CALIFORNIA DEPARTMENT OF FISH AND GAME
SACRAMENTO VALLEY-CENTRAL SIERRA REGION
Lower Sacramento River Juvenile Salmonid Emigration Program

TIMING, COMPOSITION AND ABUNDANCE OF JUVENILE ANADROMOUS SALMONID EMIGRATION IN THE SACRAMENTO RIVER NEAR KNIGHTS LANDING SEPTEMBER 1999 – SEPTEMBER 2000

by

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SUMMARY

Juvenile salmonids emigrating via the Sacramento River to the Sacramento-San Joaquin Delta (Delta) were sampled 0.5 miles downstream of the town of Knights landing at river mile (RM) 89.5 from 28 September 1999 – 30 September 2000. Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*O. mykiss*) were the target species. Sampling was conducted using two 8-ft diameter rotary screw traps (RST). From 28 September – 30 December 1999 one 5-ft RST was used to replace one 8-ft RST when it was taken from the river for servicing. On 31 December 1999, the 5-ft RST was removed from the Knights Landing site and two 8-ft RST traps were used through the end of the survey. This time period was the fifth consecutive year of emigration monitoring conducted by the California Department of Fish and Game (DFG) at Knights Landing (Snider and Titus 2000a, 2000b).

Mean weekly flow ranged from 4,506 cfs in week 45 (31 October – 6 November 1999) to 27,607 cfs in week 10 (27 February - 4 March 2000). Mean daily flow peaked at 28,135 cfs on 16 February 2000. Mean weekly water temperature decreased from 64˚F in week 40 (26 September -2 October 1999) to 47˚F in week 2 (2 – 8 January 2000). Temperature then remained low (≤ 53˚F) through week 12 (12 – 18 March 2000) before increasing overall from 55˚F in week 13 to 72˚F in week 29 (9 – 15 July 2000). Mean weekly water transparency, measured as Secchi disk depth, was poor throughout the survey and ranged from 0.3 ft to 4.8 ft.

A total of 23,963 juvenile salmon was collected in 15,666 hours of trapping (1.5 fish/h). The total catch included 61 marked salmon, and 23,902 unmarked salmon. Fall-run salmon were predominating in the unmarked group comprising 99.14% of the catch (based upon size criteria) although fall-run catch was only 48% of the marked catch (based upon coded-wire tag information). Late-fall-run salmon comprised 0.07% of the unmarked salmon catch and 44% of the marked catch. Winter-run salmon comprised 0.22% of the unmarked catch and 8% of the marked salmon catch, and spring-run salmon made up 0.57% of the unmarked catch (there were no marked spring-run salmon captured). As in previous studies, based upon comparisons with hatchery-reared fall-run released from Coleman National Fish Hatchery (CNFH) during late-spring, spring-run-sized fish collected after the hatchery fish releases (week 12) were considered to be CNFH-produced fall-run. As a result, 72% of spring-run-sized salmon were considered hatchery-produced fall-run and only 0.16% of the total unmarked salmon catch was considered spring-run.

Primary emigration occurred from late-January 2000 (week 3) through mid-May (week 21). The main body of fall-run fish coincided with the substantially greater flow increase beginning week 4 (16 - 22 January 2000) and lasting through week 12 (12 - 18 March 2000), peaking during week 8 (13 – 19 February 2000). A second wave of fall-run salmon was associated with the large releases of CNFH-produced fish beginning week 13 (19 March 2000).

Twelve in-river produced (unmarked) late-fall-run juveniles from BY 1999 were collected from week 45 through week 4 (31 October 1999 – 22 January 2000). A total of 4 in-river produced late-fall-run juveniles from BY2000 were also collected from week 17 through week 19 (16 April – 6 May 2000).

A total of 52 in-river produced winter-run Chinook salmon was collected from week 40 through week 12 (26 September 1999 – 18 March 2000). The main bulk of the migration came through in February with 61 % of the catch during weeks 6 – 10. November, December and January combined saw 27% of the catch, and 12% in March.

In-river produced spring-run Chinook salmon (based on size criteria) were collected from week 4 through week 12 (16 January – 18 March 2000). A total of 38 in-river produced spring-run juveniles were collected by RST.

Altogether, 23,796 unmarked fall-run sized juvenile salmon were collected. Fall-run were first collected during week 2 (2 January 2000) and then in every subsequent week through week 21 (14 May 2000). One additional fall-run salmon was collected in week 25 (11 June 2000).

A total of 7 unmarked, yearling steelhead trout were caught between week 8 through week 19 (13 February – 6 May 2000). Most were caught in week 17 (n = 5) and one each caught in week 8 and in week 19. We also collected 2 adult unmarked steelhead trout between week 7 and week 9 and 28 marked steelhead between week 3 through week 17 (9 January – 22 April 2000).

Estimates of the relative abundance of juvenile salmonids emigrating past Knights Landing are provided based upon a mean RST efficiency of 0.25% (range: 0.0% - 1.16%; 80% CI: 0.12% - 0.38%; n = 13). The estimated number of in-river salmon that passed Knights Landing included 7,600 BY 1999 late-fall run and 2,000 BY 2000 late-fall run; 27,600 BY 1999 winter run; 21,200 spring run; and 12,981,449 fall run. The estimated number of in-river produced steelhead passing Knights Landing was 3,600.

The estimated number of hatchery-produced Chinook salmon passing Knights Landing was 16,000 late-fall run, 2,400 winter run, and 152,951 fall run. The estimated number of hatchery-produced steelhead trout passing Knights landing was 18,000.

Emigration from the upper Sacramento River system to the Delta is exclusively through Knights Landing until flow increases cause a diversion through the Sutter Bypass, upstream of Knights Landing. Typically, diversion via the Tisdale Weir occurs when flow exceeds about 23,000 cfs. In 1999 – 2000, flow exceeded this mark during weeks 8 through 12 (13 February – 12 March 2000). Since the proportion of juvenile salmonids that emigrates through the bypass is unknown, the magnitude of salmonids emigrating to the Delta cannot be estimated by just using Knights landing results. However, the temporal distribution and, likely, the relative abundance of juvenile salmonids migrating toward the Delta are reflected in the Knights Landing results.

