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

CENTRAL VALLEY ANADROMOUS FISH-HABITAT EVALUATIONS
October 1996 through September 1997

Annual Progress Report
Prepared for
U.S. Fish and Wildlife Service
Central Valley Anadromous Fish Restoration Program

Stream Evaluation Program
Technical Report No. 98-4
January 1998

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2/ Stream Evaluation Program Technical Report No. 98-2.

INTRODUCTION

In July 1995, the California Department of Fish and Game(DFG) entered into an agreement with the U.S. Fish and Wildlife Service (FWS) to evaluate anadromous salmonid habitat requirements in Central Valley streams. Various studies have been developed and are being implemented by the Stream Evaluation Program to provide the FWS Central Valley Anadromous Fish Restoration Program with reliable scientific information. The information is to be used by DFG and FWS to develop flow recommendations to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B).

The basic approach to the evaluations is outlined in "*Proposal to define instream flow and habitat requirements for anadromous resources in Central Valley Streams, September 1994*. The approach includes developing a better understanding of the life history of chinook salmon and steelhead trout emphasizing the relationships between life stage requirements and manageable habitat attributes (e.g., flow, water temperature, channel conditions, etc.). Initially, the evaluations are to be conducted in the Sacramento and American rivers and will include individual investigations of spawning, rearing and migration.

One of the requirements of the agreement is to provide the FWS with annual progress reports (based upon the federal fiscal year, October 1 - September 30). This report covers the investigations conducted in the Sacramento River during the period October 1996 through the last week of September 1997. During that period, DFG conducted five general investigations in the Sacramento River (Table 1).

Table 1. Investigations conducted by the Department of Fish and Game to determine anadromous salmonid habitat requirements in Central Valley streams - October 1995 through the last week of September 1996.

Investigation	Sacramento River
Habitat mapping	Completed
Fall-run chinook salmon spawning	X
Late fall-run chinook salmon spawning	Discontinued due to high flows
Winter-run chinook salmon spawning	X
Spring-run chinook salmon spawning	X
Juvenile salmonid rearing	X
Juvenile salmonid emigration	X

The results of two investigations conducted during the reporting period are presented as Appendices III and IV. These reports cover fall-run and winter-run chinook salmon spawning in the Sacramento River.

The purpose of this annual progress report is only to generally describe ongoing investigations and to summarize data being collected to evaluate anadromous fish habitat needs in California's Central Valley. No attempt is made herein to analyze data March 12, 1998ata analysis will be the subject of the final report.

UPPER SACRAMENTO RIVER REARING HABITAT EVALUATION

Rearing habitat investigations are intended to determine temporal and spatial distributions of the various juvenile life stages of anadromous salmonids in the upper Sacramento River. These investigations compliment juvenile emigration evaluations and should be conducted year around to fully describe behavior of juvenile salmonids relative to habitat conditions in the upper Sacramento River. Some of the information to be gained from both the trapping and rearing evaluations include: relative significance of upper river habitat to the various life stages under varying conditions; temporal and physical significance of various habitat conditions in the upper river; and significance of stream conditions downstream of the study area - basically an overall understanding of the relationship between fish and habitat in the upper river as it is influenced by potentially manageable biotic and abiotic, habitat attributes. The results presented here represent the second year of a 5-year study.

Evaluation of anadromous salmonid rearing habitat using seine and snorkel surveys was initiated in August 1996. The study area was located between river mile 271 (just below the mouth of Battle Creek) and river mile 302 (Keswick Dam) (Figure 1). Most sites sampled were located above Battle Creek, and hence upstream of direct hatchery influence. Sample sites were selected from 143 habitat units located in the study area; these units had been previously mapped by DFG (Appendix I). The habitat mapping was based on channel morphology using a stratified classification system similar to that used on the American River. Habitat types (e.g., pool, riffle, run, and glide) were stratified by habitat zone (flat water, bar complex, side channel, and off channel). Three replicates of 11 habitats present in the upper Sacramento River were randomly selected and sampled, if possible, twice per month. (For this report, all the data from the 2 similar habitats distinguished by zone [i.e. flat water pool and bar complex pool] were combined to represent 5, instead of 11 habitats: riffle, pool, glide, run, and off-channel). During the snorkel survey, two swimmers would survey a 150-ft long section randomly selected along each bank of the habitat unit. Data recorded included species, size in 25 mm size classes, and general habitat attributes (mean depth, mean velocity, cover, etc.). During the seining surveys, a site within the habitat unit was also sampled with a 50 x 4 ft beach seine. Up to two seine hauls were made per unit. Data acquired included number of salmonids (by species), size of up to 50 salmon and trout, per haul, (i.e., fork length [FL] to the nearest 0.5 mm, and weight, to the nearest 0.1 g), and general habitat attributes of the site seined.

A total of 362 surveys were conducted from 29 September 1996 (week 39) through 27 September 1997 (week 39). Survey sites included 124 riffles, 39 pools, 86 glides, 112 runs and 1 off-channel (Table 2). Of the 143 units mapped, 109 sites were snorkeled and 45 were seined (Table 2).

Table 2. Weekly distribution of habitat types sampled during the upper Sacramento River rearing habitat evaluation study, October 1996 - September 1997.

Week	Riffle	Pool	Glide	Run	Off-channel
40	4	3	5	3	0
41	0	3	5	4	1
42	5	2	4	4	0
43	3	3	6	4	0
44	5	0	3	4	0
45	2	0	2	3	0
46	6	5	7	6	0
47	1	0	0	0	0
48	0	2	1	0	0
49	4	3	3	2	0
50	1	3	3	6	0
51	6	3	4	6	0
52	4	1	4	6	0
1			No sampling		
2	1	0	2	5	0
3-19			No sampling weeks 3-19		
20	4	1	2	1	0
21	6	0	2	1	0
22	2	1	1	3	0
23	5	0	3	4	0
24	3	0	1	1	0
25	6	0	3	4	0
26	8	0	3	5	0
27	5	0	2	6	0
28	9	0	4	7	0
29	6	0	2	8	0
30	7	0	3	2	0
31	0	0	0	2	0
32	1	0	1	1	0
33	1	1	1	1	0
34	5	3	3	4	0
35	3	0	2	1	0
36	3	0	2	3	0
37	2	0	0	0	0
38	4	2	1	2	0
39	2	3	1	2	0
TOTAL	127	39	86	112	1

Table 3. Distribution of habitat units (identification numbers per Appendix Table I) sampled by both seine and snorkel during the upper Sacramento River rearing habitat evaluation study, October 1996 - September 1997.

Week	Seine only	Seine and Snorkel	Snorkel only
40	-	110, 130	57, 63, 64, 67, 70, 73, 108, 118, 121, 123, 125, 139, 140
41	91, 130	104, 110	74, 87, 90, 96, 101, 115, 129, 133, 139
42	-	6, 7, 10, 16, 18, 21, 29	14, 22, 32, 40, 42, 43, 47, 64
43	-	38, 43, 63, 75, 81, 91	44, 64, 70, 84, 105, 111, 113, 118, 120, 139
44	-	7, 10, 16, 18, 21, 26	2, 3, 14, 22, 34, 36
45	-	38, 53, 63, 75, 81, 91, 104	-
46	-	-	3, 5, 12, 15, 17, 18, 19, 27, 28, 29, 45, 49, 55, 56, 73, 88, 91, 101, 109, 113, 118, 123, 132, 133
47	-	6	-
48	-	-	28, 39, 44
49	-	21	5, 7, 16, 17, 18, 28, 38, 39, 44, 59, 63
50	18, 20, 22, 28, 57, 63, 75, 81, 82, 96,131	130	
51	-	-	9, 13, 17, 20, 23, 28, 36, 45, 50, 54, 55, 58, 73, 80, 90, 109, 120, 130, 134
52	6, 10, 12, 16, 18, 21, 38, 63, 75, 81, 82, 91, 104, 110, 130	-	-
1	No sites sampled		
2	62, 90, 91, 104, 109, 123, 131, 134	-	-
3-19	No sites sampled weeks 3-19		
20	6, 8, 10, 18, 123, 128, 131, 139	-	-
21	21, 29, 36, 38, 66, 69, 75, 78, 81	-	-
22	96, 104, 110, 123, 128, 131, 139	-	-
23	6, 9, 10, 18, 21, 23, 29, 36, 38, 91, 104, 110	-	-
24	66, 69, 75, 81, 82	-	-
25	6, 8, 9, 10, 18, 21, 23, 30, 31, 38, 63, 128, 131	-	-
26	6, 9, 10, 18, 21, 23, 69, 75, 81, 82, 91, 104, 110, 123, 128, 131	-	-
27	30, 31, 38, 63, 66, 69, 75, 82, 91, 104, 110, 123, 131	-	-
28	6, 8, 9, 10, 18, 21, 23, 30, 31, 63, 66, 69, 75, 81, 91, 96, 104, 110, 123, 131	-	-
29	18, 21, 23, 30, 31, 63, 66, 69, 75, 82, 91, 96, 104, 110, 121, 131	-	-
30	-	6, 8, 18, 21, 23, 30, 31, 38, 63, 66, 69, 75	-
31	-	82, 91	-
32	-	104, 110, 123	-
33	-	128, 130	14, 34
34	-	-	41, 44, 52, 83, 84, 87, 99, 101, 105, 106, 108, 118, 128, 133, 137
35	-	21, 30, 31, 36, 38,	-
36		6, 8, 9, 10, 18, 23 63, 104, 110	-
37	-	66, 69	
38	-		66, 77, 78, 85, 96, 111, 118, 124, 128, 129
39	-	- -	9, 12, 13, 15, 28, 33, 4

Snorkel Survey Results

Chinook Salmon

A total of 5,618 juvenile chinook salmon was counted during the snorkel survey (Table 4). The mean weekly number of salmon counted per sample site ranged from 0 (weeks 47 and 50) to 165.9 (week 39). No snorkel observations were made for most of the period between week 51 of 1996 (16 December) and week 30 of 1997 (21 July), due to poor water clarity (generally <3 feet).

Most salmon counted (79.4%, n = 4,461) were in the 26-50 mm FL range (Table 4; Figure 2). The count for salmon < 25 mm FL was 213 (3.8%), the count for salmon 51-75 mm FL was 669 (11.9 %), the count for salmon 76-100 mm FL was 247 (4.4 %), and the count for salmon > 100 mm FL was 28 (0.5 %). Small, recently emerged salmon (≤50 mm FL) dominated the counts during most weeks (Figures 3-8). The greatest percentage of larger salmon were observed during week 46 when 63% of the total catch ≥ 76 mm FL.

Temporal salmon distribution varied both among and within habitat types (Table 5; Figures 9-14). The mean weekly salmon count was greatest for pools (0.135 fish/ft). Run counts averaged 0.097 fish/ft. Glide counts averaged 0.049 fish/ft followed closely by riffle counts which averaged 0.047 fish/ft. When fish were the most abundant (week 39), the number of fish/ft were greatest in runs, followed by glides, riffles, and lastly pools. When larger fish (≥76 mm FL) comprised the highest portion (week 46), the numbers of fish/ft were greatest in pools followed by glides, riffles, and runs.

Rainbow trout (steelhead)

A total of 4,101 rainbow trout was counted during the snorkel survey (Table 6). The mean weekly number of rainbow trout counted per sample site ranged from 0 (weeks 47 and 50) to 127 (week 45).

Most trout were in the 26-50 mm FL range (31.5%) (Table 6; Figure 15). For the remaining size categories, 4.1% were <25 mm FL, 29.1% were in the 51-75 mm FL range, 19.2% were in the 76-100 mm FL range, and 16.1% were >100 mm FL. The greatest percentages of the larger fish were observed during weeks 41, 42, 46, and 48 (October and early November 1996) (Figures 16-21); they were absent from week 30 though week 37 period (July to mid-September 1997). The greatest percentages of smaller fish (≤50 mm FL) were observed during week 40 and from weeks 30 through 38 (20 July through 20 September 1996).

Rainbow trout distribution over time varied among and within habitat types (Table 7; Figures 22-27). The overall mean number of fish/ft were 0.126 for runs, 0.042 for pools, 0.038 for riffles, and 0.020 for glides. Runs were the favored habitat of both large and small rainbow trout.

Table 4. Summary of chinook salmon data collected during snorkel surveys of rearing habitat in the upper Sacramento River, October 1996 - September 1997.

Week (beginning date)	Number of sites	Total count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
40 (01 Oct)	15	775	51.7	0.6	83.6	11.6	4.1	0
41 (06 Oct)	11	109	9.9	0	49.5	41.3	9.2	0
42 (13 Oct)	15	235	15.7	0	66.0	21.3	12.8	0
43 (20 Oct)	16	473	29.6	0	79.1	17.8	3.2	0
44 (27 Oct)	12	85	7.1	0	47.1	52.9	0	0
45 (03 Nov)	7	23	3.3	0	0	100	0	0
46 (10 Nov)	24	274	11.4	0	4.7	32.1	54.0	9.1
47 (17 Nov)	1	0	0	0	0	0	0	0
48 (24 Nov)	3	4	1.3	0	0	0	100	0
49 (01 Dec)	12	30	2.5	3.3	90	0	0	6.7
50 (08 Dec)	1	0	0	0	0	0	0	0
51 (15 Dec)	19	280	14.7	38.6	42.9	18.2	0	0.4
52-29 (29 Dec 96 - 13 Jul 97)					No sites sampled			
30 (20 Jul)	12	331	27.6	5.7	88.2	6	0	0
31 (27 Jul)	2	22	11.0	27.3	68.2	0	0	4.5
32 (03 Aug)	3	81	27.0	0	93.8	6.2	0	0
33 (10 Aug)	4	34	11.3	0	100	0	0	0
34 (17 Aug)	15	330	22.0	10.6	73.6	15.8	0	0
35 (24 Aug)	6	222	37.0	0	77.5	18.0	4.5	0

Table 4 (cont.)

Week (beginning date)	Number of sites	Total count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
36 (31 Aug)	8	206	25.8	0	87.9	12.1	0	0
37 (07 Sep)	2	48	24.0	0	95.8	4.2	0	0
38 (14 Sep)	10	729	72.9	0	98.8	1.1	0	0.1
39 (21 Sep)	8	1,327	165.9	3.0	94.1	2.9	0	0
Total (mean)	206	5,618	(27.3)	(3.8)	(79.4)	(11.9)	(4.4)	(0.5)

Table 5. Summary of total counts and counts per foot, by habitat type, of chinook salmon counted during snorkel surveys of upper Sacramento River rearing habitat, 01 October, 1996 - 15 September, 1997.

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft
40	4	123	0.068	3	459	0.383	5	22	0.012	3	171	0.127
41*	0	0	0	2	0	0	5	0	0	3	25	0.021
42	5	0	0	2	0	0	4	0	0	4	235	0.132
43	3	22	0.021	3	75	0.071	6	309	0.137	4	67	0.041
44	5	0	0	0	0	0	3	0	0	4	85	0.047
45	2	0	0	0	0	0	2	0	0	3	23	0.019
46	6	36	0.013	5	140	0.062	7	95	0.030	6	3	0.001
47	1	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	2	0	0	1	4	0.009	0	0	0
49	3	0	0	3	0	0	4	15	0.008	2	15	0.017
50	One site sampled but no salmon observed											
51	6	67	0.045	3	12	0.011	4	33	0.020	6	168	0.124
52-59	No sites sampled											
30	7	64	0.033	0	0	0	3	210	0.280	2	57	0.095
31	0	0	0	0	0	0	0	0	0	2	22	0.037
32	1	0	0	0	0	0	1	25	0.083	1	56	0.187
33	1	10	0.033	1	15	0.050	1	0	0	1	9	0.030
34	5	79	0.5	3	98	0.131	3	47	0.052	4	106	0.079

Table 5 (cont.)

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft

Table 5. (cont.)

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft	Sites	Count	#/ft
36	3	139	0.071	0	0	0	2	33	0.031	3	34	0.017
37	2	48	0.053	0	0	0	0	0	0	0	0	0
38	4	119	0.012	2	542	0.602	1	1	0.002	3	67	0.056
39	2	195	0.217	3	139	0.103	1	153	0.340	2	840	0.933
Total (mean)	63	1,007	(0.047)	33	1,480	(0.135)	55	1,048	(0.049)	54	1,999	(0.097)

* Also one off-channel site: Count = 84; n/ft = 0.187

Table 6. Summary of rainbow trout data collected during snorkel surveys of rearing habitat in the upper Sacramento River, October 1996 - September 1997.

