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 2012 – December 2012[1]

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LIST OF ABBREVIATIONS AND ACRONYMS

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
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
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
RPAs	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 near Knights Landing, California to develop information on the temporal distribution, relative abundance, and composition of race and species of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (anadromous *O. mykiss*) emigrating from the upper Sacramento River to the Sacramento-San Joaquin River Delta (Delta). These data are collected at two separate locations utilizing two paired rotary screw traps (RSTs) outfitted with 2.4m cone. The most downstream location is 0.8km downstream of Knights Landing, CA at Sacramento rKm 144.

The monitoring program entered its 17th consecutive year of sampling at the Knights Landing monitoring site beginning on October 1, 2012. Sampling concluded on December 15, 2012, for a total of 11 weeks of sampling. Unlike previous seasons in which sampling continued through June, sampling was discontinued early due to high catch of federally listed fish in excess of permitted limits. Data collection is permitted under ESA Section 10(a)(1)(A) Permit issued by National Marine Fisheries Service (NMFS) for handling federally listed winter and spring-run Chinook salmon and Central Valley steelhead.

During the season, 1,410 unmarked (non-adipose fin clipped) juvenile Chinook salmon were captured in 3,588.75 hours of sampling, yielding an average CPUE of 0.39 salmon per hour. Peak catch occurred during calendar week 49, where 1,042 unmarked juvenile Chinook were captured. Juvenile Chinook salmon were identified to run utilizing length-at-date criteria developed by Fisher (1992) and modified by Greene (1992). The length-at-date based run assignments is a widely used technique in the Central Valley for identifying juvenile Chinook salmon where multiple run are present (Harvey 2011). Of the total juvenile Chinook salmon captured, 998 (70.78%) were identified as winter-run, 289 (20.5%) identified spring-run, 95 (6.74%) identified as fall-run, and 31 (2.2%) identified as late fall-run. No natural origin steelhead were captured during the sampling season.

A total of 133 hatchery produced Chinook salmon were captured by the Knights Landing RSTs. These were identified by a missing adipose fin which is removed by the hatchery prior to release. Of the 133 individuals captured, 108 (81.20%) were designated as late fall-run, 22 (16.54%) were designated as fall-run, and three (2.26%) were designated as winter-run utilizing Greene's (1992) length-at-date criteria. During the sampling period, one release of brood year (BY)2012 late fall-run Chinook salmon by Coleman National Fish Hatchery (CNFH) occurred upstream of the sampling site. It is assumed that all marked Chinook salmon observed were from this release. No hatchery origin steelhead were captured during the sampling season.

Environmental data collected included parameters such as: river flow volume, water temperature, water transparency, and water turbidity. These data were averaged over the calendar week for reporting. River flows at the start of the sampling season, in week 40, had a weekly mean of 5,905 cubic feet per second (CFS). River flows at the end of the sampling season, in week 50, had a weekly mean of 15,029 CFS. Flows ranged greatly between the start and finish of the sampling season. In week 49 weekly mean flows peaked at 24,872 CFS and in

week 46 the lowest weekly mean flows were observed at 3,921 CFS. Weekly mean water temperature ranged from 18.9°C at the start of sampling during week 40 and 11.3°C at the end of sampling during week 50. Mean weekly water transparency varied between a high of 180 cm during week 44 to a low of 11.2 cm of during week 49. Mean weekly turbidity at the sampling site varied from a low of 4 nephelometric turbidity units (NTU) during week 40, to a high of 462.7 NTU during week 49.

Mark and recapture methodology is typically used to evaluate trap capture efficiency. Trap efficiency is applied to catch data to estimate passage for all runs of Chinook salmon. The abbreviated monitoring season limited ability to conduct trap efficiency trials and none were completed. To provide an estimate of passage during the sampling period, the historical average trap capture efficiency of 0.0068 was used. This historical average is based from 186 trap capture efficiency trials across 16 years and includes a broad range of life stages for juvenile Chinook salmon. Using the historical trap efficiency, it is estimated that 207,353 natural origin, or in-river produced, Chinook salmon and 19,559 hatchery origin Chinook salmon passed the sampling site during the 11-week sampling period with peaks in migration observed during weeks 48 through 50.

The California Department of Fish and Wildlife can be found at: https://www.wildlife.ca.gov/

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

Annual reports and daily catch updates for the Central Valley Juvenile Salmonid Monitoring program can be found at: http://www.calfish.org/Home.aspx

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 (anadromous *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; winter-run (federally and State listed endangered), spring-run (federally and State listed threatened), late fall-run and fall-run, as well as native Central Valley winter steelhead trout (federally listed threatened). The monitoring program consists of two sampling locations. The Knights Landing sampling site is the most downstream monitoring site and is located 0.8km downstream of Knights Landing, CA, at rKm 144. All in-river produced (naturally spawned) salmonids captured by the RSTs at Knights Landing are assumed to be produced in the upper Sacramento River and its tributaries because the sampling site is located above the confluence with large salmonid baring 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 life stages (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 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 typically migrate between the months of March through June and between November and April as yearlings. Winter-run juveniles have a residency period of five to ten months and will migrate as YOY or as yearlings in the months of November through May 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 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-run 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 river flows and water temperatures during migration periods. 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 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 a coded wire tag (CWT) into the snout of each fish. 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 upstream of the sampling site. All releases of steelhead are marked externally at a rate of 100%. The winter and late fall-runs of Chinook salmon are injected with a CWT and externally marked at a rate of 100%, while fall-run Chinook salmon are tagged and externally marked at a rate of 25%. Portions of the hatchery releases are subsequently captured by the RSTs.

The abundance of native anadromous salmonids in California's Central Valley has dropped precipitously 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-1800s and mid-1900s has blocked access to over 72% of salmonid holding, spawning, and rearing areas (Yoshiyama *et al*. 2001). Dams tend to create unsuitable habitat downstream by altering river historical temperature and flow regimes while reducing 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 for flood protection and to aid agricultural needs. Loss of available rearing habitat generally decreases primary productivity and increases predation and disease transmission, ultimately reducing 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 State Water Project's (SWP) Harvey Banks Delta Pumping Plant and the Central Valley Projects (CVP) Tracy Pumping Plant (Kimmerer 2008).

