

CALIFORNIA DEPARTMENT OF FISH AND GAME
Environmental Services Division
Stream Flow and Habitat Evaluation Program

Lower American River
EMIGRATION SURVEY
November 1994 - September 1995

by

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September 1997

SUMMARY

Rotary screw traps were used to gather information on emigrating anadromous fishes in the lower American River. Two traps were originally deployed near river-mile 9 in early November 1994. One trap was removed in early March, due to a mechanical breakdown. Trapping was nearly continuous through the middle of September 1995.

Emigrants of four anadromous fishes were collected: chinook salmon (*Oncorhynchus tshawytscha*), steelhead trout (*O. Mykiss*), Pacific lamprey (*Lampetra tridentatas*) and American shad (*Alosa sapidissima*). We collected 45,478 salmon between 22 December 1994 and 9 August 1995. We also collected 27 young-of-the-year (YOY) steelhead between 18 March and 31 July 1995, two yearling steelhead on 30 December 1994 and 14 February 1995 and one adult on 9 August 1995. Also collected were 242 lamprey between 8 November 1994 and 15 September 1994, and 522 American shad between 3 November 1994 and 8 September 1995.

The number of chinook salmon emigrants caught in 1995 (45,478) was considerably lower than in 1994 (162,089; Snider and Titus 1995). Average salmon catch per unit effort was also lower (9.3 fish/h in 1995 v. 24.8 fish/h in 1994).

Peak chinook salmon catches in 1995 took place from mid-February through early March, similar to the time of peak catches during 1994. As in 1994, there was no evidence that peak emigration was related to peak winter or spring flows. Most emigrating salmon were caught when flow ranged from 4,000 to 10,000 cfs, whereas maximum winter-spring flow ranged from 30,000 cfs in January to 40,000 cfs in March.

Chinook salmon emigrants were described by life stage as yolk-sac fry, fry, parr, silvery parr and smolts. Fry were most abundant, comprising 70.5 % of the chinook salmon catch. Yolk-sac fry comprised 3.5%, parr comprised 25.5%, silvery parr comprised 0.1%, and smolts comprised 0.4%. Yolk-sac fry were collected between 11 January and 1 April 1995, fry between 22 December 1994 and 17 April 1995, parr between 12 January and 5 May 1995, silvery parr between 19 January and 14 June 1995, and smolts between 25 April and 31 July 1995.

Yolk-sac fry size ranged from 23 to 39.5 mm fork length (FL), fry from 31 to 48 mm FL, parr from 31.5 to 74 mm FL, silvery parr from 52 to 81 mm FL, and smolts from 63 to 98 mm FL. Fulton's condition factor (K) was determined for representatives of each life stage.

The majority (9.6%) of chinook salmon emigrants captured in both 1994 and 1995 were pre-smolts. As in 1994, most salmon captured in 1995 (86%) were recently emerged (≤ 45 mm FL) requiring further growth and development before entering the ocean. These findings again emphasize the need for suitable salmonid rearing habitat in the river and delta environments downstream of the lower American River to ensure cohort success.

INTRODUCTION

Anadromous fish emigration was monitored in the American River in 1995 as part of a multi-year effort to understand the timing and magnitude of primarily chinook salmon and steelhead migration. The timing and life stage composition of emigrating salmonids can directly affect cohort survival. Chronic changes in emigration can ultimately affect population persistence (Park 1969). Various abiotic conditions are known to directly and indirectly alter emigration. Some of these conditions can be effected by human alteration of the aquatic environment. Flow change (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 emigration from the lower American River is vulnerable to all such conditions potentially resulting from flow regulation at Folsom Dam. An important objective of the Lower American River Technical Advisory Committee to the Alameda County Superior Court is to identify relationships between timing, magnitude and composition of emigrating chinook salmon in the lower American River 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 survival. 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 fall-run chinook salmon emigration in the lower American River has been part of a comprehensive investigation of the influences of altered flow on chinook salmon habitat requirements. The data reported herein were collected during the 1994-1995 emigration period, the second consecutive year such data were collected as part of this investigation.

Our investigation has several objectives. The primary objective is to identify the general attributes of emigration in the lower American River, including timing, relative 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 empirical model to link emigration with flow through repetitive investigations during years with varying chinook salmon population sizes and/or environmental conditions. Additionally, we are developing procedures to quantify or index the size of the emigrating population. Ultimately, we propose to associate production and survival with environmental conditions by combining emigration data with information being collected on spawner population size, numbers and distribution of redds, and the magnitude and dynamics of the rearing phase of chinook salmon precedent to emigration. Emigration evaluations conducted in the lower American River during 1992 and 1993 dealt primarily with overcoming the logistical difficulties innate to such a study (Snider 1992, Fothergill 1994). In 1994 we were able to sample continuously throughout the emigration period, allowing us to achieve certain of the objectives listed above (Snider and Titus 1995).

BACKGROUND

Chinook Salmon Emigration

Snider and Titus (1995) outlined some of the key elements that likely determine emigration success of salmonids produced in the lower American River.

- Young fish generally spend their pre-smolt growth and development period in two locations: the natal stream and in the lower river or estuary. The more time spent in the natal stream, the shorter the residence time necessary downstream.
- As residence time in the natal stream decreases, it becomes increasingly important to maintain suitable environmental conditions in downstream environs.
- Timing of emigration is crucial if habitat suitability in downstream environs varies over time. The more restricted the period of downstream habitat suitability, the more critical it is to understand the factors that control timing of emigration.
- Factors which may affect emigration timing and the life stage at which salmon migrate include timing of the spawning run, time of spawning, length of incubation, the time of emergence, flow, inter- and intraspecific fish interactions, turbidity and water temperatures.

Various schemes have been used to classify the life stages of juvenile chinook salmon (Kjelson and Brandes 1989; Healey 1991). For the purposes of this study, we characterize fish as yolk-sac fry, fry, parr, silvery parr, and smolts based upon development stages (Titus 1991, Titus and Mosegaard 1992; based primarily on Allan and Ritter 1977). Young chinook are classified as yolk-sac fry in the period following emergence when the yolk sac is visible and acts as the primary source of nutrition. Fry is the short transitional life stage beginning with independence from the yolk sac and ending with dispersal from the redd area. The term "fry" herewith will apply only to this life stage, and unless otherwise indicated, will not include yolk-sac fry. Fish enter the parr stage when they disperse from the redd and become completely dependent on exogenous feeding for nutrition. Parr are typically characterized by distinct parr marks and the complete absence of a yolk sac. Silvery parr is the transitional life stage between parr and smolt and is characterized by faint parr marks and a silvery appearance. Smolt is the life stage at which fish are morphologically, physiologically, and behaviorally prepared to enter the marine environment. Smolts are generally characterized by a bright silvery or whitish appearance, deciduous scales, and a reduced condition factor (i.e. the ratio of weight to length is lower than in previous life stages).

Lower American River Chinook Salmon Emigration

Salmon emigration has been monitored in the lower American River on a number of occasions (Snider and Titus 1995).

- Emigration was monitored in the American River from 1945-1947 (USFWS 1953). Fry emigrants (defined as salmon <45 mm FL) were detected as early as January, but did not increase in numbers until March, attaining a peak in April. Fingerling (defined as salmon \geq 45 mm FL) emigration began in late May and lasted as late as mid-June.
- In 1988 and 1989 Beak Consultants Inc. used Kodiak trawls to sample emigrants from the lower American River. In 1988, sampling did not begin until late April and no fry (salmon <45 mm FL) were caught. In 1989, fry emigration apparently peaked in early March, although sampling did not begin until 1 March. In both years, fingerling (salmon \geq 45 mm FL) emigration peaked in mid-May.
- In 1992 and 1993, various methods to capture emigrating salmonids were employed by the Stream Evaluation Program of the California Department of Fish and Game. It was determined during this period, that the most effective means of capturing emigrants was the rotary screw trap (Snider and Titus 1995).

The first year we were able to continuously monitor emigration in the lower American River throughout the emigration period was 1994. We caught 162,089 chinook salmon emigrants between 13 January and 13 July 1994. Peak emigration occurred in mid- to late February. Timing of emigration was similar to that observed during trawling surveys conducted in 1988 and 1989, but much earlier than that observed in emigration studies from 1945 through 1947 (Snider and Titus 1995).

Most salmon emigrants captured in 1994 were fry or yolk-sac fry (>96%), and nearly all were pre-smolts (>99 %). These results indicated that juvenile salmon must undergo significant development in river environs downstream from the study site prior to ocean entry.

Fulton's condition factor (K) was calculated for a subset of emigrating fish in 1994. A decrease in K is usually associated with the onset of smolting in anadromous salmonids (Folmar and Dickhoff 1980, Wedemeyer *et al.* 1980, Titus and Mosegaard 1992). In 1994, however, there was no detectable difference in K between fish classified as smolts and those classified as parr.

Other Anadromous Fishes

Emigrating anadromous fish species other than chinook salmon that were captured in the lower American River in both 1994 and 1995 included steelhead trout, Pacific lamprey and American shad. Snider and Titus (1995) provided a brief description of the life histories of these species.

METHODS

The lower American River, downstream from Nimbus Dam to the Sacramento River, is a large, sixth order stream (Figure 1). Flow in this 23-mile-long section is regulated by the U.S. Bureau of Reclamation (USBR) at Folsom Dam to provide water supply, flood protection, hydroelectric power production, and to maintain fish and wildlife habitats. Flow during salmon emigration 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's margin.

As in 1994, rotary screw traps in 1995 were fished immediately downstream of the Watt Avenue bridge (Figure 1). Beginning 3 November 1994, one trap was fished on the north side of a large, mid-channel bar (north trap; Figure 2). A second trap was operated on the south side of the bar (south trap; Figure 2) starting 15 November 1994. On 3 March 1995, operation of the north trap stopped due to a mechanical failure. The south trap was then moved to the north side of the bar to replace the inoperative north trap.

There were several periods in which neither trap operated. There was a delay from 5 to 14 March 1995 (in weeks 10 & 11) between the breakdown of the north screw trap and its replacement by the south screw trap. From 22 to 27 March 1995 (in weeks 12 & 13), the trap experienced mechanical problems and did not collect fish. From 28 April to 4 May 1995 (in weeks 17 & 18), and from 18 to 30 May 1995 (in weeks 20 to 22), algae and debris accumulations made fishing impossible. A final interruption occurred from 17 to 24 July 1995 (in weeks 29 & 30) due to a rapid increase in river flow associated with a gate failure at Folsom Dam. Prior to mid-January and after mid-May, the trap was operated only on weekdays.

Traps were serviced nearly each day of operation through July 1995. In August 1995, servicing was done three times a week. At each servicing, fish were removed from the trap, sorted, and counted by species. Up to 50 individuals of each species were measured and weighed (fork length to the nearest 0.5 mm, and weight to the nearest 0.1 g). Length and weight data were later used to calculate K as $10^5(\text{weight, g})/(\text{FL, mm})^3$. Measured salmonids were visually classified as yolk-sac fry, fry, parr, silvery parr, or smolts. Yolk-sac fry were defined as newly-emerged fish with a visible yolk sac. Fry were defined as fish whose yolk sac was fully absorbed and whose pigmentation was largely undeveloped. Parr were defined as darkly pigmented fish with characteristic dark, oval-to-round parr marks. Silvery parr were defined as fish having faded parr marks and a sufficient accumulation of purine to produce a silvery 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. Only live fish were classified.

Water transparency (secchi depth at the north trap), water temperature, and effort (hours fished since last service) were recorded during each trap servicing. The East Bay Municipal Utility District (EBMUD) provided additional mean daily water temperature data from an instream Hydro-Lab temperature meter they operated near river mile (RM) 4. Flow data were obtained from USBR release records for Nimbus Dam. Turbidity data (in Nephelometric Turbidity Units, NTU) were obtained from the City of Sacramento Fairbairn Water Treatment Plant (RM 7).

RESULTS

General

Mean daily flows during the 1995 emigration period ranged from 1,519 cfs on 7 January 1995 to 39,905 cfs on 12 March 1995 (Figure 3). Between 9 January and 31 July 1995, flows remained higher than 4,000 cfs except for a four-day period in late February. Most daily flows exceeded 5,000 cfs. Average flow from 1 January to 31 July 1995 was 10,441 cfs. In 1994, average flow during the same period was only 1,579 cfs.

Figure 4 shows water temperature measured by EBMUD at river mile 4 starting 1 January 1995. After a minor peak in mid-January, temperatures fell to a low of 48° F on 29 January 1995, then gradually and consistently increased through the end of June 1995. The rate of increase in temperature was slightly higher in July 1995 than in the previous five months.

Turbidity data for the lower American River were not available between 2 February and 29 March 1995 (Figure 5). The major peak in turbidity of 60 NTU in mid January 1995 was coincident with the increase in flow on 11 January 1995 from 1,600 cfs to over 10,000 cfs. In contrast, maximum turbidity in 1994 was only 5 NTU (Snider and Titus 1995).

Twenty-six fish species were collected in the rotary screw traps (Table 1). Most of the fish caught were juvenile chinook salmon (total cumulative catch = 45,478), threadfin shad (672), American shad (522), squawfish (248), lamprey (247), and Japanese smelt (163). In 1994, the six most frequently caught fish species were chinook salmon (162,089), lamprey (283), squawfish (137), Japanese smelt (98), American shad (88), and sculpin (76).

Chinook Salmon

Chinook salmon emigration occurred from 22 December 1994 (week 51) through 9 August 1995 (week 32) (Table 2). A total of 45,478 juvenile salmon was caught.

In 1995, weekly catch peaked in week 8, beginning 19 February 1995 (14,834 fish) and peak catch rate occurred in week 9 (52.6 fish/h) (Figure 6 and 7). In 1994, weekly catch and catch rate both peaked during week 8, beginning 20 February 1994, and were nearly four times greater (56,608 fish, 241.9 fish/h) than what occurred in 1995.

The highest daily catch (3,371 fish) occurred on 24 February 1995 (Figure 8). On that date, all salmon were caught in the north trap yielding a catch rate of 67.4 fish/h. The highest daily catch rate in 1995 (101.6 fish/h) occurred on 3 March (Figure 9) when only the south trap was fishing. The daily salmon catch peaked on nearly the same day in 1994 (23 February 1994), but was much larger (14,887 fish). The peak daily catch rate in 1994 (677 fish/h) also occurred on 23 February.

Table 1. Fish species caught by screw trap during the lower American River emigration survey, November 1994 - September 1995.

Species	Number caught	Range of dates caught
American shad	522	3 Nov. 1994 - 8 Sep. 1995
Black bullhead	14	8 Nov. 1994 - 27 Jun. 1995
Bluegill	26	8 Nov. 1994 - 8 Aug. 1995
Centrarchid juveniles	44	8 Nov. 1994 - 9 Aug. 1995
Chinook salmon adult	82	8 Nov. 1994 - 29 Dec. 1994
Chinook salmon juvenile	45,478	22 Dec. 1994 - 9 Aug. 1995
Crappie	3	8 Nov. 1994 - 14 Aug. 1995
Gambusia	28	8 Nov. 1994 - 1 Mar. 1995
Golden shiner	6	6 Dec. 1994 - 25 Aug. 1995
Goldfish	2	20 Mar. 1995 - 5 Jun. 1995
Hardhead	127	3 Nov. 1994 - 21 Apr. 1995
Japanese smelt	163	15 Dec. 1994 - 15 Sep. 1995
Lamprey ammocoete	204	8 Nov. 1994 - 15 Sep. 1995
Lamprey juvenile	43	15 Nov. 1994 - 11 Jun. 1995
Largemouth bass	60	8 Nov. 1994 - 15 Sep. 1995
Lepomis spp.	15	9 Nov. 1994 - 28 Apr. 1995
Mississippi silverside	29	18 Jan. 1995 - 28 Jul. 1995
Redear sunfish	11	15 Nov. 1994 - 5 Dec. 1994
Sacramento sucker	22	3 Nov. 1994 - 9 Aug. 1995
Sculpin	25	16 Nov. 1994 - 16 Aug. 1995
Smallmouth bass	18	15 Nov. 1994 - 13 Sep. 1995
Squawfish	248	3 Nov. 1994 - 25 Jun. 1995
Steelhead YOY	27	18 Mar. 1995 - 31 July. 1995
Steelhead yearling	3	30 Dec. 1994 - 9 Aug. 1995
Threadfin shad	672	9 Nov. 1994 - 31 Jul. 1995
Tuleperch	64	3 Nov. 1994 - 8 Sep. 1995
White catfish	22	22 Nov. 1994 - 16 Aug. 1995

Table 2. Summary of juvenile chinook salmon catch statistics, lower American River emigration survey, 18 December 1994 - 13 August 1995.

Week	Beginning date	Hours fished	Total catch	Catch /h	Size statistics (FL in mm)			
					Mean	Max	Min	Std
51	18-Dec-94	185	1	0.0	33.0	33	33	0.00
52	25-Dec-94	140	0	0.0				
1	1-Jan-95	145	0	0.0				
2	8-Jan-95	117	4	0.0	31.6	37	28.5	3.90
3	15-Jan-95	183	221	1.2	35.4	74	23	4.62
4	22-Jan-95	287	249	0.9	36.0	41	29	2.36
5	29-Jan-95	195	386	2.0	36.2	41	30.5	2.25
6	5-Feb-95	239	2,583	10.8	37.8	43	30.5	2.14
7	12-Feb-95	334	9,152	27.4	37.3	48	31	1.89
8	19-Feb-95	337	14,834	44.0	37.0	41	31	1.70
9	26-Feb-95	292	14,328	49.1	36.9	45	31.5	1.68
10	5-Mar-95	22	139	6.3	36.6	40	32	1.62
11	12-Mar-95	67	999	14.9	37.5	47	32	2.65
12	19-Mar-95	93	787	8.5	38.8	49	33	2.99
13	26-Mar-95	120	711	5.9	38.5	55	32	4.53
14	2-Apr-95	166	554	3.3	42.3	68	32	6.28
15	9-Apr-95	167	160	1.0	43.9	65.5	32	7.09
16	16-Apr-95	167	18	0.1	49.1	66	34	10.29
17	23-Apr-95	144	19	0.1	59.2	94.5	37	15.15
18	30-Apr-95	18	0	0.0				
19	7-May-95	145	22	0.2	68.2	90	47	11.30
20	14-May-95	98	203	2.1	75.2	105	55	8.22
21	21-May-95	0	0	0.0				
22	28-May-95	44	9	0.2	76.1	85	59	8.28
23	4-Jun-95	190	38	0.2	79.9	93	65	6.73
24	11-Jun-95	164	36	0.2	81.7	93	74	4.60
25	18-Jun-95	171	13	0.1	84.1	92	69.5	5.87
26	25-Jun-95	146	9	0.1	85.6	93	80	4.10
27	2-Jul-95	48	0	0.0				
28	9-Jul-95	96	1	0.0	89.0	89	89	0.00
29	16-Jul-95	50	0	0.0				
30	23-Jul-95	66	0	0.0				
31	30-Jul-95	74	1	0.0	94.0	94	94	0.00
32	6-Aug-95	166	1	0.0	76.0	76	76	0.00
Total		4876	45,478	9.3	41.2	105	23	11.70

Beginning in week 2 (8-14 January 1995) through week 26 (ending 1 July 1995), salmon were caught in every week that the traps were fished except for week 18 (Table 2, Figure 6). In week 18 no salmon were caught since traps were largely inoperative (e.g., only 18 h of fishing in week 18). The traps were not fished during week 21. Catch rate increased from <0.1 fish/h in week 2 to a peak of 49.1 fish/h in week 9 (Table 2, Figure 7). Ninety percent of the salmon catch occurred between weeks 6 and 9 (Table 2). After week 9, the salmon catch declined rapidly. Weekly catch rate dropped to less than 1 fish/h in week 16 (16 April 1995) and remained at less than 1 fish/h through week 32, with the exception of week 20 (14-20 May 1995), when the weekly catch rate increased to 2.1 fish/h.

