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

Lower American River EMIGRATION SURVEY October 1998-September 1999

by

Bill Snider
and
Robert G. Titus

Prepared under the direction of
Larry Week, Chief
Native Anadromous Fish and Watershed Branch

Stream Evaluation Program
Technical Report No. 02-2
September 2002

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

Lower American River EMIGRATION SURVEY October 1998 - September 1999[1/]

by

Bill Snider
and
Robert G. Titus

Prepared under the direction of
Larry Week, Chief
Native Anadromous Fish and Watershed Branch

September 2002

1/ Stream Evaluation Program Technical Report 02-2.

TABLE OF CONTENTS

SUMMARY

Rotary screw traps (RSTs) were used for the sixth consecutive year to acquire data on emigrating anadromous salmonids on the lower American River. Trapping occurred near river mile 9, from 2 October 1998 through 27 September 1999.

A total of 119,049 Chinook salmon emigrants was collected from 29 November 1998 to 26 July 1999. Four races of juvenile Chinook were collected (race determined by size-at-time criteria): 118,986 fall-run-sized salmon were collected from 11 December 1998 to 26 July 1999, eight spring-run-sized Chinook were collected from 1 December 1998 to 12 May 1999, 19 winter-run-sized Chinook were collected from 29 November 1998 to 21 March 1999, and 36 late-fall-run-sized Chinook were collected including one yearling on 30 December 1998 and 35 young-of-the-year from 1 April to 21 July 1999. We also collected 97 young-of-the-year steelhead from 9 May to 30 July 1999 and 2 yearling steelhead: 1 in week 41 of 1998 and 1 in week 22 of 1999.

Chinook salmon emigrants were described by life stage as yolk-sac fry, fry, parr, silvery parr and smolts. Most captured fall-run salmon were fry (79.3%), followed by yolk-sac fry (14.4%), parr (5.1%), silvery parr (0.9%), and smolts (0.3%). Fall-run yolk-sac fry were collected between 12 December 1998 and 11 April 1999, fry between 28 December 1998 and 26 April 1999, parr between 30 January 1998 and 2 June 1999, silvery parr between 17 March and 23 July 1999, and smolts between 9 May and 19 July 1999.

Salmon yolk-sac fry lengths ranged from 28 to 40 mm fork length (FL), fry ranged from 28 to 46 mm FL, parr ranged from 33 to 89 mm FL, silvery parr ranged from 45 to 98 mm FL, and smolts ranged from 69 to 105 mm FL.

Fall-run Chinook salmon emigration spanned 34 weeks, from 11 December 1998 (week 50 of 1998) through 26 July 1999 (week 31 of 1999). A total of 118,986 fall-run Chinook salmon was caught in 6,215 hours of fishing effort (mean = 19.2 fish/h). Daily catch peaked several times between early February and early March. Peaks in the daily catch reached at least 5,000 salmon/day during this period. The highest daily catch occurred during week 6 on 2 February (6,012 fish, 283 fish/h). The highest weekly catch (26,414 fish, 162 fish/h) occurred in week 10 (28 February–7 March 1999). The second greatest weekly catch occurred in week 6 and was just slightly less than that observed during week 10 (22,678 fish, 142 fish/h).

Flow during the 1999 survey year was moderately high. Several high flow events [>10,000 cubic feet per second (cfs)] occurred during the survey period, beginning in mid January 1999. The highest flow event occurred during early February (>23,000 cfs). Flow remained between 3,500 and 4,000 cfs from mid March to early August 1999.

Trapping efficiency was measured using mark-and-recapture techniques. The measured mean weekly efficiency in 1999 was the highest observed during the six survey years (1.22%).

The number of juvenile Chinook salmon emigrating from the lower American River during the 1999 season was estimated by 1) expanding weekly catches to account for fish that could have been collected if the trap had fish 100% of the time, 2) summing the expanded weekly catches to obtain an expanded catch for the entire emigration period, then 3) dividing the expanded catch by mean trap efficiency (1.22). The estimated expanded catch was 150,891; the estimated number of emigrants leaving the lower American River was 12.4 million.

Correlation analyses were run to determine the strength of the relationship between trap efficiency and each of eight independent variables (e.g., flow, turbidity). A moderately strong and significant, negative correlation occurred with weekly mean river flow. This was the first time a significant relationship between trap efficiency and flow was observed during the eight years of sampling with RSTs on the American River. We developed a model that related efficiency to flow. Weekly trap efficiencies were calculated to reflect the weekly flow conditions and were used to calculate weekly emigration numbers (e.g., expanded weekly catch/efficiency as f(flow). The resultant expanded estimate of the total emigration number was nearly four times that estimated using the mean trap efficiency and total catch. This was done for demonstration purposes only, as we concluded that the efficiency:flow relationship, although somewhat intuitive, could be anomalous, and requires further investigation.

INTRODUCTION

Anadromous fish emigration was monitored on the lower American River, Sacramento County, California (Fig. 1) from October 1998 through September 1999. This was the sixth consecutive year that emigration was monitored on the lower American River as part of a multi-year effort to evaluate flow and other habitat requirements of anadromous salmonids (Snider and Titus 1995, Snider et al. 1997, Snider et al. 1998, Snider and Titus 2000, 2001).

The timing and life-stage composition of emigrating salmonids can directly affect cohort success and chronic changes in emigration can ultimately affect population persistence (Park 1969). Various abiotic conditions, many induced by human activities, are known to directly or indirectly alter emigration. Flow changes (increases and decreases), flow magnitude, water temperature, turbidity, and habitat availability are some conditions that may be altered and affect emigration.

Fall-run Chinook salmon, *Oncorhynchus tshawytscha,* emigration from the lower American River is vulnerable to all such conditions potentially resulting from flow regulation at Folsom Dam. An important objective of our investigations into flow-habitat relationships on the lower American River is to identify relationships between timing, magnitude, and composition of emigrating Chinook salmon and flow, temperature, and other factors potentially controlled by operation of the Folsom Project.

Since emigration can be influenced by anthropogenic disturbances in environmental conditions, it is essential that the relationships between such conditions and emigration, and ultimately survival to spawning, be understood if management of altered systems is to accommodate both short- and long-term persistence of salmon and steelhead, *O. mykiss*, populations. Evaluation of the emigrating population can also relate production and survival of Chinook salmon to precedent conditions of spawning, incubation, and rearing. As such, monitoring salmon emigration in the lower American River has been part of an investigation of the influences of altered flow on Chinook salmon habitat requirements.

Our investigation has several objectives. The primary objective is to identify the general attributes of emigration on the lower American River, including timing, abundance, fish size, life-stage composition, and fish condition, and to relate these attributes to primarily flow-dependent, environmental conditions. We aim to develop an empirically-based model to link emigration with flow through repetitive investigations during years with varying Chinook salmon population sizes and/or environmental conditions. Additionally, we aim to develop procedures to quantify or index the size of the emigrating population. Ultimately, we propose to associate production and survival with environmental conditions by relating emigration data with information being collected on spawner population size, numbers and distribution of redds, and the dynamics of the rearing phase of Chinook salmon precedent to emigration.

METHODS

Anadromous fishes using the American River are restricted to the lowermost 23 miles, from Nimbus Dam to the Sacramento River (Fig. 1). Flow in this reach is regulated by Folsom Dam, which is operated by the U.S. Bureau of Reclamation (USBR) to provide water supplies, flood protection, hydroelectric power, and to maintain fish and wildlife habitats. Flow during the migration period can range from less than 1,000 cubic feet per second (cfs) to more than 100,000 cfs. Large amounts of debris typically accompany flow changes as increased stage picks up debris along the river margins. Urban runoff from several flood control drains also introduces a variety of debris into the river.

Emigrating salmonids were sampled using one 8-ft diameter and one 5-ft diameter rotary screw trap (RST). The traps were located immediately downstream of the Watt Avenue bridge at about river mile (RM) 9 (Fig. 1) on the north side of a large, mid-channel bar (Fig. 2). The same location was sampled during the previous five survey years. Sampling during the 1999 survey period extended from 2 October 1998 through 27 September 1999. The 8-ft diameter RST was used throughout the survey period; the 5-ft diameter trap was used during weeks 19–40 of 1999 (8 May–27 September 1999). Substantial interruptions in sampling occurred three times. Sampling was interrupted for 3 days during week 4 (17–23 January 1999), and for 3 days during week 8 (1–7 February); no sampling occurred during week 7. Interruptions were associated with increased flow and accompanying debris buildup.

Trap checks occurred at varying intervals depending upon the density of migrating salmonids and the potential for debris buildup. The RSTs were serviced two to three times a week from October through late December 1998. The traps were serviced at least every weekday and sometimes on weekends from late December 1998 through mid-January 1999, and then every day from mid-January through late May, except as noted above. Trap servicing during the last five months was conducted two to three times a week.

During each servicing, fish were removed from the trap, sorted, and counted by species (and race for Chinook salmon[1/]). All captured steelhead, and all salmon appearing to be outside the fall-run size criteria for the time of capture, were measured (fork length, FL, to the nearest 0.5 mm, and weight to the nearest 0.1 g). When the catch of fall-run-sized salmon was high (>300 fish per trap), a subsample of 150 fish from each trap was measured comprising 50 salmon taken at the beginning of the count, 50 taken midway through the count, and 50 taken at the end of the count. All measured salmonids were morphologically assessed as yolk-sac fry, fry, parr, silvery parr, or smolts. Yolk-sac fry were defined as newly-emerged fish with a visible yolk sack ("unzipped"). Fry were defined as recently-emerged fish with a fully absorbed yolk sac ("zipped-up") and undeveloped pigmentation. Parr were defined as

---

1/ Chinook salmon race was determined using size-at-time criteria developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Division.

darkly pigmented fish with characteristic dark, oval-to-round parr marks, no silvery coloration, and firmly set scales. Silvery parr were defined as fish having faded parr marks and a sufficient accumulation of purine to produce a silvery, but not fully smolted, appearance. Salmon lacking or having highly faded parr marks, a bright silver or nearly white color, a pronounced fusiform body shape, and deciduous scales were classified as smolts. If all captured fish were not classified or measured, the total weekly catch was expanded for each life stage by multiplying the weekly percentage of each life stage by the weekly count.

Flow data were obtained from USBR release records for Nimbus Dam. The City of Sacramento provided turbidity data (Nephelometric Turbidity Units, NTU) from measurements taken at the Fairbairn Water Treatment Plant at RM 7. Water temperature was continuously measured at the trap site throughout the survey period at two-hour intervals using an Onset Stowaway thermograph affixed to the RST. Water transparency (Secchi depth), water and air temperatures, and trapping effort (hours fished since last service) were measured and recorded at each servicing.

Trap efficiency was measured from 28 January 1999 (week 5) to 29 May 1999 (week 22). During the weeks when efficiency was measured, all captured salmon and steelhead were marked, using Bismarck Brown *Y* stain (Deacon 1961), then released approximately 0.9 km upstream of the trap. Marked fish were released from Saturday through Wednesday of each week. Recaptured fish caught from Sunday through Saturday were considered to have been released during the same week of capture. (The lag time between release and recapture observed during previous survey years showed that essentially 100% of all recaptured fish are collected within 4 days of release). The percentage of marked fish recaptured during the week provided a measure of trap efficiency.

An estimate of the total number of salmon emigrating past the trap site was made by dividing the expanded catch (to account for time in weeks when trapping occurred less than 100% of the time available) by mean trap efficiency. Weekly catches were expanded by multiplying the total number of potential trap hours for the week (e.g., 336 h per week for two traps) by the corresponding weekly catch rate[2/]. The mean trap efficiency was calculated as the mean of all measured trap efficiencies when the number of marked fish was ≥100 salmon.

2/ Catch during weeks 7 and 8 were expanded using a weighted catch rate. Catch in week 7 was estimated using the average catch rate measured during weeks 6 and 8 since sampling did not occur during week 7. Catch in week 8 was expanded using the mean catch measured during week 8.

RESULTS and DISCUSSION

General

Flow was moderately high during most of the 1998-99 survey period (Fig. 3). Initially, flow was maintained near 2,000 cfs from October through mid-November 1998, then increased to 3,000 cfs through the end of December 1998. The first high flow event occurred when flow peaked above 19,000 cfs in late January 1999. Flow then receded to 4,500 cfs before the second high flow event occurred during mid February when it peaked near 24,000 cfs on 10 February 1999. Higher flows persisted until mid-March when flow declined to 4,000 cfs then was maintained between 3,500 and 4,000 cfs until early August 1999.

Mean daily water temperature gradually declined from 60°F in early October 1998 to a low of 43°F in early February 1999 (Fig. 3), then gradually increased to a high of 66°F in mid August 1999. Mean daily temperature remained below 50°F from early December 1998 into mid-April 1999. It then increased to above 50°F in mid-April, 56°F in mid-May, 60°F in mid-June, and then 65°F in early August.

Measured turbidity averaged less than 3 NTU during the survey period. The highest turbidity level (19.2 NTU) occurred during the second high flow event in mid-February 1999 (Fig. 4). Turbidity averaged 5 NTU during the first high flow event (range: 3.2–9.3 NTU), and 8.5 NTU during the second event (range: 3.1–19.2 NTU). In comparison, turbidity was quite high in the 1997 survey period, surpassing 600 NTU, but it rarely exceeded 10 NTU during the 1994, 1995, 1996 and 1998 survey periods.

Twenty-one fish species were collected (Table 1). Juvenile Chinook salmon accounted for the majority of captured fish (n = 119,049), followed by Japanese smelt (n = 1,803), Pacific lamprey (n = 709), sculpin (n = 217), and Sacramento pikeminnow (n = 155).

Fall-run-sized Chinook Salmon

Fall-run Chinook salmon emigration spanned 34 weeks, from 11 December 1998 (week 50 of 1998) through 26 July 1999 (week 31 of 1999) (Table 2). A total of 118,986 fall-run Chinook salmon was caught in 6,215 hours of fishing effort (mean = 19.1 fish/h). Daily catch peaked several times between early February and early March 1999 (Fig. 5). Peaks in the daily catch reached at least 5,000 salmon/day during this period. The highest daily catch occurred during week 6 on 2 February (6,012 fish, 283 fish/h) (Figs. 5 and 6). The highest weekly catch (26,414 fish, 162 fish/h) occurred in week 10 (28 February–7 March 1999). The second greatest weekly catch occurred in week 6 and was just less than that observed during week 10 (22,678 fish, 142 fish/h) (Table 2, Figs. 7 and 8). The temporal distribution of emigration observed in 1999 was comparable to that observed in 1994, 1995, 1997 and 1998 (Snider and Titus 1995, Snider et al. 1997, Snider and Titus 2000, 2001). Although

Table 1. Summary of fish species collected during the 1999 lower American River emigration survey, October 1998 - September 1999. The species are listed in alphabetical order by common name.