The altered aquatic environment in the Central Valley may also affect the success of nonnative fish species. Nonnative 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: the smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), and striped bass (*Morone saxatilis*), introduced in to the Delta in 1874, 1879 and 1891, respectively (Dill 1997), have had considerable impacts to native salmonid stocks. These nonnative 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). Nonnative 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, as well as 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 in an effort 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.

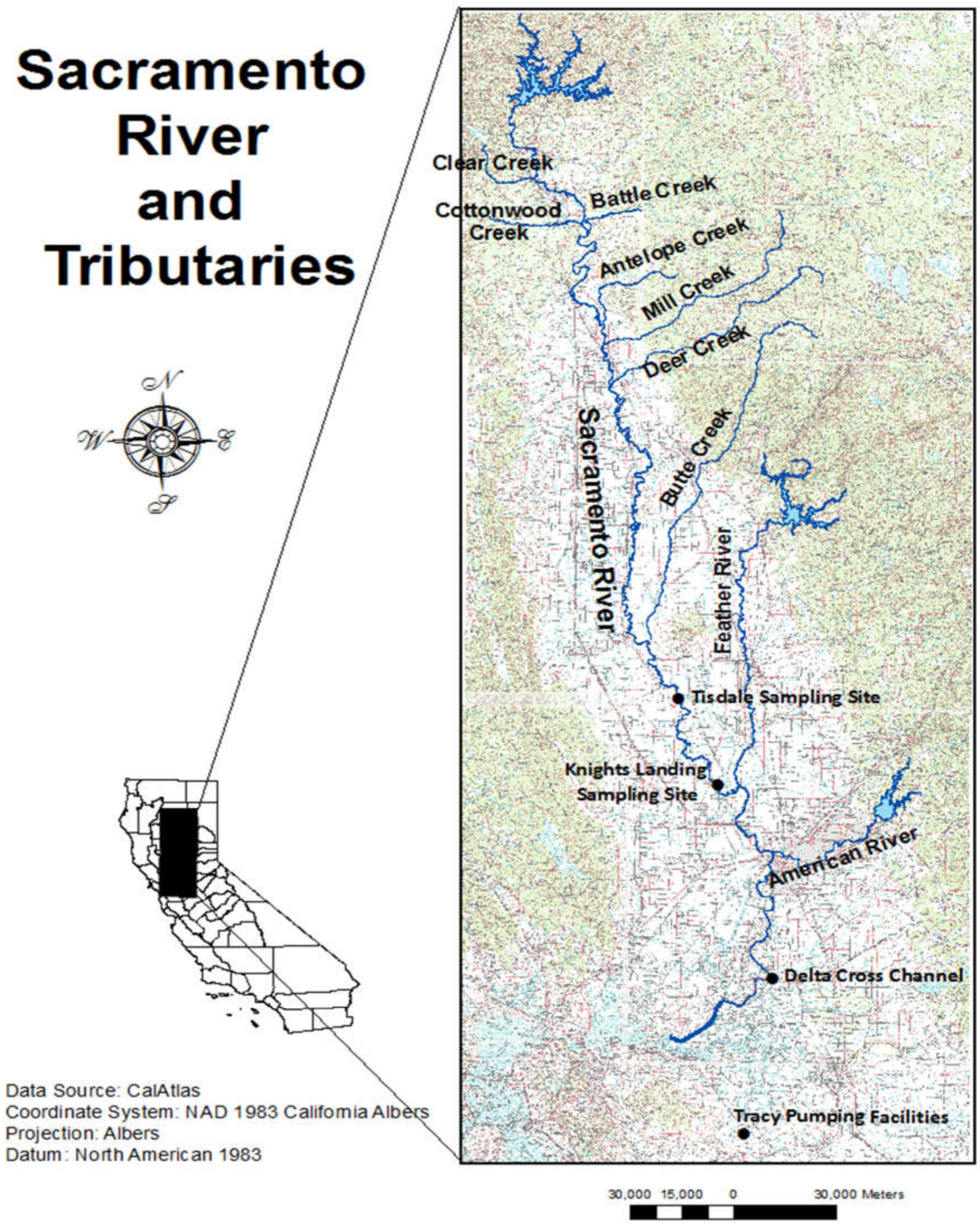
The NMFS recognized SWP and CVP Delta water operation practices as hazardous to listed salmonid species through loss at the south Delta pumping facilities or migratory delay and disorientation in the interior Delta. In response, NMFS suggested Reasonable and Prudent Alternatives (RPAs) that would enable water export activities to continue in compliance with the Federal Endangered Species Act (ESA) 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 CDFW Middle Sacramento River Juvenile Salmonid Emigration Monitoring 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 was distributed to constituents by CDFW 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.

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.

Figure 1. Map of the Sacramento River and tributaries depicting locations of CDFW juvenile monitoring sites, the DCC, and the Delta pumping facilities.



METHODS

Juvenile salmonid emigration monitoring at the Knights Landing sampling site began on October 1, 2012. Monitoring was terminated on December 15, 2012 for a total of 76 days of continuous sampling. The sampling location was downstream of the town of Knights Landing, on the Sacramento River at approximately rKm 144 (Figure 1). This sampling location was chosen due to its favorable river channel structure and flow conditions, as well as its position within the Sacramento River system upstream of the confluence with two other major California Central Valley tributaries: the American and Feather rivers (at Sacramento rKm 96.7 and rKm 128.8, respectively).

Similar to all previous season, two fish traps commonly referred to as auger traps or RSTs (described in Kennen et al. 1994 and Volkhardt et al. 2007) were utilized. The RST was designed by fisheries biologists in the 1980s to capture juvenile fishes from medium to large streams in the Pacific Northwest states and was subsequently patented by EG Solutions Inc., Oregon. RSTs are a useful tool that allows for the collection of data that can be used to describe juvenile salmonid species and race composition, abundance, emigration timing, emigration rates, and age and size at emigration.

