, F)	D In-river Produced Estimate (B-C)
Late fall-run BY 2010	5	554 (342-1,462)	0	554 (342-1,462)
Late fall-run BY 2011	3	333 (205-877)	0	333 (205-877)
Winter-run	104	11,530 (7,113-30,409)	0	11,530 (7,113-30,409)
Spring-run	961	106,541 (65,732-280,994)	0	106,541 (65,732-280,994)
Fall-run	17,085	1,894,124 (1,168,605-4,995,614)	50,359 (31,069-132,820)	1,843,765 (1,137,536-4,862,794)
Total Chinook	18,158	2,013,082 (1,241,997-5,309,357)	57,839 (35,686-152,548)	1,955,243 (1,206,311-5,156,809)
Steelhead	16	1,774 (1,094-4,678)	0	1,774 (1,094-4,678)

DISCUSSION

Numerous studies have shown that juvenile salmonid emigration is triggered by increases in flow (Michel et. al. 2013, Kemp et. al 2005, Giorgi et. al. 1997). During the 2011-2012 sampling season, there were three distinct flow increases in the Sacramento River near Knights Landing, which coincided with increases in catch rates of salmonids (Figure 2). This trend was similar to those observed in previous years, when increased flows coincided with increased salmonid capture at the Knights Landing sampling site (CDFW unpublished data). While catch increases with increasing flow, it may be that the cue to move downstream is more closely related with the declining limb of the hydrograph following high flow events. Catch data resolution, trap capture efficiency, and uncertainty in the geographic distance fish are traveling prior to capture makes correlating emigration cues with catch data difficult.

