CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

TIMING, COMPOSITION AND ABUNDANCE OF JUVENILE ANADROMOUS SALMONID EMIGRATION IN THE SACRAMENTO RIVER NEAR KNIGHTS LANDING OCTOBER 2000–SEPTEMBER 2001

by

Bill Miller,
and
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Stream Evaluation Program
Technical Report No. 00-6
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TABLE OF CONTENTS

SUMMARY (2000-2001)

Juvenile chinook salmon (*Oncorrhynchus tshawytscha*) and steelhead trout (*O. mykiss*) emigrating via the Sacramento River to the Sacramento-San Joaquin Delta (Delta) were sampled 0.5 miles downstream of the town of Knight's Landing at river mile (RM) 89.5 from 6 October 2000 to 21 September 2001. However, because no salmonids were captured between 16 June 2001 and the end of the sampling period, that data is not included in this report. Sampling gear consisted primarily of two 8-ft diameter rotary screw traps (RSTs), except that a single 5-ft RST was used during 6 October 2000 – 20 October 2001 (weeks 41-43) and a single 8-ft RST was used between 24 October 2000 – 02 November 2000 (weeks 44 and 45). Additionally, only one 8-ft RST was operated between 11 May 2001 and 18 May 2001 (weeks 19 and 20); two traps fished during week 21, and only one RST was operated till the end of the sampling period. The California Department of Fish and Game has monitored emigrating salmonids at Knights' Landing for five consecutive years.

Mean weekly flow stayed at around 6,200 cfs until January and then rose to a maximum of 21,512 cfs in week 10 (4-10 March 2001) and declined over the next 9 weeks to 4,237 cfs in week 19 (6-12 May 2001). Peak mean daily flow was 27,400 cfs on 6 March 2001. Mean weekly water temperature decreased from 67°F in week 41 to a low of 44°F in week 5 (28 January 2001 – 3 February 2001), then increasing to a maximum of 72°F in week 21 (20-26 May 2001). Water turbidity varied from 3.52 to 235 NTUs and appeared to be strongly correlated to flow.

Overall, the rotary screw traps at Knight's Landing fished for 10,449 hours and yielded a total of 80,530 juvenile salmon (7.7 fish/h). About 3.1% (2,466) of the total juvenile salmon catch were adipose-fin clipped chinook released from Coleman National Fish Hatchery (CNFH) or Livingston Stone National Fish Hatchery (LSNFH). The first hatchery marked Chinook salmon was caught in the traps during week 52 and the last was caught during week 20, with peak catch rates occurring in week 19. The remaining 78,064 unmarked fish were considered in-river produced fish except when large releases of unmarked hatchery fall run could not be distinguished from in-river produced Chinook. The first unmarked fish was collected in week 46 and the last was collected in week 24, with peaks during weeks 5, 9, 18, and 19. Fall run juvenile salmon formed the major portion of both hatchery marked and unmarked salmon catch. Nearly all (95.7%) of the adipose-clipped salmon were considered fall run Chinook, with winter run and late-fall run forming 0.7% and 3.6% of the total marked catch, respectively. An even greater proportion (99.28%) of the unmarked fish were fall-run-sized fish, with spring run, winter run, and late-fall run sized fish comprising 0.25%, 0.45%, 0.02% of the unmarked catch, respectively.

The first adipose-clipped Chinook salmon was a late-fall run collected by RST during week 52, with peak catches occurring during weeks 3 and 5. The last late-fall marked salmon was collected during week 7 for a total of 88 marked late-fall run. Winter run marked fish of hatchery origin formed the smallest proportion (n = 18) of marked fish with 2 collected in week 7, 12 in week 9, and 4 in week 11. Of the 2360 marked fall run

salmon collected, 56 were caught in week 16, increasing to a peak of 1756 in week 19, then dropping off sharply to 96 caught in week 20, and then none were caught thereafter.

The first 2 unmarked late fall run sized fish was collected in week 46, followed by 2 in week 50, increasing slightly to 4 caught in both weeks 52 and 53, decreasing slightly to 2 in week 2, and then ending with 3 in week 5 (n = 17 total).

Like late-fall run sized salmon, the first unmarked winter run sized salmon was caught in week 46. Following a few weeks of no winter-run sized salmon, catches began again in week 51 and continued nearly every week thereafter until week 11 with peaks occurring during week 3 (n = 57), week 5 (n = 141), and week 9 (n = 66). The last of the 349 winter-run sized Chinook salmon collected were caught during weeks 16 and 17.

Catches of the 196 unmarked spring-run sized juvenile salmon were spread out over 22 weeks beginning in week 52 and ending in week 20. Catches were initially sporadic with peaks in weeks 5, 7 and 9. However catches were made every week for 10 weeks beginning in week 11 with modes in week 13 and 16.

The first of the 77,502 unmarked fall-run sized salmon were collected in week 52 with catches made nearly every week thereafter until week 24. The first 2 peaks in catch were made in weeks 3 and 5 and coincident with the first increases in flow. The second 2 peaks in weeks 7 and 9 were coincident with the second major increase in flow. There after catch numbers declined until large numbers of unmarked fall run salmon were released from the CNFH in week 15. After that numbers increased to a peak in week 19 and then decreased every week thereafter.

Of the 264 steelhead collected at the Knights Landing RSTs, 249 (94.3%) were adipose-clipped of hatchery origin, 14 (5.3%) were sized as unmarked yearlings, and the remaining single fish (0.4%) was sized as an unmarked adult. The first adipose-clipped steelhead was collected during week 2 with fish collected every week thereafter until week 11, and then a single marked steelhead in weeks 14 and 19. The 14 yearlings were spread out with 0-4 individuals collected from weeks 4 to 20. The single adult-sized steelhead was collected during week 20.

Capture efficiency evaluations for the RSTs were conducted for every week that enough fish were available for mark-recapture tests, beginning in week 5. Tests were run during every week thereafter until week 20 except in weeks 12 and 14-16. Overall 13,157 salmon were marked and 45 were recaptured for an overall efficiency of 0.34%. Mean weekly efficiency was 0.37% (SD = 0.32%) and was used to estimate relative abundance.

We estimate that 25 million (80% CI, 18.9 million – 38.6 million) juvenile Chinook salmon emigrated past Knights Landing on their way to the Delta and the ocean. About 5.0 million (19.9%) of those were estimated to be of hatchery origin. Both hatchery and in-river produced salmon were dominated by fall run fish forming over 99% of the estimated total. For steelhead, 82,162 (80% CI, 62,041 – 126,667) emigrated past the traps at Knights Landing with about 94.4% of those of hatchery origin.

INTRODUCTION

California's native, anadromous salmonid population of the Central Valley have declined significantly due to a variety of anthropogenic changes to their habitat since the mid-1800's. Namely, dam construction, agricultural and urban run off, flood control, and water diversion projects have altered habitat availability, flow regimes, or water chemistry to the detriment of anadromous populations of Chinook salmon (*Oncorhyncus* tshawytscha) and steelhead (*O. mykiss*) (Snider and Titus 1998, Snider and Titus 2000b,c,d).

Among the most daunting of the water diversions, are the Central Valley Water Project's Tracy Pumping Plant and the State Water Project's Harvey Banks Delta Pumping Plant, both found in the Sacramento-San Joaquin Delta. These water diversions provide great benefit to the citizens of California; however, water management measures can affect the survival of anadromous salmonids. Accurate knowledge of the abundance and timing of emigrating salmonids entering the Delta can help managers to make informed decisions regarding water management activities to the benefit of fish and people (Snider and Titus 1998, Snider and Titus 2000b,c,d).

The upper Sacramento River system, above the Feather River (RM 80), provides spawning and rearing habitat for several anadromous salmonid populations listed as threaten or endangered under State or Federal law (Figure 1). For Central Valley's anadromous salmonid populations, endemic winter-run Chinook[1], all spring-run Chinook[2], and all late-fall-run Chinook spawn and rear only in the upper Sacramento River system. In addition, most in-river produced fall-run Chinook salmon and steelhead trout[3] spawn and rear in the upper Sacramento and its tributaries. Existing emigrating salmonid monitoring programs were either too far upstream to provide accurate estimates of timing and abundance, or were to close to the Delta to distinguish between fish produced in the upper Sacramento from those produce in the Feather river or American River systems (Snider and Titus 1998, Snider and Titus 2000b,c,d).