Week (beginning date)	Number of sites	Total count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
40 (01 Oct)	15	278	18.53	0	16.9	51.8	15.5	15.8
41 (06 Oct)	11	28	2.55	0	0	17.9	0	82.1
42 (13 Oct)	15	30	2.00	0	0	66.7	0	33.3
43 (20 Oct)	16	328	20.50	0	30.5	37.8	16.5	6.1
44 (27 Oct)	12	43	3.58	0	4.7	18.6	11.6	65.1
45 (03 Nov)	7	889	127.00	0	0	25.1	39.4	35.5
46 (10 Nov)	24	540	22.50	0	3.1	18.9	39.1	38.9
47 (17 Nov)	1	0	0	0	0	0	0	0
48 (24 Nov)	3	86	28.67	0	0	0	98.8	1.2
49 (01 Dec)	12	45	3.75	13.3	48.9	20.0	13.3	4.4
50 (08 Dec)	1	0	0	0	0	0	0	0
51 (16 Dec)	19	4	0.21	0	75.0	0	0	25.0
52-29 (29 Dec 96 - 13 Jul 97)					No sites sampled			
30 (20 Jul)	12	460	38.33	13.0	83.9	2.8	0.2	0
31 (27 Jul)	2	113	56.50	19.5	70.8	8.8	0.9	0
32 (03 Aug)	3	26	8.67	0	76.9	3.8	19.2	0
33 (10 Aug)	4	17	5.67	0	70.6	23.5	5.9	0
34 (17 Aug)	15	138	9.20	12.3	74.6	12.3	0.7	0

Table 6 (cont.)

Week (beginning date)	Number of sites	Total count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
35 (24 Aug)	6	22	3.67	0	36.4	63.6	0	0

Table 6. (cont.)

Week (beginning date)	Number of sites	Total count	#/site	Size composition (%)				
				<25 mm	26-50 mm	51-75 mm	76-100 mm	>100 mm
36 (31 Aug)	8	581	72.63	0	61.4	35.1	3.4	0
37 (07 Sep)	2	6	3.00	0	50.0	50.0	0	0
38 (14 Sep)	10	45	4.50	2.2	75.6	13.3	0	8.9
39 (21 Sep)	8	422	52.75	14.2	23.5	60.4	1.4	0.5
Total (mean)	206	4,101	(19.91)	(4.1)	(31.5)	(29.1)	(19.2)	(16.1)

Table 7. Summary of total counts and counts per foot, by habitat type, of rainbow trout counted during snorkel surveys of upper Sacramento River rearing habitat, 01 October, 1996 - 15 September, 1997.

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Counts	#/ft	Sites	Count	#/ft	Sites	Count	#/ft
40	4	90	0.050	3	42	0.035	5	108	0.060	3	38	0.028
41*	0	0	0	2	0	0	5	0	0	3	28	0.023
42	5	0	0	2	0	0	4	0	0	4	30	0.017
43	3	15	0.014	3	1	0.001	6	3	0.001	4	309	0.187
44	5	11	0.005	0	0	0	3	2	0.001	4	30	0.017
45	2	0	0	0	0	0	2	0	0	3	889	0.741
46	6	168	0.062	5	123	0.055	7	76	0.024	6	173	0.064
47	1	0	0	0	0	0	0	0	0	0	0	0
48	0	0	0	2	0	0	1	86	0.191	0	0	0
49	3	25	0.021	3	0	0	4	1	0.001	2	19	0.021
50	One site sampled (pool) , no rainbow trout observed											
51	6	1	0.001	3	0	0	4	3	0.002	6	0	0
52-29	No sites sampled											
30	7	75	0.0038	0	0	0	3	91	0.121	2	294	0.490
31	0	0	0	0	0	0	0	0	0	2	113	0.188
32	1	0	0	0	0	0	1	15	0.050	1	11	0.037
33	1	0	0	1	2	0.007	1	0	0	1	15	0.050
34	5	40	0.030	3	34	0.045	3	18	0.020	4	46	0.034
35	3	7	0.008	0	0	0	2	15	0.025	1	0	0

* Also one off-channel site sampled: Count = 0, #/ft = 0.

Table 7. (cont.)

Week	Riffle			Pool			Glide			Run		
	Sites	Count	#/ft	Sites	Counts	#/ft	Sites	Count	#/ft	Sites	Count	#/ft
36	3	59	0.049	0	0	0	2	2	0.003	3	520	0.433
37	2	6	0.007	0	0	0	0	0	0	0	0	0
38	4	27	0.016	2	6	0.007	1	0	0	3	12	0.010
39	2	97	0.108	3	248	0.018	1	5	0.011	2	72	0.080
Total (mean)	63	621	(0.038)	33	456	(0.042)	55	425	(0.020)	54	2,599	(0.126)

Seine Survey Results

Chinook salmon

A total of 4,226 salmon were collected by seine from 224 sites (Table 8). The weekly mean salmon size ranged from 31.0 mm FL (week 49) to 59.1 mm FL (weeks 22 and 23). Recently emerged fish (<50 mm FL) were collected during most weeks. Smolt-sized fish (≥70 mm FL) were also frequently collected although less often than the smaller fish.

Habitat types were not equally represented in the overall seining effort due to varying sampling conditions between habitat types. Catch per habitat unit were as follows: 89 riffles yielded a mean catch 16.1 fish/site, 8 pools yielded of 3.6 fish/site, 51 glides yielded 28.6 fish/site, and 76 runs yielded 17.2 fish/site (Table 8).

The size distribution of seine-caught fish are presented in Figures 28-35. Size ranges for both the seining and snorkel surveys were similar for weeks when both sampling techniques were used (weeks 40, 41, 42, 43, 44, 45, 47, 49, 30, 31, 32, 33, 35, 36, and 37).

Rainbow trout (Steelhead)

A total of 149 rainbow trout was collected from 224 sites (Table 9). The mean weekly mean size ranged from 29.9 mm FL (week 21) to 125.0 mm FL (week 52). Recently emerged fish (<35 mm FL) were collected from week 20 through week 24 and weeks 26, 27, 29, 30 and 37. Larger smolt-sized fish (typically ≥100 mm FL) were caught only during week 23.

Catches per habitat unit were as follows: 89 riffles yielded a mean catch of 0.6 fish per site, 8 pools yielded 2.1 fish per site, 51 glides yielded 1.0 fish per site, and 76 runs yielded 0.4 fish per site (Table 9).

The size distributions of seine caught fish are presented in Figures 36-41. The size ranges of seine-caught trout was different from the size ranges of rainbow trout observed during the snorkel surveys. For the weeks that both seines and snorkel surveys were conducted (weeks 40, 41, 42, 43, 44, 45, 47, 49, 30, 31, 32, 33, 36, and 37), many more larger trout (>100 mm FL) were observed during the snorkel surveys than were captured in seines. The discrepancy may be due to larger trout avoiding the seine.

Table 8.Weekly catch statistics by habitat type for chinook salmon caught by beach seine in the upper Sacramento River, October 1996 - September 1997.

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FLmean(range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)
40 (01 Oct)	No sites sampled			1	19	38.4 (34-54)	1	18	47.4 (31-75)	No sites sampled			2	37	42.8 (31-75)
41 (06 Oct)	No sites sampled			1	1	65.0	1	1	45.0	2	55	51.9 (34-85)	4	57	52.0 (34-85)
42 (13 Oct)	3	66	50.0 (36-66)	No sites sampled			2	100	46.9 (33-58)	2	100	64.9 (33-105)	7	266	54.4 (33-105)
43 (20 Oct)	1	8	44.0 (33-53)	No sites sampled			3	61	57.6 (35-78)	2	30	42.5 (33-51)	6	99	51.9 (33-78)
44 (27 Oct)	3	53	60.4 (44-75)	No sites sampled			2	26	44.0 (36-51)	1	3	53.0 (47-58)	6	82	54.9 (36-75)
45 (03 Nov)	2	2	54.5 (54-55)	No sites sampled			2	7	57.1 (50-65)	3	0	-	7	9	56.6 (50-65)
46 (10 Nov)	No sites sampled														
47 (17 Nov)	1	0	-	No sites sampled			No sites sampled			No sites sampled			1	0	-
48 (24 Nov)	No sites sampled														
49 (01 Dec)	1	1	31.0	No sites sampled			No sites sampled			No sites sampled			1	1	31.0
50 (08 Dec)	1	0	-	2	6	81.5 (43-114)	3	78	38.2 (30-97)	7	6	51.7 (35-85)	13	90	42.0 (30-114)
51 (15 Dec)	No sites sampled														
52 (22 Dec)	4	91	37.5 (32-94)	1	2	35.5 (34-37)	4	252	40.8 (29-130)	6	180	36.0 (28-67)	15	525	38.8 (28-130)
1 (29 Dec)	No sites sampled														
2 (05 Jan)	1	0	-	No sites sampled			2	0	-	5	1	40.0	8	1	40.0
3 - 19 (12 Jan - 04 May 97)	No sites sampled														
20 (11 May)	4	10	52.0 (46-60)	1	1	52.0	2	2	52.5 (46-59)	1	115	55.5 (43-77)	8	128	55.1 (43-77)
21 (18 May)	6	336	55.2 (35-91)	No sites sampled			2	8	55.3 (51-64)	1	1	39.0	9	345	55.1 (35-91)
22 (25 May)	2	38	55.2 (39-75)	1	0	-	1	165	53.0 (34-148)	3	280	63.3 (33-93)	7	483	59.1 (33-148)

Table 8. (cont.)

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)
23 (01 Jun)	5	244	50.4 (35-102)	No sites sampled			3	30	59.4 (36-97)	4	54	53.3 (35-84)	12	328	59.1 (35-102)
24 (08 Jun)	3	302	42.7 (28-90)	No sites sampled			1	30	49.3 (36-42)	1	41	41.3 (35-49)	5	373	42.3 (28-90)
25 (15 Jun)	6	4	46.0 (36-74)	No sites sampled			3	15	40.5 (35-49)	4	7	42.0 (37-50)	13	26	41.7 (35-74)
26 (22 Jun)	8	123	42.7 (34-82)	No sites sampled			3	160	44.5 (35-55)	5	29	41.7 (36-50)	16	312	43.5 (34-82)
27 (29 Jun)	5	30	39.7 (35-52)	No sites sampled			2	1	71.0	6	271	47.7 (35-78)	13	302	47.0 (35-78)
28 (06 Jul)	9	48	48.0 (38-80)	No sites sampled			4	198	48.4 (38-71)	7	130	52.6 (37-175)	20	376	49.8 (37-175)
29 (13 Jul)	6	9	41.6 (37-47)	No sites sampled			2	0	-	8	0	-	16	9	41.6 (37-47)
30 (20 Jul)	7	3	56.7 (42-81)	No sites sampled			3	153	48.6 (37-68)	2	4	75.8 (60-95)	12	160	49.5 (37-95)
31 (27 Jul)	No sites sampled			No sites sampled			No sites sampled			2	0	-	2	0	-
32 (03 Aug)	1	1	33.0	No sites sampled			1	0	-	1	0	-	3	1	33.0
33 (10 Aug)	1	0	-	1	0	-	No sites sampled			No sites sampled			2	0	-
34 (17 Aug)	No sites sampled														
35 (24 Aug)	3	14	40.5 (35-87)	No sites sampled			2	5	37.8 (37-39)	1	0	-	6	19	39.8 (35-87)
36 (31 Aug)	4	11	39.8 (35-52)	No sites sampled			2	148	52.2 (37-92)	2	0	-	8	159	51.3 (35-92)
37 (07 Sep)	2	39	37.6 (34-52)	No sites sampled			No sites sampled			No sites sampled			2	39	37.6 (34-52)
38 (14 Sep)	No sites sampled														
39 (21 Sep)	No sites sampled														
Totals [mean]	89	1,433	[47.8] (28-102)	8	29	[48.5] (34-114)	51	1,458	[47.2] (29-148)	76	1,307	[53.0] (28-175)	224	4,227	[49.1] (28-175)

Table 9. Weekly catch statistics by habitat type for rainbow trout by beach seine in the upper Sacramento River, October 1996 - September 1997.

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)
40 (01 Oct)	No sites sampled			1	3	48.7 (46-51)	1	27	52.3 (39-65)	No sites sampled			2	30	52.0 (39-65)
41 (06 Oct)	No sites sampled			1	0	-	1	1	40.0	2	9	61.8 (50-75)	4	10	59.6 (40-75)
42 (13 Oct)	3	1	42.0	No sites sampled			2	0	-	2	0	-	7	1	42.0
43 (20 Oct)	1	1	46.0	No sites sampled			3	0	-	2	0	-	6	1	46.0
44 (27 Oct)	3	1	70.0	No sites sampled			2	0	-	1	0	-	6	1	70.0
45 (03 Nov)	2	0	-	No sites sampled			2	1	54.0	3	0	-	7	1	54.0
46 (10 Nov)	No sites sampled														
47 (17 Nov)	1	0	-	No sites sampled			No sites sampled			No sites sampled			1	0	-
48 (24 Nov)	No sites sampled														
49 (01 Dec)	1	0	-	No sites sampled			No sites sampled			No sites sampled			1	0	-
50 (08 Dec)	1	0	-	2	0	-	3	0	-	7	0	-	13	0	-
51 (15 Dec)	No sites sampled														
52 (22 Dec)	4	0	-	1	0	-	4	1	125.0	6	0	-	15	1	125.0
1 (29 Dec)	No sites sampled														
2 (05 Jan)	1	0	-	No sites sampled			2	0	-	5	0	-	8	0	-
3 - 19 (12 Jan - 04 May 97)	No sites sampled														
20 (11 May)	4	0	-	1	8	34.8 (26-42)	2	0	-	1	0	-	8	8	34.8 (26-42)
21 (18 May)	6	7	30.0 (26-32)	No sites sampled			2	1	29.0	1	0	-	9	8	29.9 (26-32)
22 (25 May)	2	1	39.0	1	6	31.7 (27-36)	1	0	-	3	0	-	7	7	32.7 (27-39)
23 (01 Jun)	5	0	-	No sites sampled			3	2	46.5 (28-65)	4	2	105.0 (50-160)	12	4	75.8 (28-160)

Table 9. (cont.)

Week (beginning date)	Riffle			Pool			Glide			Run			Total		
	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)	No. Sites	Count	FL mean (range)
24 (08 Jun)	3	14	51.0 (38-65)	No sites sampled			1	3	34.7 (32-38)	1	0	-	5	17	48.1 (32-65)
25 (15 Jun)	6	0	-	No sites sampled			3	0	-	4	3	57.3 (39-87)	13	3	57.3 (39-87)
26 (22 Jun)	8	14	36.3 (22-88)	No sites sampled			3	9	44.4 (27-65)	5	5	32.2 (30-35)	16	28	38.1 (22-88)
27 (29 Jun)	5	6	30.7 (27-38)	No sites sampled			2	0	-	6	7	45.0 (26-77)	13	13	38.4 (26-77)
28 (06 Jul)	9	1	34.0	No sites sampled			4	0	-	7	1	34.0	20	2	34.0
29 (13 Jul)	6	1	29.0	No sites sampled			2	0	-	8	1	30.0	16	2	29.5 (29-30)
30 (20 Jul)	7	1	33.0	No sites sampled			3	2	32.5 (27-38)	2	1	25.0	12	4	30.8 (25-38)
31 (27 Jul)	No sites sampled			No sites sampled			No sites sampled			2	0	-	2	0	-
32 (03 Aug)	1	0	-	No sites sampled			1	0	-	1	0	-	3	0	-
33 (10 Aug)	1	0	-	1	0	-	No sites sampled			No sites sampled			2	0	-
34 (17 Aug)	No sites sampled														
35 (24 Aug)	3	0	-	No sites sampled			2	0	-	1	0	-	6	0	-
36 (31 Aug)	4	0	-	No sites sampled			2	2	54.5 (46-63)	2	1	36.0	8	3	48.3 (36-63)
37 (07 Sep)	2	5	36.2 (31-42)	No sites sampled			No sites sampled			No sites sampled			2	5	36.2 (31-42)
38 (14 Sep)	No sites sampled														
39 (21 Sep)	No sites sampled														
Totals [mean]	89	53	[39.4] (22-88)	8	17	[36.1] (36-51)	51	49	[49.6] (27-125)	76	30	[51.3] (25-160)	224	149	[47.7] (22-160)

UPPER SACRAMENTO RIVER EMIGRATION MONITORING

The purpose of this activity is to determine the timing and relative abundance of salmon and rainbow trout (potentially steelhead) emigration relative to precedent conditions of spawning and rearing in the upper natal stream. The results provided in this report are for the period from 1 October 1996 (week 40) through 15 September 1997 (week 38).

