CALIFORNIA DEPARTMENT OF FISH AND GAME
ENVIRONMENTAL SERVICES DIVISION
Stream Evaluation Program

Lower American River
EMIGRATION SURVEY
October 1995-September 1996

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Stream Evaluation Program
Technical Report No. 98-6
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SUMMARY

A rotary screw trap (RST) was used to collect information on emigrating anadromous fishes in the lower American River. The trap was deployed near river mile (RM) 9 at the beginning of October 1995, and was fished continuously until the end of September 1996.

Emigrants of four anadromous fishes were collected: chinook salmon, steelhead trout, Pacific lamprey and American shad. We collected 132,040 salmon emigrants between 30 November 1995 and 16 July 1995. We also collected 138 young-of-the-year (YOY) steelhead between 10 March and 12 September 1996, six yearling-sized steelhead between 14 January and 17 March, and seven adult steelhead between 19 December 1995 and 15 August 1996. Also collected were 499 Pacific lamprey, between 10 October and 30 September 1996, and 46 American shad, between 10 October 1995 and 27 September 1996.

Chinook salmon emigrants were described by life stage as yolk-sac fry, fry, parr, silvery parr and smolt. Most of the salmon collected were fry (59.6%). Yolk-sac fry comprised 22.6% of the chinook salmon catch, parr comprised 17.4%, and silvery parr comprised 0.4%. None of the salmon caught were classified as smolt. Yolk-sac fry were collected between 30 November 1995 and 8 April 1996, fry between 17 December 1995 and 16 April 1996, parr between 17 December 1995 and 10 May 1996 and silvery parr between 16 December 1995 and 16 July 1996.

Salmon yolk-sac fry lengths ranged from 25 to 48 mm fork length (FL), fry ranged from 30 to 67 mm FL, parr ranged from 30 to 72 mm FL, and silvery parr ranged from 42 to 98 mm FL. Fulton's condition factor (*K*) was determined for representatives of each life stage.

Chinook salmon emigration started and peaked much earlier in the 1996 survey-year than in the 1993-1994 and 1994-1995 survey years (Snider and Titus 1995, Snider *et al*. 1997). In the 1996 survey-year, the first salmon was caught in late-November 1995, and the peak catch period took place from mid-January through mid-February 1996. In the 1994 survey-year, the first salmon was caught during the second week of January, and in late-December during the 1995 survey-year. However, peak catches did not begin in 1994 or 1995 until mid-February. In none of the three survey-years was the timing of emigration coincident with the timing of peak spring flows.

The total chinook salmon catch of 1996 (132,040) was similar to that of 1994 (162,089) (Snider and Titus 1995), but much greater than that of 1995 (45,478) (Snider *et al*. 1997). Overall catch rate in 1996 (from capture of the first salmon to capture of the last salmon) was 25.6 fish /h, intermediate between 1995 (9.6 fish/h) and 1994 (30.4 fish/h).

All salmon caught by RST in the 1996 survey-year were pre-smolt; the majority were recently emerged (<45 mm FL; 96%). These results are consistent with those observed during the 1994 and 1995 survey-years when 96% and 86%, respectively of the total salmon catch were recently emerged.

INTRODUCTION

Anadromous fish emigration was monitored in the American River from October 1995 through September 1996. This was the third, consecutive year that migration was monitored in the lower American River 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 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 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 compared with 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 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 in the lower American River, including timing, abundance, fish size (life stage) composition, and fish condition, and to relate these attributes primarily to 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 plan 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 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, and 1995 continuous collection of data throughout the emigration period, allowed us to achieve certain of the objectives listed above (Snider and Titus 1995; Snider *et al*. 1997). This study reports on data collected from October 1995 through September 1996, the first time migration activity in the lower American River was monitored year-round.

BACKGROUND

Chinook Salmon Emigration

Snider and Titus (1995) outlined some of the key elements determining emigration success of salmonids produced in large river systems.

- Young fish generally spend their pre-smolt growth and development period in two locations: the natal stream and in the river estuary. The more time spent in the natal stream, the shorter the residence time necessary in the downstream estuary.

- 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 is it to understand the factors that control the 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, sympatric and allopatric fish interactions, turbidity and water temperatures.

- Salmon that remain in the natal stream for a long period after emerging are more likely to smolt successfully.

Various schemes have been used to classify the life stages of juvenile chinook salmon (Healey 1991; Kjelson and Brandes 1989). For the purposes of this study, we characterize fish as yolk-sac fry, fry, parr, silvery parr, and smolt 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 short 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. 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 or absent 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. A smolt is 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

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 were detected as early as January, but did not increase in numbers until March, attaining a peak in April. Fingerling (FL >50 mm) emigration began in late May and lasted until mid-June.

- In 1988 and 1989 Beak Consultants Inc. used Kodiak trawls to sample emigrants from the lower American River. In 1988, sampling began in late April and no fry were caught. In 1989, fry emigration apparently peaked in early March, although sampling did not begin until 1 March. In both years, fingerling emigration peaked in mid-May.

- In 1992 and 1993, various methods 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 RST (Snider and Titus 1995).

In 1994 and 1995, we were able to monitor emigration continuously in the lower American River throughout the emigration period. In 1994, we caught a total of 162,089 salmon emigrants between 13 January and 13 July 1994. Peak emigration occurred in mid-to-late February. The following year, 51,847 salmon emigrants were caught by RSTs between 11 January 1994 and 9 August 1995 (one additional juvenile salmon caught 8 November 1994 was a winter-run-sized salmon). Peak catches again occurred in mid-to-late February. The timing of emigration in both 1994 and 1995 was similar to that observed in 1988 and 1989 trawling surveys, but much later than that observed in emigration studies from 1945 through 1947 (Snider and Titus 1995).

A majority of chinook salmon emigrants captured in 1994 and 1995 were fry or yolk-sac fry (>96%), and nearly all were pre-smolt (>99%). These findings indicate that juvenile salmon must undergo significant development in the river and estuarine environs downstream from the study site prior to entry to the ocean.

Fulton's condition was calculated for a subset of emigrating fish in 1994 and 1995. Traditionally, a decrease in Fulton's condition factor is associated with the onset of smolting in young salmonids (Folmar and Dickhoff 1980, Wedemeyer *et al*. 1980, Titus and Mosegaard 1992). In 1994 and 1995, however, there was no detectable difference in condition factor between fish classified as smolt and those classified as parr.

RST efficiency was measured in 1994 using mark-recapture. Efficiency measurements ranged from 0.00% to 0.94%.

Other Anadromous Fishes

Emigrating anadromous fish species other than chinook salmon that were captured in the lower American River in both 1994 and 1995 include steelhead trout, Pacific lamprey and American shad. Snider and Titus (1995) provide 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 Folsom Dam, operated by the U.S. Bureau of Reclamation (USBR) to provide water supplies, flood protection, hydroelectric power production, 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 20,000 cfs. Large amounts of debris typically accompany flow changes as increased stage picks up debris along the river's margin. Urban runoff from several flood control drains also introduces a variety of debris into the river.

In 1996, one RST was fished immediately downstream of the Watt Avenue bridge (Figure 1) on the north side of a large, mid-channel bar (Figure 2), the same location fished during the 1994 and 1995 survey-years. The trap was deployed on 29 September 1995 and was fished nearly continuously until 30 September 1996 to obtain a complete year record of emigration activities. Fishing was interrupted in the following periods: 23 to 27 November 1995 (weeks 47 and 48), 22 to 26 December 1995 (week 52), 31 December 1995 to 2 January 1996 (week 1), 23 to 25 March 1996 (weeks 12 and 13), and from 26 to 28 May 1996 (week 22).

Servicing of the RST was conducted two to three times a week in October and November 1995. In the peak salmonid emergence period from December 1995 through March 1996, the trap was serviced nearly every day. In April and May 1996, the trap was serviced less frequently (a total of 17 days in April, a total of 22 days in May). In June through September, the trap was serviced each weekday.

At each servicing, fish were removed from the trap, sorted, and counted by species. Up to 300 of each species was measured (length to the nearest 0.5 mm, and weight to the nearest 0.1 g). Fulton's condition factor, K, was calculated as 10^5(weight, g)/(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 sack. Fry were defined as recently emerged 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 on their sides. 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. The total number of each life stage captured per week was calculated when the total number of salmon measured and classified was less than the number counted 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 measurement taken at the Fairbairn Water Treatment Plant at RM 7. Water temperatures were measured from October to December 1995 at two-hour intervals using a Ryan temp-meter affixed to the RST, and by a Hobotemp thermograph from 12 July to 30 September 1996. Between December 1995 and July 1996, equipment failure and loss of some equipment due to high flows required us to use temperature data gathered at the trap sites during each servicing using a hand-held thermometer. Water transparency (Secchi depth at the north trap), water and air temperatures, and trapping effort (hours fished since last service) were recorded at each servicing of the trap.

Between 24 January and 10 May 1996, a variable fraction of the fish captured (up to 300 fish/d) was dye marked using Alcian Blue, then released approximately 1 km upstream of the trap. The percentage of marked fish recaptured in the trap provided a measure of trap efficiency.

RESULTS

General

Flow was highly variable during the 1996 emigration period (Figure 3). For most of January, flow was 2,000 cfs. Flow rose abruptly to nearly 30,000 cfs in the beginning of February and remained above 10,000 cfs for the remainder of the month. From 7 March 1996 through the end of June, flows fluctuated between 4,000 cfs and 5,500 cfs except for peak flow events from 16 to 18 April of 8,000 cfs, and on 17 May of 40,000 cfs. After 1 July, flows gradually declined and remained between 1,000 cfs and 3,000 cfs through October.

Water temperature remained above 47 °F during January and reached the lowest level in mid-March (46 °F; Figure 4) reflecting the changes in flow that occurred during this period (Figure 3). When discharge declined below 5,000 cfs in March, water temperatures increased sharply to above 50 °F. Water temperatures remained between 55 and 60 °F throughout June and between 60 and 65 °F throughout most of July. One temperature reading in July exceeded 65 °F. During the first three weeks of January (weeks 1 to 3) and June (weeks 23 -26), and in early July (week 27), mean weekly water temperatures in 1996 were at least 0.5 °F higher than in corresponding weeks of 1994 (Snider and Titus 1995) and 1995 (Snider *et al*. 1997). Mean weekly water temperatures during early March 1996 (weeks 9-11) and late April 1996 (weeks 16-17) were at least 1.0 °F lower than weekly averages during the same periods in 1994 and 1995.

Turbidity data for the lower American was only measured after 1 April 1996 (Figure 5). Peaks in turbidity in early April, mid-April and late May (Figure 5) corresponded to peak discharges (Figure 3). A peak flow event in mid-May had no corresponding increase in turbidity.

Twenty-eight fish species were collected in the RST (Table 1). Juvenile chinook salmon accounted for most fish caught (total cumulative catch = 132,040), followed by squawfish (838), Pacific lamprey (499), Japanese smelt (150), steelhead (145), and sculpin (134). Forty-six American shad were also

Table 1. Summary of fish species collected during the lower American River emigration survey, October 1995-September 1996. The species are listed in alphabetical order, by common name

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	1995			1996									
Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	TOTAL
American shad (YOY)	14	1	0	0	0	0	0	0	0	0	1	18	34
American shad (adult)	0	0	0	0	0	0	0	0	3	6	3	0	12
Black bullhead (adult)	0	0	0	0	0	1	0	0	1	1	0	0	3
Bullhead (juvenile)						None caught							
Bluegill	2	0	0	0	7	0	2	3	1	1	2	19	37
Chinook salmon[1/] (fall-run)	0	1	287	40,202	76,021	14,409	676	356	54	3	0	0	132,009
Chinook salmon[1/] (spring-run)	0	0	2	4	0	0	0	2	0	0	0	0	8
Chinook salmon[1/] (winter-run)	0	0	11	1	0	0	0	0	0	0	0	0	12
Chinook salmon[1/] (late fall-run)	0	0	0	0	0	0	11	0	0	0	0	0	11
Chinook salmon (adult)	1	41	14	0	0	0	0	0	0	0	0	0	56
Crappie						None caught							
Cyprinid (juvenile)	1	0	0	2	2	0	0	0	0	0	0	6	11
Gambusia	0	1	6	2	0	0	0	1	0	0	0	1	11
Golden shiner	0	0	0	1	2	0	0	0	0	0	2	2	7
Goldfish						None caught							
Green sunfish	3	1	1	0	0	0	0	0	1	1	2	1	10
Hardhead	0	50	3	2	0	0	0	0	0	0	0	0	55
Hitch	0	0	0	1	0	0	0	0	0	0	0	0	1
Japanese smelt	0	5	3	11	100	24	3	0	2	1	1	0	
Lamprey (ammocoete)	2	4	32	13	12	22	138	98	34	24	4	10	393

Table 1 (continued)

Lamprey (subadult)	0	0	0	0	0	1	6	8	0	0	0	0	15
Lamprey (adult)	9	9	5	25	2	1	14	25	1	0	0	0	91
Largemouth bass	4	4	0	0	4	1	0	15	2	4	2	2	38
Lepomis spp.	0	1	1	0	16	0	0	0	0	0	0	0	18
Mississippi silverside	0	2	3	0	1	0	0	0	0	0	1	0	7
Redear sunfish	1	0	1	0	0	0	0	0	0	0	0	5	7
Sculpin	1	3	19	38	17	4	13	11	9	14	5	0	134
Smallmouth bass	2	0	0	1	3	0	0	0	0	0	0	0	6
Squawfish	1	0	2	1	20	2	8	20	11	4	582	131	782
Steehead (YOY)	0	0	0	0	0	16	36	49	11	23	2	1	138
Steelhead (yearling)	0	0	0	4	0	2	0	0	0	0	0	0	6
Steelhead (adult)	0	0	1	3	0	0	0	0	0	1	2	0	7
Striped bass (YOY)	0	0	0	0	0	0	0	2	0	0	1	0	3
Striped bass (yearling)	0	0	0	0	0	0	0	7	1	0	2	0	10
Striped bass (subadult)	0	0	0	0	0	0	0	0	3	0	1	0	4
Sunfish (juvenile)	0	0	0	0	6	0	1	13	2	0	0	13	35
Sucker	2	1	2	2	0	1	1	3	2	28	40	15	97
Threadfin shad	0	1	30	14	16	4	1	0	0	0	0	1	67
Tule perch	10	1	2	0	10	0	0	0	0	4	4	7	38
Warmouth	0	0	0	0	0	0	0	3	0	0	0	0	3
White catfish	0	0	0	0	0	0	0	0	0	0	1	0	1

1/ Chinook salmon race based upon size criteria developed by F. Fisher, CA Department of Fish and Game caught by RST in 1996. The species composition of the 1996 RST catch differed from 1994 and 1995 in that steelhead ranked among the six most frequently caught species and American shad did not rank in the top six.

Chinook Salmon

Chinook salmon emigration spanned 33 weeks, from 30 November 1995 (week 48 of 1995) through 16 July 1996 (week 29 of 1996) (Table 2). A total of 132,040 salmon was caught in 5,149 hours of fishing effort (25.6 fish/h). The highest daily catch occurred 26 January 1996 (12,285 fish, 616.25 fish/h) (Figures 6 and 7), approximately one month earlier than in 1994 and 1995 (Snider and Titus 1995; Snider *et al*. 1997). The highest weekly catch also occurred in week 4 of 1996 (28,423 fish, 163.8 fish/h) (Figures 8 and 9).

Salmon were caught in each week from week 48 of 1995 (beginning 26 November) through week 29 of 1996 (ending 20 July) with the exception of week 49 (1995), week 26 and week 28 (1996) (Figure 8). The catch-rate increased from less than 0.01 fish/h in week 48 (of 1995) to more than 163 fish/h during week 4 (21 January 1996) (Figure 9). After week 4, catch-rate decreased gradually to 0.01 fish/h in week 29 (14 July 1996).

Salmon length ranged from 25 to 98 mm FL (Table 2). Mean weekly length ranged from 33.8 to 88.3 mm FL (Table 2, Figure 11). Most (98%) of the fish collected through week 14 (20 March 1996) were <45 mm FL (Figure 10). Between week 51 (17 December 1995) and week 14 (31 March 1996) mean length increased very gradually from 33.8 mm to 40.6 mm (Figure 10). After week 14, mean length steadily increased (4.5 mm/wk) until week 23, when mean weekly length was 81.3 mm FL.

The 1996 catch began and peaked much earlier than in 1994 and 1995 (Appendix I). Total catch, size of peak catch, and peak catch rate in 1996 were similar to 1994. In both survey-years, these parameters were at least two times greater than in 1995. The overall average catch rate (from first to last capture of salmon) in 1996 (25.6 fish/h) was appreciably lower than in 1994 (30.4 fish/h), but much greater than in 1995 (9.6 fish/h).

Life-stage Distribution

The chinook salmon RST catch in the 1996 survey-year comprised 22.6% yolk-sac fry, 59.6% fry, 17.4% parr, and 0.4% silvery parr (Table 3). None of the captured fish were classified as smolt.

Life-stage distribution in 1996 differed slightly from that observed in 1995 and 1994 (Table 4). Notably, the proportion of yolk-sac fry caught in 1996 (22.6%) was much greater than in 1995 (3.5%), (yolk-sac fry were not distinguished from fry in 1994), and the proportion of fry was much smaller (1996: 59.6%; 1995: 70.5%) (Table 4). The combined fraction of fry and yolk-sac fry in 1996 (82.2%) was intermediate between 1994 (96.7%) and 1995 (74.0%). Also, 1996 was the first year in which no smolt were captured.

Table 2. Summary of chinook salmon catch statistics, lower American River emigration survey, November 1995-July 1996.

Week	Beginning date	Total catch	Catch/hour	Size statistics (FL in mm)			
				Mean	Minimum	Maximum	Standard deviation
48	26 Nov 1995	1	0.01	29.0	29	29	0
49	3 Dec 1995	0	0				
50	10 Dec 1995	10	0.06	43.5	25	92	23.45
51	17 Dec 1995	150	1.21	35.0	28	77	9.65
52	24 Dec 1995	140	1.24	33.8	29	37	1.27
1	31 Dec 1995	510	4.14	34.2	28	40	1.91
2	7 Jan 1996	1,765	10.57	35.1	28	43	1.91
3	14 Jan 1996	9,508	57.11	35.8	31	62	1.57
4	21 Jan 1996	28,423	163.82	35.9	30	54	1.62
5	28 Jan 1996	25,484	153.70	36.8	30	46	1.87
6	4 Feb 1996	19,291	114.69	36.5	29	49	1.75
7	11 Feb 1996	16,152	112.32	36.5	30	47	1.85
8	18 Feb 1996	10,497	63.62	36.3	30	51	1.81
9	25 Feb 1996	4,597	27.53	36.9	30	54	2.39
10	3 Mar 1996	7,757	65.29	37.1	30	52	2.56
11	12 Mar 1996	5,280	31.15	37.9	28	56	3.35
12	17 Mar 1996	1,125	6.76	37.9	31	65	4.10
13	24 Mar 1996	247	2.81	40.8	33	74	6.80
14	31 Mar 1996	529	3.57	40.6	32	80	7.99
15	7 Apr 1996	81	0.48	49.0	33	70	11.37
16	14 Apr 1996	62	0.33	49.8	34	83	9.54
17	21 Apr 1996	15	0.10	57.9	45	85	10.84
18	28 Apr 1996	54	0.32	63.7	47	98	10.00
19	5 May 1996	109	0.41	66.8	48	94	8.95
20	12 May 1996	93	0.69	70.5	51	92.5	7.76
21	19 May 1996	25	0.14	76.2	66	89	5.39
22	26 May 1996	78	0.67	76.0	60.5	91	5.65
23	2 June 1996	33	0.19	81.3	66	89.5	5.19
24	9 June 1996	17	0.12	80.6	64	93.5	6.26
25	16 June 1996	4	0.02	85.6	79	95	6.55
26	23 June 1996	0	0				
27	30 June 1996	1	0.01	88.0	88	88	0
28	7 July 1996	0	0				
29	14 July 1996	2	0.01	88.3	81	95.5	7.25
Total or average		132,040	24.2	51.4	25	98	5.50

Table 3. Expanded catch distribution of chinook salmon life stages caught by rotary screw trap during the lower American River emigration survey, November 1995 through July 1996.