In November 1995, a pilot monitoring program was established by water and fishery managers to determine the feasibility of using rotary screw traps (RSTs) at Knights Landing (RM 89.5) to improve estimates on the timing, abundance and composition of emigrating salmonids (Snider and Titus 1998). Knights Landing was chosen due to its favorable channel and flow conditions, as well as its position within the Sacramento River system. Moreover, nearly all of the juvenile salmon and steelhead of interest emigrate past Knights Landing during most flow conditions[4].

1 Listed as endangered under both the California and Federal Endangered Species acts.
2 Listed as threatened under both the California and Federal Endangered Species acts.
3 Listed as threatened under the Federal Endangered Species Act.
4 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.

The stated goals of the monitoring program put forth by water and fishery managers were 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.

The monitoring program was successful and has continued for 11 consecutive years (Snider and Titus 1998, Snider and Titus 2000b,c,d, Vincik per. comm..). This report summarizes the findings obtained from the sixth (2000-2001) year of monitoring.

METHODS

Juvenile salmonids emigrating from the upper Sacramento River to the Delta were sampled 0.5 miles downstream of the town of Knights Landing at RM 89.5 (Figure 1) from 6 October 2000 through 21 September 2001 (weeks 41 – 39). Sampling was conducted using one 5-ft RST during 6 October 2000 through 20 October 2001 (weeks 41-43) and a single 8-ft RST was used between 24 October 2000 through 02 November 2000 (weeks 44 and 45). Following that, only one 8-ft RST was operated between 11 May 2001 and 18 May 2001 (weeks 19 and 20). Additionally, two traps fished during week 21, and then only one RST was operated during week 22. After that, 2 RSTs fished till the end of the sampling period.

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 1/4" diameter wire rope. Water depth at the trap location was 18 ft at 10,000 cfs (Figure 2). 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 classified by race for Chinook salmon[5]. All salmon classified as winter run, spring run and late-fall run were measured (fork length [FL] in mm and wet weight in g). At each trap servicing, up to 150 fall-run-sized salmon per trap were selected and measured using a random-

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

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 2001 (i.e., contains 1 January 2001). Weeks prior to week 1 were consecutively numbered in descending order from 53; 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 turbidity (NTUs) was measured each day by collecting water samples at the RST, and then using a turbidimeter in the lab. Water temperature was measured using electronic recording thermographs attached to the RSTs.

Trap efficiency was evaluated using a mark-and-recapture technique. All trapped chinook salmon (except winter-run-sized chinook) were marked using Bismark Brown *Y* stain (e.g., 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 $\geq$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 5 (28 January 2001 – 3 February 2001) and continued through week 20 (13–19 May 2001). No marked fish were released during week 12 and weeks 14–16 as fewer than 100 fish were collected during those periods.

All adipose-fin clipped (marked) fish were collected and coded-wire tags (CWTs) were extracted and read to determine the fish's origin including race, except during weeks 17-20 (22 April 2001-12 May 2001), when numbers of marked fish exceeded the ability of field crews to process and many were released. 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.

Table 1. **Summary of mean weekly sampling conditions in the Sacramento River near Knight's Landing during the juvenile salmonid emigration investigation.**

		Sampling conditions		
Week	Beginning date	Mean flow (cfs)	Mean water temperature (F)	Mean turbidity (NTU)
41	01 Oct 2000	6298	67	4.0
42	08 Oct 2000	5816	58	5.0
43	15 Oct 2000	5937	61	5.7
44	22 Oct 2000	5057	55	5.7
45	29 Oct 2000	6337	54	11.5
46	05 Nov 2000	5448	54	7.3
47	12 Nov 2000	5647	49	4.6
48	19 Nov 2000	5961	47	6.2
49	26 Nov 2000	6345	49	8.9
50	3 Dec 2000	6458	48	10.1
51	10 Dec 2000	6605	49	9.8
52	17 Dec 2000	6671	47	13.3
53	24 Dec 2000	6247	45	6.9
1	31 Dec 2000	6139	44	5.4
2	07 Jan 2001	8598	46	21.3
3	14 Jan 2001	8500	44	19.3
4	21 Jan 2001	10638	46	15.6
5	28 Jan 2001	10782	44	32.9
6	04 Feb 2001	7067	47	15.2
7	11 Feb 2001	10977	45	23.2
8	18 Feb 2001	15378	48	46.9
9	25 Feb 2001	18176	48	35.0
10	04 Mar 2001	21512	48	118.0
11	11 Mar 2001	14128	54	28.3
12	18 Mar 2001	10919	58	12.9
13	25 Mar 2001	9973	59	12.9
14	01 Apr 2001	8322	58	9.4
15	08 Apr 2001	8402	54	7.0
16	15 Apr 2001	6428	58	11.1
17	22 Apr 2001	6553	62	17.7
18	29 Apr 2001	5527	63	16.6
19	06 May 2001	4943	68	17.2
20	13 May 2001	5951	65	19.5
21	20 May 2001	6487	72	14.2
22	27 May 2001	6585	65	12.0
23[a]	03 Jun 2001	6937	—	—
24	10 Jun 2001	8463	67	9.5

[a] No visit to RST's this week.

RESULTS and DISCUSSION

General Sampling Conditions

Mean weekly flow averaged approximately 6,200 cfs until January and then rose to 10,782 cfs in week 5 (28 January – 3 February 2001). After a brief decline to 7,067 cfs in week 6 (4-10 February 2001), mean weekly flow increased to a maximum of 21,512 cfs in week 10 (4-10 March 2001) and then declined to a minimum of 4,237 cfs in week 19 (6-12 May 2001) over the next 9 weeks (Table 1, Figure 4). Mean daily flow ranged from 4,733 cfs on 7 May 2001 to 27,400[6] on 6 March 2001 (Figure 3) and was more episodic and less sustained than in the previous 5 years of monitoring at Knights Landing (Snider and Titus 1998, Snider and Titus 2000b, c,d, and data from CDEC).

Mean weekly water temperature ranged from 44°F in weeks 1 (31 December 2000 – 6 January 2001) to 72°F in week 21 (20–26 May 2001). Initially, temperature followed a period of decline from about 67°F in week 41 (1-7 October 2000) to 44°F in week 1 (31 December 2000 – 6 January 2001). Water temperature then averaged about 46°F until week 10 (4-10 March 2001). After week 10, mean weekly water temperature steadily increased (Table 1). As in prior years, mean daily water temperature appeared to be weakly negatively correlated with flow (r = -0.27, $Df.$ = 270), but is more likely associated with seasonal ambient temperature changes.

Mean weekly water turbidity was closely tied to mean weekly flow (Figure 4) and ranged from 4.0 NTUs in week 41 (1-7 October 2000) to 118.0 NTUs in week 10 (4-10 March 2001) (Table 1). A moderately strong correlation existed between flow and turbidity and a significant linear regression existed between the square-root of turbidity to flow (r = 0.84, $Df.$ = 35, $p < 0.00001$, NTU = (0.790711 + 0.000365723*(cfs)^2).

Effort during the primary emigration period (weeks 41-24) averaged 311 h/week out of a possible 336 h/week. The RSTs operated successfully over a varied range of flow regimes (Figure 5). Interruptions were typically due to debris buildup or trap maintenance.

Rotary Screw Trap Results

Chinook Salmon Emigration

The first fish captured during the 2000-2001 sampling period were 2 winter-run sized fish and 2 late-fall-run sized fish captured during week 46. During weeks 50-53, thirty-seven fish were collected from the RSTs that were mostly dominated by winter-run and late-fall-run sized fish. The main emigration period occurred from week 2 to week 22 with fish caught every week. One salmon fry was caught in week 24 and none were collected thereafter.

6 Flow >23,000 cfs at Wilkins Slough indicates that Sacramento River flow is being diverted into the Sutter Bypass (Bypass) at Tisdale Weir, and may be substantially higher upstream of the Bypass.