Juvenile salmon size ranged from 23 mm FL in week 3 (15-21 January 1995) to 105 mm FL in week 20 (14-20 May 1995) (Table 2). Weekly mean size ranged from 31.6 mm FL in week 2 (8-14 January 1995) to 94.0 mm FL in week 31 (ending 5 August 1995) when only one salmon was caught (Table 2, Figure 10). Prior to week 14, salmon FL was very consistent (Figure 10). Ninety-seven percent of the fish collected between week 2 and week 13 (8 January - 1 April 1995) were 35 - 40 mm FL (Figure 11). This trend was also exhibited in the mean daily FL which began to increase after 1 April 1995 (Figure 12).

Between week 14 and week 20, mean weekly size increased relatively quickly (5.5 mm/wk) (Figure 10), then dropped off to an increase of approximately 1.7 mm/wk after week 20. A similar pattern of increase in mean weekly size was seen in 1994, except that in 1994, mean weekly FL exceeded 40 mm and increased to 5 mm/wk by week 12, two weeks earlier than in 1995 (Snider and Titus 1995).

Life Stage Distribution

Fry was the most abundant salmon life stage collected, comprising 70.5% of the total salmon catch. Yolk-sac fry comprised 3.5% of the salmon catch, parr comprised 25.5%, silvery parr comprised 0.1%, and smolts comprised 0.4%. Yolk-sac fry were collected between 11 January and 1 April 1995 (Figure 13), fry between 19 January and 17 April 1995 (Figure 13), parr between 12 January and 9 May 1995 (Figure 13), silvery parr between 19 January and 14 June 1995 (Figure 13), and smolts between 25 April and 31 July 1995 (Figure 13).

Proportionately fewer fry were caught in 1995 than in the previous year. In 1994, fry and yolk-sac fry combined comprised 96.7 % of the catch. Parr, silvery parr and smolts comprised 1.6, 1.4 and 0.3 % of the catch respectively. Interruptions in screw trap operation in 1995 reduced the number of fishing hours during the peak emigration period of both fry and of the larger life stages (parr, silvery parr and smolts) and may have influenced the total catch of these life stages.

Chinook salmon yolk-sac fry and fry sizes fell within relatively narrow ranges (Figure 14). Yolk-sac fry ranged from 23 to 38.5 mm FL; 91% were between 32 and 37 mm FL (mean FL = 33.8 ± 2.0 mm). Fry ranged from 31 to 48 mm FL; 93 % were between 34 and 40 mm FL (mean FL = 37.0 ± 1.9 mm). The yolk-sac fry size distribution had a slight positive skew, while the fry size distribution was nearly normal (Figure 14).

In contrast, chinook salmon parr ranged from 30 to 74 mm FL (Figure 14); 96% were between 34 and 53 mm FL (mean FL = 39.9 ± 5.5 mm). There was a pronounced positive skew in the parr size distribution possibly reflecting a relatively gradual transition from parr to silvery parr compared to the transition from fry to parr.

The size of silvery parr and smolts caught in the screw trap was also quite variable (Figure 14). Silvery parr ranged from 52 to 81 mm FL (mean FL = 68.1 ± 8.0 mm). Smolt size ranged from 63 to 98 mm (mean FL = 80.8 ± 6.9 mm).

Most yolk-sac fry were caught in weeks 3 through 9 (Figure 15). None were caught after week 13. Weekly mean size increased between week 2 and week 7 from 29.8 to 35.2 mm FL and then varied from 32.5 to 34.7 mm FL from week 8 to week 13 (Figure 15).

Salmon fry were caught between week 3 and week 16 (Figure 15) with maximum numbers (catches >2,000 fry/wk) appearing in weeks 6 through 9. Between week 3 and 6, mean FL varied only from 37.1 to 38.1 mm, then generally decreased through week 16 (Figure 15).

Salmon parr were caught between week 2 and week 19, with peak catches occurring in weeks 8 and 9 (Figure 15). The weekly mean size of salmon parr varied little from week 2 to week 13 (mean FL range = 36.9 to 41.0 mm; Figure 15). From week 14 to week 20, weekly mean FL increased steadily from 42.4 mm to 60.3 mm.

All silvery parr but one were caught between week 15 and week 24 (Figure 15), with the greatest catch occurring in week 20. Overall, weekly mean size increased during this period (Figure 15) from 55.1 mm FL in week 15 to 76.3 mm FL in week 24.

All smolts but three were caught between week 19 and week 26 (Figure 15). Weekly mean size steadily increased during these weeks, from 76.5 to 85.6 mm FL (Figure 15).

Condition Factor

Mean condition factor (K) for all life stages in 1995 was 0.79, slightly lower than in 1994 when mean K was 0.87 (Snider and Titus 1995). Life stage appears to have some effect on K . In 1995, K decreased between the yolk-sac and fry stages (Table 3), an expected outcome of yolk-sac absorption. Contrary to the general observation that condition decreases as juvenile salmonids smolt (Folmar and Dickhoff 1980), mean K in 1995 increased with life stage from fry through smolt (Table 3). A similar result was observed in 1994 (Table 4).

Regressing K on FL, using fish with FL >45 mm to remove excessive heteroscedasticity introduced by the inclusion of yolk-sac fry and fry, showed K to increase with length (Figure 16). The slope was significantly different from zero (t -test, $p < 0.001$). Regressing K on FL for salmon classified as smolts showed a slightly negative slope (Figure 17) (slope coefficient = -0.0006, $p = 0.048$). However, when two outliers with $K > 2.00$ were removed, the slope was not significantly different from zero ($p > 0.1$).

Table 3. Condition factor (*K*) statistics by life stage for chinook salmon collected during the lower American River emigration survey, November 1994 - August 1995.

Condition factor	Yolk-sac fry	Fry	Parr	Silvery parr	Smolt
Minimum	0.21	0.19	0.23	0.90	0.75
Maximum	1.78	1.46	1.95	1.23	2.62
Mean	0.93	0.74	0.78	1.05	1.15
C.V. (%)	27	24	23	10	18
Standard deviation	0.25	0.18	0.18	0.11	0.21
Sample size	263	1,435	1,220	23	115

Table 4. Mean condition factor for various life stages of emigrating chinook salmon caught by screw trap in the lower American River, 1994 and 1995.

Life stage	1994	1995
Yolk-sac fry		0.93
Fry	0.79 *	0.74
Parr	1.01	0.78
Silvery parr	1.07	1.05
Smolt	1.14	1.15

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

North vs. South trap

Salmon catch results reported thus far represent data pooled from both the north and south traps. Similar salmon size distributions for both trap catches (when both traps were fishing) (Figure 18) suggests that similar populations of fish were being sampled at both locations, supporting this approach. However, apparent differences in distribution of catch between traps require further discussion.

When both traps fished simultaneously and juvenile salmon were being caught (i.e., week 51 and weeks 3 through 9), the majority of salmon was captured in the north trap. The one exception occurred in week 9 when both the total catch and catch/h were higher in the south trap (Figures 19 and 20). During this period, catch steadily increased in the north trap through week 8, then declined in week 9. Catch rate also showed an increasing trend in the north trap through week 8,

with the exception of a slight decrease during week 4. Conversely, catch and catch rate in the south trap showed a constant decline through week 8, except for a minor increase in both statistics during week 4.

Unfortunately, the north trap stopped operating at the end of week 9, when the highest catches occurred in the south trap. We relocated the south trap to the north trap's location beginning in week 11, with only one day fished at the south trap location during week 10. These occurrences were concurrent with extremely high flow conditions that began during week 9 (1 March 1995) and lasted until week 14 (1 April 1995) (Figure 2). It is likely that the increase in catch observed in the south trap, and relative decrease in the north trap during week 9 was due to improved trapping conditions at the south site, and possibly a worsening in trapping conditions at the north site. The change in flow may also have altered the pathway fish used through the trapping location, substantially influencing catch in both traps.

Using the north trap data exclusively, versus the combined trap data, would result in only a slight difference in interpretation of when the peak of emigration occurred (week 8 versus week 9) (Figures 21 and 22). However, what would be omitted, as such, would be the observation that the high flows may have influenced the decline in migration. The decline in catch and, in particular, catch rate following week 9 support the observation that the peak of emigration occurred during week 9. This observation was based upon the combined results of both traps. If the north trap data were used exclusively, the peak would appear to have occurred during week 8 although the highest daily catch rates occurred at the end of week 9, peaking with the dramatic increase in flow.

Comparison with seining data

A seining survey to determine the temporal and spatial distribution of fish within the 13.5-mile-long reach of the lower American River upstream of our trapping site, was conducted concurrent with our 1995 emigration survey (Snider and Titus 1996). Newly-emerged salmon (FL <45 mm) disappeared from the catch in both surveys at about the same time (week 19, 7 May 1995) (Figure 23). In both cases, <1% of all salmon <45 mm FL were caught after week 16. Similarly, weekly mean FL increased in both surveys from approximately 39 mm in week 8 to over 80 mm in week 24. Weekly seining catch rates were highest in week 14 (starting 2 April 1995), week 8 (19 February 1995), and week 12 (19 March 1995) (Figure 23). Comparison of total catch and catch rates may not be appropriate since seining efficiency was noticeably influenced by sampling conditions (Snider and Titus 1996).

Steelhead

Thirty steelhead, including one adult and 29 juveniles were captured by screw trap in the lower American River between 30 December 1994 and 9 August 1995. The life stage of 27 of the juveniles was classified based on appearance: 22 were parr, three were silvery parr and two were smolts. Parr were captured between 18 March and 7 July 1995, silvery parr were captured between 14 and 31 July 1995, and the two smolts on 30 December 1994 and 14 February 1995.

The captured steelhead were also classified by size (FL) into year groups (Figure 24). Twenty-seven were classified as young-of-the-year (YOY) (FL <150 mm), two as yearling (150 ≤ FL <350 mm) and one as an adult (FL ≥350 mm). The two steelhead classified as smolts fell into the yearling size class (FL between 150 and 349 mm). The one adult-sized fish (370 mm FL) was captured on 9 August 1995.

The mean weekly FL of YOY steelhead increased from 28 mm in week 11 to 88 mm in week 28 (Figure 25). The maximum size of steelhead caught in the trap was 88 mm FL. The maximum size of steelhead YOY caught in the seine survey was 96 mm FL. Substantially more YOY steelhead were caught during the seining survey (1,231 v. 27 fish) suggesting that the few steelhead, if any, actively emigrate as YOY.

Pacific Lamprey

Lampreys collected in the screw traps were classified either as ammocoetes, the filter-feeding larval stage or adults. Ammocoetes ($n = 204$) were collected in greater numbers than adults ($n = 43$). Ammocoetes appeared in the trap nearly every week from 8 November 1994 through 15 September 1995 (Figure 26). Catches were greatest in weeks 8 and 17 (week 8 was the week in which chinook salmon catch peaked as well). Seventy percent of adult lamprey were caught in weeks 15, 16 and 17.

American shad

We caught 522 American shad between November 1994 and September 1995 (Figure 27). Fork length ranged from 47 to 465 mm ($n = 270$) (Figure 28). Twenty-one percent were <75 mm FL, 74 % were between 75 and 300 mm FL, and 4.8 % exceeded 300 mm FL.

DISCUSSION

Several significant findings have resulted from the emigration data reported herein.

- The timing of both fry and fingerling emigrations was substantially different from that recorded before construction of the Folsom Complex (1945-1947), but was similar to 1994.

The only data on salmon emigration in the lower American River prior to construction of the Folsom Project (USFWS 1953) showed both fry and fingerling emigration to occur substantially later than that observed during the 1994 and 1995 emigration surveys. The 1944-1946 brood stocks had access to the upper reaches of the American River. The 1945-1947 emigration timing may have been due to longer incubation, later emergence, and slower growth typically associated with the colder, more oligotrophic conditions found in the upper reaches of the American River.

The emigration timing in 1994 and 1995 was comparable to that described in the lower Sacramento River near Hood both prior to completion of Shasta Dam in 1899 (Rutter

1903) and in 1939-1941 (Hatton and Clark 1942), and following completion in 1973 and 1974 (Schaffter 1980). It was also comparable to fall-run chinook salmon emigration observed in post-Oroville Project Feather River from 1967 through 1975 (Painter *et al.* 1977).

- The downstream environs are very important to the survival of most of the chinook salmon produced in the lower American River.

As in 1994, most (74%) emigrating chinook salmon captured were fry or yolk-sac fry, and only a small percentage (0.4%) had reached the smolt stage in the river. Only one captured emigrant was greater than 100 mm FL (105 mm FL). These findings suggest that the smolting process continues well after migrants leave the lower American River and enter the Delta and the estuary. Suitable habitat conditions in these downstream environs is therefore of key importance to the ultimate survival of American River chinook salmon.

- Using size as a sole criterion for distinguishing life stages is unreliable.

Hoar (1976) speculated that smolt characteristics such as decreased condition and silvering were associated with size. Our results indicate that such size criteria should be applied with caution. Condition factor actually increased with FL in 1995, and silvering occurred over a wide range of sizes (silvery parr were as small as 52 mm FL and parr were as large as 74 mm FL).

- The proportion of fry, parr, silvery parr and smolt emigrants is variable from year to year.

The proportion of yolk-sac fry and fry emigrants in 1995 (74%) was smaller than in 1994, when 96.7% of emigrants were classified as fry. Some of the factors which may have influenced these results include:

- Flows in the early part of 1995 were much greater than in 1994 (mean flow from January through March in 1994 was 1,590 cfs; in 1995 it was 10,686 cfs). It is possible that high flows affected the life stage at which emigration occurred in 1995. It is also possible that flow influenced trap efficiency when most of the fry were emigrating. If a relatively smaller portion of the fry emigration was trapped in 1995, the overall proportion of fry to larger life stages would have been reduced.
- Differences in flow and/or other physical conditions in the river between years may have caused changes in the migration pattern. For example, in 1994, peak catches coincided with periods of increased turbidity. The different turbidity conditions in 1995 may have delayed emigration, allowing more fry to become parr before emigrating. Although turbidity was substantially higher in 1995, a lack of turbidity data from February and March of 1995 prevents us from evaluating specific relationships between turbidity and catch.

- Higher flows in 1995 may have provided more rearing habitat for fry, resulting in fewer fish leaving while in the recently-emerged fry stage.
- Flow conditions could influence trap efficiency between years and within years. Differences in fishing effort between years certainly can influence catch. The breakdown of the north trap during week 9, when the highest daily catch rate occurred with only the south trap fishing, likely reduced the total number of fry caught that week. For example, if the north trap had fished all of week 9 and had caught the same number of fry as the south trap, the proportion of fry and yolk-sac fry in the total catch would have increased to over 80%.
- Our life-stage classification system is based solely on visual appraisal of fish in the field. The classification system is somewhat subjective and its application may vary among workers and may be influenced by ambient light conditions or similar factors. As such, the opportunity exists for differences in classification to occur between years, especially where subtle differences in appearance are used to define life stage (e.g., silvery parr versus smolt).

To fully evaluate the effect of environmental conditions in the lower American River on chinook salmon emigration requires continued monitoring of fish populations in years to come. Future emigration studies will focus on maintaining constant fishing effort, constant evaluation of trap efficiency and on improving the objectivity in classifying the life stages of juvenile chinook salmon and steelhead.

ACKNOWLEDGMENTS

The study was carried out under the guidance of the Lower American River Technical Advisory Committee, primarily Paul Bratovich of Surface Water Resources Inc., representing the County of Sacramento, and Chuck Hanson of Hanson Environmental, Inc. representing East Bay Municipal Utilities District, Felix Smith representing Save the American River Association and John Williams representing the Alameda County Superior Court. Field data were collected by Elizabeth Cook, Hal MacLean, Jeff Weaver and Steve Whiteman of the Department of Fish and Game.

