CALIFORNIA DEPARTMENT OF FISH AND GAME
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Fisheries Program

TIMING, COMPOSITION, AND ABUNDANCE OF JUVENILE SALMONID EMIGRATION IN THE SACRAMENTO RIVER NEAR KNIGHTS LANDING OCTOBER 2001-JULY 2002 [1/]

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SUMMARY

Juvenile salmonids emigrating down the Sacramento River to the Sacramento-San Joaquin Delta were sampled 0.5 miles down stream of Knights Landing at river mile 89.5 (RM) from October 2001 to July 2002. Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*) were the target species. Sampling was conducted using two eight foot diameter rotary screw traps (RST).

Mean weekly flow ranged from 3,943 cubic feet per second (cfs) in week 43 (October 2001) to 25,203 cfs in week 2 (January 2002). Mean weekly water temperature ranged from a low of 46 ˚F (week 5) to a high of 74 ˚F (week 28). Water temperature steadily dropped during week 43 through week 5, and then started to rise steadily until the end of the sampling season. Mean water turbidity ranged from 6.94 NTU to 116.93 NTU.

A total of 22,812 juvenile salmon were collected in 13,004 hours of trapping (1.75 fish/hour). The total catch included 478 adipose clipped marked salmon. Fall-run salmon accounted for 94% of the total unmarked catch and 48% of the total marked catch. Late-fall-run salmon accounted for less then 1% of the total unmarked catch, while accounting for 46% of the total marked catch. Winter-run salmon accounted for 2% of the total unmarked catch, and 6% of the total marked catch. Spring-run salmon accounted for 4% of the total unmarked catch and 0% of the total marked catch. The unmarked spring-run salmon caught after week 12 are assumed to be fall-run hatchery salmon released from Coleman National Fish Hatchery and account for 69% of the total spring-run salmon catch.

The majority of in-river-produced winter-run and late-fall-run salmon were caught between week 46 and week 2. In-river fall-run and spring-run salmon catch was spread out through the whole sampling season, starting in week 48 and ending in week 26.

A total of 41 unmarked steelhead were caught between week 4 and week 24. The majority of these steelhead (70%) were caught between weeks 13 and 21. We also collected 112 marked steelhead between weeks 4 and 20. The majority of these marked steelhead (91%) were caught between weeks 4 and 10.

Estimates of the abundance of juvenile emigrating salmonids passing Knights Landing are provided based on mean weekly rotary screw trap efficiency of 0.40% (range 0.0%-1.08% ; SD = 0.37% ; 80% CI: 0.027% - 0.052% ; n= 16). The estimated number of in-river-produced salmon that passed Knights Landing was 6,400,942. This total included 20,250 late-fall-run Brood Year (BY) 2001; 250 late-fall-run BY 2002; 171,462 winter-run BY 2001; 500 winter-run BY 2002; 156,000 spring-run; and 6,052,480 fall-run. The estimated number of in-river-produced steelhead passing Knights Landing was 40,489.

The total estimate of hatchery-produced salmon passing Knights Landing was 132,308. This total was comprised of 64,000 late-fall-run BY 2001; 8,288 winter-run BY 2001; and 60,020 fall-run. The estimated number of hatchery steelhead passing Knights Landing was 29,761.

Emigrating juvenile salmonids from the upper Sacramento River have to pass by the Knights Landing sampling site to reach the Delta, until flows increase to a level were diversion above Knights Landing through the Sutter Bypass is required. Usually diversion to the Sutter Bypass occurs when flows exceed 23,000 cfs. This occurred twice during the sampling season during weeks one and two. Since the proportion of juvenile salmonids emigrating via the Sutter Bypass is unknown, the amount of salmonids emigrating to the Delta cannot be estimated by Knights Landing results alone. The time frame of emigration and abundance of juvenile salmonids emigrating towards the Delta are reflective of the Knights Landing results.

INTRODUCTION

Juvenile anadromous salmonid emigration was monitored on the Sacramento River near Knights Landing (RM 89.5) for the seventh consecutive year (Snider and Titus 1998). Monitoring was conducted to gain information about emigration timing, race and species composition, and abundance of juvenile Chinook salmon and Steelhead leaving the upper Sacramento River in route to the Sacramento-San Joaquin Delta (Delta). This sampling site provides early warning of juvenile salmonid emigration into the Delta to allow implementation of management actions necessary to protect emigrating juvenile salmonids as they pass into and through the Delta. Long term monitoring will increase understanding of juvenile salmonid emigration and allow implementation of new management practices to help protect and recover the Sacramento River anadromous salmonid populations.

The salmonid populations of the California Central Valley have been drastically reduced due to a variety of alterations to their habitat. The dams constructed on almost every major stream in the Central Valley extirpated salmonids from 90% of their historic spawning habitat. The increased need for flood protection has led to severe stream channel modification which has adversely affected spawning and rearing grounds. Decreased water quality such as increased temperature and pesticides from agriculture has also led to decreased salmonid populations. Water diversion for urban and agricultural use has led to changes in flow that sustain the remainder of the salmonids habitat.

Emigrating salmonids are in constant risk of mortality as they try to navigate the many diversions that lie between their spawning grounds and the Pacific Ocean. The most threatening of these diversions are the State Water Project's Harvey Banks Delta Pumping Plant and the Central Valley Project's Tracy Pumping Plant, which are both located in the southern part of the Delta. The information in this report is part of an ongoing effort upon the part of water developers and fishery managers to reduce the impacts of these pumping plants on the Central Valley emigrating salmonids.

Juvenile salmonids emigrating from their natal grounds in the upper Sacramento River are of special concern. The upper Sacramento River and several of its tributaries (Figure 1) provide the majority of the spawning and rearing habitat for the Central Valleys depleted salmonid populations. Winter-run Chinook salmon[1] are unique to the California's Central Valley, and their spawning and natal grounds are exclusive to the upper Sacramento River. Spring-run Chinook[2] salmon are nearly exclusive to the upper Sacramento River were small populations occur in isolated locations including Deer, Mill, and Butte Creeks (Figure 1). All late-fall-run Chinook salmon, most steelhead trout[3], and a major

[1] Listed as endangered under the California and Federal Endangered Species Acts.
[2] Listed as threatened under the California and Federal Endangered Species Acts.
[3] Listed as threatened under the Federal Endangered Species Act.

part of the natural (in-river-produced) fall-run Chinook salmon spawn and rear in the upper Sacramento River and its tributaries. To help protect and possibly increase the populations of these salmonids it is crucial to protect them as they emigrate down the Sacramento River and through the Delta to the Pacific Ocean. The ability to accurately estimate the quantities and timing of the emigrating juvenile salmonids as they enter the Delta would improve the ability to address critical water management questions. Water management in the Delta has huge effects on the survival of juvenile salmonids as they emigrate through. Therefore water diversion in the Delta is limited during times when winter-run Chinook salmon are present or emigrating through. This same management decision could be used for other emigrating salmonids of concern if there was better information about their emigration timing and abundance. The ability to more accurately predict the movement of emigrating salmonids as they reach the Delta will allow for better fishery management plans with respect to water export.