Week	Sac-fry	Fry	Parr	Silvery parr
48	1	0	0	0
49	0	0	0	0
50	8	0	0	2
51	131	10	7	1
52	135	20	0	0
1	461	48	1	0
2	1,564	200	2	0
3	6,399	3,100	10	0
4	6,767	19,451	2,161	44
5	2,513	16,857	6,114	0
6	5,324	11,719	2,238	10
7	3,110	9,114	3,870	58
8	2,188	5,714	2,582	13
9	622	2,844	1,131	0
10	247	5,618	1,892	0
11	255	3,114	1,898	13
12	46	643	422	14
13	1	14	224	7
14	21	157	325	26
15	5	13	41	22
16	0	1	38	23
17	0	0	13	2
18	0	0	36	17
19	0	0	12	147
20	0	0	0	0
21	0	0	0	25
22	0	0	0	78
23	0	0	0	33
24	0	0	0	17
25	0	0	0	4
26	0	0	0	0
27	0	0	0	1
28	0	0	0	0
29	0	0	0	2
Total	29,798	78,637	23,017	559
Mean proportion	22.6%	59.6%	17.4%	0.4%

Table 4. Proportion of total chinook salmon catch in each year comprised by various life stages in lower American River emigration surveys 1994 -1996.

Life stage	1994	1995	1996
Yolk-sac fry		3.5%	22.6%
Fry	96.7%	70.5%	59.6%
Parr	1.6%	25.5%	17.4%
Silvery parr	1.4%	0.1%	0.4%
Smolt	0.3%	0.4%	***

Yolk-sac fry were caught from 30 November 1995 (week 48) to 3 April 1996 (week 15) (Figure 13). Only one yolk-sac fry was caught in week 48; no more were caught until 15 December 1995. The peak yolk-sac fry catch occurred in week 3 (*n* = 6,399) and week 4 (*n* = 6,767) with a secondary peak occurring in week 6 (*n* = 5,324) (Figure 13). Ninety-nine percent of yolk-sac fry were caught by 19 March 1996 (week 12). Yolk-sac fry lengths were fairly uniform in 1996 (Figures 14 and 15). Lengths ranged from 25 to 48 mm FL (mean = 35.0 mm FL, SD = 1.72), and 88% of yolk-sac fry were between 33 and 37 mm FL (Figure 14). Mean weekly length increased from 31.9 mm to 35.4 mm FL between week 50 and week 3 (Figure 15), then leveled off thereafter to about 35 mm.

Fry were caught from 17 December 1995 (week 51) through 16 April 1996 (week 16); 92% of the catch occurred from week 4 through week 12 (Figure 16). Fry numbers peaked in week 4 (*n* = 19,451) and week 5 (*n* = 16,857). The fry length distribution was nearly normal (Figure 17); 97% were between 30 and 39 mm FL. Fry length ranged from 29 to 67 mm FL (mean = 36.3, SD = 1.59). Mean weekly fry length was relatively constant, ranging from 34.6 to 36.7 mm FL, except in week 51 (38.1 mm FL) and in week 16 (34.0 mm FL) (Figure 18).

Parr were caught from 16 December 1995 (week 50) through 8 May 1996 (week 19) (Figure 19): 96% of the catch occurred between weeks 4 and 14. Parr length ranged from 30 to 72 mm FL (mean = 39.5 mm FL, SD = 5.09) (Figure 20). A strong positive skew in parr length distribution (Figure 20) suggests that the length at which salmon change from parr to silvery parr is more variable than the length at which they change from fry to parr. None-the-less, more than 90% of measured parr were between 34 and 45 mm FL. Prior to week 4 of 1996, parr length was variable (Figure 21). (These parr were not fall run, by far the predominant chinook salmon race in the river). Between week 4 and week 20, mean weekly length increased steadily from 36 to 60 mm FL (Figure 21).

Silvery parr were caught from 21 December 1995 (week 5) to 16 July 1996 (week 29). Catch peaked in week 19 (*n* = 147) (Figure 22). There appeared to be three groups of emigrating silvery parr: the first group was very early (week 50 of 1995) and consisted of a few, large (>65 mm FL) non-fall run, the second group consisted of fall-run juveniles that left relatively early (weeks 4 through 8) at a relatively small size (mean <50 mm FL), and the third group generally increased in both number and size starting in week 11. Silvery parr length ranged from 35 to 98 mm FL (mean = 70.3 mm FL, SD = 10.73) (Figure 23). The lack of a distinct peak in the length distribution further suggests that the length at which silvering begins in juvenile salmon is highly variable. Mean weekly lengths were quite variable throughout the emigration period (Figure 24) although after week 7, a trend toward increasing mean weekly length was noticeable.

The length distribution for each life stage was distinct (*t*-tests, p<0.05).

Condition Factor

As in 1994 and 1995, there is no indication that condition factor (*K*) in American river chinook salmon declines prior to emigration. In *t*-tests comparing silvery parr with other life stages, *K* for silvery parr (1.11) was significantly higher than for yolk-sac fry (0.74), fry (0.69), and parr (0.77) (Table 5) (all *t*-tests, p <0.001).

Table 5. Condition factor (*K*) statistics by life stage for chinook salmon collected during the lower American River emigration survey, November 1995-July 1996.

K Factor	Yolk-sac fry	Fry	Parr	Silvery parr
Minimum	0.278	0.233	0.27	0.405
Maximum	2.369	1.527	1.852	2.56
Mean	0.736	0.693	0.771	1.105
Coefficient of var.	21.5	18.9	22.5	10.6
Standard deviation	0.158	0.131	0.174	0.15
Sample size	502	1,765	814	273

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 25). The slope was significantly different from zero (p <0.001).

K varied slightly between years (Appendix I). *K* for yolk-sac fry was significantly lower in 1996 (0.74) than in 1995 (0.93; *t*-test, p <0.001) and *K* for silvery parr was higher in 1996 than in 1994 or 1995 (*t*-tests, p <0.001).

Mark-recapture/ trap efficiency

Percent recapture was greatest in week 5 (2.06%), the second week that marking was done. Relatively high recapture rates also occurred in week 12 (1.22%) and week 8 (1.00%) (Figure 26; Table 6). Percent recapture showed some relation to the total number of fish caught in a week (regression equation: p = 0.06) and the weekly catch per unit effort (regression equation: p = 0.05). Percent recapture was zero in all weeks where less than 100 fish were marked (weeks 15-19). The only other week with no recapture (0%) was week 4, the first week of marking. Overall trap efficiency was 0.68%.

Comparison with Concurrent Seining Survey

Seine surveys in the lower American River were conducted in weeks 13, 17, 18, 21 and 25 of 1996. The weekly life-stage distribution from seine hauls resembled those from RST surveys (Table 7).

Table 6. Results of rotary screw trap efficiency evaluation conducted with marked chinook salmon during the lower American River emigration survey, 24 January-20 May 1996.

Week	Number salmon marked	Number salmon recaptured*	Efficiency (% recaptured)
4	189	0	0
5	973	20	2.06
6	2,733	17	0.62
7	1,753	13	0.74
8	903	9	1
9	1,989	2	0.10
10	1,499	7	0.47
11	1,456	8	0.55
12	986	12	1.22
13	168	1	0.60
14	238	1	0.42
15	67	0	0
16	42	0	0
17	13	0	0
18	14	0	0
19	89	0	0
20	0	0	0
Total	13,303	90	0.68

*Number recovered has been expanded

Table 7. Chinook salmon life-stage distributions for concurrent seine and rotary screw trap catches during lower American River emigration survey, 1996.

	Week	Catch *n*	Percent Distribution				
			Yolk-sac fry	Fry	Parr	Silvery parr	Smolt
Seine	13	522	0.4	5.2	80.3	13.8	0.4
	17	56	0	0	69.6	28.6	1.8
	18	204	0	0	64.2	34.3	1.5
	21	100	0	0	16	82	2
	25	1	0	0	0	100	0
Screw trap	13	171	0.6	5.8	90.6	2.9	0
	17	13	0	0	84.6	15.4	0
	18	51	0	0	68.6	31.4	0
	21	25	0	0	0	100	0
	25	4	0	0	0	100	0

Steelhead

Juvenile steelhead captured in the RSTs represented three different groups: young-of-the-year (typically <100 mm FL), yearlings (typically >100-300 mm FL), and adults (typically ≥300 mm FL) (Table 8).

YOY steelhead were captured periodically between week 11 (10 March 1996) and week 37 (12 September 1996) (Figure 27). A total of 138 YOY were captured. Their mean length increased steadily from 28.3 mm FL in week 11 to more than 100 mm FL by week 30 (21 July 1996) (Figure 28). Two, larger steelhead collected after week 33 (11 August 1996) indicate a continued, rapid growth rate through the summer period.

Yearling steelhead (*n* = 7) were caught prior to week 13 (24 March 1996) (Table 8; Figure 27). Fish length ranged from 131.0 to 296.0 mm FL. The small, 131 mm FL steelhead was collected during week 11, when the average size of steelhead was less than 30 mm FL and therefore was considered a yearling.

A total of seven adult steelhead was trapped between week 51 (1995) and week 33 (1996). Lengths ranged from 322.0 to 457.0 mm FL (Table 8; Figure 28). Fish caught after week 28 (14 July 1996) could have been two-year old steelhead, but were identified as adult which are typically older. Scales taken from all steelhead greater than 100 m FL will be evaluated to determine the ages of these larger fish.

Table 8. Summary of steelhead catch statistics, lower American River emigration survey, December 1995-September 1996.

	Young of the Year		Yearling		Adult	
Week	Count	Mean FL (mm) and Range	Count	Mean FL (mm) and Range	Count	Mean FL (mm) and Range
51	0		0		1	366
52	0		0		0	
1	0		0		0	
2	0		0		0	
3	0		2	220.5 (197-244)	2	457-497
4	0		3	248.3 (211-296)	1	384
5	0		0		0	
6	0		0		0	
7	0		0		0	
8	0		0		0	
9	0		0		0	
10	0		0		0	
11	4	28.3 (26-33)	1	131	0	
12	8	29.6 (26-34)	1	280	0	
13	3	29.3 (26-35)	0		0	
14	9	30.9 (25-42)	0		0	
15	0		0		0	
16	12	38.8 (26-52)	0		0	
17	13	36.3 (26-49)	0		0	
18	5	35.4 (28-46)	0		0	
19	5	56.8 (49-67)	0		0	
20	15	54.3 (41-69)	0		0	
21	10	46.2 (22-61)	0		0	
22	19	51.1 (31.5-76)	0		0	
23	7	61.1 (56-74)	0		0	
24	1	63	0		0	
25	1	77.5	0		0	
26	0		0		0	
27	0		0		0	
28	4	80.6 (68-105.5)	0		1	341
29	8	88.9 (69-115)	0		0	
30	8	104.6 (85-128)	0		0	
31	3	94.2 (89.5-100.5)	0		0	
32	1	106	0		1	322
33	0		0		1	342
34	1	123	0		0	
35	0		0		0	
36	0		0		0	
37	1	162	0		0	
Total	137	54.2 (22-162)	7	233 (131-296)	7	387 (322-497)

Pacific Lamprey

Three lamprey life stages were collected: ammocoetes, the filter feeding larval stage; subadult, recently metamorphosed from the ammocoete stage to a small, adult form; and large adult sea-run, spawning life stage (>300 mm total length, TL) (Table 1).

Ammocoetes (n = 393) were periodically collected from week 41 of 1995 (10 October 1995) through week 40 of 1996 (30 September 1996) (Figure 29). The greatest weekly catch (n = 118) was during week 16 (14 April 1996). Subadult lamprey (n = 15) were periodically collected from week 11 through 20 (Figure 29). Ninety-one adult lamprey appeared in the trap between week 41 (of 1995) and week 23 (2 June 1996).

American Shad

A total of 34 juvenile and 12 adult American shad appeared in the trap in 1996. Juvenile shad were caught in weeks 41, 42, and 46 of 1995, and in weeks 35, 38, and 39 of 1996 (Figure 30). Adult shad were caught between week 24 and week 35 of 1996. Juveniles ranged in length from 28 to 71 mm FL; mean FL was 46.3 mm. Adults ranged in length from 246 to 500 mm FL with a mean FL of 377.6 mm.

DISCUSSION

Several significant findings are contained in the emigration data above.

.C The timing of both fry, or recently emerged salmon (FL <50 mm), and fingerling (FL >50 mm) emigrations was substantially different from that recorded before construction of the Folsom Complex (1945-1947), and somewhat different from that observed in 1994 and 1995.

The only data on salmon emigration in the lower American River prior to construction of the Folsom Project detected fry and fingerling emigration substantially later than post-Folsom Project evaluations (i.e., the 1988 and 1989 trawling surveys and the 1994, 1995, and 1996 trapping surveys). The 1944-1946 brood stocks had access to the upper reaches of the American River. Thus, the 1945-1947 emigration timing may have been due to longer incubation, later emergence, and slower growth associated with typically colder, more oligotrophic conditions found in the upper reaches of the American River.

.C Emigration in 1996 was substantially earlier than in 1994 and 1995.

Emigration in 1996 began and peaked approximately one month earlier than in 1994 and 1995. Water temperature may have played a role. Average water temperature in December 1995, prior to the 1996 emigration period was 55.7 ^{o}F, whereas in December 1993 and December 1994 they were 48.9 and 52.0 ^{o}F respectively.

- Using length as sole criteria for distinguishing life stages is unreliable.

  Hoar (1976) speculated that smolt characteristics such as decreased condition and silvering were associated with length. Our results indicate that such length criteria should be applied with caution. Condition factor actually increased with FL in 1995, and silvering occurred over a range of lengths (silvery parr were as small as 35 mm, and parr as large as 92 mm).

  Condition factor (*K*) increased with FL in all size classes in 1996. Since smolting is typically associated with a drop in lipid content and a decrease in *K*, it is clear that all the fish caught in 1996 required further growth and development in the downstream environs of the Delta and estuary before fully transforming into smolts.

- The proportion of fry, parr, silvery parr and smolt emigrants is variable from year to year. Notably, the proportion of yolk-sac fry in 1996 (22.6%) was considerably higher than in 1995 (3.5%). The combined fry and yolk-sac fry fraction in 1996 (82.2%) was intermediate between the 1995 fraction (74%) and the 1996 fraction (96.7%). Some of the environmental conditions which may influence these results are:

  - Mean flows in January 1996 (2,186 cfs) were similar to those in 1994 (1,755 cfs) and considerably lower than in 1995 (8,576 cfs). The high flows in January 1995 may have had some effect on the numbers of emigrating yolk-sac fry, or the ability of the RST to sample them.

  - The 1995 emigration report (Snider and Titus 1995) speculates that a high average February temperature in 1995 relative to 1994 may explain why fewer fish emigrated at the yolk-sac and fry stages in 1995. The mean monthly temperature in February 1996 (48.3) was very close to that of 1994 (48.5) and below that of 1995 (49.1) in possible support of this speculation.

- RST efficiency appears to be very low in large rivers.

  Efficiencies of less than 1% are extremely low, but are consistent with other efficiency rates for similar traps in similarly large rivers (Snider and Titus, 1998, C. Hanson, Hanson Environmental, Inc. pers. comm..). Efficiencies in the Trinity River, California, reported by Goldsmith (1993) ranged from 0.3 to 5.6%. Thedinga *et al*. (1994) reported 24% efficiencies for chinook salmon using RST with fences that fished 6-11% of the cross section of a 24 m wide stream. Kennen *et al*. (1994) reported efficiency estimates ranging from 11.2-17.3% for chinook salmon smolts in a small (7-9 m wide) stream.

  A mark-recapture study of the lower American River RST in 1994 revealed a trap efficiency of 0.94%, slightly higher than that of 1996 (0.68%). Increasing the number of traps or using additional capture methods (e.g., Kodiak trawl, round-fyke traps) could increase the cumulative efficiency. Improving on marking techniques could improve our ability to measure efficiency.

- The downstream environs are very important to the survival of lower American River fall-run chinook salmon.

In 1996, all emigrating chinook salmon were pre-smolt, and as in 1994 and 1995, most emigrants were either fry or yolk-sac fry (82.2%). No captured emigrants were longer than 100 mm FL. These findings suggest that the smolting process is not completed in the lower American River, but will continue downstream, likely in the Delta and the estuary. These facts point to the importance of the downstream environs to ultimate survival of American River chinook salmon.

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APPENDIX

Appendix I. Comparison of results from lower American River emigration surveys conducted 1994 through 1996.

	Year		
	1994	1995	1996
Salmon emigration start date	Week 2 (of 1994)	Week 51 (of 1994)	Week 48 (of 1995)
Salmon emigration end date	Week 28	Week 32	Week 29
Date of peak salmon catch	23 Feb	24 Feb	26 Jan
Maximum daily salmon catch	14,887	3,371	12,285
Maximum daily salmon catch rate	677 fish/h	141 fish/h	614 fish/h
Total catch (juvenile chinook salmon)	162,089	45,478	132,040
Total catch (juvenile steelhead)	43	30	145
Total catch (American shad)	91	522	46
Total catch (Pacific lamprey)	321	247	499
Average catch (juvenile chinook salmon)	30.4 fish/h	9.6 fish/h	25.6 fish/h
Salmon life-stage composition			
Yolk-sac fry*	96.7%	3.5%	22.3%
Fry*		70.5%	50.7%
Parr	1.6%	25.5%	20.6%
Silvery parr	1.4%	0.1%	2.3%
Smolt	0.3%	0.4%	--
Salmon condition factors (mean)			
Yolk-sac fry*	0.79	0.93	0.74
Fry*		0.74	0.69
Parr	1.02	0.78	0.77
Silvery parr	1.07	1.05	1.11
Smolt	1.14	1.15	--

* Yolk-sac fry and fry combined as one life stage in 1994.