Table 2. Weekly summary of catch statistics for Chinook salmon caught by rotary screw trap in the Sacramento river near Knights Landing, 6 October 2000 15 June 2001.

				Size statiatics (FL in mm)			
Week	Effort (h)	Total catch	Catch/h	Mean	Minimum	Maximum	Standard deviation
41	215.50	0	0.00				
42	140.75	0	0.00				
43	190.75	0	0.00				
44	168.00	0	0.00				
45	146.25	0	0.00				
46	378.75	4	0.01	88.0	71.0	111.0	18.2
47	336.50	0	0.00				
48	334.25	0	0.00				
49	343.75	0	0.00				
50	336.50	2	0.01	112.5	107.0	118.0	7.8
51	338.25	1	0.00	68.0	68.0	68.0	0.0
52	327.00	27	0.08	74.2	32.0	128.0	26.1
53	381.00	7	0.02	90.3	37.0	115.0	29.6
1	292.00	0	0.00				
2	382.50	34	0.09	90.8	37.0	135.0	25.8
3	266.25	3420	12.85	41.3	32.0	119.0	14.2
4	336.25	61	0.18	53.9	35.0	115.0	26.6
5	373.00	14328	38.41	43.3	31.0	145.0	18.0
6	328.50	76	0.23	42.7	34.0	107.0	14.6
7	337.75	2970	8.79	39.7	32.0	123.0	9.2
8	287.75	632	2.20	39.9	31.0	111.0	7.3
9	271.00	12746	47.03	41.4	31.0	137.0	13.5
10	145.75	556	3.81	39.8	31.0	106.0	7.6
11	330.50	690	2.09	43.5	32.0	113.0	10.9
12	335.25	137	0.41	52.7	36.0	92.0	11.0
13	333.00	192	0.58	60.1	36.0	93.0	13.0
14	341.00	41	0.12	69.0	48.0	93.0	9.5
15	330.00	30	0.09	78.8	63.0	91.0	7.8
16	337.00	1215	3.61	77.4	62.0	145.0	5.9
17	337.00	1523	4.52	78.2	60.0	116.0	4.6
18	339.25	21042	62.03	76.9	63.0	109.0	5.0
19	241.00	19766	82.02	77.6	61.0	112.0	5.9
20	165.75	996	6.01	79.6	62.0	114.0	6.5
21	343.75	26	0.08	82.0	71.0	95.0	6.7
22	75.50	7	0.09	84.8	76.0	94.0	7.3
23[a]	—	—	—				
24[b]	332.00	1	0.00				
Total	10499.00	80530	7.67				

[a] No visit to RST's this week.
[b] Fish not measured.

As in the prior years of monitoring, the 2000-2001 emigration period appeared to have three phases characterized by flow and fry availability (Figure 7, Table 4). The first phase of emigration occurred between week 46 and 53 but was not as clearly tied to initial flow increases as was seen in 1995-1996 and 1998-1999 (Snider and Titus 1998, 2000c); however a relatively high proportion of the catch was characterized by winter-run and late-fall-run sized fish. It seems likely that phases 1 and 2 of the 2000-2001 emigration period fit the pattern seen in the 1996-1997 emigration period, where initial flow increases occurred late in the year, followed by larger flow increases and fall-run emergence, effectively overlapping phases 1 and 2 (Figure 7, Table 4).

Phase 2 began during week 3 with a catch of 697 fall-run sized fish (Table 4), and continued until week 15. The greatest flows occurred during this time and 46% of all fall-run fish were caught at this time. Weeks 5 and 9 saw peak catches during this phase that were also associated with increased flows. The significant increase in fall-run salmon fry and increases in flows are consistent with phase 2 as described in prior studies (Snider and Titus 1998, 2000ab).

Snider and Titus (1998, 2000abc) describe phase 3 as associated with releases from the Coleman National Fish Hatchery and the 2000-2001 emigration period was no different. This phase began in week 16 and peaked during week 18 (Figure 7, Table 3). This phase was also associated with decreasing flows.

Late-Fall-Run-Sized Chinook Salmon

All unmarked late-fall run sized fish were considered to be in-river produced, because all late-fall run fish of hatchery origin were marked by an adipose clip (Table 3). We caught 17 in-river produced late-fall run chinook fry with the first collected during week 46 (Table 4). The last was collected during week 5 and most (>70%) were collected from week 50 to week 2. Twelve late-fall run fish collected during weeks 46, 50, 52 and 53 were considered to be in-river produced fish for BY 2000. They ranged from 94 to 128 mm FL. Only five late-fall run sized fish were considered to be part of BY 2001 for in-river produced fish and were sampled by RST during weeks 2 and 5. They ranged from 127 to 135 mm FL.

Eighty-eight adipose-clipped late-fall run fish were collected by RST from week 52 to week 7 with nearly 84% of the catch made in weeks 2-3 (n = 47) and 5 (n = 27). Fifty-one fish had CWTs that classified them as late-fall run. In addition, 36 fish that were classified as winter-run based on size-at-date criteria (Greene) were reclassified as late-fall run based on CWT or time of capture as compared to hatchery release dates.

Winter-Run-Sized Chinook Salmon

Nearly all winter run fish of hatchery origin were marked by adipose fin clip with only 0.02% (n = 41) unmarked (Table 5). As such, we considered all winter run-sized fish with intact adipose fins to be in-river produced. A total of 349 winter run fry were collected during the 2000-2001 sampling season. The first fish was caught during week 46 and the last was caught in week 17. Most (76%) winter-run-sized Chinook fry were captured during weeks 3, 5 and 9, reaching 70%

Table 3. **Summary of juvenile Chinook salmon and steelhead produce 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 and without coded-wire tags [CWTs]), and release date and location.**

Species & Race (for chinook)	Week of release (date)	No. marked w/CWT	No. marked w/o CWT	No. unmarked	Release location (RM)[a]
Chinook					
Late-fall run	46 (3 Nov 2000)	58050	1805	0	CNFH (271.5)
Late-fall run	50 (8 Dec 2000)	54568	1979	0	CNFH (271.5)
Late-fall run	1 (2 Jan 2001)	365776	3963	0	BC (271.5)
Late-fall run	2 (9 Jan 2001)	65285	1683	0	BC (271.5)
Winter run[b]	5 (1 Feb 2001)	162198	3662	41	LRP (298.5)
Fall run	7 (16 Feb 2001)	44594	4955	0	RBDD (243.)
Fall run	11 (5 Mar 2001)	46413	4036	0	RBDD (243.)
Fall run	15 (13 Apr 2001)	858812	4861	5259838	BC (271.5)
Fall run	17 (27 Apr 2001)	891458	5347	5396674	BC (271.5)
Steelhead					
	2 (8 Jan 2001)	0	391173	0	BB (257.5)
	4 (23 Jan 2001)	111615	3314	0	BB (257.5)
	4 (24 Jan 2001)	84949	5906	0	BB (257.5)

[a] BC = Battle Creek; BB = Bend Bridge; CNFH = Coleman National Fish Hatchery; LRP = Lake Redding Park; RBDD = Red Bluff Diversion Dam.
[b] All winter run Chinook where raised at Livingston Stone National Fish Hatchery.

of the cumulative total catch in week 5. The timing of emigration appears to be coincident with the first major flow increases.

In addition to the 349 in-river produced Chinook, 50 marked winter-run-sized fish were also collected. Of those 50, 36 were determined to actually be late-fall run as discussed above. Likewise, 4 adipose-clipped fish that were sized as spring run were reclassified as winter run based on CWT data. All marked winter run fish were collected in just three weeks (7, 9, and 11) with the most (67%) collected during week 9 (Table 5).

Spring-Run-Sized Chinook Salmon

A total of 196 unmarked, spring run salmon were caught by RST during the 2000/2001 sampling season based on size criteria. No hatchery produces spring run fish for release into the Sacramento River above Knight's Landing leading one to believe these 196 fish to be in-river produced. However, fall run fish of hatchery origin can be sized as spring run if the size distribution of released hatchery fall-run fish overlaps the spring-run-sized fish as indicated on Greene's race designation chart. Thus distinguishing in-river produced spring run fish from hatchery produced fall run is problematic.