INTRODUCTION

Juvenile anadromous salmonid emigration was monitored on the Sacramento River near Knights Landing (RM 89.5) for the fifth consecutive year (Snider and Titus 1998, Snider and Titus 2000b, c). Monitoring was conducted to develop information on timing, composition (race and species), and relative abundance of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) emigrating from the upper Sacramento River system. This information provides early warning of emigration into the Sacramento-San Joaquin Delta (Delta) to enable implementation of management actions deemed necessary to protect juvenile anadromous salmonids as they pass into and through the Delta. Data acquired over several years will improve understanding of the attributes of emigration and identify implications of management actions both up- and downstream of the Delta relative to protection and recovery of the Sacramento River's anadromous salmonid populations.

The indigenous, anadromous salmonid populations of California's Central Valley have been severely reduced due to a variety of man-caused alterations to their environment. The region's Chinook salmon and steelhead trout populations have been extirpated from most of their historic range and the existence of the few remaining populations is constantly challenged. Beginning in the mid-1800's through the mid-1900's, the construction of dams on most of the major streams within the Valley progressively eliminated use of more than 90% of these fishes' historic habitat. Changes in water quality and drastic modifications in stream channel form began with the unbridled quest for gold in 1849 and continue today with escalating urban expansion and intensive agriculture and industrial development. Stream channels have been modified to protect cities and agriculture. Pollutants ranging from elevated water temperatures to treated effluent have further degraded much of the region's stream habitats. Increasing water diversion continues to modify the timing and magnitude of flow that sustain most of the remaining habitat.

Emigrating fish are continually lost as they attempt to navigate the many diversions that lie between their natal streams and the Pacific Ocean. Potentially, the most imposing of these diversions are the State Water Project's Harvey Banks Delta Pumping Plant and the Central Valley Project's Tracy Pumping Plant, both located in the southern Sacramento-San Joaquin Delta. The work summarized in this report is a portion of an ongoing effort upon the part of water developers and fishery managers to deduce the deleterious impacts of these facilities on Central Valley salmon and steelhead, to preserve one of California's valued natural heritages.

Anadromous salmonids produced in the Sacramento River system upstream of the Feather River (RM 80) are of special concern. The upper Sacramento River and several of its tributaries (Figure 1) provide most of the essential spawning and rearing habitat for the Central Valley's depleted, anadromous salmonid populations. The winter-run Chinook salmon (Listed as endangered under both the California and Federal Endangered Species acts), unique to California's central Valley, spawns and rears exclusively in the upper Sacramento River. Central Valley spring-run Chinook salmon (Listed as threatened under both the California and Federal Endangered Species acts) are nearly exclusive to the upper Sacramento system where remnant populations occur in a few isolated locations including Deer, Mill and butte creeks (Figure 1). All late-fall-run Chinook salmon, most steelhead trout (Listed as threatened under the Federal Endangered Species act), and a major portion of the natural, or in-river-produced, fall-run Chinook salmon spawn and rear in the upper Sacramento River and its tributaries. The continued existence of these populations could well depend upon the ability to protect the juveniles as they emigrate from their natal waters, into and through the Delta on their way to the Pacific Ocean.

Accurate estimates of the abundance and timing of emigrating anadromous salmonids as they enter the Delta would improve the ability to address critical water management questions. Water management activities in the Delta can influence survival of anadromous salmonids. Various restrictions have been placed on project operations to protect juvenile salmonids migrating through and residing within the Delta. For example, Delta diversions are limited seasonally predicated on the presence of winter-run Chinook salmon. Water management decisions could be considered for the other anadromous salmonids under increasing concern (i.e., spring-run Chinook salmon and steelhead trout) if better information existed on timing, abundance, and overall emigration attributes. Improved estimates of the timing and relative abundance of these species as they enter the Delta should improve confidence in defining impacts and protective measures to enhance overall protection, and potentially maximize water management flexibility.

An appropriately located and operated monitoring site would provide early warning of emigrating juvenile salmonids entering the Delta and improve the ability to use water project flexibility and other actions to protect winter-run Chinook salmon and, potentially, other anadromous species of concern. As such, representatives of agencies involved in fisher and water management issues within the Central Valley recommended establishing a monitoring station to:

1) Provide early warning to trigger Central Valley Project and State Water Project operation modifications (e.g., manipulation of Delta Cross Channel gate operation and water export levels).

2) Provide a monitoring station intermediate between the Glenn-Colusa Irrigation District (GCID) diversion and the Delta.

3) Provide opportunity to follow movement of juvenile salmonids downstream in response to various environmental conditions, including flow.

4) Determine the relative proportion of winter-run Chinook salmon fry and pre-smolts that enter and potentially rear in the lower river and Delta through the fall and early-winter months.

5) Develop abundance estimates for juvenile salmonids entering the lower river and Delta.

To address the feasibility of monitoring the timing and abundance of juvenile anadromous salmonids emigrating exclusively from the upper Sacramento River system into the Sacramento-San Joaquin Delta, a pilot monitoring station was established near Knights Landing on the Sacramento River at RM 89.5 (Figure 1) in November 1995. Potentially, progenies of all Central Valley winter-run and late-fall- run, most spring-run, a major portion of fall-run, and most in river-produced steelhead trout emigrate past the Knights landing sampling site. The exception being that emigrants can enter the Sutter bypass, upstream of Knights Landing, when flow in the vicinity of the bypass surpasses 23,000 cfs. The proportion of emigrants entering the bypass is unknown; their survival to the Delta is also unknown. Other monitoring programs within the Sacramento river system are either too far upstream of the Delta to accurately monitor the timing and abundance of emigration into the Delta (e.g., Red Bluff Diversion Dam (RBDD) at RM 245 and GCID diversion at RM 206), or are too close to the Delta to discriminate fish originating from the upper Sacramento River system from those produced in the Feather and American rivers (e.g., Sacramento at RM 55).