FIGURES

LOWER AMERICAN RIVER

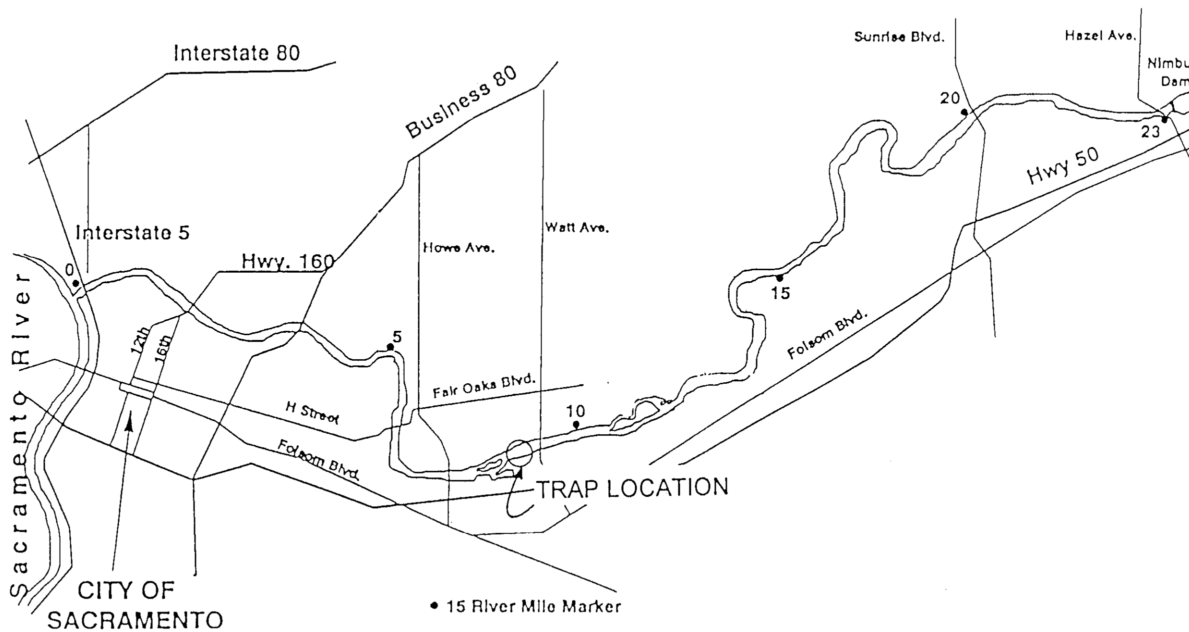

Figure 1. General location of the rotary screw traps used during the lower American River emigration survey, October 1995 - September 1996.

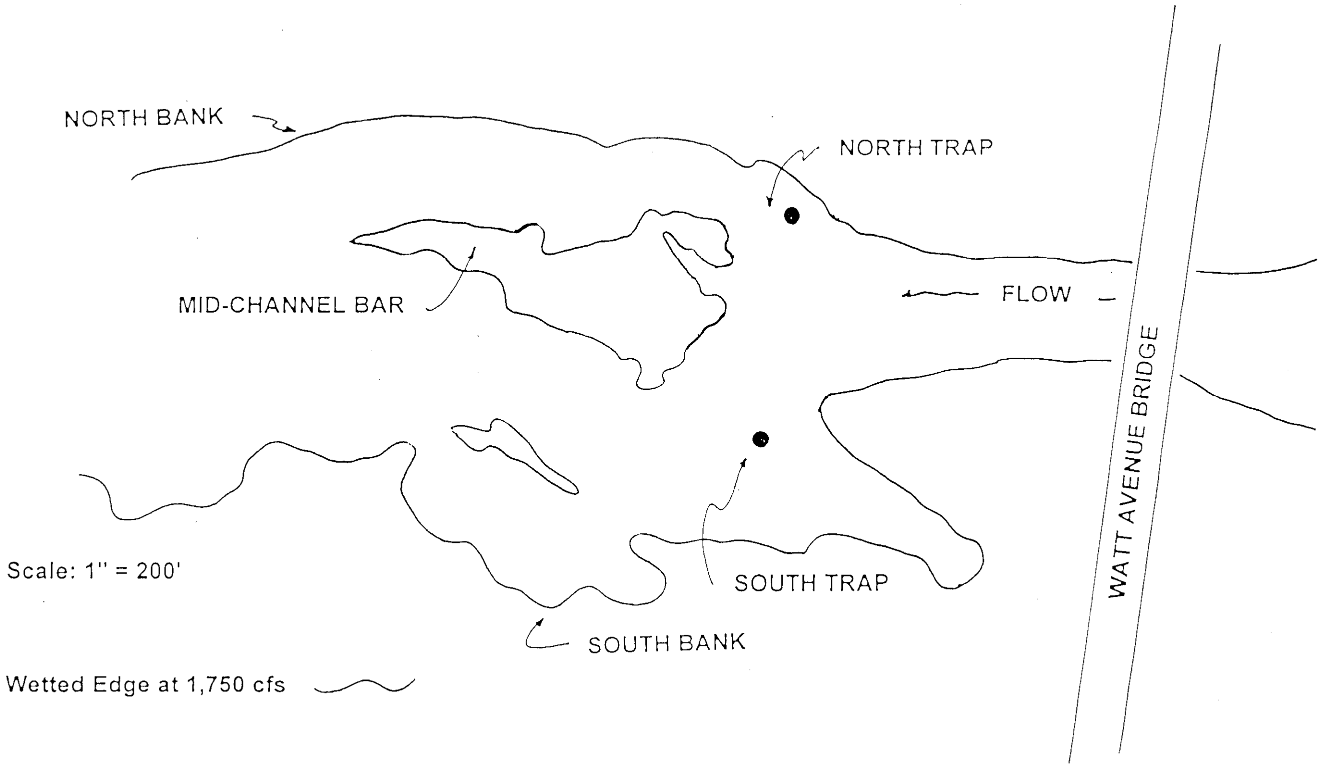

Figure 2. Specific location of the rotary screw traps near river mile 9 of the lower American River, October 1995 -September 1996.

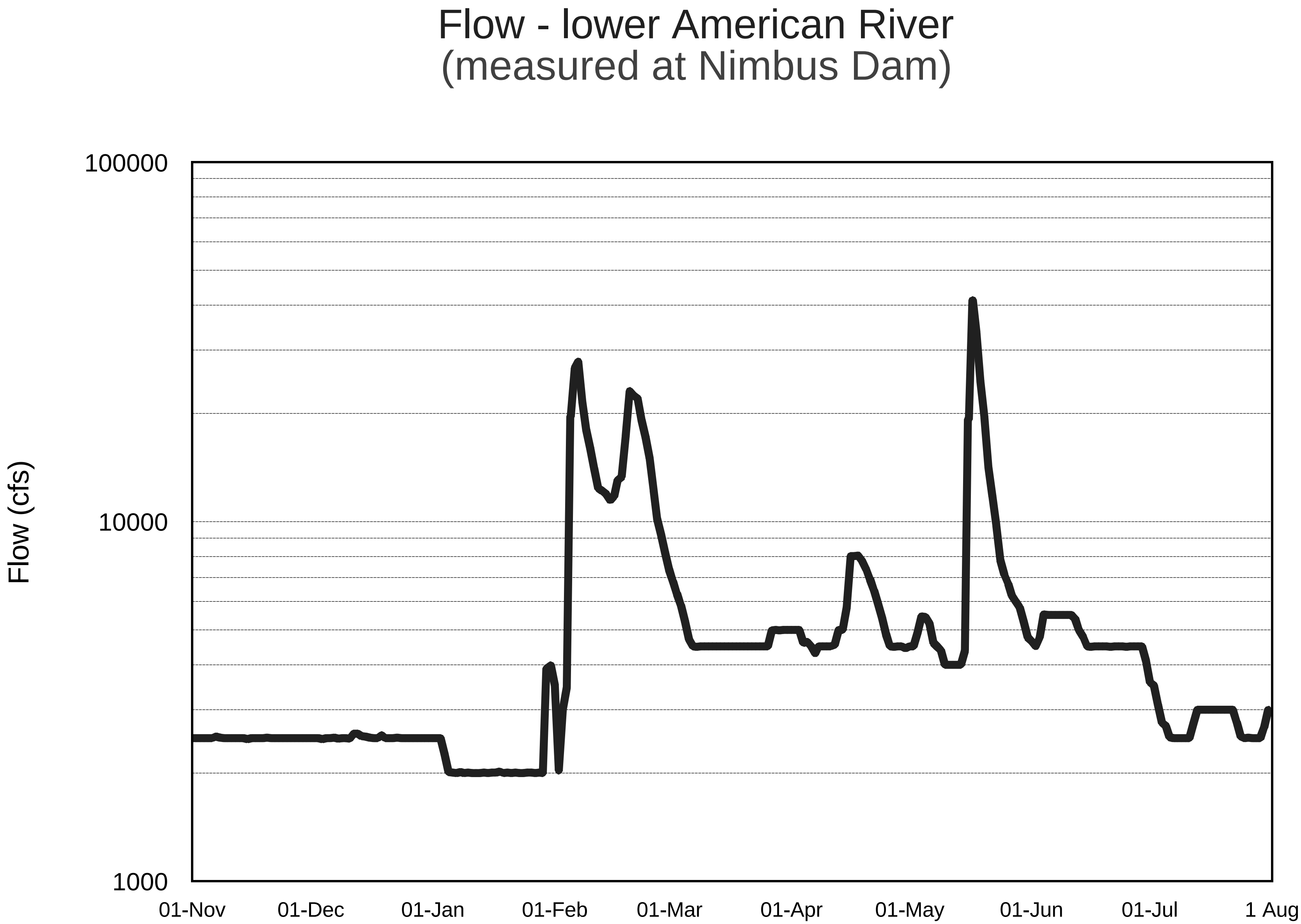

Figure 3. Flow in cfs measured at Nimbus Dam during the lower American River emigration survey, November 1995 - July 1996.

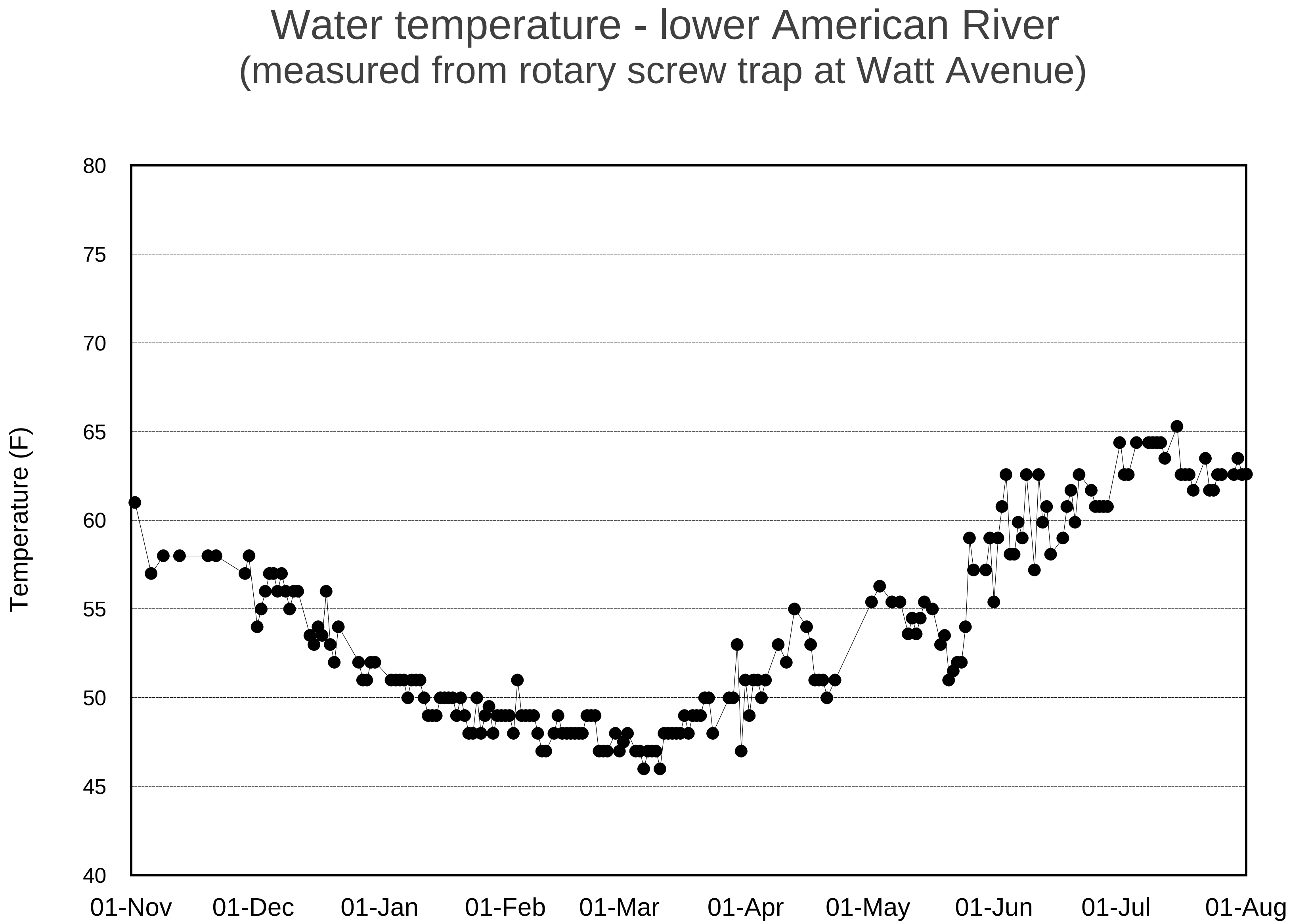

Figure 4. Average daily water temperature measured from the Watt Avenue rotary screw trap, lower American River emigration survey, November 1995 - July 1996.

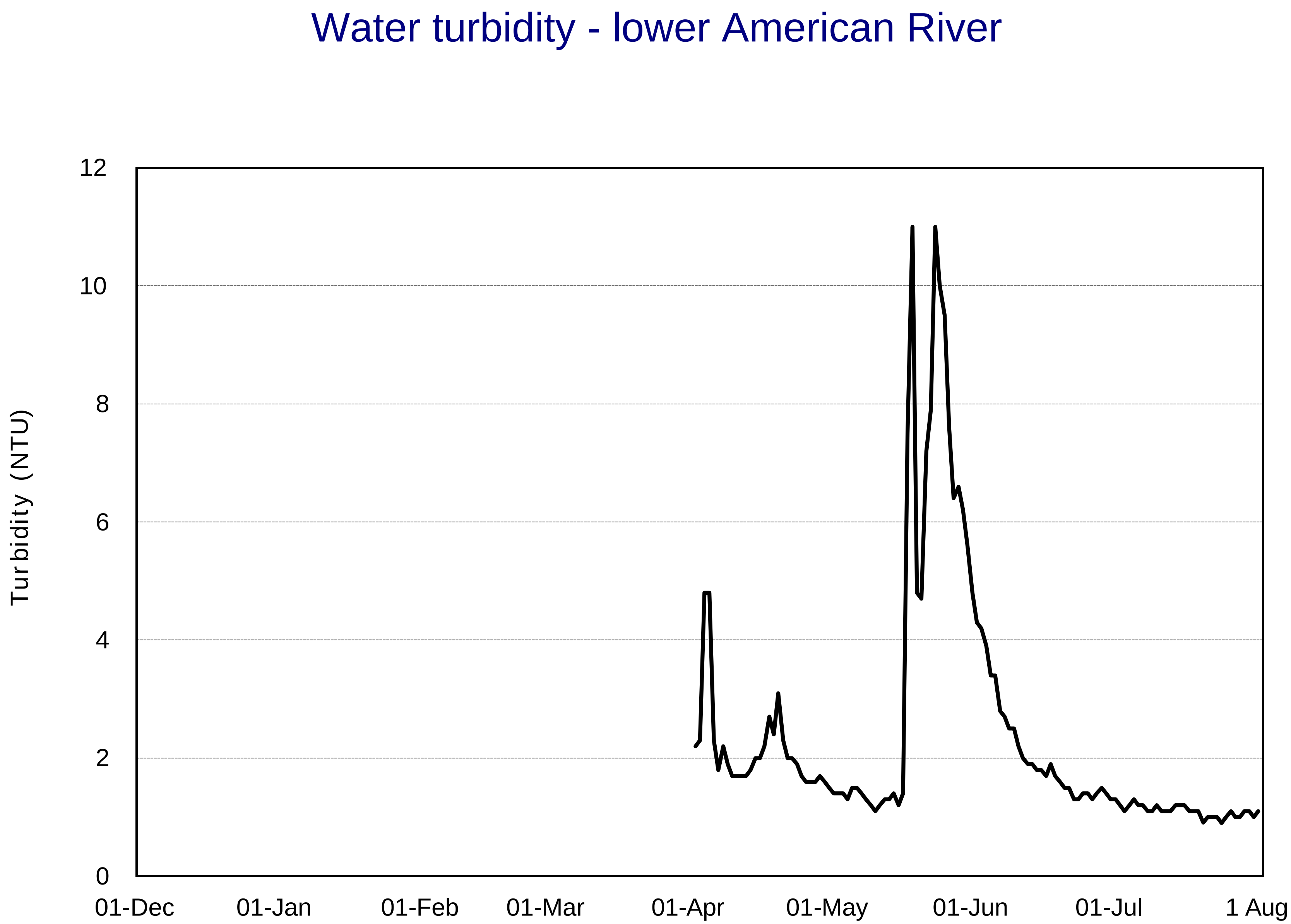

Figure 5. Water turbidity measured near Watt Avenue during the lower American River emigration survey, December 1995 - July 1996.