	1998			1999									
Species	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
American Shad	0	0	1	0	0	0	0	1	1	12	4	1	20
Bullhead	0	0	0	0	1	0	0	0	0	0	0	0	1
Bluegill	52	49	9	2	2	0	0	0	0	0	0	2	116
Chinook salmon[3/] (fall-run)	0	0	57	13,779	46,807	56,255	852	885	330	21	0	0	118,986
Chinook salmon[3/] (spring-run)	0	0	3	1	1	2	0	1	0	0	0	0	8
Chinook salmon[3/] (winter-run)	0	1	13	3	1	1	0	0	0	0	0	0	19
Chinook salmon[3/] (late-fall-run)	0	0	1	0	0	0	27	4	1	3	0	0	36
Crappie	0	0	0	0	0	0	0	0	0	0	0	1	1
Gambusia	0	23	0	1	0	0	0	0	0	0	0	0	24
Golden shiner	0	1	0	0	1	0	0	1	0	0	0	0	3
Green sunfish	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardhead	0	0	0	0	0	0	5	0	0	0	0	0	5
Japanese smelt	0	0	40	166	824	762	5	6	0	0	0	0	1,803
Lamprey (ammocoete)	8	16	7	57	49	298	4	101	10	0	0	0	550
Lamprey (subadult)	1	5	2	67	38	20	3	21	0	0	0	0	157

Table 1. (cont.)

Species	1998			1999									Total
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Lamprey (adult)	0	0	0	0	1	1	0	0	0	0	0	0	2
Largemouth bass	0	0	0	0	0	0	0	0	0	0	0	2	2
Mississippi silverside	0	1	0	0	0	0	0	0	0	1	0	0	2
Sacramento Pike Minnow	3	100	10	3	1	13	3	1	0	16	2	3	155
Sculpin	0	0	17	12	19	41	10	7	1	15	30	65	217
Smallmouth bass	0	0	0	0	0	0	0	7	0	0	0	0	7
Splittail	0	0	0	0	0	0	0	0	0	0	0	0	0
Steelhead (YOY)	0	0	0	0	0	0	0	40	44	13	0	0	97
Steelhead (yearling)	1	0	0	0	0	0	0	1	0	0	0	0	2
Striped bass	0	0	0	0	0	0	0	0	0	0	0	1	1
Sucker	0	10	1	5	0	1	0	5	0	76	14	3	115
Threadfin shad	0	2	0	6	26	2	1	0	0	0	0	0	37
Tule perch	5	1	0	2	0	0	0	0	0	0	0	0	8
Warmouth	0	0	0	0	0	0	0	0	0	0	0	0	0
White catfish	0	0	0	3	0	0	0	0	0	0	0	0	3

3/ Chinook salmon race based upon size criteria developed by F. Fisher, California Department of Fish and Game

Table 2. Weekly catch statistics for juvenile fall-run Chinook salmon caught during the 1999 lower American River emigration survey, October 1998 - July 1999.

Week	Beginning Date	Hours fished	Total catch	Catch/h	Size statistics (FL in mm) Mean	Min	Max	SD
50	6 Dec 1998	166.25	4	0.02	30.8	28	33	2.2
51	13 Dec 1998	170.25	4	0.02	32.0	30	34	1.8
52	20 Dec 1998	140.5	17	0.12	33.6	29	37	1.9
1	27 Dec 1998	144.5	32	0.22	33.9	30	37	1.8
2	3 Jan 1999	214.5	132	0.62	34.8	30	38	1.5
3	10 Jan 1999	165.5	190	1.15	35.2	28	38	1.6
4	17 Jan 1999	95.5	304	3.18	36.4	33	40	1.5
5	24 Jan 1999	117.75	11,009	93.49	36.4	30	42	1.7
6	31 Jan 1999	160	22,678	141.74	37.4	30	45	1.8
8	14 Feb 1999	90	5,149	57.21	37.1	30	41	1.7
9	21 Feb 1999	167.5	17,060	101.85	37.3	31	45	1.7
10	28 Feb 1999	163.5	26,414	161.55	37.1	31	53	1.7
11	7 Mar 1999	140.25	18,482	131.78	37.2	31	54	1.9
12	14 Mar 1999	168.5	10,524	62.46	37.6	30	60	2.4
13	21 Mar 1999	162.5	3,326	20.47	38.4	32	69	3.2
14	28 Mar 1999	168.75	2,213	13.11	38.0	28	65	3.6
15	4 Apr 1999	146	133	0.91	38.3	34	64	3.7
16	11 Apr 1999	163.75	56	0.34	41.5	35	70	6.6
17	18 Apr 1999	168	6	0.04	42.8	38	52	5.0
18	25 Apr 1999	145.25	17	0.12	47.8	39	57	6.3
19	2 May 1999	122	15	0.12	66.9	48	83	12.9
20	9 May 1999	338.75	217	0.64	70.8	48	95	8.9
21	16 May 1999	279.75	284	1.02	71.7	50	98	7.5
22	23 May 1999	336.75	310	0.92	73.4	50	99	7.7
23	30 May 1999	286.75	216	0.75	76.9	55	96	7.8
24	6 Jun 1999	184.25	68	0.37	79.3	65	100	6.9
25	13 Jun 1999	382.75	60	0.16	80.5	70	91	5.2
26	20 Jun 1999	337.5	29	0.09	84.1	64	105	7.8
27	27 Jun 1999	238	22	0.09	80.8	70	87	5.0
28	4 Jul 1999	143.75	2	0.01	77.0	70	84	9.9
29	11 Jul 1999	195.75	7	0.04	87.3	73	98	8.4
30	18 Jul 199	136.75	4	0.03	81.0	76	87	4.7
31	25 Jul 1999	173.25	2	0.01	84.0	83	85	1.4
	Total	6,214.75	118,986	19.15	44.1	28	105	

1996 (Snider et al. 1998), several peak daily catches during weeks 9 and 10 were comparable to that the largest daily catch occurred about 4–5 weeks earlier (during week 6) than in 1994, 1995, 1997 and 1998, and only 1 week later than in observed in week 6 (5,237 in week 9 and 5,869 and 5,382 in week 10). Comparison with temporal distributions observed during the 1998 survey period show that the peaks of migration were coincident in both 1998 and 1999 when substantial peaks in migration occurred during weeks 6 and 10 in both survey years, and that the differences in the intra-annual magnitude of the peaks was very slight.

Fall-run salmon were caught each week beginning 11 December 1998 (week 50 of 1998) through 26 July 1999 (week 31 of 1999), except in week 7 when trapping did not occur (Fig. 7). The catch-rate increased from <0.1 fish/h in week 50 (of 1998) to essentially 100 fish/h or greater in weeks 5 through 11, except when trapping was interrupted during weeks 7 and 8 (Fig. 8). Catch rate peaked at 162 fish/h in week 10 (Fig. 8). After week 11, catch-rate decreased rapidly to less than 1 fish/h in week 15, and then to generally less than 0.5 fish/h through the end of July (Table 2, Fig. 8).

Fall-run Chinook salmon length ranged from 28 to 105 mm FL (Table 2). Mean weekly length ranged from 30.8 mm FL (week 50 of 1998) to 87.3 mm FL (week 29 of 1999) (Table 2, Fig. 9). Between week 50 of 1998 and week 18 of 1999, nearly all salmon caught (>99% of the catch) were recently-emerged-sized fish ($\leq$45 mm FL)[4/] (Figs. 9 and 10). Between 11 December 1998 (week 50) and 24 April 1998 (week 17), mean length increased very gradually from 30.8 mm to 42.8 mm (Table 2, Figs. 9 and 10). Mean length then increased from 47.8 mm FL in week 18 to 66.9 mm FL in week 19, then steadily increased to 84.1 mm FL in week 26 (20–26 June 1999). Mean FL remained near or above 80 mm FL for the next 5 weeks.

The length frequency distribution for all fall run exhibited two size groupings (Fig. 11). The first group ranged from 28 mm to 50–55 mm FL (mode = 37 mm FL). This group contained the majority of salmon caught. The second group ranged from about 55 mm to 105 mm FL (mode = 75 mm FL), and contained proportionately fewer captured salmon.

Life Stage Distribution

The fall-run Chinook salmon catch comprised 14.4% yolk-sac fry, 79.3% fry, 5.1% parr, 0.9% silvery parr, and 0.3% smolts (Table 3). Life stage composition in 1999 was similar to that observed in 1994, 1995, 1996, and 1998 but differed substantially from that observed in 1997 (Table 4). Notably, the

---

4/ The size classification identifies recently-emerged-sized salmon as being late-fall-run beginning 1 April. To maintain consistency with the race classification system, all recently emerged salmon collected after 1 April were designated as late-fall run, although the change in race designation appears to be an artificial break in a continuum of salmon emergence that lasted through 8 May 1998 (week 19).

Table 3. Expanded catch distribution of Chinook salmon life stages collected during the 1999 lower American River emigration survey, October 1998 - June 1999.

Week	Yolk-sac	Fry	Parr	Silvery parr	Smolt	Total
50	4	0	0	0	0	4
51	4	0	0	0	0	4
52	17	0	0	0	0	17
1	17	15	0	0	0	32
2	50	82	0	0	0	132
3	89	101	0	0	0	190
4	125	179	0	0	0	304
5	7,331	3,665	13	0	0	11,009
6	5,422	17,256	0	0	0	22,678
8	532	4,617	0	0	0	5,149
9	1,521	15,490	49	0	0	17,060
10	1,543	24,848	23	0	0	26,414
11	355	17,992	135	0	0	18,482
12	123	5,754	4,616	31	0	10,524
13	38	2,962	163	163	0	3,326
14	13	1,280	890	30	0	2,213
15	1	112	19	1	0	133
16	1	30	21	4	0	56
17	0	3	3	0	0	6
18	0	5	12	0	0	17
19	0	0	6	9	0	15
20	0	0	6	195	16	217
21	0	0	15	181	88	284
22	0	0	33	192	85	310
23	0	0	4	118	94	216
24	0	0	0	17	51	68
25	0	0	0	49	11	60
26	0	0	0	26	3	29
27	0	0	0	22	0	22
28	0	0	0	0	2	2
29	0	0	0	7	0	7
30	0	0	0	3	1	4
31	0	0	0	2	0	2
Total	17,186	94,391	6,008	1,050	351	118,986
Percent	14.4	79.3	5.1	0.9	0.3	100

Table 4. Life-stage composition of fall-run Chinook salmon captured during emigration surveys on the lower American River from 1994 through 1999. Values are percentages.

Life stage	1994[5/]	1995	1996	1997	1998	1999
Yolk-sac fry		3.5	22.6	12.5	14.6	14.4
Fry	96.7	70.5	59.6	35.8	79.1	79.3
Parr	1.6	25.5	17.4	47.7	5.5	5.1
Silvery parr	1.4	0.1	0.4	3.9	0.8	0.9
Smolt	0.3	0.4	0.0	<0.1	<0.1	0.3

5/ Yolk-sac fry and fry life stages were not differentiated in 1994.

proportion of parr caught in 1997 (47.7%) was much greater than in any other survey year. Similarly, the combined proportion of yolk-sac fry and fry was lower in 1997 than during the other four survey years. The combined proportion of yolk-sac fry and fry was 48.3% in 1997 compared with 96.7% in 1994, 93.7% in both 1998 and 1999, 82.2% in 1996, and 74.0% in 1995 (Table 4).

Fall-run yolk-sac fry (*n* = 17,186) were caught during every week from 11 December 1998 (week 50) to 17 April 1999 (week 16) (Table 3, Figs. 12 and 13). The peak yolk-sac fry catch occurred in week 5 (n = 7,331) (Fig. 13). Yolk-sac fry lengths were fairly uniform (Figs. 13 and 14). Lengths ranged from 28 to 40 mm FL (mean = 35.0 mm FL, SD = 1.9); 90% of yolk-sac fry were from 31 mm to 38 mm FL (Fig. 13). Mean weekly length increased from about 32 mm to a little more than 34 mm FL from week 50 to week 3 (Fig. 13), then remained between 35 and 36 mm FL through week 16 (except during week 13 when mean FL was 34.3 mm FL).

Fall-run fry (*n* = 94,391) were caught from 27 December 1997 (week 1 of 1999) through 1 May 1999 (week 18); 95% of the fry catch occurred from week 5 through week 12 (Table 3, Fig. 12). Fry numbers peaked in week 10 (*n* = 24,848; Fig. 13). Fry lengths appeared to be normally distributed (Fig. 14); 99% of measured fry were from 34 to 38 mm FL. Fry length ranged from 28 to 46 mm FL (mean = 37.1, SD = 1.7). Mean weekly fry length was relatively constant, ranging from 34.5 to 38.0 mm FL except during the last two weeks of their capture (weeks 17 and 18) when mean size was >40 mm FL (Fig. 13).

Fall-run parr (*n* = 6,008) were caught from 24 January 1999 (week 5) through 5 June 1999 (week 23) (Table 3, Fig. 12). Parr lengths ranged from 33 mm to 89 mm FL (mean = 39.8 mm FL, SD = 6.0) (Figs. 13 and 14); 95% of measured parr were from 33 to 55 mm FL (Fig. 14). A strong positive skew in parr length distribution (Fig. 14) suggests that the length at which salmon develop from parr to silvery parr is more variable than the length at which they develop from fry to parr. Mean weekly parr length was relatively high (weeks 5 through 11), then decreased and varied only slightly between week 12 and week 16 (mean FL = 38.7, SD = 2.7). Mean weekly parr length increased steadily from week 16 through week 23, from 47.0 to 67.8 mm FL (Fig. 13).

Fall-run silvery parr (n = 1,050) were caught from 14 March (week 12) to 24 July 1999 (week 31) (Table 3, Fig. 12). Catch peaked in week 20 (n = 195) (Fig. 13). As in 1998, there were two groups of emigrating silvery parr. The first group (n = 229) comprised early (weeks 12 through 16), relatively small (mean <55 mm FL) migrating fall run. The second group generally increased in both number (n = 818) and size (mean >70 mm FL) starting in week 19 and peaking in week 22. Silvery parr lengths ranged from 45 mm to 98 mm FL (mean = 71.4 mm FL, SD = 8.0) (Figs. 13 and 14).

A total of 351 fall-run smolts was collected from 9 May (week 20) to 19 July 1999 (week 30) (Table 3, Fig. 12). Size ranged from 69 mm to 105 mm FL (mean = 81.2 mm FL, SD = 6.0) (Figs. 13 and 14).

Fall-run Chinook salmon lengths varied significantly as a function of life stage (Kruskal-Wallis test of medians, $p<0.01$). Average length increased from about 35 mm FL in yolk-sac fry to 81 mm FL in smolts, although there was great overlap in size ranges in adjacent life stages as described above (Fig. 14).

Mark-recapture Trap Efficiency

Trap efficiency was measured nine times from week 5 through week 23 (24 January–29 May 1999) (Table 5). Trap efficiencies were distinctly calculated for those periods when only one 8-ft RST was being fished (week 50 of 1998–week 19 of 1999), and when two traps (one 5-ft diameter and one 8-ft diameter RST) were being fished (weeks 19–40). Trap efficiency for the single trap operation period was calculated using the results of measurements made from week 5 through week 13 (Table 5a), when 60,540 salmon were marked and 638 were recaptured. Overall trap efficiency was 1.05%. Percent recapture (efficiency) during this period ranged from 0.22% (week 9) to 2.08% (week 13) (Table 5a; Fig. 15). Mean weekly trap efficiency was 1.22% (SD = 0.74, 80% CI = 0.78–1.67). Trap efficiency when two traps were operating was calculated using the results of measurements made during weeks 22 and 23 (Table 5b). A total of 444 salmon was marked and five were recaptured during this two-week period. Mean efficiency was 1.14%.