Knights Landing was chosen as a monitoring site to provide information to the fishery and water management agencies. The recommended goals for the Knights Landing monitoring site are:

1. Provide early warning of emigrating listed salmonids moving into the Delta, so that the Central Valley and State Water projects could modify their water export techniques (close the Delta Cross Channel gate).
2. Provide a monitoring station between Glenn-Colusa Irrigation District (GCID) and the Delta.
3. Follow movements of emigrating salmonids in response to environmental conditions.
4. Estimate emigrating salmonids entering the lower Sacramento River and the Delta.

The monitoring sites already present on the Sacramento River did not have the ability to accurately monitor the timing and abundance of salmonids from the upper Sacramento River emigrating into the Delta. The GCID monitoring site is too far upstream to accurately measure the timing of salmonids entering the Delta. The monitoring sites below Knights Landing are too far down stream to accurately distinguish upper Sacramento River salmonids from the Feather or American river salmonids.

METHODS

Juvenile salmonids emigrating down the Sacramento River to the Delta were sampled one half mile downstream of the town of Knights Landing (RM 89.5) from October 2001 to July 2002. Sampling was conducted using two eight foot rotary screw traps. The rotary screw traps were lashed together and located on the outside of a wide bend in the river approximately 100 feet from the east bank per Snider and Titus (2000).

Data was collected from each trap servicing and included total time fished since last servicing; current velocity in front of the trap; average cone revolutions per minute; and the total number of cone revolutions since last servicing. All salmonids were identified and were counted by race[4]. All spring, winter, and late-fall-run salmon were measured by fork length and weighed in grams. The first 150 fall-run fish (randomly sampled) were measured and weighed during each trap servicing (no fall-run salmon under 40 mm were weighed) and the remaining fall-run salmon were tallied. All juvenile steelhead trout were counted and measured. Each trap was serviced up to two times per day.

The data was reported on a weekly time scale to help smooth out daily variation in effort and trap efficiency while retaining detail to analyze for trends in timing and abundance per Snider and Titus (2000).

Flow at Knights Landing was obtained from records of the USGS gauging station at Wilkins Slough. Water transparency was measured daily using a secchi disk per standard methods (Orth 1983) and taking water samples which were later analyzed in the lab for water turbidity (NTU). Water temperature was measured using electronically recording thermographs and a hand held thermometer.

Trap efficiency was evaluated using a mark-and-recapture technique. All salmon except yolk sac fry were marked using Bismark Brown Y stain (e.g., Deacon 1961) then released one half mile upstream of the traps. Staining and release protocols were the same as Snider and Titus (2000). Mean weekly mark recapture percentages were used to calculate trap efficiency.

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

[4] Salmon race was determined using size-at-time criteria developed by Frank Fisher (California Department of Fish and Game, Northern California – North Coast Region, unpublished data).

RESULTS AND DISCUSSION

General Sampling Conditions

Mean weekly flow ranged from 3,943 cfs in week 43 to 25,203 cfs in week 2. In weeks 1 and 2 flow was higher then 23,000 cfs (Table 1) and during this time period excess water was diverted into the Sutter Bypass via the Tisdale Weir. The total flow upstream of the Tisdale Weir could have been significantly higher than what was recorded at the Wilkins Slough monitoring station, which could have affected juvenile salmonid emigration.

Mean weekly water temperature ranged from a low of 46˚F (week 5) to a high of 74˚F (week 28). Water temperature steadily dropped during week 43 through week 5, and then started to steadily rise the rest of the sampling season (Table 1). Mean weekly temperature and mean weekly flow showed a significant linear regression ($R^2 = 35.2$ with a p value < 0.001, see figure 2). As flow increased water temperature decreased (Figure 2). Roughly 35% of the change in temperature can be accounted for by change in water flow.

Mean water turbidity ranged from 6.94 NTU to 116.93 NTU (Table 1). Mean weekly water turbidity and mean weekly flow also showed a significant linear regression ($R^2 = 71.3$ with a p value < 0.001, see figure 3). As flow increased water turbidity increased (Figure 3). Approximately 70% of the change in turbidity can be accounted for by the change in water flow.

Table 1. Summary of mean weekly sampling conditions in the Sacramento River near Knights Landing during the juvenile salmonid emigration, 21 October 2001-July 13, 2002.

Week	Beginning date	Mean flows (cfs)	Mean water temperature (°F)	Mean turbidity (NTU)
43	21 Oct 2001	3,943	61	8.14
44	28 Oct 2001	4,587	60	
45	4 Nov 2001	4,736	60	7.33
46	11 Nov 2001	6,098	59	16.53
47	18 Nov 2001	6,652	58	16.83
48	25 Nov 2001	11,821	51	37.40
49	2 Dec 2001	18,089	50	28.35
50	9 Dec 2001	11,693	48	20.84
51	16 Dec 2001	16,637	48	31.57
52	23 Dec 2001	18,834	49	50.73
1	30 Dec 2001	24,849	53	79.65
2	6 Jan 2002	25,203	51	116.93
3	13 Jan 2002	17,632	48	33.16
4	20 Jan 2002	12,584	47	19.73
5	27 Jan 2002	10,822	46	13.93
6	3 Feb 2002	9,435	49	12.28
7	10 Feb 2002	9,252	51	9.97
8	17 Feb 2002	13,387	54	38.51
9	24 Feb 2002	12,469	55	24.40
10	3 Mar 2002	11,412	54	10.39
11	10 Mar 2002	13,221	54	12.87
12	17 Mar 2002	10,043	54	7.40
13	24 Mar 2002	9,583	55	8.11
14	31 Mar 2002	7,720	60	6.94
15	7 Apr 2002	6,823	62	7.49
16	14 Apr 2002	5,731	59	9.02
17	21 Apr 2002	4,416	64	14.03
18	28 Apr 2002	5,234	62	13.82
19	5 May 2002	4,974	65	14.83
20	12 May 2002	5,716	67	10.07
21	19 May 2002	9,064	65	23.33
22	26 May 2002	7,950	70	10.05
23	2 June 2002	6,518	72	10.58
24	9 June 2002	6,013	72	
25	16 June 2002	7,550	72	9.57
26	23 June 2002	8,587	70	9.52
27	30 June 2002	8,306	74	7.31
28	7 July 2002	8,097	74	8.57

Rotary Screw Trap Results

Chinook Salmon Emigration

Week 46 was the first period when juvenile salmon were captured in the RST (Table 2), which is the typical start of the primary migration period (Snider and Titus 1998). Salmon were caught on a consistent basis throughout the monitoring season until week 24 (Table 4). Only three salmon were captured in the traps after week 24: one in week 25, one in week 26, and one in week 28. 56% of the total catch for the year was caught between weeks 52 and 11.