Two RSTs with 2.4m diameter cones, were chained together and placed on the east side of the Sacramento River channel (river left). As flows in the Sacramento River changed over the sampling season, the traps were either pulled to within approximately 3.4 m from shore to sample during flooding events, or were placed in the thalweg, approximately 10 m from shore to sample during normal river flow conditions.

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, the RSTs were checked more frequently, 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. The RSTs were accessed using a pontoon boat 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 on trap performance were collected during all RST service checks. This included: time since last trap service (recorded to the nearest quarter of an hour), average cone revolutions per minute (RPM), total cone revolutions since last RST service, total hours fished[2], water velocity entering each RST cone, and depth of water where the RSTs were positioned. Water velocity was measured using a Global Water® flow probe (model FP111) and water depth at each trap was estimated using an electronic depth finder.

Environmental data collected and recorded during each RST service included: water temperature, water transparency, water turbidity, and Sacramento River flow rate. Continuous water temperature data was collected with an electronic Onset HOBO® temperature logger,

[2] RST total hours fished = ((cone revolutions/rotations per minute)/60 minutes)

placed within the live well of the bank side trap, and daily water temperatures were recorded during each trap service with a handheld H-B USA standard liquid thermometer. Water transparency at the sampling location was measured 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 which were subsequently analyzed using a LaMotte 2020® Turbidity Meter, then averaged and reported in NTU. Sacramento River flow rate, measured in cubic feet per second, 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 were measured to the nearest mm. Salmonids greater than 40 mm fork length (FL) were weighed to the nearest tenth of a gram. Juvenile Chinook salmon were also distinguished by race: fall-run, spring-run, winter-run, and late fall-run using Chinook salmon race length-at-date identification tables (Greene 1992). Salmonid life stages were recorded as alevin, fry, parr, silvery parr, or smolt. Catch per unit of effort for each race of Chinook salmon and steelhead trout was calculated as the total number of fish captured divided by the total hours of sampling[3].

All data were recorded on water-proof datasheets, transported to a CDFW office and checked for quality assurance and quality control (QAQC). Once all datasheets were checked for QAQC, data were entered into an Excel spreadsheet and emailed to resource agencies and various stakeholders the same day the data were recorded. This allowed for near real-time reporting of trap catch data.

Daily Chinook salmon and steelhead trout data were calculated and analyzed as weekly totals 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 2012 and concluded sampling in week 50 of 2012 (started October 1, 2012 and concluded December 15, 2012).

[3] Catch per unit of effort = (total number of fish captured)/(total RST hours fished)

RESULTS

Environmental Conditions

Mean daily flow reported at the DWR Wilkins Slough gauge during the sampling season (October 1, 2012 through December 15, 2012) was 10,476 CFS (7,601 CFS standard deviation (SDM). Maximum flow recorded was 26,421 CFS on December 4 (week 49) and the minimum flow recorded during the sampling period was 3,810 CFS on November 14 (week 46) (Table 1, Figure 2). Water temperatures decreased over the 11 week sampling season (Table 1, Figure 2). Mean water temperature during the sampling period was 13.7 °C (2.2 °C SD). The minimum water temperature recorded during the sampling period was 10.0 °C, on December 12 (week 50), while the maximum water temperature recorded was 18.8 °C on October 4 (week 40).

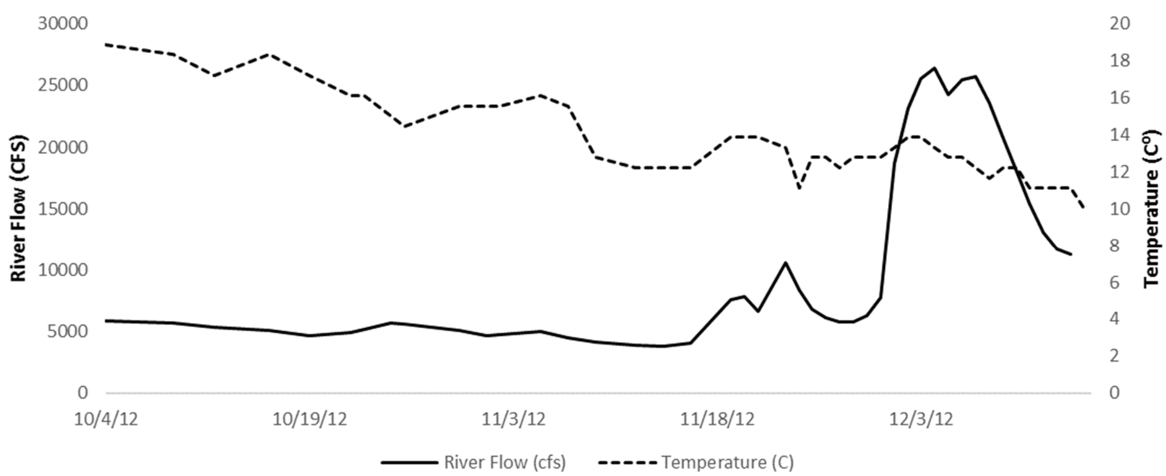


Figure 2. Daily water temperature (C°) values collected at the sampling site during the 2012/2013 sampling season. Water flow rate was reported by CDEC, Wilkins Sough gauge and reported in cubic feet per second (cfs).

Water transparency recorded at the sampling site ranged from 253 cm at the beginning of the season on October 30 (week 44) to 6.1 cm on December 7 (week 49). Mean daily water transparency for the sampling season was 75.0 cm (61.7 cm SD) (Table 1, Figure 3). Turbidity at the sampling site ranged from 2.96 NTU on November 1 (week 44) to 1201 NTU on December 4 (week 13). Mean daily turbidity during the sampling season was 95.2 NTU (266.2 NTU SD) (Table 1, Figure 3).