Correlation analyses were run to determine the strength of the relationship among eight independent variables and trap efficiency (Table 6). These analyses were made to: (i) reveal and better understand any systematic influences on trap efficiency; and (ii) identify a potential predictor variable or combination of variables that might logically be used to estimate trap efficiency in weeks when mark-recapture trials were not conducted. With reliable trap efficiency estimates for each week, abundance estimates may then be made for each week based on an expansion of actual weekly catches and summed to provide a total estimate for the emigration season (see next section).

Moderately strong and significant correlations occurred with weekly mean river flow and weekly mean trap rotation rate (RPM) (Table 6). The significant negative correlation between efficiency and trap rotation rate suggests that as trap rotation rate increased, trap efficiency decreased. This result is counterintuitive because the entrainment principle with the screw trap is that trap efficiency is a positive function of approach velocity to the trap and resultant cone rotation rate up to some optimum (e.g., Kennen et al. 1994). An analysis of combined data for 1997-98 and 1998-99, when efficiency has been significantly and negatively correlated with trap rotation rate (Table 6), suggests consistency in

Table 5a. Results of rotary screw trap efficiency evaluations for a single, 8-ft diameter trap conducted with marked Chinook salmon during the 1999 lower American River emigration survey, October 1998 through September 1999.

Week	Number salmon marked	Number salmon recaptured	Efficiency (% recaptured)
5	Results discarded due to large numbers of salmon that were not checked for marks		
6	10,414	175	1.68
9	7,644	17	0.22
10	17,001	76	0.45
11	15,037	189	1.26
12	8,187	134	1.64
13	2,257	47	2.08
Total	60,540	638	1.05 (mean = 1.22)

Table 5b. Results of rotary screw trap efficiency evaluations for the combination of one 8-ft diameter and one 5-ft diameter trap conducted with marked Chinook salmon during the 1999 lower American River emigration survey, October 1998 through September 1999.

Week	Number salmon marked	Number salmon recaptured	Efficiency (% recaptured)
22	233	2	0.86
23	211	3	1.42
Total	444	5	1.13 (mean = 1.14)

Table 6. Correlation matrix of weekly, rotary screw trap capture efficiency for juvenile Chinook salmon, and (i) number of salmon marked per week for efficiency tests, (ii) total salmon catch per week, (iii) weekly mean salmon FL, (iv) weekly mean water temperature (°F), (v) weekly mean water turbidity (NTU), (vi) weekly mean river flow (cfs), (vii) weekly total trapping effort (h), and (viii) weekly mean trap rotation rate (rpm), during lower American River emigration surveys in 1995–1996, 1996–1997, 1997–1998, and 1998–1999.

Season	No. salmon marked	Total salmon catch	Mean FL	Mean water temp.	Mean turbidity	Mean river flow	Total trapping effort	Mean trap RPM
1995–96	–0.02	0.20	–0.08	0.11	–	–0.02	0.11	–
1996–97	–0.38	–0.31	0.12	0.76*	–0.05	0.05	0.26	0.13
1997–98	0.35	0.34	–0.19	–0.24	–0.11	–0.24	–0.54*	–0.70*
1998–99	–0.31	–0.37	–0.03	0.04	–0.66	–0.85*	–0.12	–0.88*

* Denotes a significant correlation at $p \leq 0.05$.

this relationship with a negative linear fit where *efficiency* = 4.19437 - 0.717167*Mean RPM, r^2 = 0.51, p<0.0001 (Fig. 16a). However, because there is a positive, linear relationship between trap rotation rate and flow for these years, where *mean RPM* = 2.94465 + 0.000187441**mean flow*, r^2 = 0.37, p = 0.0008 (Fig. 16b), we suspect that river flow is the primary determinant of trap efficiency in the relationship between these two variables.

Indeed, the significant negative correlation between trap efficiency and river flow in 1998-99 is an intuitive relationship although not one observed in three other years of identical analyses in which the trapping configuration on the lower American has been consistent (Table 6). While simple logic suggests that increases in river flow will result in decreases in efficiency simply by virtue of the fact that a trap is sampling a smaller proportion of the cross-sectional area of the channel, we also know from experience that trap efficiency can vary considerably within a flow level, for example, as a result of debris influences on trap function. There are probably also flow ranges within which efficiency does not change considerably, if the primary pathway the fish are traveling down the channel relative to the screw traps is not altered. For demonstration purposes, we used the negative exponential fit of trap efficiency on mean river flow to predict trap efficiency in weeks when not measured directly, where *efficiency* = exp(1.56222 - 0.000253465**mean flow*), r^2 = 0.82, p = 0.0019 (Fig. 16c). Weekly efficiencies – both measured and estimated – were used to generate weekly emigration totals that were then summed for the overall number of emigrants for the 1998-99 season (see next section).

Because screw trap efficiency on the lower American River has not varied consistently with any measured variable within observed ranges and levels of measurement resolution (Table 6), we also calculated the 1998-99 abundance of emigrating fall-run Chinook as in past annual reports (Snider and

Titus 1998, Snider et al. 1998, Snider and Titus 2000, 2001) by using the mean of weekly trap efficiency estimates along with confidence intervals using standard statistical methods (Zar 1984; next section).

Estimated Abundance of Emigrating Fall-Run Chinook Salmon

The total number of captured fall run (n = 118,986) was expanded to account for the time the traps were not fishing. The estimated number of fall-run salmon juveniles that would have been caught if the traps had fished 100% of the time when fall run were present was 150,891 (149,521 from week 50 of 1998 through week 19 of 1999, and 1,371 from week 20 through week 31 of 1999). This estimate was divided by the overall mean of weekly trap efficiencies[6/] to yield an expanded estimate of 12,566,322 emigrating salmon (80% CI = 9,912,066–17,162,037). This estimated total number of emigrants is intended to be used as an index of emigration rather than an absolute measurement *per se*.

The total number of emigrants based on the sum of weekly estimates was 48,724,628 salmon, about 3.9 times greater than the above estimate. Weekly mean efficiency, using the combination of directly-measured and model-estimated efficiencies, was 1.49%, about 19% greater than mean measured efficiency. At this point in the development of this work on the lower American, we have reservations about generating the emigration estimate with this method for two primary reasons. The first is that the model of efficiency as a function of weekly mean river flow was based on flows ranging from 4,060 to 10,860 cfs. However, weekly mean flow values were outside the modeled range in 13 of the 33 weeks that salmon were captured during the 1998-99 season. Ten mean flow values ranged from 2,524 to 4,031 cfs, while three values ranged from 10,930 to 17,443 cfs. While we do not know how significant an influence this disparity may have on applying the model to estimate efficiency in weeks when it was not measured directly, the practice does violate the rule of using a predictive model only within the range of independent variable values upon which the model is based (Zar 1984, p. 267).

The second and perhaps most important reason is that 1998-99 is the first season we have observed a strong and significant relationship between trap efficiency and river flow (Table 6). If there was indeed a predictable functional relationship between these two parameters, we would expect to see at least a stronger suggestion of such a trend in other years given consistency in both trap configuration in the river channel and approach to gear efficiency evaluation. Data analysis is underway for data collected during 1999-00 and 2000-01, and data for 2001-02 are currently being collected (B. Snider and R. Titus, CDFG, unpubl. data). These additional years of data should help us determine with more certainty whether there is an emerging functional relationship between trap efficiency and flow.

6/ This mean (1.20%; 80% CI ±0.32%) included efficiency measurements from weeks when both one and two traps were fished, as mean efficiency between these two groups did not differ significantly (t-test, t = 0.14, p = 0.89; F-test of variances, F = 3.43, p = 0.76).

Spring-run-sized Chinook Salmon

Juvenile spring-run-sized Chinook salmon were periodically captured from week 49 of 1998 (1 December 1998) through week 20 of 1999 (12 May 1999) (Table 7). In total, eight spring-run-sized Chinook juveniles were collected. Two of the eight were marginally larger than the minimum size criterion (i.e., within 3 mm FL) defining spring run for the date captured. One spring-run-sized salmon was classified as a yolk-sac-fry, one as a fry, three as parr, two as silvery parr, and one as a smolt.

Winter-run-sized Chinook Salmon

Nineteen juvenile winter-run-sized Chinook salmon were collected by RST (Table 8). These fish were captured from 29 November 1998 through 21 March 1999. All winter run were well within the size range defining winter-run juveniles for the dates of capture (at least 10 mm FL larger than the minimum size criteria). Ten of the winter-run-sized salmon were classified as parr, eight were classified as silvery parr, and one as a smolt.

Late-fall-run-sized Chinook Salmon

One yearling, late-fall-run sized salmon (126 mm FL) was captured on 30 December 1998 (Table 9). As discussed above, the size-at-time criteria used to classify Chinook salmon race defines recently-emerged-sized salmon as late-fall run beginning 1 April. We collected 32 recently-emerged salmon from 1 April to 2 July 1999 that were classified as late-fall run, and two larger late-fall run in late July 1999 (Table 9). The size range for these 35 salmon was 31–66 mm FL (mean = 37.1). The peak catch of YOY late-fall run (10 fish) occurred during week 16 (13–19 April 1999).

Table 7. Summary of catch statistics for spring-run-sized Chinook salmon collected during the 1999 lower American River emigration survey, October 1998 through September1999.

Week	Beginning date	Total catch	Size statistics (mm)			
			Mean	Min	Max	SD
49	29 Nov 1998	3	39.7	34	44	4.2
5	24 Jan 1999	1	52	52	52	0
6	31 Jan 1999	1	62	62	62	0
14	28 Mar 1999	2	76	72	80	4.0
20	9 May 1999	1	104	104	104	0
Total		8	66.7	34	104	

Table 8. Summary of catch statistics for winter-run-sized Chinook salmon collected during the 1999 lower American River emigration survey, October 1998 through September 1999.

Week	Beginning Date	Total Catch	Size statistics (mm)			
			Mean	Min	Max	SD
49	29 Nov 1998	9	61.1	50	70	5.9
1	27 Dec 1998	5	82.4	72	96	9.2
2	3 Jan 1999	1	75.0	75	75	0
5	24 Jan 1999	2	70.0	68	72	2.0
6	31 Jan 1999	1	105	105	105	-
13	21 Mar 1999	1	100	100	100	-
Total		19	72.7	50	105	

Table 9. Summary of catch statistics for late-fall-run-sized Chinook salmon collected during the 1999 lower American River emigration survey, October 1998 through September 1999.

Week	Beginning Date	Total Catch	Size statistics (mm)			
			Mean	Min	Max	STD
1	27 Dec 1998	1	126.0	126.0	126.0	-
14	28 Mar 1999	1	33.0	-	-	-
15	4 Apr 1999	5	33.0	31.0	34.0	1.2
16	11 Apr 1999	10	34.4	32.0	35.0	1.0
17	18 Apr 1999	5	34.8	32.0	37.0	1.9
18	25 Apr 1999	6	36.3	35.0	38.0	1.2
19	2 May 1999	2	35.5	35.0	36.0	0
21	16 May 1999	2	34.5	34.0	35.0	0.7
23	30 May 1999	1	49.0	49.0	49.0	-
27	27 Jun 1999	1	39.0	39.0	39.0	-
30	18 Jul 1999	2	65.5	65.0	66.0	0.7
	BY 1998	1	126.0	-	-	-
Totals	BY 1999	35	37.1	31.0	66.0	-

Steelhead Trout

Juvenile steelhead captured in the RSTs represented two groups: young-of-the-year (typically <100 mm FL), and in-river produced yearlings (typically 100–300 mm FL) (Table 10). A total of 97 YOY steelhead was captured from week 20 (9 May 1999) through week 31 (1 August 1999) (Fig. 17). Most YOY (54%) were captured during weeks 22–24. The highest weekly catch occurred during week 22 (20 fish). Mean weekly length ranged from 40.4 mm FL in week 20 to 93.5 mm FL in week 31 (Fig. 18).

Life stage was identified for 83 YOY steelhead (Table 11). One was classified as a fry, 55 as parr, 26 as silvery parr, and one as a smolt. Two, in-river-produced, yearling steelhead were caught; one in week 41 of 1998 (4–10 October 1998) and one in week 22 (23–29 May 1999) (Table 10; Fig. 17). Fish lengths were 192 and 195 mm FL (Fig. 18). The life stage of the only yearling steelhead that could be classified was identified as a smolt (Table 11).

Table 10. Summary of steelhead catch statistics, lower American River emigration survey, October 1998 - June 1999.

	Young-of-the-Year		Yearlings	
Week	Count	Mean FL (range) in mm	Count	Mean FL (range) in mm
41			1	195
20	12	40.4 (33–46)		
21	5	53.6 (48–74)		
22	20	53.1 (35–69)	1	192
23	13	59.8 (46–79)		
24	19	63.3 (48–83		
25	2	65.5 (63–68)		
26	7	69.1 (51–89)		
27	8	84.5 (69–102)		
29	5	80.8 (69–92)		
30	4	81.5 (69–94)		
31	2	93.5 (87–100)		
Total	97	61.9 (33-102)	2	193.5 (192-195)

Table 11. Life stage composition and size statistics, by age group, for steelhead caught during the 1999 lower American River emigration survey, October 1998 through September 1999.

	Young-of-the-Year		Yearlings	
Life stage	Count	Mean FL (range) in mm	Count	Mean FL (range) in mm
Fry	1	33		
Parr	55	55.8.(34-84)		
Silvery parr	26	73.1 (48-96)		
Smolts	1	102	1	192

ACKNOWLEDGMENTS

The California Department of Fish and Game would like to recognize the many staff members that participate in the 1998-99 lower American River emigration survey including: Nina Bacey, Katherine Berry, Anthony Ciarico, Robert Coyan, Bill Guthrie, Matt Icanberry, Jennifer Ikemoto, Warren Nichols, Shawn Oliver, Brigid Payne, Glenn Sibbald, Bob Solecki, Steven Stiehr, Ray Von Flue, C. J. White, Olivia Willis, and Celia Zamora.

REFERENCES

Deacon, J. E. 1961. A staining method for marking large numbers of small fish. Progressive Fish-Culturist 23:41–42.

Kennen, J.G., S.J. Wisniewski, N.H. Ringler, and H.M. Hawkins. 1994. Application and modification of an auger trap to quantify emigrating fishes in Lake Ontario tributaries. North American Journal Journal of Fisheries Management 14:828–836.

Park, D.L. 1969. Seasonal changes in downstream migration of age-group 0 Chinook salmon in the upper Columbia River. Transactions of the American Fisheries Society 2:315-317.

Snider, B. 1992. Emigration survey lower American River 1992. Calif. Dept. Fish and Game, Environmental Services Division, unpubl. rpt. 14 pp.