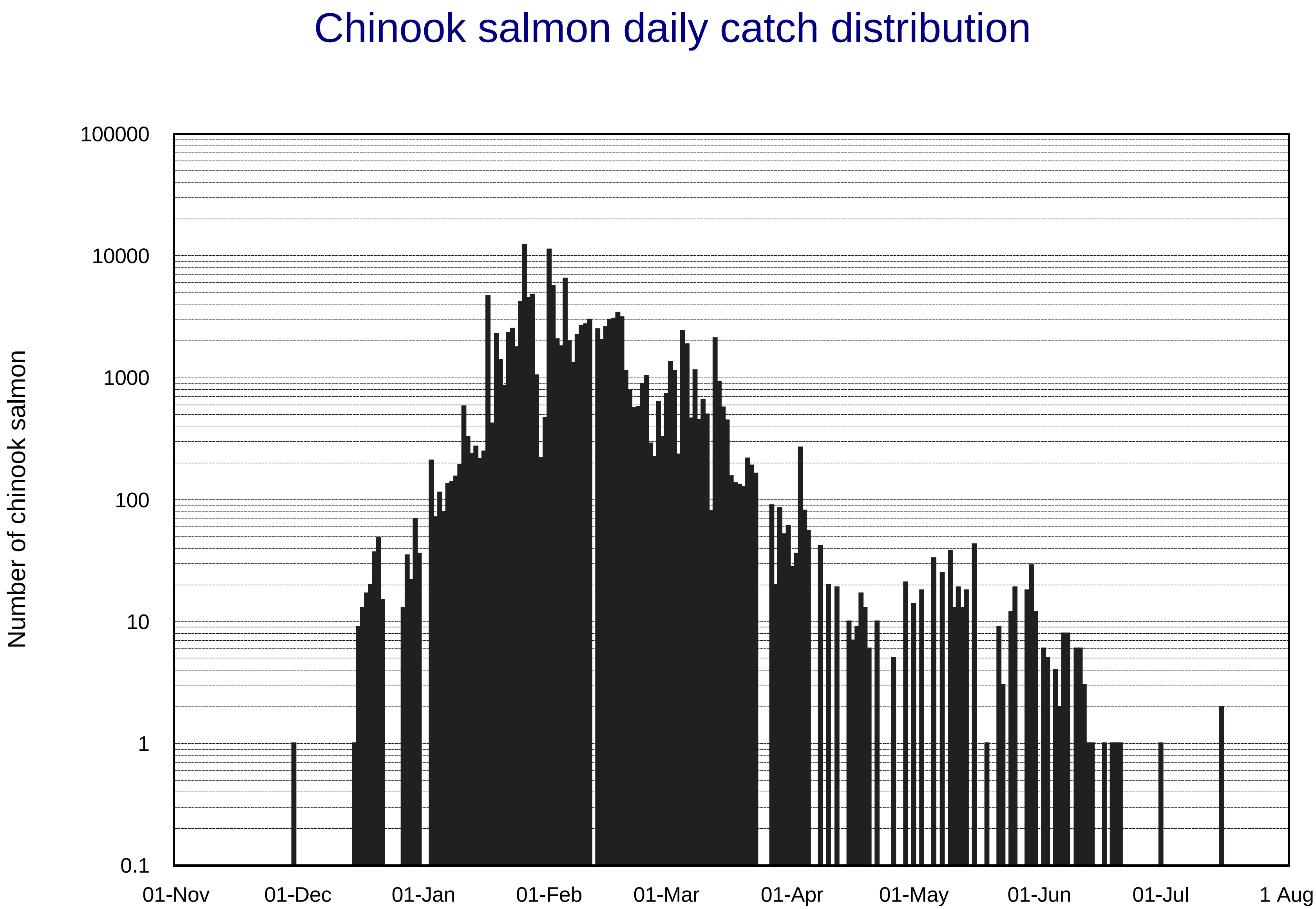

Figure 6. Daily catch distribution of chinook salmon caught by rotary screw trap during the lower American River emigration survey, November-July 1996.

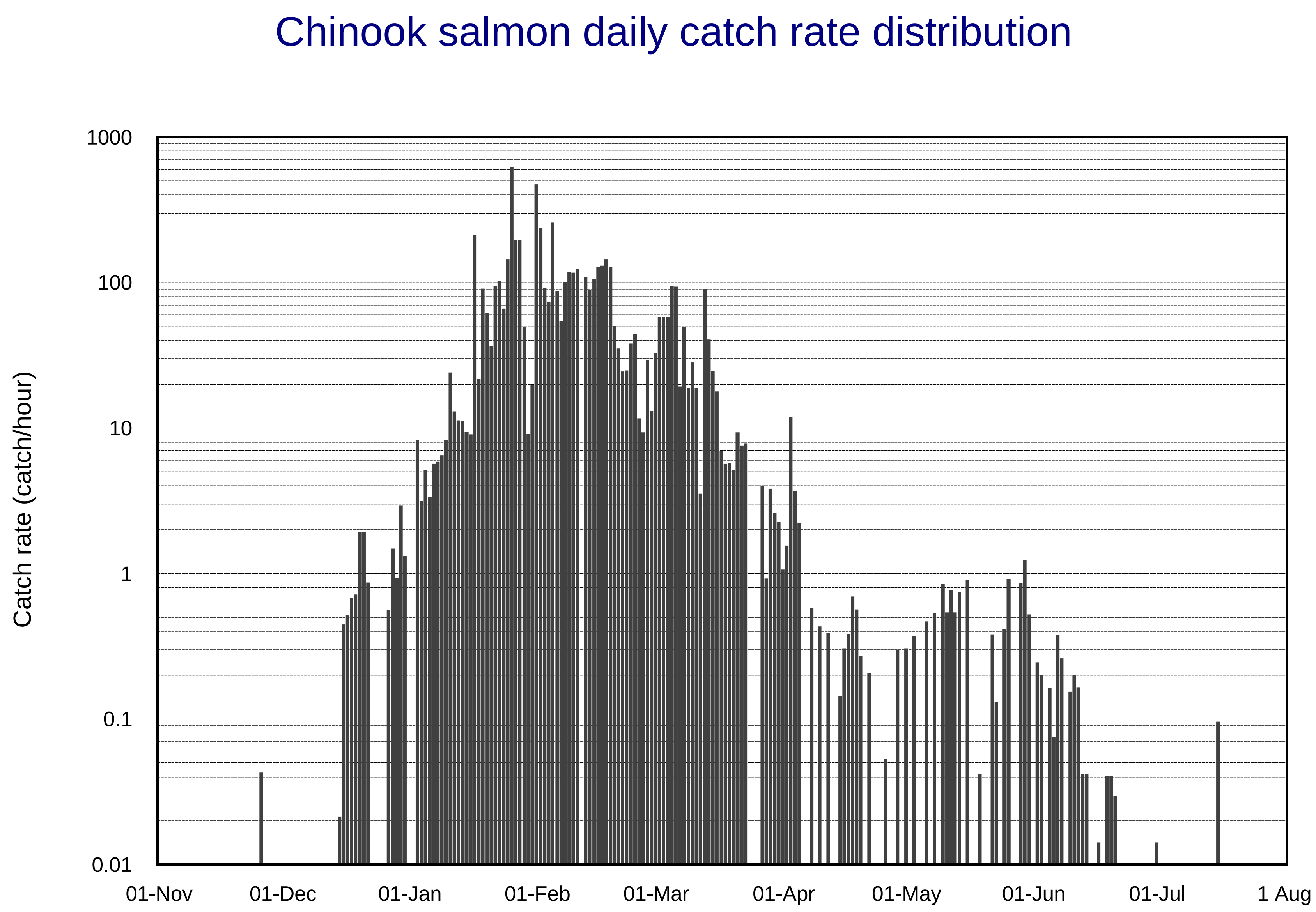

Figure 7. Daily catch rate distribution of chinook salmon caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

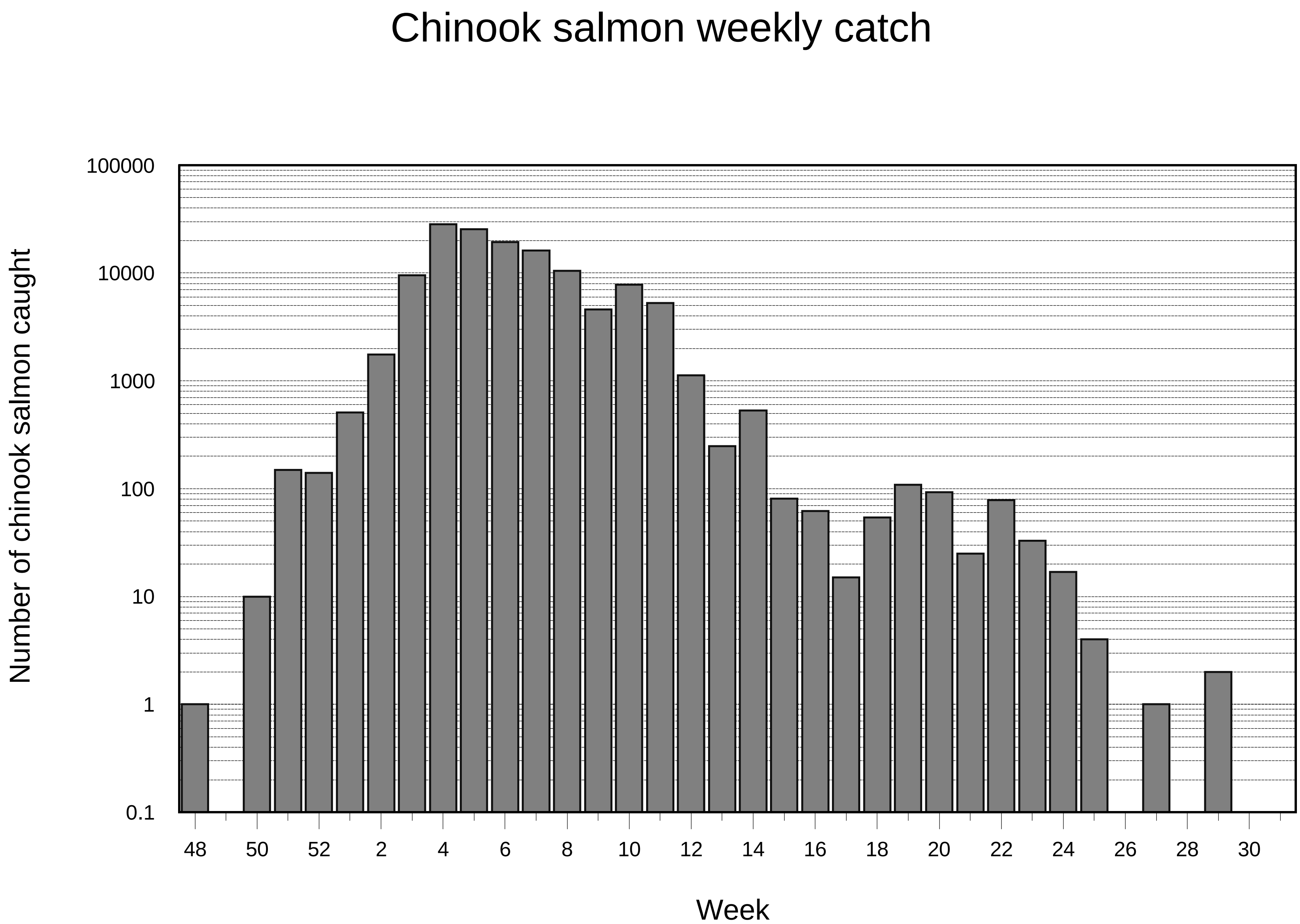

Figure 8. Weekly catch of chinook salmon caught by rotary screw trap during the lower American River emigration survey, November 1995 -July 1996.

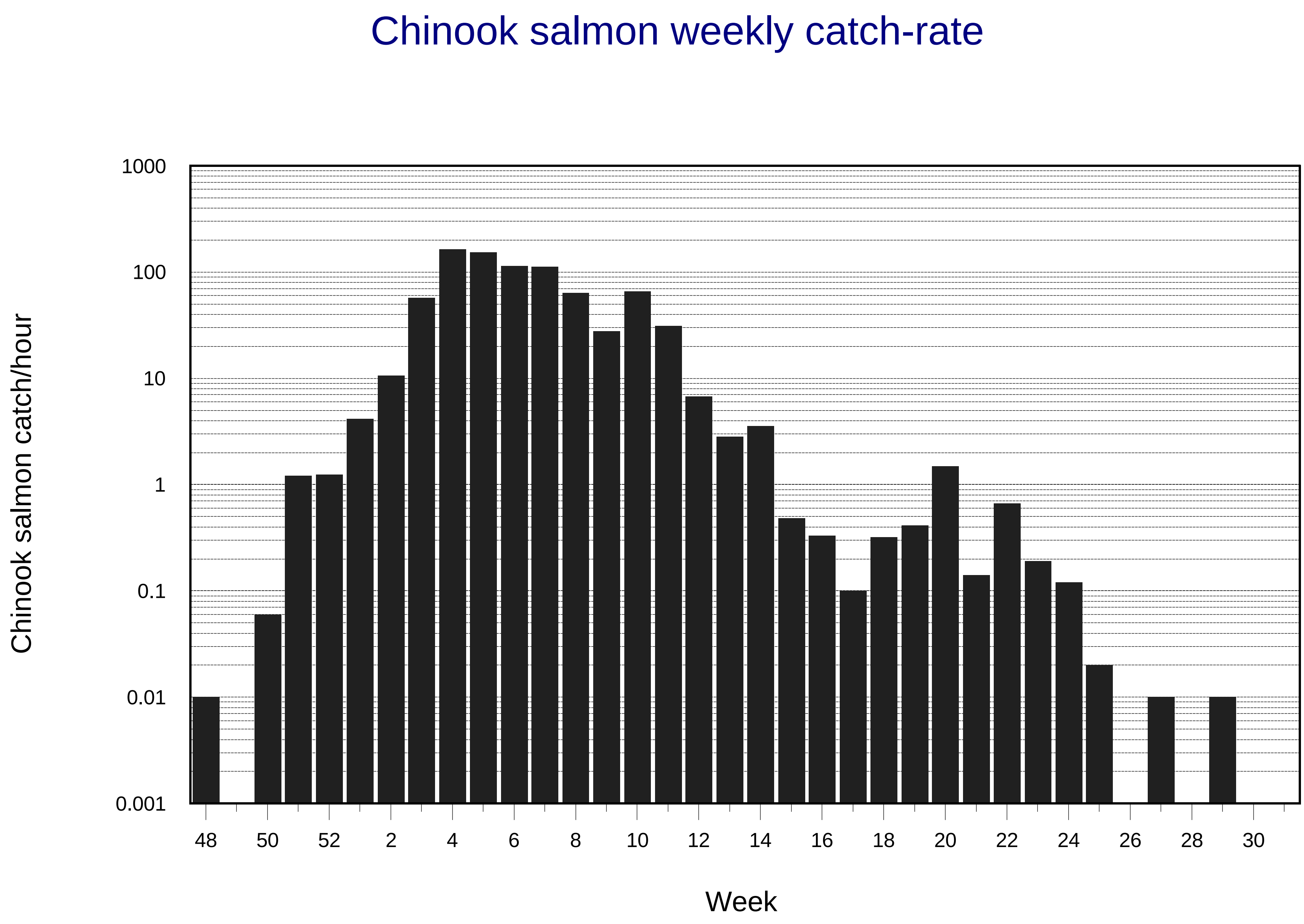

Figure 9. Mean weekly catch-rate (n/hour) of chinook salmon caught by rotary screw trap during the lower American River emigration survey, November 1995 -July 1996.

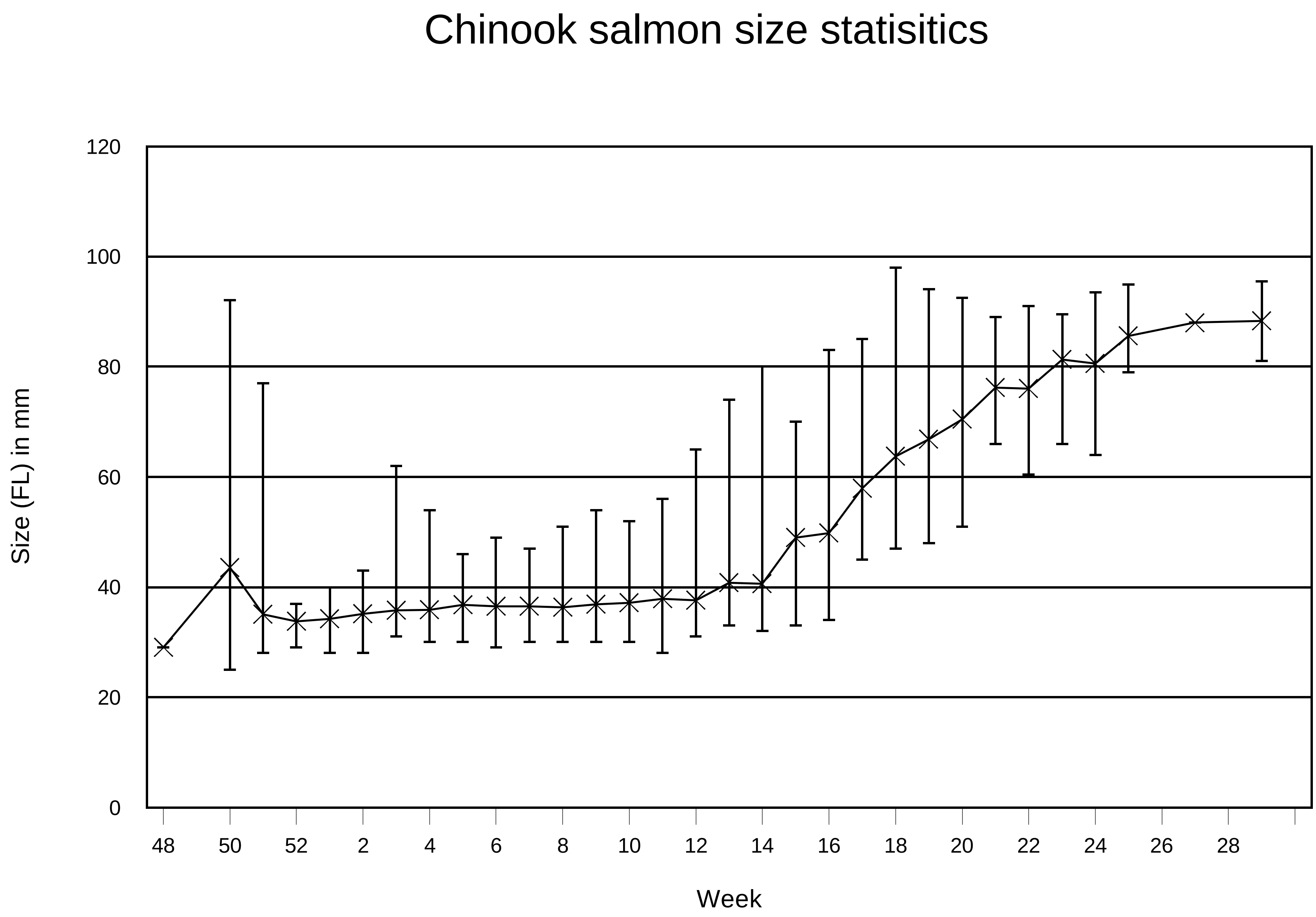

Figure 10. Mean forklength and size range of chinook salmon caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