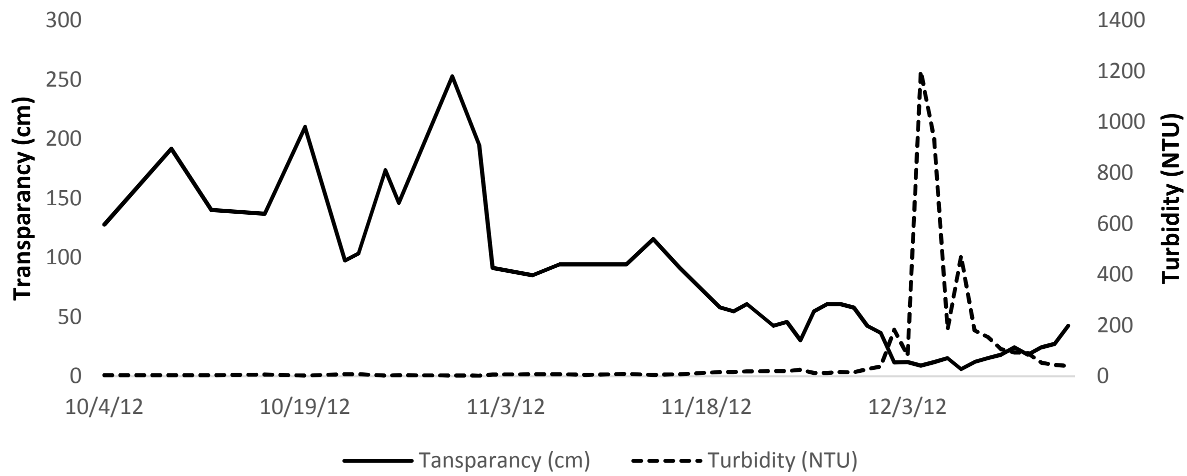


Figure 3. Daily water transparency (cm) and turbidity (NTU) values collected at the sampling site during the 2012/2013 sampling season.

Table 1. Weekly summaries of environmental conditions recorded at the RSTs located on the Sacramento River near Knights Landing, California during the period of October 1, 2012 through December 15, 2012.

Week	Beginning Date	Mean River Flow (CFS)	Mean Water Temp (C°)	Mean Secchi Depth (cm)	Mean Water Turbidity (NTU)
40	10/1/2012	5,905	18.9	128.0	4.7
41	10/7/2012	5,509	17.8	166.2	5.2
42	10/14/2012	4,879	17.8	173.8	5.5
43	10/21/2012	5,354	15.4	130.3	6.2
44	10/28/2012	4,814	15.6	179.9	4.4
45	11/4/2012	4,547	14.8	91.5	7.8
46	11/11/2012	3,921	12.2	100.6	7.9
47	11/18/2012	8,192	13.2	52.4	19.2
48	11/25/2012	8,184	12.8	49.2	22.0
49	12/2/2012	24,873	12.9	11.3	462.7
50	12/9/2012	15,030	11.3	24.4	84.1

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 1,543 juvenile salmon were captured, in which 1,410 unmarked salmon accounted for 91.4% of the total catch and 133 hatchery produced salmon accounted for 8.6% of the total catch.

The first juvenile Chinook salmon was captured during week 44. Peak catch occurred during week 49 when 1,044 salmon consisting of all races were captured with a CPUE of 3.12 fish per hour, representing 67% of the season total catch.

In-river Produced Chinook Salmon

Winter-run

All unmarked winter-run Chinook salmon were assumed to be in-river produced as Livingston Stone National Fish Hatchery marks 100% of their production of this race prior to release. A total of 998 in-river produced winter-run were captured and the first fish of this run was captured during week 44. Catch of winter-run was consistently high during weeks 48 and 49, with 606 captured during week 49. This appeared to correspond with the first increase in Sacramento River flows, a decrease in river temperatures, and an increase in turbidity. During week 49, winter-run CPUE for winter-run peaked at 1.81 fish captured per hour. All winter-run captured during the sampling period were BY2012 based on size at capture. The number of winter-run Chinook salmon observed during the 2012/2013 sampling season was unprecedented and surpassed the take limit provided to the project under the Section 10 Permit approved and issued by NMFS. This exceedance resulted in the termination of sampling on December 15, 2012.

Table 2. Summary of weekly catch of in-river produced juvenile winter-run Chinook salmon sampled during the 2012/2013 sampling season.

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)
42	10/14/2012	335.75	1	0.003	42	42	42	n/a
47	11/18/2012	385.00	68	0.177	58	45	79	6.9
48	11/25/2012	334.25	226	0.676	57	44	85	7.4
49	12/2/2012	334.75	606	1.810	60	45	93	8.7
50	12/9/2012	334.25	97	0.290	62	47	94	9.7

Spring-run

A total of 286 unmarked spring-run Chinook salmon were captured during weeks 48 through 50. Peak catch occurred during week 49 when 241 spring-run were captured, representing 84% of the total unmarked spring-run captured this sampling season. Mean CPUE during this period was approximately 0.72 fish per hour of RST sampling. All juvenile spring-run Chinook salmon were BY2012 based on size at capture.

Table 3. Summary of weekly catch of in-river produced juvenile spring-run Chinook salmon sampled during the 2012/2013 sampling season.

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)
48	11/25/2012	334.25	4	0.012	36	34	40	2.7
49	12/2/2012	334.75	241	0.720	36	34	46	3.0
50	12/9/2012	334.25	41	0.123	38	35	46	3.6

Fall-run

A total of 95 unmarked fall-run Chinook salmon were captured during weeks 49 and 50. All juvenile fall-run Chinook salmon were BY2012 based on size at capture.

Table 4. Summary of weekly catch of un-marked juvenile fall-run Chinook salmon sampled during the 2012/2013 sampling season.

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)
49	12/2/2012	334.75	63	0.188	41	28	191	36.6
50	12/9/2012	334.25	32	0.096	33	30	35	1.2

Late fall-run

All unmarked late fall-run Chinook salmon were assumed to be in-river produced, CNFH marks 100% of their production of this race prior to release. A total of 31 in-river produced juvenile late fall-run Chinook salmon were captured by the RSTs during weeks 48 through 50 (Table 5). All late fall-run were BY2012 based on size at capture.

Table 5. Summary of weekly catch of in-river produced juvenile late fall-run Chinook salmon sampled during the 2012/2013 sampling season.