In-river-produced salmon were primarily caught during weeks 48 through 12. Week 12 was the start of hatchery-produced salmon captured from CNFH that extended through week 17 (Table 3). During typical years CNFH released over two million salmon. During the 2002 sampling season CNFH released over three million juvenile salmon. 68% of the salmon released from CNFH were fall-run, 23% late-fall-run, and 8% winter-run (Table 3).

Size of salmon captured by the RSTs ranged from 29 to 208 mm FL (Table 2). Large salmon (>90 mm FL) were captured during every week between week 48 and week 21. Recently emerged-sized salmon (<45 mm FL) were captured in weeks 47 through week 14.

Of the 478 marked salmon collected, 355 of the salmon were accurately raced by size designation when compared to the CWTs. Three of the 478 collected salmon were not adipose clipped. Seven of the collected salmon did not have CWT and six tags were lost during extraction or CWT reading.

Table 2. Weekly summary of catch statistics for Chinook Salmon caught by the RSTs in the Sacramento River near Knights Landing, 21 October 2001 – 13 July 2002.

Week	Effort (h)	Total catch	Catch/h	Size statistics (FL in mm)			
				Mean	Minimum	Maximum	Standard deviation
43	484.25	0	0.00				
44	426	0	0.00				
45	338.75	0	0.00				
46	429.25	2	0.00	72.0	71.0	73.0	1.41
47	383	16	0.04	63.1	44.0	88.0	9.84
48	240.25	247	0.42	58.9	31.0	115.0	16.84
49	18.25	32	1.75	52.0	32.0	113.0	22.87
50	276.75	37	0.13	57.2	32.0	118.0	23.37
51	208.75	110	0.52	50.5	32.0	163.0	24.56
52	223.5	651	2.91	38.3	30.0	154.0	10.26
1	275.5	991	3.83	38.3	30.0	124.0	9.13
2	243	2,417	9.65	43.4	29.0	184.0	23.20
3	326.25	1,516	4.39	44.9	30.0	208.0	26.35
4	334	292	0.82	43.5	31.0	142.0	22.22
5	334.5	243	0.71	40.2	31.0	131.0	12.67
6	335	334	0.95	43.3	31.0	146.0	15.03
7	332.25	347	1.03	42.3	31.0	127.0	10.16
8	283	3,247	11.34	42.0	32.0	127.0	13.26
9	324.75	2,072	6.32	41.1	32.0	131.0	9.38
10	332.5	97	0.29	43.6	35.0	108.0	13.15
11	288.75	387	1.33	42.8	32.0	104.0	9.79
12	331.5	61	0.18	47.1	36.0	91.0	11.94
13	334.75	73	0.22	62.8	36.0	97.0	17.98
14	329.75	71	0.21	69.4	40.0	118.0	16.47
15	329.75	50	0.15	71.8	53.0	136.0	13.67
16	335	95	0.28	74.1	47.0	94.0	10.28
17	322.75	5,761	17.54	80.6	61.0	120.0	4.75
18	324.75	2,571	7.76	80.0	60.0	95.0	5.20
19	326.25	814	2.38	79.8	59.0	100.0	5.67
20	334.25	133	0.35	80.5	56.0	97.0	6.18
21	261.25	105	0.39	75.8	60.0	96.0	7.76
22	373.25	17	0.05	75.2	67.0	80.0	4.71
23	190.75	13	0.07	70.6	54.0	79.0	7.54
24	238.5	7	0.00	70.0	58.0	79.0	8.12
25	385	1	0.01	67.0	67.0	67.0	
26	287.5	1	0.00	83.0	83.0	83.0	
27	384	0	0.00				
28	477	1	0.00	55.0	55.0	55.0	
Total	13,004	22,812	1.75				

Late-Fall-Run Chinook Salmon

All late-fall-run salmon released from CNFH were marked. Therefore we considered all unmarked late-fall-run salmon to be in-river-produced based on size criteria (F. Fisher and S. Greene, unpublished data). The first in-river-produced late-fall-run salmon was caught in week 47. A total of 24 late-fall-run salmon were captured from BY 2000, and one from BY 2001. BY 2000 late-fall-run salmon were caught between the weeks of 47 and 4. The only late-fall-run BY 2001 salmon was caught in week 28. The highest catch of late-fall-run salmon occurred between the weeks of 48 and 51 (n= 20). The BY 2000 late-fall-run salmon ranged from 88 to 208 mm FL. The BY 2001 late-fall-run salmon was 55 mm FL (Table 4).

A total of 218 marked late-fall-run salmon were collected. These salmon were collected between the weeks 48 and 14. All but three hatchery-produced late-fall-run salmon were collected between week 51 through week 9 (Table 5). Two late-fall-run salmon were caught prior to this period (week 48) and one after this period (week 14).
Of the total 218 marked late-fall-run salmon 89 were designated winter-run by size (this data error was fixed in the office through reading CWTs).

A total of 700,121 late-fall-run hatchery-produced salmon at CNFH were marked, tagged with CWTs and released into Battle Creek 180 miles upstream of the Knights Landing monitoring site. Three release groups containing 11 tag numbers were made over a period of 9 weeks (week 46 through week 2) (Table 3). We captured 3 (<.01%) from the first release, 10 (0.01%) from the second release, and 208 (0.04%) from the third release. The 3 salmon from the first release were captured 13 to 58 days after being released. The salmon from the second release were captured 8 to 56 days later. The salmon from the third release group were captured 3 to 46 days later.

Winter-Run Chinook Salmon

Unlike the late-fall-run salmon from CNFH, not all of the winter-run salmon from Livingston Stone National Fish Hatchery (LSNFH) were marked. Based upon the survival percentage of the hatchery-produced salmon (Table 8), 38 of the captured non-marked salmon were probably hatchery-produced salmon from BY 2000. A total of 435 in-river-produced winter-run BY 2000 salmon were captured during weeks 46 to 17. 91% of the BY 2000 winter-run salmon were captured between week 47 and week 3 (the end of November through mid January). Three BY 2000 winter-run salmon (by size designation) were captured during week 17. These three salmon could very well be large BY 2001 winter-run salmon. Two BY 2001 winter-run salmon (by size designation) were caught in week 15. The BY 2000 winter-run salmon ranged from 71 to 124 mm FL and the BY 2001 winter-run salmon ranged from 44 to 75 mm FL (Table 4).