Knights Landing was selected as the pilot monitoring site, relative to downstream locations, due to apparent favorable channel and flow conditions. It appeared to have greater opportunity for using a diversity of fish sampling methods including relatively efficient gear types such as rotary screw traps (RST). The river channel is relatively narrow and there is less flow than in the Sacramento River downstream of the Feather and American Rivers and upstream of the Sutter Bypass. The site also provided an intermediate monitoring point between GCID, the next sampling station upstream (RM 206), and the Delta.

METHODS

Juvenile salmonids emigrating via the Sacramento River to the Delta were sampled 0.5 miles downstream of the town of Knights Landing at RM 89.5 (Figure 1) from 26 September 1999 through 30 September 2000. Two 8-ft diameter and one 5-ft diameter RSTs were used from 26 September (week40) to 30 December (week 1), and two 8-ft diameter RSTs were used from 31 December (week 2) through the end of the survey.

The RSTs were lashed together and located on the outside of a wide bend in the river approximately 100 ft from the east bank. Three 40-pound Dansforth anchors and 3/8” diameter wire ropes were used to position and secure the traps in the stream channel. The

trap complex was also secured to the east bank with a safety line of ¼" diameter wire rope. Water depth at the trap location was 18 ft at 10,000 cfs (Depth was 20 ft and mean current velocity was 3.0 ft/s at a flow of 15,000 cfs).
Data acquired from each trap per servicing included total time fished since the last servicing, current velocity at the trap opening, the average number of cone revolutions per minute, and the cumulative number of cone revolutions since the last servicing. All salmonids were counted by species, and race assigned to Chinook salmon using size-at-time criteria developed by Frank Fisher (California Department of Fish and Game, Northern California-North Coast Region, unpublished data). All salmon classified at winter-run, spring-run, and late-fall-run were measured and weighed (fork length [FL] in mm and weight in g). At each trap servicing, up to 150 fall-run sized salmon per trap were selected and measured using a random-stratified subsampling protocol. All juvenile steelhead trout were counted and measured. The traps were serviced up to two times per day: once in mid-morning and once near dusk.

The data are reported on a weekly time step to smooth variation in effort and trap efficiency while retaining sufficient detail to evaluate trends in timing and abundance. Data were typically reduced to weekly sums or weekly means. Weeks began on Sunday and ended on Saturday and were identified by number. Week 1 was defined as the first week of 2000 (i.e., contains 1 January 2000). Weeks prior to week 1 were consecutively numbered in descending order from 52; weeks after week 1 were numbered in ascending order.

Flow at Knights Landing was obtained from records of the U.S. Geological Survey gauging station at Wilkins Slough. Water transparency was measured each day at the RSTs using a Secchi disk following standard methods (Orth 1983). Water samples were collected and turbidity measured in Nephelometric Turbidity Units (NTU). Water temperature was also measured using electronic recording thermographs attached to the RSTs.

Trap efficiency was evaluated using a mark-recapture technique. All trapped Chinook salmon (except winter-run sized Chinook) were marked using a Bismark Brown *Y* stain (Deacon 1961) then released about 0.5 miles upstream of the traps. Our objective was to mark and release at least 100 salmon per trial. When <100 salmon were collected in a day, fish were held until ≥100 fish were available for marking, or up to 3 days maximum, whichever occurred first. Efficiency was calculated as the percentage of marked fish that were recaptured in the traps on a weekly basis. Salmon marking was initiated during week 6 (30 January – 5 February) and continued through week 18 (23 – 29 April). No marked fish were released during weeks 40 – 5 and 19 – 40 as fewer than 100 fish were collected to allow marking.

All adipose-fin clipped (marked) fish were collected and coded-wire tags (CWTs) were read to determine the fish's origin including race. Information on race derived from the tag was compared with the original race designation based upon size. Race classification was changed to reflect the tag data for individual fish and groups of fish when the tagged fish appeared to represent the unmarked portion of the catch.

RESULTS and DISCUSSION

General Sampling Conditions

Mean weekly flow ranged from 4,506 cfs in week 45 (31 October – 6 November) to 27,607 cfs in week 10 (27 February – 4 March) (Table 1). Mean daily flow peaked at 28,135 on 16 February 2000. The initial flow increase occurred much later than the 1998/99 survey (Snider and Titus 2000) when flows increased in November. In 2000, flows increased from about 7,000 cfs in early January to 14,444 in mid January to 22,608 by the end of January. Mean flows remained above 23,000 cfs (Sacramento River flow is diverted into the Sutter Bypass via the Tisdale Weir at flows ≥ 23,000 cfs) from week 8 through 12 (13 February – 12 March 2000) then declined to about 11,000 cfs in week 16 (9 April 2000). Mean weekly flows increased slightly peaking at about 15,000 cfs (week 17) then gradually declined to about 9,000 cfs by week 28 (2 July 2000).

Mean weekly water temperature decreased from 64˚F in week 40 (26 September – 2 October 1999) to 47˚F in week 2 (2 – 8 January 2000). Temperature then remained low (≤ 53˚F) through week 12 (12 – 18 March 2000) before increasing overall from 55 degrees in week 13 to 70 degrees in week 26.

Mean daily water temperature was weakly negatively correlated with mean daily river flow ($r = -0.35$) and although there was a significant linear regression ($p<0.0000$) of temperature on flow, the model only explained about 12% of the variation in temperature as a function of flow. As is previous studies (Snider and Titus 2000) it has been noted that water temperature at Knights Landing is primarily a function of seasonal variation in ambient temperature.

Mean weekly water turbidity ranged from 104.81 NTU to 3.86 NTU (Table 1). Turbidity was strongly correlated to flow ($r = 0.81$) with a significant linear regression ($p < 0.0202$) and the model explaining 65% of the variability. The higher the number of NTUs, the lower the water clarity so in effect, the strong correlation between flow and NTUs shows that flow has a negative effect on water clarity and the high turbidity readings translate to poor water transparency.