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FIGURES

LOWER AMERICAN RIVER

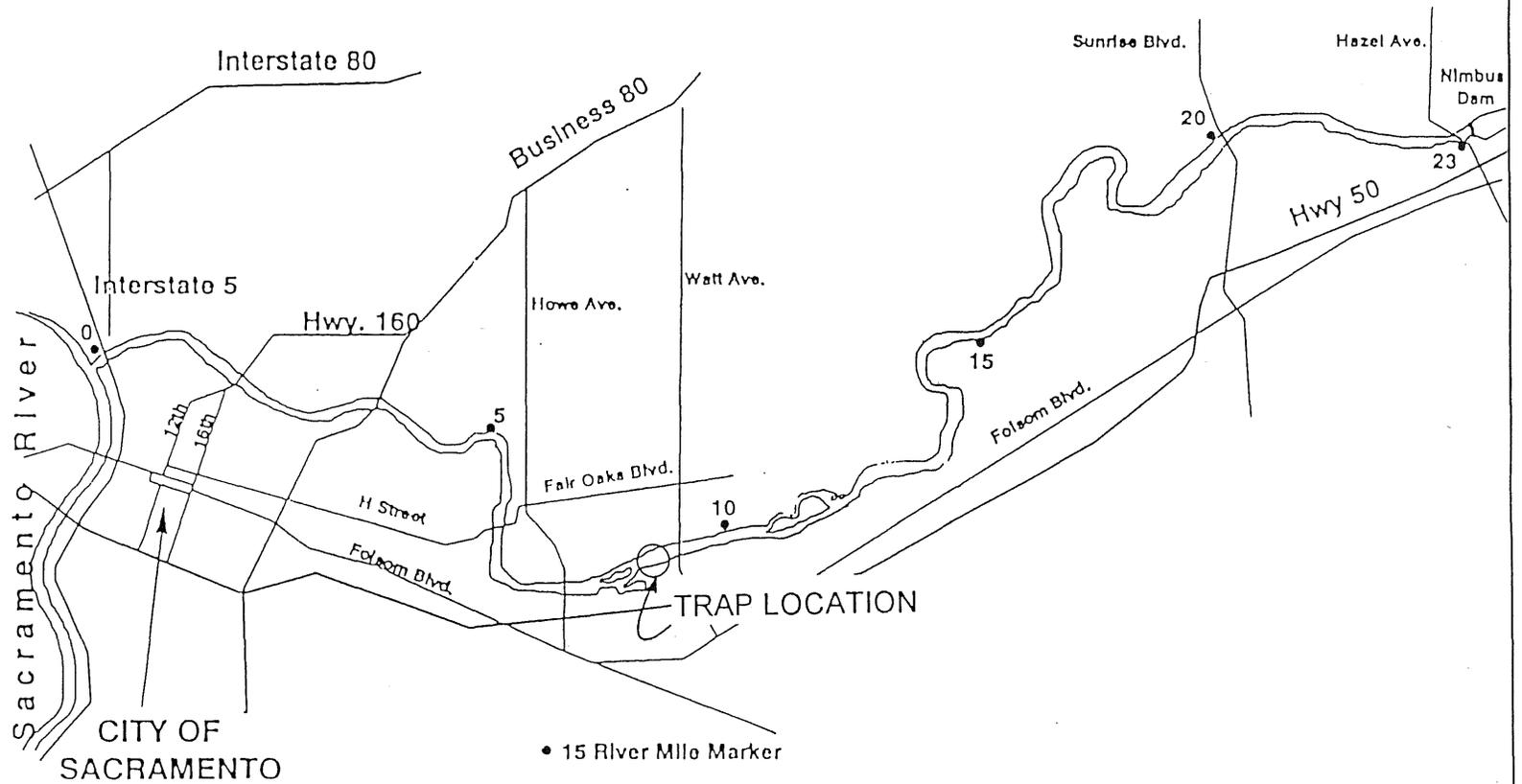


Figure 1. General location of the rotary screw traps used during the lower American River emigration survey, November 1994 - September 1995.

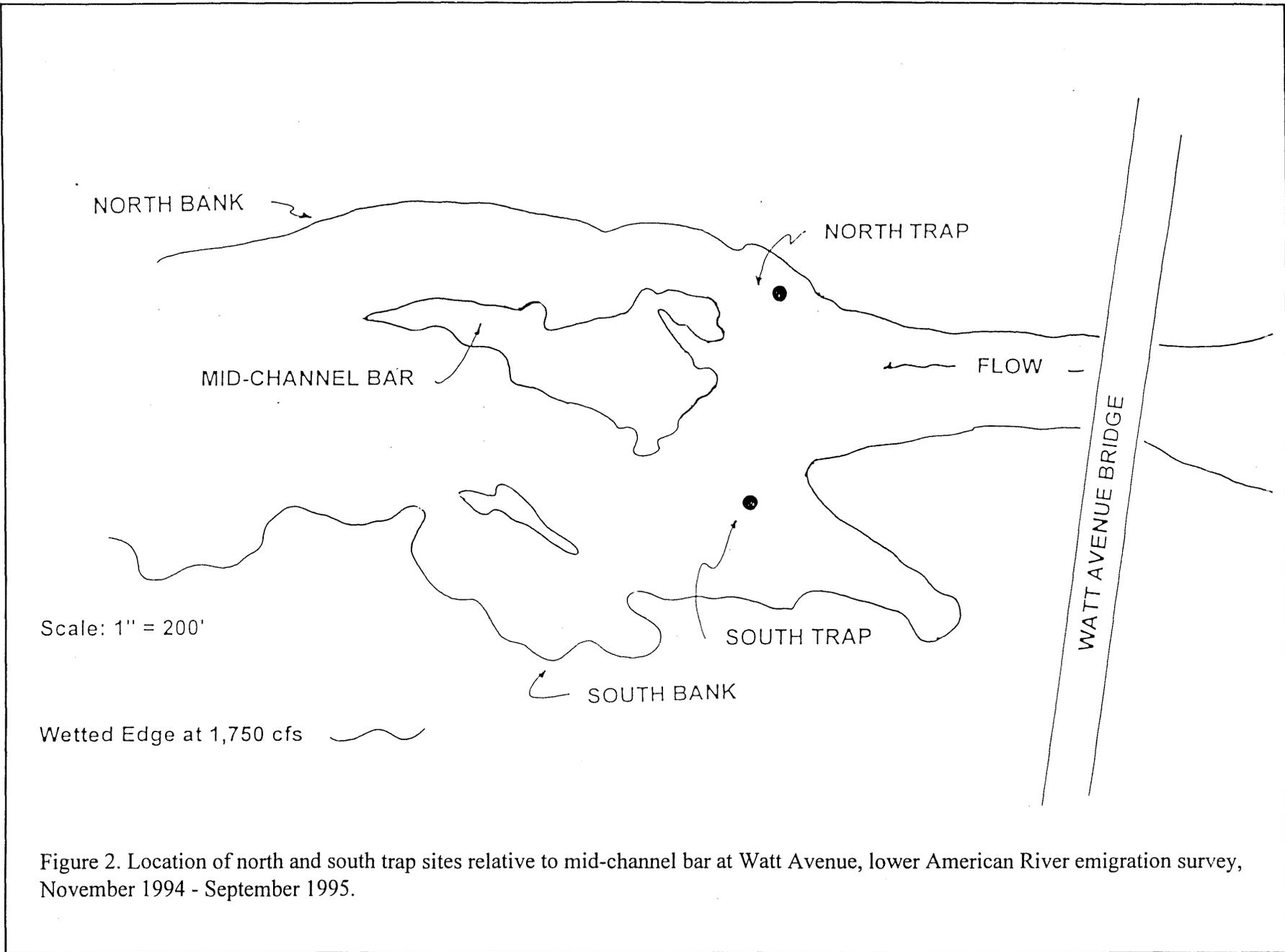


Figure 2. Location of north and south trap sites relative to mid-channel bar at Watt Avenue, lower American River emigration survey, November 1994 - September 1995.

Flow - lower American River measured at Nimbus Dam

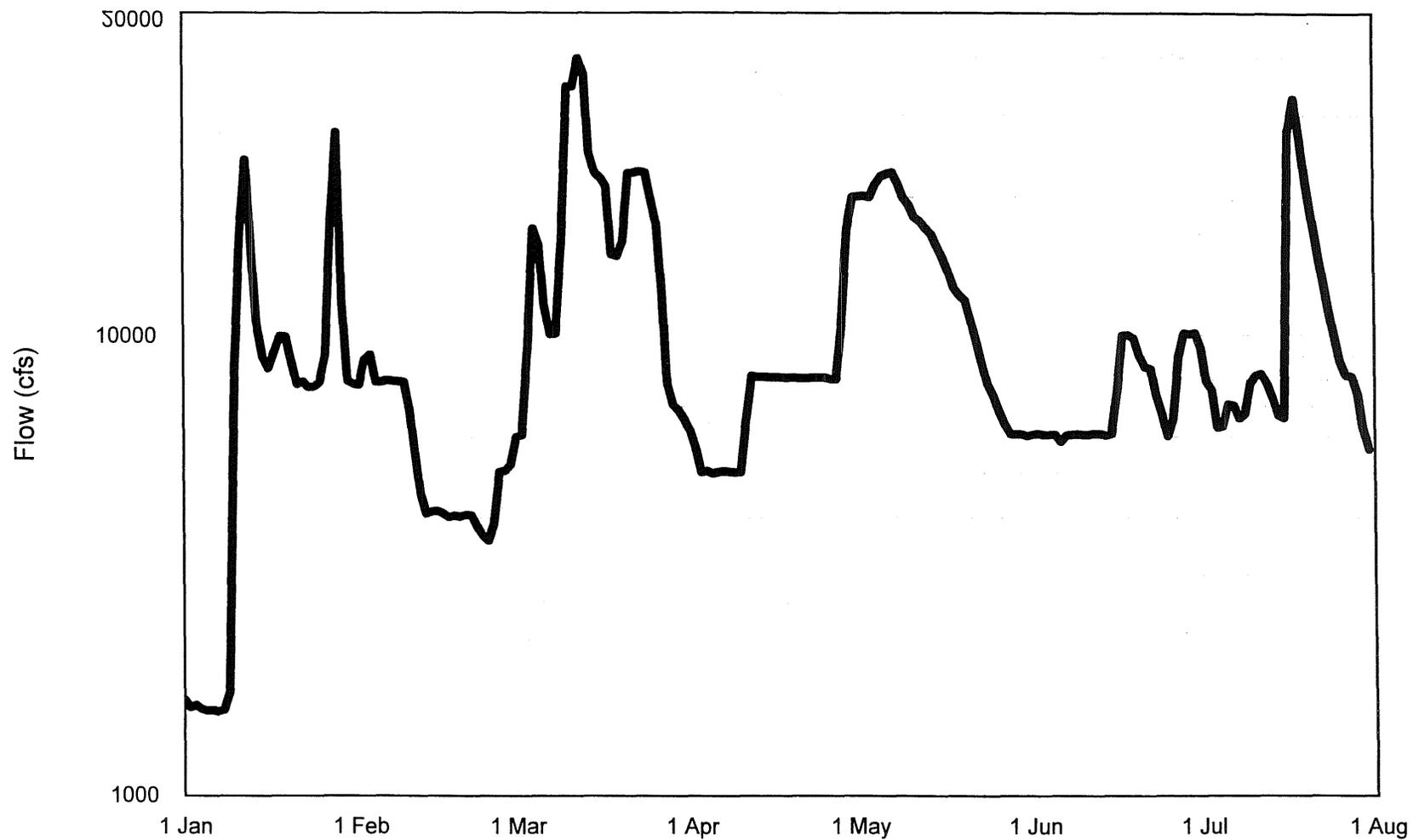


Figure 3. Flow in cfs measured at Nimbus Dam during the lower American River emigration survey, January through July 1995.

Water temperature - lower American River near river mile 4

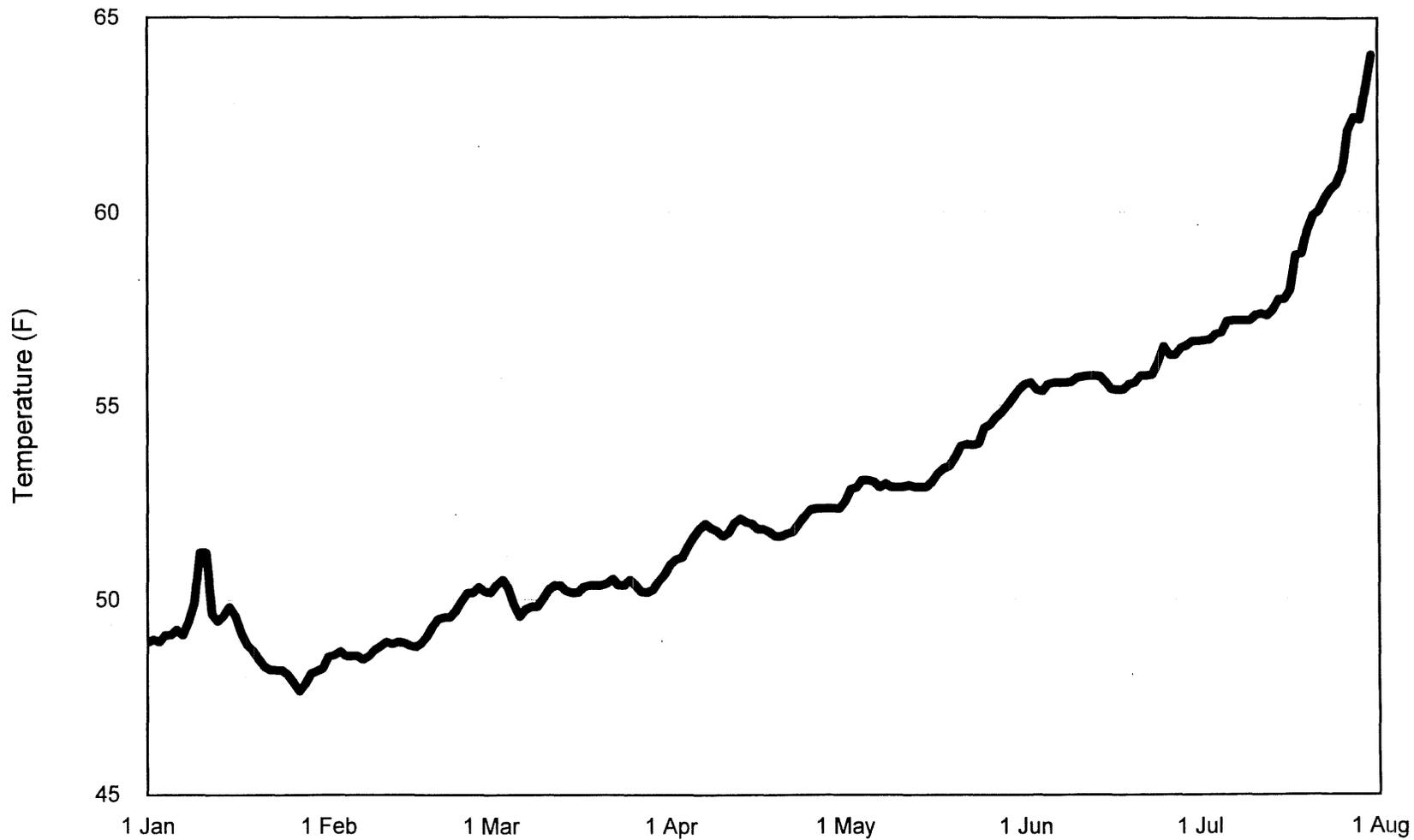


Figure 4. Water temperature measured near river mile 4 during the lower American River emigration survey, January through July 1995.

Water turbidity - lower American River measured at the Fairbairn Water Treatment Plant

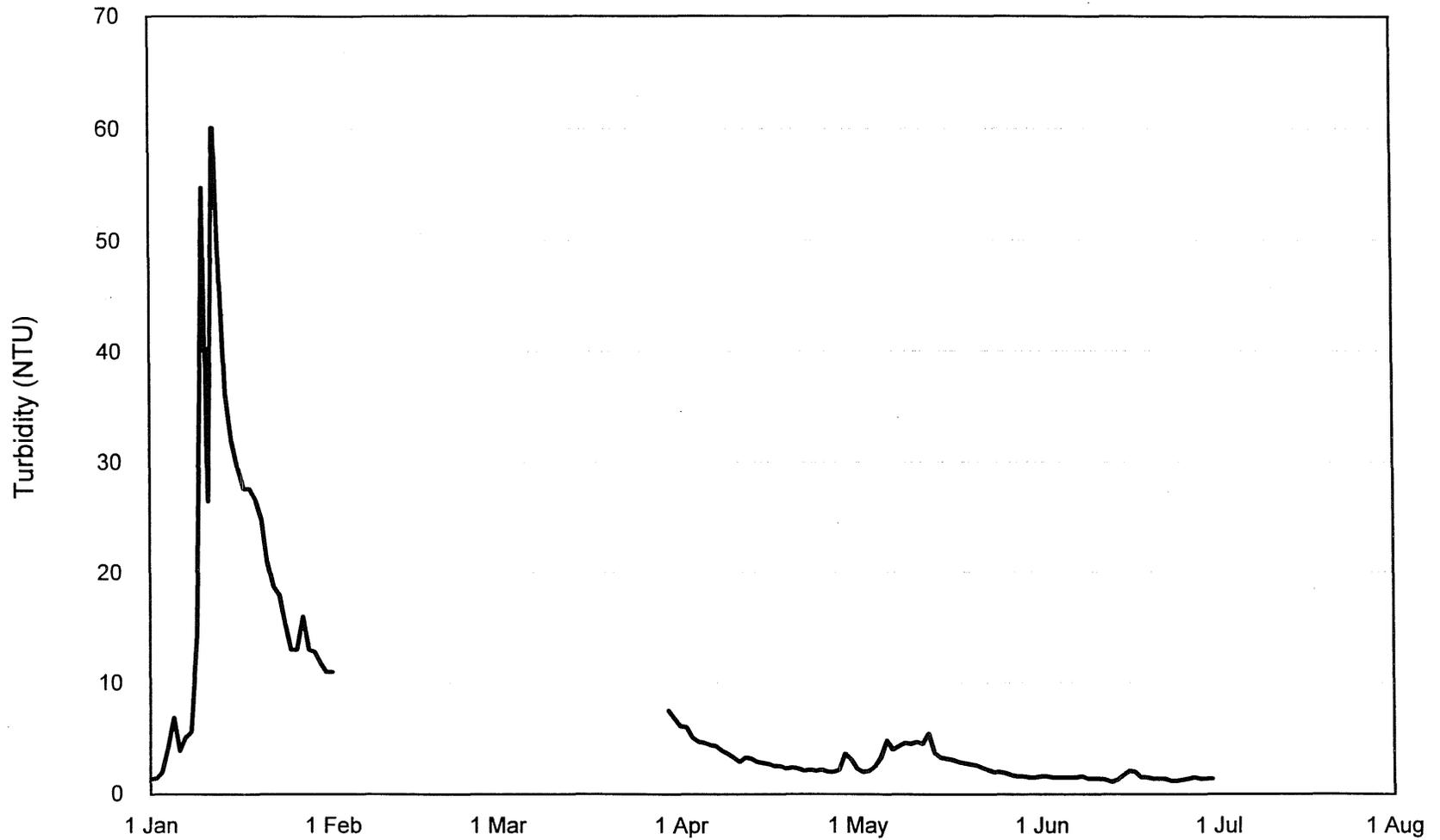


Figure 5. Water turbidity measured near river mile seven during the lower American River emigration survey, January through July 1995.