A total of 31 marked winter-run salmon were collected. These salmon were collected between the weeks 6 and 14. The quantity of marked winter-run salmon captured was highest during weeks 6 to 8 and then tapered off to zero after week 14 (Table 5). Of the total 31 marked winter-run salmon, 19 were spring-run salmon by size designation (this error was corrected in the office by reading CWT data).

A total of 243,539 winter-run salmon marked and CWT were released into the upper Sacramento River 209 RM above the Knights Landing monitoring site. 31 (0.01%) of these salmon were captured during week 1 through 8. These salmon were captured 6 to 60 days after being released.

<u>Spring-Run Chinook Salmon</u>

No hatchery-reared spring-run salmon were released into the Sacramento River upstream of Knights Landing. A total of 892 unmarked spring-run salmon were captured during weeks 48 to 20. All unmarked spring-run salmon were captured between weeks 48 and 1. Beginning in week 13, all spring-run salmon (based on size) were considered fall-run hatchery-produced salmon (Tables 4 & 5). Of the total unmarked spring-run captured 612 are assumed to be unmarked hatchery-produced fall-run salmon from CNFH. The in-river-produced spring-run salmon were captured betweens weeks 49 and 12. The assumed fall-run hatchery-produced salmon (spring-run based on size) were captured between the weeks of 13 and 20. The majority (79%) of these hatchery-produced fall-run (spring-run based on size) were captured in week 17. The in-river-produced spring-run salmon ranged from 31 to 91 mm FL and the assumed hatchery-produced fall-run salmon (spring-run by size) ranged from 74 to 100 mm FL (Table 4).

<u>Fall-Run Chinook Salmon</u>

Fall-run salmon clearly dominated the catch of in-river-produced juvenile salmon in the RSTs. A total of 20,987 fall-run salmon were captured and accounted for 93% of the total in-river-produced catch. Fall-run salmon were collected between weeks 49 and 26 (Table 4). Salmon captured prior to week 16 can be assumed in-river-produced with confidence. The salmon captured prior to week 16 show a significant linear regression with flow (p value = 0.01 and R^2 = 25.57, see figure 4), as flow increased catch increased. Roughly 25% of the weekly catch can be explained by flow.

A total of 1,256 unmarked fall-run salmon were released upstream of the sampling site prior to week 16. Using survival calculations an estimate of 38 unmarked hatchery-produced fall-run salmon were captured. A total of 7,728 unmarked hatchery-produced fall-run salmon were released in week 16 and 17. Using survival calculations an estimate of 232 unmarked hatchery-produced fall-run salmon were captured in the traps during this time period (Table 8).

Over two million hatchery-produced fall-run salmon from CNFH were released into the upper Sacramento River above Knights Landing between week 8 and week 17 (Table 3). 2,893 of these salmon were not marked and 17,358 were ad-clipped only, the rest of the released fall-run salmon were ad-clipped and marked with CWTs. The majority of these salmon were released in weeks 16 and 17 from CNFH (98%). Of the 229 marked fall-run salmon collected 18 of them were race designated by size to be spring-run, which was later corrected when CWT data was read.

A total of 2,056,214 marked and CWT fall-run salmon were released 154 to 182 RM upstream of the Knights Landing monitoring site between weeks 8 and 17. The fall-run salmon releases were in 5 groups and contained 28 distinct CWT numbers. Of this total release 229 marked and CWT fall-run salmon were captured at the Knights Landing monitoring site. 31 (0.06%) fall-run salmon from the first release were captured 3 to 10 days later. Seven (0.01%) fall-run salmon from the second release were captured 7 to 39 days later. 118 (0.01%) fall-run salmon from the third release were captured 6 to 20 days later. Six (<0.01) fall-run salmon from the fourth release were captured 6 to 17 days later. 79 (<0.01) fall-run salmon were captured from the final release 5 to 27 days later.

Unmarked fall-run salmon ranged in size from 29 to 96 mm FL. Recently emerged fall-run salmon (<45 mm FL) comprised 65% of the catch. Recently emerged fall-run salmon were caught during week 49 through 14. Smolt-sized fall-run (>70 mm FL) accounted for over 27% of the total catch and were caught during week 14 through 26.

Table 3. Summary of juvenile Chinook salmon and steelhead produced at Coleman National Fish Hatchery or Livingston Stone National Fish Hatchery and released in 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.

Race (for Chinook salmon)	Week of release (date)	Number marked w/ CWT	Number marked w/o CWT	Number unmarked	Release location (RM)[2/]
		Chinook salmon			
Late-fall-run	46 (14 Nov 2001)	88,039	0	0	BC (271.5)
Late-fall-run	50 (12 Dec 2001)	73,856	746	0	BC (271.5)
Late-fall-run	2 (Jan 8 2002)	538,226	2,143	0	BC (271.5)
Winter-run [1/]	5 (Jan 30 2002)	243,539	9,025	1,256	LRP (298.5)
Fall-run	8 (Feb 19 2002)	49,373	501	251	RBDD (243)
Fall-run	11 (Mar 11 2002)	48,956	251	1,004	RBDD (243)
Fall-run	16 (18 Apr 2002)	977,928	9,110	4,108	CNFH (271.5)
Fall-run	17 (24 Apr 2002)	78,898	317	0	CNFH (271.5)
Fall-run	17 (25 Apr 2002)	901,059	7,179	3,621	CNFH (271.5)
		Steelhead			
	1 (11 Jan 2002)	0	156,779	0	BB (257.5)
	3 (14 Jan 2002)	0	55,928	0	BB (257.5)
	3 (15 Jan 2002)	111,289	47,236	232	BB (257.5)
	3 (18 Jan 2002)	0	124,111	0	BB (257.5)
	4 (24 Jan 2002)	32,880	3,857	0	BB (257.5)
	4 (25 Jan 2002)	44,192	43,908	0	BB (257.5)

1/ All winter-run Chinook salmon were raised at Livingston Stone National Fish Hatchery.
2/ BC = Battle Creek; BB = Bend Bridge; CNFH = Coleman National Fish Hatchery; LRP = Lake Redding Park; RBDD = Red Bluff Diversion Dam.

Table 4. Weekly summary of catch and size (mm) range data for in-river-produced [1/] Chinook salmon (by run) caught by rotary screw traps in the in the Sacramento River near Knights Landing, 21 October 2001-July 13, 2002.