The RSTs were successfully operated over a wide range of flows (~4,500 to ~28,000 cfs). Interruptions in sampling were typically less than 24 h within a week and were generally due to debris buildups that disabled the traps. Longer interruptions occurred during week 4 (16 January 2000) when the traps were down for several days due to the first major increase of flow bringing debris and a holiday that left the traps unchecked one extra day.

Rotary Screw Trap Results

Chinook Salmon Emigration

In previous studies, the typical initiation of the primary migration period occurs in late November (Snider and Titus 1998). Ten winter-run sized salmon were collected between week 48 (21 November 1999) and week 2 (2 January 2000) and eleven late-fall-run sized salmon were collected between week 45 (31 October 1999) and week 2 (2 January 2000) (Table 4). The primary emigration period of 1999 - 2000 began during week 3 (9 January 2000) when 22 juvenile salmon were collected (Table 2). Thereafter, salmon were captured every week through week 21 (14 May) (Table 2). Only one salmon was collected (week 25) after week 21.

The initiation of juvenile salmon migration was strongly linked to the initial flow increase of the season. This relationship was also observed in previous studies (Snider and Titus 1998, Snider and Titus 2000b, c). During the period between week 46 (7 November 1999) and week 2 (2 January 2000), 69% of the total late-fall-run salmon were collected and 19% of winter-run sized salmon collected. There were no fall-run salmon collected prior to week 2.

Primary emigration began when flows more than doubled between week 3 (9 January 2000) and week 4 (16 January 2000). Flows continued to increase and peaked during week 8 (13 February) and remained high (< 18,000 cfs) through week 13 (19 March 2000). During this period, 22,816 fall-run emigrants were collected representing 95 % of the total captured fall-run. The peak weekly catch of salmonids (8,275) coincided with the peak mean weekly flow during week 8.

As in previous survey years, fingerling-sized fall run Chinook salmon were released from Coleman National Fish Hatchery (CNFH). The releases began during week 11 (6 March 2000) and continued through week 17 (21 April 2000). The releases coincided with higher catches in week 17 (16-22 April 2000) and week 18 (23-29 April 2000).

Size of salmon captured by the RSTs ranged from 29 to 157 mm FL (Table 2). With the exceptions of week 50 (5 December 1999), week 15 (2 April 2000), and week 20 (7 May 2000), large salmon (>90 mm FL) were captured during every week between week 47 (14 November 1999) and week 21 (14 May 2000). With the exception of week 15 (2 April), recently emerged-sized salmon (<45 mm FL) were captured during every week between week 2 (2 January 2000) and week 19 (30 April) (Table 2).

Late-Fall-Run-Sized Chinook Salmon

All late-fall run released from CNFH were marked with an adipose-fin clip. As such, we considered all unmarked late-fall-run Chinook salmon to have been produced in-river, based on size criteria (F. Fisher and S. Greene, unpubl. data). The first in-river-produced late-fall-run Chinook salmon was caught during week 45. Altogether, 12 in-river-produced late-fall-run juveniles from BY 1999 were collected from week 45(31 October 1999) through week 4 (16 January 2000) and 4 in-river-produced late-fall-run juveniles from BY 2000 were collected from week 17 (16 April 2000) through week 19 (30 April 2000). These fish ranged from 36 to 154 mm FL (Table 4).

We collected 27 marked late-fall run from week 49 (28 November 1999) through week 13 (19 March 2000) (Table 5). Seven of the marked fish were designated as winter-run based on their FL, but were determined to be late-fall-run by their tag codes.

A total of 827,259 late-fall run produced at CNFH were marked, tagged with CWTs and released upstream of Knights Landing into the Sacramento River. Of these, an estimated 13,561 were marked but either shed or otherwise did not have a CWT when released. An initial release from the Red Bluff Diversion Dam (RBDD) of ~5,000 CWT salmon was made between week 43 (18 October 1999) and week 45 (3 November 1999) for RST efficiency trials. Five releases from CNFH were made over a period of 9 weeks between 12 November 1999 and 12 January 2000 (table 3).
We captured 27 adipose-clipped fish representing 0.003% of the releases. Marked fish were collected from week 49 (28 November 1999) to week 13 (19 March 2000).

Winter-Run-Sized Chinook Salmon

As with late fall from CNFH, all winter-run released upstream of Knights Landing were marked and all unmarked winter-run (based on size) were considered to have been produced in-river. A total of 52 in-river-produced winter-run Chinook salmon from BY 1999 were collected from week 48 (21 November 1999) to week 12 (12 March 2000). These fish ranged from 65 to 129 mm FL (Table 4).

A total of 30,840 winter-run produced at CNFH were marked, tagged with CWTs and released about 200 miles upstream of Knights Landing into the Sacramento River. Of these, an estimated 407 were marked but either shed or otherwise did not have a CWT when released. Marked fish were released during week 5 (27 January 2000). We captured 5 adipose-clipped winter-run sized fish representing 0.016% of the release. Marked fish were collected from week 8 (13 February 2000) and week 11 (5 March 2000).

Spring-Run-Sized Chinook Salmon

No hatchery-reared spring-run Chinook salmon were released into the Sacramento River upstream of Knights Landing. All unmarked, spring-run sized Chinook salmon captured through week 12 (12 – 18 March 2000) were considered in-river produced spring-run. Beginning in week 13, all spring-run-sized salmon were considered fall-run juveniles based upon the following information:

- An increase in the catch of spring-run-sized salmon began in week 13 concurrent with the arrival of marked, hatchery-produced fall run released into the upper river during week 11 (Tables 3 and 5).
- Many of the fall-run measured just prior to their release during week 11 were spring-run sized.

In-river-produced spring-run Chinook salmon (based on size criteria) were collected from week 4 (16 January 2000) up to week 12 (12 March 2000).

Fall-Run-Sized Chinook Salmon

A total of 23,697 in-river-produced fall-run-sized Chinook were caught in the RSTs, dominating the catch. Fall-run were first collected when one fish was caught in week 2 (2 January 2000) and then en every subsequent week through week 21 (16 May 2000). One additional fall-run was collected week 25 (13 June).