Snider, B. and R.G. Titus. 1995. Lower American River emigration survey November 1993–July 1994. Calif. Dept. Fish Game, Environmental Services Division, unpubl. Rpt. 102 pp.

Snider, B. and R.G. Titus. 1998. Evaluation of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing November 1995–July 1996. Calif. Dept. Fish Game, Environmental Services Division, unpubl. Rpt. 71 pp.

Snider, B., R.G. Titus and B.A. Payne. 1997. Lower American River emigration survey November 1994–September 1995. Calif. Dept. Fish Game, Environmental Services Division, unpubl. Rpt. 16 pp plus figures and appendix.

Snider, B., R.G. Titus and B.A. Payne. 1998. Lower American River emigration survey October 1995–September 1996. Calif. Dept. Fish Game, Environmental Services Division, unpubl. Rpt. 19 pp plus figures and appendix.

Snider, B. and R.G. Titus. 2000. Lower American River emigration survey October 1996–September 1997. Calif. Dept. Fish Game, Habitat Conservation Division, Stream Evaluation Rpt. 00-2, unpubl. Rpt. 25 pp plus figures and appendix.

Snider, B. and R.G. Titus. 2001. Lower American River emigration survey October 1997–September 1998. Calif. Dept. Fish Game, Habitat Conservation Division, Stream Evaluation Rpt. 01-6, unpubl. Rpt. 21 pp plus figures and appendix.

Zar, J. H. 1984. Biostatistical analysis, 2nd ed. Prentice Hall, Englewood Cliffs, NJ. 718 pp.

APPENDIX

Appendix I. Comparison of results from lower American River emigration surveys conducted 1994 through 1999.

	Survey Year					
	1994	1995	1996	1997	1998	1999
Salmon emigration start date (fall run juveniles)	Week 2 (of 1994)	Week 51 (of 1994)	Week 48 (of 1995)	Week 51 (of 1996)	Week 51 (of 1997)	Week 50 (of 1998)
Salmon emigration end date	Week 28	Week 32	Week 29	week 25[1/]	Week 31	Week 31
Date of peak salmon catch	23 Feb	24 Feb	26 Jan	25 Feb	7 Mar	2 Feb
Maximum daily salmon catch	14,887	3,371	12,285	3,083	9,219	6,012
Maximum daily salmon catch rate	677 fish/h	141 fish/h	614 fish/h	54 fish/h	397 fish/h	283 fish/h
Total salmon catch	162,089	45,478	132,040	32,064	194,819	119,049
Total steelhead catch	43	30	145	112	117	99
Average juvenile salmon catch	30.4 fish/h	9.6 fish/h	25.6 fish/h	7.4 fish/h	21.9 fish/h	19.2 fish/h
<u>Salmon life stage composition</u>						
Yolk-sac fry		3.5%	22.3%	12.5%	14.6%	14.4%
Fry	96.7%[2/]	70.5%	50.7%	35.8%	79.0%	79.3%
Parr	1.6%	25.5%	20.6%	47.7%	5.5%	5.1%
Silvery parr	1.4%	0.1%	2.3%	3.9%	0.8%	0.9%
Smolt	0.3%	0.4%	--	0.01%	0.03%	0.3%

1/ Trapping was ended before catch reached zero.
2/ Yolk-sac fry and fry combined as one life stage in 1994.
3/ Only includes fish $\geq$40 mm FL

Appendix II. Comparison of results from lower American River emigration surveys conducted 1994 through 1999 and corresponding spawner escapements.

	Survey Year					
	1994	1995	1996	1997	1998	1999
Total catch (fall run)	162,089	45,478	132,040	32,064	194,409	150,891
Mean efficiency	0.72	0.72[1/]	0.68	0.75	1.09	1.22
Estimated emigration population	18.2 million	5.9 million	20.3 million	4.3 million	18.9 million	12.4 million
Spawner escapement	28,754	27,733	65,972	67,000	46,888	43,042
Emigration survival index	633	213	308	64	405	287

1/ Estimated as the mean efficiency observed during 1994, 1996 and 1997.

FIGURES

LOWER AMERICAN RIVER

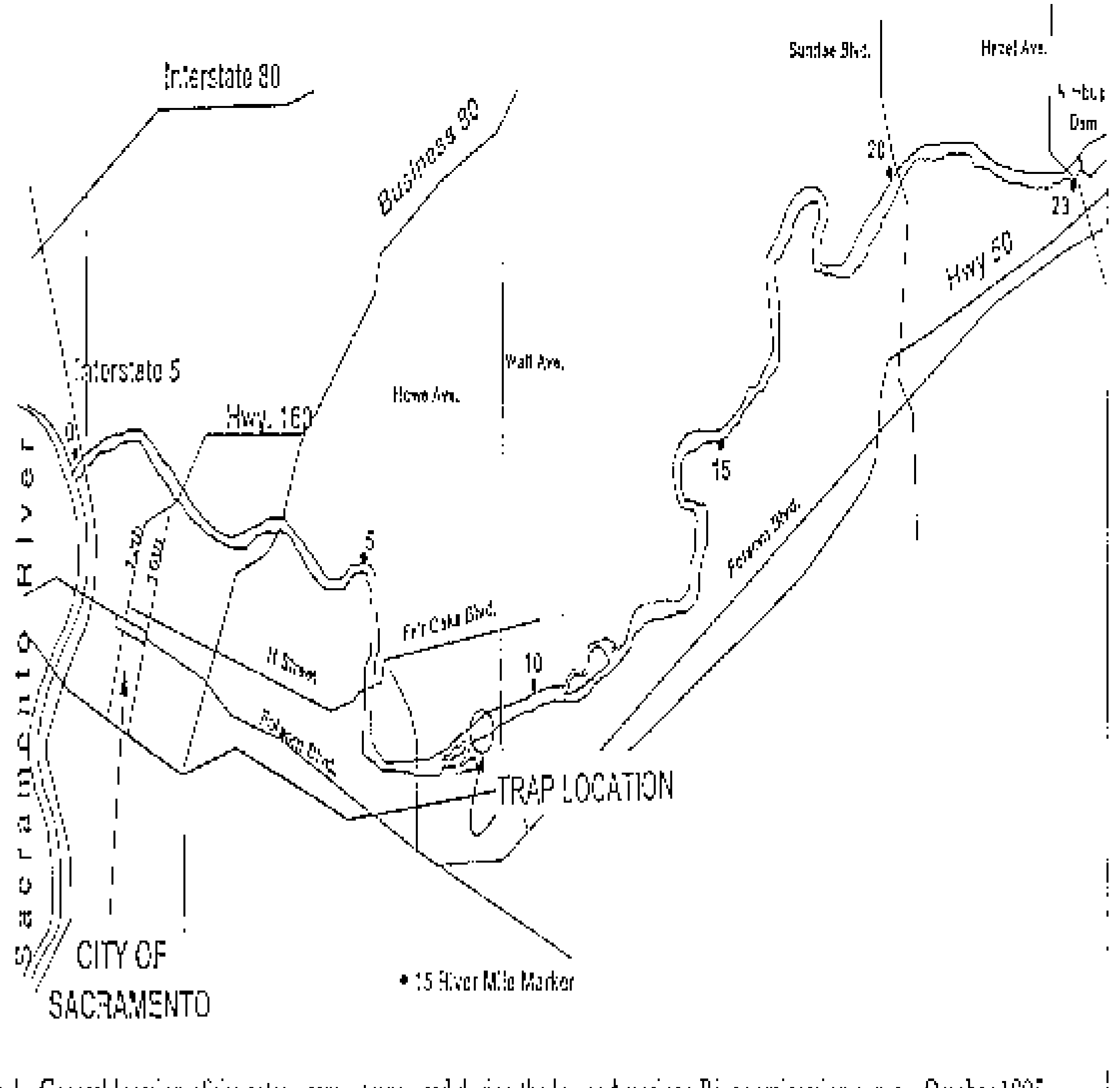

Figure 1. General location of the rotary screw traps used during the lower American River emigration survey, October 1995 -

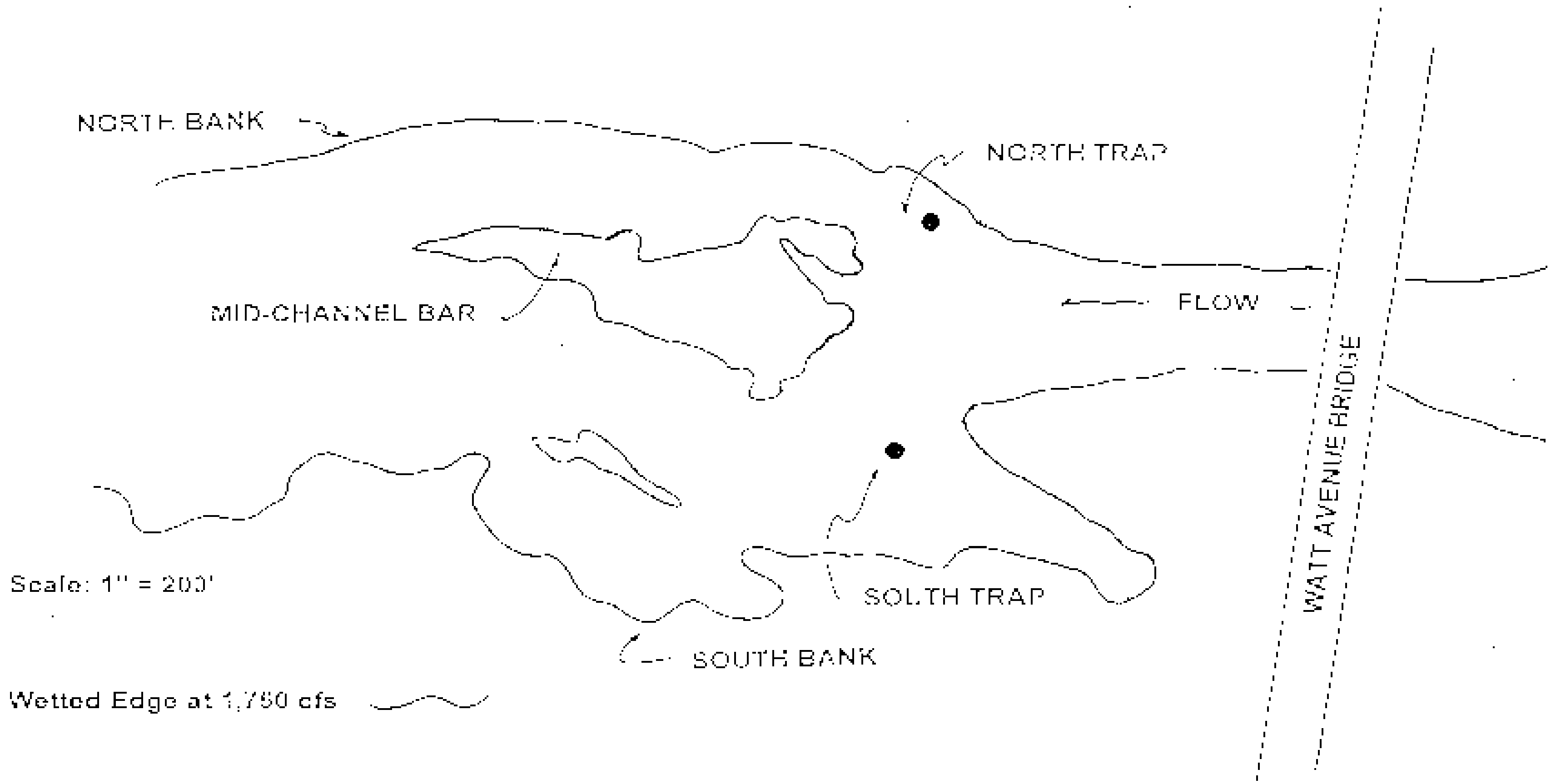

Figure 2. Specific location of the rotary screw traps near river mile 9 of the lower American River, October 1995 -September

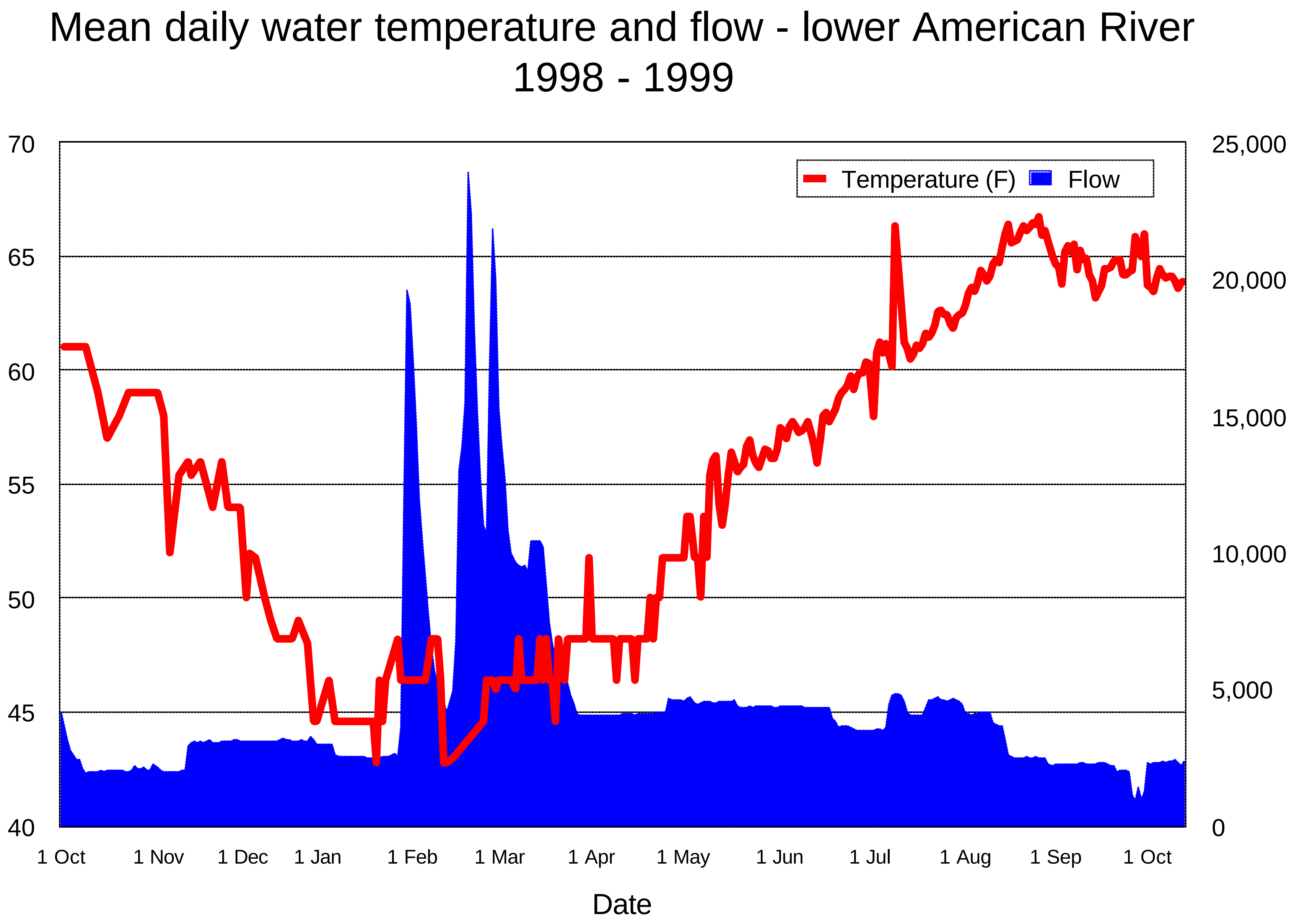

Figure 3. Mean daily flow (cfs), measured at Nimbus Dam, and water temperature (F), measured at Watt Avenue, during the lower American River emigration survey, October 1998 through September 1999.