Week	Fall-run [2/]		Spring-run		Winter-run		Late fall-run	
	Number	FL range	Number	FL range	Number	FL range	Number	FL range
43-45	0		0		0		0	
46	0		0		2	71-73	0	
47	0		0		15	44-75	1	88-88
48	0		53	31-39	184	45-88	8	88-115
49	3	32-33	15	34-44	11	47-71	3	105-113
50	8	32-34	9	35-40	17	54-89	3	97-118
51	50	32-37	24	37-41	29	50-98	6	104-126
52	561	30-39	57	39-52	31	53-102	0	
1	932	30-40	20	40-49	36	55-106	1	124-124
2	2,289	29-43	11	43-58	44	61-108	0	
3	1,393	30-44	12	44-53	31	61-120	1	208-208
4	268	31-46	3	52-56	1	73-73	1	140-140
5	234	31-48	3	57-65	1	70-70	0	
6	313	31-50	3	53-56	1	124-124	0	
7	325	31-53	13	53-71	4	80-96	0	
8	3,183	32-56	20	55-75	7	82-119	0	
9	2,026	32-59	20	59-77	7	80-120	0	
10	90	35-54	2	62-63	4	86-108	0	
11	370	32-64	12	66-81	2	87-104	0	
12	57	36-62	3	69-91	0		0	
13	**49**	**36-66**	**23**	**75-92**	0		0	
14	**43**	**40-75**	**25**	**74-97**	0		0	
15	**40**	**53-76**	**8**	**79-87**	2	44-75	0	
16	**70**	**47-82**	**25**	**81-91**	0		0	
17	**5,173**	**61-92**	**486**	**84-97**	3	116-120	0	
18	**2,487**	**60-92**	**34**	**88-95**	0		0	
19	**765**	**59-93**	**10**	**92-100**	0		0	
20	**117**	**56-94**	**1**	**97-97**	0		0	
21	102	60-96	0		0		0	
22	17	67-80	0		0		0	
23	13	54-79	0		0		0	
24	7	58-79	0		0		0	
25	1	67-67	0		0		0	
26	1	83-83	0		0		0	
27	0		0		0		0	
28	0		0		0		1	55-55
Total	20,987	29-96	892 [3/] 612 [4/]	31-91 74-100	435 [5/] 2 [6/]	71-124 44-75	24 [5/] 1 [6/]	88-208 55

1/ Unmarked salmon were considered in-river-produced salmon except as noted below.
2/ A large portion of the fall-run salmon listed in this table were likely of hatchery origin since in-river and hatchery-produced fall-run salmon could not be distinguished (see text).
3/ All spring-run sized salmon collected after week 12 (bold area) were considered fall-run salmon based upon CWT data and size distribution of fall-run released from CNFH (see text).
4/ Total captured after week 12, considered CNFH-produced fall-run salmon.
5/ BY 2001
6/ BY 2002

Table 5. Weekly summary of catch and size (mm) range data for adipose-clipped Chinook salmon (by run) caught by rotary screw trap in the in the Sacramento River near Knights Landing, 21 October 2001-July 13, 2002.

Week	**Fall-run**		**Winter-run**		**Late fall-run**	
	Number	FL range	Number	FL range	Number	FL range
43-47	0		0		0	
48	0		0		2	101-109
49	0		0		0	
50	0		0		0	
51	0		0		1	163-163
52	0		0		2	133-154
1	0		0		2	91-108
2	0		0		73	100-184
3	0		0		79	90-179
4	0		0		19	105-142
5	0		0		5	105-142
6	0		8	61-93	9	105-146
7	0		3	64-84	2	98-127
8	12	52-59	8	70-90	17	87-127
9	7	54-61	6	65-85	6	111-131
10	0		1	82-82	0	
11	0		3	85-103	0	
12	1	61-61	0		0	
13	0		1	94-94	0	
14	1	72-72	1	95-95	1	118-118
15	0		0		0	
16	2	82-85	0		0	
17	99	72-95	0		0	
18	50	68-90	0		0	
19	39	72-90	0		0	
20	15	74-88	0		0	
21	3	79-86	0		0	
22-28	0		0		0	
Total	229	52-95	31	61-103	218	87-184

Steelhead Trout Emigration

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

Young-of-the-year Steelhead

We collected 3 unmarked young-of-the-year steelhead (93, 50, and 49 mm FL), one during week 4 and two during week 17 respectively (Table 6).

Yearling Steelhead

We collected 33 unmarked yearling steelhead between week 3 and 23. Roughly half (48%) of the yearling steelhead were collected between weeks 17 and 19. The majority (80%) of the total catch occurred after week 12. The unmarked yearling steelhead ranged from 164 to 287 mm FL (Table 6).

A total of 620,412 hatchery-raised yearling steelhead were released at Bend Bridge (RM 257.5) during weeks one, three, and four. Of the total steelhead planted all were marked except 232. Roughly one third (188,361) of these steelhead were ad-clipped and had CWTs, while 431,819 of the total released steelhead were ad-clipped only (Table 3). We collected 112 (~0.02%) marked yearling steelhead from week 4 through 20. Sixty six percent of the marked yearling steelhead collected were in week 4 through 6. The marked yearling steelhead ranged from 170 to 274 mm FL (Table 6).

Adult Steelhead

Five adult-steelhead were collected: one each in week 2 (370 mm FL); week 4 (385 mm FL); week 9 (315 mm FL); week 14 (375 mm FL); week 19 (435 mm FL). These steelhead were likely two years or older smolts produced in-river. Scale analysis will provide further age-size information (Table 6).

Table 6. Weekly summary of catch statistics for steelhead trout caught by rotary screw trap in the in the Sacramento River near Knights Landing, 21 October 2001 – July 13, 2002.

Week	Catch statistics							
	Young-of-year		Yearling (no clip)		Yearling (adipose clip)		Adult	
	Number	Mean FL (mm) (range)	Number	Mean FL (mm) (range)	Number	Mean FL (mm) (range)	Number	Mean FL (mm) (range)
43-52								
1								
2							1	370
3			1	267				
4	1	93	2	228 (210-245)	23	208 (176-235)	1	385
5			2	232 (196-268)	28	213 (170-267)		
6					23	214 (193-241)		
7					5	208 (194-224)		
8					11	206 (172-245)		
9			1	164	11	201 (179-227)	1	315
10					1	184		
11								
12								
13			1	201	1	221		
14			3	191 (169-203)	2	210	1	375
15			1	211				
16			2	243 (238-248)	1	236		
17	2	50 (49-50)	5	213 (201-230)	3	237 (221-269)		
18			5	231 (193-287)	2	266 (257-274)		
19			6	220 (188-244)			1	435
20			2	208 (204-211)	1	235		
21			1	198				
22								
23			1	247				
24								
25								
26								
27								
28								
Total	3	64 (49-93)	33	219 (164-287)	112	214 (170-274)	5	376 (315-435)

Rotary Screw Trap Gear Efficiency Using Mark-Recapture

Salmon were marked for efficiency evaluations beginning in week 48 (fourth week of November 2001). A total of 7,496 Chinook salmon were marked from week 48 through week 20. A total of 45 (0.60%) BBY marked salmon were recaptured. The percent recaptured by week ranged from 0% to 1.08%. The mean weekly trap efficiency during the 16 week period was 0.40% (SD = 0.37%) (Table 7).