After the first fall-run sized fish was caught in week 2, numbers increased and were greatest in weeks 5 through 8 (> 2800) with the largest catch in week 8 (13 February 2000). Although not as great as earlier catches, the numbers of collected fish increased during week 17 (16 April 2000) coincident with the arrival of known hatchery-reared fall run released from CNFH (Table 3).

Nearly 12 million, fingerling-sized fall-run from CNFH were released into the upper Sacramento River system from weeks 11 through 17. Just over 10% of these fish were marked. The fish were released below the CNFH at river mile 271.5, the greatest number of released fish occurring in weeks 16 and 17 (14 – 21 April 2000). An additional 40,142 hatchery-reared fall-run fry (34 to 48 mm FL) were released below RBDD (RM 243) during weeks 4 through 7.

A total of 29 fall-run-sized, adipose fin clipped fish were caught by RST: 25 contained tags that identified them as fall run released from CNFH into Battle Creek and one that was released into the Sacramento River near the RBDD. Released fish were collected at Knights landing 3 – 13 days after release (mean = 7 days) and recaptures made up 0.4% of released CWT salmon.

Unmarked fall run ranged in size from 29 to 94 mm FL (Table 4). Recently emerged-sized fish (< 45 mm FL) made up 86% of the total measured fish. Recently emerged-sized fall run were collected from week 2 through week 17 of 2000. Smolt-sized fall run (>70 mm FL) were collected from week 14 through 21 of 2000 and accounted for 7% of the total catch of marked fall run.

Steelhead Trout Emigration

Steelhead trout captured in the RSTs represented three age groups: young-of-the-year (YOY)(<100 mm FL), both in-river and hatchery produced yearlings (100 – 300 mm FL), and adults (>300 mm FL). Scales collected from fish >100 mm FL and marked fish will be analyzed and should help further define these groups.

<u>Young-of-the-year Steelhead</u>

No YOY steelhead were collected (two were collected in the 1999 survey).

<u>Yearling Steelhead</u>

We collected 7 unmarked, yearling sized steelhead from week 8 though week 19 (13 February – 6 May 2000) (Table 6). The largest number of captures (71%) occurred during week 17 (16 April 2000).

A total of 520,201 marked steelhead was planted about 180 river miles upstream from Knights Landing during weeks 2 and 3 (Table 3). We collected 28 (.005%) marked yearling steelhead from week 3 through week 17 (3 January – 16 April 2000) (Table 6).

Unmarked yearling steelhead ranged from 175 to 241 mm FL (mean = 214 mm FL). Marked yearling steelheads on average were slightly larger with a mean size of 220 mm FL and ranged from 169 – 254 mm FL (Table 6).

<u>Adult Steelhead</u>

Two adult steelhead were collected (Table 6): one in week 7 (335 mm FL) and one in week 9 (372 mm FL). These fish were likely ≥ 2-year-old smolts produced in-river. Scale analyses will provide further age-at-size information for these fish.

RST Gear Efficiency Using Mark-Recapture

Salmon were marked for efficiency evaluation beginning in week 6 (Table 7). A total of 13,628 Chinook salmon were marked from week 6 though week 18 (30 January – 23 April 2000). Overall, 53 (0.39%) salmon were recaptured. The percent recaptured, by week, ranged from 0% during weeks 11 through 15 to 1.16% during week 18. The mean trap efficiency during the 11 week period was 0.25%.

Because trap efficiency at Knights Landing does not vary consistently with any measured factor, and to allow for determination of confidence intervals using standard statistical methods (e.g. Zar 1984), abundance estimates were calculated using the mean of weekly trap efficiency estimates.

Relative Abundance Estimates

A primary objective of monitoring at Knights Landing is to make an abundance estimate for juvenile salmonids emigrating from the upper Sacramento River system into the lower river and Delta. Mean weekly trap efficiency (0.0025) and associated 80% confidence interval (0.0012-0.0038) were used to estimate the abundance of each salmon run and steelhead. Both the in-river and hatchery-produced portions of each group were estimated. Estimates of hatchery-produced juveniles were made only for groups containing marked fish. Thus, no attempt was made to determine the number of salmon captured at Knights Landing that came from the unmarked fall-run fry planted from weeks 11 – 17.

In order to estimate the number of fish that passed Knights Landing during the entire emigration period, including those few weeks when trapping effort was less than 100%, we expanded the total catch of each species and race to represent 100% effort. The weekly catch was estimated for those weeks when trapping effort was less than 100% by expanding the catch in proportion to the percentage of actual effort (Snider and Titus, 2000). These numbers were added to the actual counts and used in the calculation of the total estimates (Tables 8 and 9).

The estimated number of marked and unmarked hatchery-produced fish was determined (Table 8). Estimated survival to Knights Landing of hatchery salmonids by run/species ranged from 1.3% to 7.8%.

In-river produced fish were estimated by subtracting the estimated hatchery-produced component passing Knights Landing (from Table 8), by cohort, from the estimated total abundance of each cohort moving past the site (Table 9). Overall, an estimated 13.2 million Chinook salmon (80% CI, 8.6 million – 27.4 million) emigrated past Knights landing into the lower Sacramento River and Delta. About 98% of those were estimated to have been produced in-river. An estimated 21,600 yearling steelhead (80% CI, 14,211 – 45,000) emigrated past Knights Landing. In contrast to salmon, only 17% of those fish were estimated to have been produced in-river.

Emigration from the upper Sacramento River system to the Delta is exclusively through Knights Landing until flow increases require diversion through the Sutter Bypass, upstream of Knights Landing. Typically, diversion to the bypass via the Tisdale Weir occurs when flow exceeds about 23,000 cfs. Since the proportion of juvenile salmonids that emigrate through the bypass is unknown, the magnitude of salmonids emigrating to the Delta cannot be estimated by just using Knights Landing results. However, the temporal distribution and, likely, the relative abundance of juvenile salmonids migration toward the Delta are reflected in the Knights landing results.