Chinook salmon weekly catch

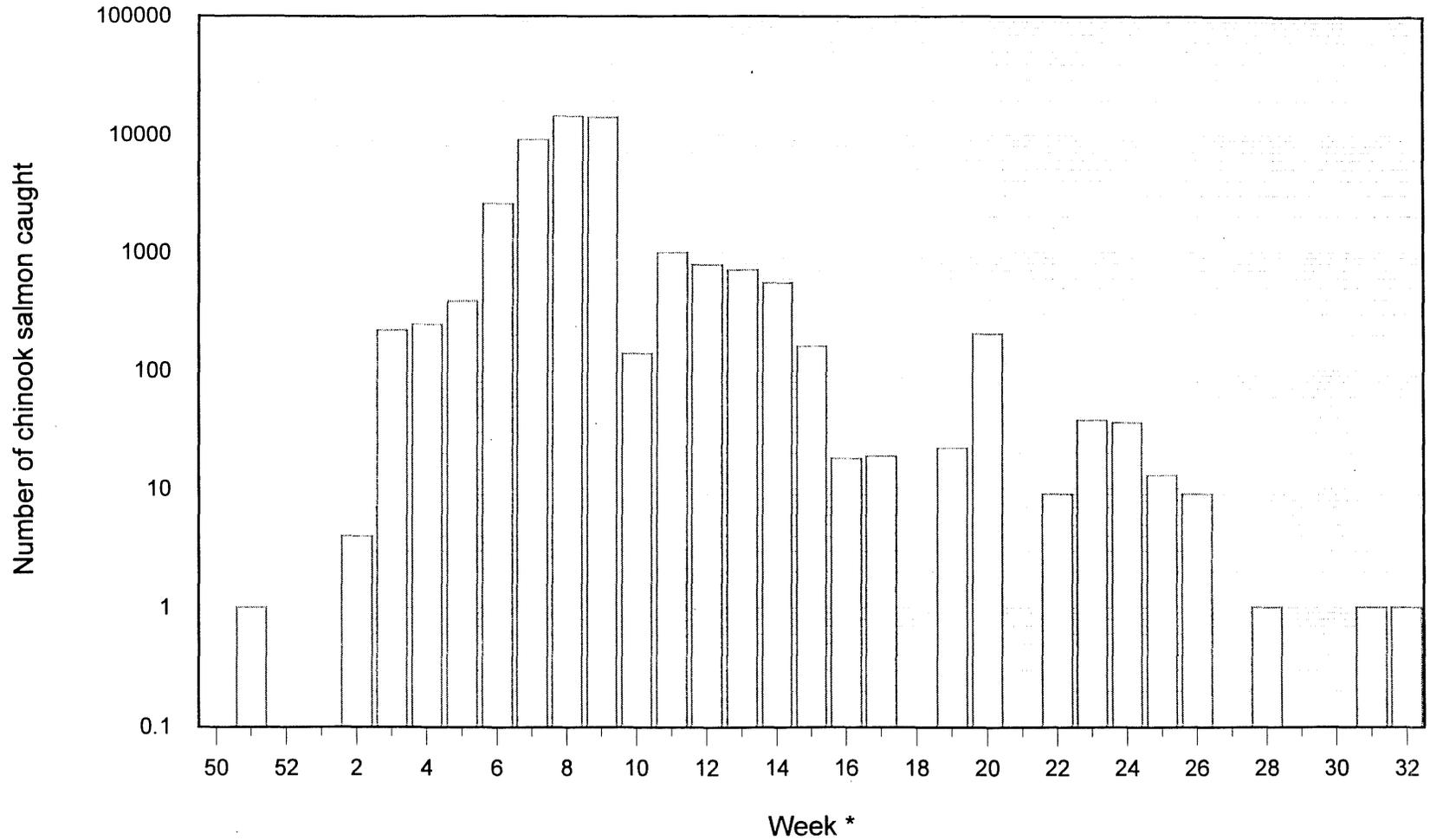


Figure 6. Weekly catch of chinook salmon caught by screw trap during the lower American River emigration survey, December 1994 - August 1995.

* Week 1 begins 1 Jan 1995

Chinook salmon weekly catch-rate distribution

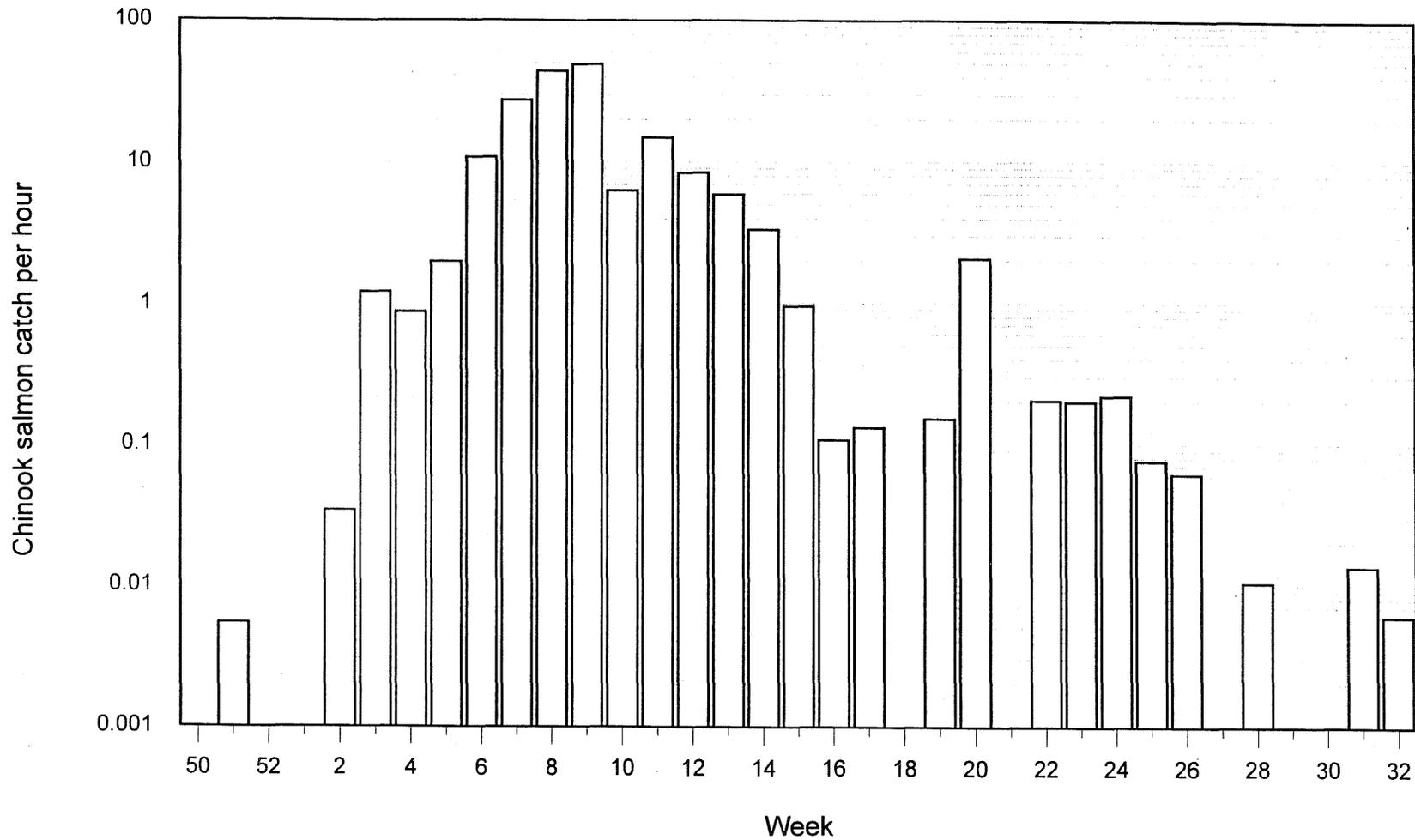


Figure 7. Mean weekly catch rate (n/ hour) of chinook salmon caught by screw trap during the lower American River emigration survey, December 1994 - August 1995.

Chinook salmon daily catch distribution

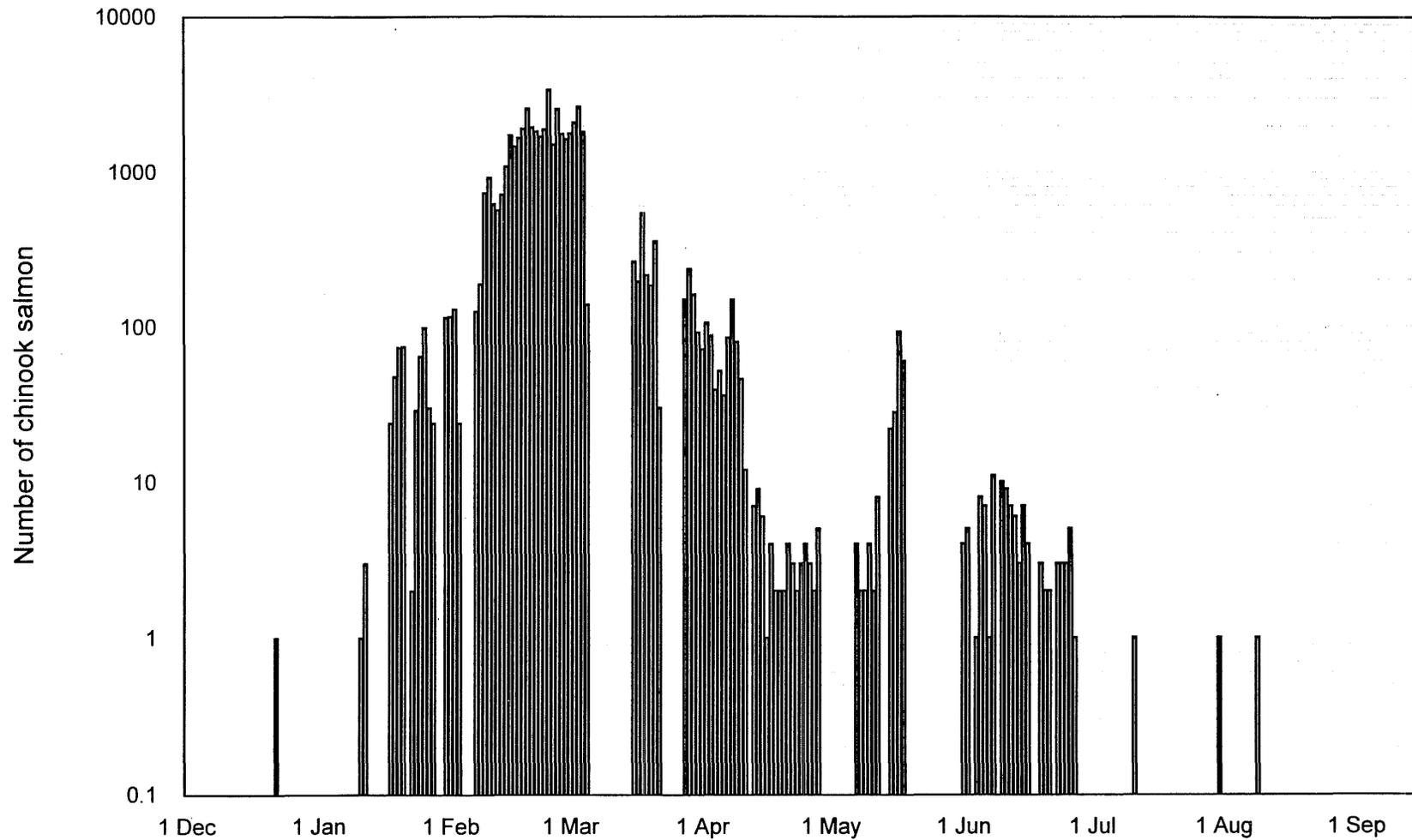


Figure 8. Daily catch distribution of juvenile chinook salmon caught by screw trap during the lower American River emigration survey, December 1994 - September 1995.

Chinook salmon daily catch rate distribution

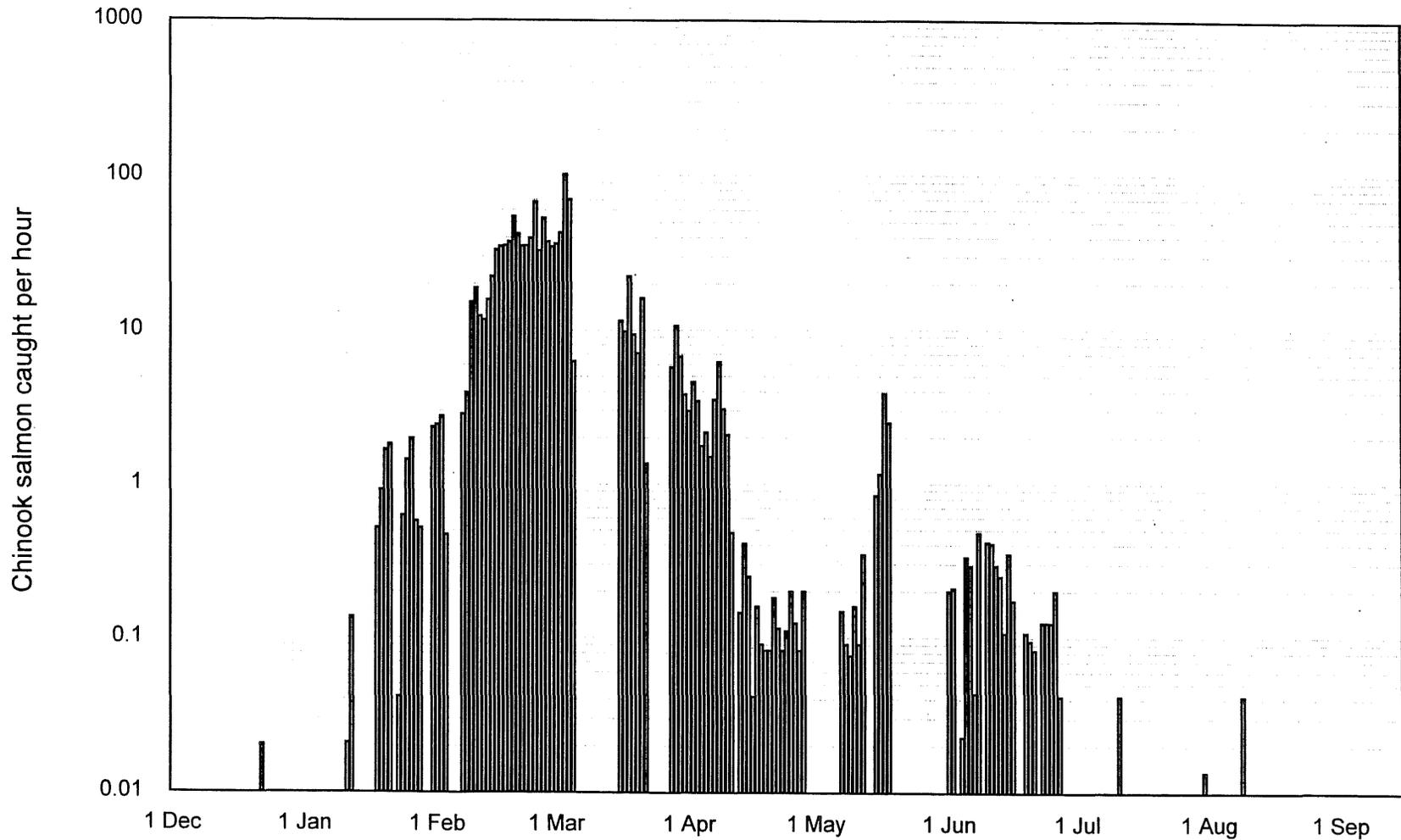


Figure 9. Mean daily catch rate (n/h) of juvenile chinook salmon caught by screw trap during the lower American River emigration survey, December 1994 - September 1995.

Chinook salmon size statistics and weekly catch

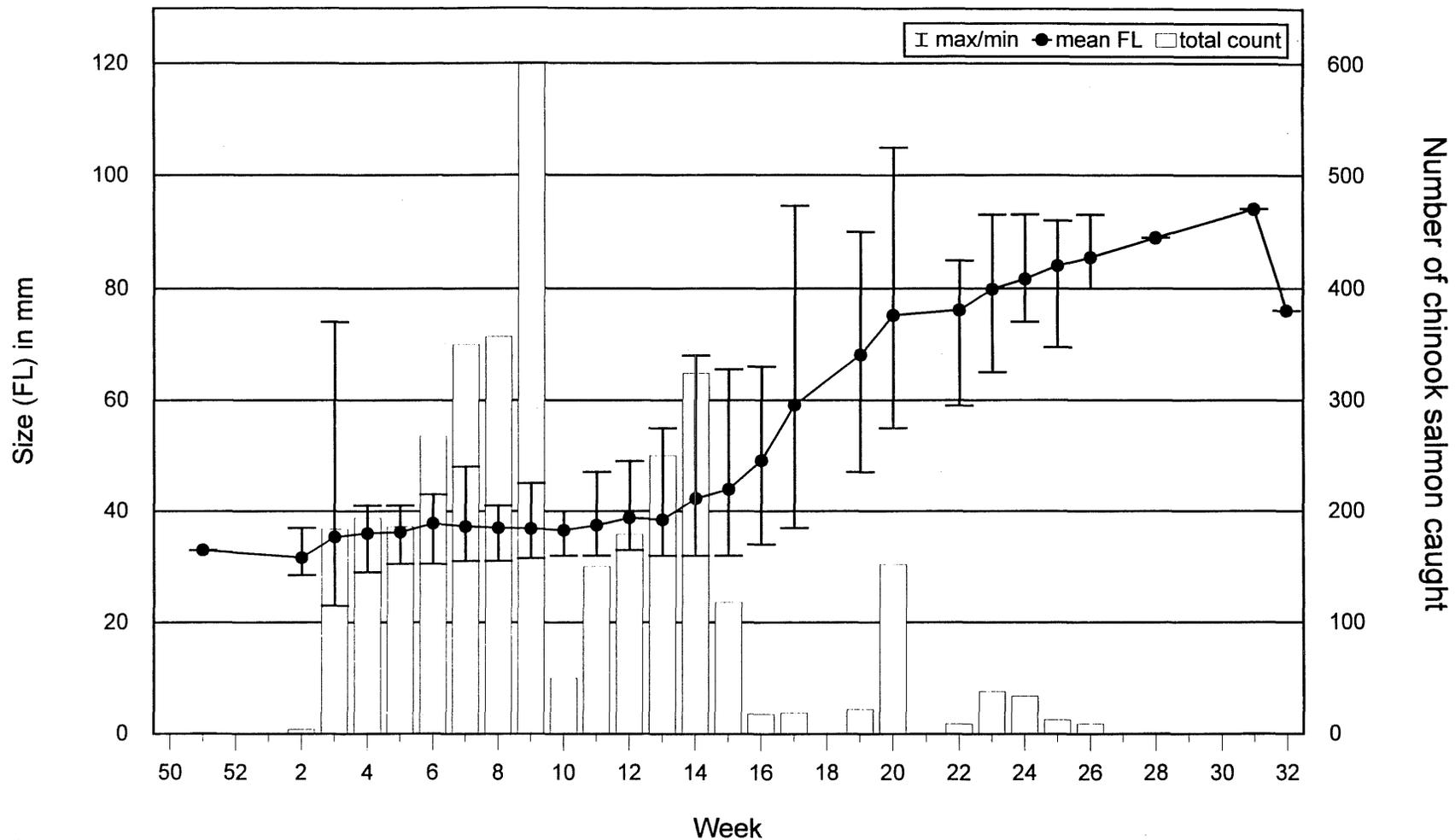


Figure 10. Mean fork length, size range and weekly numbers of measured salmon caught by screw trap during the lower American River emigration survey, December 1994 - August 1995.