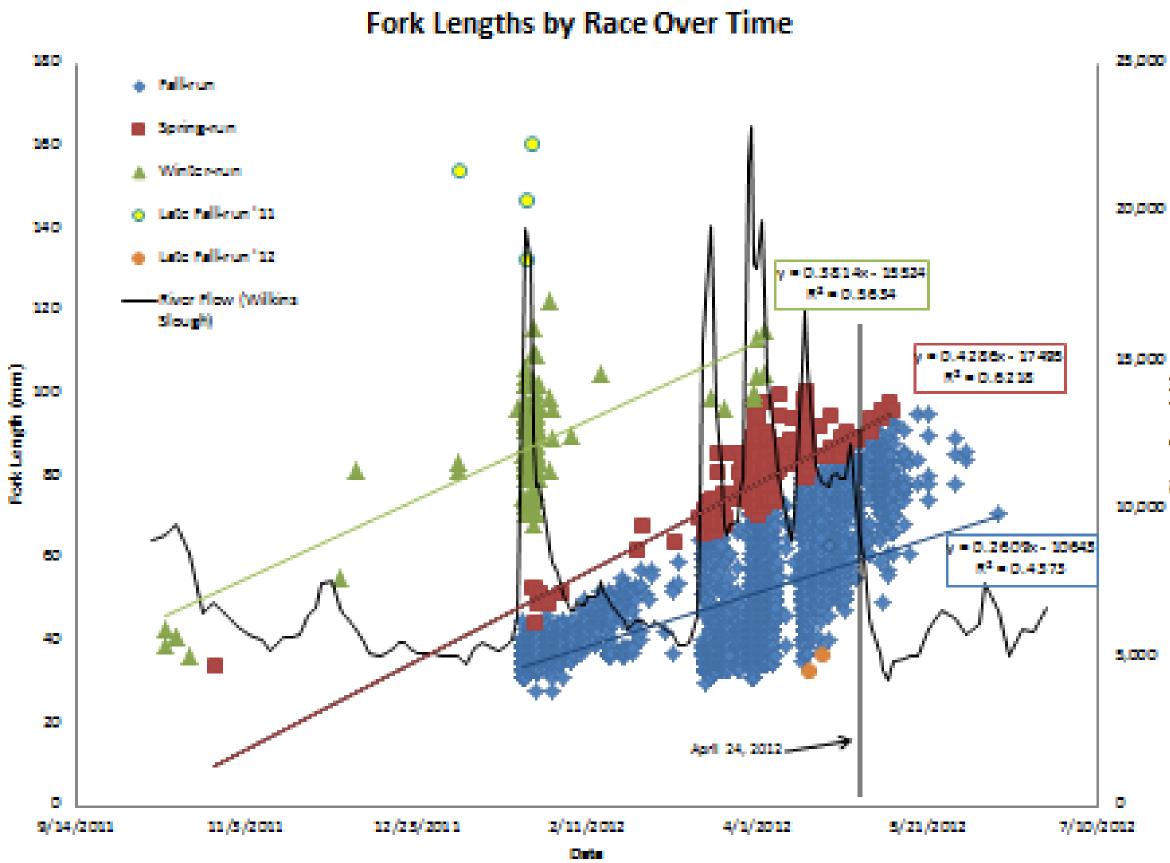

Figure 2. Mean weekly salmonid catch rate and mean weekly Sacramento River flow rate for the sampling period of October 6, 2011 through June 25, 2012. Salmonid catch includes all unmarked races of Chinook salmon and steelhead. The first hatchery produced juvenile fall-run was captured on April 24, 2012. Flow was reported by CDEC, Wilkins Sough gauge and reported in cubic feet per second (cfs).

Trapping efficiency for the 2011-2012 season was 0.90 percent, slightly lower than the historical mean of 1.18 percent (CDFW unpublished data). Passage estimates for this report were developed using the 2011-2012 season mean trap efficiency of 0.90 percent rather than the program's historical mean of 1.18 percent. Trapping efficiency can be affected by factors such as flow, turbidity, debris load, water temperature, predation, and fish size. In particular, elevated Sacramento River flows can mobilize and transport trees, branches, leaves and other course particulate matter and deposit them on or in the RSTs, reducing their ability to capture fish. Keeping the traps free of woody debris was considered paramount as an increase in catch of salmonids was expected to occur during and shortly after such events. More frequent trap efficiency evaluations throughout the sampling season may improve passage estimates.

An important factor to consider which affects potential capture at the Knights Landing sampling site, and therefore passage and survival estimates, is juvenile salmonid emigration routes. All juvenile salmonids emigrating down the Sacramento River are assumed to have the potential of being captured at the Knights Landing sampling site if they remain in-channel from point of origin to the sampling site. However, in times of excessive river flow, flood control diversions including Moulton Weir, Colusa Weir, and Tisdale Weir, located upstream of the Knights Landing sampling site, divert Sacramento River flows and entrain juvenile salmonids into the Sutter Bypass (Appendix B). Salmonids emigrating down the Sutter Bypass are unable to return to the Sacramento River until they reach Rkm 135 near Fremont Weir, which is eight Rkm downstream of the Knights Landing sampling site.

Comparison of salmonid capture by sampling season and by monitoring location may demonstrate the effect of weir overtopping events, with the caveat that other factors influencing capture must be taken into consideration (e.g., seasonal differences in juvenile production, flow, turbidity, predation, trap capture efficiency, etc.). For example, a total of 13,622 unmarked Chinook salmon were caught during the 2011-2012 sampling season which is nearly two-fold greater than the 2010-2011 season total catch of 6,983 unmarked Chinook salmon. During the 2011-2012 sampling season, the Sacramento River crested the Tisdale Weir from March 29 through March 30, 2012, presenting a short window for salmonids emigrating down the river to enter the Sutter Bypass. In contrast, Sacramento River flows overtopped Tisdale Weir three times for a total of 46 days during the 2010-2011 sampling season (CDEC, Tisdale Weir). However, without comparisons of capture data at upstream monitoring locations upstream of the weirs that convey flows into the Sutter Bypass (e.g., the Tisdale RST sampling location), it is difficult to identify whether differences in catch between seasons is due to increased production or the longer duration overtopping events.