Tables

Table 1. Summary of mean weekly sampling conditions in the Sacramento River near Knights Landing during juvenile salmonid emigration investigation, 26 September 1999 - 30 September 2000.

Week	Beginning date	Mean flow (cfs)	Mean water temperature F	Mean turbidity (N)
40	26 Sep 1999	6,577	64	8.41
41	03 Oct 1999	6,038	62	5.97
42	10 Oct 1999	5,293	63	7.39
43	17 Oct 1999	4,822	58	6.75
44	24 Oct 1999	5,177	58	7.08
45	31 Oct 1999	4,506	58	8.71
46	07 Nov 1999	6,116	57	10.10
47	14 Nov 1999	7,008	56	10.40
48	21 Nov 1999	7,992	51	14.58
49	28 Nov 1999	9,140	51	14.00
50	05 Dec 1999	9,813	48	10.45
51	12 Dec 1999	8,928	48	6.28
52	19 Dec 1999	7,434	49	6.92
1	26 Dec 1999	7,094	49	5.29
2	02 Jan 2000	6,636	47	3.86
3	09 Jan 2000	6,976	49	8.48
4	16 Jan 2000	14,444	50	22.83
5	23 Jan 2000	19,561	50	37.31
6	30 Jan 2000	22,608	49	24.34
7	06 Feb 2000	21,464	51	21.48
8	13 Feb 2000	27,263	51	104.81
9	20 Feb 2000	26,952	50	58.59
10	27 Feb 2000	27,607	50	47.32
11	05 Mar 2000	27,603	50	50.24
12	12 Mar 2000	25,204	53	33.35
13	19 Mar 2000	18,784	55	33.43
14	26 Mar 2000	13,529	58	19.45
15	02 Apr 2000	10,771	62	13.85
16	09 Apr 2000	10,926	63	11.28
17	16 Apr 2000	14,960	58	37.58
18	23 Apr 2000	11,690	62	17.25

Table 1. (Continued)

Week	Beginning date	Mean flow (cfs)	Mean water temperature F	Mean turbidity (N)
19	30 Apr 2000	10,199	63	11.31
20	07 May 2000	10,042	61	15.95
21	14 May 2000	8,628	62	26.50
22	21 May 2000	10,215	69	7.35
23	28 May 2000	9,076	67	10.50
24	04 Jun 2000	7,331	68	-
25	11 Jun 2000	8,287	69	26.00
26	18 Jun 2000	7,945	70	
27	25 Jun 2000	8,131		
28	02 Jul 2000	8,660		
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				

Table 2. Weekly summary of catch and size statistics for Chinook salmon caught by rotary screw traps in the Sacramento River near Knights Landing, 26 September 1999 - 30 September 2000.

Week	Effort	Total catch	Catch/h	Size statistics (FL in mm)			
				Mean	Minimum	Maximum	Standard deviation
40	185.50	0	0	-	-	-	-
41	431.00	0	0	-	-	-	-
42	433.00	0	0	-	-	-	-
43	504.75	0	0	-	-	-	-
44	493.25	0	0	-	-	-	-
45	514.25	1	0.002	131.0	131	131	0.00
46	503.00	0	0	-	-	-	-
47	457.00	1	0.002	107.0	107	107	0.00
48	238.75	4	0.017	104.8	66	129	28.77
49	446.00	8	0.018	95.2	65	128	22.02
50	524.50	5	0.010	75.4	68	85	7.70
51	500.25	0	0	-	-	-	-
52	413.50	1	0.002	117.0	117	117	0.00
1	477.50	9	0.019	122.9	96	138	15.08
2	344.00	3	0.009	104.7	36	154	61.33
3	375.00	22	0.059	61.0	35	156	45.23
4	144.75	242	1.672	40.0	33	148	15.12
5	248.75	3643	14.645	38.2	29	157	7.05
6	278.25	2867	10.304	38.4	29	119	6.23
7	335.50	5394	16.078	38.2	29	116	4.77
8	290.50	8275	28.485	38.5	29	129	7.11
9	306.00	1159	3.788	38.3	30	122	5.03
10	337.00	588	1.745	38.1	30	129	8.00
11	332.50	533	1.603	37.5	30	115	6.76
12	291.00	93	0.320	46.2	31	127	18.12
13	335.75	112	0.334	52.8	33	128	13.83
14	334.25	161	0.482	65.8	38	96	10.24
15	336.00	27	0.080	65.5	48	84	10.67
16	342.50	66	0.193	72.1	44	90	9.98
17	308.00	502	1.630	74.6	36	98	8.07
18	333.00	208	0.625	77.2	37	93	6.10

Table 2. (Continued)

Week	Effort	Total Catch	Catch/H	Size Statistics (FL in mm)			
				Mean	Minimum	Maximum	Standard Deviation
19	340.25	25	0.073	76.2	38	93	11.31
20	142.25	4	0.028	77.0	73	85	6.93
21	484.50	9	0.019	82.6	70	94	7.72
22	241.50	0	0	-	-	-	-
23	471.00	0	0	-	-	-	-
24	-	-	-	-	-	-	-
25	530.00	1	0.002	-	-	-	-
26	478.5	0	0	-	-	-	-
27	239.25	0	0	-	-	-	-
28	-	-	-	-	-	-	-
29	359.0	0	0	-	-	-	-
30	-	-	-	-	-	-	-
31	287.5	0	0	-	-	-	-
32	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-
35	697.5	0	0	-	-	-	-
36							
37							
38							
39							
40							
Total	**15,666.25**	**23,963**	**1.5/hr**				

Table 3. Summary of juvenile chinook salmon and steelhead produced at Coleman National Fish Hatchery and released into the Sacramento River upstream of Knights Landing, including run, number marked with an adipose clip (with and without coded-wire tags [CWTs]), and release date and location.