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)
48	11/25/2012	334.25	1	0.003	90	90	90	n/a
49	12/2/2012	334.75	22	0.066	119	94	165	21.6
50	12/9/2012	334.25	8	0.024	101	98	105	2.8

Hatchery Produced Chinook Salmon

On November 29, CNFH released 848,000 late fall-run Chinook salmon into Battle Creek, a tributary to the upper Sacramento River. This was the only hatchery release occurring while sampling during the 2012/2013 season. All CNFH hatchery-produced late fall-run Chinook salmon are marked externally by the removal of the adipose fin and injected in the snout with a CWT marked with a six digit number unique to the release.

Table 6. Summary of hatchery production of juvenile Chinook salmon by CNFH, released upstream from the Knights Landing sampling site during the sampling period of October 4, 2012 through December 12, 2012.

BY & Race	Week	Release date	Number marked with CWT	Number marked without CWT	Number unmarked	Release location[1]
BY2012 Late Fall	48	11/29/2012	848,000	0	0	CNFH

[1] CNFH = Battle Creek release location at CNFH.

Following the release, a total of 133 adipose fin-clipped Chinook salmon were captured by the RSTs consisting of three races using the length at date (LAD) criteria for race determination. A subsample of these were euthanized for the collection of the CWT suggesting that all marked catch during this monitoring season were late fall-run from the November 29 release by CNFH.

Table 7. Summary of weekly catch of hatchery produced juvenile Chinook salmon sampled during the 2012/2013 sampling season.

Week	Beginning date	Effort (h)	Total Catch	Catch per Hour	Mean FL (mm)	Minimum FL (mm)	Maximum FL (mm)	Standard Deviation FL (mm)
49	12/2/2012	334.75	112	0.335	143	90	193	24.5
50	12/9/2012	334.25	21	0.063	128	71	196	30.9

Summary of Steelhead Trout Emigration

During the reduced 2012/2013 sampling season, no data were collected on the emigration timing of steelhead trout as there was zero (0) catch of in-river and hatchery produced steelhead trout.

Trap Efficiency Trials and Passage Estimates

Trap efficiency trials were not conducted during the 11 week monitoring period. Therefore, Chinook abundance and passage estimates were calculated by applying efficiency estimate data from 186 trap capture efficiency trials over the previous 16 years at Knights Landing. Efficiency estimates from the 1997 to 2012 seasons were averaged and applied to the 2012/2013 catch data.

The historical mean trap capture efficiency (0.0068) and associated 95% confidence interval (CI) (0.0046 – 0.0090) was applied to the total catch for all marked, hatchery origin Chinook salmon. An estimated 19,559 hatchery produced Chinook salmon (95% CI, 14,797 – 28,841) emigrated past the Knights Landing sampling site into the lower Sacramento River and Delta (Table 8). It is unknown what portion of the total hatchery production release passed the sampling site after the termination of sampling. Therefore, this process likely underestimates the number of hatchery origin late fall-run Chinook salmon released that entered the Delta.

Table 8. Estimates of hatchery produced Late Fall-run Chinook Salmon that passed the Knights Landing sampling location during the 2012/2013 sampling season. Historical mean trap capture efficiency of 0.0068 with associated 95% CI (0.0046 – 0.0090) 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	133	19,559 (14,797-28,841)	848,000	0.023 (0.017-0.034)	0	0	19,559 (14,797-22,807)

Total passage and relative abundance of unmarked, in-river produced, Chinook salmon was estimated using the same methods described above. The historical mean trap capture efficiency (0.0068) and associated 95% CI (0.0046 – 0.0090) was applied to the total catch of late-fall, winter, spring, and fall-run Chinook salmon. Additionally, this was completed for the total catch of all runs combined. An estimated 207,353 unmarked Chinook salmon (95% CI, 156,868-305,755) emigrated past the sampling site near Knights Landing into the lower Sacramento River and Delta. Similar to the hatchery origin Chinook salmon estimates, it is unknown what proportion of each natural origin cohort had emigrated past the sampling site after the termination of sampling. Therefore, these calculations likely underestimate the total number entering the Delta (Table 9).

Table 9. Estimates of in-river produced Chinook salmon that passed the Knights Landing sampling location during the 2012/2013 sampling season. Historical mean trap capture efficiency of 0.0068 with associated 95% CI (0.0046 – 0.0090) was used to calculate values.

Cohort	Total Effort-adjusted Unmarked	Unmarked Estimate (A/efficiency)	Unmarked Hatchery Estimate (from table 15, F)	In-river Produced Estimate (B-C)
Late fall-run	31	4,559 (3,449-6,722)	0	4,559 (3,449-6,722)
Winter-run	998	146,765 (111,031-216,414)		146,765 (111,031-216,414)
Spring-run	286	42,059 (31,819-62,018)	0	42,059 (31,819-62,018)
Fall-run	95	13,971 (10,569-20,601)	0	13,971 (10,569-20,601)
Total Chinook	1,410	207,353 (156,868-305,755)	0	207,353 (156,868-305,755)

Other Fish Species Captured

There were a total of 1,775 non-target fishes representing 27 species captured by the RSTs during the sampling period (Table 10). All non-target fish species were enumerated and measured for FL. Of these 27 fish species, 19 were native to the Sacramento River and its tributaries while 18 of the non-target fish species encountered were introduced to the Sacramento River. Native fishes comprised 40% and non-native fishes comprised 60% of the non-salmonid 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. Additionally, some members of the sunfish family (*Lepomis spp.*) were unable to be identified to species in the field and were grouped by genus and labeled "Unknown juvenile sunfish" and totaled 108 individuals. All other non-target catch were identified to species.

Table 10. Summary of non-target fish species captured during the 2012/2013 sampling season.