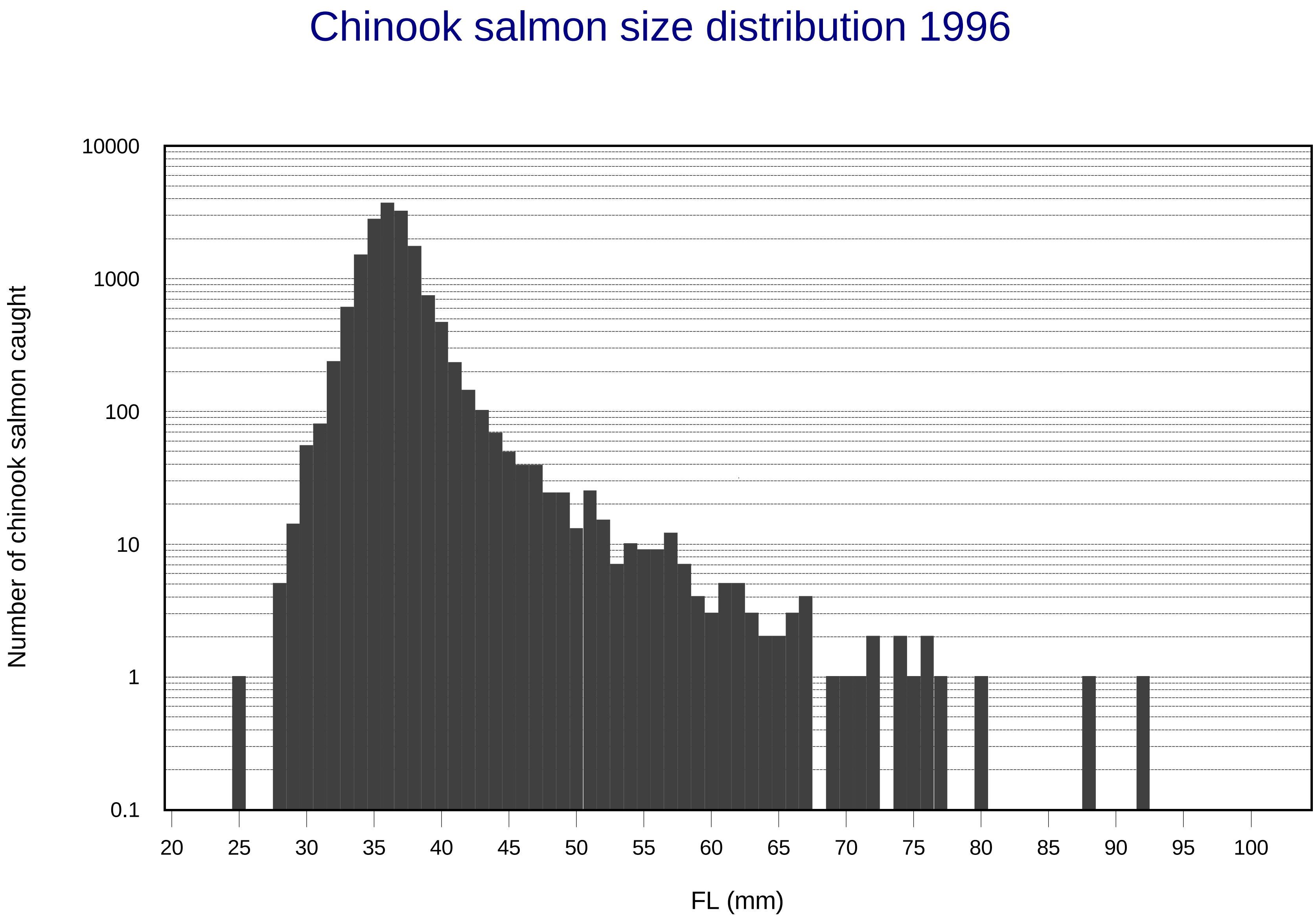

Figure 11. Length-frequency distribution of chinook salmon caught by rotary screw trap through week 14 of the lower American River emigration survey, 30 Novemenber 1995 - 06 April 1996.

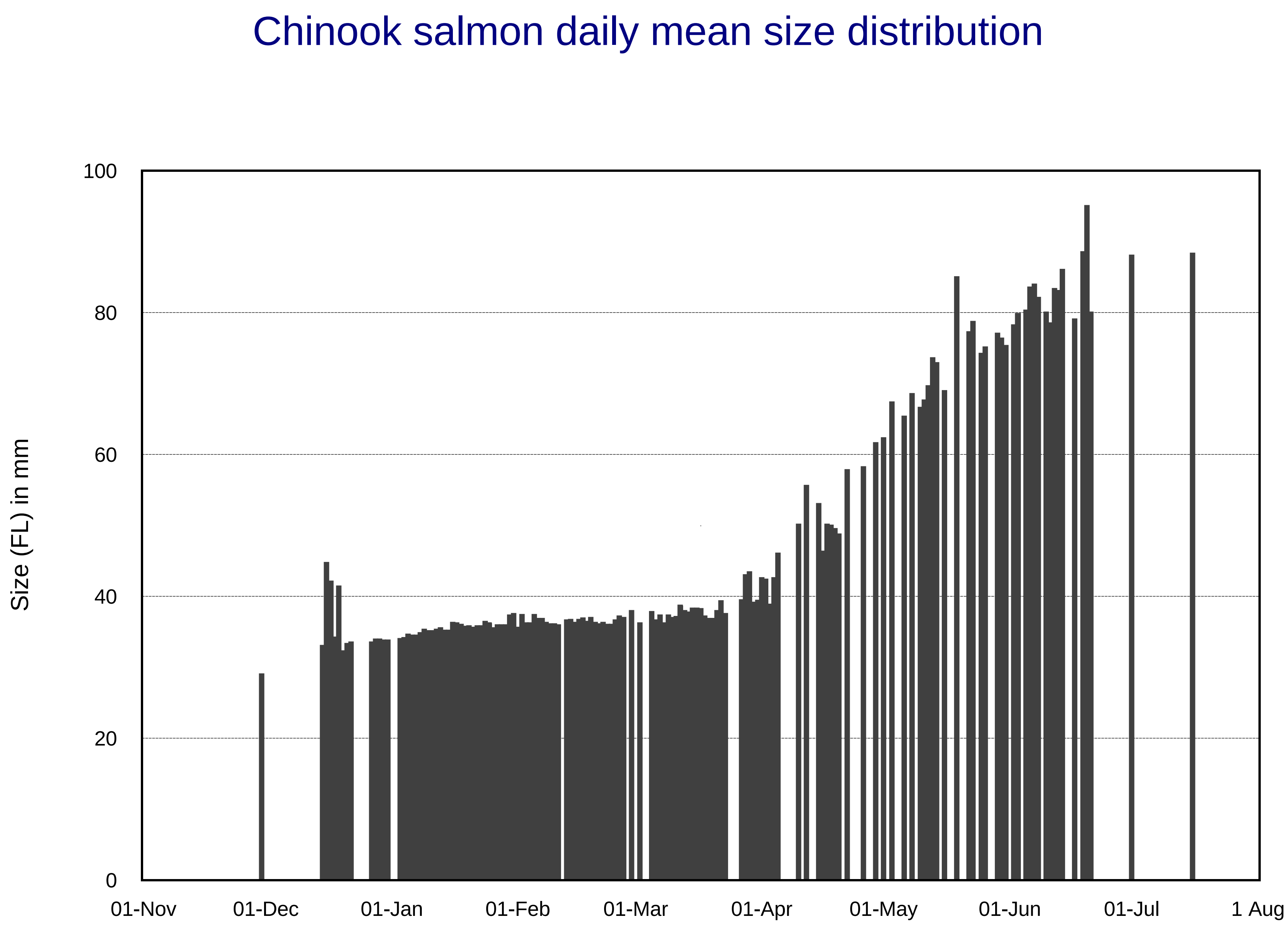

Figure 12. Daily mean forklength of chinook salmon caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

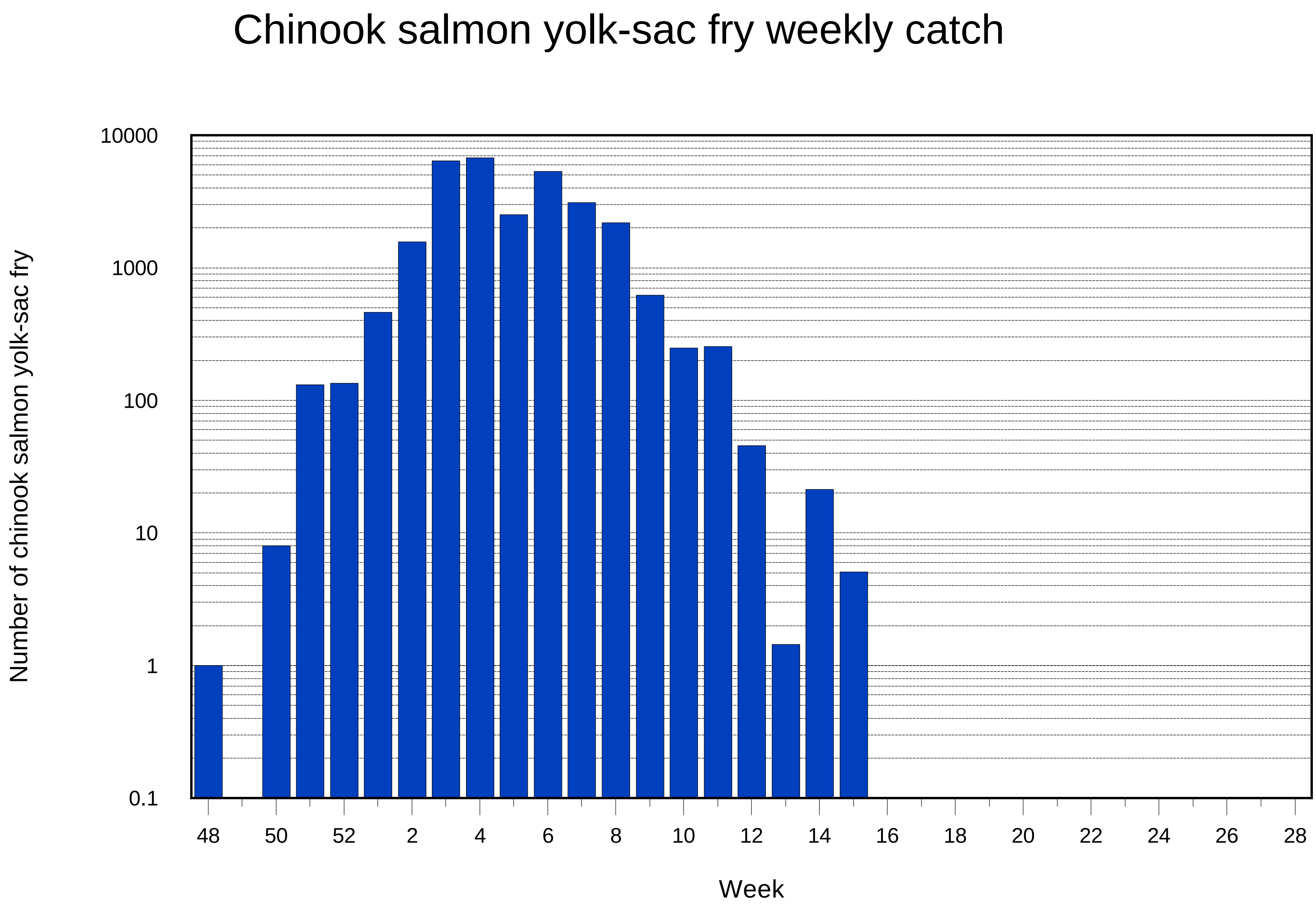

Figure 13. Weekly catch distribution of chinook salmon yolk-sac fry caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

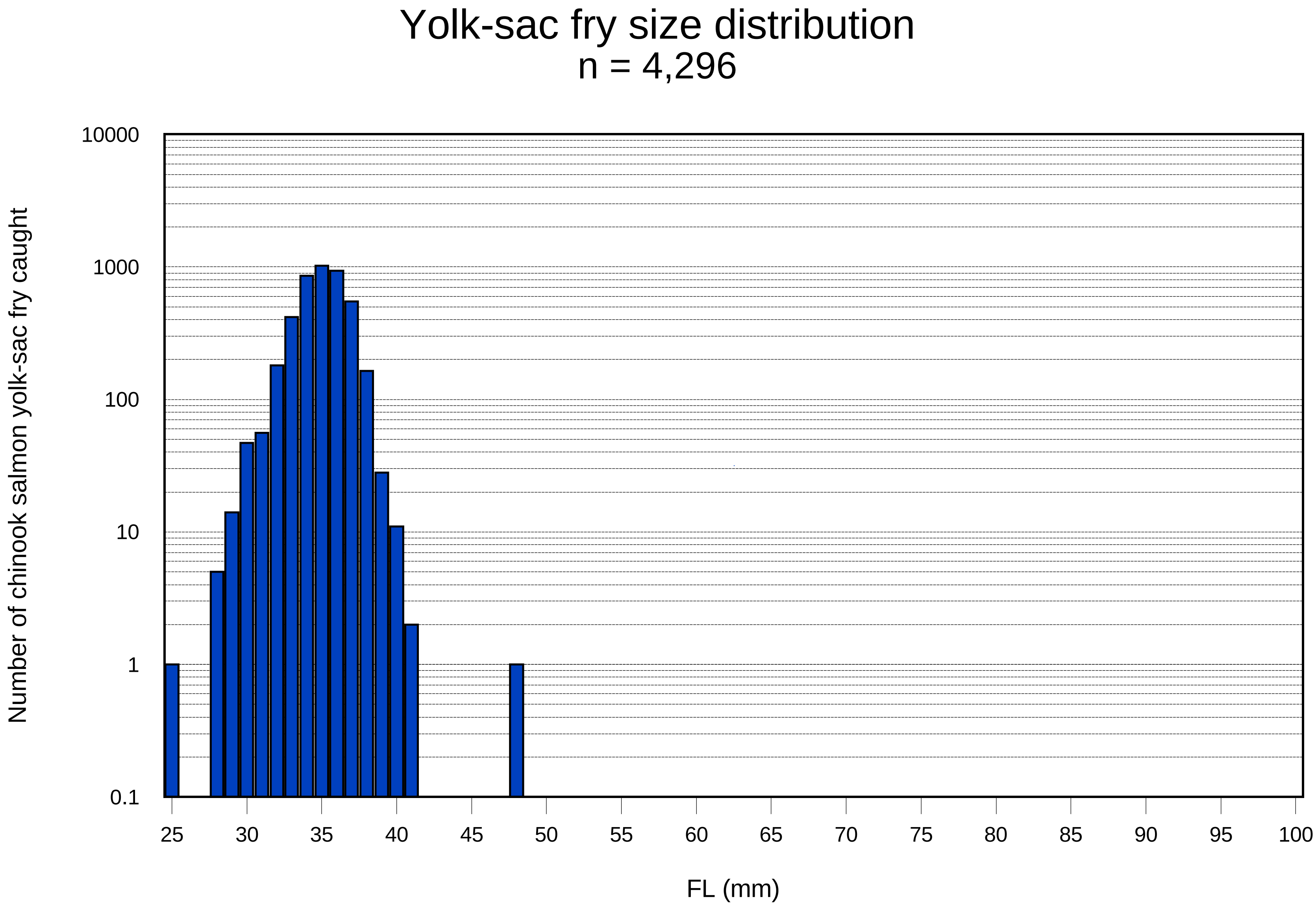

Figure 14. Size distribution of chinook salmon yolk-sac fry caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

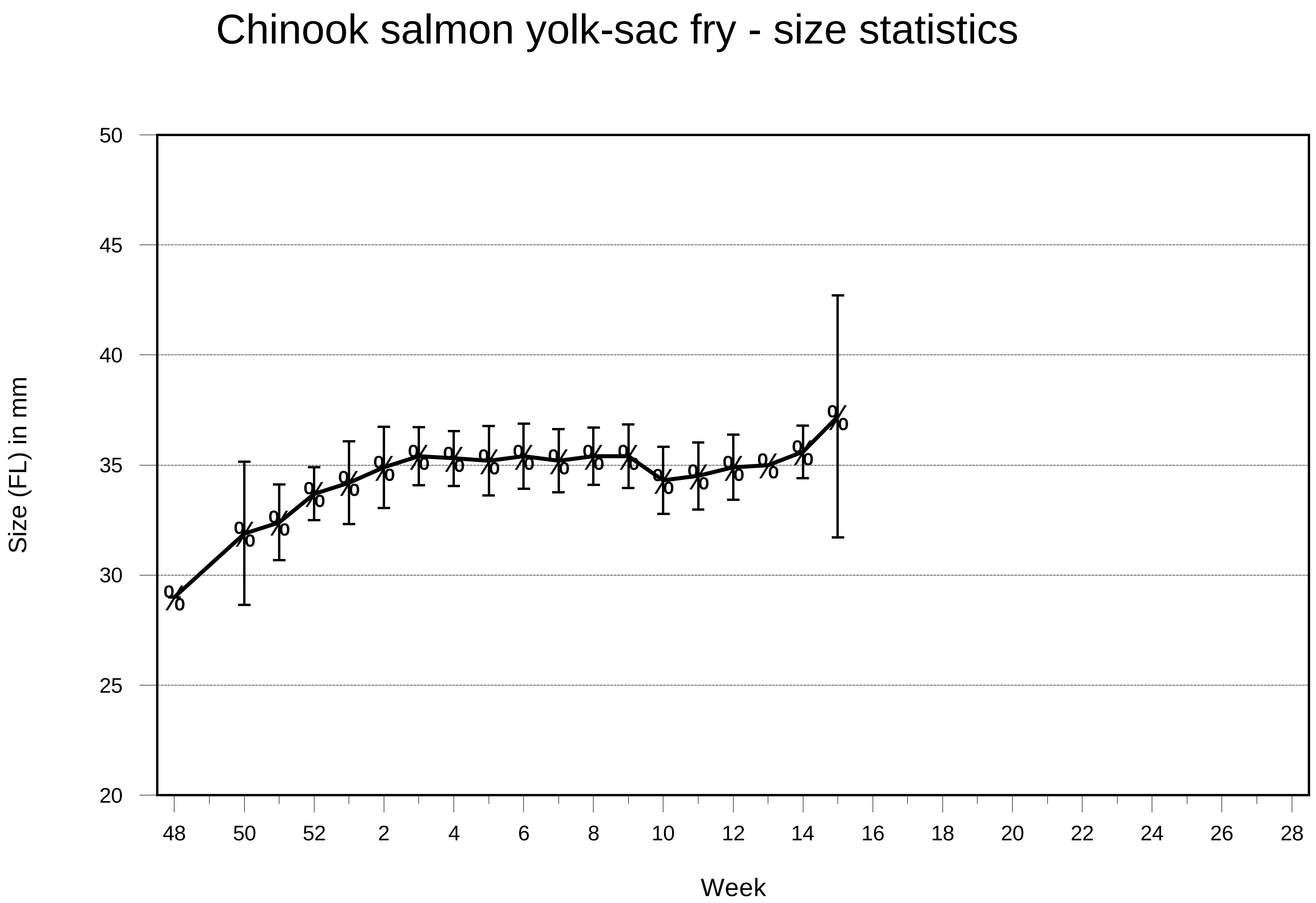

Figure 15. Mean fork length +/- one standard deviation of chinook salmon yolk-sac fry caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