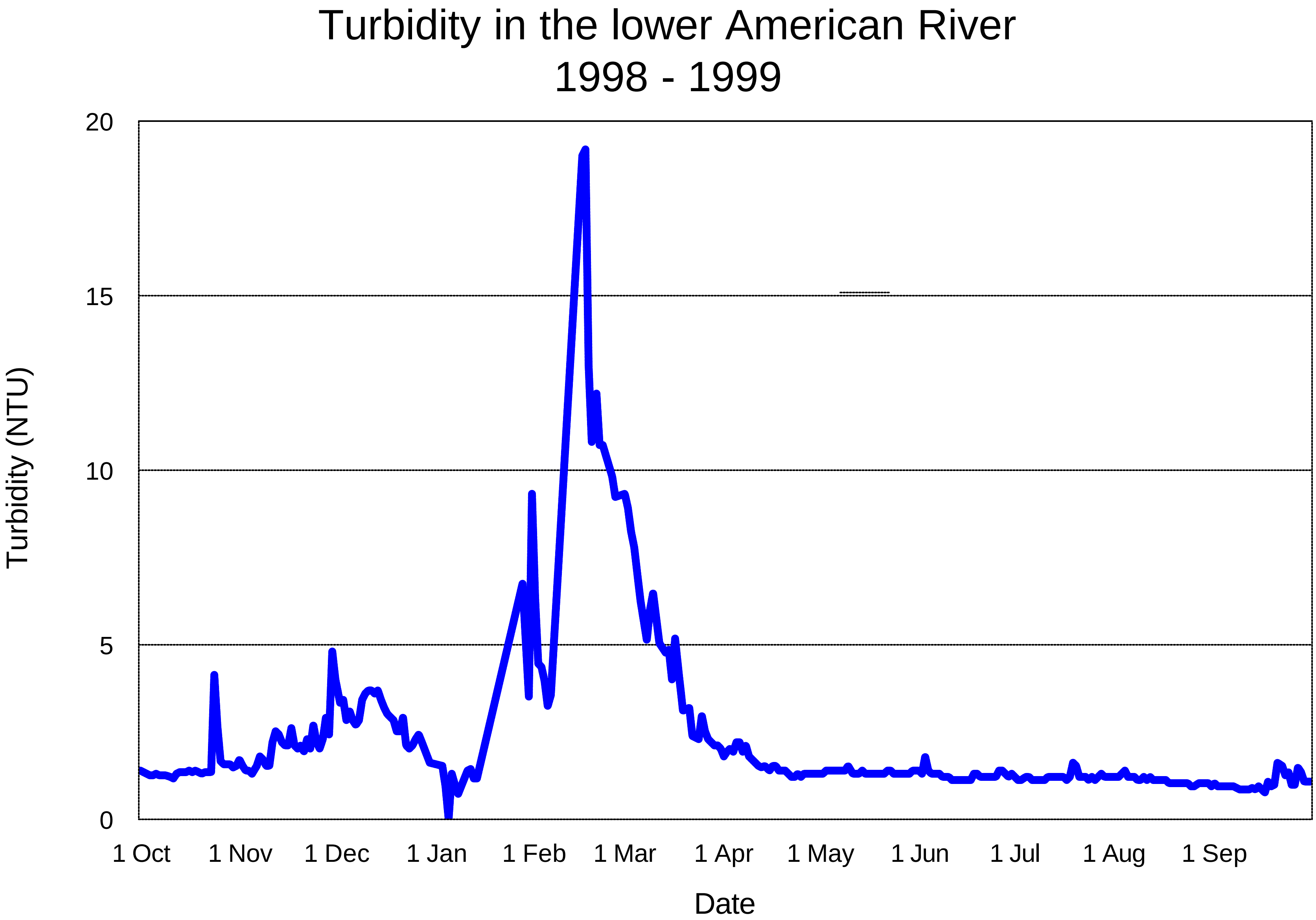

Figure 4. Water turbidity (NTU) measured at the Fairbairn Water Treatment Plant during the lower American River emigration survey, October 1998 through September 1999.

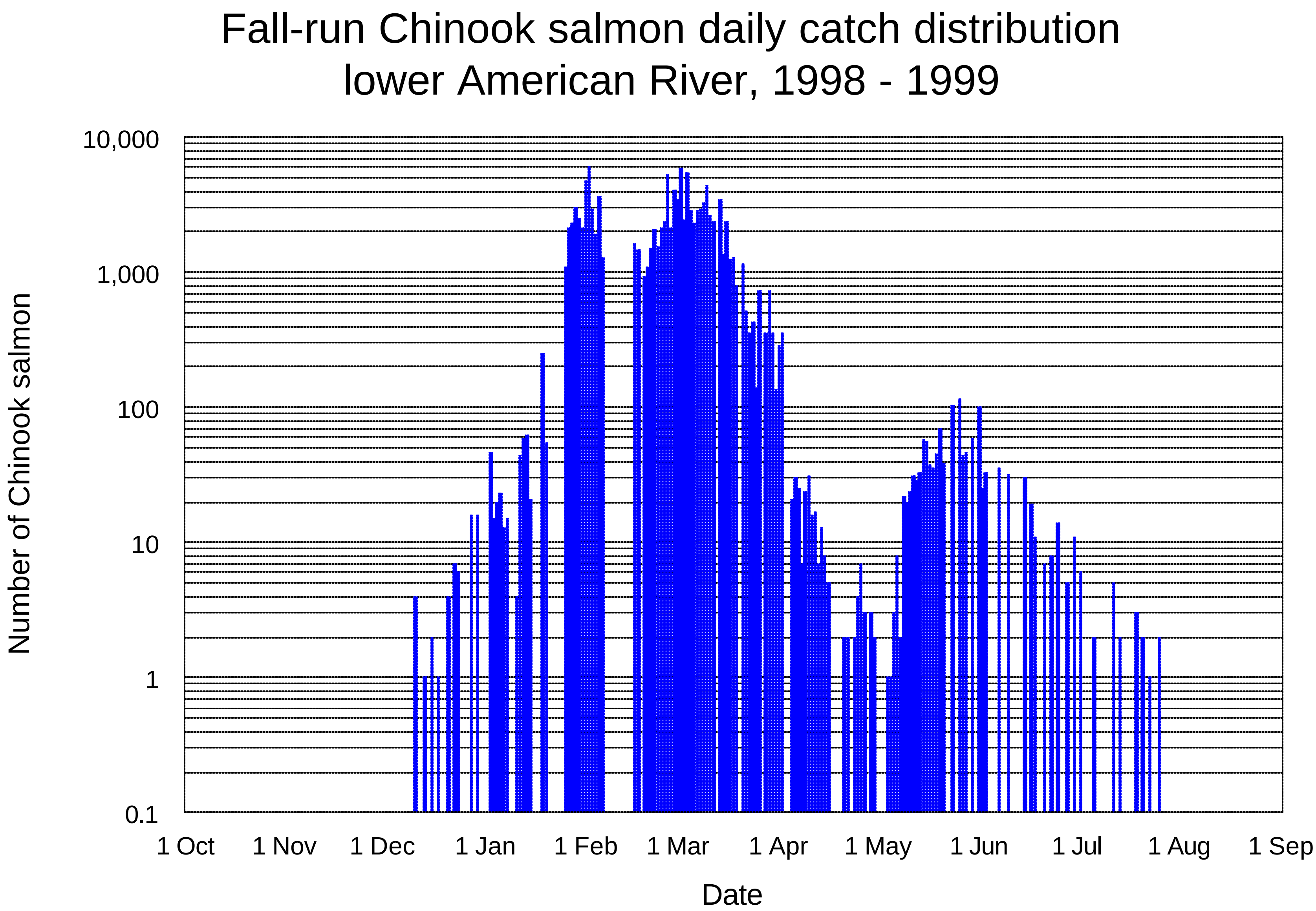

Figure 5. Daily catch distribution of fall-run Chinook salmon caught by screw trap during the 1999 lower American River emigration survey, October 1998 through September 1999.

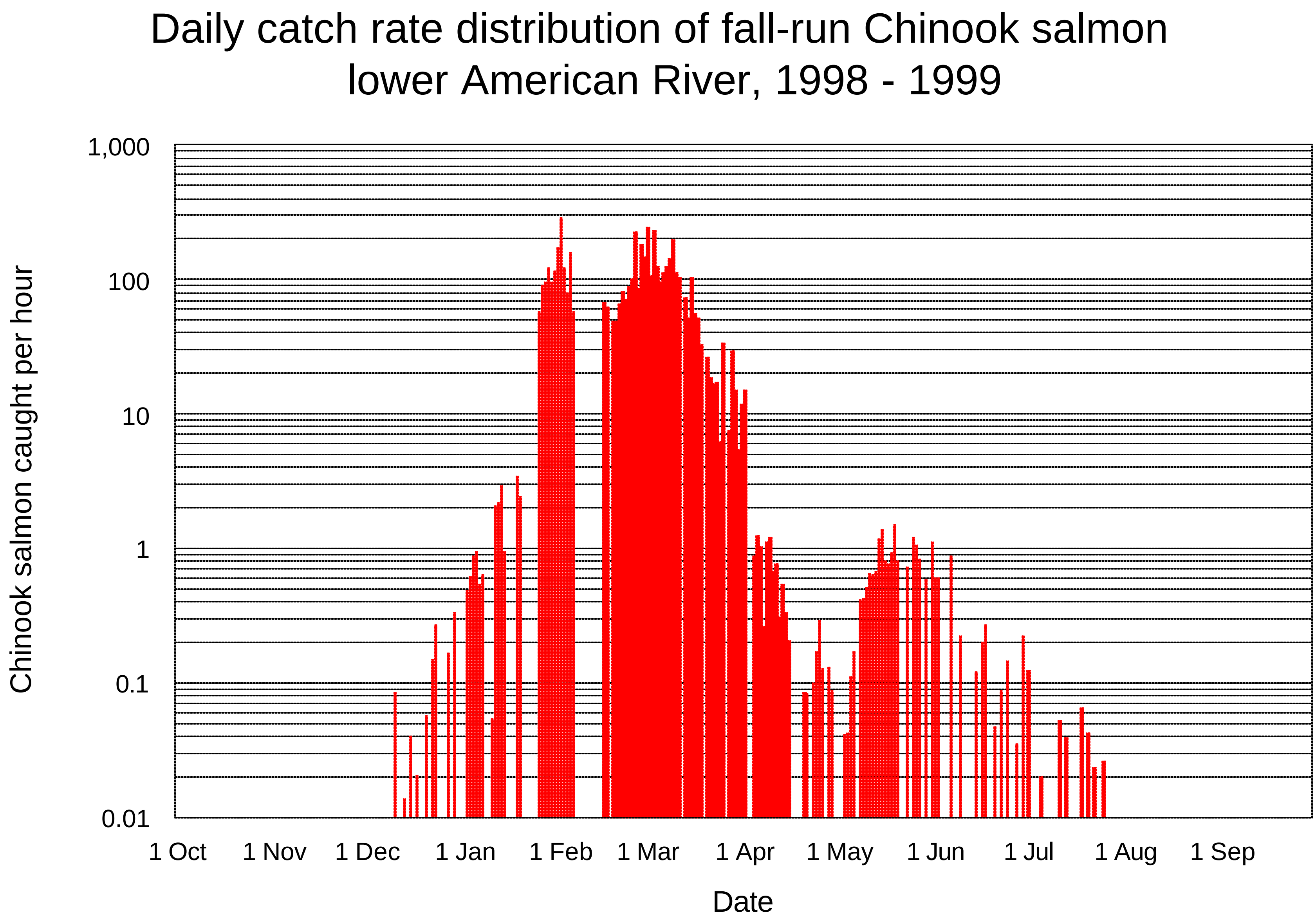

Figure 6. Daily catch rate (n/ hour) of fall-run Chinook salmon caught by screw trap during the 1999 lower American River emigration survey, October 1998 through September 1999.

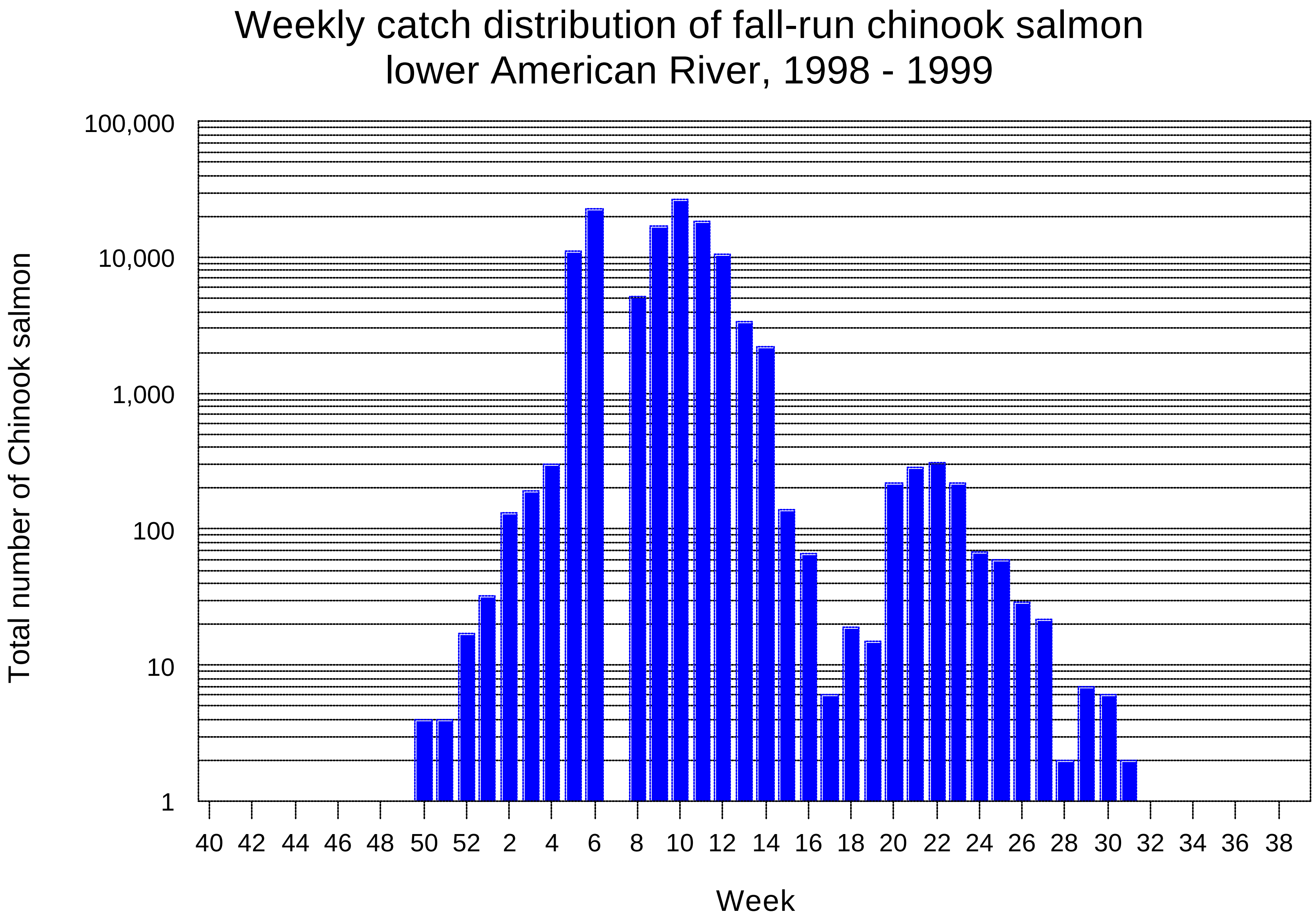

Figure 7. Weekly catch distribution of fall-run Chinook salmon caught by rotary screw trap during the lower American River emigration survey, October 1998 through September 1999.