Common Name	Scientific Name	Number Captured	Mean Size FL (mm)	Min Size FL (mm)	Max Size FL (mm)	Std Dev
Inland silverside	*Menidia beryllina*	407	60	37	98	10.6
Mosquitofish	*Gambusia affinis*	215	32	20	48	5.1
Lamprey ammocete[1]	*Lampetra spp.*	150	123	80	317	28.1
Juvenile River lamprey	*Lampetra ayresi*	148	121	69	174	15.0
Sacramento sucker	*Catostomus occidentalis*	144	32	19	67	7.3
Threadfin shad	*Dorosoma petenense*	130	89	42	125	15.3
Unknown juvenile sunfish[2]	*Lepomis spp.*	108	35	18	68	8.3
Juvenile Pacific lamprey	*Lampetra tridentata*	104	124	29	166	18.3
Sacramento pikeminnow	*Ptychocheilus grandis*	91	62	20	169	21.0
Black crappie	*Pomoxis nigromaculatus*	57	95	31	255	50.9
Threespine stickleback	*Gasterosteus aculeatus*	51	32	22	43	3.8
Golden shiner	*Notemigonus crysoleucas*	24	68	34	99	16.3
Largemouth bass	*Micropterus salmoides*	23	57	35	84	14.1
Fathead minnow	*Pimephales promelas*	23	40	21	61	11.4
Goldfish	*Carassius auratus*	19	49	38	76	12.8
Warmouth	*Lepomis gulosus*	15	49	35	70	9.8
Common carp	*Cyprinus carpio*	13	55	31	83	17.9
Bluegill	*Lepomis macrochirus*	10	106	40	212	61.9
Prickly sculpin	*Cottus asper*	9	103	86	119	9.7
Tule perch	*Hysterocarpus traski*	7	76	65	120	19.8
Redear sunfish	*Lepomis microlophus*	7	104	51	178	52.2
Brown bullhead	*Ameiurus nebulosus*	4	171	139	220	36.0
Channel catfish	*Ictalurus punctatus*	4	238	37	358	175.4
Green sunfish	*Lepomis cyanellus*	4	33	25	48	10.2
Riffle sculpin	*Cottus gulosus*	2	96	95	97	1.4
Hardhead	*Mylopharodon conocephalus*	2	55	45	65	14.1
White crappie	*Pomoxis annularis*	2	79	63	95	22.6
Red shiner	*Cyprinella lutrensis*	1	67	67	67	n/a
Smallmouth bass	*Micropterus dolomieu*	1	49	49	49	n/a

[1]**Ammocetes were grouped by genus (*L. tridentata* and *L. ayresi*)**

[2]**Sunfish not able to be identified to species were grouped by genus (*Lepomis spp.*)**

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 2012/2013 sampling season, there were two distinct flow increases in the Sacramento River near Knights Landing, which coincided with increases in catch rates of salmonids (Figure 4). 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. However, in the eight days following the first increase in river flows, peaking at 10,633 CFS on November 23, total catch for all unmarked Chinook was 283. This consisted of 278 winter-run, four spring-run, and one late fall-run. Sacramento River flows increased a second time from 7,768 CFS on November 30 to 18,692 CFS on December 1. Here, another increase in catch was observed following a peak in river flows. Over the succeeding 15 days, total combined catch for all unmarked juvenile Chinook salmon was 1,147, consisting of 718 winter-run, 282 spring-run, 95 fall-run, and 30 late fall-run. The increase in catch of LAD winter-run Chinook salmon of this magnitude was unforeseen and unprecedented. Ultimately, this forced the termination of sampling on December 15 due to the exceedance of take limits outlined in the program's ESA Section 10 permit. (Figure 4)