Chinook salmon size distribution through week 13 (1 April 1995)

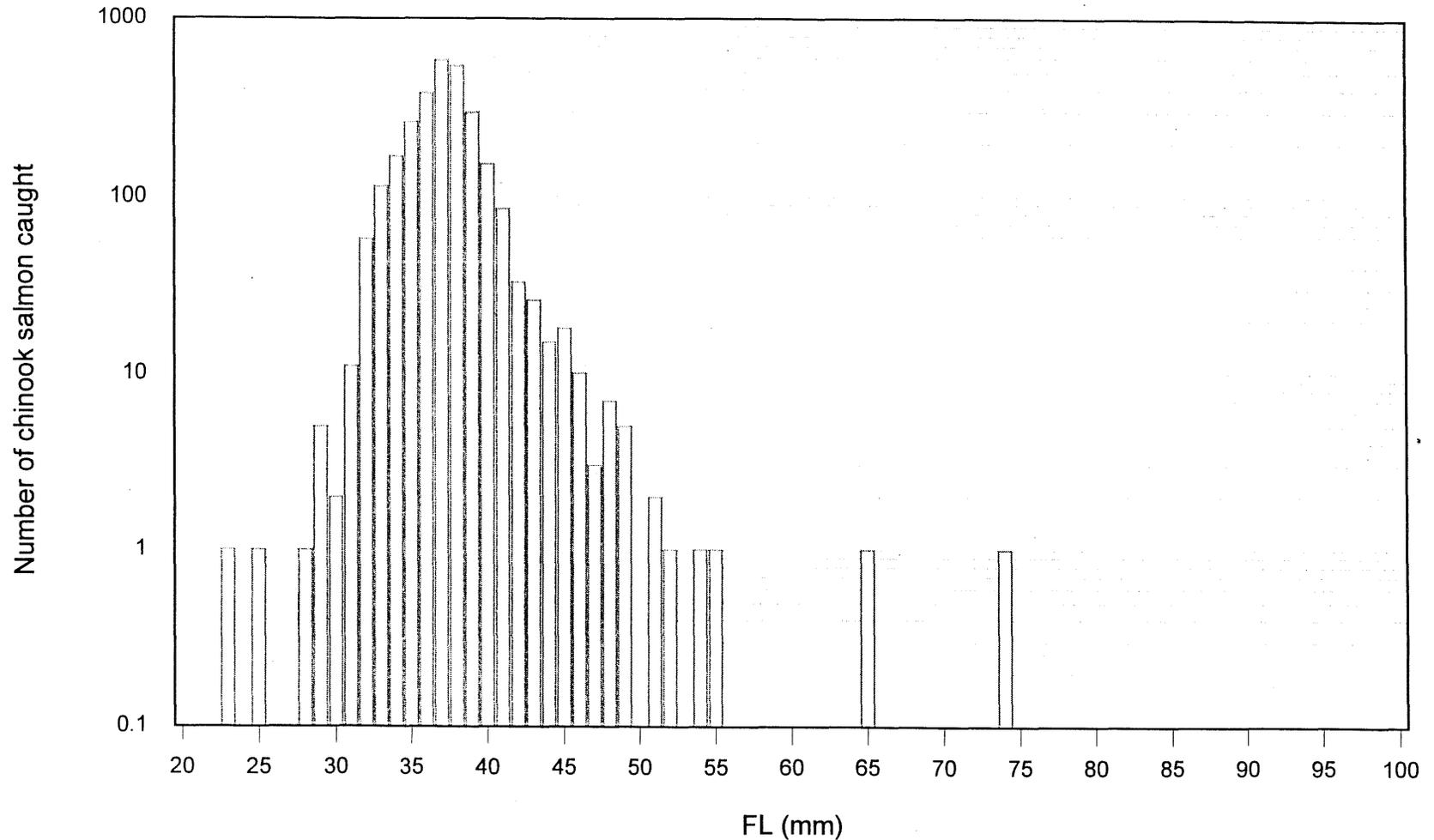


Figure 11. Length frequency distribution of chinook salmon caught by screw trap through week 13 (1 April 1995) during the lower American River emigration survey, December 1994 - August 1995.

Chinook salmon daily mean size distribution

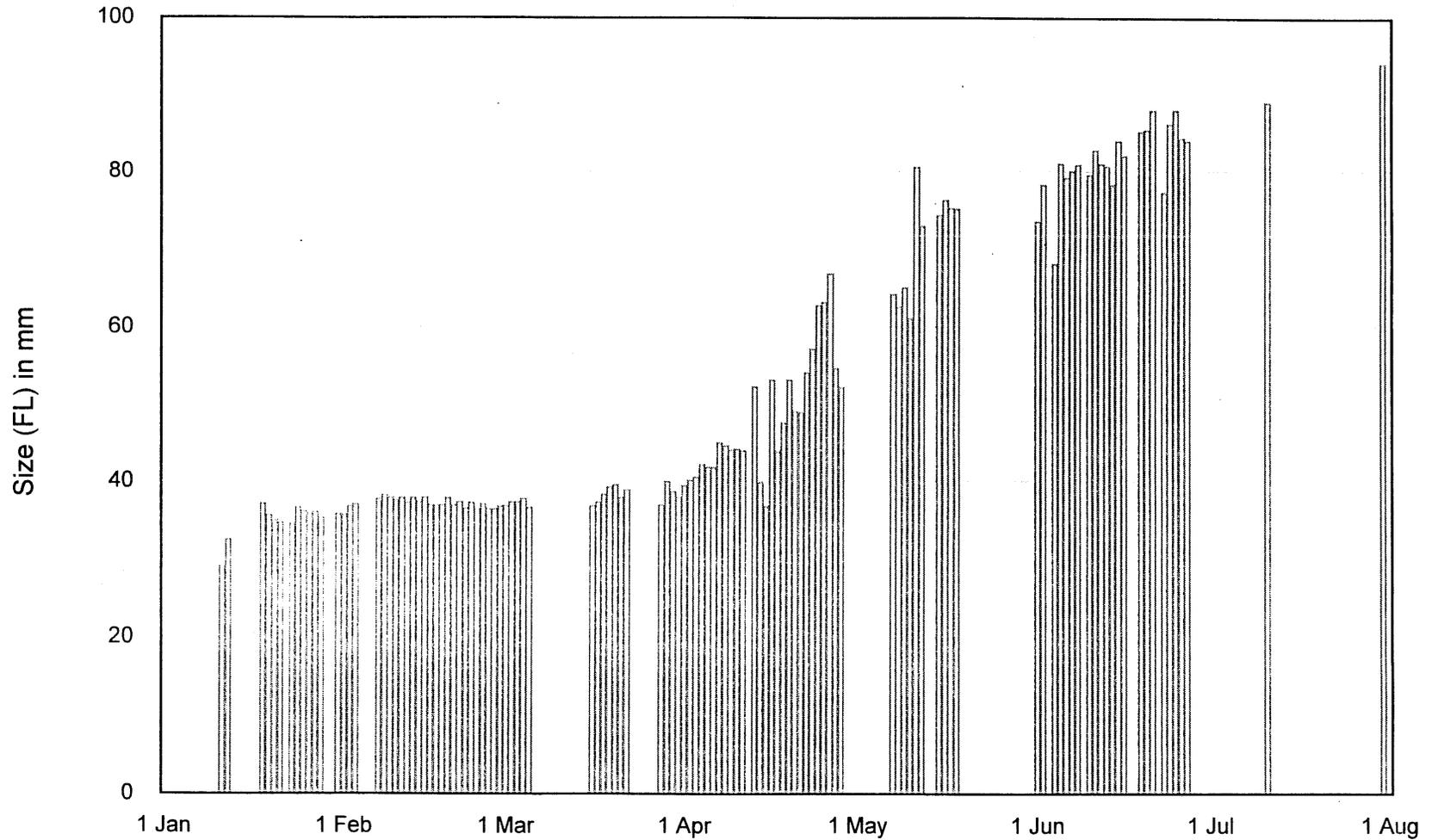


Figure 12. Daily mean fork length of chinook salmon caught by screw trap during the lower American River emigration survey, January - July 1995.

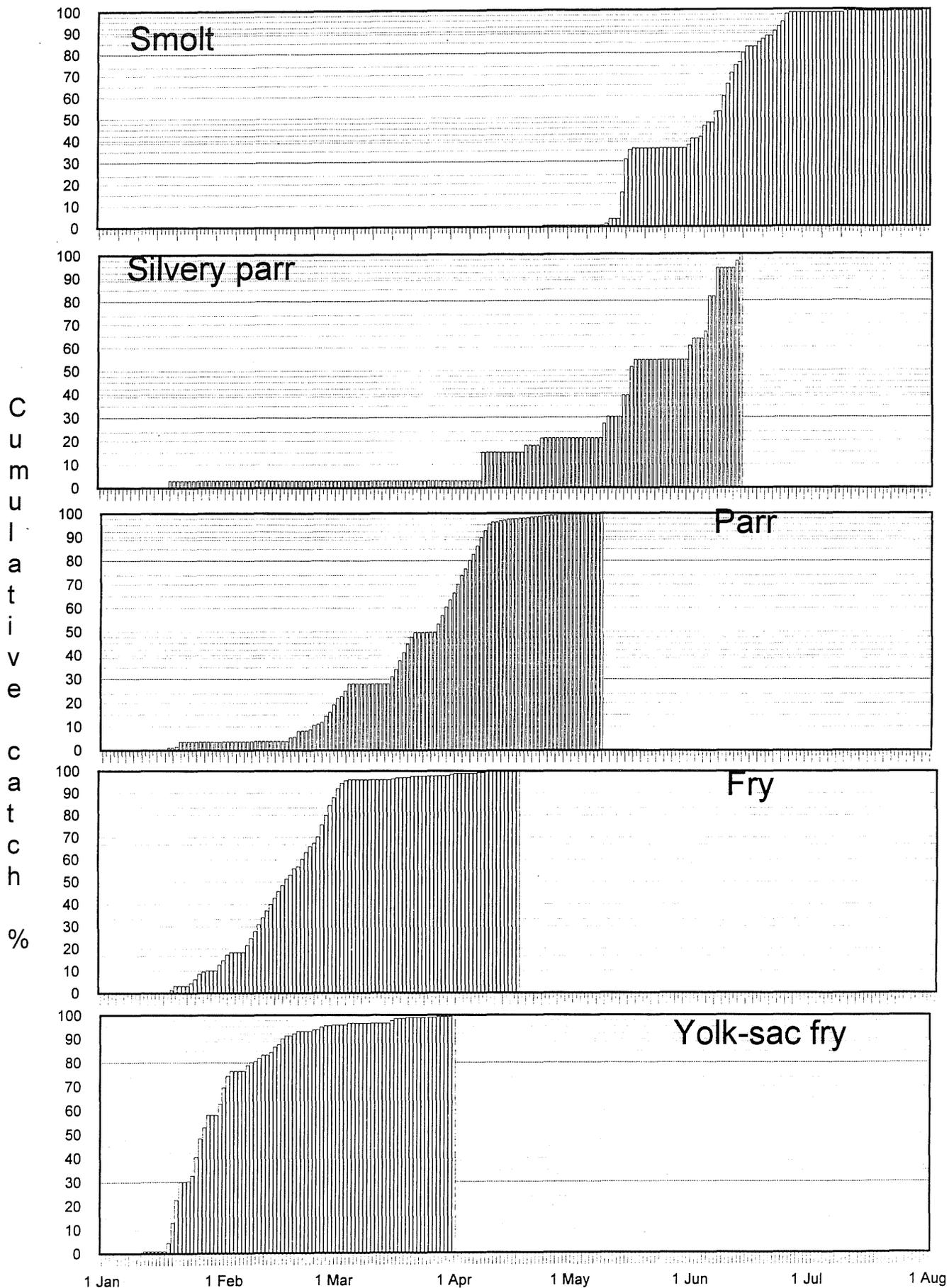


Figure 13. Cumulative catch (%) for yolk-sac fry, fry, parr, silvery parr and smolts collected during the lower American River emigration survey, January - July 1995.

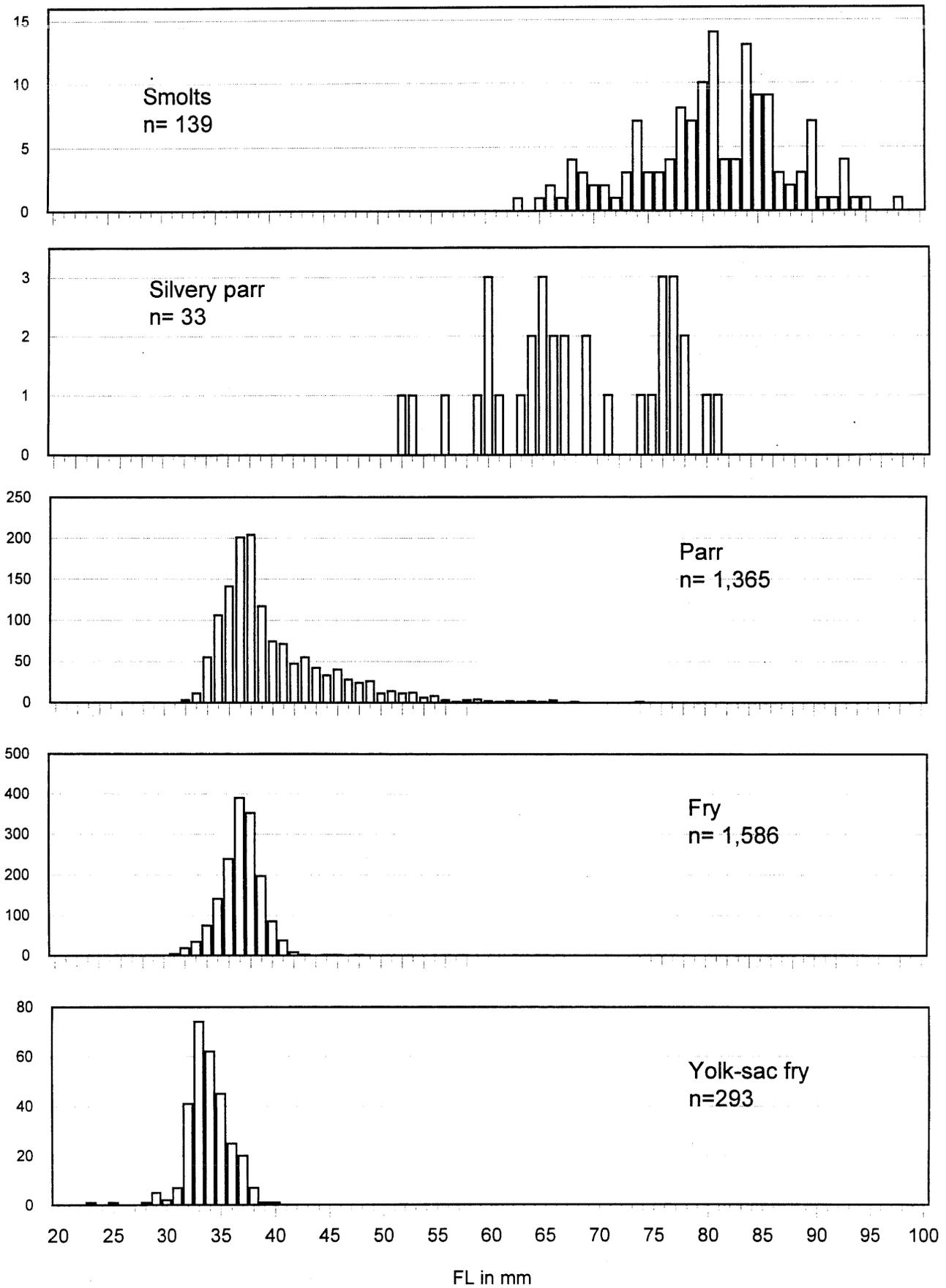


Figure 14. Length frequency distribution of chinook salmon yolk-sac fry, fry, parr, silvery parr and smolts collected during the lower American River emigration survey, January - July 1995.