Table 4. **Summary of catch and size range data for in river produced[a] Chinook salmon (by run) caught by rotary screw traps in the Sacramento River near Knight's Landing, 6 October 2000 to 15 June 2001.**

	Fall run[b]		Spring run		Winter run		Late fall run	
Week	No.	FL range	No.	FL range	No.	FL range	No.	FL range
46	0		0		2	71-76	2	94-111
47	0		0		0		0	
48	0		0		0		0	
49	0		0		0		0	
50	0		0		0		2	107-118
51	0		0		1	68	0	
52	4	32-36	2	38-39	16	67-101	4	104-128
53	1	37	0		2	71-77	4	109-115
1	0		0		0		0	
2	1	37	1	46	13	72-111	2	127-135
3	3329	32-44	4	46-48	57	66-119	0	
4	41	35-44	0		12	82-115	0	
5	14138	31-49	19	49-66	141	71-131	3	135-145
6	69	34-45	2	55-62	4	93-107	0	
7	2932	32-53	19	45-62	14	75-123	0	
8	626	31-54	0		5	83-111	0	
9	12651	31-59	17	60-75	66	81-137	0	
10	550	31-56	0		6	92-106	0	
11	673	32-59	6	65-75	7	88-113	0	
12	126	36-69	11	71-92	0		0	
13	158	36-78	34	71-93	0		0	
14	34	48-74	7	74-93	0		0	
15	12	63-79	18	78-91	0		0	
16	1129	62-83	28	82-88	2	132-145	0	
17	1332	60-86	15	86-95	1	116	0	
18	20759	63-90	6	90-109	0		0	
19	18004	61-94	6	93-112	0		0	
20	899	62-98	1	114	0		0	
21	22	71-95	0		0		0	
22	7	76-94	0		0		0	
23	0		0		0		0	
24	1[c]		0		0		0	
			140[d]	38-93				
Totals	77502	31-98	56[e]	82-114	349	66-145	17	94-145

[a] Unmarked salmon were considered in-river produced except as noted below.
[b] 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 (see text).
[c] One fish tallied only, not measured.
[d] All spring-run-sized fish captured after week 15 were considered fall run based on CWT data and release dates of large amounts of unmarked fall run fish from CNFH (see text).
[e] Total captured after week 15, considered fall run produced from CNFH.

We considered all spring-run-sized fish caught after week 15 to be fall run fish as no unmarked fall run hatchery fish were released until 13 April 2001 (Table 3). Furthermore, numbers of fall run hatchery juveniles released into the upper Sacramento River were relatively low prior to week 15. In support of this division, three spring-run-sized adipose clipped fish caught during week 17 were verified to be fall run based on CWTs.

Adjusted catch totals for spring run fry then are 140 in river produced spring run salmon. The first was caught during week 52 with a major peak in number caught during week 13. They ranged in size from 38 to 93 mm FL.

Only 7 spring-run-sized salmon were caught that were marked with an adipose-clip. Of the seven 4 were determined to be winter run as described above and 3 were determined to be fall run as described above.

Fall-Run-Sized Chinook Salmon

Fall-run-sized fish accounted for almost the entire portion of salmon caught by RST during the 2000-2001 monitoring period with a catch of 77,502 (99.3% of total catch) (Table 4). The first and last fish were caught during week 52 and week 24, respectively. Two periods are apparent in the timing of fall run emigration: the first appears to be associated with flow and the second appears to be associated with hatchery releases (Figure 7, Table 4). Five fish were caught in week 52-53 and fall-run-sized fish were caught every week from week 2 to week 22. Major peaks in catch (>12,000) occurred during weeks 5, 9, 18 and 19 accounting for 85% of total catch. The first two peaks occurred during period one and the last two peaks occurred during period 2.

As in prior years, distinguishing between hatchery-reared fall run salmon and in-river produced salmon is difficult due to the high number of unmarked hatchery fish released into the Sacramento River system above Knights Landing. Although the CNFH began to release fall run salmon in weeks 7 and 11, all of the nearly 100,000 fish were marked, and would have been distinguishable from in-river produced fish (Table 3). However, in weeks 15 and 17 over 10 million unmarked and 1.7 million marked fish were released into Battle Creek. Moreover, of the 56 adipose-clipped fish caught during week 16, thirty-nine of them were verified to be fall run released during week 15. The remainder had either lost their tags or were released. Thus we consider all fall-run-sized salmon collected prior to week 16 to be in-river produced fish. After week 15, we were unable to distinguish between hatchery produced and river produced fall run salmon.

A total of 2,360 adipose-clipped fall-run-sized fish were collected by RST from weeks 16-20. But only 543 of those were examined in the lab for CWTs; the rest were released to facilitate sampling as there were so many fish being captured at this time. Of the 543 collected, 447 were confirmed as fall run. An additional 3 marked spring-run-sized fish were confirmed to be fall run as described above.

Table 5. Summary of catch and size range data for adipose clipped, hatchery produced Chinook salmon (by run[a]) caught by rotary screw traps in the Sacramento River near Knights Landing, 6 October 2000 15 June 2001.

Week	Fall run		Winter run		Late-fall run	
	N	FL Range	N	FL Range	N	FL Range
41	0		0		0	
42	0		0		0	
43	0		0		0	
44	0		0		0	
45	0		0		0	
46	0		0		0	
47	0		0		0	
48	0		0		0	
49	0		0		0	
50	0		0		0	
51	0		0		0	
52	0		0		2	90-123
53	0		0		0	
1	0		0		0	
2	0		0		17	101-172
3	0		0		30	89-176
4	0		0		8	101-139
5	0		0		27	93-161
6	0		0		1	108
7	0		2	72-75	3	96-135
8	0		0		0	
9	0		12	71-93	0	
10	0		0		0	
11	0		4	85-94	0	
12	0		0		0	
13	0		0		0	
14	0		0		0	
15	0		0		0	
16	56	67-85	0		0	
17	175 (114)[b]	68-87	0		0	
18	277 (143)[b]	66-90	0		0	
19	1756 (177)[b]	68-93	0		0	
20	96 (65)[b]	72-100	0		0	
21	0		0		0	
22	0		0		0	
23[c]	—	—	—	—	—	—
24	0		0		0	
Total	2360	66-100	18	71-94	88	89-176

[a] Based on size-at-time criteria developed by Frank Fisher (California Department of Fish and Game, Northern California - North Coast Region, unpubl. data) but corrected based on cwt returns and hatchery release dates.
[b] Parenthetical numbers show number measured.
[c] No visit to RSTs this week.

Steelhead Trout Emigration

Steelhead trout captured in the RSTs represented three age groups: young-of-the-year (<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.

Young-of-the-year Steelhead

No young-of-the-year steelhead were collected (Table 6).

Yearling Steelhead

A total of 14 yearling steelhead were collected by RST at Knights Landing (Table 6). The first six were captured in weeks 5-6, 9, 11 and 13, while the remaining 8 were captured in just 3 weeks (19-20). The first set of captures appear to be associated with the first and second major increases in flow but the second set runs counter to that idea. The most yearling steelhead were caught in week 19. Altogether, they ranged in size from a maximum of 260 to a minimum of 199 mm FL.

Adult Steelhead

Only 1 adult steelhead was caught during week 14, measuring 308 mm FL (Table 6).

Marked Steelhead

A total of 249 marked steelhead were collected at Knights Landing with the first collected during week 2 and then every week thereafter until week 11 (Table 6). After that one fish was caught during week 14 and one during week 19. The major peak occurred during week 5 with 123 steelhead and the second major peak occurred during week 3 with 53 fish. The CNFH first released over 39,000 marked steelhead into Battle Creek during week 2, followed by a release of over 250,000 during week 4. This period was also coincident with the first major flow increases for the Sacramento River (Figure 3, Figure 7). Thus a delay of about one week was seen between fish releases and initial capture at Knights Landing during the 2000/2001 sampling period.

Table 6. Summary of catch statistics for steelhead trout caught by roatary screw trap in the Sacramento River near Knights Landing, 6 October 2000 – 15 June 2001.