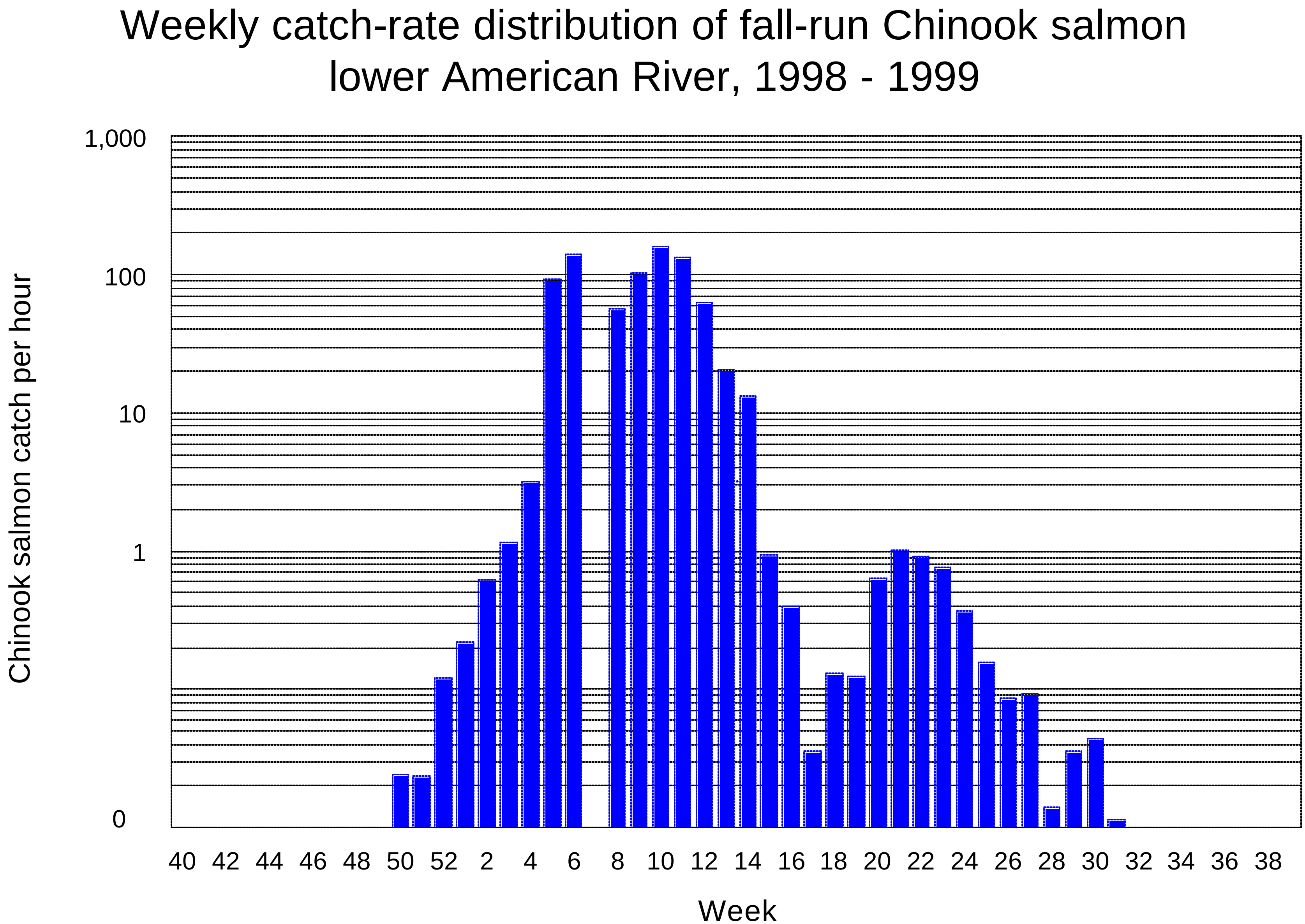

Figure 8. Mean weekly catch rate (n/hour) for fall-run Chinook salmon caught by rotary screw trap during the lower American River emigration survey, October 1998 through September 1999.

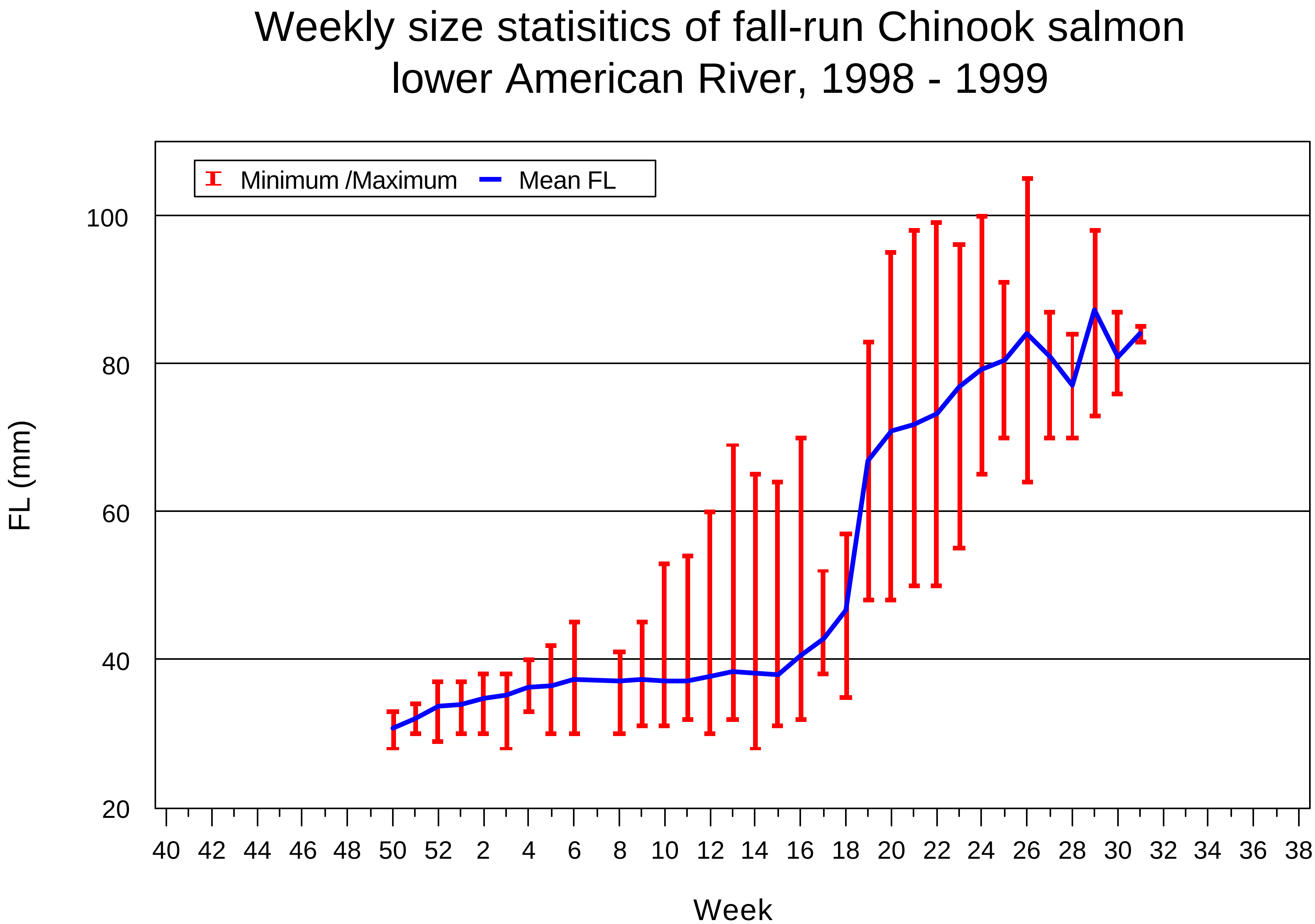

Figure 9. Mean weekly fork length and size range of fall-run Chinook salmon caught by screw trap during the 1999 lower American River emigration survey, October 1998 through September 1999.

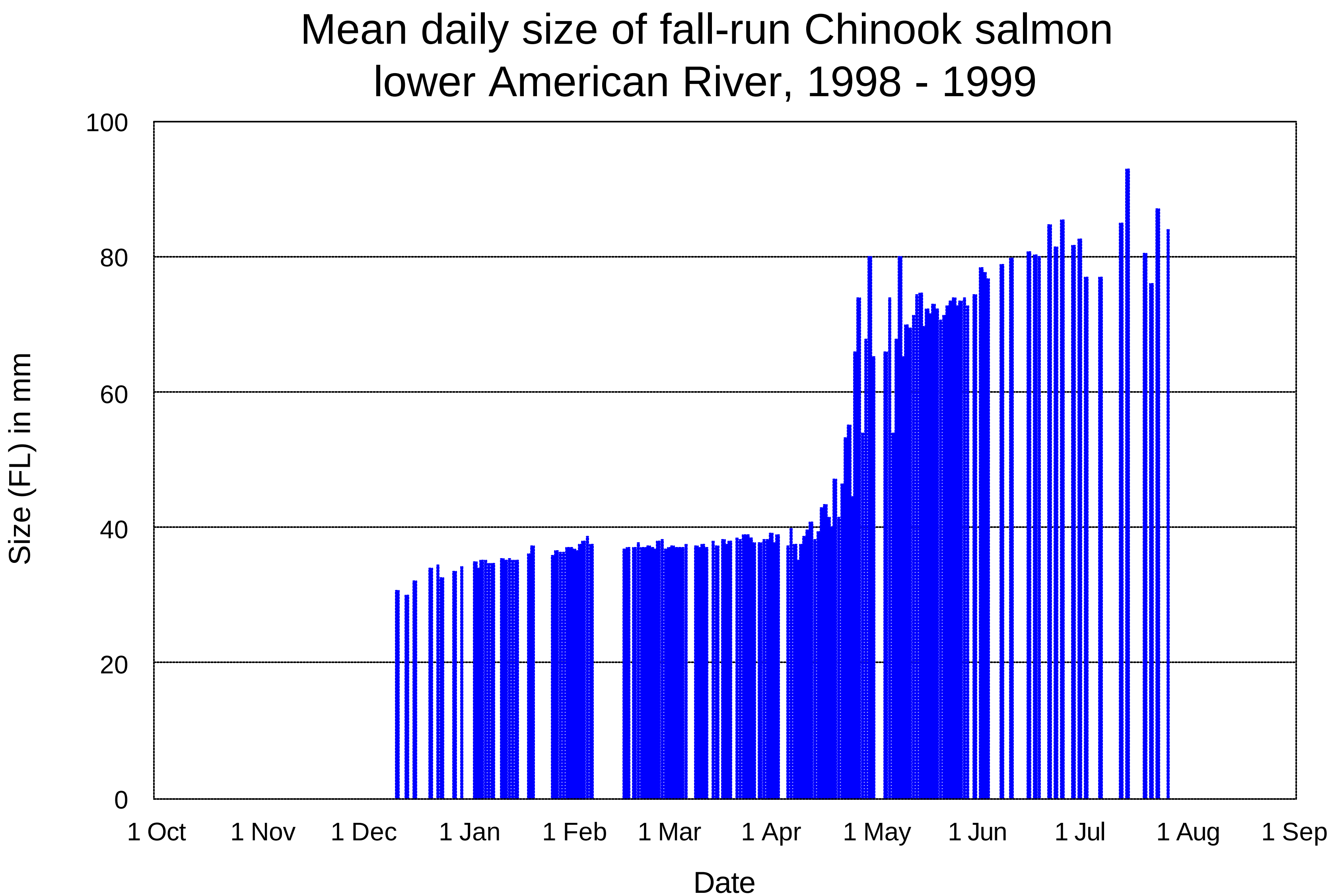

Figure 10. Mean daily fork length of fall-run Chinook salmon caught by screw trap during the 1999 lower American River emigration survey, October 1998 through September 1999.