Emigrating juvenile salmonids were monitored at sites located near Balls Ferry Bridge (RM 278) and at Deschutes Road Bridge (RM 281). Sampling was conducted using two rotary screws traps at RM 278 and one at RM 281. The upstream trap was first used on 15 March 1997. It was typically fished 2 days/week primarily to determine the efficiency of the downstream traps using a mark-and-recapture approach. No traps were fished from 29 December 1996 to 5 February 1997 due to the very high flow conditions. Sampling ceased on 15 September 1997 due to an unpredicted, large number of winter-run chinook salmon fry which resulted in our achieving the take allotted per our Section 10 research permit earlier than expected.

The traps at RM 278 were normally fished 24 h/day for 7 days/week. Beginning 18 May through 3 July, however, large amounts of algae started to collect on the traps requiring them to be frequently cleaned while they were fishing. In response to this problem, we stratified our sampling to represent a 24 h/day, 7 days/week effort. During these weeks, the traps were fished in 10 hour shifts: either 0130 to 1130 h (dawn shift) or 1400 to 2400 h (dusk shift). Each shift was rotated every 4 days. During each shift, the traps were checked and cleaned each hour. When algae build-up subsided, we resumed fishing the traps 24 h/day, 7 days/week.

Data recorded each time the screw traps were checked included the number of hours fished and the number of juvenile salmonids collected by species and race. (Race for chinook salmon was determined using the length-at-time criteria developed by Frank Fisher of the DFG). All salmon identified as winter run, spring run, and late-fall run were measured and weighed (FL in mm and weight in g). All juvenile rainbow trout were measured. Up to 300 fall-run-sized salmon were randomly selected per trap up to twice daily, then measured and weighed.

Trap efficiency was evaluated using a mark-and-recapture approach. Typically, all captured salmon, except winter-run-sized salmon, were marked and released. Fish captured and marked at the Balls Ferry were transported upstream about 2,500 feet and released. Those marked at Deschutes Road Bridge were released at that site. During the efficiency test, all fish measured at Balls Ferry were checked for marks. Fish were marked using dyes, either by bathing them in Bismark brown (at Balls Ferry) or injecting them with Alcian blue (at Deschutes Road).

Emigration Results

Chinook Salmon

Juvenile salmon were collected every week sampled (Table 10; Figure 42). Mean weekly size ranged from 36.0 mm FL (week 51) to 82.1 mm FL (week 44) (Figure 43). Recently emerged-sized fish (< 35 mm FL) were collected every week that samples were collected except weeks 43 and 44. Larger smolt-sized fish (≥ 70 mm FL) were caught every week except weeks 1 and 38 (Appendix II; Figures 1-12).

Catch rates ranged from 0.15 fish/h (week 20) to 36.04 fish/h (week 9) (Table 10; Figure 42). Weekly mean catch rates were highest during February when fall-run salmon were emigrating and lowest during May, June, July, October, and November. Trap effectiveness, thus catch rates, were likely affected by the large amounts of algae collected on the trap cones during the spring and fall Trapping efficiency, as measured by the recovery of dye-marked fish, was highest during December 1996 and March 1997 (Table 11).

A combined total of 70,717 chinook salmon was caught by all three rotary screw traps. Peak salmon catches occurred during weeks 8-13 when fall run dominated the catch (Table 10; Figure 43). We caught 1,441 spring-run sized salmon; 54,405 fall-run sized salmon; 3,504 late-fall-run sized salmon; and 11,367 winter-run sized salmon. The spring-run catch peaked in December 1996 (Figure 44). Fall run were caught throughout the year with the peak catch occurring from mid-February 1997 to early March 1997. The late-fall-run catch peaked in June 1997. The peak of the winter run was appeared to be occurring in mid-September 1997 when rotary screw trap sampling was terminated.

Spring-run sized salmon ranged from 25 to 137 mm FL (Figure 45). Fall run ranged from 28 to 160 mm FL; late-fall run ranged from 26 to 254 mm FL; and winter run ranged from 22 to 169 mm FL. Smolt-sized spring run were observed from February 1997 to early June 1997. Smolt-sized fall run were observed from late March 1997 until mid-September 1997. Smolt-sized late-fall run were observed from October through December 1996 and from July to mid-September 1997. Smolt-sized winter run were observed from November 1996 until early May 1997.

Rainbow Trout (Steelhead)

Rainbow trout (potentially steelhead) were collected in all but three weeks of the survey (Table 11; Figure 46). Mean weekly size ranged from 32.3 mm FL (week 28) to 134.9 mm FL (week 14). Total catch ranged from 0 (weeks 1, 20, and 38) to 118 (week 31). Catch rate ranged from 0.0 fish/h (weeks 1, 20, and 38) to 0.5 fish/h (week 40) (Figure 47).

Table 10. Summary of chinook salmon catch statistics, upper Sacramento River emigration survey using rotary screw traps, 01 October 1996 - 15 September 1997.

Week	Start Date	Weekly Catch	Catch/h	Size Statistics (FL in mm)			
				Mean	Minimum	Maximum	SD
40	01 Oct	332	5.68	38.3	22	118	15.7
41	06 Oct	113	1.31	44.3	32	140	22.9
42	13 Oct	44	0.80	50.0	30	124	24.4
43	20 Oct	15	0.20	72.9	44	105	20.5
44	27 Oct	41	0.49	82.1	44	135	26.0
45	03 Nov	47	0.26	74.8	25	160	26.2
46	10 Nov	38	0.21	66.3	30	133	29.0
47	17 Nov	41	0.40	69.5	28	115	23.8
48	24 Nov	321	1.60	59.6	29	140	23.7
49	01 Dec	761	2.92	40.4	29	146	17.5
50	08 Dec	234	3.08	36.3	29	123	9.2
51	15 Dec	2,344	7.74	36.0	28	137	8.4
52	22 Dec	2,052	16.82	36.4	30	131	5.9
1	29 Dec	82	10.25	35.9	29	42	2.2
			No sampling Weeks 2-5				
6	02 Feb	1,049	10.68	37.6	30	124	8.2
7	09 Feb	2,589	19.95	38.1	29	134	10.9
8	16 Feb	8,699	33.98	37.4	30	130	6.7
9	23 Feb	12,098	36.04	38.9	29	134	12.8
10	02 Mar	6,080	18.10	39.0	30	147	11.8
11	09 Mar	4,826	14.46	38.6	30	160	10.5
12	16 Mar	2,589	8.59	37.8	30	159	7.9
13	23 Mar	4,641	12.06	39.2	29	169	13.3
14	30 Mar	3,594	11.49	40.8	30	203	16.8
15	06 Apr	2,020	5.82	44.3	32	254	21.9

Table 10. (cont.)

Week	Start Date	Weekly Catch	Catch/h	Size Statistics (FL in mm)			
				Mean	Minimum	Maximum	SD
16	13 Apr	543	1.73	60.4	28	150	27.6
17	20 Apr	243	1.19	65.5	31	145	23.1
18	27 Apr	418	1.49	63.3	30	110	16.0
19	04 May	334	1.22	68.7	33	139	13.3
20	11 May	26	0.15	65.8	26	88	6.3
21	18 May	270	2.10	70.5	32	115	20.9
22	25 May	170	0.33	69.0	33	113	22.2
23	01 Jun	508	2.59	50.9	26	137	22.3
24	08 Jun	319	2.11	54.0	32	104	22.6
25	15 Jun	460	2.53	51.1	31	106	22.7
26	22 Jun	436	2.54	46.5	33	103	18.1
27	29 Jun	102	0.94	54.2	26	100	21.6
28	06 Jul	440	1.15	42.3	29	105	13.6
29	13 Jul	742	2.33	41.6	29	122	13.6
30	20 Jul	923	2.88	43.8	31	113	15.0
31	27 Jul	966	2.93	45.0	22	113	17.0
32	03 Aug	1,020	3.05	42.8	30	108	15.6
33	10 Aug	863	3.60	42.6	30	119	16.1
34	17 Aug	1,050	6.27	41.6	30	99	14.1
35	24 Aug	967	5.82	37.0	31	89	7.2
36	31 Aug	1,767	14.14	37.3	30	110	8.1
37	07 Sep	3,498	20.82	36.9	31	107	7.6
38	14 Sep	2	0.36	36.5	36	37	0.5
Total		70,717	7.50	41.7	22	254	15.8

Table 11. Results of rotary screw trap efficiency evaluations conducted with marked chinook salmon during the upper Sacramento River emigration survey, 01 October, 1996 - 15 September, 1997.

Week	Number marked	Number recaptured	Efficiency (%)
40	289	3	1.03
41	99	0	-
42	51	0	-
43	0	0	-
44	0	0	-
45	8	0	-
46	20	0	-
47	8	0	-
48	201	1	0.50
49	326	7	2.15
50	74	1	4.25
51	1,551	40	2.58
52	430	18	4.19
1	0	0	-
No sampling Weeks 2-5			
6	938	0	-
7	1,166	3	0.26
8	6,145	20	0.33
9	10,426	217	2.08
10	4,961	129	2.60
11	2,524	130	5.15
12	2,097	23	1.10
13	2,235	56	2.51
14	2,915	51	1.75
15	1,237	37	2.99
16	383	6	1.57

Table 11. (cont.)

Week	Number marked	Number recaptured	Efficiency (%)
17	139	1	0.72
18	273	3	1.10
19	117	1	0.85
20	2	0	-
21	0	0	-
22	0	0	-
23	235	6	2.55
24	235	6	2.55
25	376	7	1.86
26	367	2	0.54
27	34	1	2.94
28	320	5	1.56
29	398	5	1.26
30	300	1	0.33
31	238	4	1.68
32	142	2	1.41
33	142	3	2.11
34	113	3	2.65
35	10	0	-
36	10	0	-
37	24	0	-
38	0	0	-
Total	41,559	46	1.91

Table 12. Summary of rainbow trout catch statistics, upper Sacramento River emigration survey using rotary screw traps, 01 October, 1996 - 15 September, 1997.

Week	Start Date	Weekly Catch	Catch/h	Size Statistics (FL in mm)			
				Mean	Minimum	Maximum	SD
40	01 Oct	37	0.53	71.1	48	110	13.5
41	06 Oct	6	0.07	74.0	58	89	11.7
42	13 Oct	9	0.16	82.1	55	150	25.4
43	20 Oct	3	0.04	96.7	70	115	19.3
44	27 Oct	10	0.12	89.5	74	150	21.5
45	03 Nov	4	0.02	80.3	75	86	5.3
46	10 Nov	4	0.02	71.5	58	85	9.9
47	17 Nov	16	0.06	93.8	57	120	23.8
48	24 Nov	25	0.12	98.2	79	170	17.9
49	01 Dec	9	0.03	82.1	69	103	9.7
50	08 Dec	1	0.01	95.0	95	95	0
51	15 Dec	6	0.02	103.5	76	178	35.4
52	22 Dec	1	0.01	95.0	95	95	0
1	29 Dec	0	0	-	-	-	-
No sampling Weeks 2-5							
6	02 Feb	6	0.06	58.3	19	160	53.4
7	09 Feb	9	0.07	77.9	24	150	41.2
8	16 Feb	28	0.11	89.2	46	140	20.4
9	23 Feb	39	0.12	100.1	25	200	33.8
10	02 mar	16	0.05	73.5	25	115	35.7
11	09 Mar	13	0.04	77.5	23	200	59.9
12	16 Mar	9	0.03	91.8	27	140	30.1
13	23 Mar	8	0.02	130.7	72	197	41.5
14	30 Mar	17	0.06	134.9	26	290	76.0
15	06 Apr	12	0.03	112.8	45	200	44.6

Table 12. (cont.)

Week	Start Date	Weekly Catch	Catch/h	Size Statistics (FL in mm)			
				Mean	Minimum	Maximum	SD
16	13 Apr	10	0.03	61.8	21	190	50.0
17	20 Apr	15	0.07	40.5	24	84	20.4
18	27 Apr	35	0.12	47.4	24	160	25.4
19	04 May	26	0.09	46.8	25	76	14.4
20	11 May	0	0	-	-	-	-
21	18 May	1	0.01	75.0	75	75	0
22	25 May	4	0.07	60.8	48	77	10.4
23	01 Jun	9	0.05	59.6	35	84	16.8
24	08 Jun	8	0.05	66.0	27	206	55.3
25	15 Jun	19	0.10	44.2	23	74	14.4
26	22 Jun	12	0.07	48.7	25	170	38.4
27	29 Jun	7	0.06	57.7	27	89	19.1
28	06 Jul	98	0.26	32.3	23	90	11.8
29	13 Jul	82	0.26	32.4	22	75	11.5
30	20 Jul	81	0.25	31.2	22	66	9.3
31	27 Jul	118	0.36	43.2	20	236	27.6
32	03 Aug	89	0.27	38.7	21	92	16.1
33	10 Aug	63	0.26	47.2	20	97	16.0
34	17 Aug	41	0.24	56.4	24	96	14.6
35	24 Aug	13	0.08	53.2	40	95	13.8
36	31 Aug	16	0.13	56.6	42	78	9.6
37	07 Sep	37	0.22	55.4	32	95	13.6
38	14 Sep	0	0	-	-	-	-
Total		1,072	0.11	54.7	19	290	34.0

FIGURES

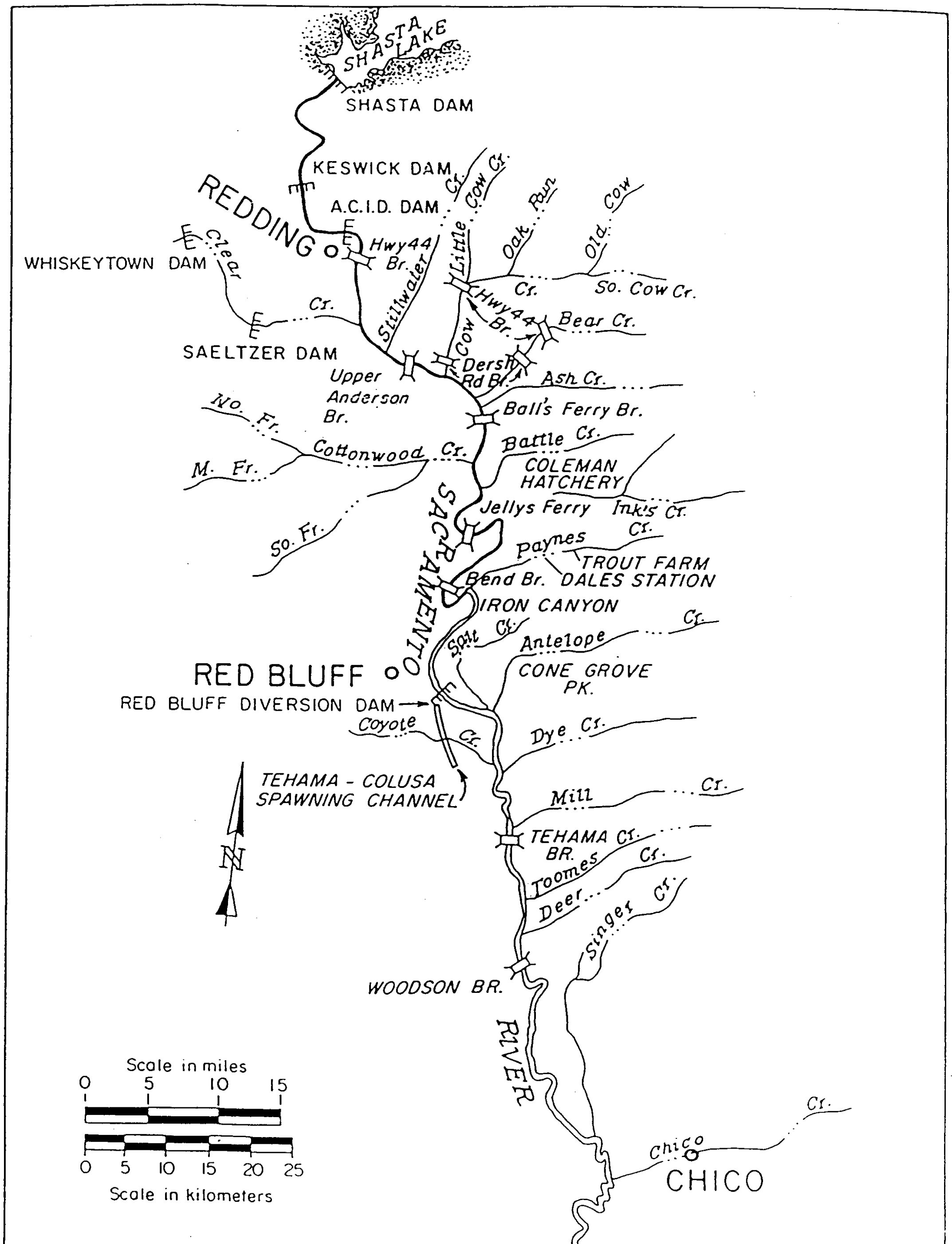


Figure 1. Upper Sacramento River.