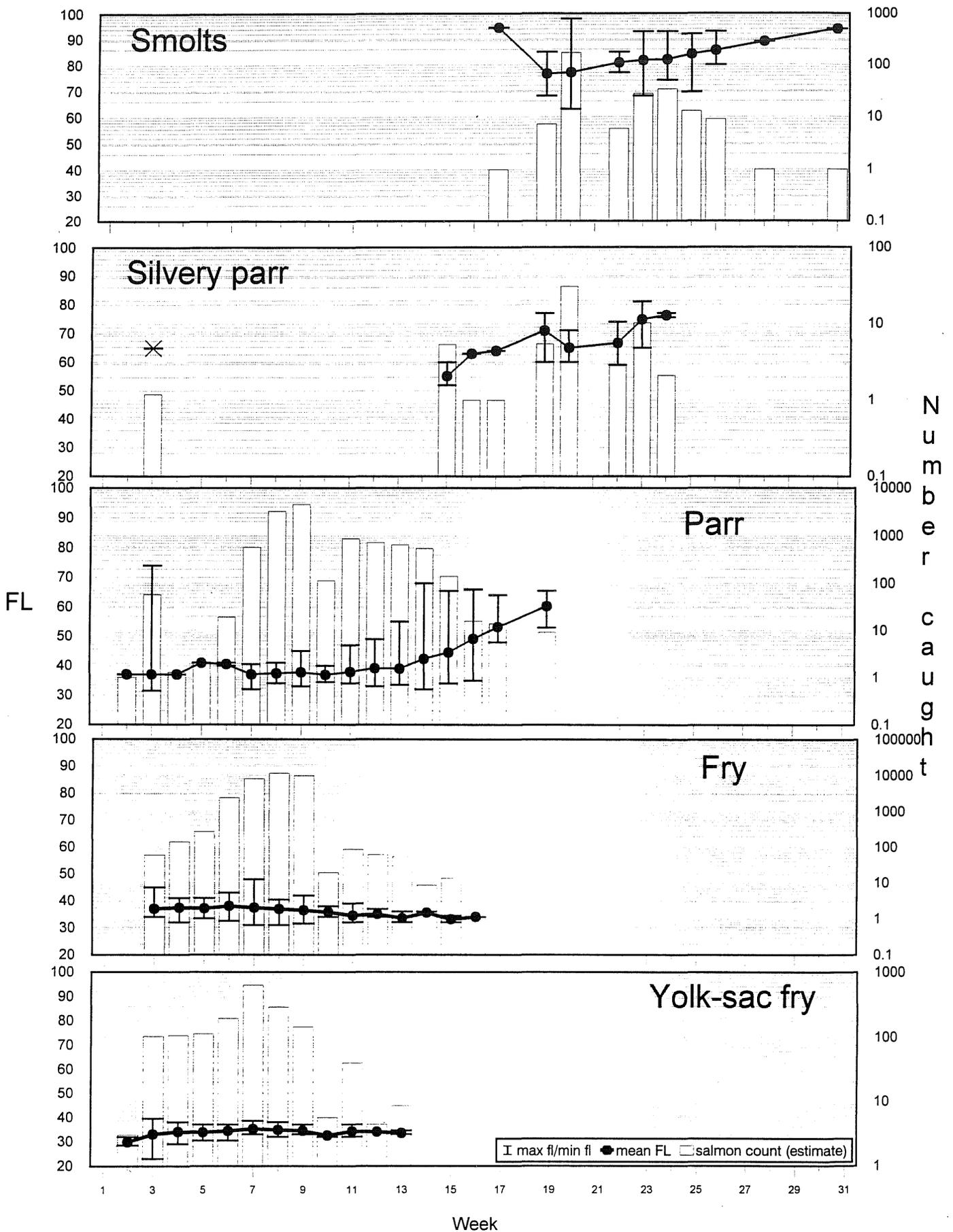


Figure 15. Weekly size and catch distribution of yolk-sac fry, fry, parr, silvery parr and smolts collected during the lower American River emigration survey, January - July 1995.

Condition factor as a function of FL

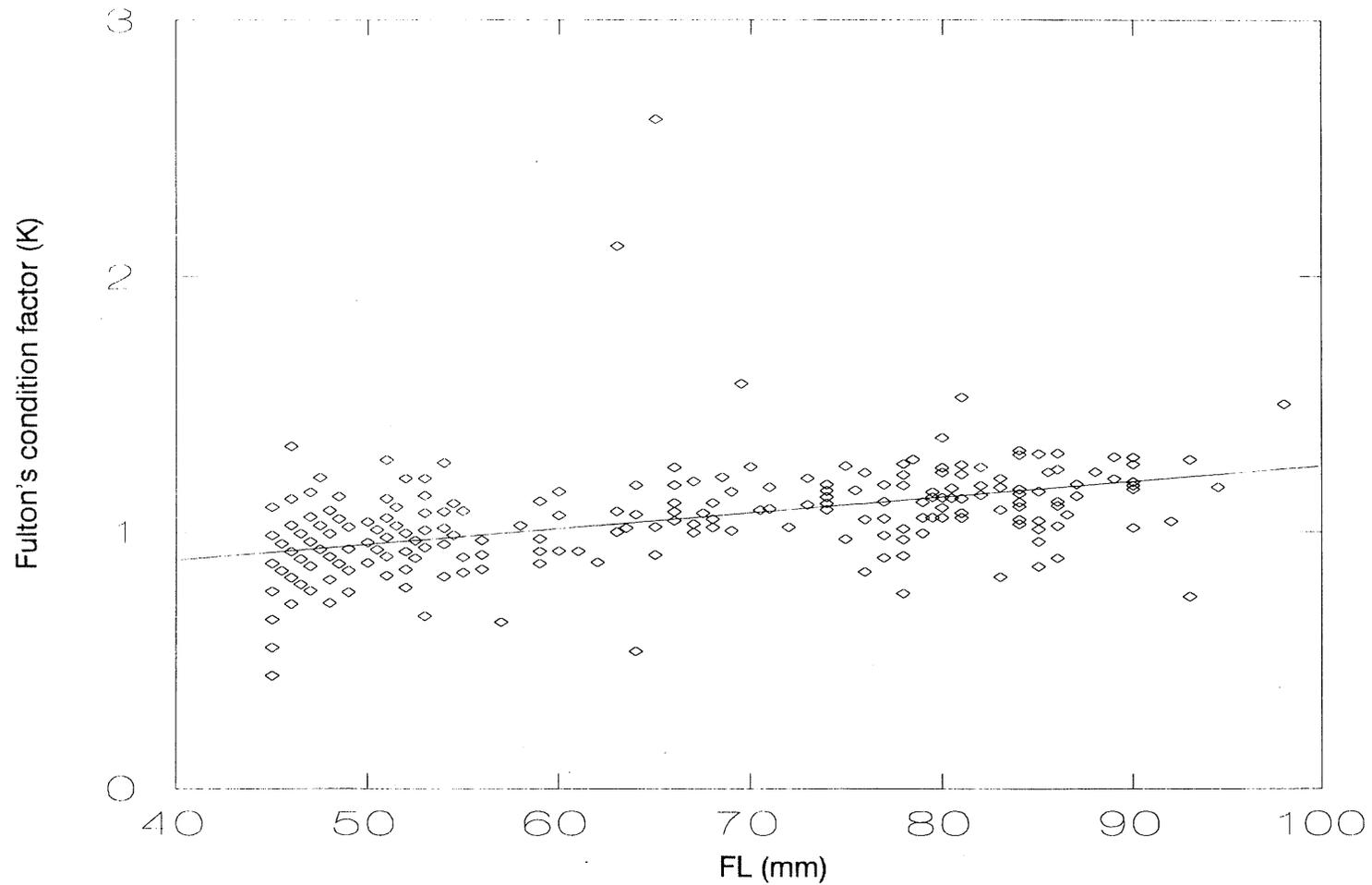


Figure 16. Fulton's condition factor (K) as a function of FL for chinook salmon ≥ 45 mm FL caught by rotary screw trap during the 1995 lower American River emigration survey, January to July 1995.

Condition factor as a function of FL

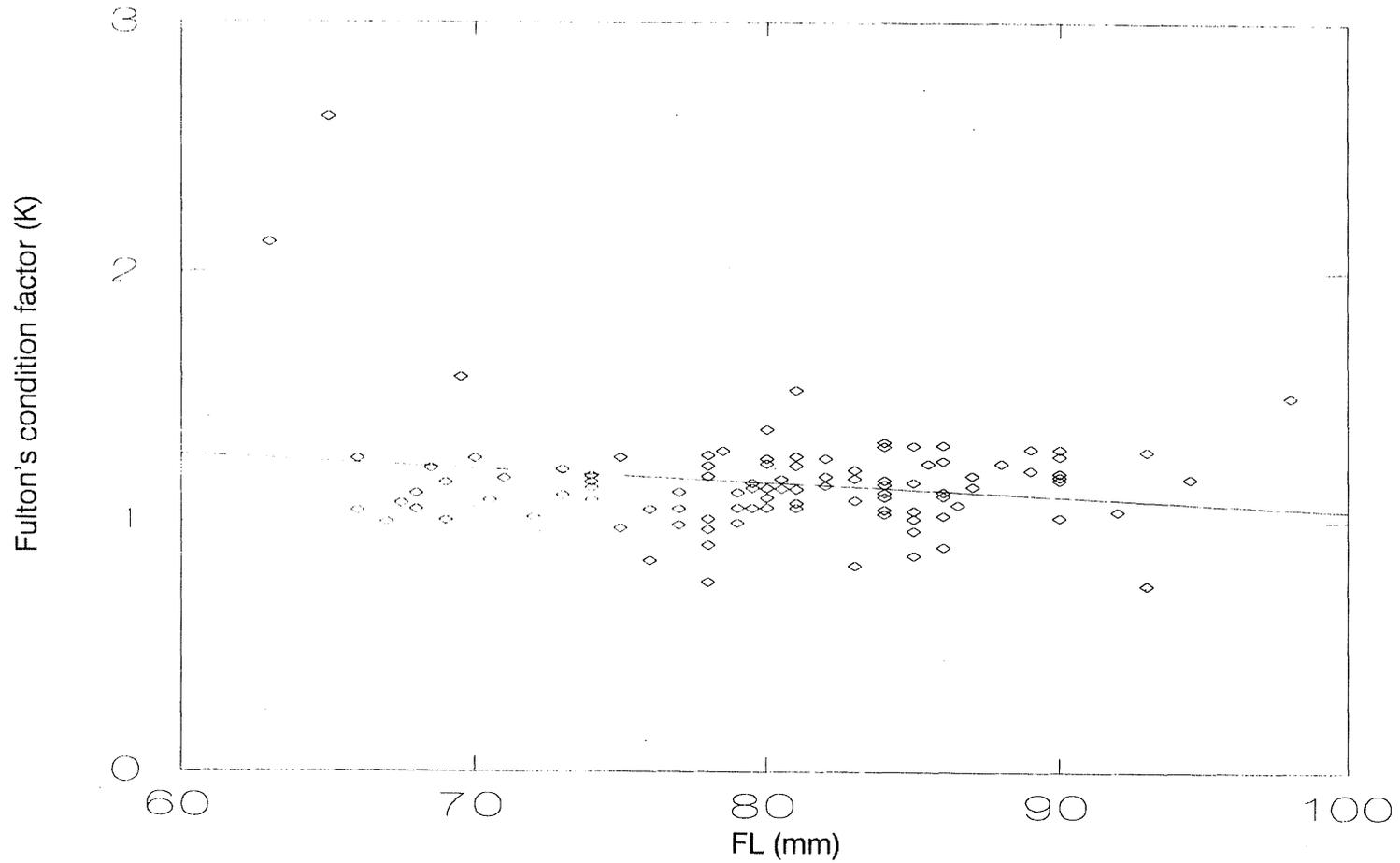


Figure 17. Fulton's condition factor (K) as a function of FL for chinook salmon smolts caught by rotary screw trap during the 1995 lower American River emigration survey, January to July 1995.

Chinook salmon size distribution north v. south trap

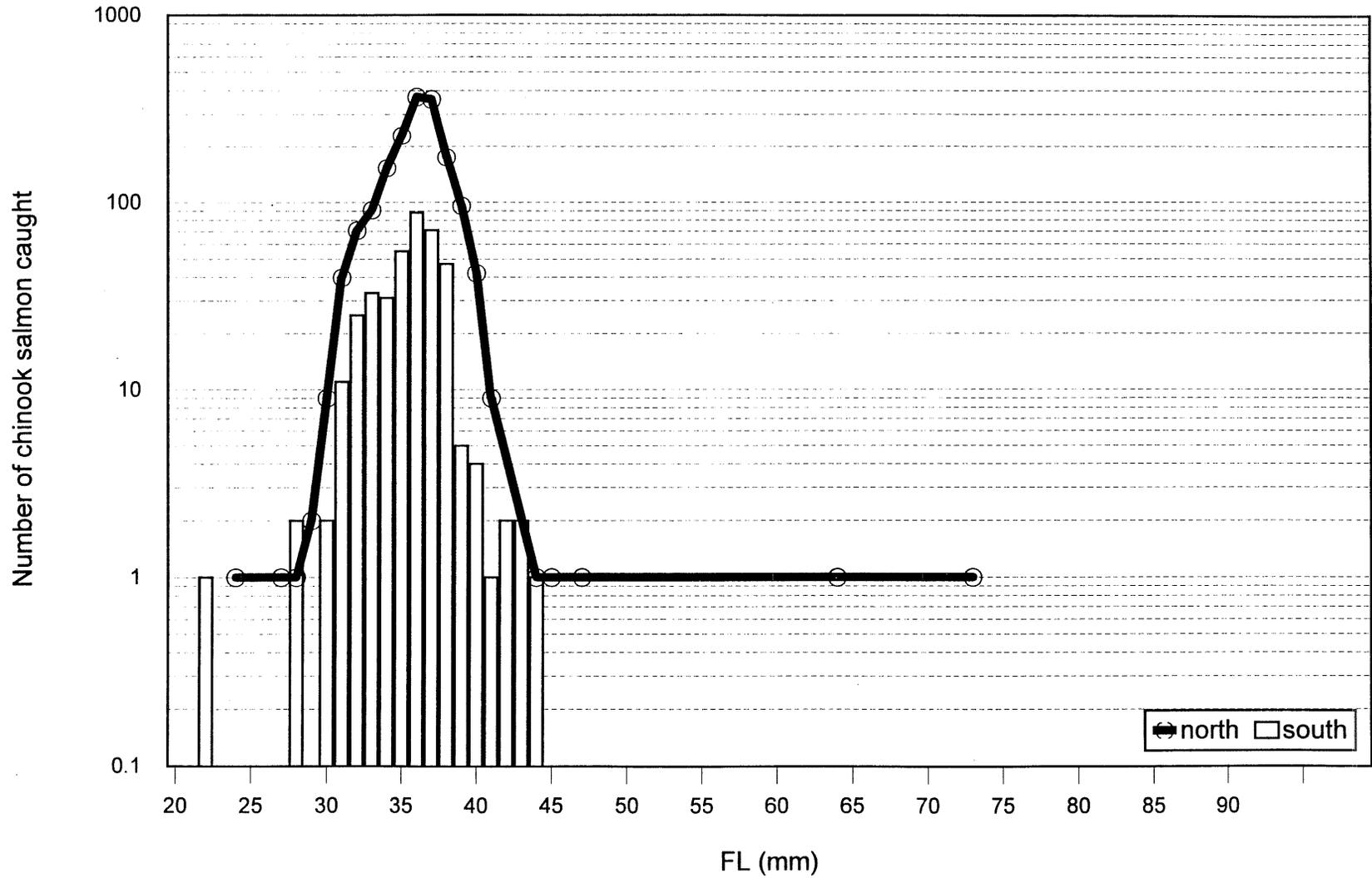


Figure 18. Comparison of size cumulative distributions of juvenile chinook salmon caught in the north versus south traps when both traps were fishing simultaneously during the lower American River emigration survey, December 1994 - March 1995.

Comparison of catch between north and south traps

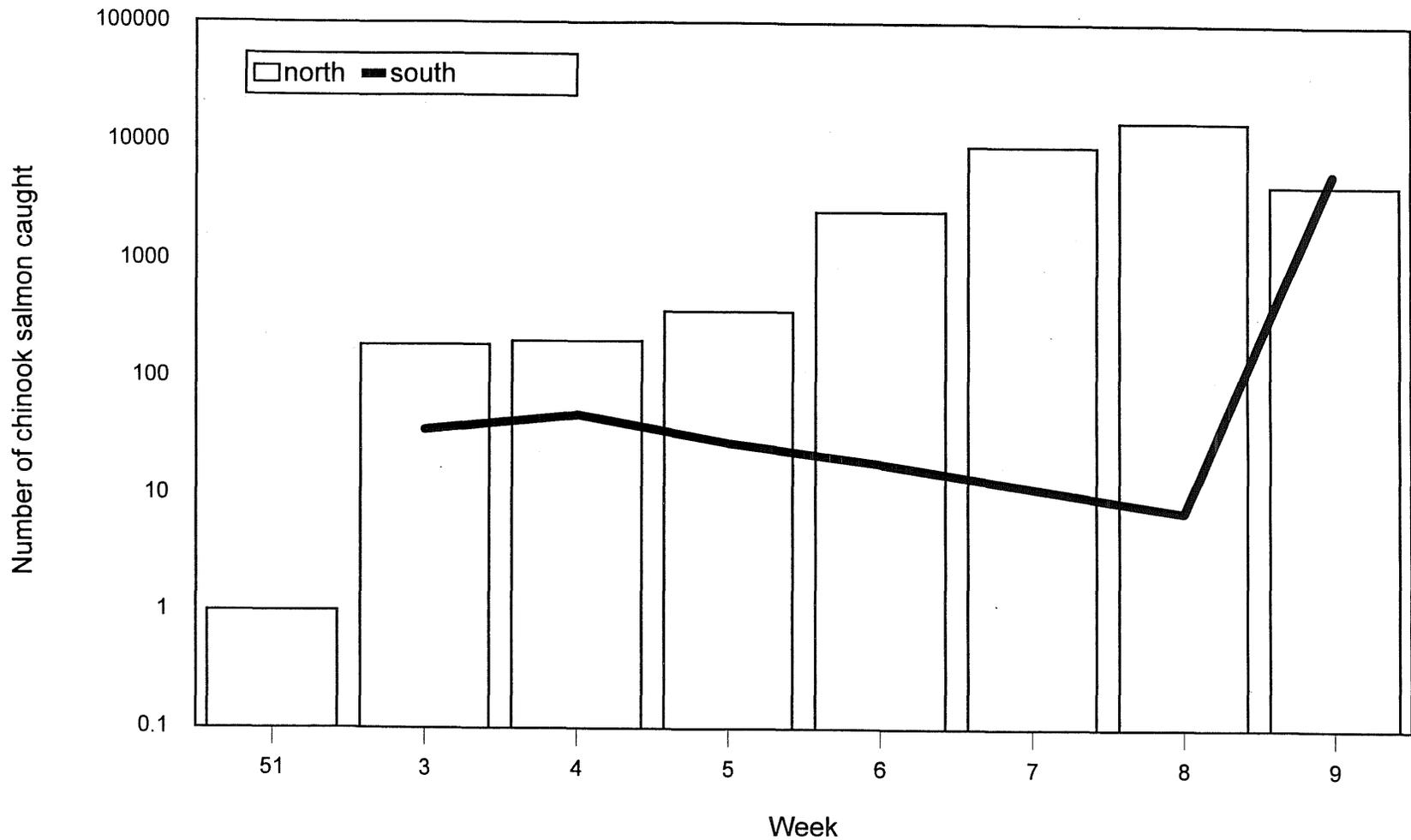


Figure 19. Comparison between north and south trap catch of chinook salmon when both traps were fishing simultaneously during the lower American River emigration survey, December 1994 - March 1995.