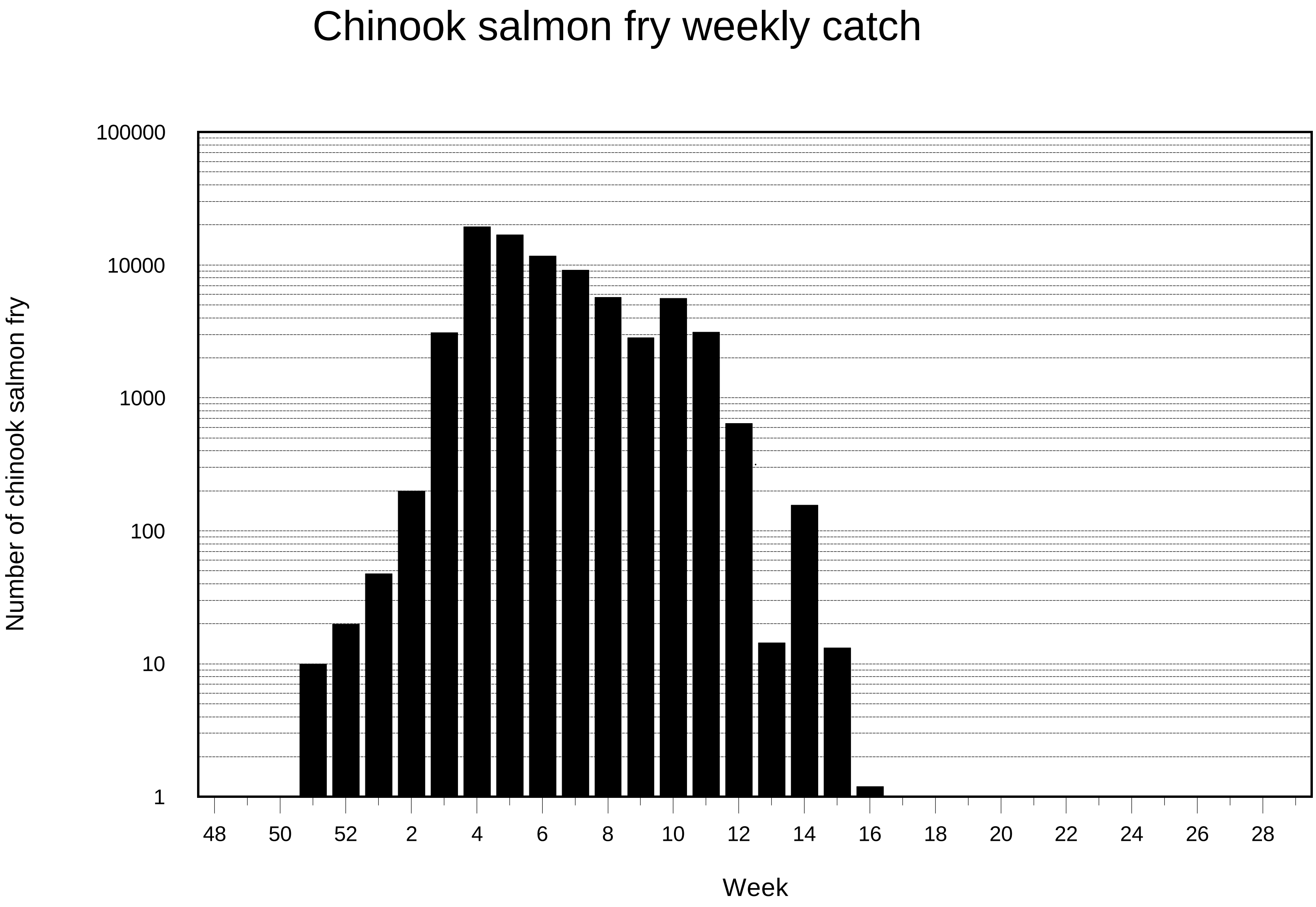

Figure 16. Weekly catch distribution of chinook salmon fry caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

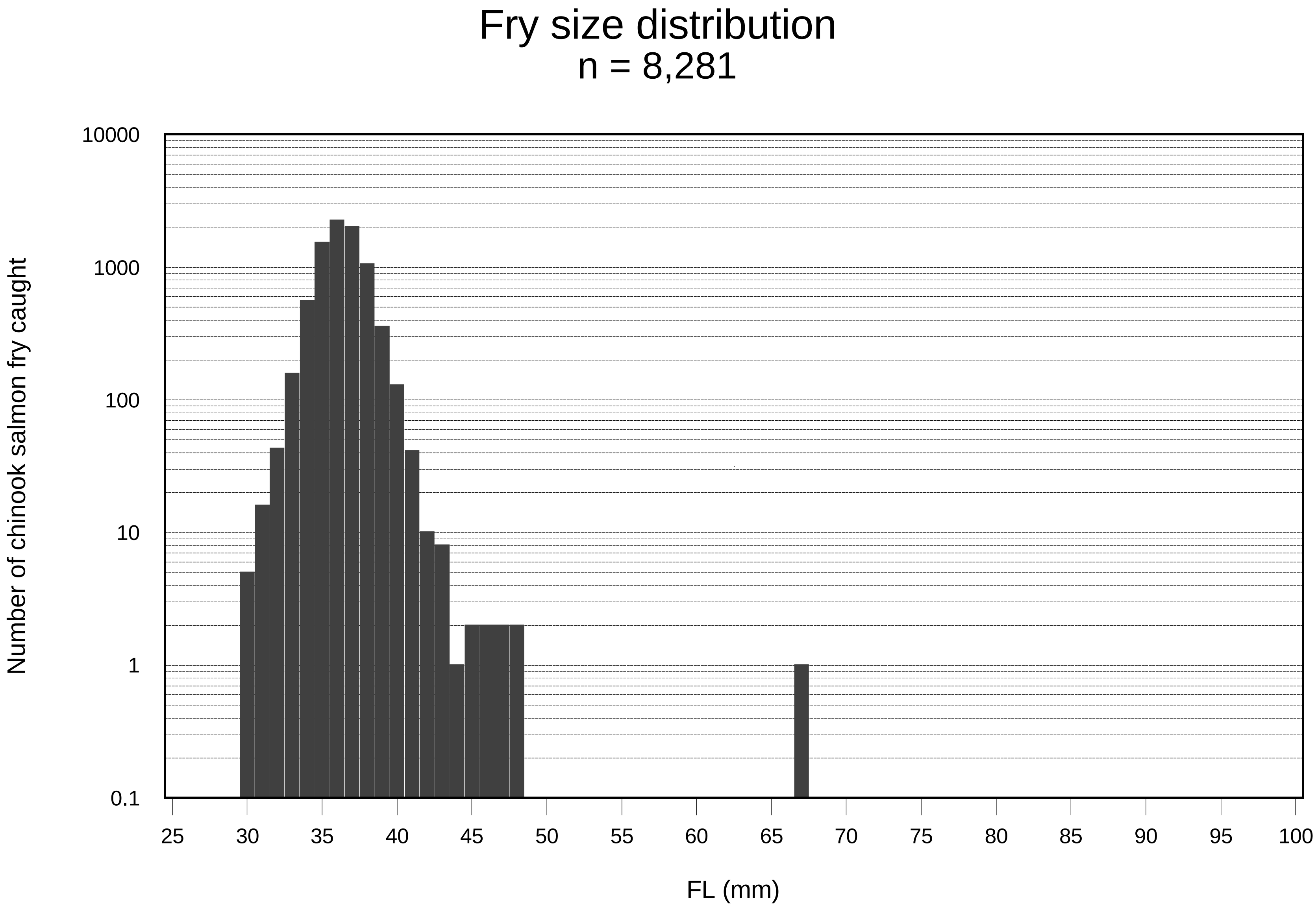

Figure 17. Size distribution of chinook salmon fry caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

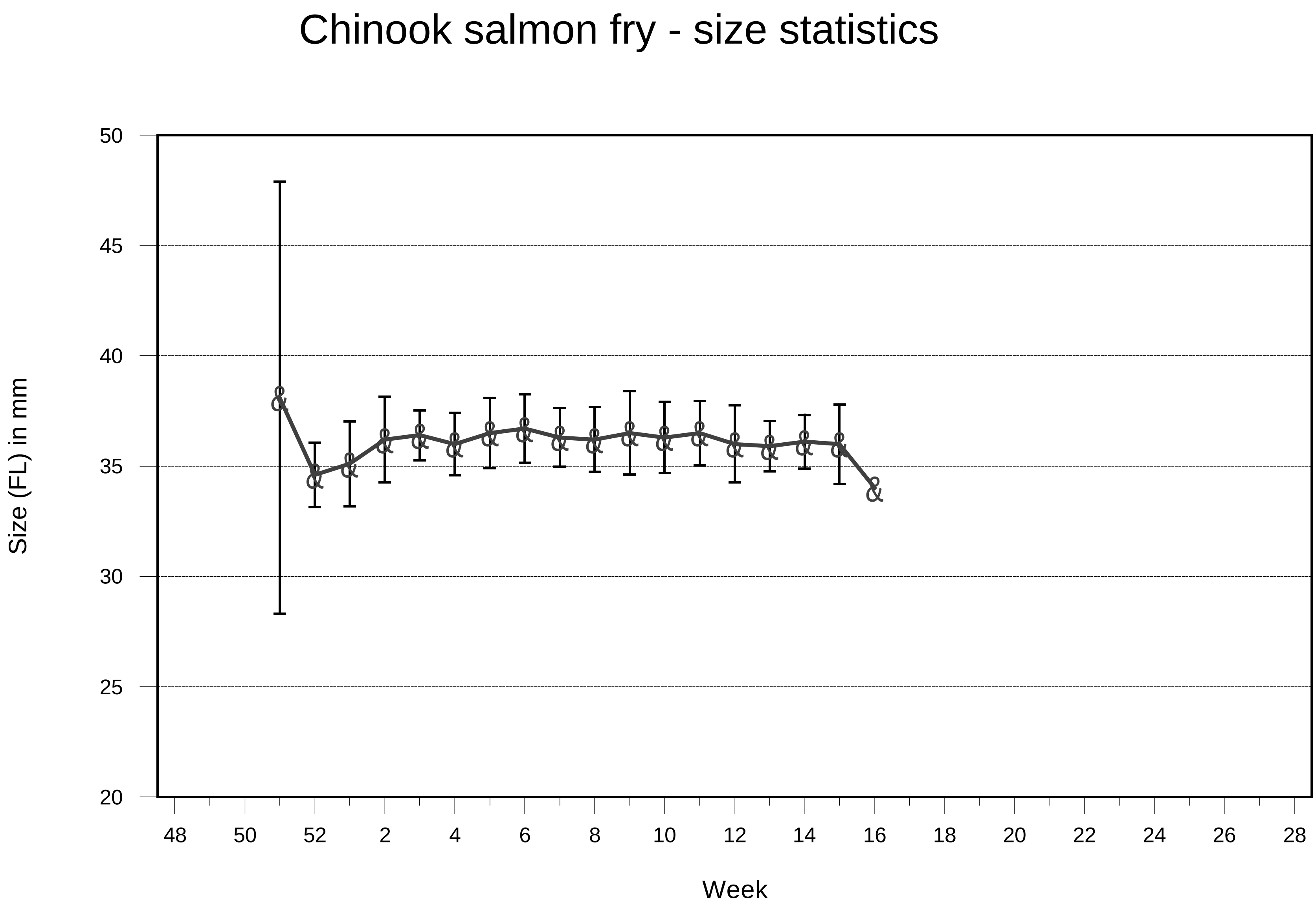

Figure 18. Mean fork length +/- one standard deviation of chinook salmon fry caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

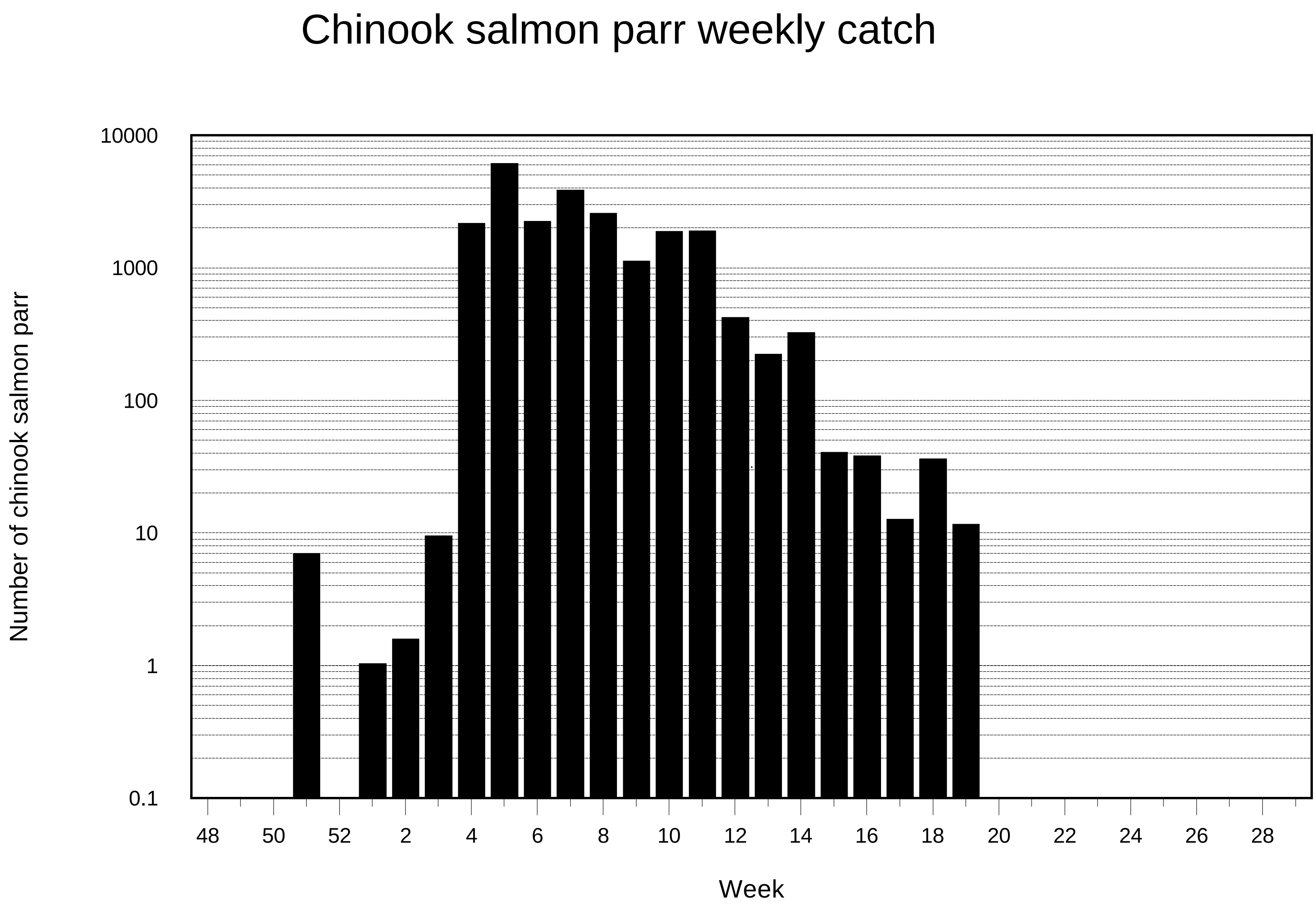

Figure 19. Weekly catch distribution of chinook salmon parr caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

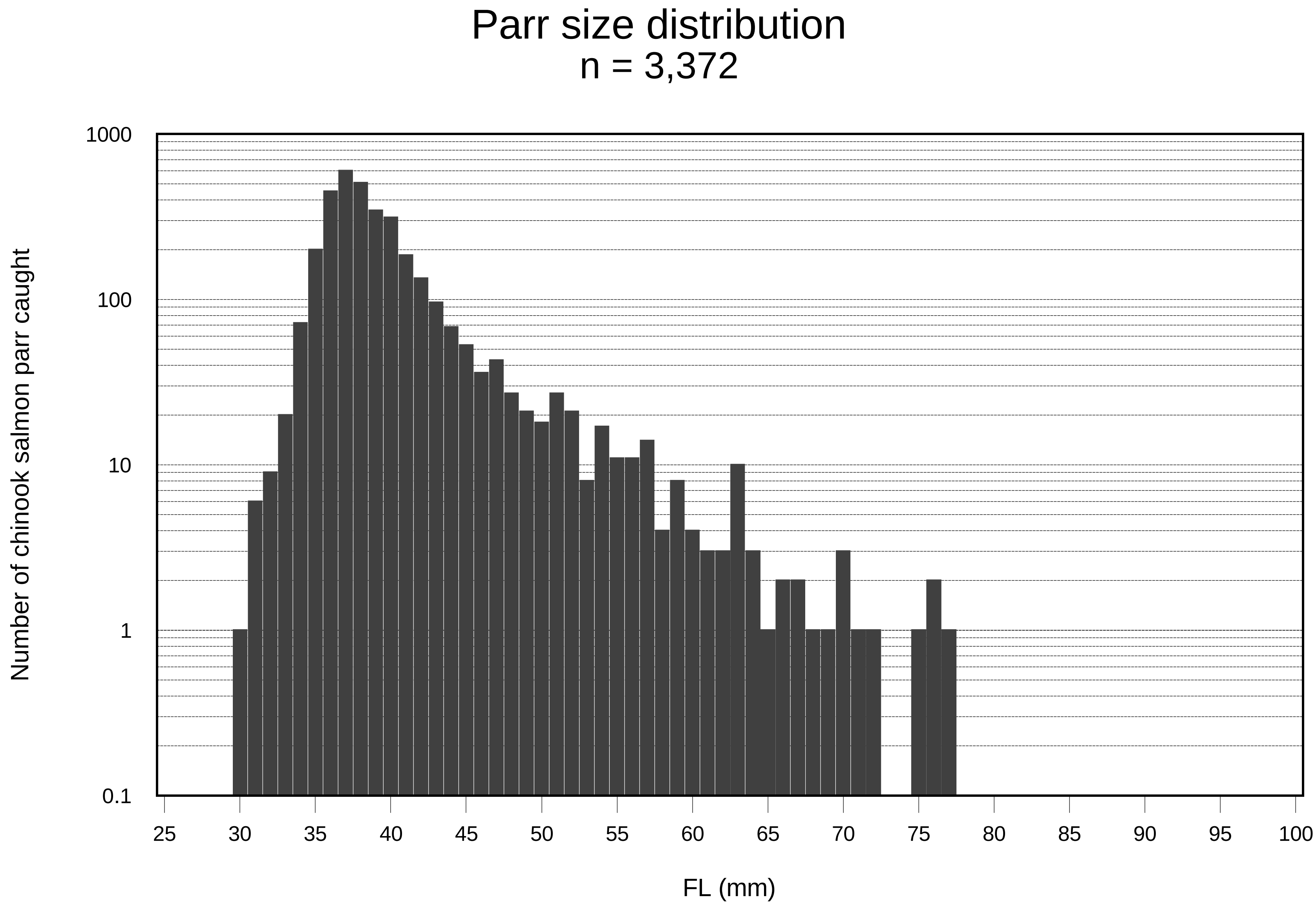

Figure 20. Size distribution of chinook salmon parr caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