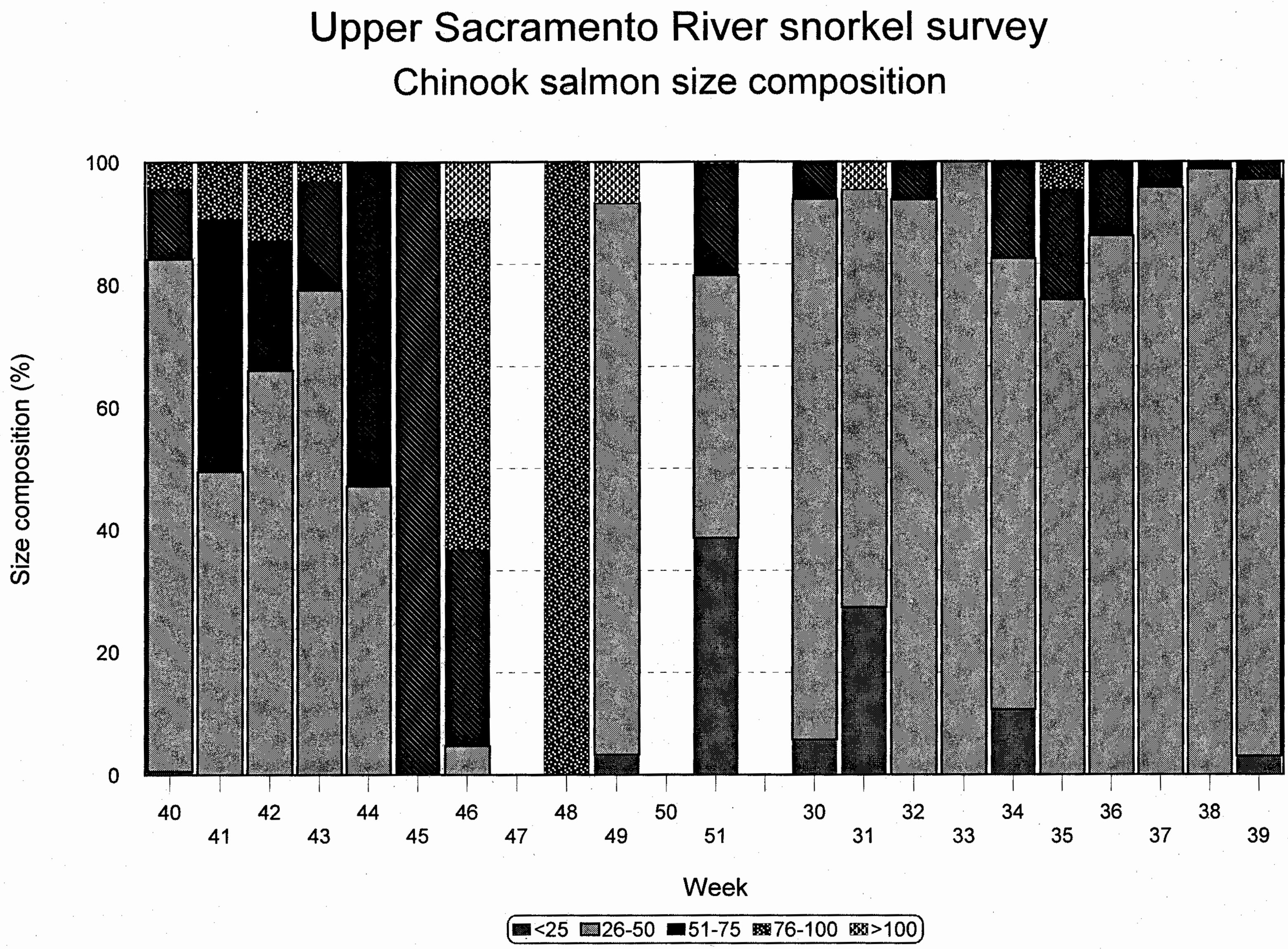


Figure 2. Weekly size composition of chinook salmon observed during the upper Sacarmento River snorkel survey, October 1996 - September 1997. No sites were sampled Weeks 1 through 29.

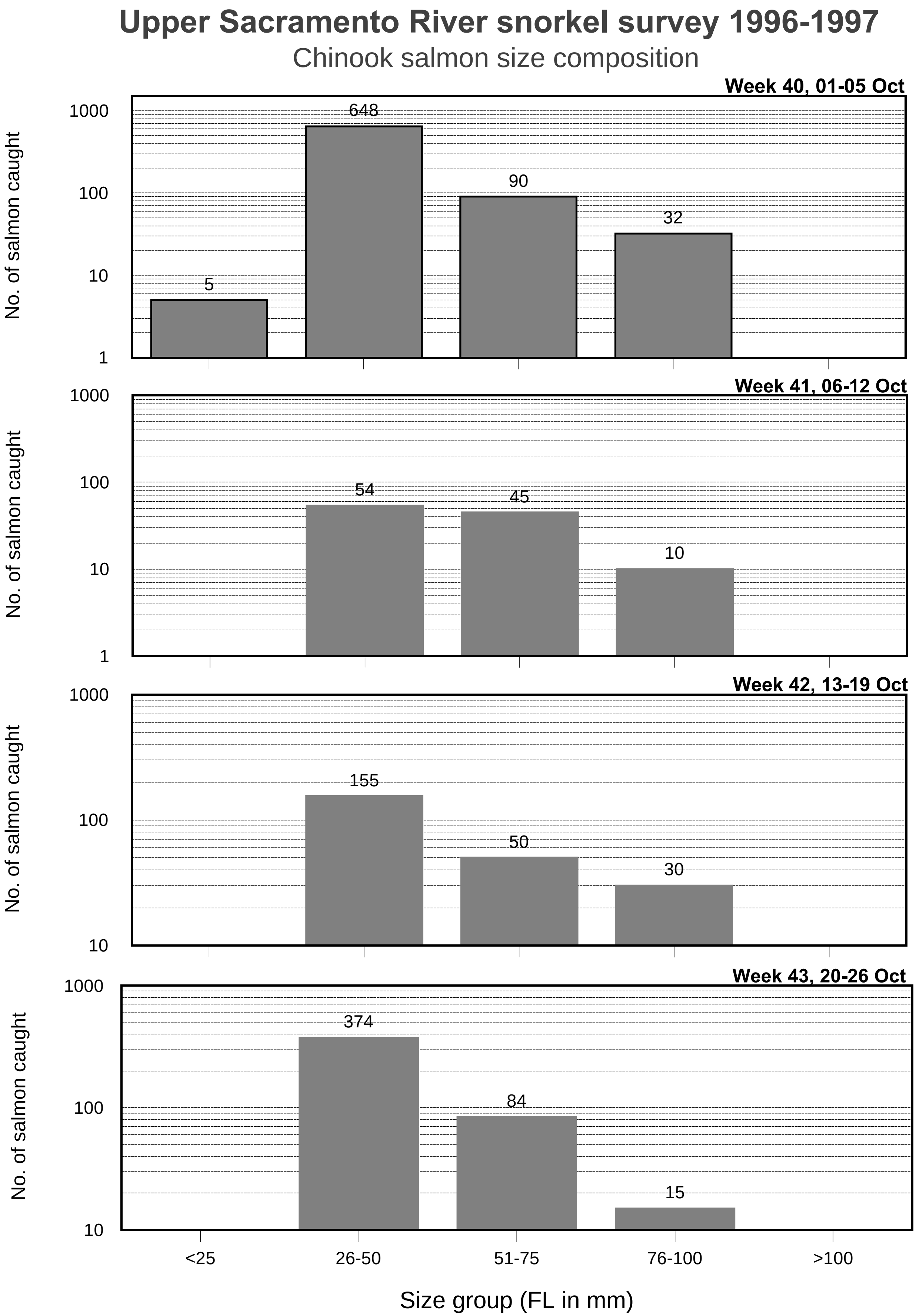


Figure 3. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 01-26 October, 1996.

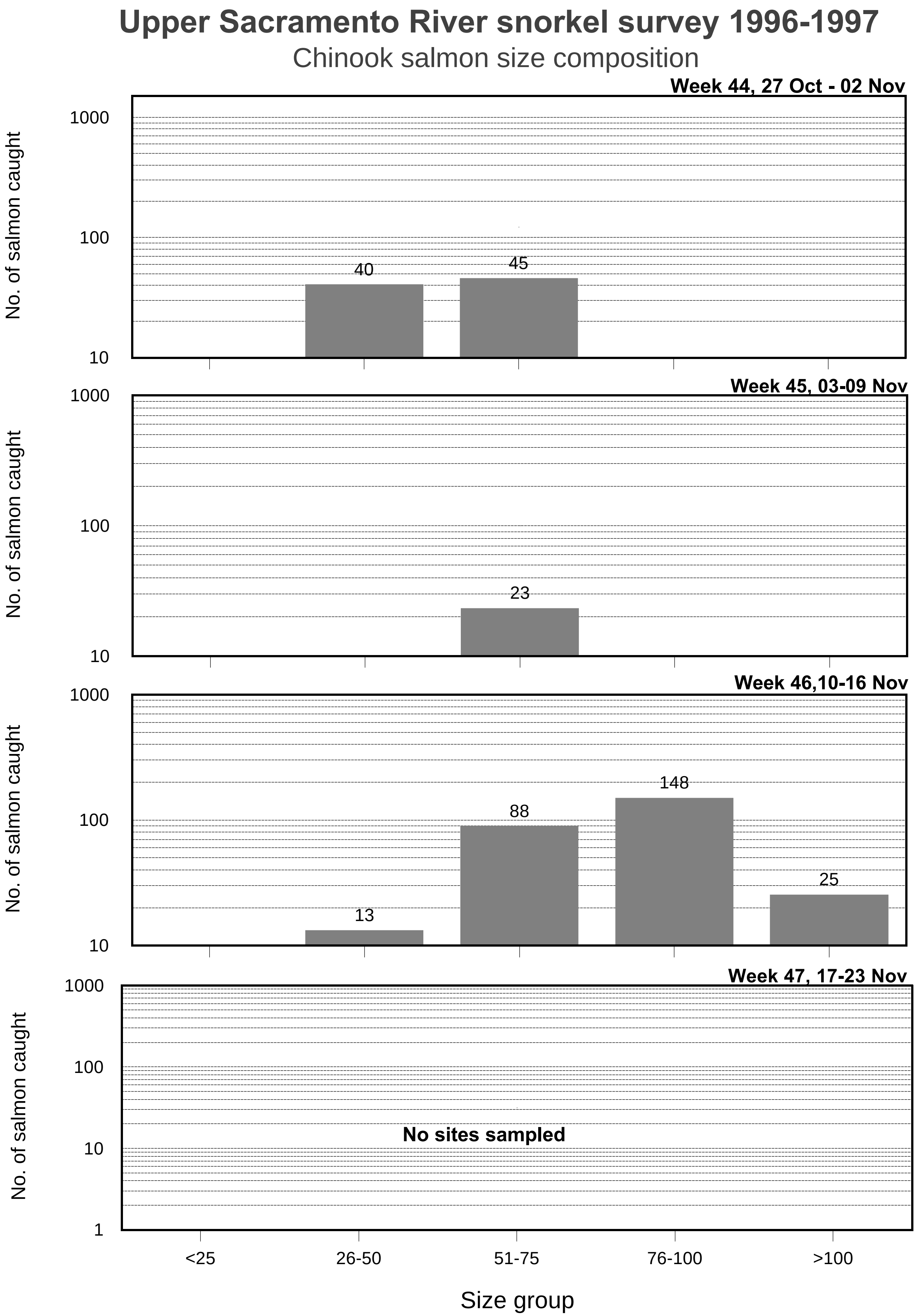


Figure 4. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 27 October - 23 November, 1996.

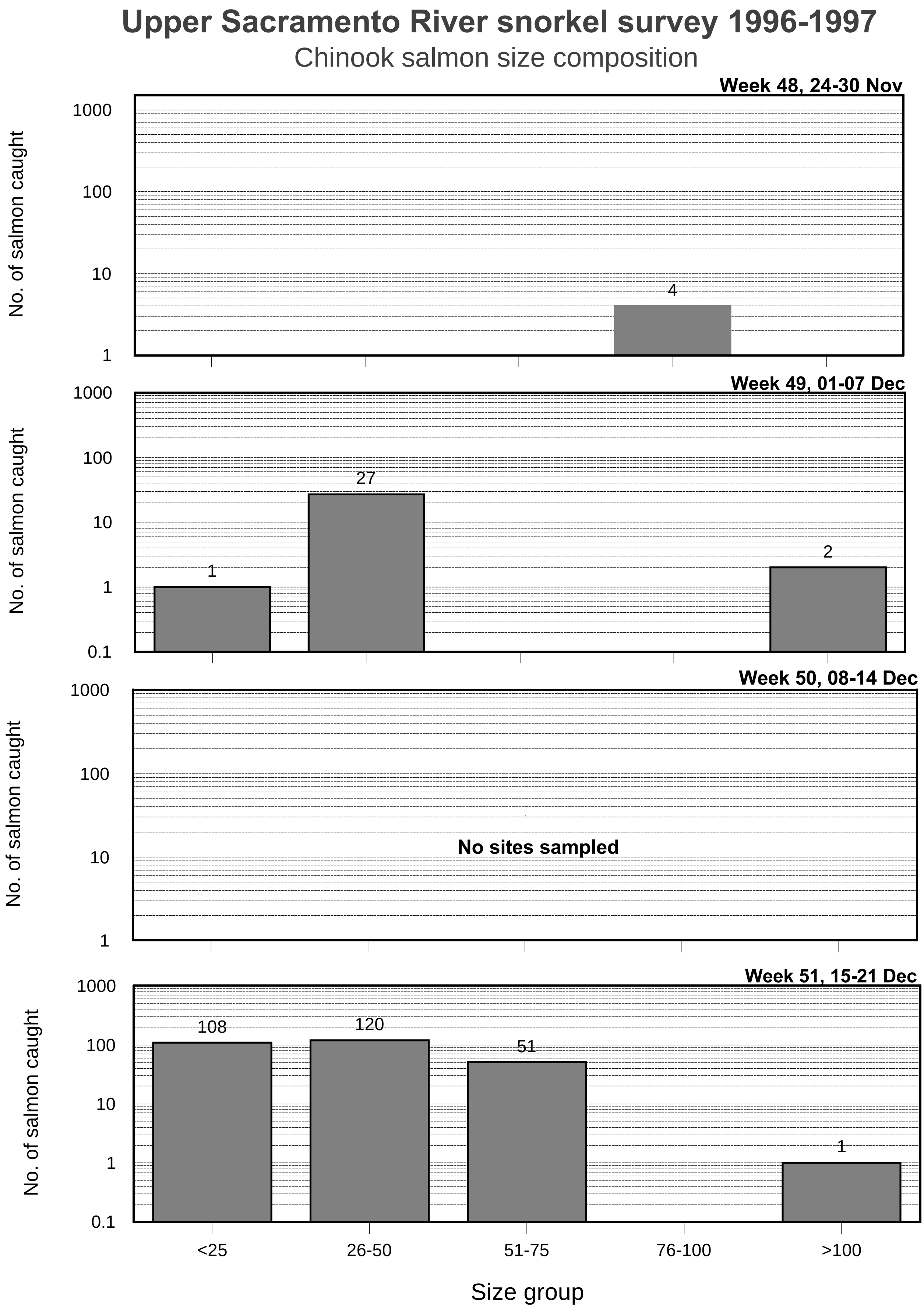


Figure 5. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 24 November - 21 December, 1996.