For comparison, mean ± SD RST efficiency on other large Central Valley rivers was: 0.81% ± 0.89% on the upper Sacramento River at Balls Ferry (RM 278) during 1997–1998 (California Department of Fish and Game 1999); 0.80% (range = 0.39%–1.75%) at Thermalito and 0.20% (range = 0.00%–0.53%) at Live Oak on the Feather River during 1997–1998 (California Department of Water Resources 1999); and 0.75% ± 0.70% at Watt Avenue on the lower American River during 1996–1997 (Snider and Titus 2000a). Mean trap efficiency at Knights Landing was within the low ranges of RST efficiencies seen on other large Central Valley rivers.

The size distributions of marked and recaptured salmon were compared for size-selectivity by the RSTs. Overall marked salmon averaged 53.5 mm FL (+/- 22.7 mm) while the recaptured salmon averaged 47.7 mm FL (+/- 19.93 mm). The range of marked salmon was 29 to 208 mm FL while the size range of recaptured salmon was only 32 to 89 mm FL.

Similar to previous years there were no significant correlations between weekly trap effiency and: the number of salmon marked per week; number of salmon caught per week; mean weekly water transparency; mean weekly water temperature; or mean weekly flow. We have found no consistent relationship between trap efficiency and these variables in previous years (Snider and Titus 2000).

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 weekly trap efficiency estimates (Snider and Titus 2000).

Table 7. Summary of capture efficiency test results for Chinook salmon collected by rotary screw traps in the Sacramento River near Knights Landing, 21 October 2001-July 13, 2002			
	NUMBER MARKED	**NUMBER RECOVERED**	**EFFICIENCY (%)**
48	164	0	0.00
52	168	1	0.60
1	173	1	0.58
2	386	0	0.00
4	463	5	1.08
5	128	0	0.00
6	207	1	0.48
7	317	1	0.32
8	263	1	0.38
9	2,963	24	0.81
10	205	0	0.00
11	110	1	0.91
12	112	0	0.00
18	685	5	0.73
19	1,045	5	0.48
20	107	0	0.00
Total	**7,496**	**45**	**0.60** **Mean weekly (0.40)**

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 Sacramento River and Delta. Mean weekly trap efficiency (0.0040) and associated 80% confidence interval (0.0027–0.0052) were used to estimate the abundance of each salmon run (fall, spring, winter, late-fall) and steelhead. Estimates of hatchery-produced juveniles were made only for groups containing marked salmonids.

In order to estimate the number of salmonids that passed Knights Landing during the entire emigration period, including times when trapping effort was less than 100%, we expanded the total catch of each species and race to represent 100% trap 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. For example if the traps effort was only 200 hours for the week and the traps captured 100 salmonids, you would take [100/(200/336)] to find 100% trap effort (336 hours/week). This calculation would expand your catch from 100 to 168 salmonids to show 100% trap effort. These numbers were used in the calculation of the total estimates (Tables 8 and 9).

The estimated number of marked and unmarked hatchery-produced salmonids was determined (Table 8). Estimated survival to Knights Landing of hatchery salmonids by run/species ranged from 3% to 9%.

In-river-produced salmonids were estimated by subtracting the estimated hatchery-produced salmonids passing Knights Landing (results from Table 8), by cohort, from the estimated total abundance of each cohort moving past the monitoring site (Table 9). Overall, an estimated 6.4 million Chinook salmon (80% CI, 4.8 million–9.5 million) emigrated past Knights Landing into the lower Sacramento River and Delta. About 90% of those were estimated to have been produced in-river. An estimated 20,968 yearling steelhead (80% CI, ~16,500–28,900) emigrated past Knights Landing. In contrast to salmon, only 35% of the steelhead were estimated to have been produced in-river.

Emigration from the upper Sacramento River system to the Delta is exclusively through Knights Landing until increased flow requires diversion through the Sutter Bypass upstream of Knights Landing. When flows exceed 23,000 cfs diversion typically occurs through the Tisdale Weir. Flows only exceeded 23,000 cfs during week 1 and 2. Since the proportion of juvenile salmonids that emigrate through the bypass is unknown, the total abundance of salmonids emigrating to the Delta cannot be estimated with Knights Landing RST results alone. The temporal distribution and relative abundances migrating toward the Delta are reflected in the Knights Landing results.

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, 21 October 2001 – July 13, 2002.

Cohort	A Marked caught [2/]	B Marked estimate (A/0.0040)	C No. planted marked	D Survival percentage (B/C)*	E No. planted unmarked	F No. estimated unmarked (D*E)	G No. estimated hatchery total (B+F)
Late-fall-run	256	64,000 (49,231-94,815) [1/]	703,010	0.09	0	0	64,000 (49,231-94,815) [1/]
Winter-run	33	8,250 (6,346-12,222)	252,564	0.03	1,256	38	8,299 (6,387-12,263)
Fall-run	239	59,750 (45,962-88,519)	2,073,572	0.03	8,984	270	60,020 (46,221-88,778)
Steelhead	119	29,750 (22,885-44,074)	620,180	0.05	232	11	29,761 (22,896-44,085)

1/ 80% CI of 0.0040 used in estimates was 0.0027–0.0052.
2/ Marked caught data is extrapolated to show 100% trap efficiency

Table 9. Estimates (80% CI) 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, 21 October 2001 – July 13, 2002.

Cohort	A Total Caught [3/]	B Estimated Total (A / 0.0040) [1/]	C Hatchery total (from Table 9)	D In-river-produced total (B-C)
Late-fall-run (BY 2001)	337	84,250 (64,808-124,815) [2/]	64,000	20,250 (808-60,815)
Late-fall-run (BY 2002)	1	250 (192-370)	0	250 (192-370)
Winter-run (BY 2001)	719	179,750 (138,269-266,296)	8,288	171,462 (129,978-258,005)
Winter-run (BY 2002)	2	500 (385-741)	0	500 (385-741)
Spring-run	624	156,000 (120,000-231,111)	0	156,000 (120,000-231,111)
Fall-run [1/]	24,450	6,112,500 (4,701,923-9,055,556)	60,020	6,052,480 (4,641,914-8,995,547)
Total Salmon	26,133	6,533,250 (5,025,577-9,678,889)	**132,300**	**6,400,942** (4,893,277-9,546,589)
Steelhead	281	70,250 (54,039-104,074)	29,761	40,489 (24,278-74,313)

1/ Includes spring-run-sized salmon collected after week 12.
2/ 80% CI of 0.0040 used in estimates was 0.0027–0.0052.
3/ Total caught is extrapolated to show 100% trap efficiency.