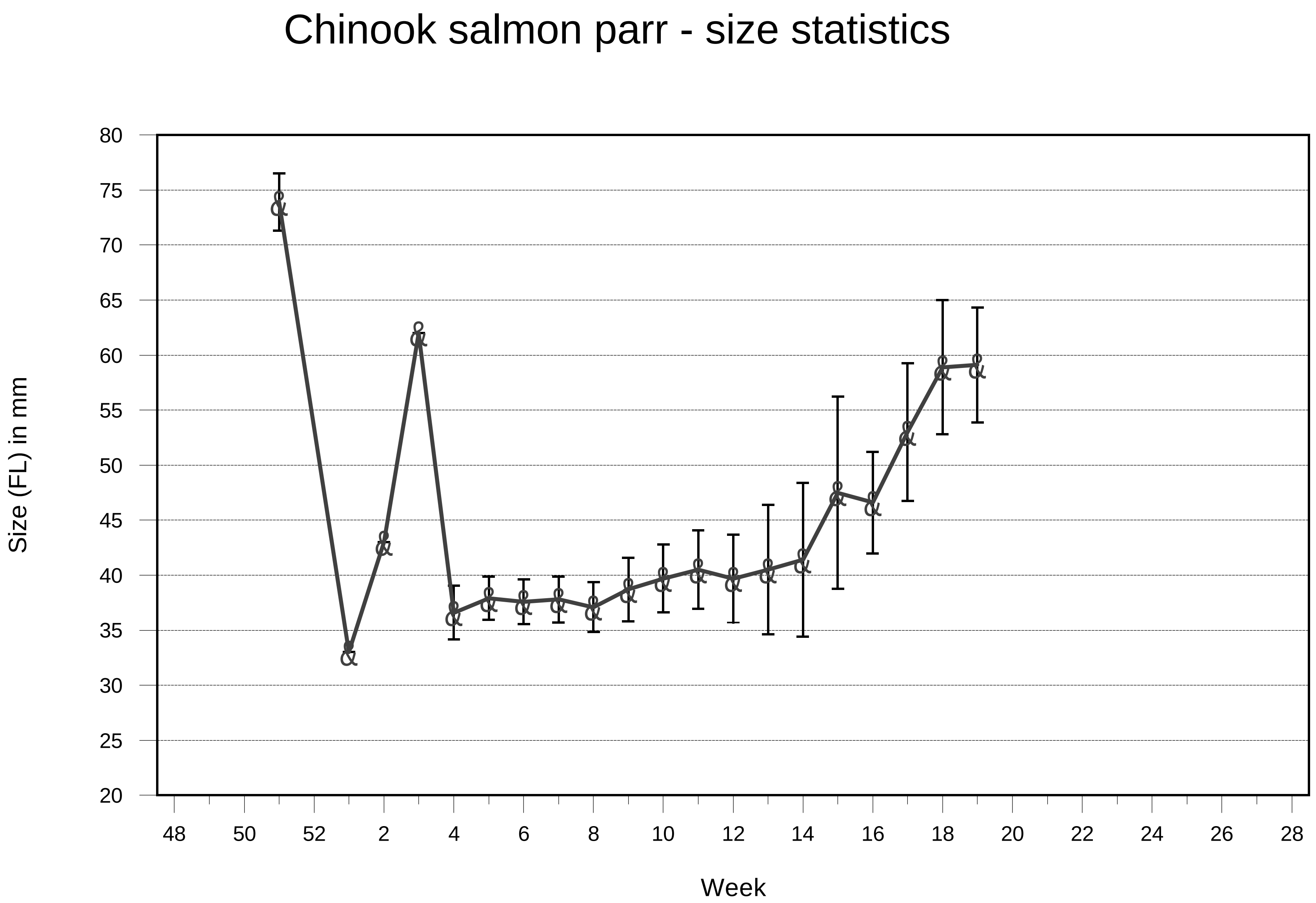

Figure 21. Mean fork length +/- one standard deviation of chinook salmon parr caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

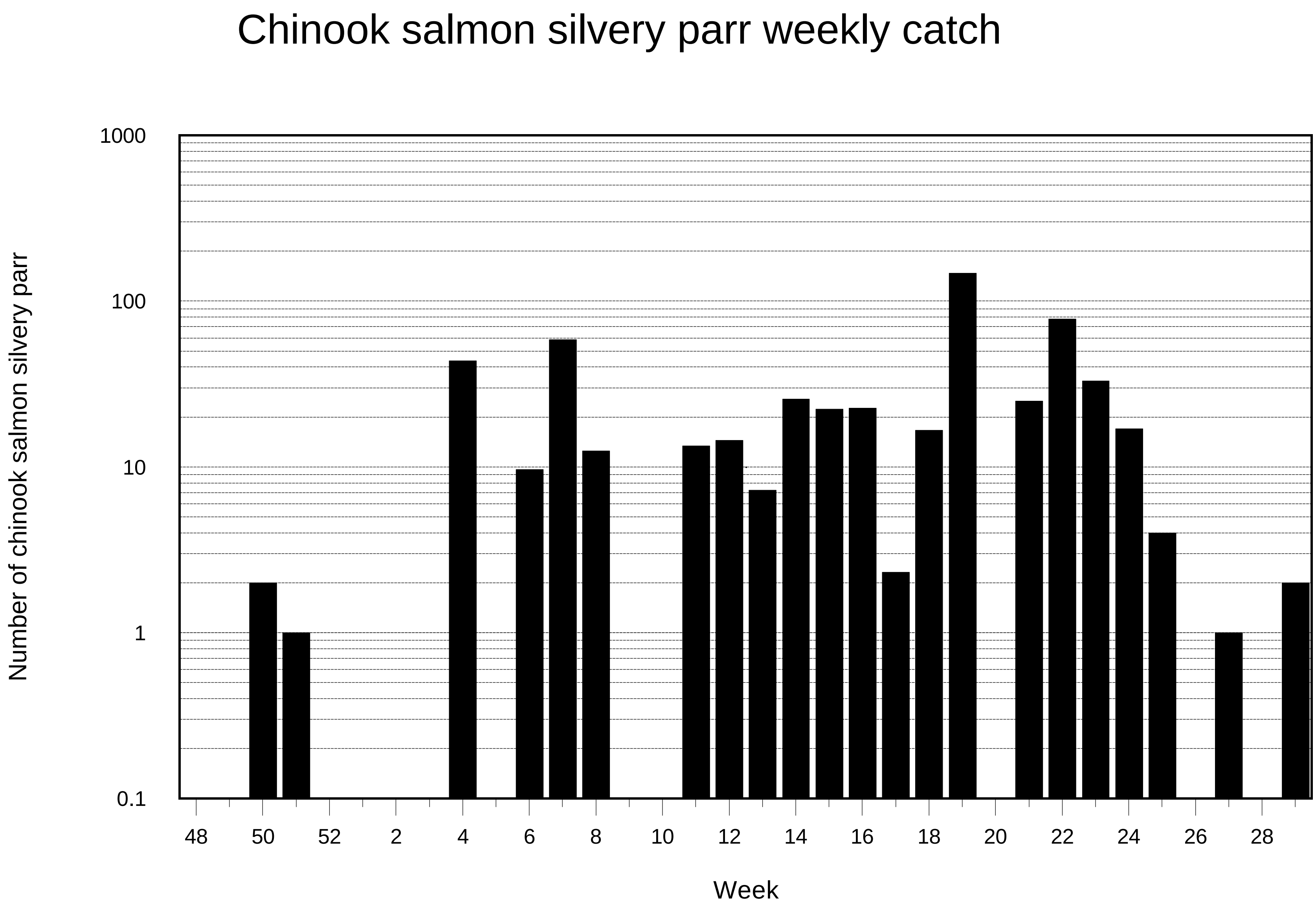

Figure 22. Weekly catch distribution of chinook salmon silvery parr caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

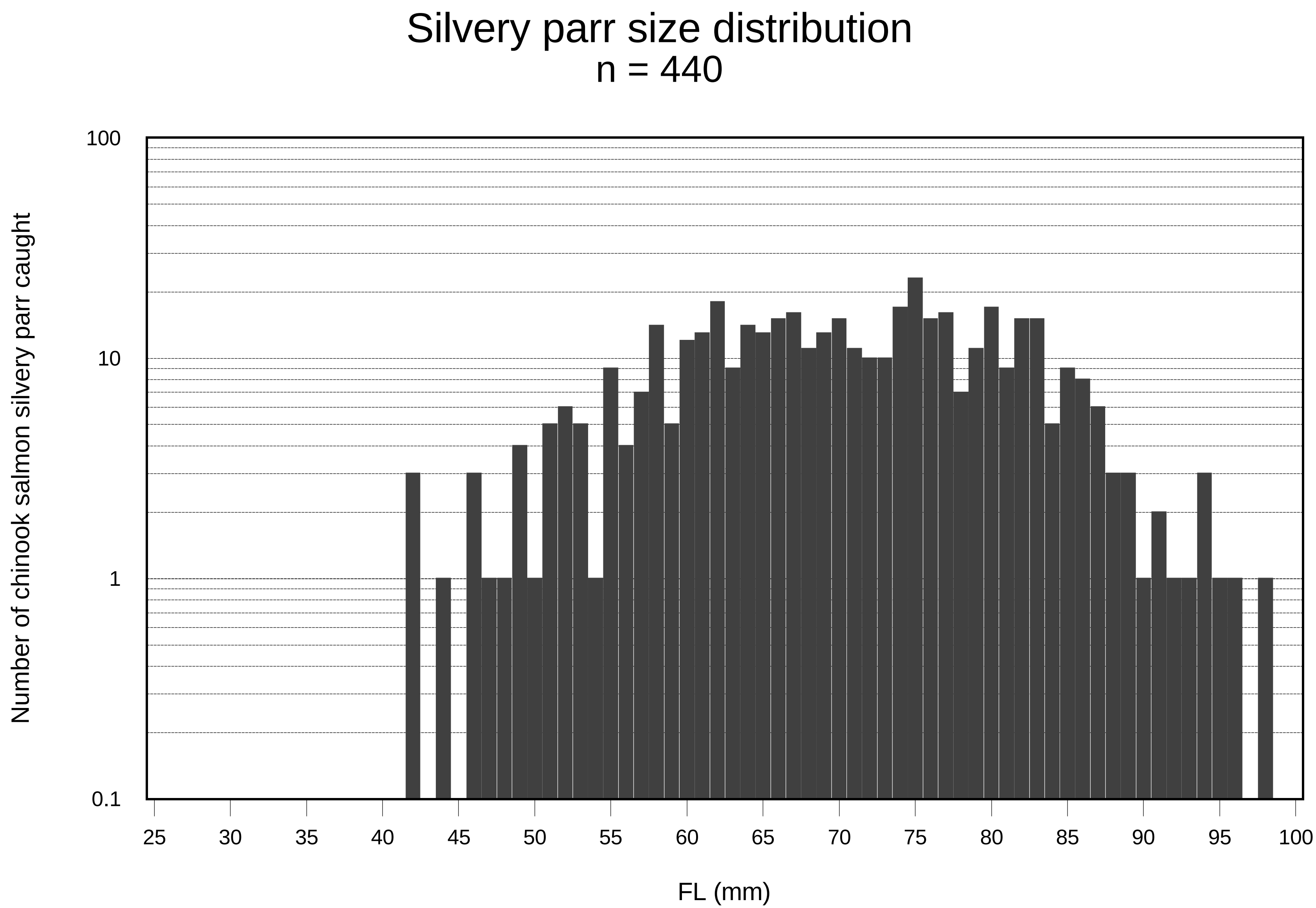

Figure 23. Size distribution of chinook salmon parr caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

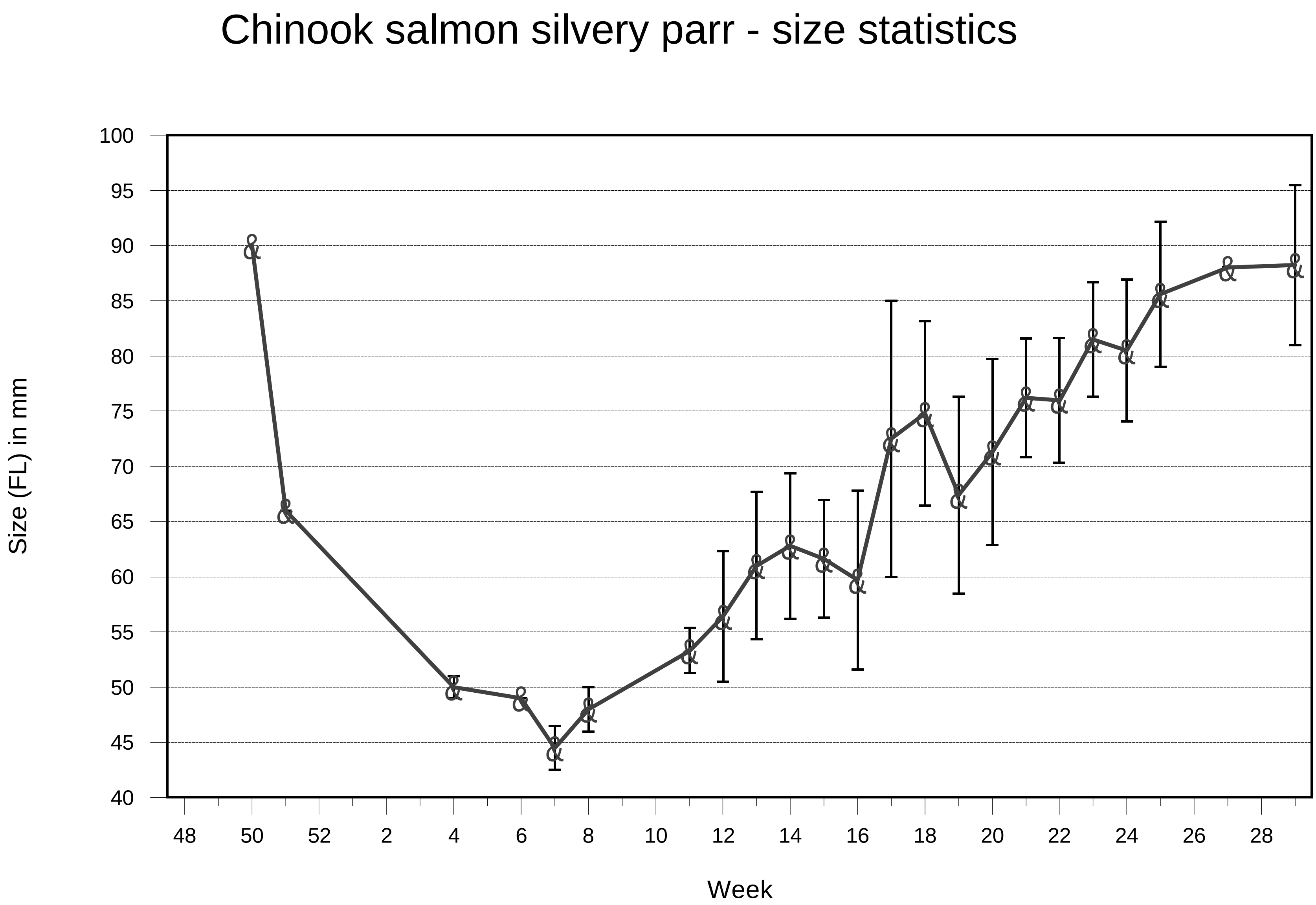

Figure 24. Mean fork length +/- one standard deviation of chinook salmon silvery parr caught by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

Fulton's condition factor(*k*) for chinook salmon ≥45 mm FL

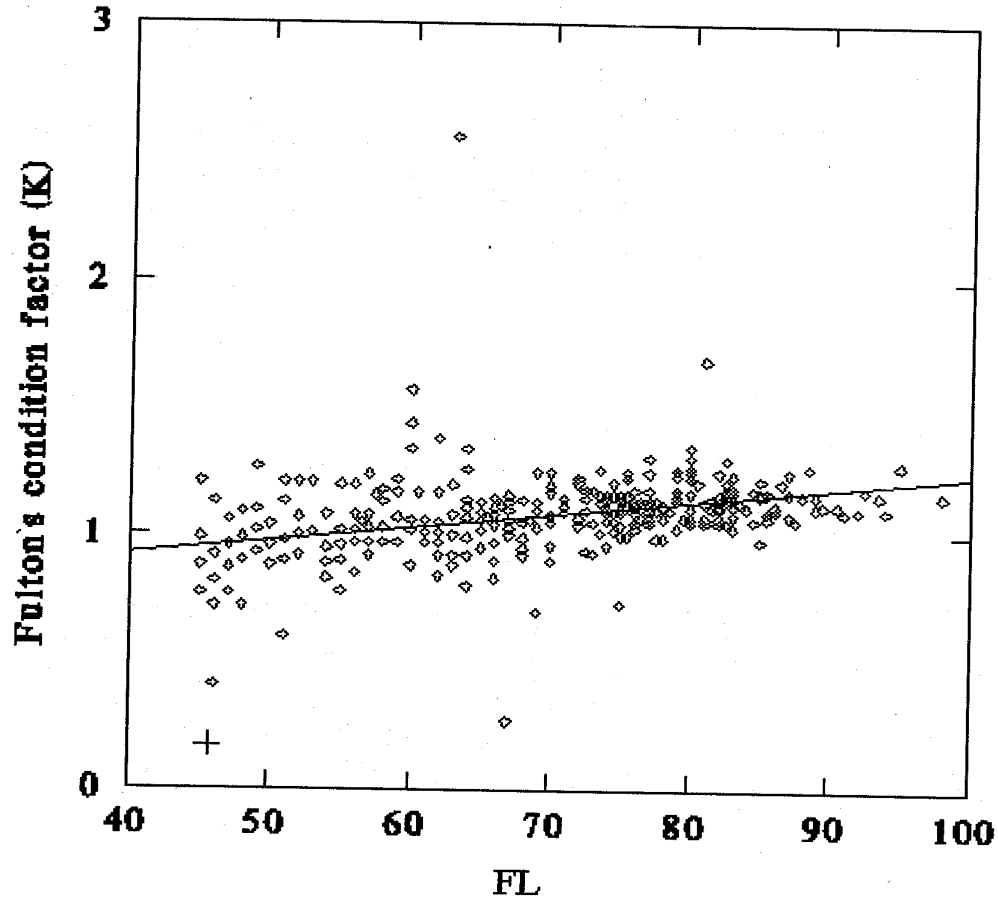

Figure 25. Condition factor as a function of FL for chinook salmon ≥45 mm FL caught by rotary screw trap during the lower American River emigration survey, November 1995-July 1996.