	Young of year <100mmr		Yearling 100-300mm		Adult >300mm		Adipose clipped	
Week	No.	Mean FL (range) mm	No.	Mean FL (range) mm	No.	Mean FL (range) mm	No.	Mean FL (range) mm
41	0		0		0		0	
42	0		0		0		0	
43	0		0		0		0	
44	0		0		0		0	
45	0		0		0		0	
46	0		0		0		0	
47	0		0		0		0	
48	0		0		0		0	
49	0		0		0		0	
50	0		0		0		0	
51	0		0		0		0	
52	0		0		0		0	
53	0		0		0		0	
1	0		0		0		0	
2	0		0		0		1	308
3	0		0		0		53	190 (118-226)
4	0		1	233	0		9	174 (117-200)
5	0		1	220	0		123	195 (98-233)
6	0		0		0		19	201 (164-220)
7	0		0		0		32	200 (116-250)
8	0		0		0		1	223
9	0		2	237 (213-260)	0		4	215 (195-247)
10	0		0		0		2	181 (164-197)
11	0		1	199	0		3	292 (179-501)
12	0		0		0		0	
13	0		1	233	0		0	
14	0		0		0		1	169
15	0		0		0		0	
16	0		0		0		0	
17	0		0		0		0	
18	0		4	226 (211-238)	0		0	
19	0		2	236 (234-238)	0		1	241
20	0		2	245 (237-252)	1	308	0	
21	0		0		0		0	
22	0		0		0		0	
23[a]	—		—		—		—	
24	0		0		0		0	
Total	0		14	231 (199-260)	1	308	249	197 (98-501)

[a] No visit to RSTs this week.

Table 7. Summary of capture efficiency test results for chinook salmon collected by rotary screw traps in the Sacramento River near Knights Landing, 6 October 2000 – 15 June 2001.

Week	Number marked	Number recovered	Efficiency (%)
5	393	2	0.51
6	1145	1	0.09
7	91	0	0.00
8	2546	17	0.67
9	1164	9	0.77
10	630	5	0.79
11	469	2	0.43
12	0	0	—
13	127	0	0.00
14	0	0	—
15	0	0	—
16	0	0	—
17	843	0	0.00
18	525	3	0.57
19	4428	2	0.05
20	796	4	0.50
Total	13157	45	0.34

RST Gear Efficiency Using Mark-Recapture

Efficiency evaluations using salmon marked with Bismark Brown began in week 5 (Table 7). Overall, 13,157 Chinook were marked from week 5 to week 20, and 45 of those were recaptured. Weekly efficiency ranged from 0% (Weeks 8, 13, and 17) to a maximum of 0.79% (Week 10), with an overall trap efficiency of 0.34%. Mean trap efficiency was 0.37% (SD = 0.32%).

Prior studies at Knights Landing using RSTs failed to show differences in size of recaptured fish, or any consistent relationship between selected environmental factors and efficiency (Table 8). This year's sampling season appears to be no different; thus, mean trap efficiency was used to calculate abundance estimates (Table 8).

Relative Abundance Estimates

One of the main objectives of monitoring at Knights Landing is to estimate the abundance of emigrating juvenile salmonids emigrating from the upper Sacramento River system into the lower river and the Delta. Both in-river produced and hatchery-produced numbers of each species and race were estimated using mean weekly trap efficiency (0.0037) and the associated 80% confidence interval (0.0024-0.0049). In addition, we adjusted total catch numbers to reflect 100% effort by adjusting the catch in proportion to the percentage of actual effort. For example, if effort was 80% the estimate was made by dividing the actual catch by 0.8 (Table 9).

We estimated the number of hatchery-produced salmonids by first estimating the number of marked salmon passing Knights landing using the number caught and mean trap efficiency. As

Table 8. **Correlation matrix of weekly rotary screw trap capture efficiency for juvenile Chinook salmon at Knights Landing on the Sacramento River, and (i) number of salmon marked per week for efficiency tests, (ii) total salmon catch per week, (iii) weekly mean water temperature, (iv) weekly mean water transparency (Secchi depth, ft; except 2000-01, NTUs), and (v) weekly mean river flow, in 1995–1996, 1996–1997, 1997–1998, and 1998–1999. * denotes a significant correlation at $p \leq 0.05$.**

Season	No. salmon marked per week	Total salmon catch per week	Weekly mean water temp.	Weekly mean transparency	Weekly mean river flow
1995–96	0.22	0.62*	–0.32	–0.37	0.26
1996–97	–0.34	–0.30	–0.29	–0.21	0.41
1997–98	0.23	0.19	–0.31	0.24	–0.47*
1998–99	–0.43	–0.35	0.26	0.42	–0.57*
2000–01	–0.07	0.17	–0.30	0.62*	0.63*

the number of marked salmonids released is known, this allows for estimating survival of each species and race of salmonids to Knights Landing. The number of unmarked fish passing Knights landing can then be estimated as a product of survival and the number of unmarked juveniles released, also a known quantity. The estimated total salmonids of hatchery origin passing Knights Landing is then the sum of the estimated marked and unmarked (Table 10).

In-river produced fish were then estimated by subtracting the estimated hatchery-produced component passing Knights Landing (results from Table 10), by species and race, from the estimated total abundance of each species or race moving past the site (Table 11).

All together, an estimated 25.0 million juvenile Chinook salmon (80% CI, 18.9 million – 38.6 million) emigrated past Knights Landing during the 2000-2001 sampling season into the lower Sacramento River and the Delta. About 20% of those were estimated to have been produced from fish hatcheries. For steelhead, about 82,000 yearling steelhead (80% CI, 62,041 – 126,667) emigrated past Knights Landing, with about 94% of hatchery origin.

Table 9. **Estimates of catch adjusted for total effort (100%) using RSTs at Knights Landing, from 6 October 2000 to 15 June 2001.**

	Late-fall run		Winter run		Spring run		Fall run		Steelhead	
	No Clip	Clip	No Clip	Clip	No Clip	Clip[a]	No Clip	Clip	No Clip	Clip
Original Catch	17	88	349	18	140	–	77,558	2,360	15	249
Adjusted Catch	20	101	402	21	161	–	89,245	2,716	17	287

[a] No hatchery released spring run salmon upstream of Knights Landing.

Table 10. **Estimates 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, from 6 October 2000 – 15 June 2001, using mean weekly efficiency (0.0037) and the associated 80% CI (0.0024-0.0049).**

Cohort	A Marked caught	B Marked estimate (A/efficiency)	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	101	27,297 (20,612–42,083)	486,141	0.056 (0.042–0.087)	0	0	27,297 (20,612–42,083)
Winter run	21	5,676 (4,286–8,750)	165,860	0.034 (0.026–0.053)	41	1 (1–2)	5,677 (4,287–8,752)
Fall run	2,716	734,054 (554,286–1,131,667)	1,860,476	0.395 (0.298–0.608)	10,656,512	4,204,545 (3,174,861–6,482,008)	4,938,599 (3,729,147–7,613,674)
Steelhead	287	77,568 (58,571–119,583)	596,957	0.130 (0.098–0.200)	0	0	77,568 (58,571–119,583)

Table 11. **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, from 6 October 2000 – 15 June 2001, using mean weekly efficiency (0.0037) and the associated 80% CI (0.0024-0.0049).**

Cohort	A Total caught	B Estimated total (A/efficiency)	C Hatchery total (from Table 10)	D In-river total (B-C)
Late-fall run	121	32,703 (24,694–50,417)	27,297 (20,612–42,083)	5,405 (4,082–8,333)
Winter run	423	114,324 (86,327–176,250)	5,677 (4,287–8,752)	108,647 (82,040–167,498)
Spring run	161	43,514 (32,857–67,083)	0	43,514 (32,857–67,083)
Fall run	91,961	24,854,324 (18,767,551–38,317,083)	4,938,599 (3,729,147–7,613,674)	19,915,725 (15,038,404–30,703,409)
Total Chinook	92,666	25,044,865 (18,911,429–38,610,833)	4,971,574 (3,754,046–7,664,510)	20,073,291 (15,157,383–30,946,324)
Steelhead	304	82,162 (62,041–126,6670	77,568 (58,571–119,583)	4,595 (3,469–7,083)