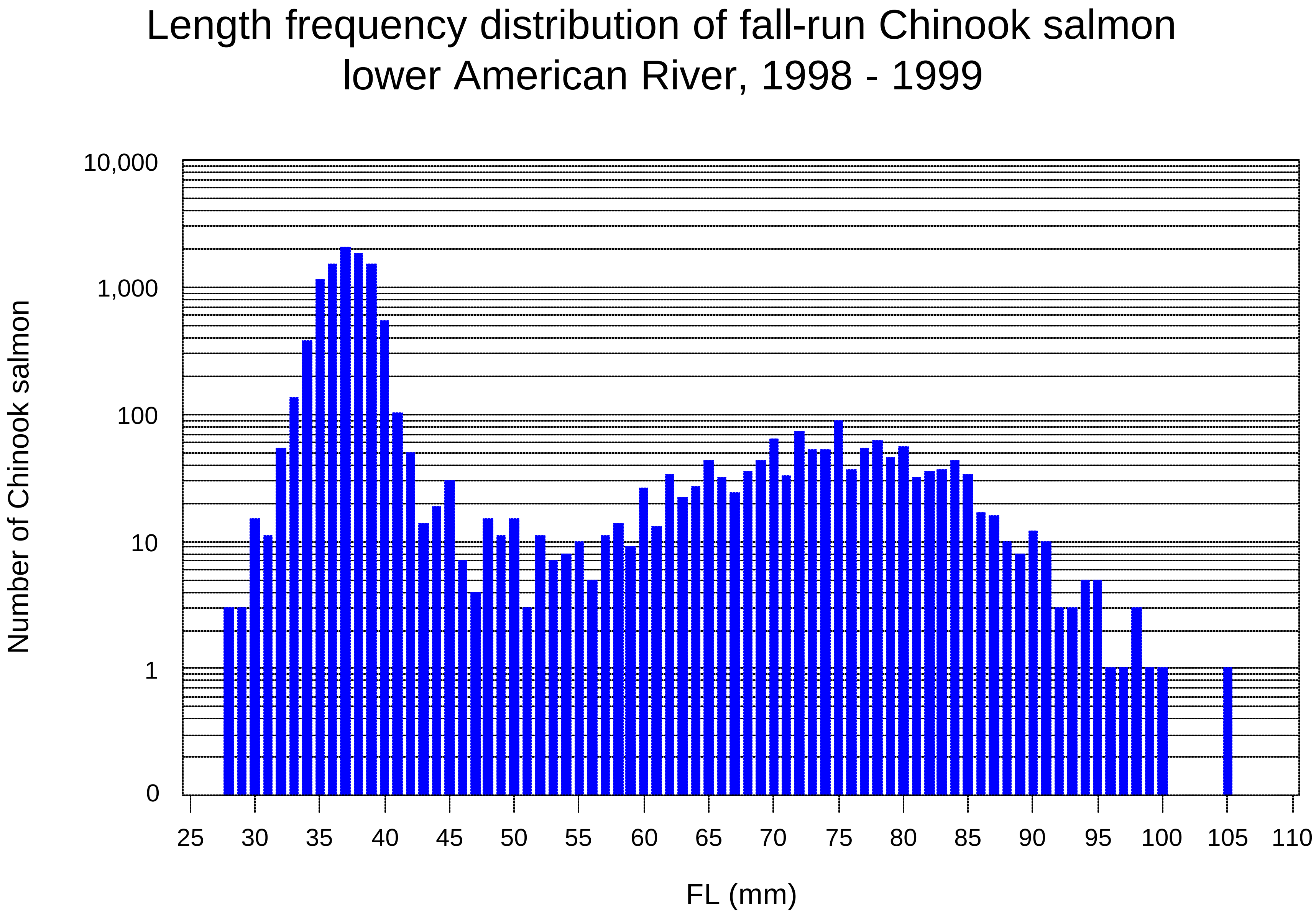

Figure 11. Length frequency distribution of fall-run Chinook salmon caught by rotary screw trap during the 1999 lower American River emigration survey, October 1998 through September 1999.

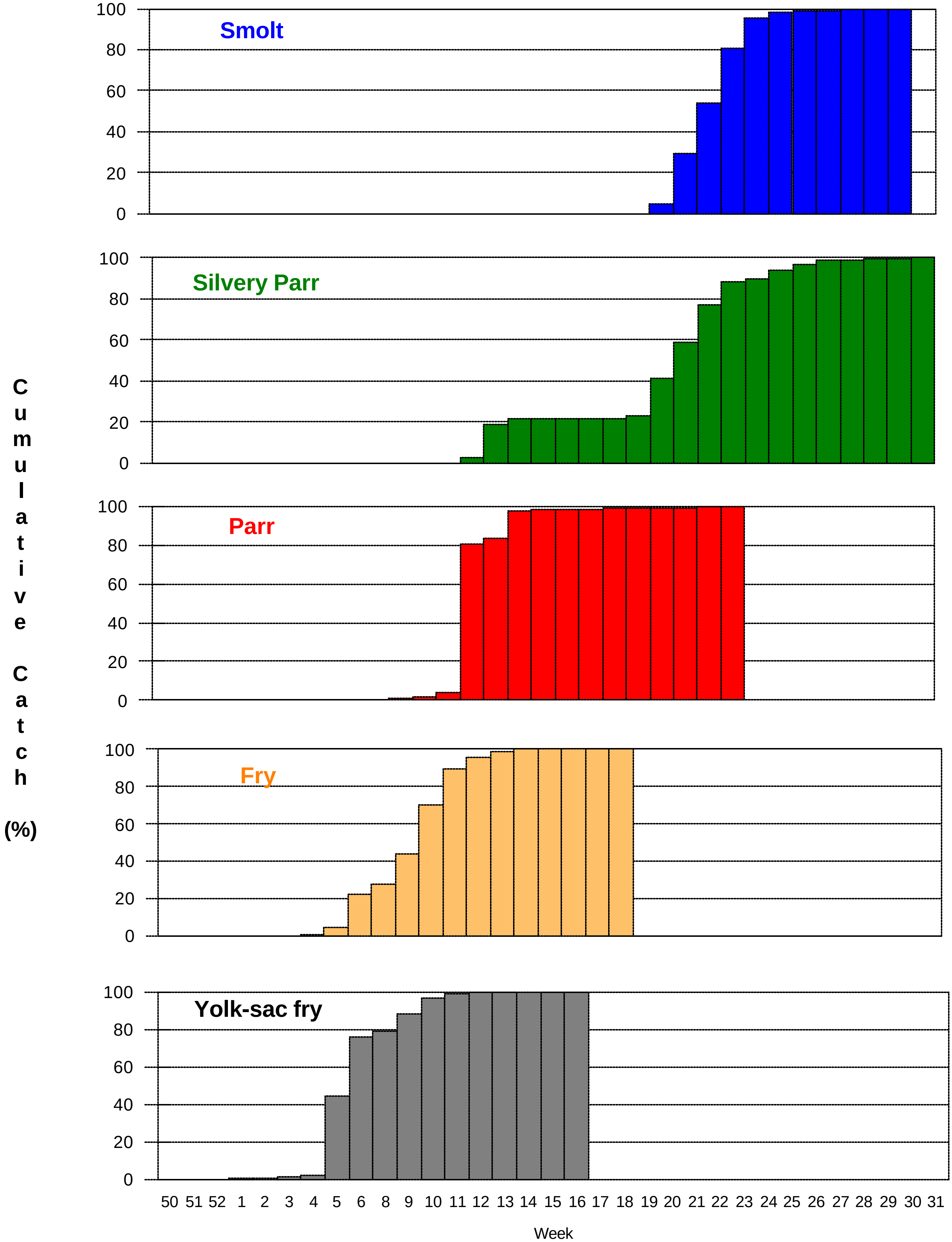

Figure 12. Cumulative catch (%) of fall-run Chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected during the 1999 lower American River emigration survey, October 1998 through September 1999.

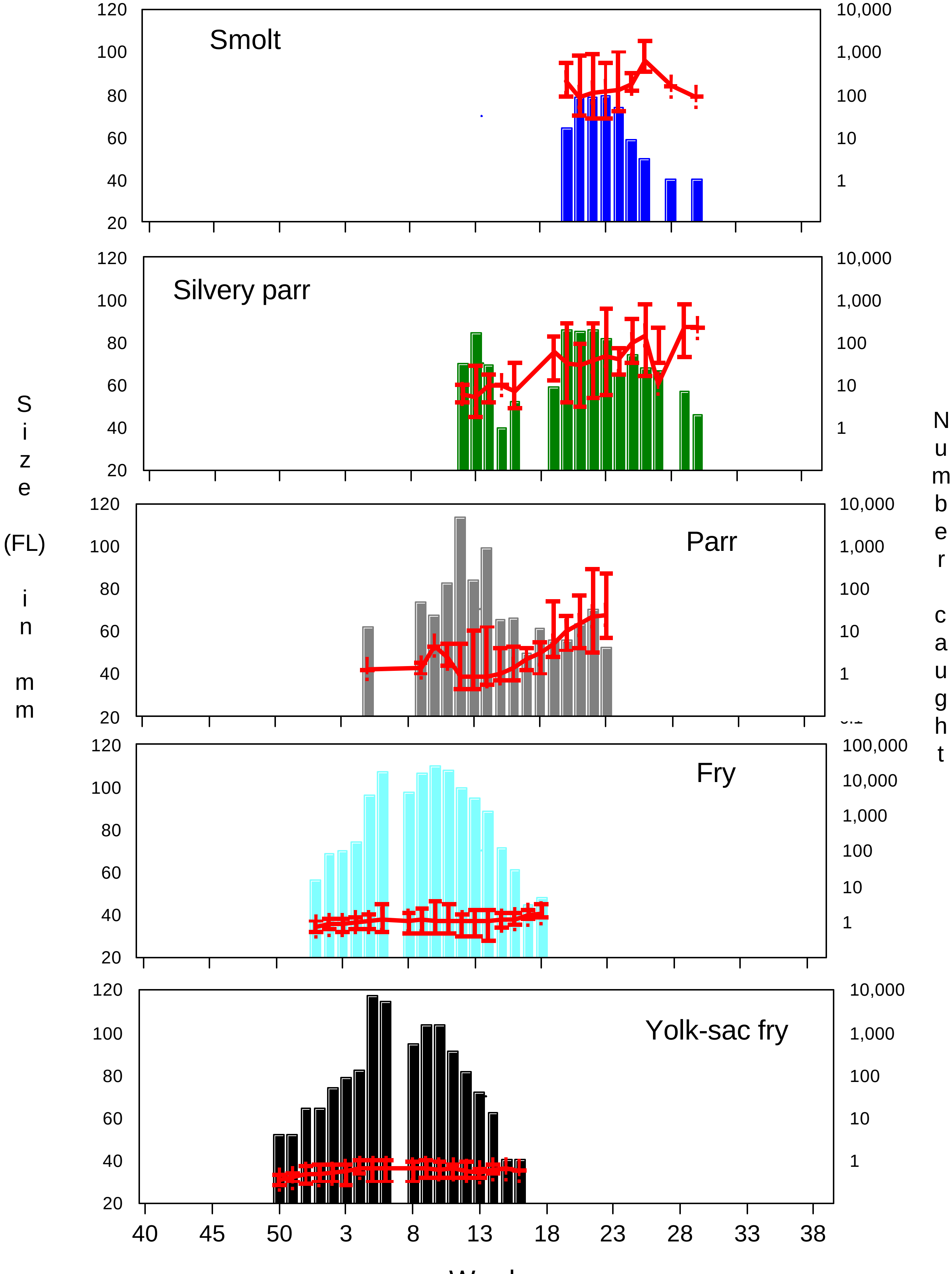

Figure 13. Weekly size and catch distribution of fall-run Chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected by rotary screw trap during the lower American River emigration survey, October 1998 through September 1999.

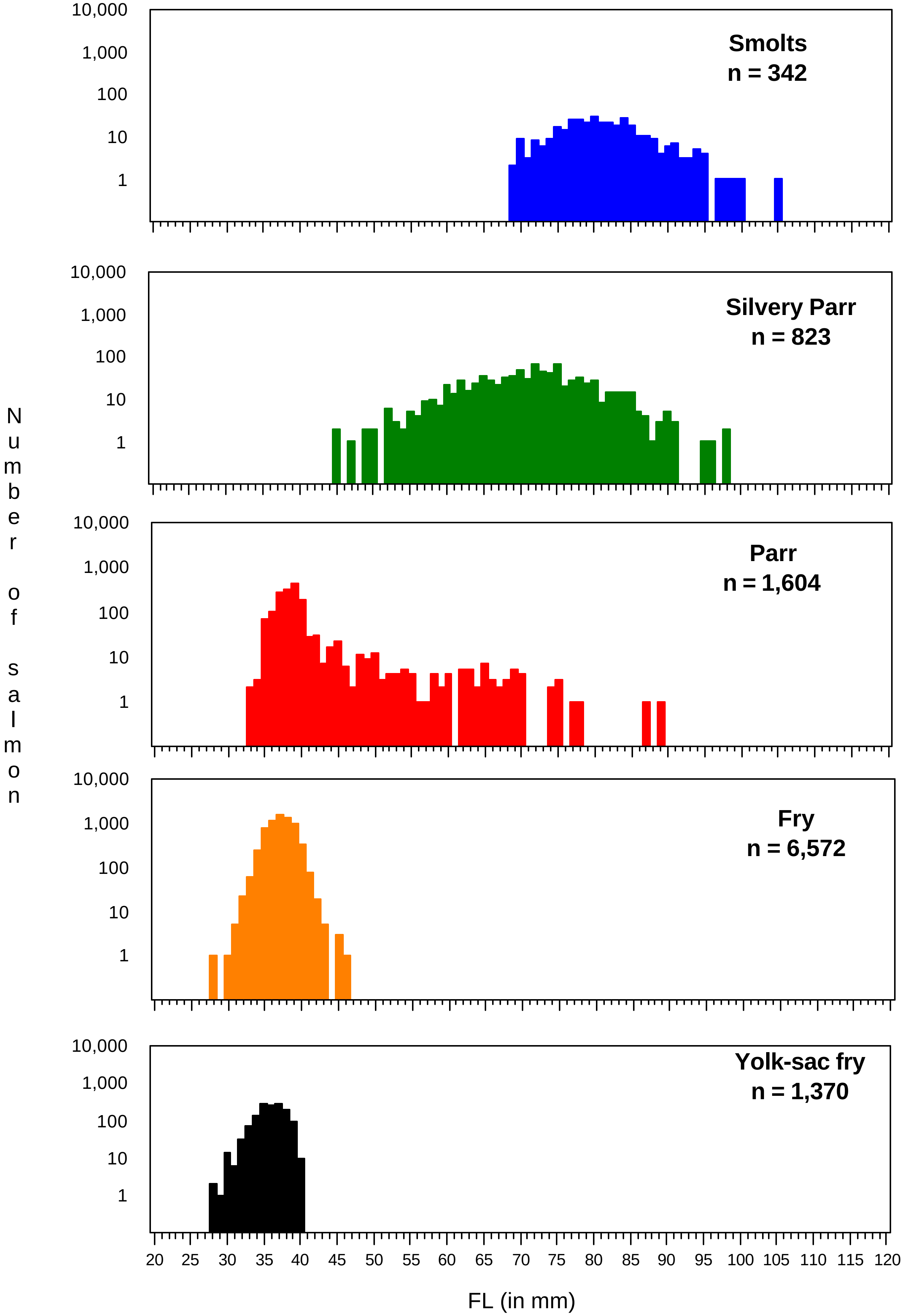

Figure 14. Length frequency distribution of fall-run Chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected during the lower American River emigration survey, October 1998 - September 1999.