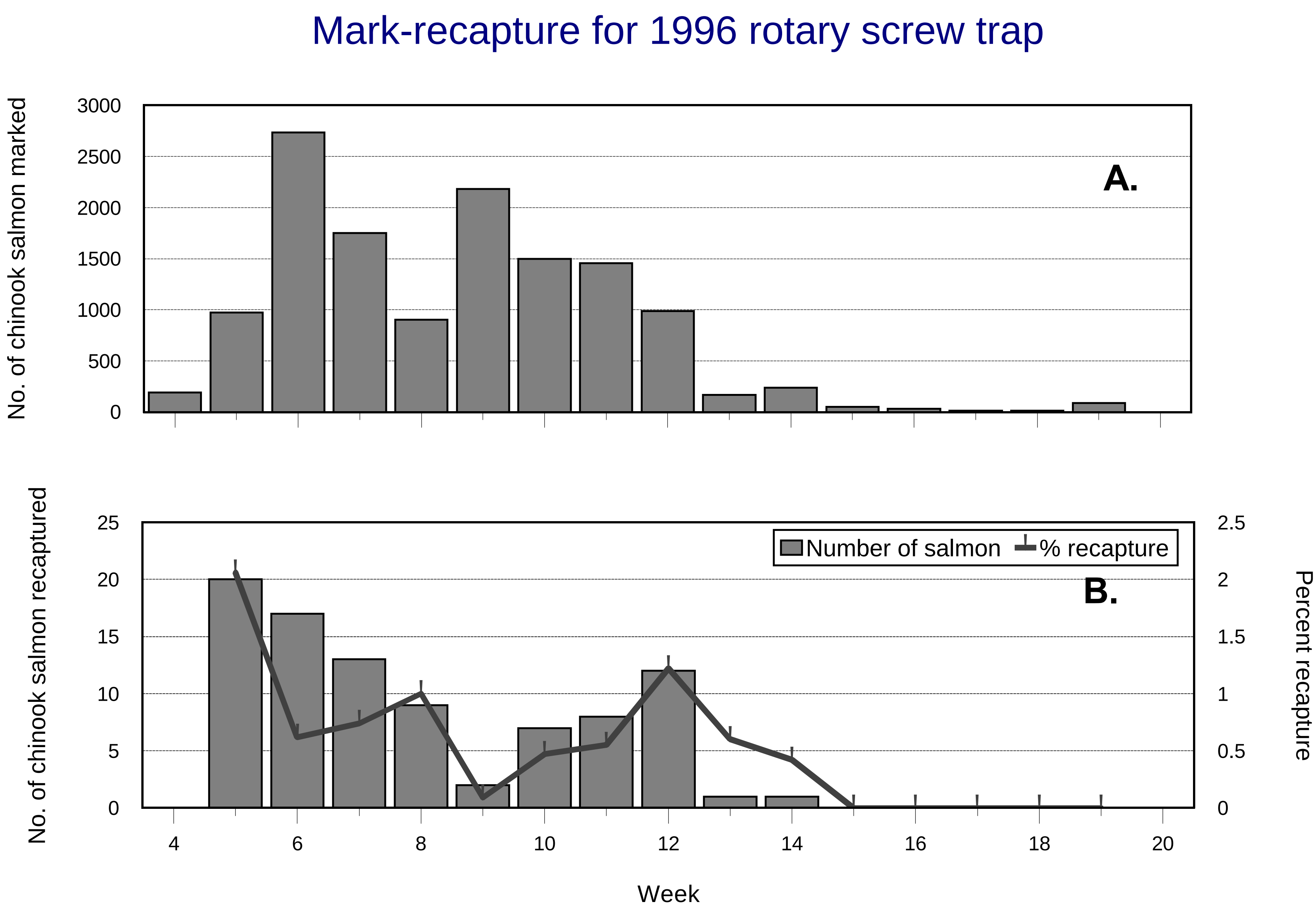

Figure 26. Number of chinook salmon marked (**A**) and recaptured (**B**) by rotary screw trap during the lower American River emigration survey, November 1995 - July 1996.

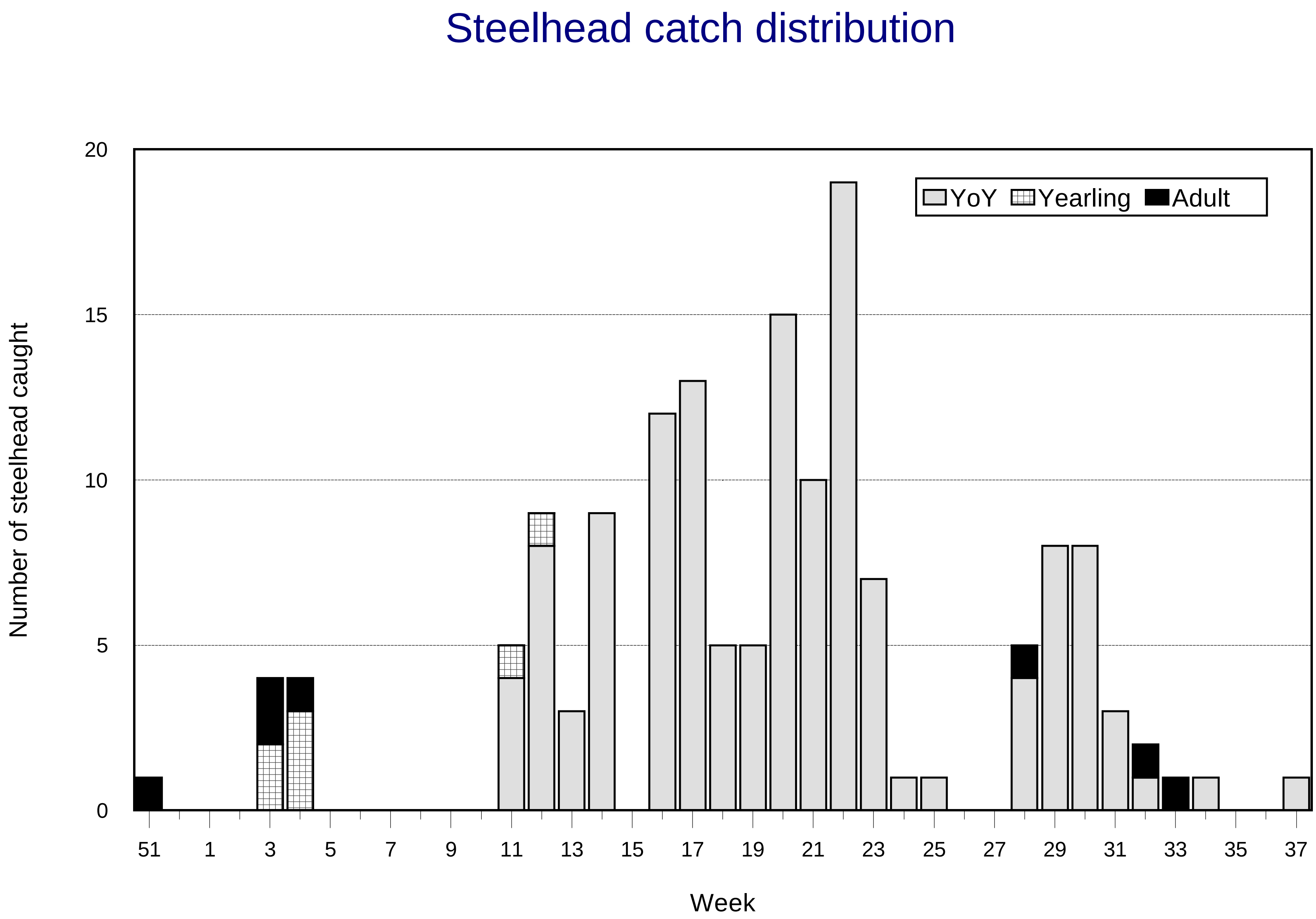

Figure 27. Catch distribution of young of the year (YoY), yearlings and adult steelhead caught by rotary screw trap during the lower American River emigration survey, December 1995 - August 1996.

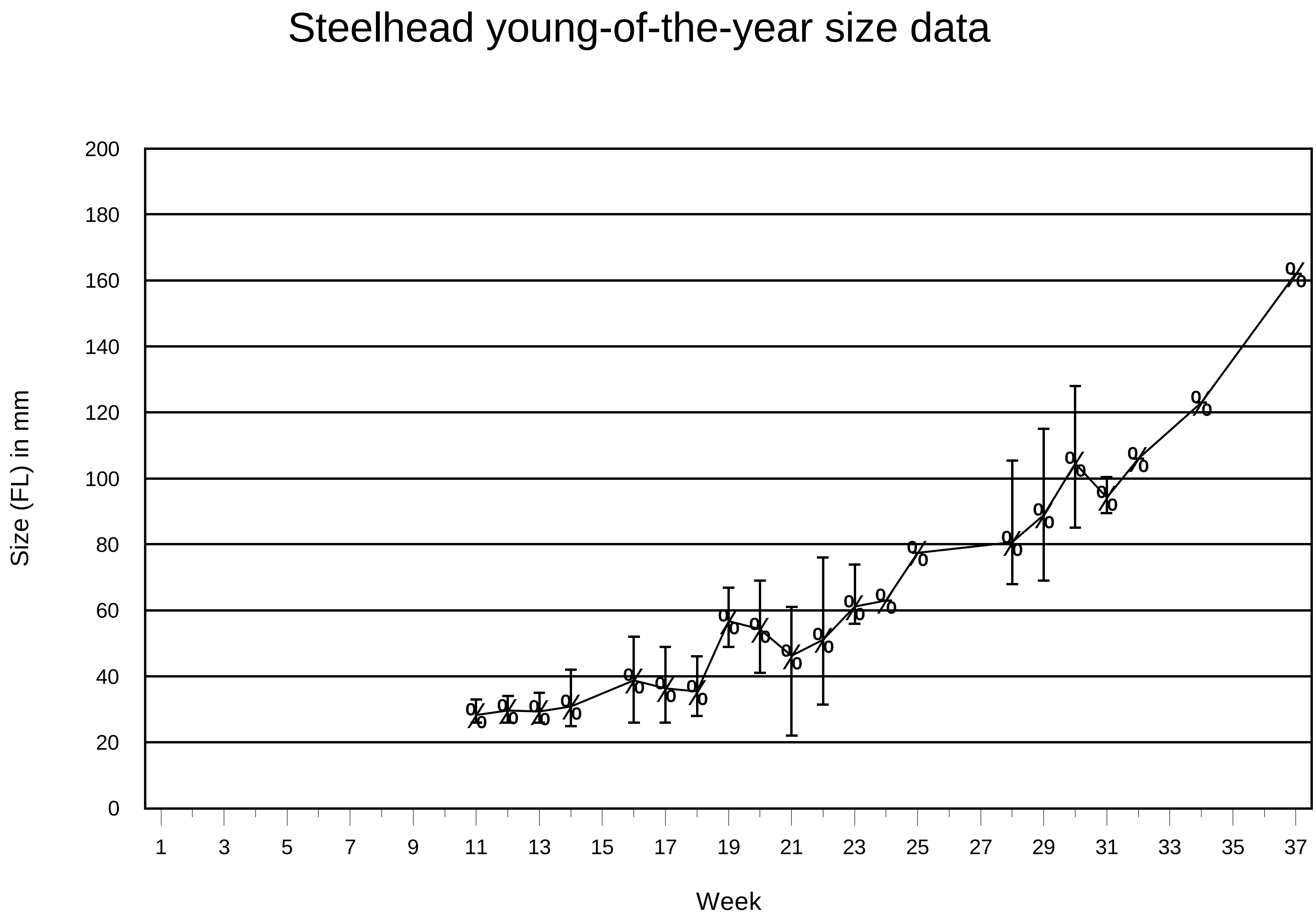

Figure 28. Mean fork length and size range of young-of-the-year steelhead caught by rotary screw trap during the lower American River emigration survey, January-August 1996.

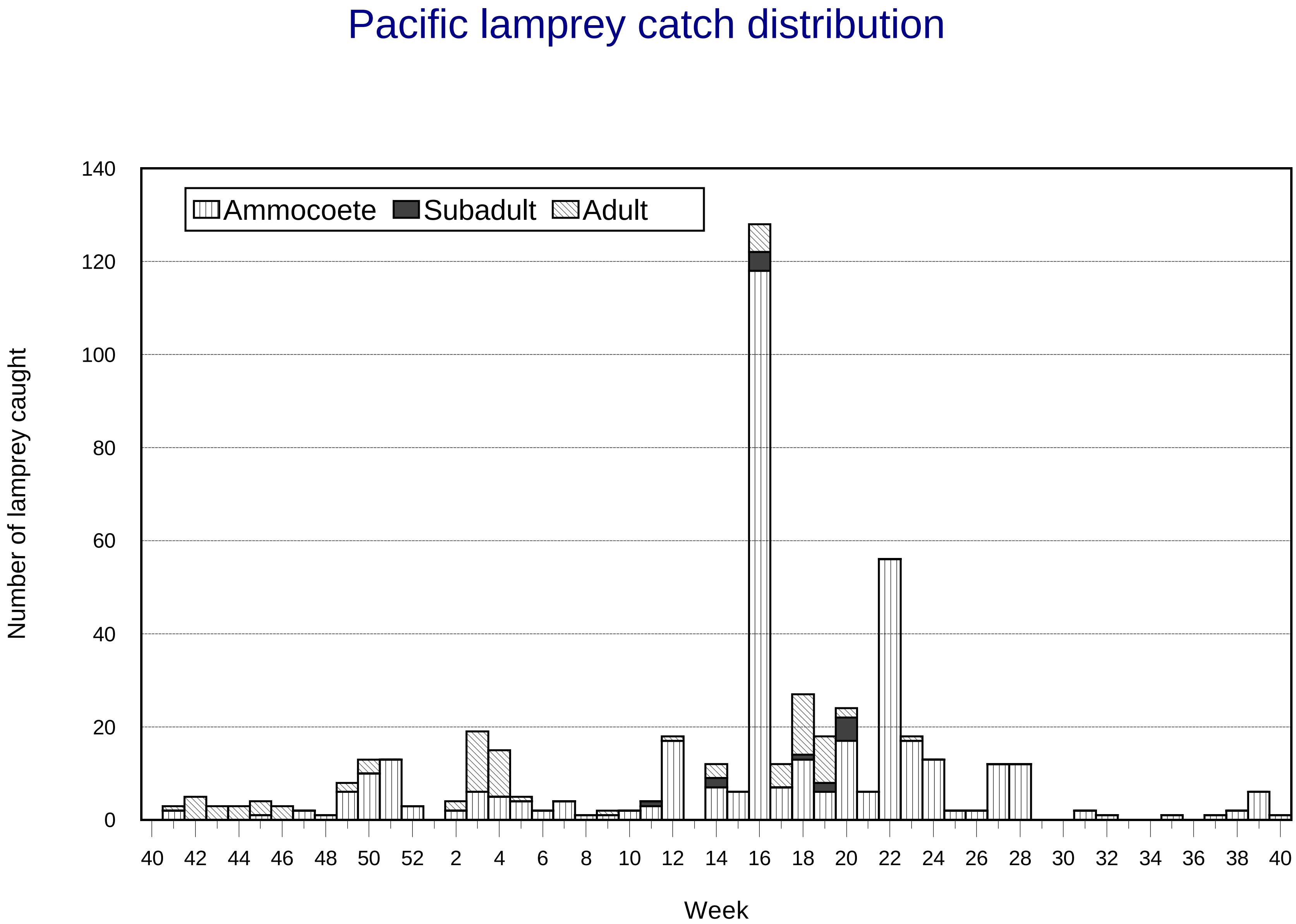

Figure 29. Catch distribution of Pacific lamprey ammocetes, subadults and adults caught during the lower American River emigration survey, October 1995 - September1996.

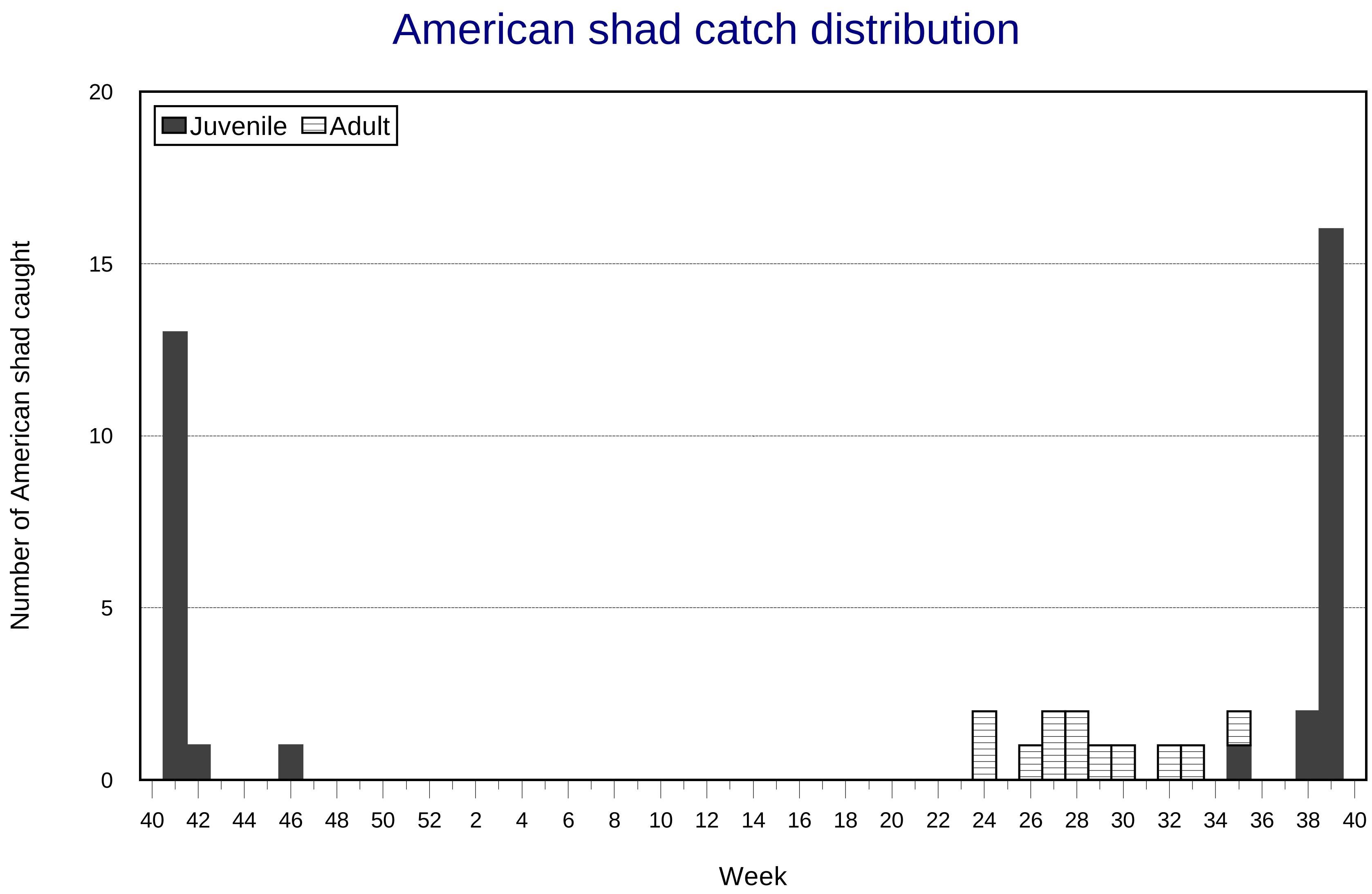

Figure 30. Catch distribution of American shad caught during the lower American River emigration survey, October 1995 - September 1996.