ACKNOWLEDGMENTS

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FIGURES

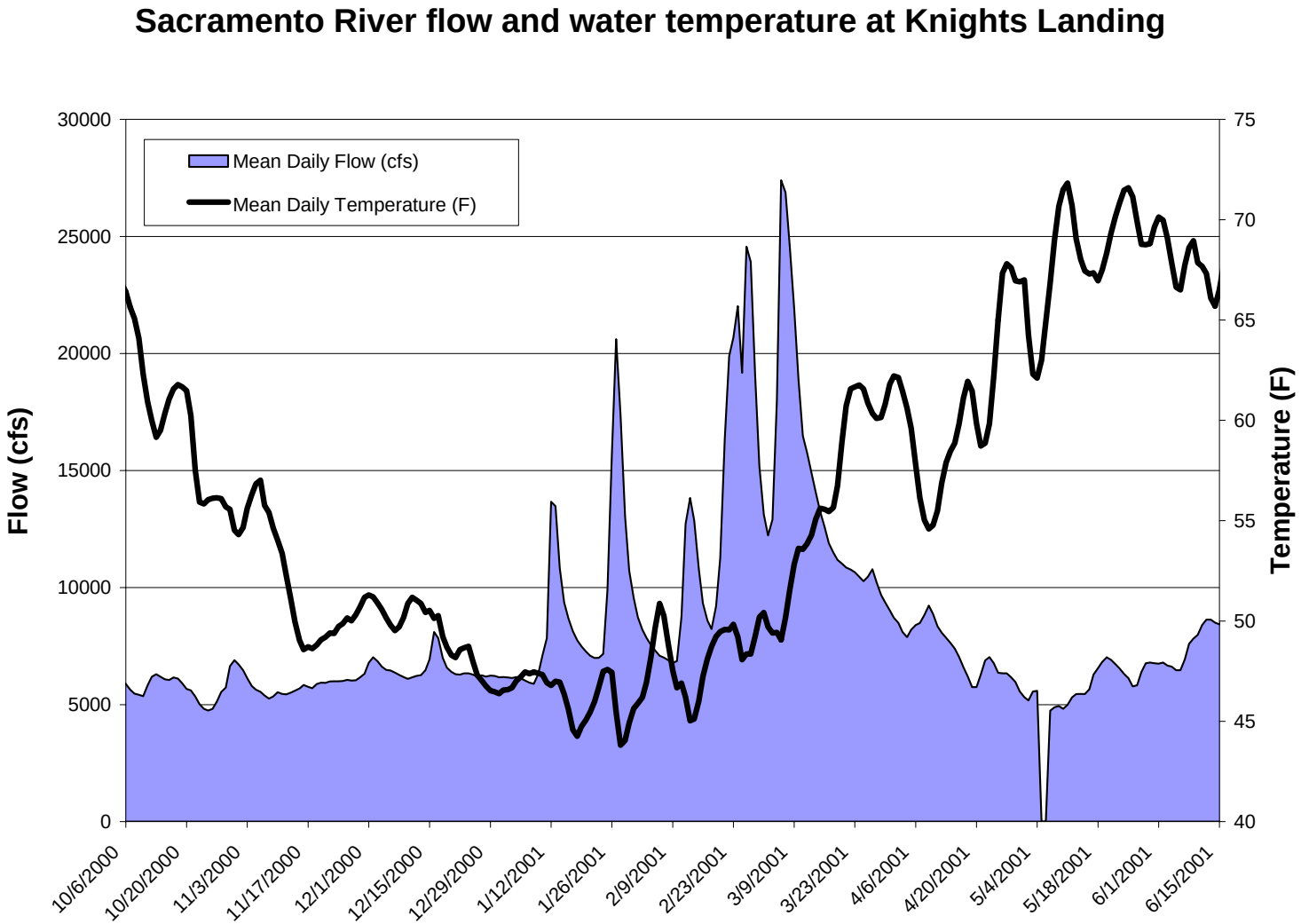

Figure 3. Mean daily flow measured in the Sacramento River near Knights Landing at Wilkins Slough, and mean daily water temperature measured at Knight's Landing.

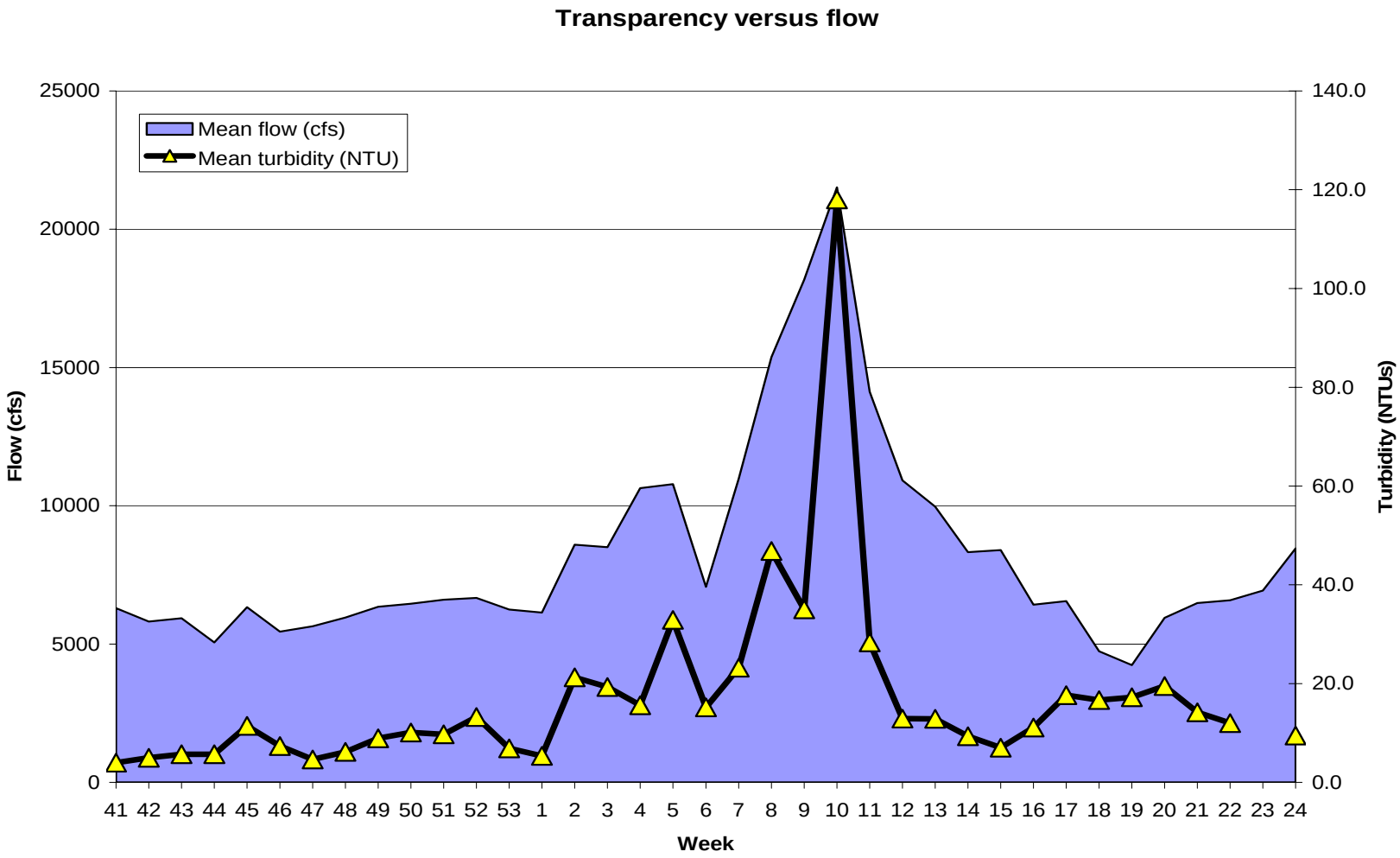

Figure 4. Mean weekly flow compared with mean weekly turbidity (NTUs) measured in the |Sacramento River near Knights Landing, 6 October 2000 15 June 2001.