Chinook salmon run	Week of release (Date)	Number marked w/CWT	Number marked w/o CWT	Number unmarked	Release location (RM)1/
Late-fall run	43 (18 Oct 1999)2/	5,034	103	0	RBDD (243)
Late-fall run	46 (12 Nov 1999)	70,500	3,711	0	CNFH (271.5)
Late-fall run	50 (09 Dec 1999)	75,948	4,848	0	CNFH (271.5)
Late-fall run	52 (21 Dec 1999)	83,383	0	0	CNFH (271.5)
Late-fall run	2 (04 Jan 2000)	497,153	3,232	0	CNFH (271.5)
Late-fall run	3 (12 Jan 2000)	81,680	1,667	0	CNFH (271.5)
Winter run	5 (27 Jan 2000)	30,433	407	0	CP (298)
Fall run fry	4 (21 Jan 2000)	10,365	321	0	RBDD (243)
Fall run fry	6 (31 Jan 2000)	10,154	534	0	RBDD (243)
Fall run fry	7 (07, 11 Feb 2000)	17,455	1,313	0	RBDD (243)
Fall run	11 (06 Mar 2000)	47,342	1,464	0	CNFH (271.5)
Fall run	12 (13 Mar 2000)	48,798	493	0	CNFH (271.5)
Fall run	13 (22 Mar 2000)3/	0	0	9,432	CNFH (271.5)
Fall run	15 (07 Apr 2000)	67,912	3,953	896,838	CNFH (271.5)
Fall run	16 (14 Apr 2000)	406,187	27,482	5,022,714	CNFH (271.5)
Fall run	17 (21 Apr 2000)	450,029	21,760	4,804,510	CNFH (271.5)
Steelhead	2 (05-07 Jan 2000)	141,670	248,281	0	SRB (258)
Steelhead	3 (10 Jan 2000)	0	130,250	0	CNFH (271.5)

1/ CNFH = Coleman National Fish Hatchery; CP = Caldwell Park; RBDD = Red Bluff Diversion Dam; SRB = Sacramento River Bend
2/ Releases spread over weeks 43-45, 18 Oct-03 Nov, for rotary screw trap efficiency trials
3/ Releases spread over weeks 13-14, 22-28 Mar

Table 4. Summary of catch and size range data for in-river produced[1/] chinook salmon (by run) caught by rotary screw traps in the Sacramento River near Knights Landing, 26 September1999 - 30 September 2000.

Week	Fall run[2/]		Spring run[3/]		Winter run		Late-fall run	
	Number	FL range	Number	FL range	Number	FL range	Number	FL range
40	0	-	0	-	0	-	0	-
41	0	-	0	-	0	-	0	-
42	0	-	0	-	0	-	0	-
43	0	-	0	-	0	-	0	-
44	0	-	0	-	0	-	0	-
45	0	-	0	-	0	-	1	131
46	0	-	0	-	0	-	0	-
47	0	-	0	-	0	-	1	107
48	0	-	0	-	1	66	3	100-129
49	0	-	0	-	3	65-78	4	94-128
50	0	-	0	-	5	68-85	0	-
51	0	-	0	-	0	-	0	-
52	0	-	0	-	0	-	0	-
1	0	-	0	-	1	96	1	-
2	1	36	0	-	0	-	1	154
3	17	35-43	0	-	1	109	0	-
4	236	33-44	1	47	0	-	1	124
5	3630	29-48	5	47-58	3	81-108	0	-
6	2850	29-49	8	50-62	7	70-119	0	-
7	5384	29-53	5	53-60	5	102-116	0	-
8	8250	29-55	8	55-63	14	75-119	0	-
9	1153	30-55	4	56-69	2	120-122	0	-
10	580	30-59	3	60-73	4	107-129	0	-
11	528	30-60	2	63-66	1	115	0	-
12	85	31-62	2	66-70	5	90-127	0	-
13	100	33-68	11	68-86	0	-	0	-
14	120	38-71	40	72-96	0	-	0	-
15	21	48-74	6	75-84	0	-	0	-
16	51	44-79	13	80-90	0	-	0	-
17	467	38-83	24	83-98	0	-	2	36
18	188	49-87	4	85-93	0	-	1	37

Table 4. (Continued)

Week	Fall run[2/]		Spring run[3/]		Winter run		Late-fall run	
	Number	FL range	Number	FL range	Number	FL range	Number	FL range
19	22	53-90	1	93	0	-	1	38
20	4	73-85	0	-	0	-	0	-
21	9	70-94	0	-	0	-	0	-
22	0	-	0	-	0	-	0	-
23	0	-	0	-	0	-	0	-
24	0	-	0	-	0	-	0	-
25	1	-	0	-	0	-	0	-
26	0	-	0	-	0	-	0	-
27	0	-	0	-	0	-	0	-
28	-	-	-	-	-	-	-	-
29	0	-	0	-	0	-	0	-
30	-	-	-	-	-	-	-	-
31	0	-	0	-	0	-	0	-
32	-	-	-	-	-	-	-	-
33	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-
35	0	-	0	-	0	-	0	-
36								
37								
38								
39								
40								
Total	**23,697**	**29-94**	**38[4/]** **99[5/]**	**47-73** **66-98**	**52[6/]**	**65-129**	**12[6/]** **4[7/]**	**94-154** **36-38**

1/ Unmarked salmon were considered in-river produced fish except as noted below.
2/ A large portion of the fall run listed in this table were likely of hatchery origin since in-river and hatchery-produced fall run could not be distinguished. Less than 16% of fall run released from CNFH were marked.
3/ All spring-run-sized salmon collected after week 12 (shaded area) were considered CNFH-produced fall run based upon CWT data and size distributions of fall run released from CNFH (see text).
4/ Total captured before week 13, considered in-river produced spring run.
5/ Total captured after week 12, considered CNFH produced fall run.
6/ BY 1999
7/ BY 2000

Table 5. Summary of catch and size range data for adipose-clipped, hatchery-produced chinook salmon (by run) caught by rotary screw traps in the Sacramento River near Knights Landing, 26 September 1999 - 30 September 2000.