ACKNOWLEDGMENTS

The format and background information within this report is based on the report written by Snider and Titus titled: TIMING, COMPOSITION, AND ABUNDANCE OF JUVENILE ANADROMOUS SALMONID EMIGRATION IN THE SACRAMENTO RIVER NEAR KNIGHTS LANDING OCTOBER 1998 - SEPTEMBER 1999.

The Knights Landing monitoring project is part of the Interagency Ecological Program (IEP) Salmonid Project Work Team's (SPWT) juvenile salmonid monitoring program. It was partially funded by the California Department of Water Resources (DWR) as part of DWR's contribution to the IEP. Many of the agencies and private entities involved in management activities within the Sacramento-San Joaquin Delta and its tributaries are represented on the SPWT, including the National Marine Fisheries Service, U. S. Fish and Wildlife Service, California Department of Water Resources, California Department of Fish and Game, State Water Contractors, and Metropolitan Water District.

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FIGURES

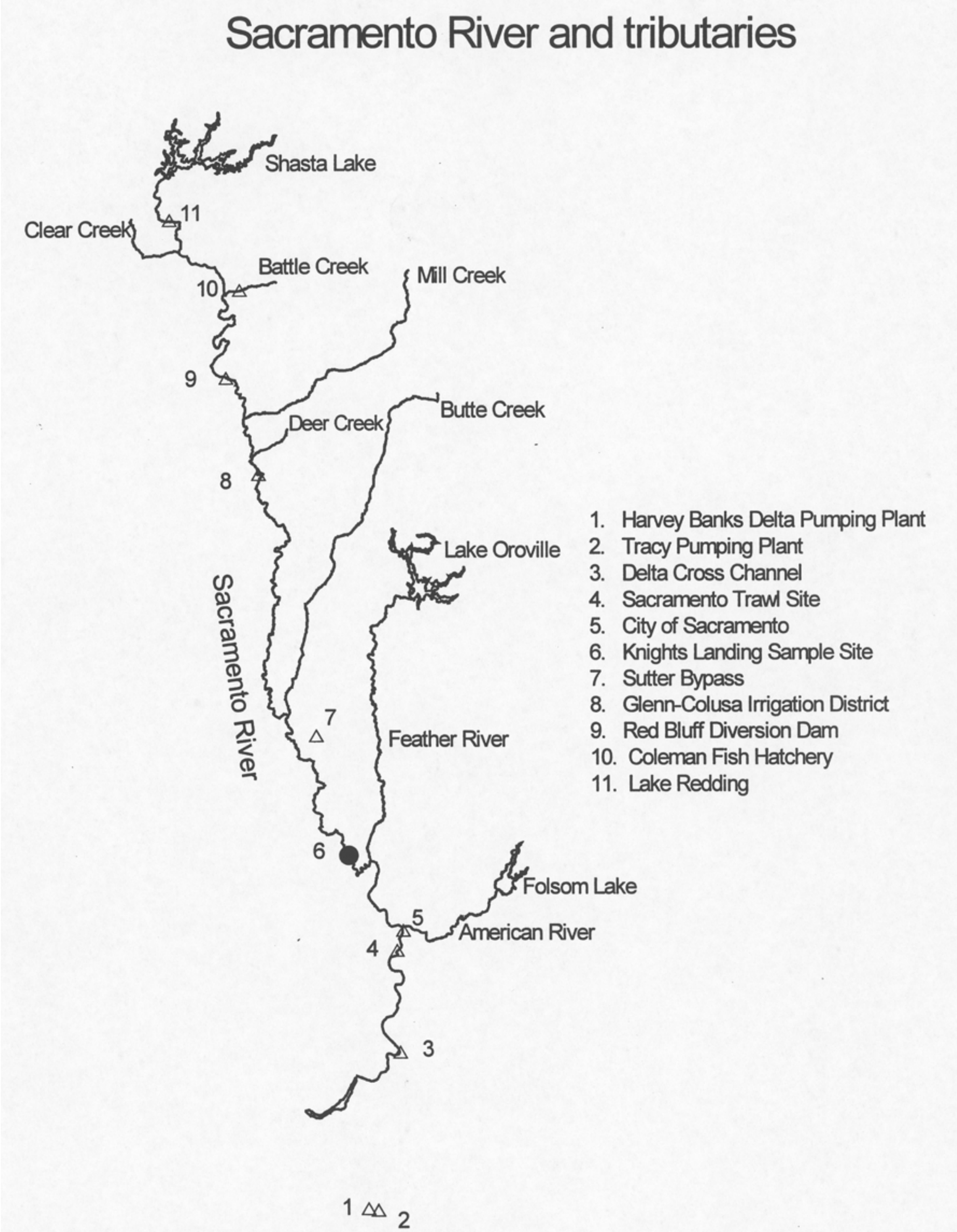
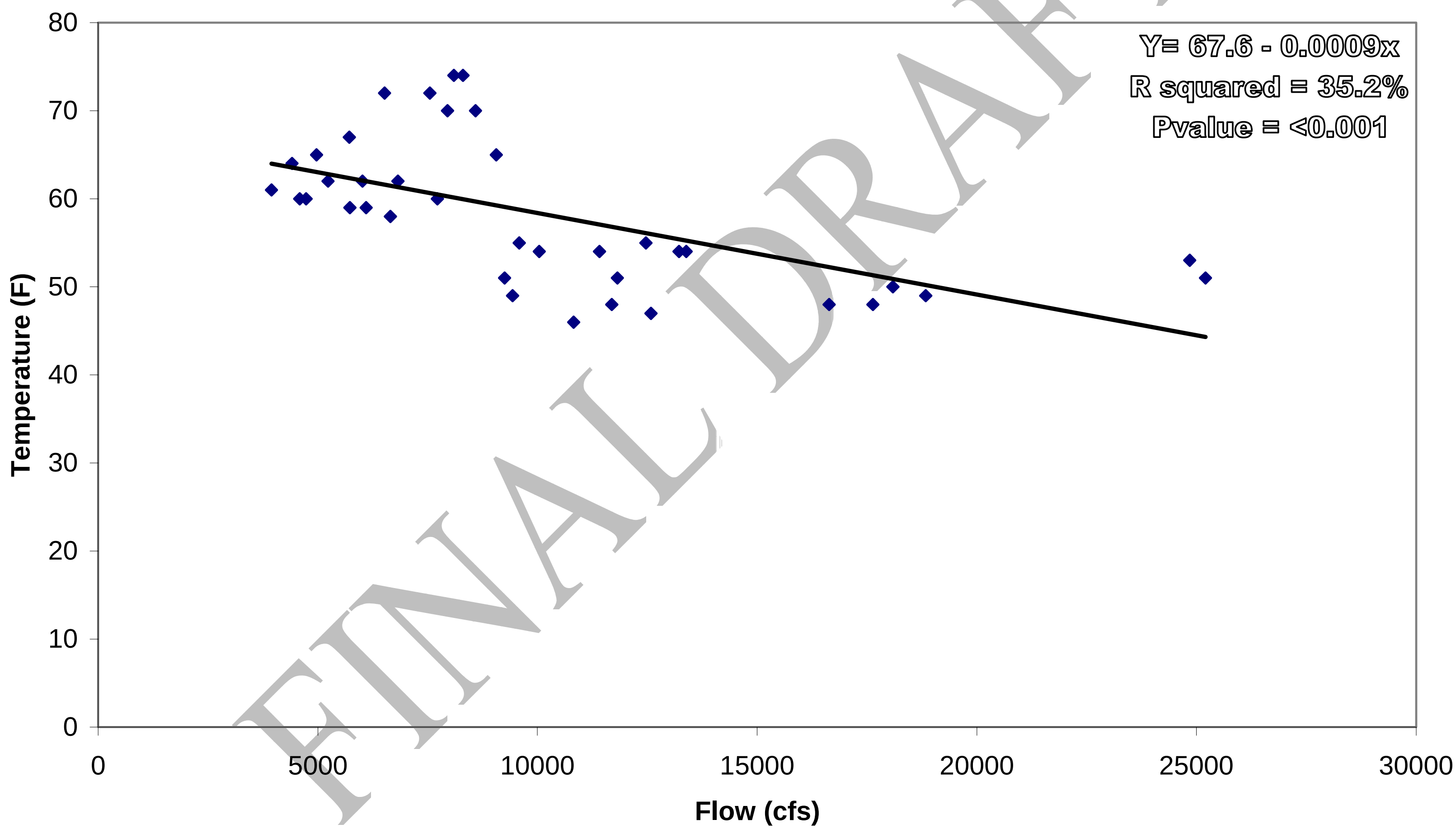