The timing, duration, and magnitude of weir overtopping events influences the likelihood of entrainment into the Sutter Bypass for each salmonid ESU. Based on the timing of the Tisdale Weir March 29 - March 30 overtopping event, some assumption can be made on the potential for catch data to be influenced by the overtopping event. Capture data show that both in-river and hatchery produced winter-run Chinook salmon were not detected at the Knights Landing sampling site after January 7 and February 4, respectively (81 and 46 days prior to the overtopping event). Therefore, it is unlikely that the overtopping event influenced catch data and passage estimates for in-river and hatchery produced winter-run Chinook salmon. The majority (64%) of spring-run Chinook salmon capture at the Knights Landing sampling site occurred after the Tisdale Weir March 29 - March 30 overtopping event, suggesting that potential capture of spring-run and passage estimates could have been affected by the overtopping event but the affect was likely minimal. Unmarked fall-run Chinook salmon include both in-river and hatchery produced fish. All fall-run captured prior to April 24, 2012 were considered to be in-river produced fish. Nineteen percent of in-river produced fall-run salmon capture at the Knights Landing sampling site occurred prior to the Tisdale Weir March 29 - March 30 overtopping event, suggesting that the overtopping event could have affected potential capture and passage estimates for in-river fall-run produced Chinook salmon. All hatchery-produced fall-run Chinook salmon were released after the Tisdale Weir March 29 - March 30 overtopping event; therefore, potential capture and both survival and passage estimates were not affected by the event. A portion (33%) of the in-river produced late fall-run Chinook salmon capture occurred after the Tisdale Weir March 29 - March 30 overtopping event, suggesting that the overtopping event affected potential capture and passage estimates (Table 17). Both in-river and hatchery produced steelhead potential capture and passage estimates could have been affected by the Tisdale Weir overtopping event; though data suggest the overtopping event likely had a greater effect on in-river produced steelhead. Seventy-five percent of in-river steelhead were captured after the overtopping event, while around nine percent of hatchery produced steelhead were captured after the overtopping event.

Table 17. Potential for the Tisdale Weir March 29 - 30 overtopping event to influence salmonid capture data for in-river and hatchery produced Chinook salmon and yearling steelhead trout.

ESU/Origin	Capture range by week	Capture range by date	Effect on program capture
Winter-run (in-river)	41 to 1	10/9/2011 to 1/07/2012	No effect
Winter-run (hatchery)	4 to 5	1/22/2012 to 2/04/2012	No effect
Spring-run (in-river)	43 to 19	10/23/2011 to 5/12/2012	Yes; 64% of catch occurred after overtopping event
Fall-run (unmarked)	4 to 24	1/22/2012 to 6/16/2012	Yes; 20.7 % of catch occurred after overtopping event
Fall-run (hatchery)			
Late fall-run (in-river)	1 to 16	1/01/2012 to 4/21/2012	Yes; 33% of catch occurred after overtopping event
Late fall-run (hatchery)	1 to 5	1/01/2012 to 2/04/0120	No effect
Steelhead (in-river)	4 to 14	1/22/2012 to 4/7/2012	Yes; 75% of catch occurred after overtopping event
Steelhead (hatchery)	4 to 16	1/22/2012 to 4/21/2012	Yes; 9.4% of catch occurred after overtopping event

Despite uncertainties in catch data introduced by weir overtopping events, data gathered from the sampling program does provide clear insight to juvenile salmonid migration timing and thus provides early warning of listed salmonids as they move toward the Delta. Data collected during the 2011-2012 Lower Sacramento River Juvenile Salmonid Emigration Program fulfilled the program's goals including:

1. Providing 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 a period sufficient to minimize entrainment of juveniles into the south Delta;
2. Documented passage of emigrating salmonids including timing, relative abundance, and response to environmental conditions;
3. Estimated emigrating salmonid numbers in the lower Sacramento River above the Delta;
4. Contributed to the long-term dataset on emigration with which to compare changes over time.

As the Sutter Bypass may provide an important and needed rearing opportunity for juvenile salmonids in the Sacramento River corridor, future data collection efforts for the North Central Region's Sacramento River Juvenile Salmonid Monitoring Program will be targeted at better defining entrainment into the Sutter Bypass.