Week	Fall run		Winter run		Late-fall run	
	Number	FL range	Number	FL range	Number	FL range
40-48	No adipose-clipped salmon were caught Week 40 through 48					
49	0	-	0	-	1	120
50	0	-	0	-	0	-
51	0	-	0	-	0	-
52	0	-	0	-	1	117
1	0	-	0	-	7	108-138
2	0	-	0	-	1	124
3	0	-	0	-	4	139-156
4	0	-	0	-	4	131-148
5	0	-	0	-	5[1/]	108-157
6	0	-	0	-	2	107-115
7	0	-	0	-	0	-
8	0	-	2	101-104	1	129
9	0	-	0	-	0	-
10	0	-	1	83	0	-
11	0	-	2	112-113	0	-
12	1	57	0	-	0	-
13	0	-	0	-	1	128
14	1	60	0	-	0	-
15	0	-	0	-	0	-
16	2	75-79	0	-	0	-
17	9	71-84	0	-	0	-
18	15	70-83	0	-	0	-
19	1	72	0	-	0	-
20-40	No adipose-clipped salmon caught after Week 19					
Total	29	57-84	5	83-113	27[2/]	107-157

1/ One fish was noted as ad-clipped, but was missing most of its head, so it could not be properly measured or checked for a tag.

2/ Seven fish were designated as winter run based on their FL, but were determined to be late fall run by their tag codes.

Table 6. Summary of catch statistics for steelhead trout caught by rotary screw trap in the Sacramento River near Knights Landing, 26 September 1999 - 30 September 2000.

Week	Catch Statistics						
	Young-of-year	Yearling (no clip)		Yearling (adipose clip)		Adult	
	Count	Count	Mean FL (mm) (range)	Count	Mean FL (mm) (range)	Count	Mean FL (mm) (range)
40-2	No steelhead caught Weeks 40 through 2						
3	0	0	-	2	221 (215-228)	0	-
4	0	0	-	4	210 (194-225)	0	-
5	0	0	-	10	217 (169-241)	0	-
6	0	0	-	4	222 (210-240)	0	-
7	0	0	-	2	215 (200-230)	1	335
8	0	1	175	0	-	0	-
9	0	0	-	0	-	1	372
10	0	0	-	2	211 (169-254)	0	-
11	0	0	-	1	236	0	-
12	0	0	-	1	247	0	-
13	0	0	-	0	-	0	-
14	0	0	-	0	-	0	-
15	0	0	-	0	-	0	-
16	0	0	-	0	-	0	-
17	0	5	219 (191-241)	2	237 (234-241)	0	-
18	0	0	-	0	-	0	-
19	0	1	228	0	-	0	-
20-40	No steelhead caught week 20 through week 40						
Total	0	7	214 (175-241)	28	220 (169-254)	2	354 (335-372)

Table 7. Summary of capture efficiency test results for chinook salmon collected by rotary screw traps in the Sacramento River near Knights Landing, 26 September 1999 - 30 September 2000.

Week	Number Marked	Number Recovered	Efficiency (%)	Week	Number Marked	Number Recovered	Efficiency (%)
40-5	No Chinook salmon marked			13	67	0	0
6	1,417	3	0.21	14	80	0	0
7	2,291	7	0.31	15	127	0	0
8	6,111	33	0.54	16	0	0	0
9	1,746	5	0.29	17	0	0	0
10	769	2	0.26	18	259	3	1.16
11	590	0	0	19-40	No Chinook salmon marked		
12	171	0	0	Total	13,628	53	0.39
				Average weekly efficiency			0.25

Table 8. Estimates (80% CI) of the number of hatchery-produced Chinook salmon and yearling steelhead trout that passed the Knights Landing monitoring site at RM 89.5 on the Sacramento River, between 26 September 1999 and 30 September 2000.

Cohort	**A** Marked caught	**B** Marked estimate (**A**/0.0025)[1/]	**C** No. planted marked	**D** Survival (**B**/**C**)	**E** No. planted unmarked	**F** No. estimated unmarked (**D*****E**)	**G** No. estimated total (**B**+**F**)
Late-Fall Run	40	16,000 (10,526-33,333)	827,259	0.019 (0.013-0.040)	0	0	16,000 (10,526-33,333)
Winter Run	6	2,400 (1,579-5,000)	30,840	0.078 (0.051-0.162)	0	0	2,400 (1,579-5,000)
Fall Run	36	14,400 (9,474-30,000)	1,115,562	0.013 (0.008-0.027)	10,733,494	138,551 (91,152-288,648)	152,951 (100,626-318,648)
Steelhead	45	18,000 (11,842-37,500)	520,201	0.035 (0.023-0.072)	0	0	18,000 (11,842-37,500)

1/ 80% CI of 0.0025 used in estimates was 0.0012-0.0038.

Table 9. Estimates of the number of in-river-produced chinook salmon and yearling steelhead trout that passed the Knights Landing monitoring site at RM 89.5 on the Sacramento River, between 26 September 1999 and 30 September 2000.

Cohort	**A** Total caught	**B** Estimated total (**A**/0.0025)[1/]	**C** Hatchery total (from Table 12)	**D** In-river total (**B-C**)
Late-fall run (1999 BY)	59	23,600 (15,526-49,167)	16,000 (10,526-33,333)	7,600 (5,000-15,834)
Late-fall run (2000 BY)	5	2,000 (1,316-4,167)	0	2,000 (1,316-4,167)
Winter run (1999 BY)	75	30,000 (19,737-62,500)	2,400 (1,579-5,000)	27,600 (18,158-57,500)
Winter run (2000 BY)	0	0	0	0
Spring run	53	21,200 (13,947-44,167)	0	21,200 (13,947-44,167)
Fall run[2/]	32,836	13,134,400 (8,641,053-27,363,333)	152,951 (100,626-318,648)	12,981,449 (8,540,427-27,044,685)
Total salmon	33,028	13,211,200 (8,691,579-27,523,333)	171,351 (112,731-356,981)	13,039,849 (8,578,848-26,896,352)
Steelhead	54	21,600 (14,211-45,000)	18,000 (11,842-37,500)	3,600 (2,369-7,500)

1/ 80% CI of 0.0025 used in estimates was 0.0012-0.0038.

2/ Includes spring-run-sized salmon collected after week 12.