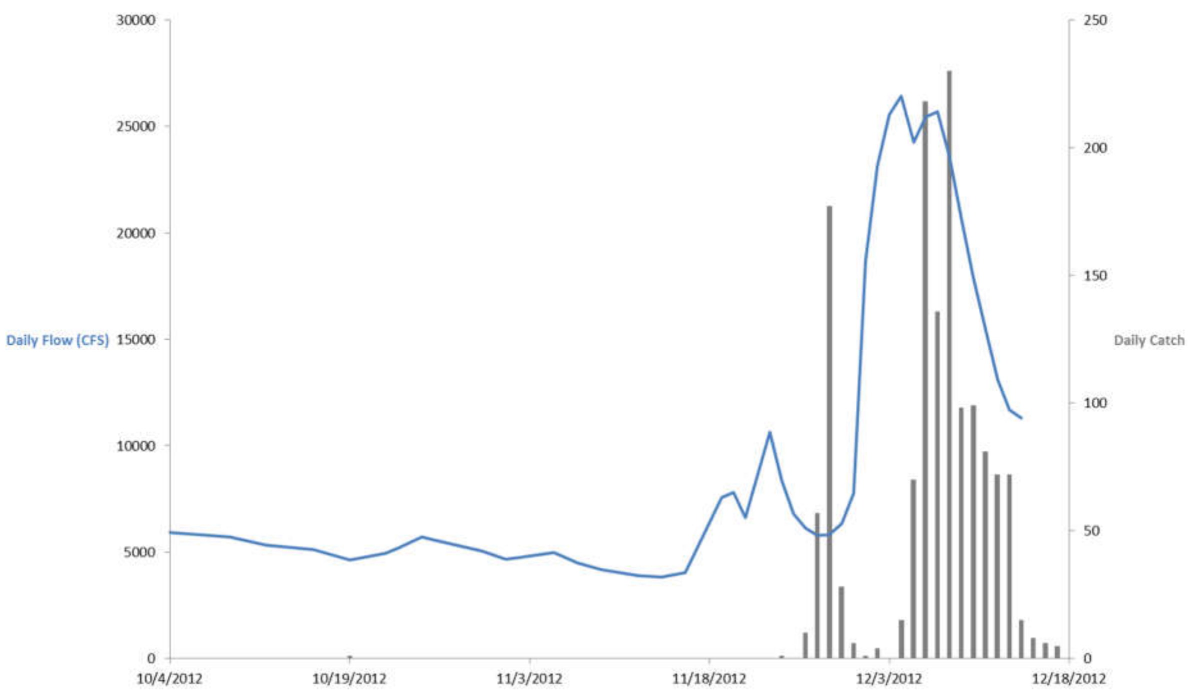
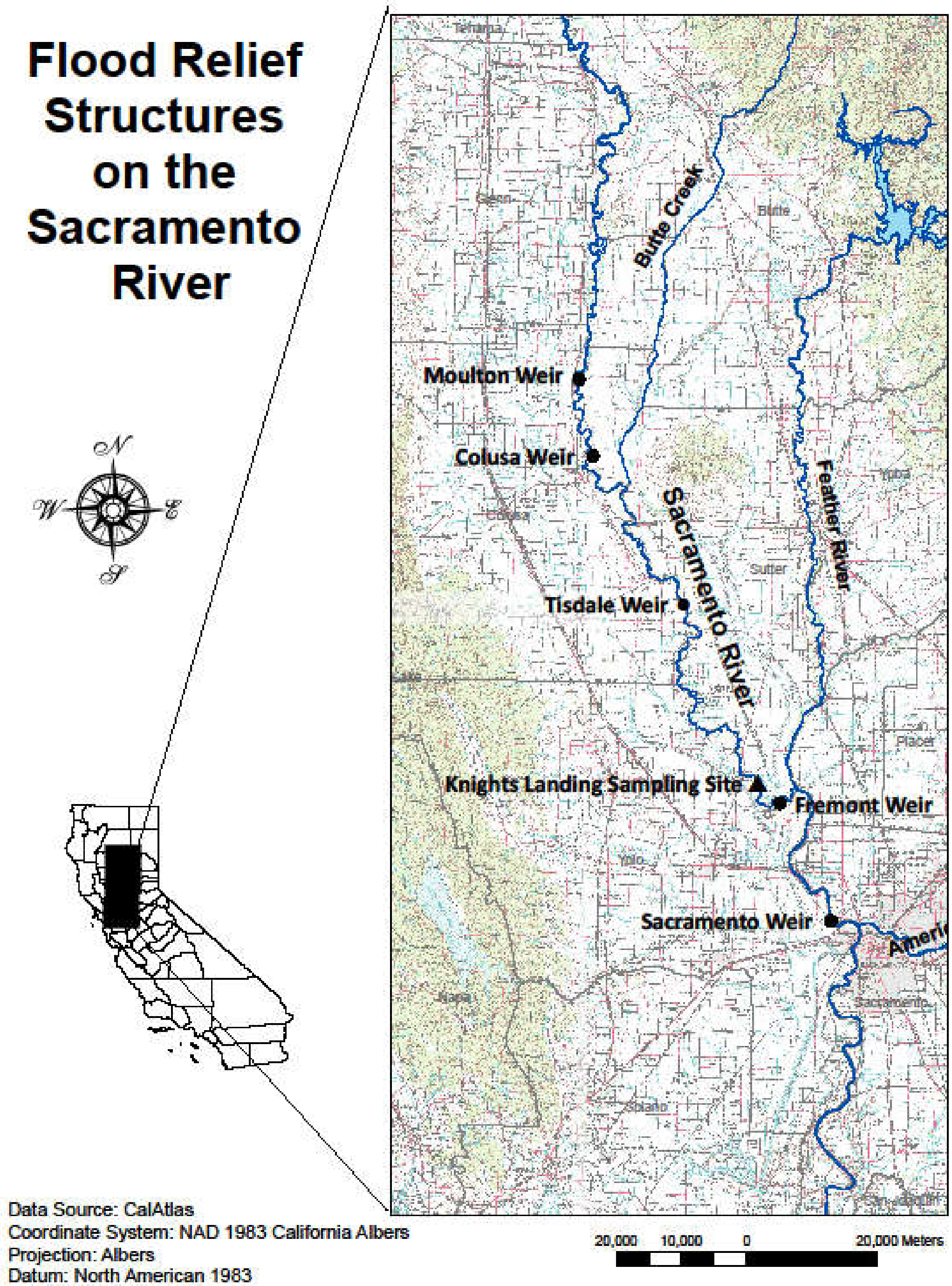


Figure 4. Daily Sacramento River flow rates and total daily catch of all unmarked juvenile Chinook salmon for the sampling season of October 1, 2012 through December 15, 2012. Water flow rate was reported by CDEC, Wilkins Sough gauge in CFS.

An important factor affecting 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. In times of excessive river flow, upstream flood control diversions, including Moulton Weir, Colusa Weir, and Tisdale Weir, divert Sacramento River flows and entrain juvenile salmonids in the Sutter Bypass (Figure 5). 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 1,410 unmarked Chinook salmon were caught during the 11 week 2012/2013 sampling season, which ended on December 15. This number is magnitudes higher than what was observed during the same time period of the 2011/2012 sampling season (n=8). Though sampling conditions were distinctly different than those observed during the 2011/2012 sampling season, it is likely that total catch was further influenced by overtopping events associated with high river discharge. The timing, duration, and magnitude of these weir overtopping events influence the likelihood of entrainment into the Sutter Bypass for each salmonid evolutionary significant unit (ESU).

Figure 5. Map of the Sacramento River and tributaries depicting locations of juvenile monitoring site a Knights Lading, CA and the flood relief structures.



During the 2012/2013 sampling season, the Sacramento River crested the Tisdale Weir from December 1 through December 9, 2012. The Colusa Weir also overtopped from December 3 to December 5 and again from December 6 to December 7. This presented a seven day window for salmonids emigrating down the river to enter the Sutter Bypass through the Tisdale Weir, in addition to a combined three day window where both Tisdale and Colusa Weirs were topped. Based on the timing of the events observed during the 2012/2013 sampling season, some assumption can be made on the potential for catch data to be influenced by the overtopping events. Capture data show that peak catch of all runs of in-river Chinook occurred during the week of December 2. This peak overlapped the time period where both weirs overtopped. These overtopping events affected potential capture and associated passage estimates as fish using the Sutter Bypass navigated around the sampling site at Knights Landing (Table 11). 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 pinpoint differences in catch between seasons and the influence overtopping events have on catch numbers. 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 could be targeted at better defining entrainment into the Sutter Bypass.