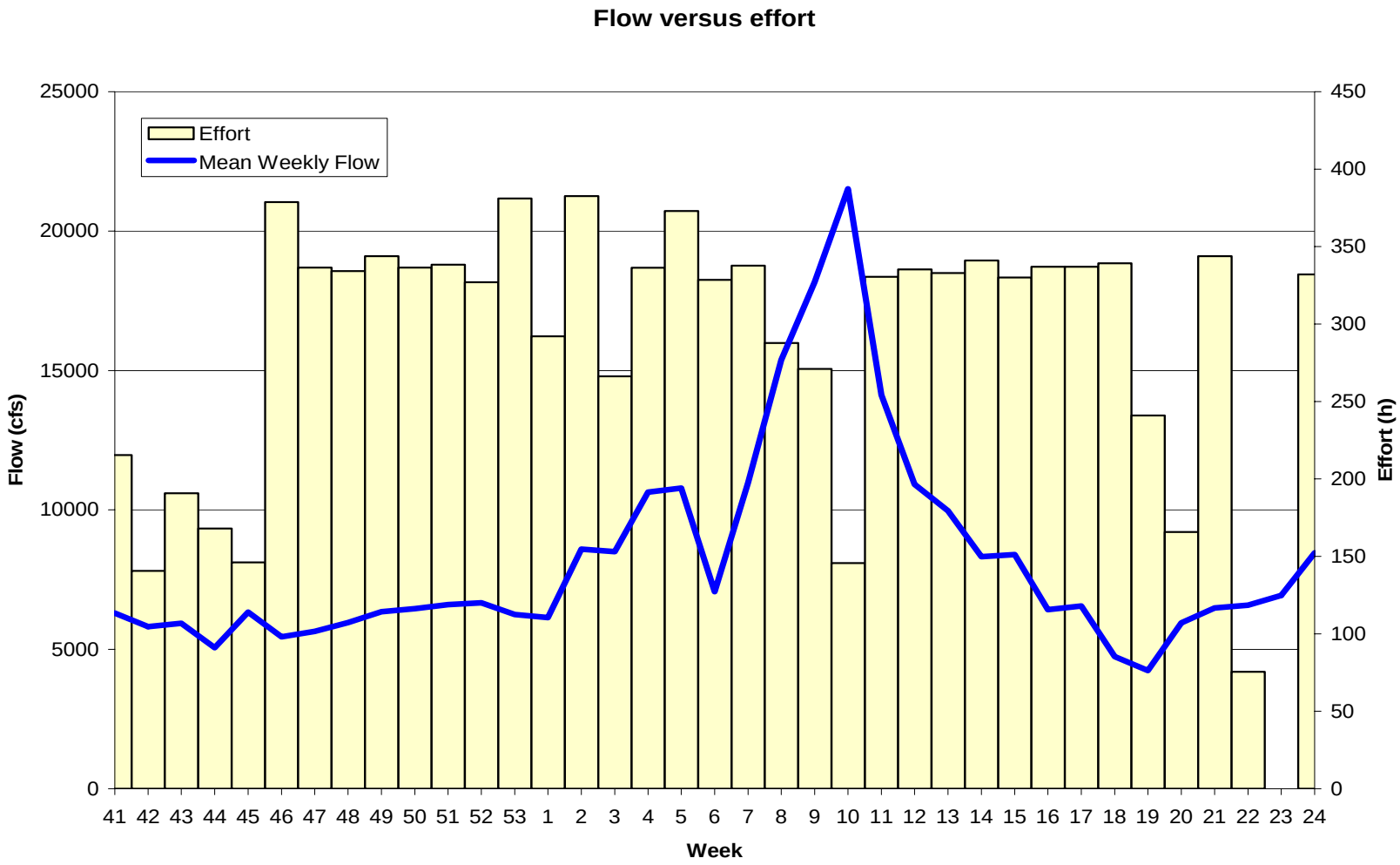

Figure 5. Flow versus effort expended by rotary screw traps in the Sacramento River near Knights Landing, 6 October 2000 – 15 June 2001.

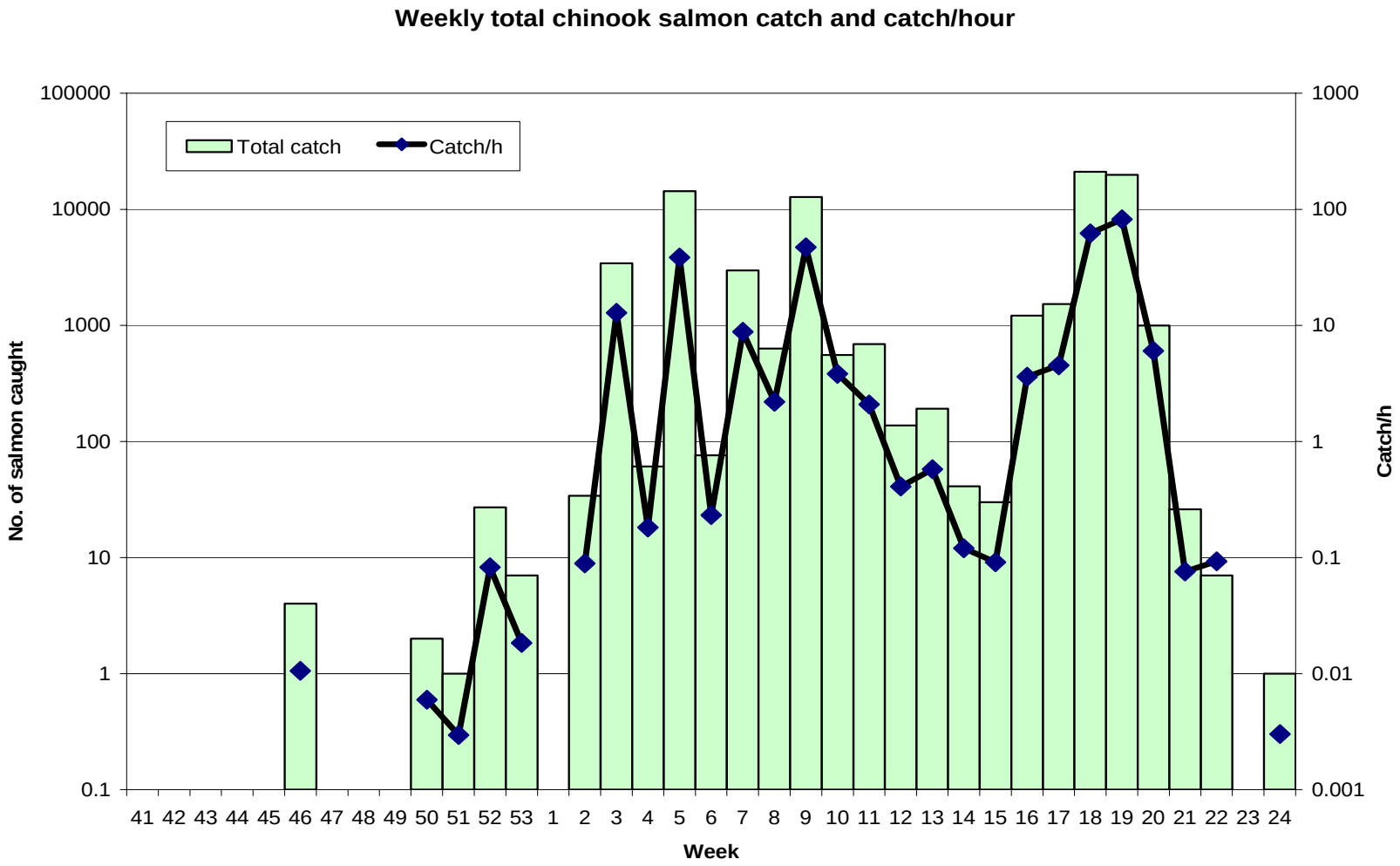

Figure 6. Comparison of weekly total catch and catch rate for Chinook salmon collected at Knights Landing in the Sacramento River by rotary screw trap, 6 October 2000 – 15 June 2001.