Comparison of catch/hour between north and south traps

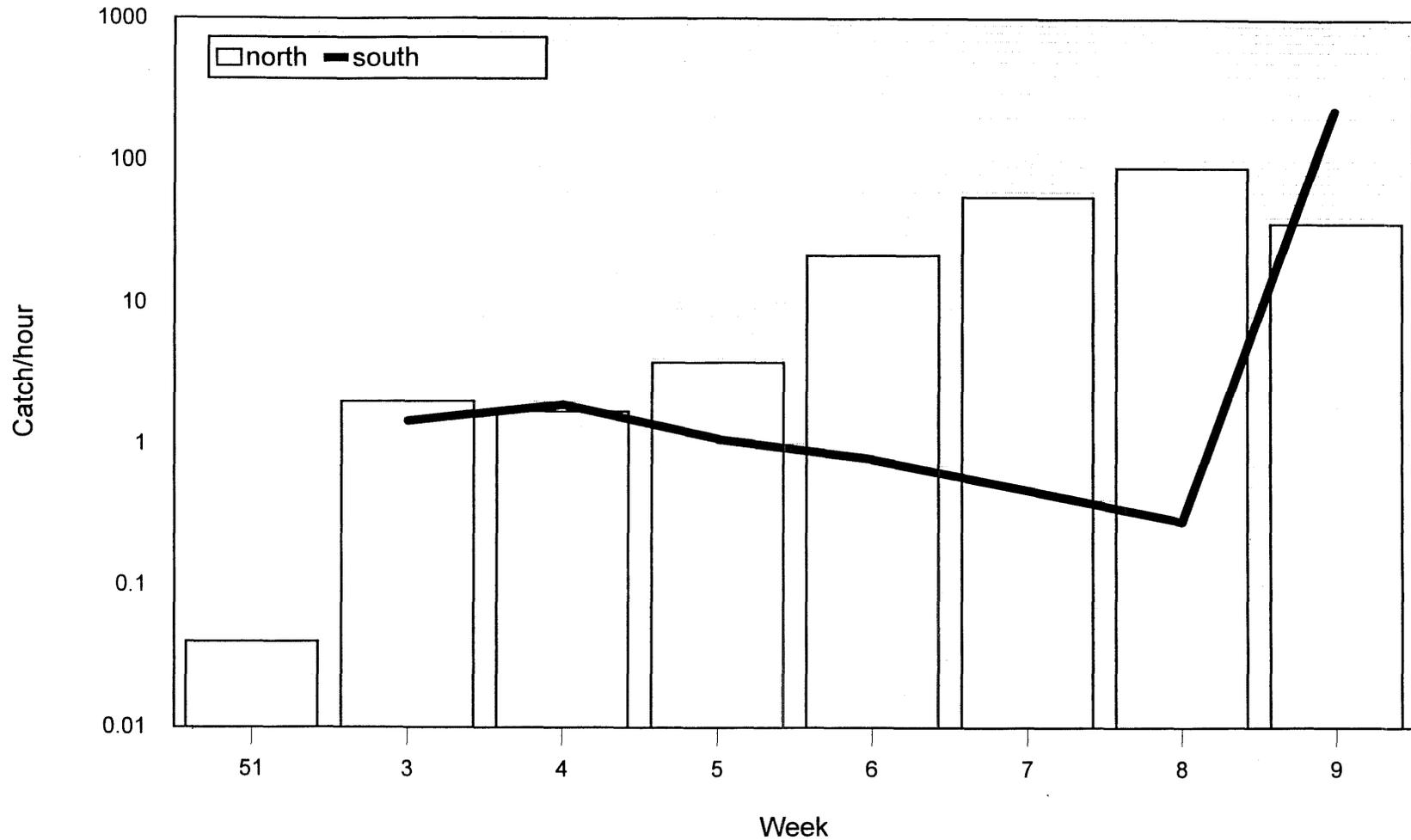


Figure 20. Comparison between north and south trap weekly catch rates of chinook salmon when both traps were fishing simultaneously during the lower American River emigration survey, December 1994 - March 1995.

Comparison of north vs. combined trap catch

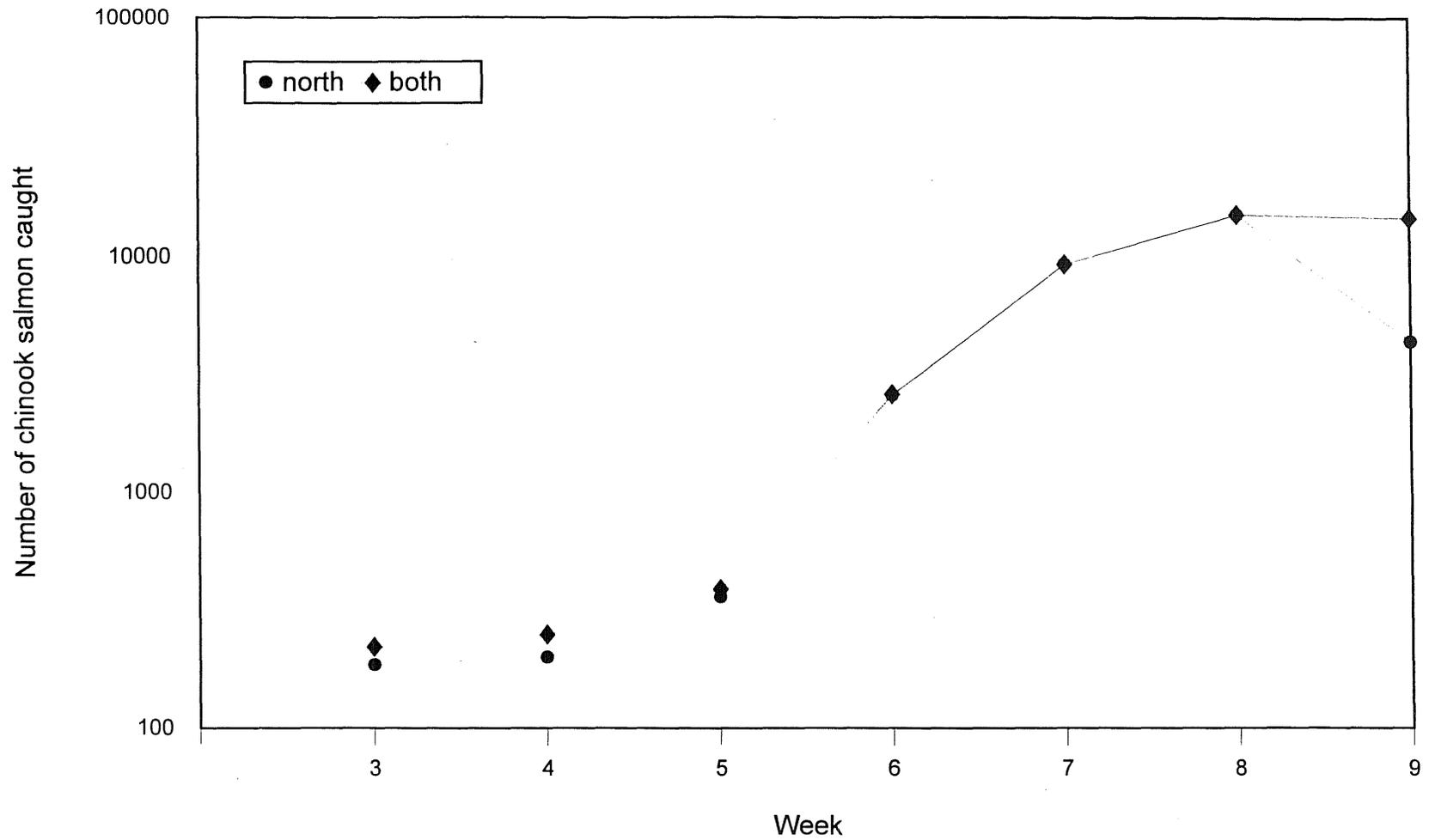


Figure 21. Comparison of north versus combined trap catch of chinook salmon when both traps were fishing simultaneously during the lower American River emigration survey, January - March 1995.

Comparison of north vs. combined trap catch rates

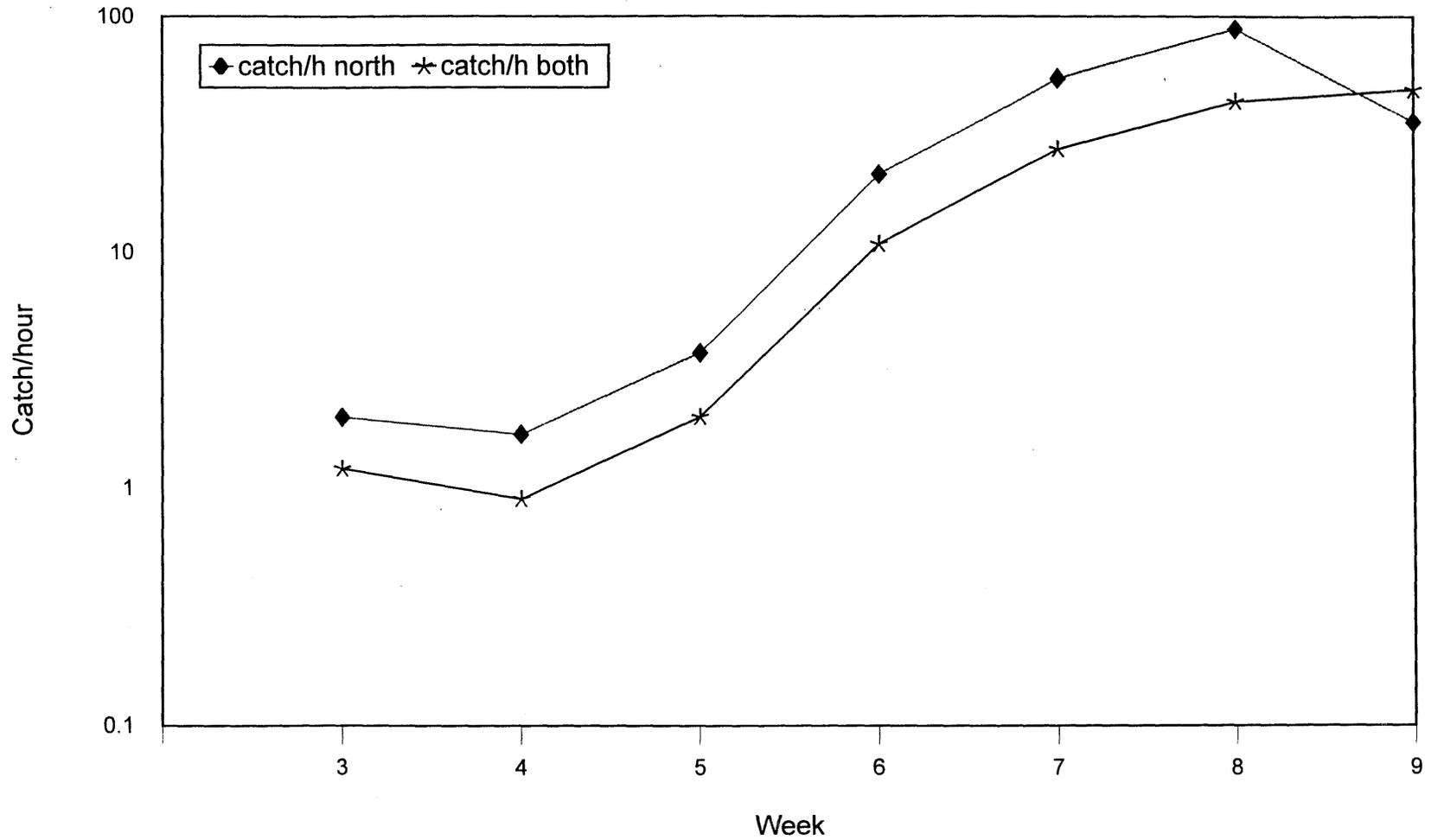


Figure 22. Comparison of north versus combined trap catch rate of chinook salmon when both traps were fishing simultaneously during the lower American River emigration survey, January - March 1995.

Chinook salmon size statistics and weekly catch for screw trap and seining surveys

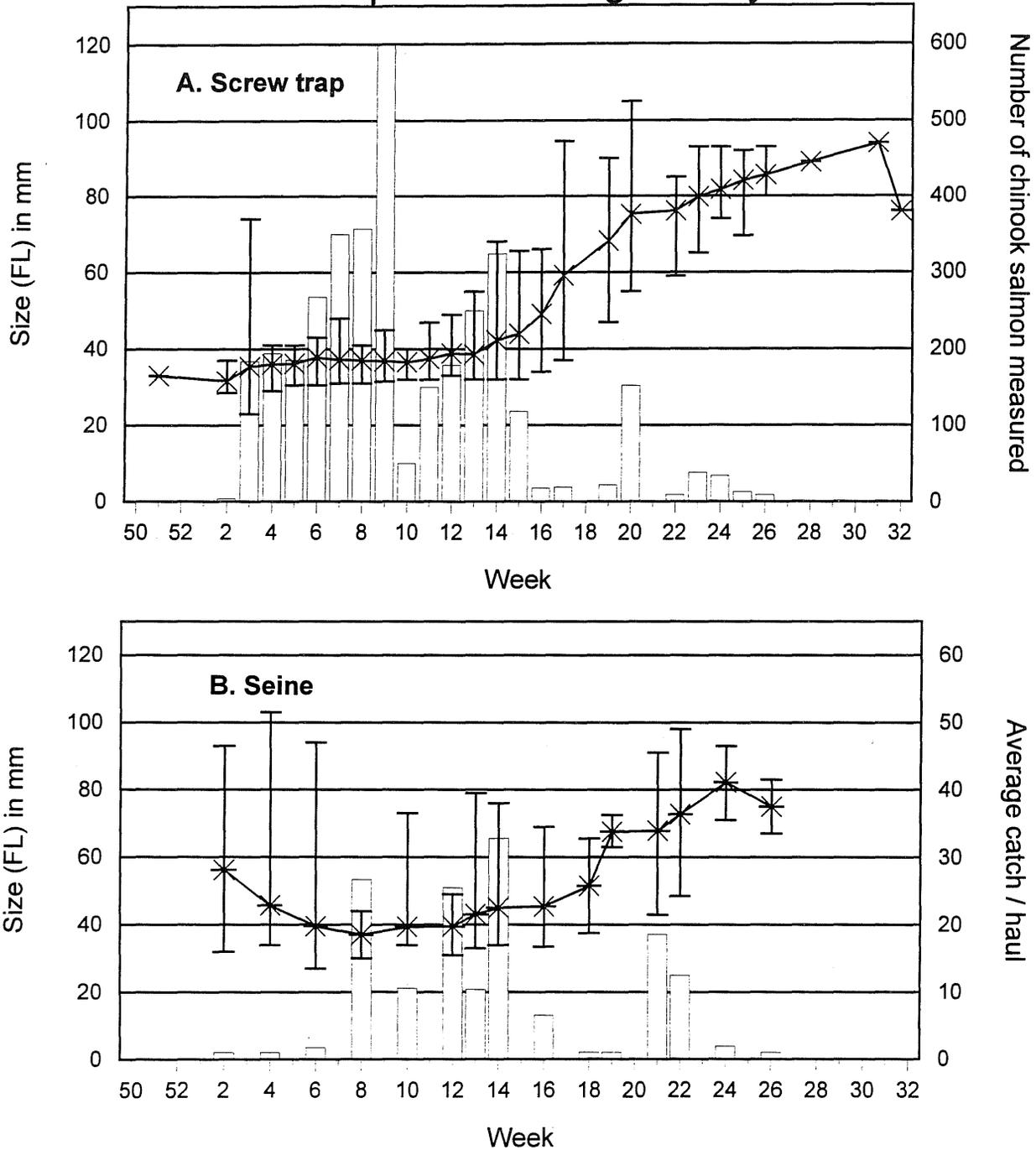


Figure 23. Mean fork length (line), size range and weekly numbers of measured salmon caught by screw trap (A) and caught by seine (B) in the lower American River between December 1994 and August 1995.