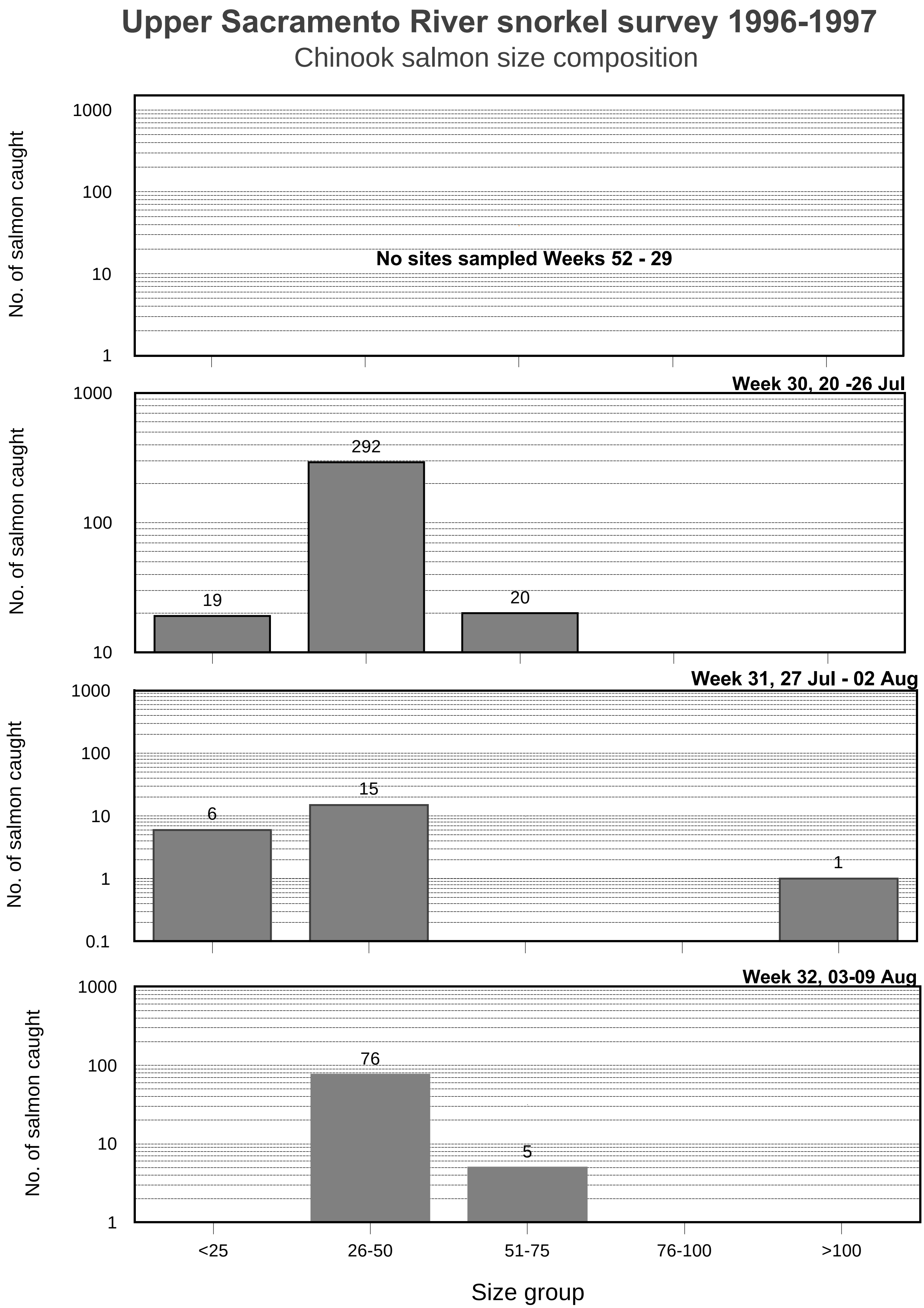


Figure 6. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 20 July - 09 August, 1997.

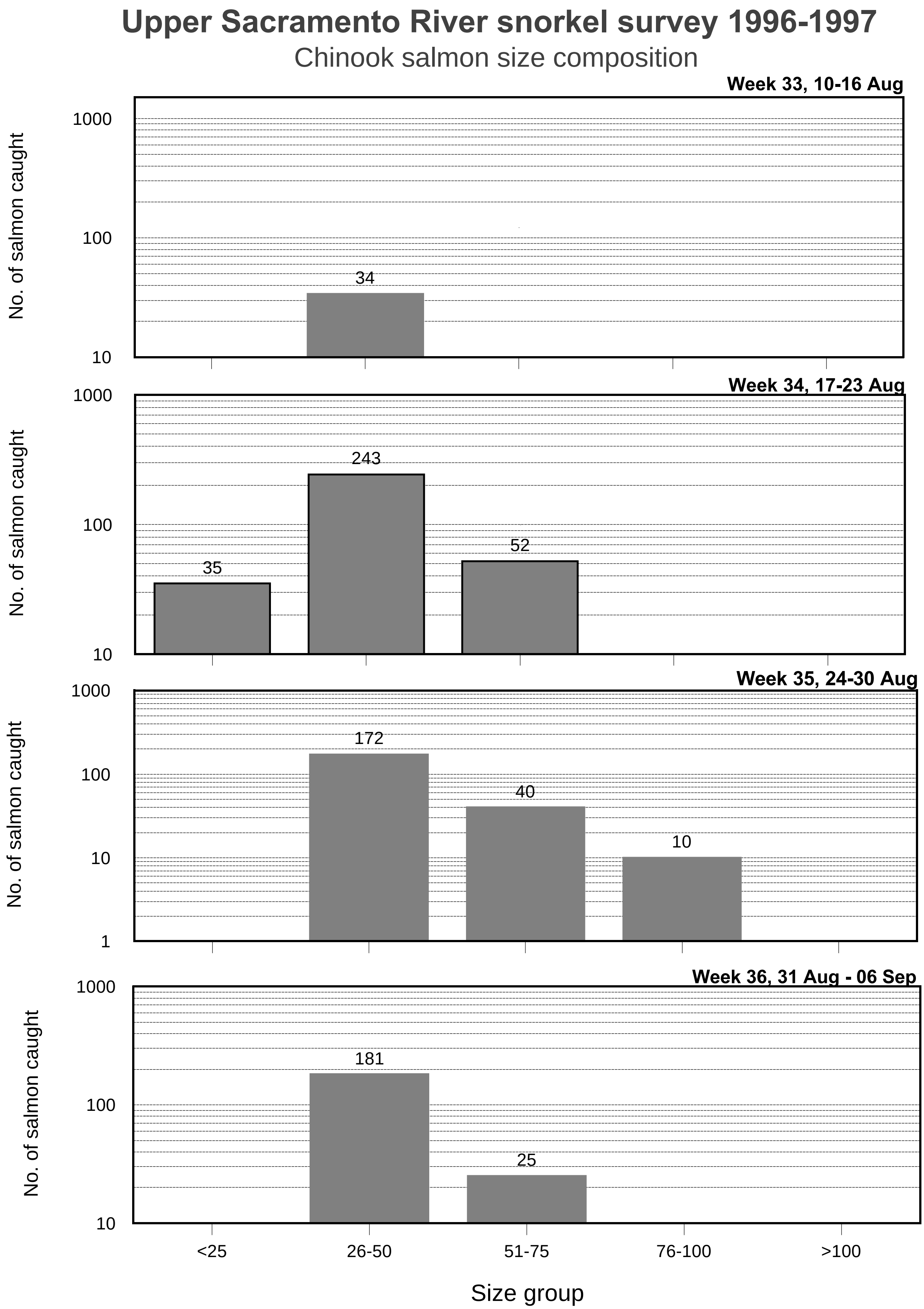


Figure 7. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 10 August - 06 September, 1997.

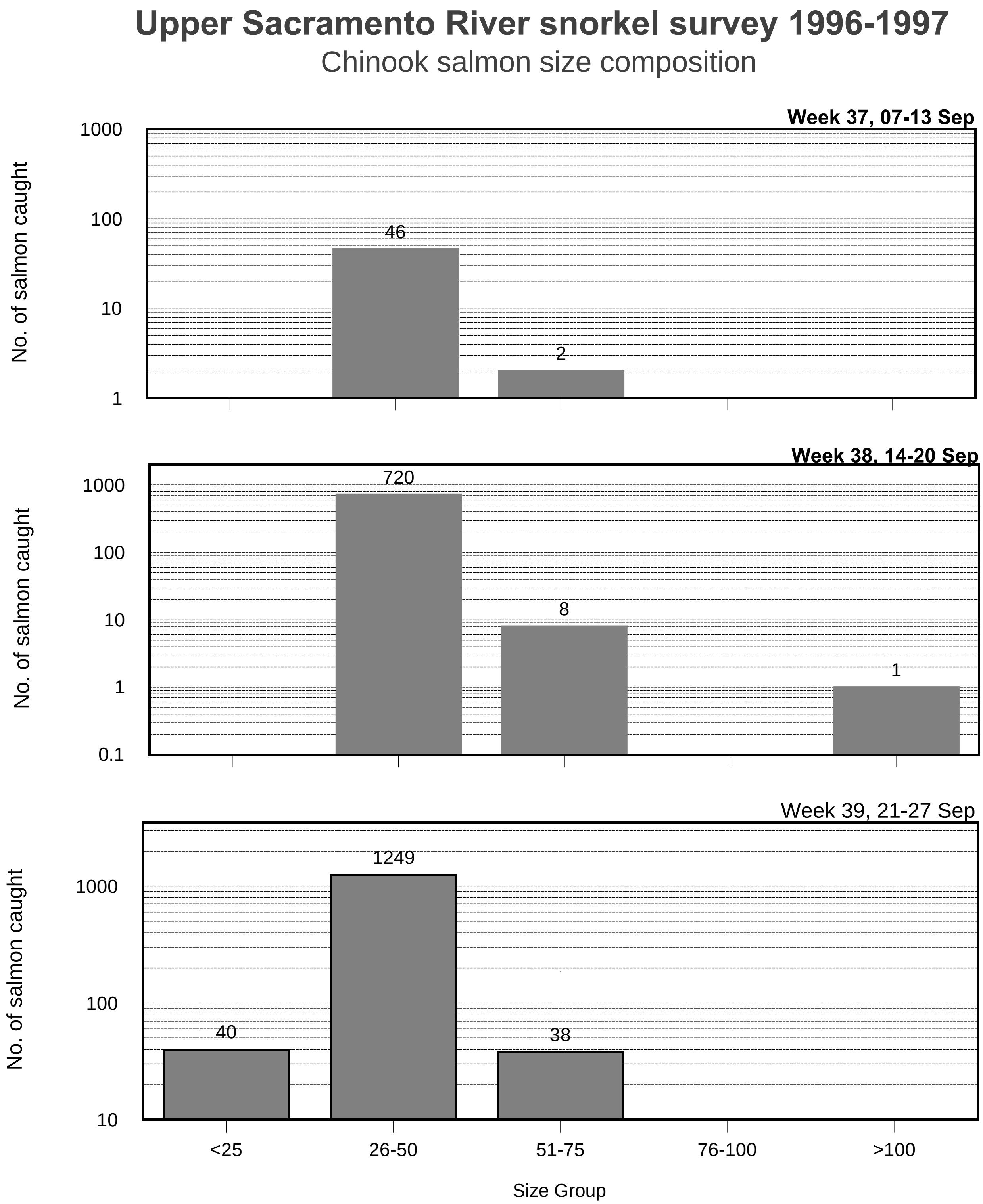


Figure 8. Weekly size composition of chinook salmon observed during the upper Sacramento River snorkel survey, 07-27 September, 1997.

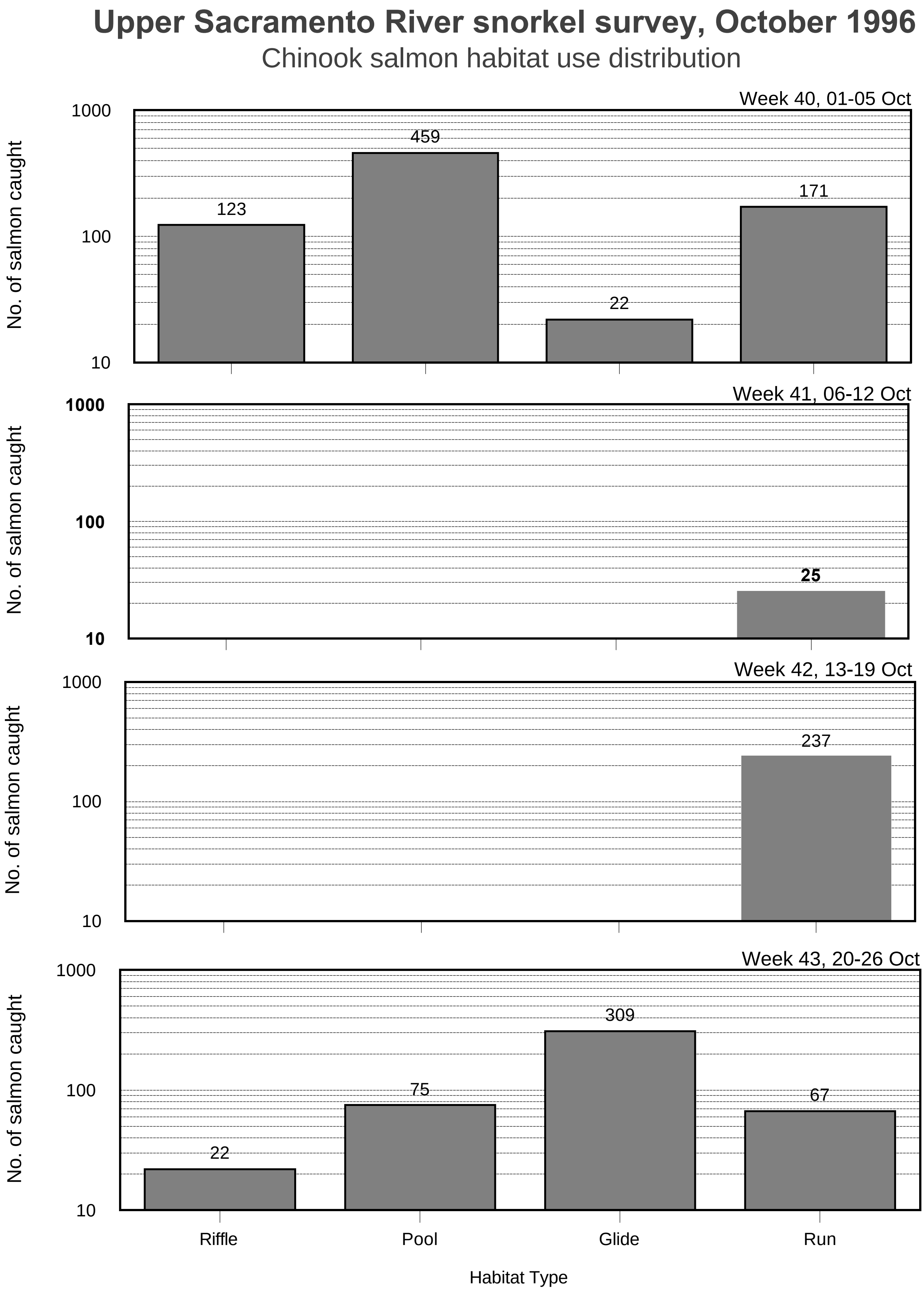


Figure 9. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 01-26 October, 1996.