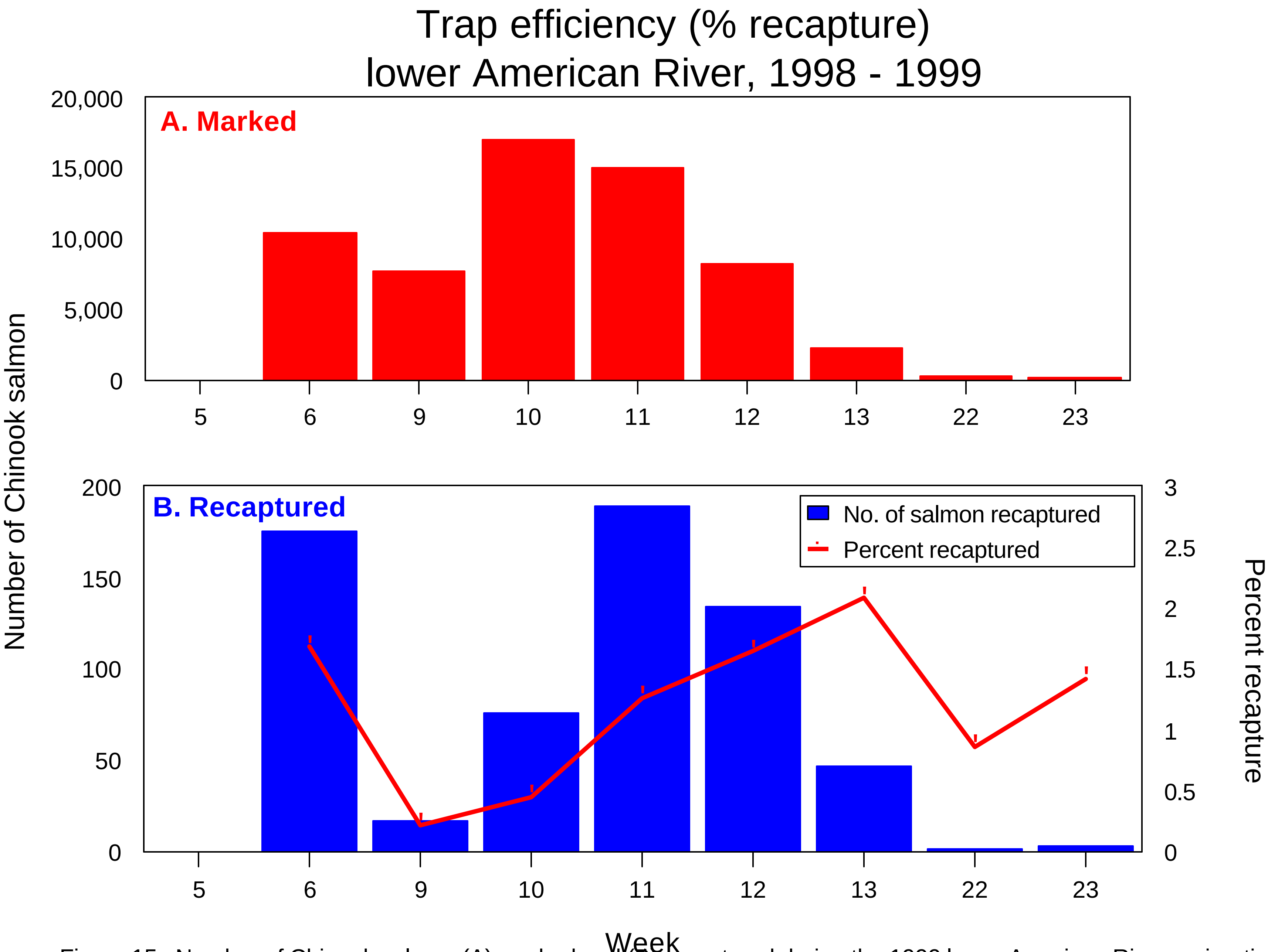

Figure 15. Number of Chinook salmon (A) marked and (B) recaptured during the 1999 lower American River emigration survey, October 1998 through September 1999.

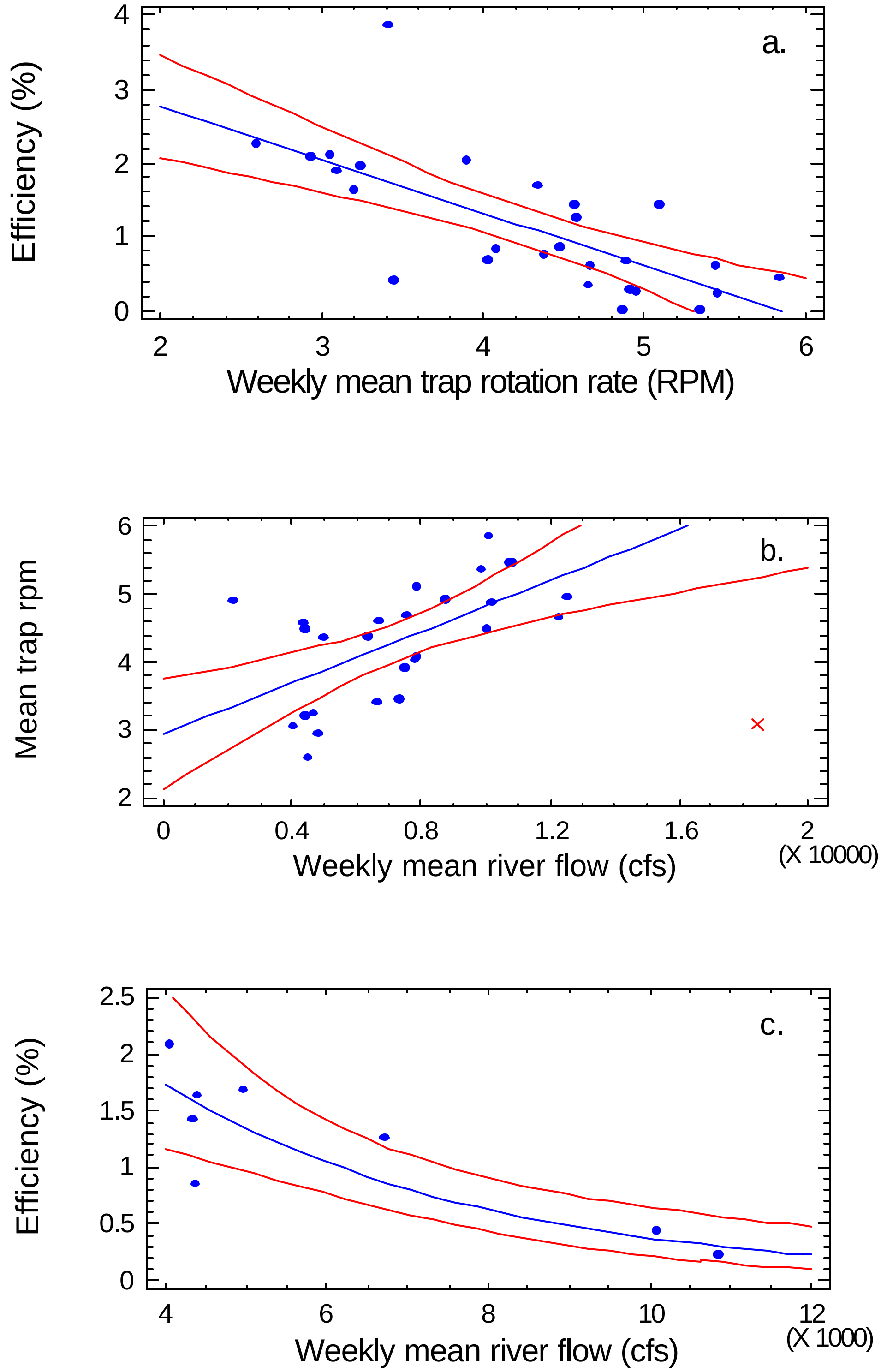

Fig 16 (a) Trap efficiency as a function of weekly mean trap rotation rate (1997-98 & 1998-99 data); (b) weekly mean trap rotation rate as a function of weekly mean river flow (1997-98 & 1998-99 data); and (c) efficiency as a function of weekly mean river flow during the lower American River emigration survey, October 1998 through September 1999.

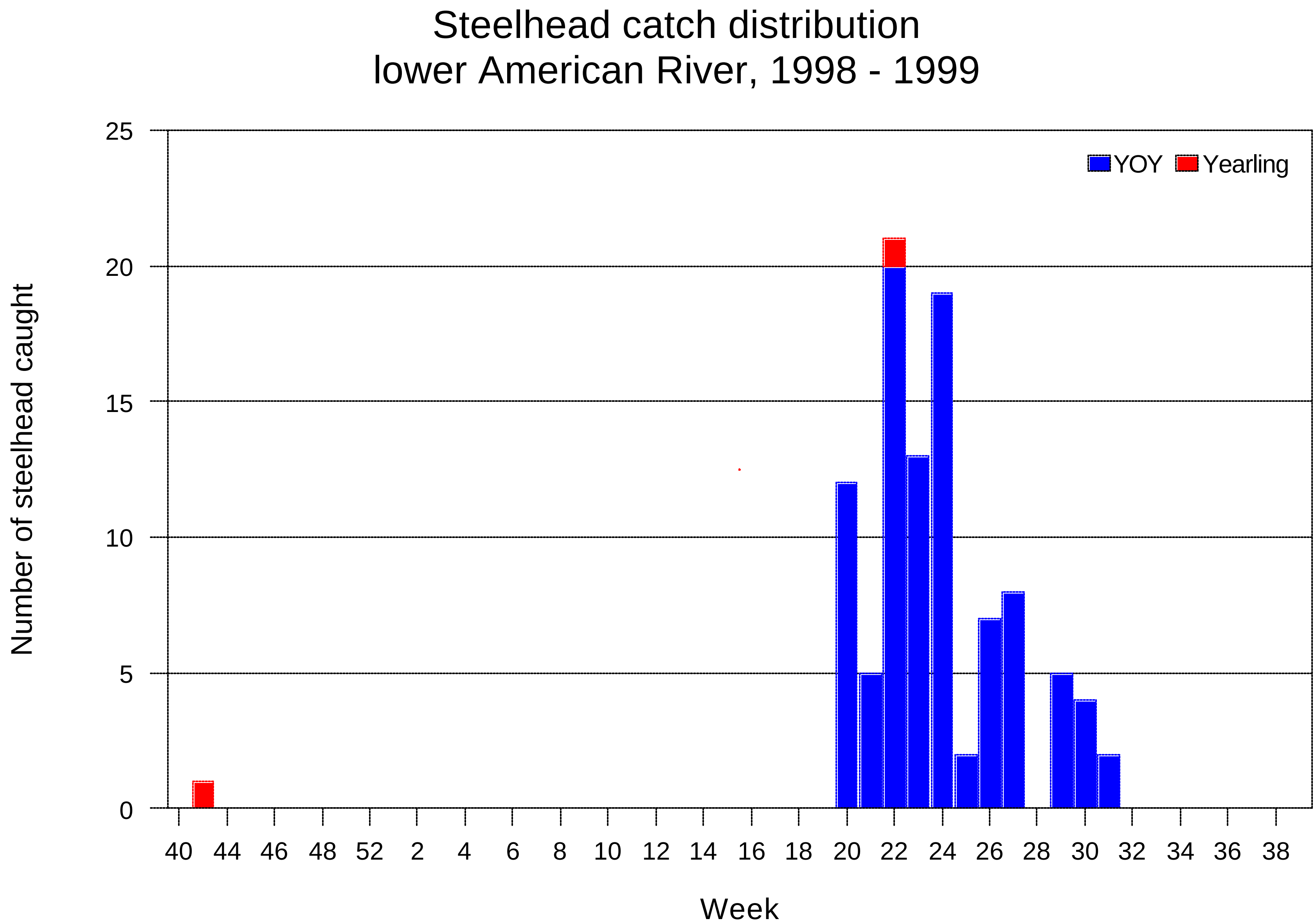

Figure 17. Catch distribution of young of the year (YOY) and yearling steelhead caught during the lower American River emigration survey, October 1998 through September 1999.

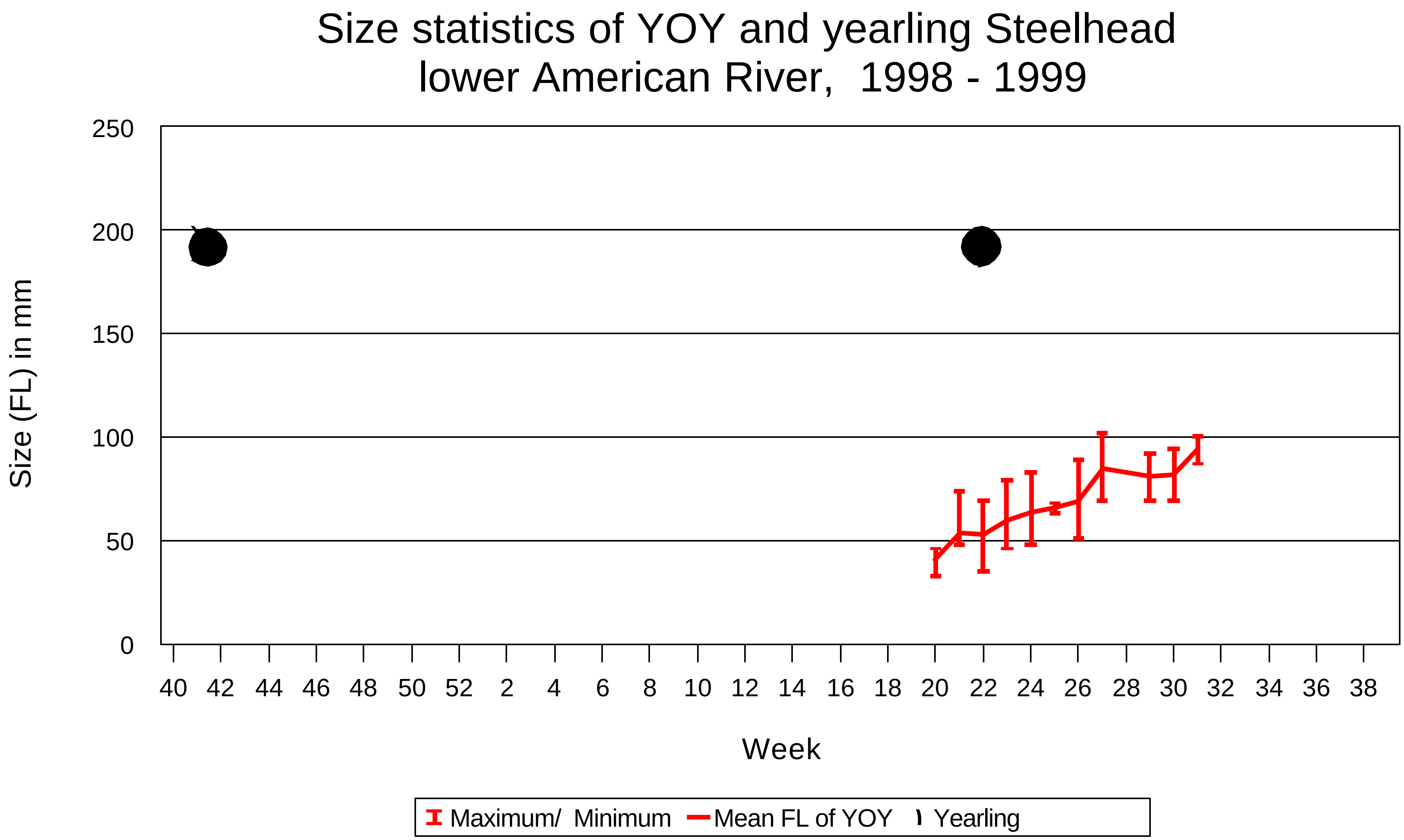

Figure 18. Mean fork length and size range of YOY and yearling steelhead caught by screw trap during the 1999 lower American River emigration survey, October 1998 through September 1999.