Steelhead catch distribution

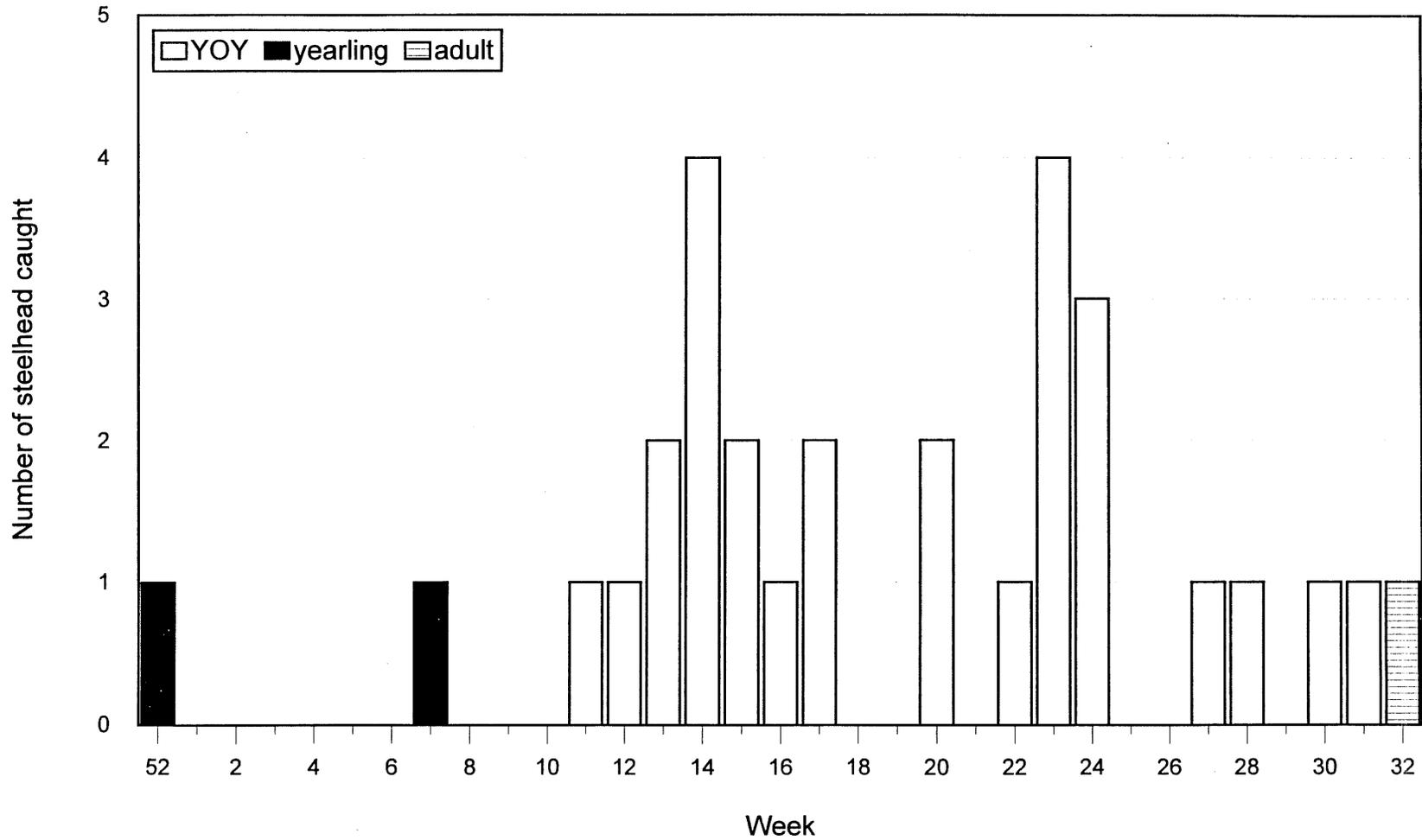


Figure 24. Catch distribution of YOY, yearlings and adult steelhead caught during the lower American River emigration survey, December 1994 - August 1995.

Steelhead young-of-the-year catch statistics

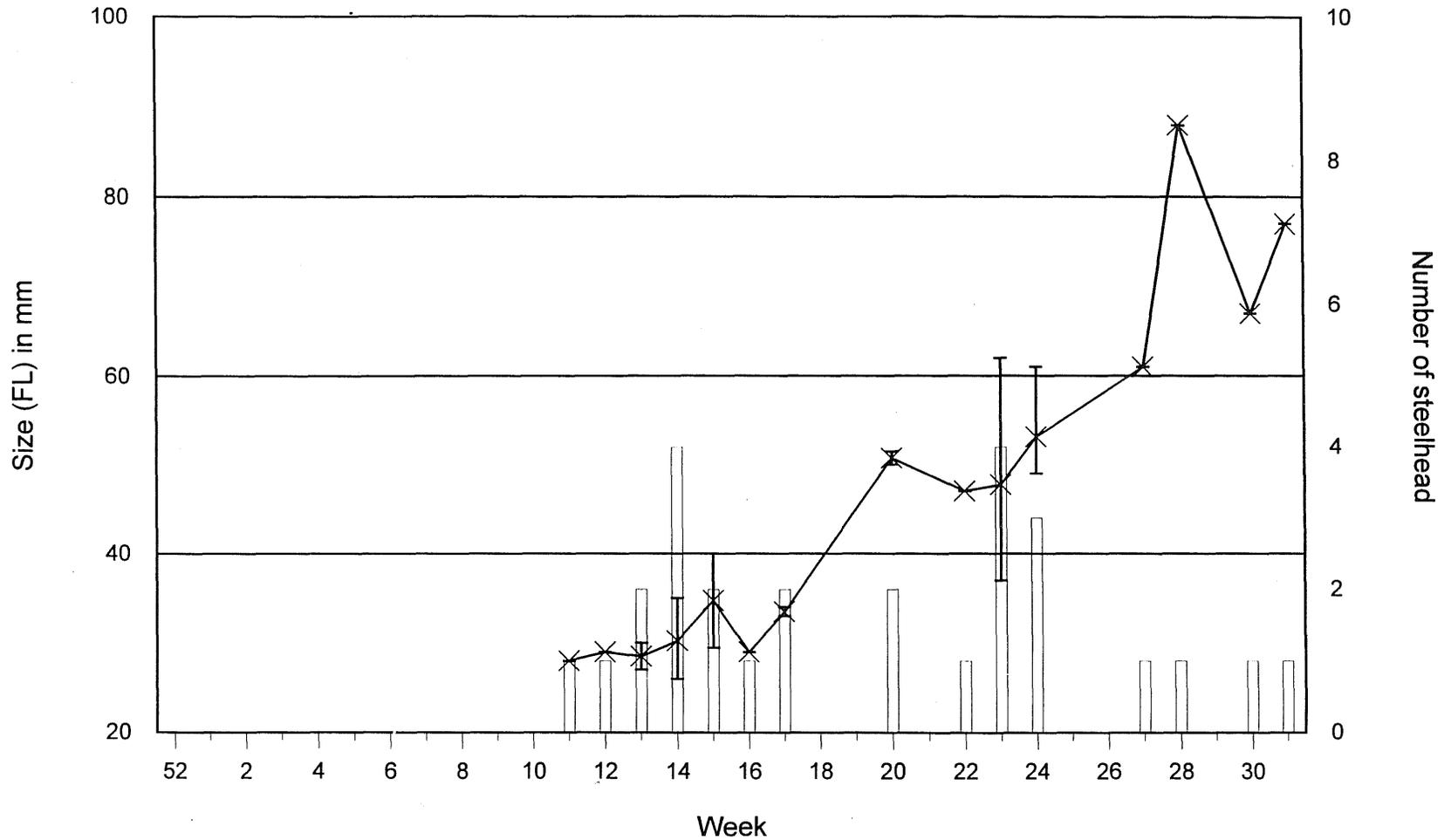


Figure 25. Weekly catch and mean weekly FL and size range of YOY steelhead caught during the lower American River emigration survey, December 1994 -July 1995.

Pacific lamprey catch

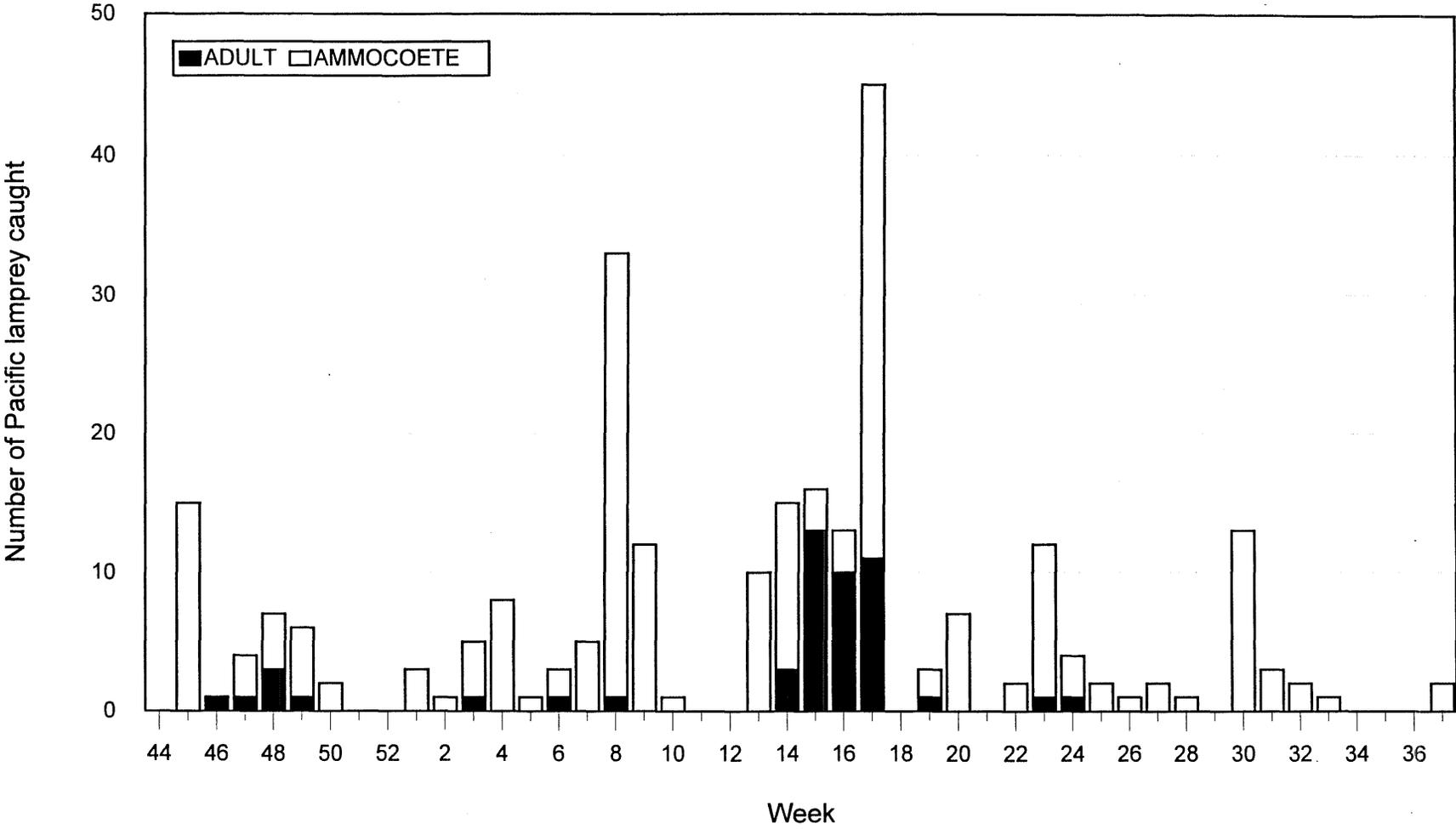


Figure 26. Catch distribution of Pacific lamprey caught by screw trap during the lower American River emigration survey, November 1994 - September 1995.

American shad catch

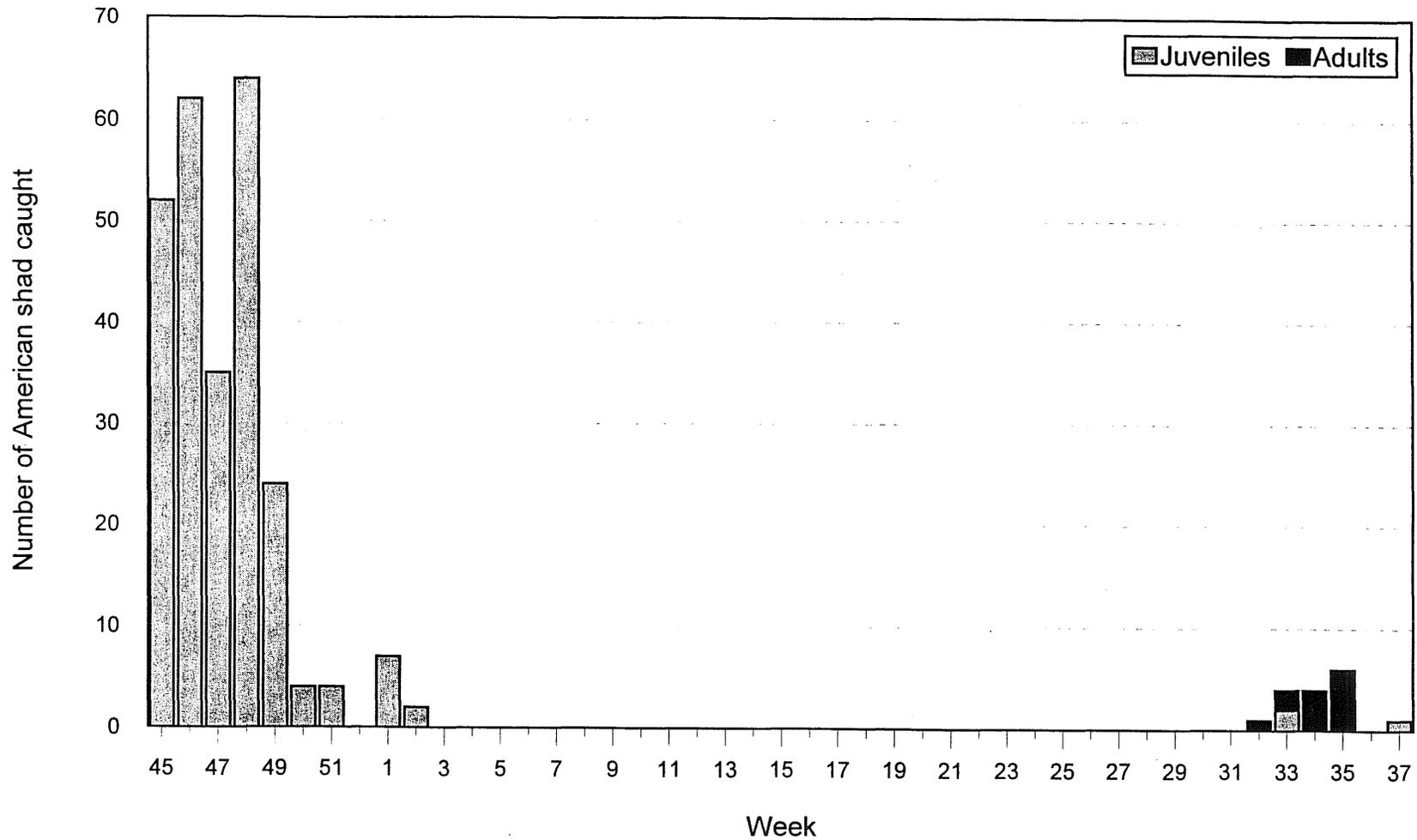


Figure 27. Catch distribution of American shad caught by screw trap during the lower American River emigration survey, November 1994 - September 1995.

American shad fork length distribution

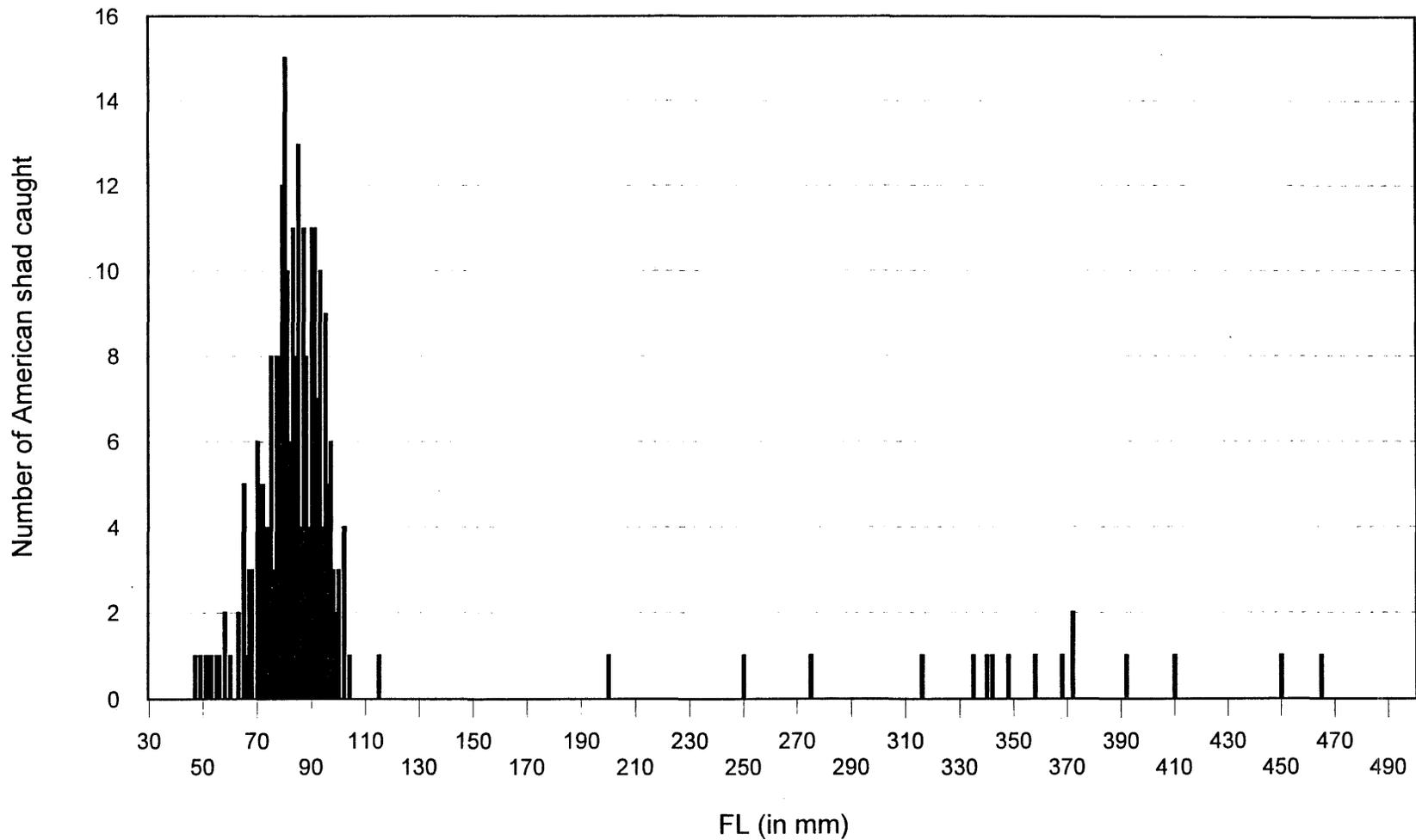


Figure 28. Fork length distribution of American shad caught by screw trap during the lower American River emigration survey, November 1994 - September 1995.