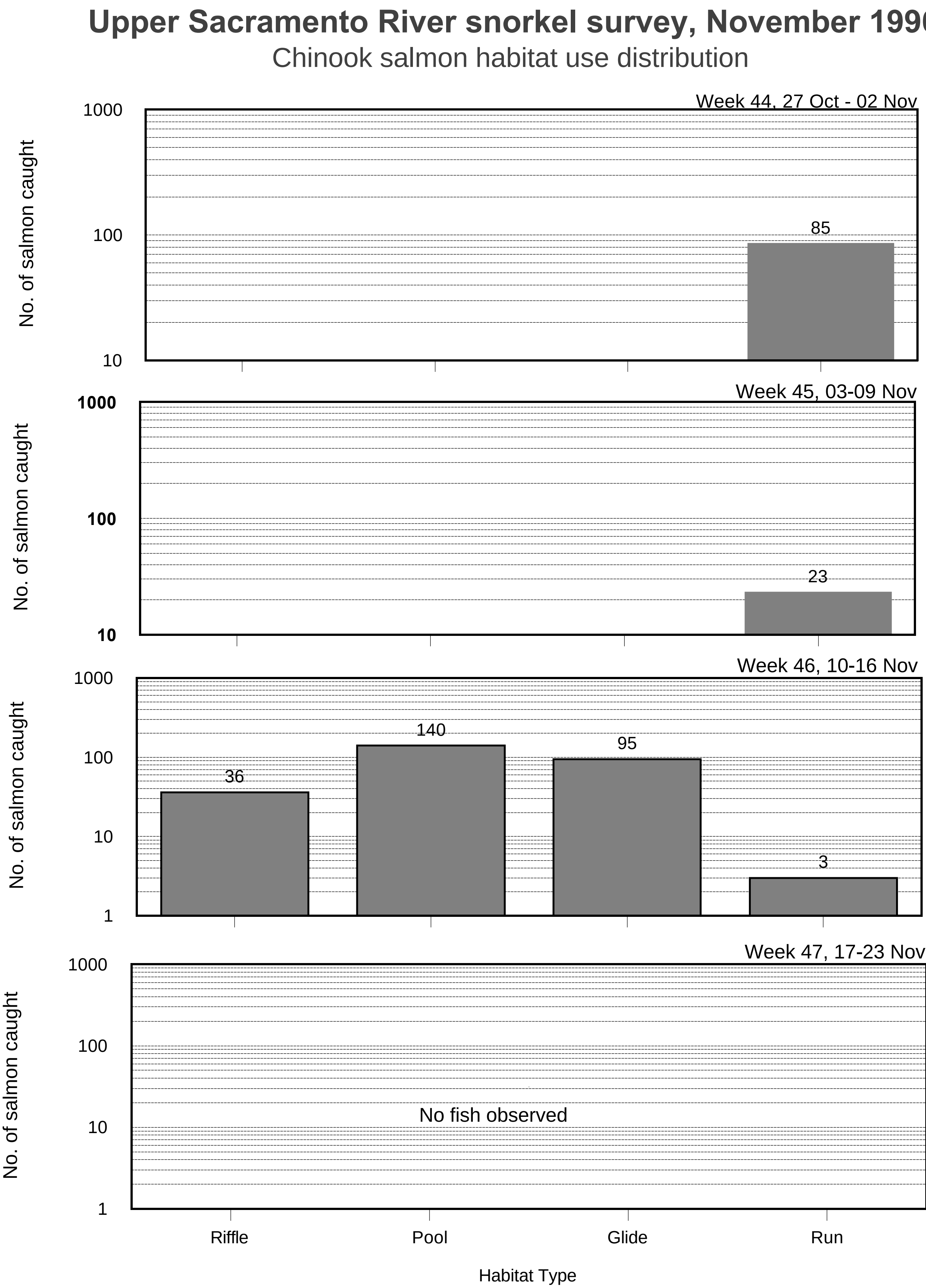


Figure 10. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 27 October - 23 November, 1996.

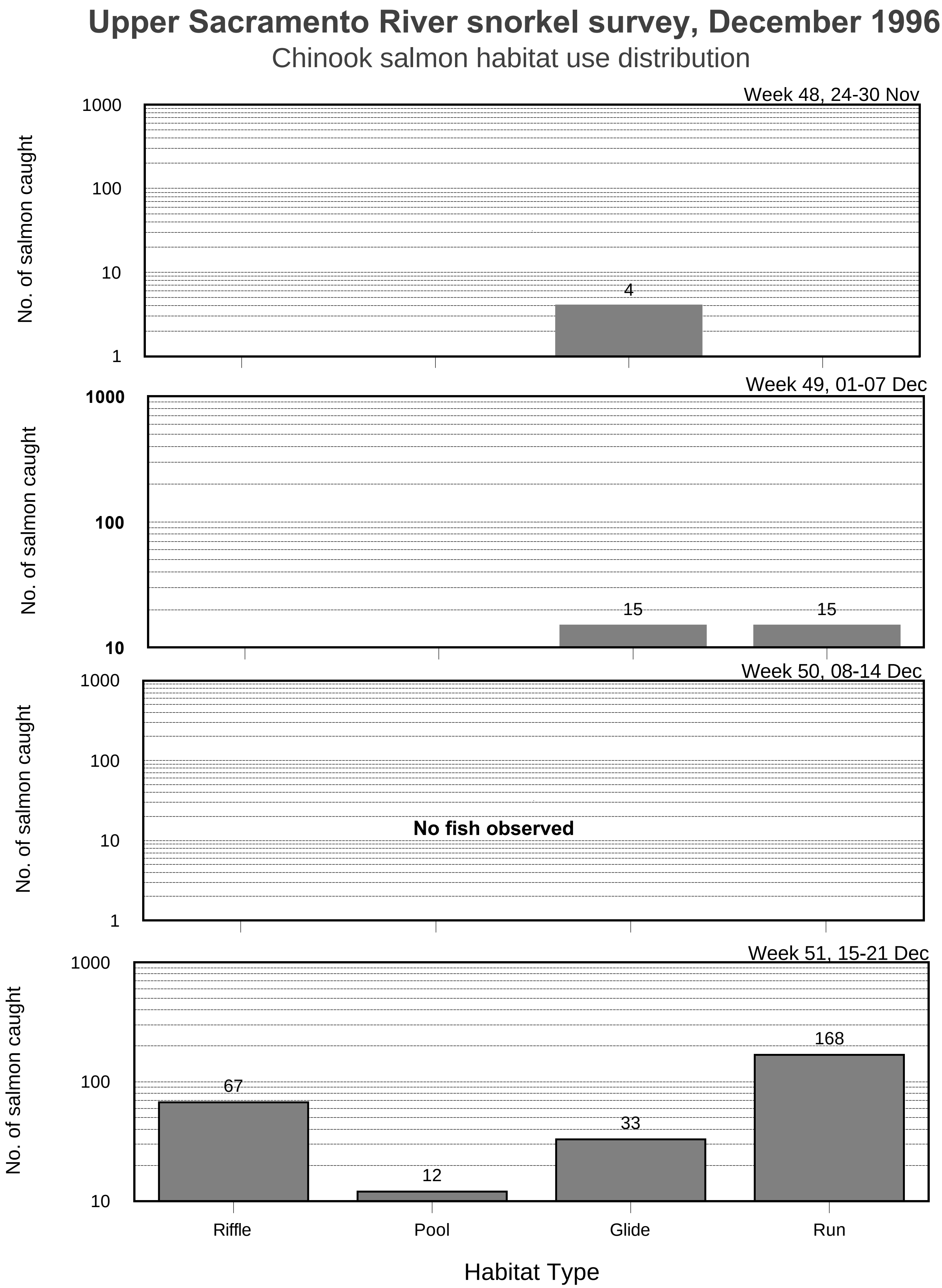


Figure 11. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 24 November - 21 December, 1996.

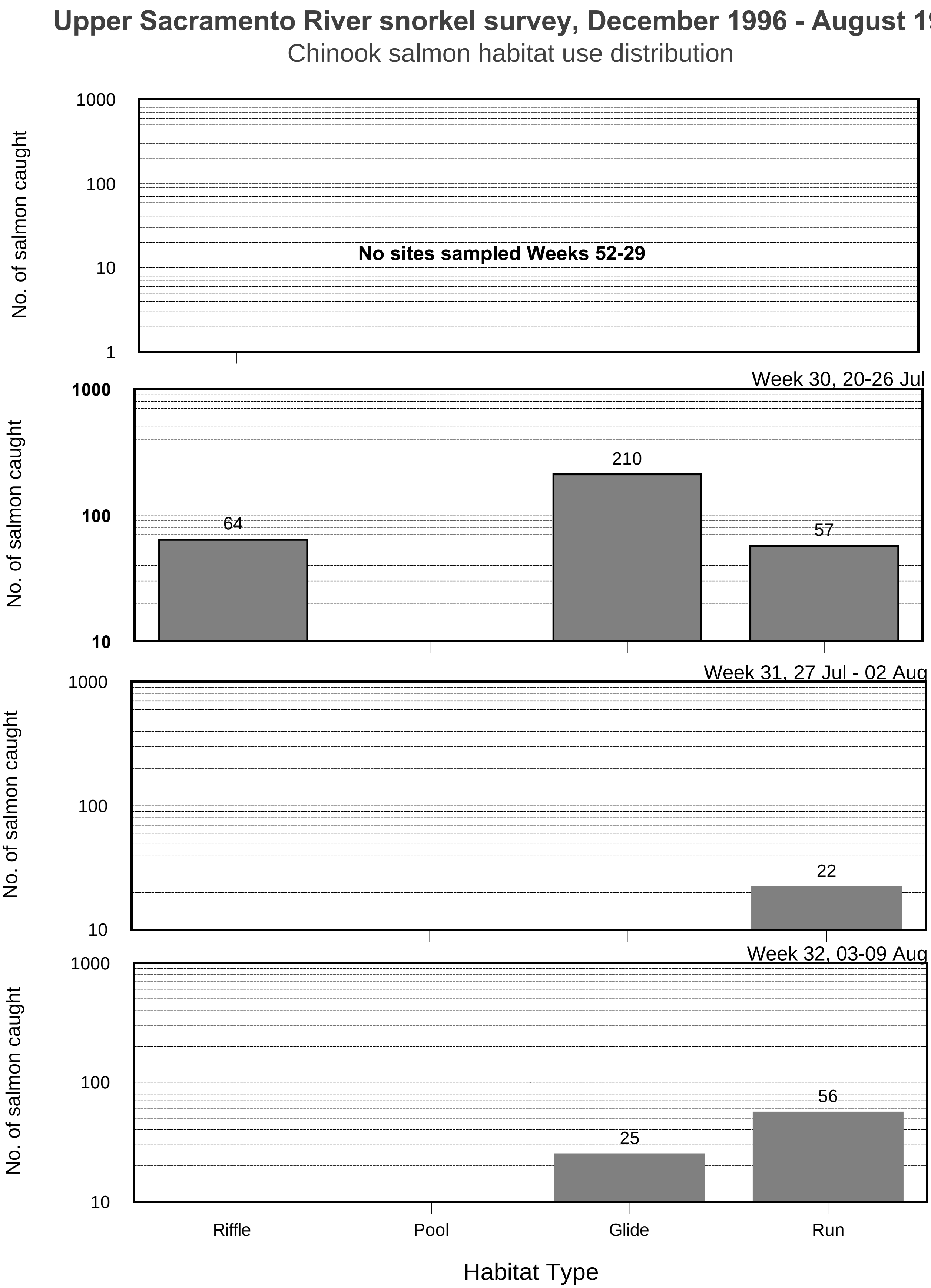


Figure 12. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 22 December 1996 - 09 August 1997.

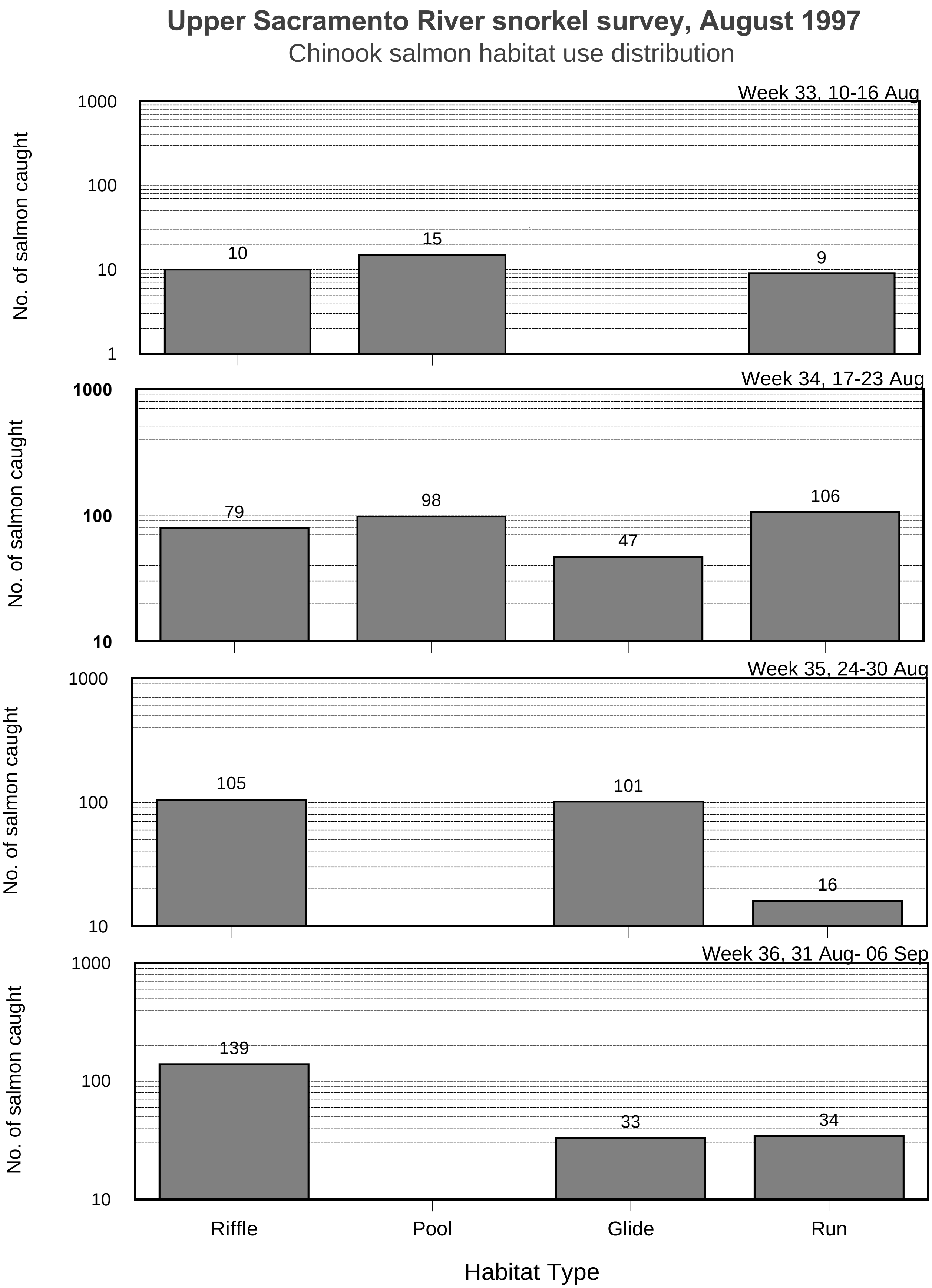


Figure 13. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 10 August - 06 September 1997.

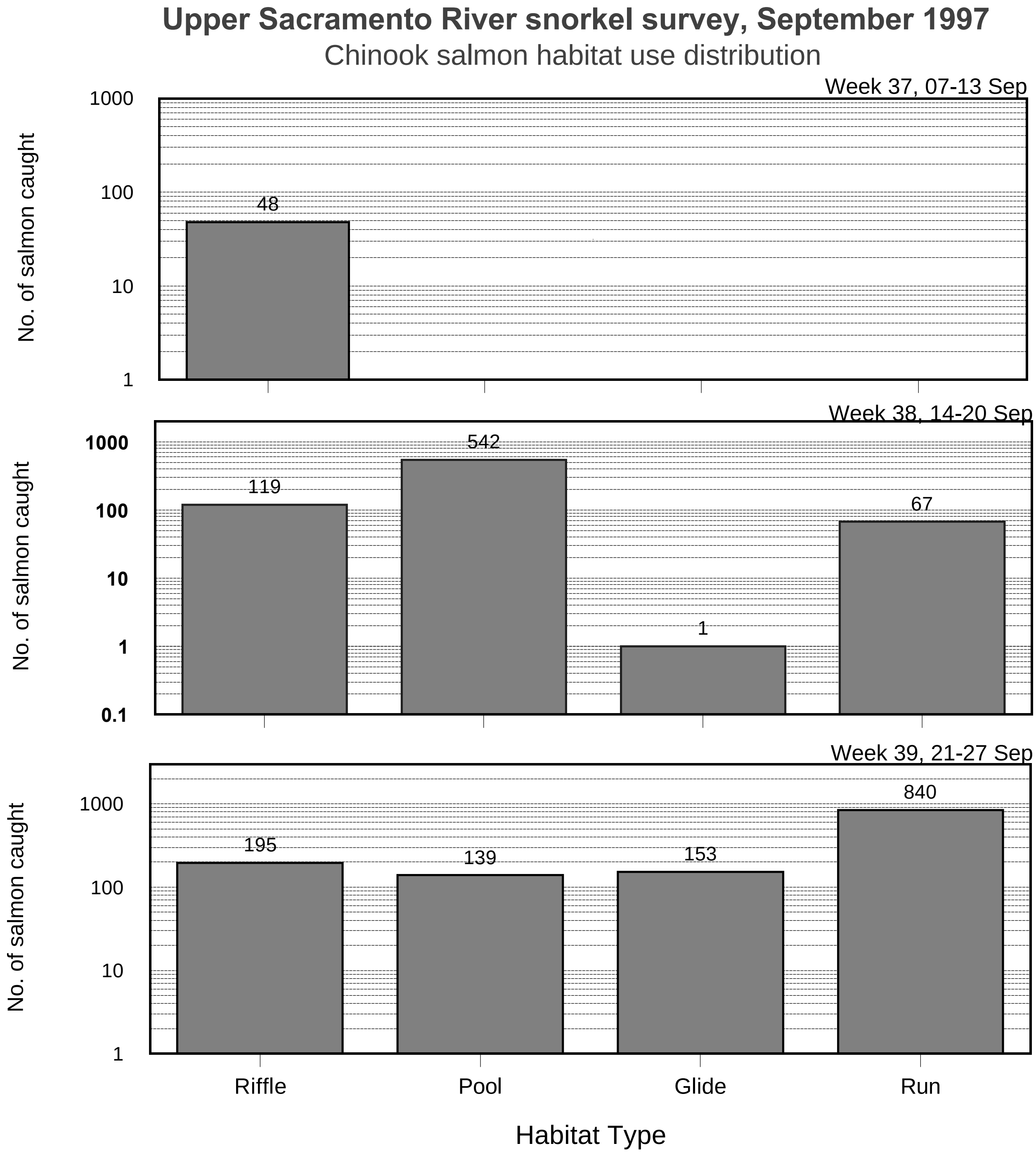


Figure 14. Weekly habitat use distribution of chinook salmon observed during the upper Sacramento River snorkel survey, 07-27 September 1997.