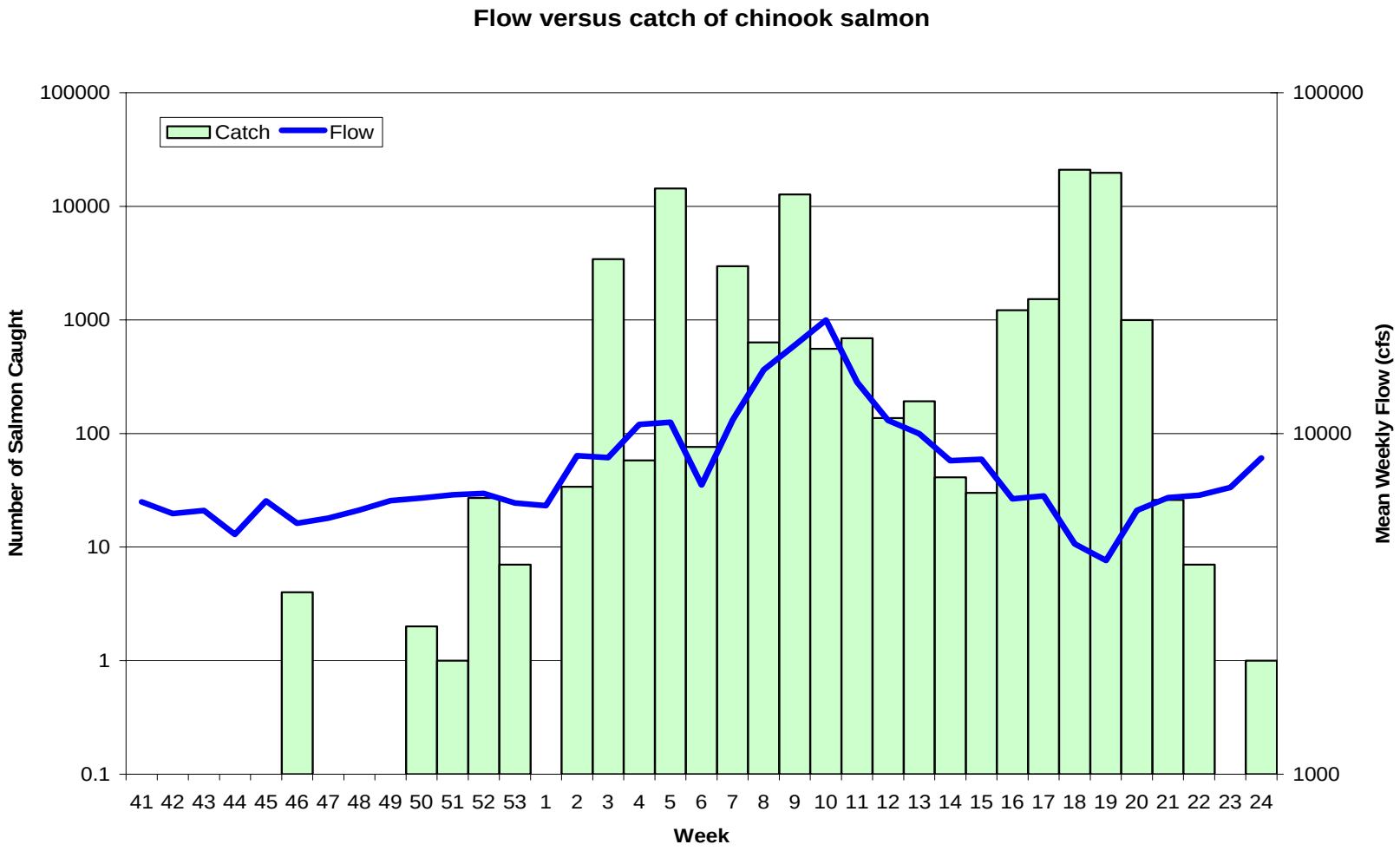

Figure 7. Mean weekly flow compared to total catch of Chinook salmon collected by rotary screw trap in the Sacramento River near Knights Landing, 6 October 2000 – 15 June 2001.

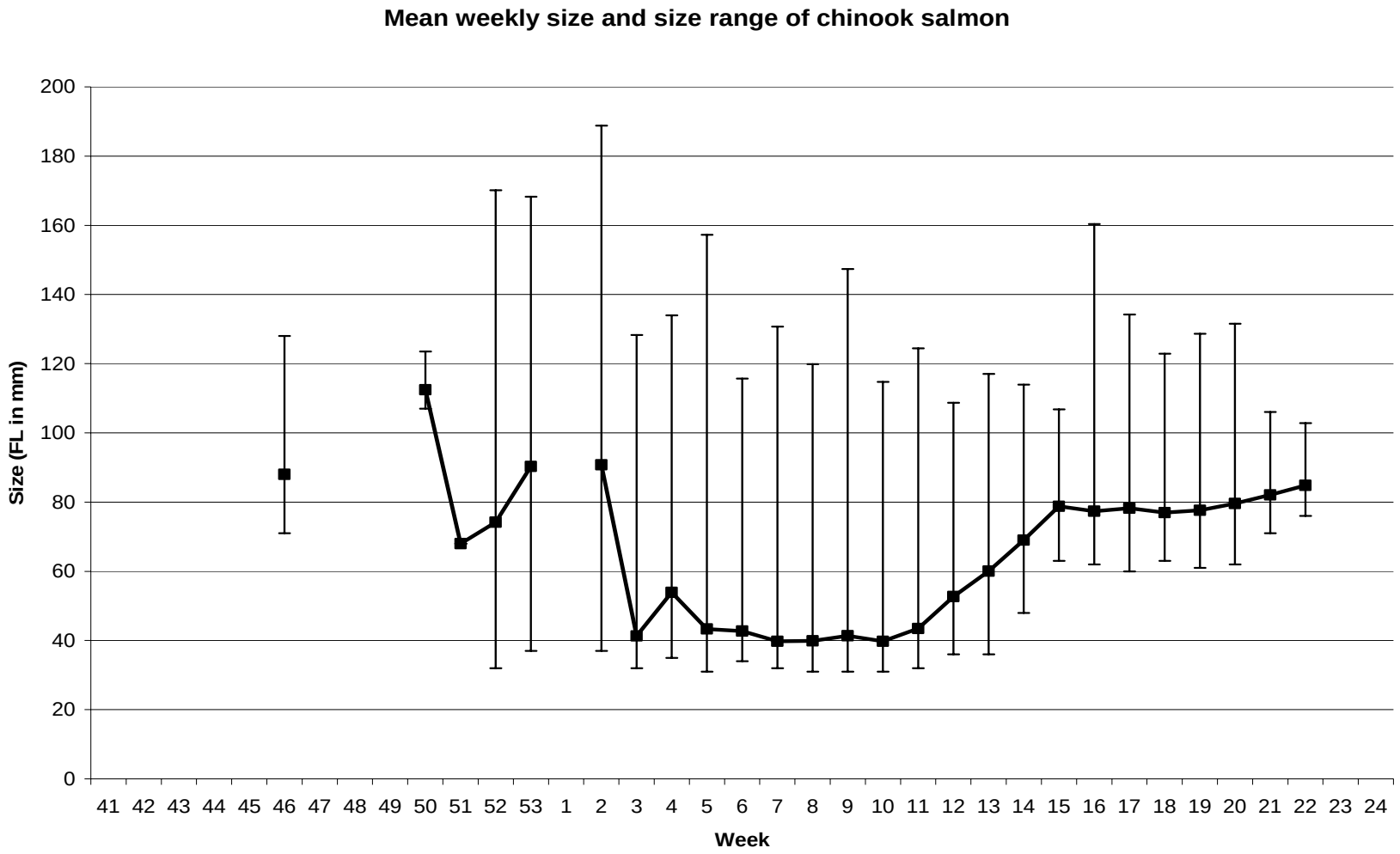

Figure 8. Mean weekly fork length (in mm) and size range of Chinook salmon caught by rotary screw trap in the Sacramento River near Knights Landing, 6 October 2000 – 15 June 2001.