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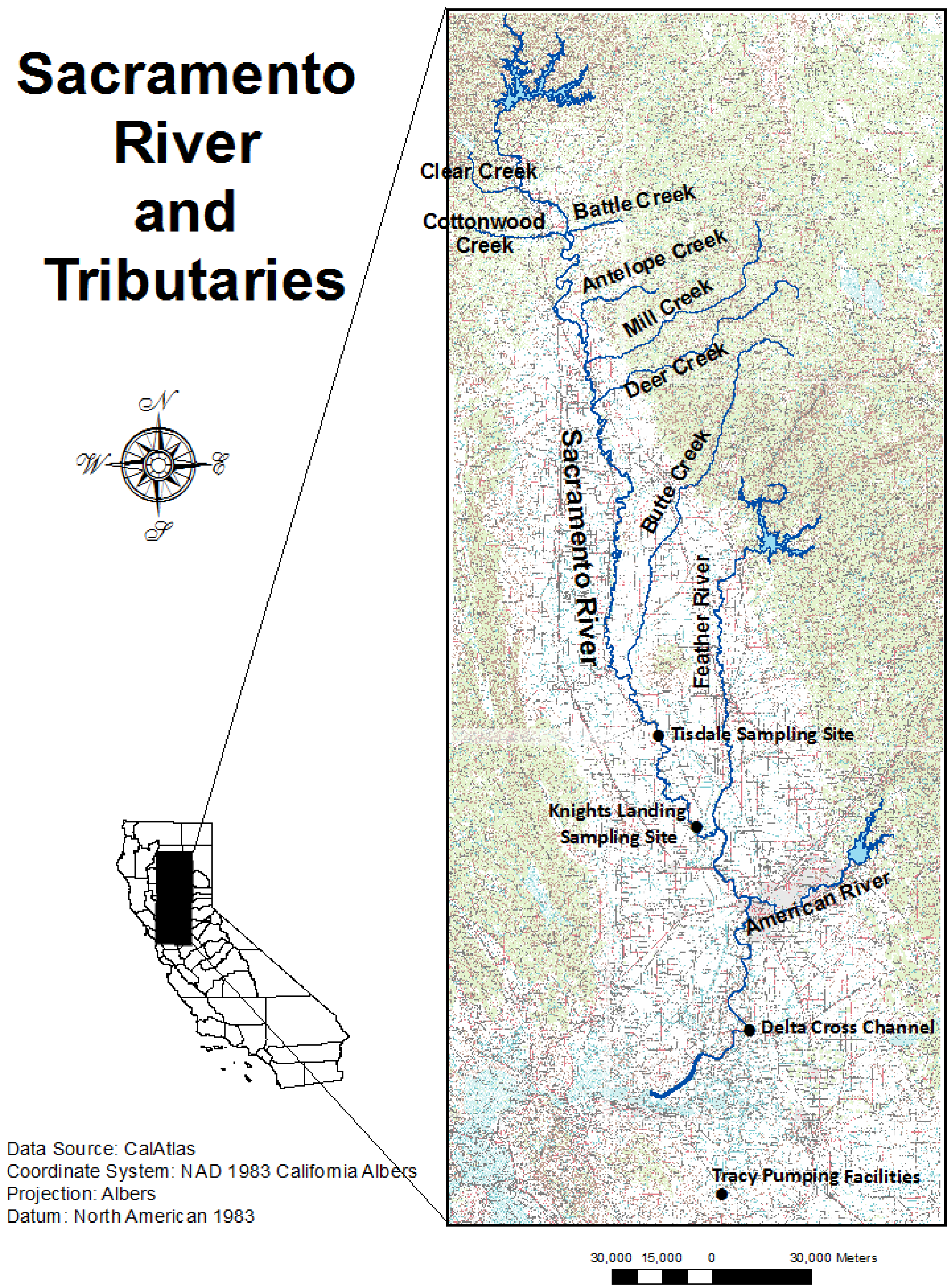
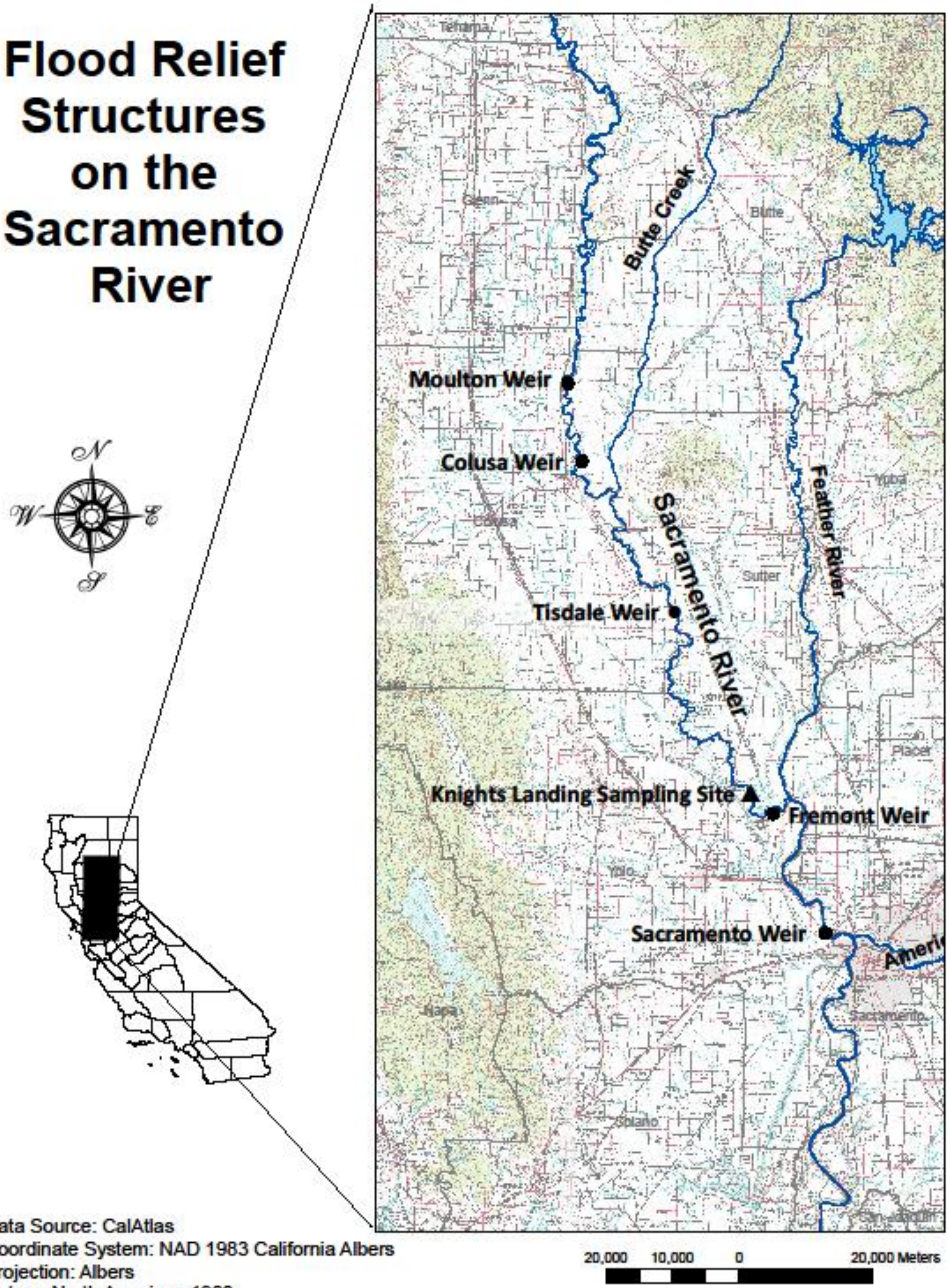
APPENDICIES

Appendix A. Map of the upper Sacramento River and tributaries depicting locations of juvenile monitoring sites, the Delta Cross Channel and the Sacramento-San Joaquin Delta pumping facilities.

Appendix B. Map of the upper Sacramento River depicting flood relief structures with the Knights Landing salmonid sampling site location for reference.


Sacramento River and Tributaries
N
W
E
S
Clear Creek
Battle Creek
Cottonwood Creek
Antelope Creek
Mill Creek
Deer Creek
Butte Creek
Sacramento River
Feather River
Tisdale Sampling Site
Knights Landing Sampling Site
American River
Delta Cross Channel
Tracy Pumping Facilities
Data Source: CalAtlas
Coordinate System: NAD 1983 California Albers
Projection: Albers
Datum: North American 1983
30,000 15,000 0 30,000 Meters

Flood Relief Structures on the Sacramento River



Data Source: CalAtlas
Coordinate System: NAD 1983 California Albers
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