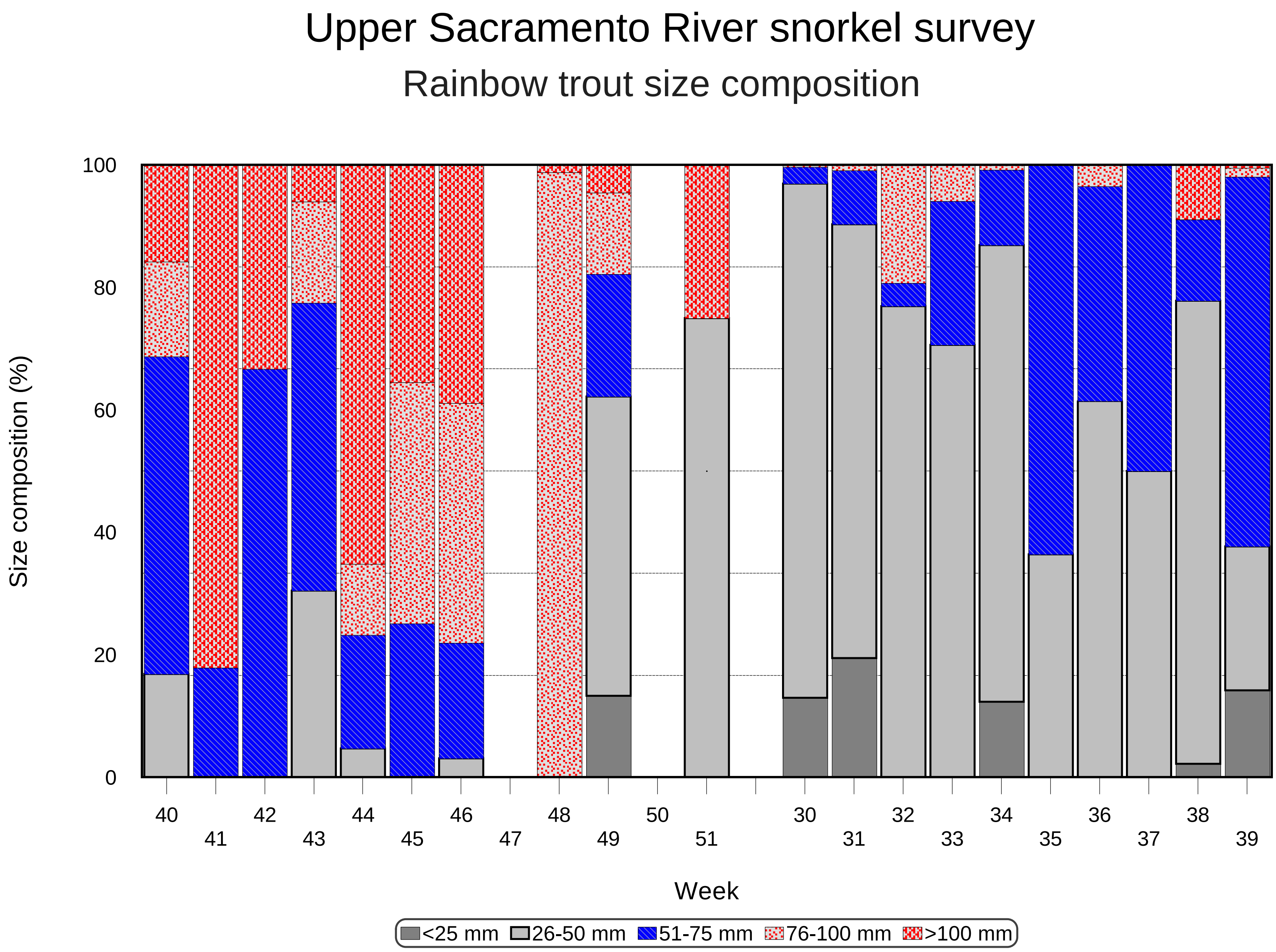


Figure 15. Weekly size composition of steelhead observed during the upper Sacramento River snorkel survey, October 1996 - September 1997. No sites were sampled Week 52 through Week 29.

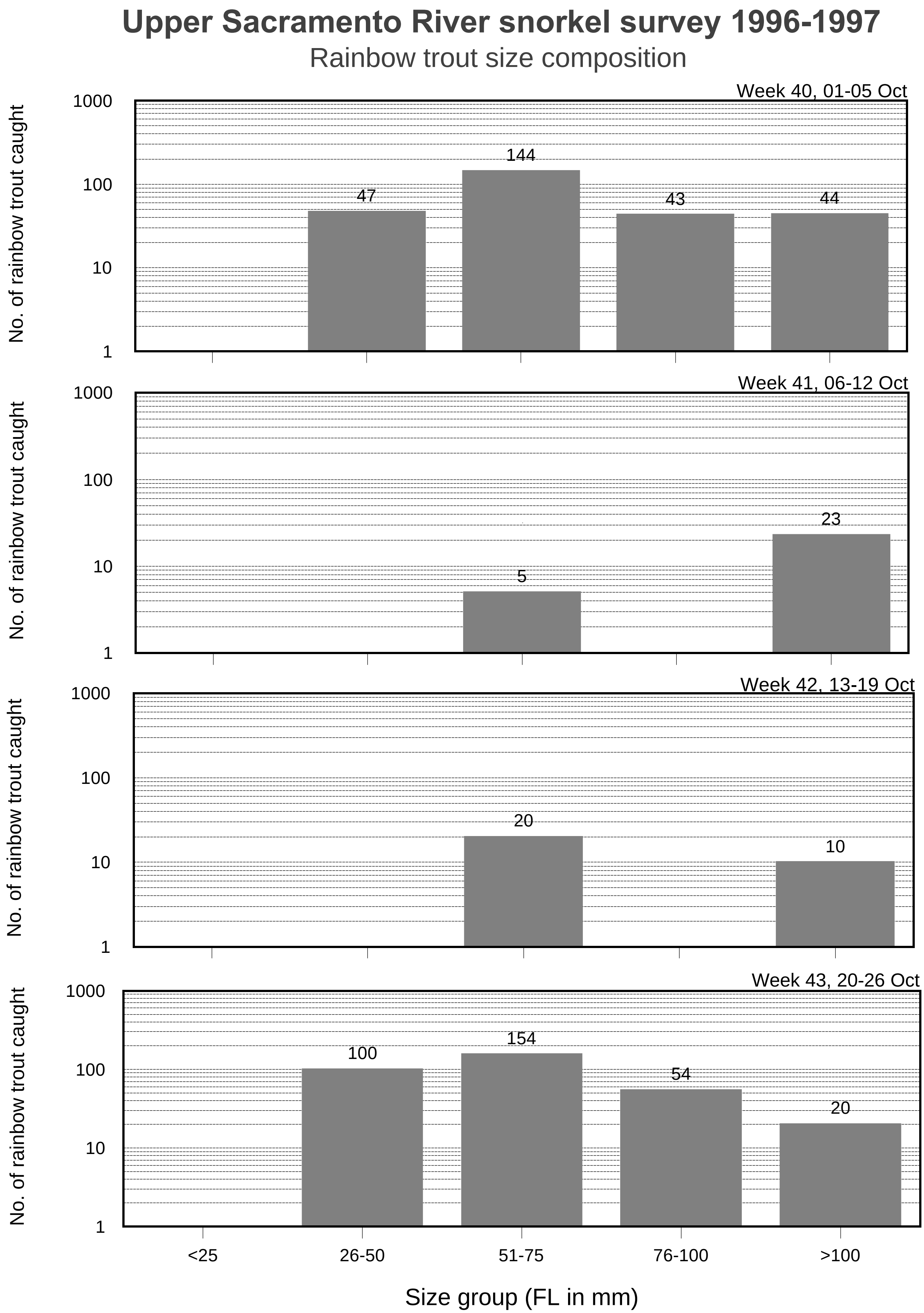


Figure 16. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 01-26 October 1996.

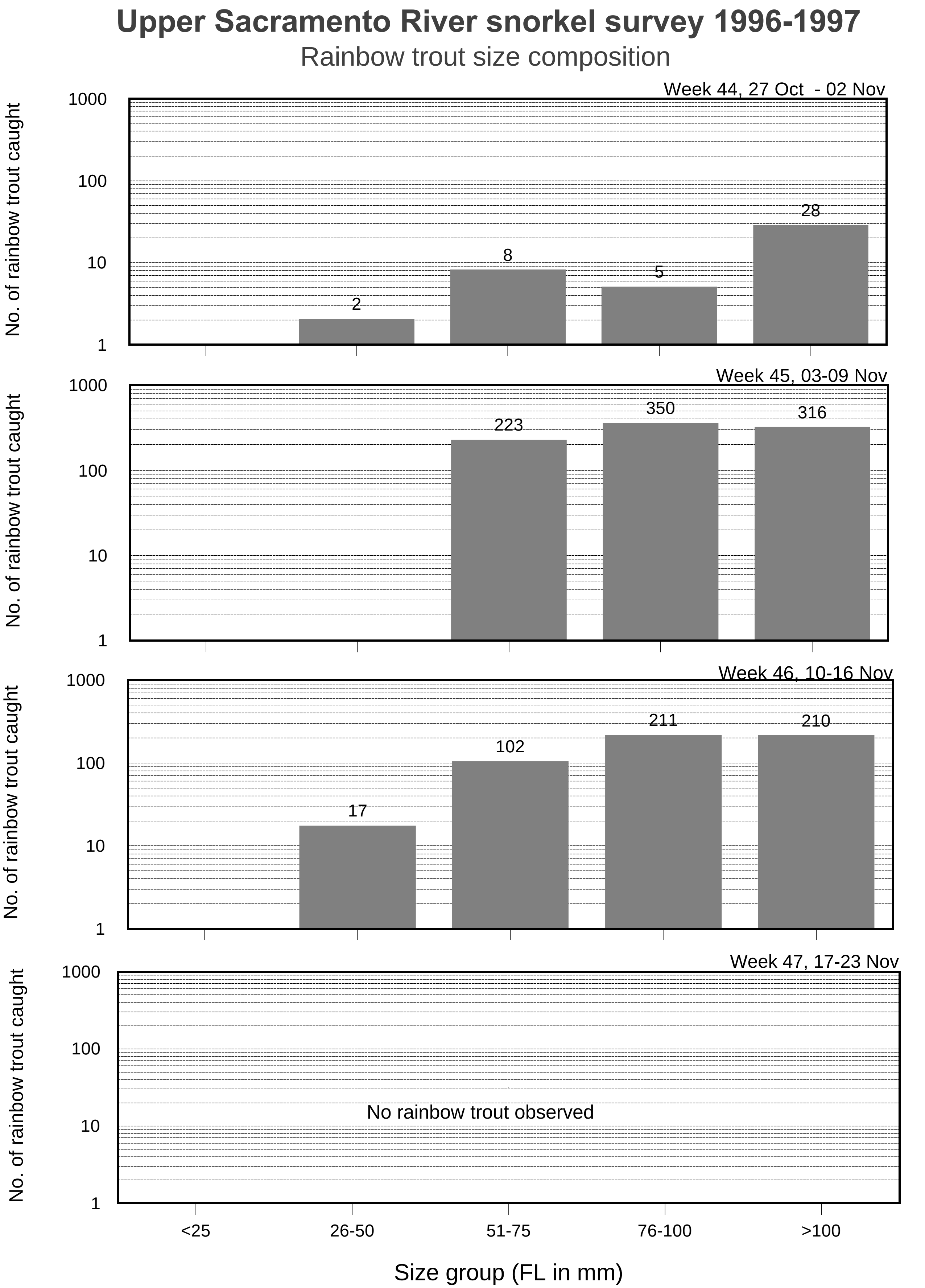


Figure 17. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 27 October - 23 November 1996.

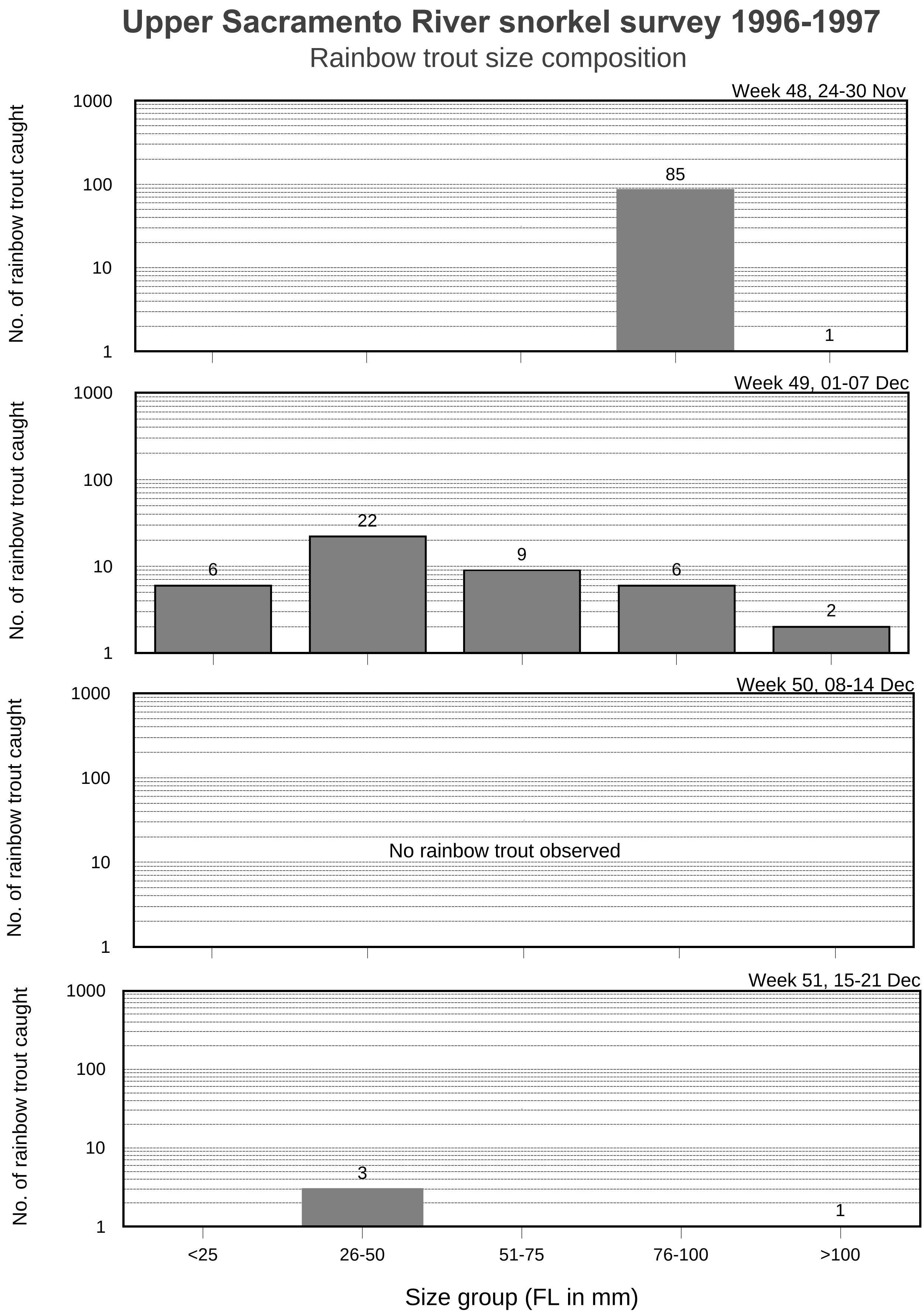


Figure 18. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 24 November - 21 December 1996.