Figure 1. Relative location of Knights Landing monitoring site in the upper Sacramento River

Figure 2:
Comparision of flow and water temperature



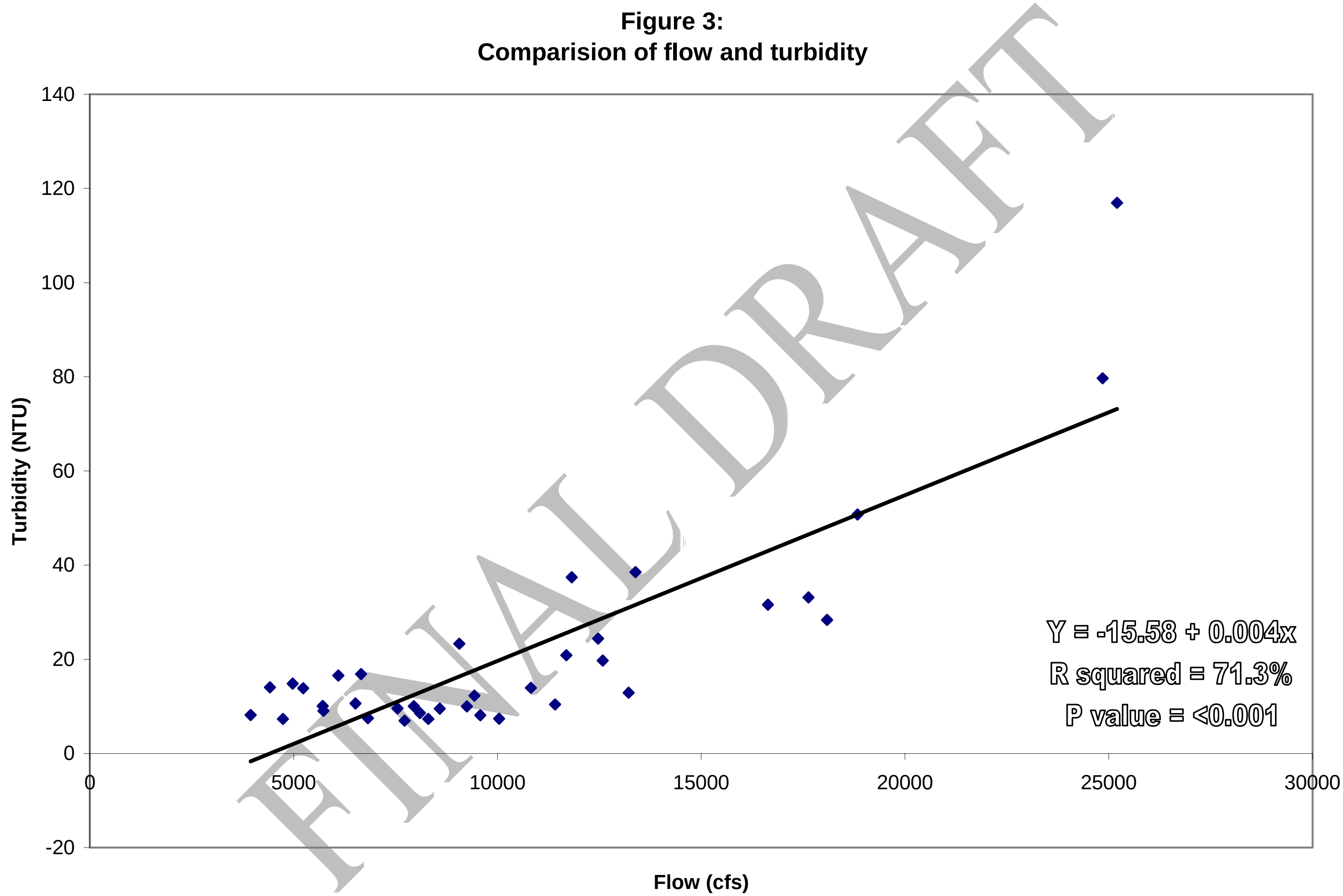


Figure 3:
Comparision of flow and turbidity
Turbidity (NTU)
140
120
100
80
60
40
20
0
-20
0
5000
10000
15000
20000
25000
30000
Flow (cfs)
Y = -15.58 + 0.004x
R squared = 71.3%
P value = <0.001

Figure: 4
Comparision of flow and in-river produced fall-run catch (weeks 43-15)