Table 11. Potential for the Tisdale Weir December 1st through 9th and the Colusa Weir overtopping events 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)	42 to 50	Oct 14 to Dec 15	71% of catch occurred after overtopping event
Spring-run (in-river)	48 to 50	Nov 25 to Dec 15	99% of catch occurred after overtopping event
Fall-run (in-river)	49 to 50	Dec 2 to Dec 15	100% of catch occurred after overtopping event
Late fall-run (in-river)	48 to 50	Nov 25 to Dec 15	97% of catch occurred after overtopping event
Late fall-run (hatchery)	49 to 50	Dec 2 to Dec 15	100% of catch occurred after overtopping event

Events occurring during the 2012/2013 sampling season limited the ability of the Middle Sacramento River Juvenile Salmonid Emigration Program to fulfill some of the program's goals identified previously in this document. The shortening of the sampling season provided an incomplete picture of the migration timing of upper Sacramento River salmonids occurring after December 15. Knights Landing RST data from 2007 through 2011 suggest most winter-run have passed the sampling site, or are present below detectable levels, by the end of April and this occurs for spring-run, fall-run, and late fall-run by the end of May (Figure 5). With the end of sampling on December 15, it is likely that a substantial portion of each run entered the Delta following the termination sampling.

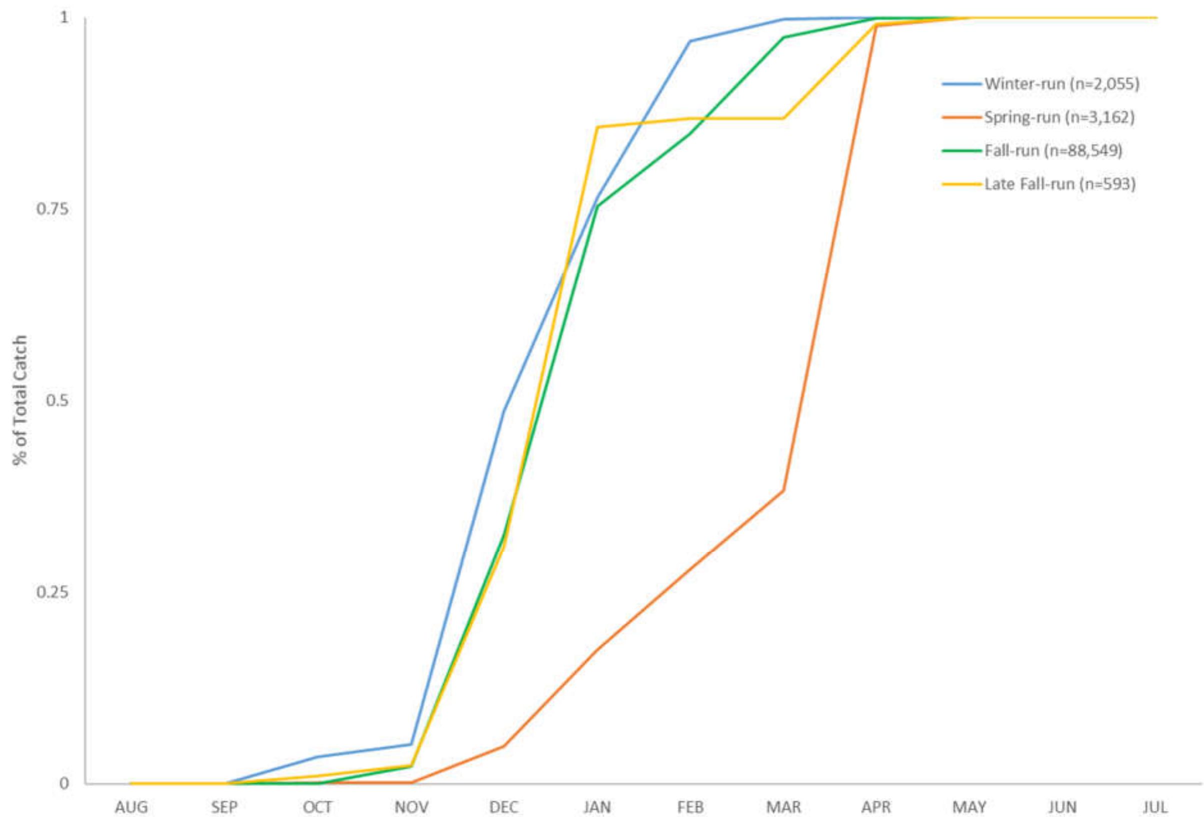


Figure 5. Central Valley Juvenile Chinook Salmon Monitoring Project, on the Sacramento River near the town of Knights Landing (rKm 144), percent of total catch by month for the 2007-2011 monitoring seasons combined, of both natural origin and hatchery origin Chinook salmon.

Monitoring data from the 2011/2012 sampling season, however, was sufficient to provide an early warning to the downstream migration of threatened and endangered salmonids to Delta water management groups allowing for protective measures of the RPA IV.1.2 on the 2009 NMFS OCAP BO to be implemented. This action allows for modification of DCC gate operations to further reduce the direct and indirect mortality of emigrating juvenile salmonids and green sturgeon (Delta Operations for Salmon and Sturgeon (DOSS), 2013). The DCC diverts water from the Sacramento River into Snodgrass Slough to supply water to the interior Delta, allowing for increased pumping at State and federal water collection facilities while maintaining Delta water quality standards. With the substantial increase in winter-run Chinook catch observed at the Knights Landing monitoring site, RPA IV.1.2 was implemented and the DCC gates were closed on November 27 (DOSS, 2013).

Additionally, the program was successful in relating migration patterns to annual differences in environmental conditions. Seasonally, river flows in October are low and clear. Increases in emigration are observed with rain producing weather systems that frequent the Central Valley during the winter months bringing increased flow and decreased water clarity. These seasonal changes in river flow and turbidity often coincide with the downstream migration of salmonids rearing in the upper Sacramento River toward the Delta and, subsequently, the San Francisco Bay and Pacific Ocean. This juvenile emigration trend was observed again in this sampling season following increases in river flows. It is assumed that, should the sampling season have continued as normal, this trend would be repeated with each increase in river flow and turbidity as seen in years past.

Lastly, although trap capture efficiency trials were not completed, passage and relative abundance of Chinook salmon were estimated using historical trap capture efficiency data from 1997 through 2012, with the caveat that there is inherent variation in annual total salmonid catch, catch per race, and trap efficiency trial results. The passage and relative abundance estimations presented here are not representative of complete cohorts emigrating from the upper river. These estimations are presented to offer insight into the unprecedented volume of Chinook salmon which passed the sampling site during the 11 week sampling season, 95% of which moved past during calendar weeks 48 through 50.

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