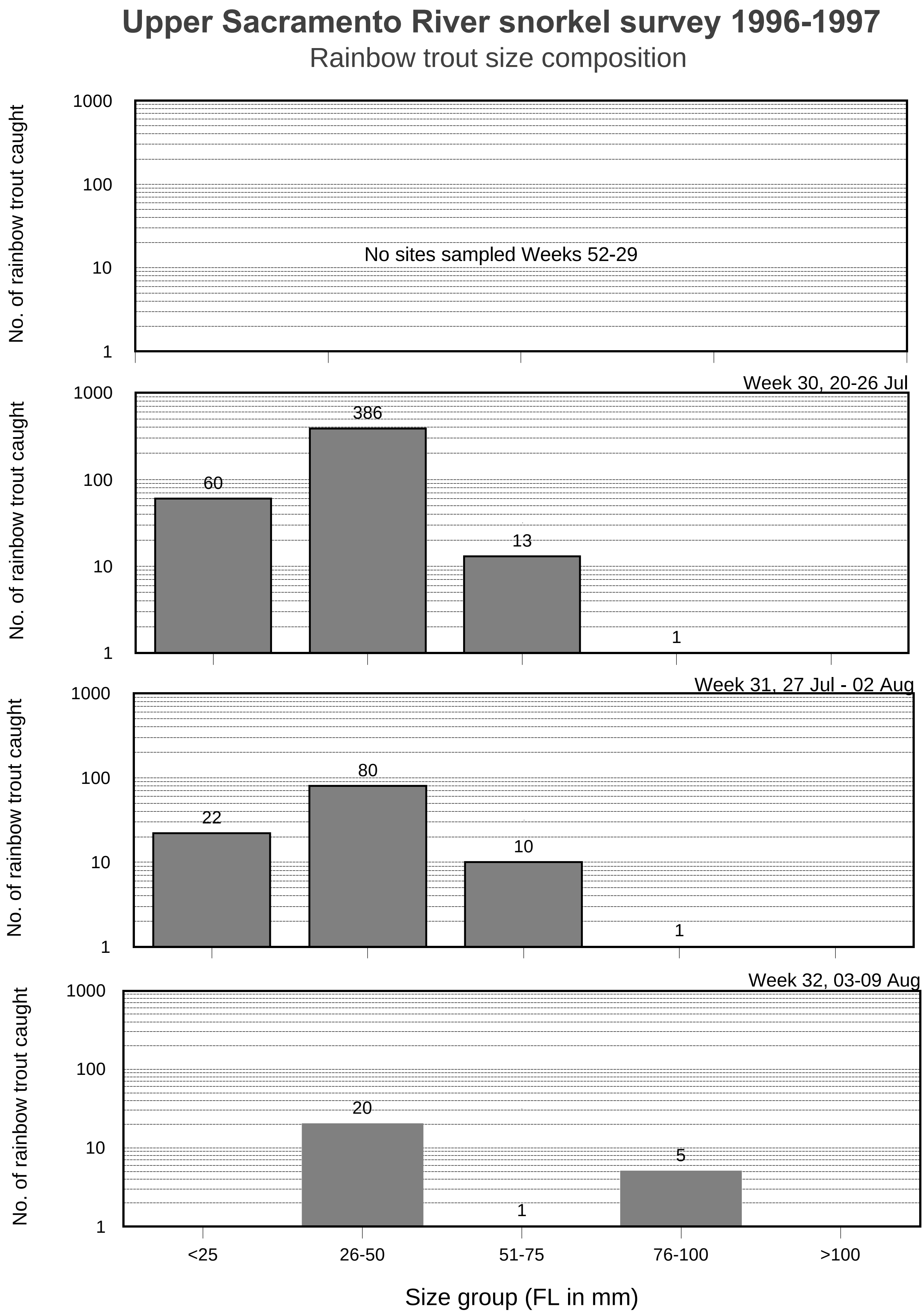


Figure 19. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 20 July - 09 August 1997.

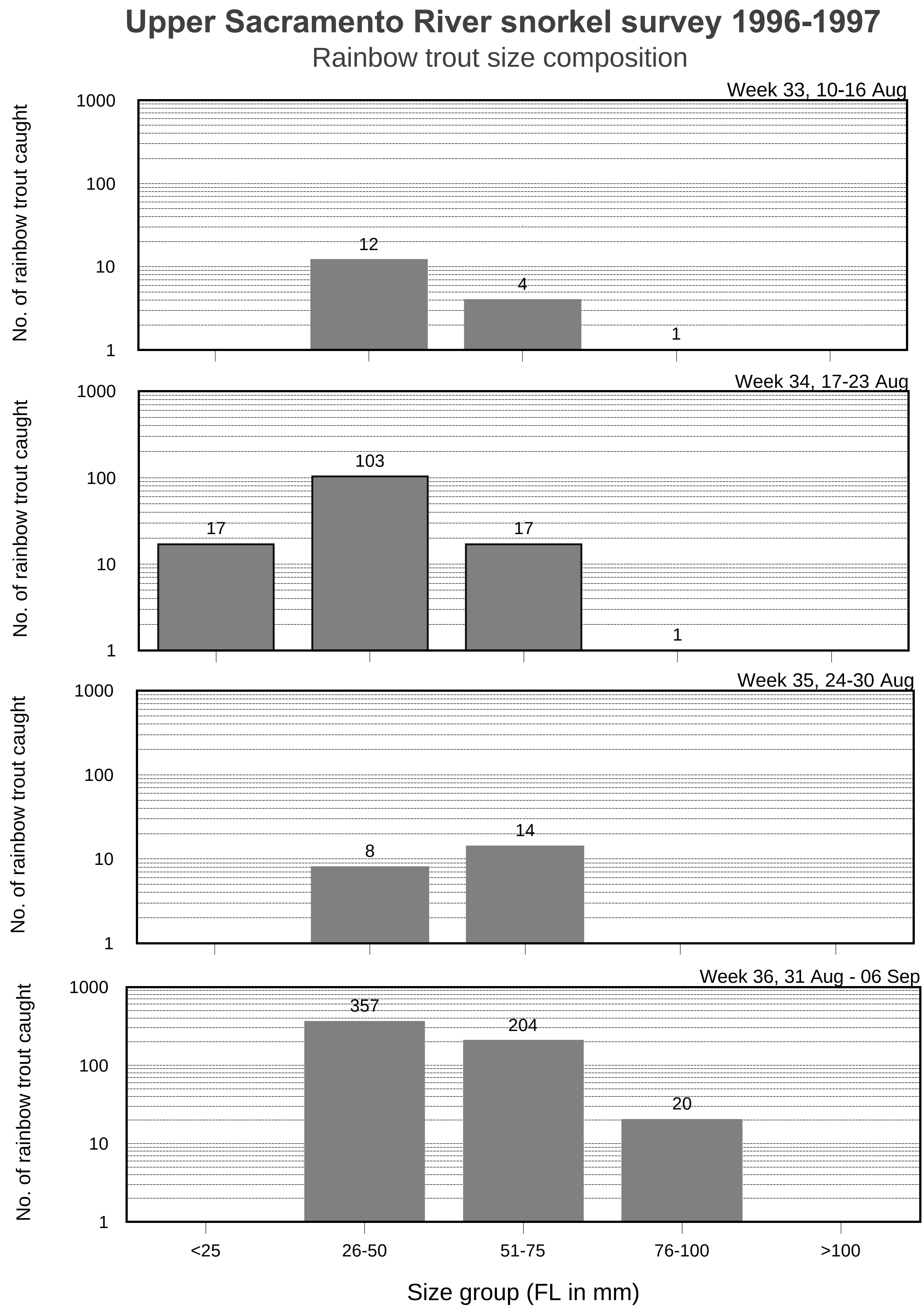


Figure 20. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 10 August - 06 September 1997.

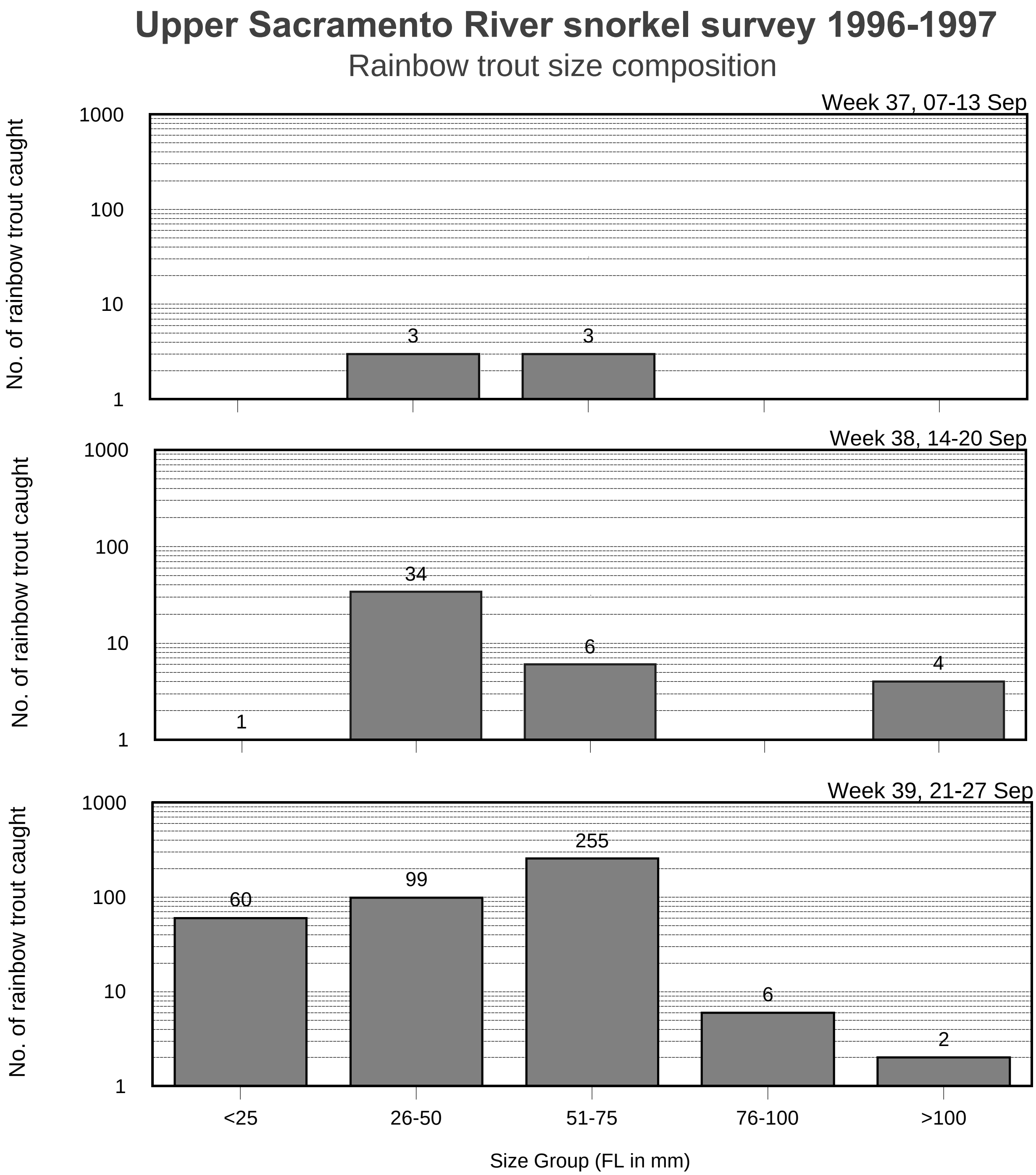


Figure 21. Weekly size composition of rainbow trout observed during the upper Sacramento River snorkel survey, 07-27 September 1997.

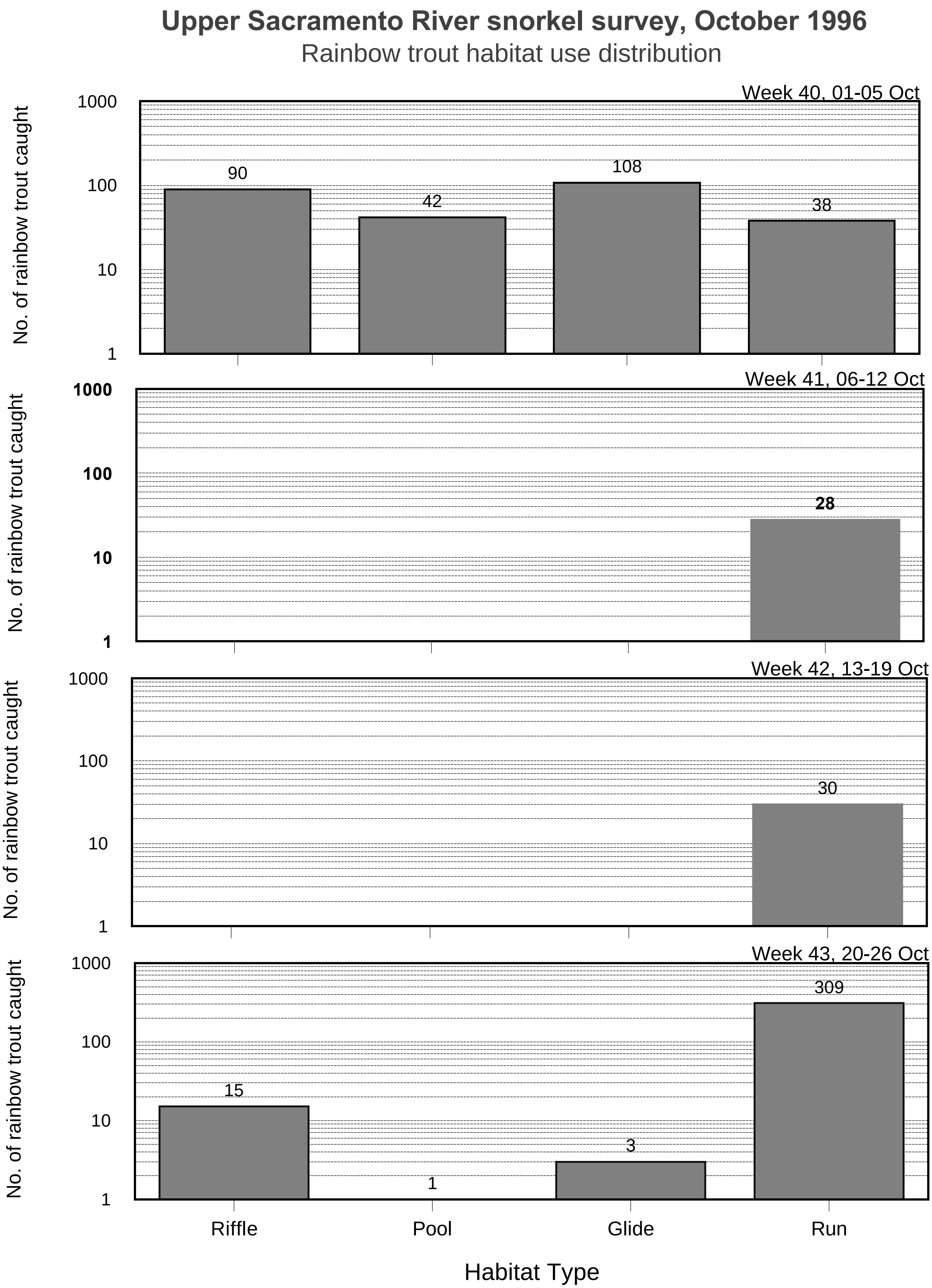


Figure 22. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 01-26 October 1996.

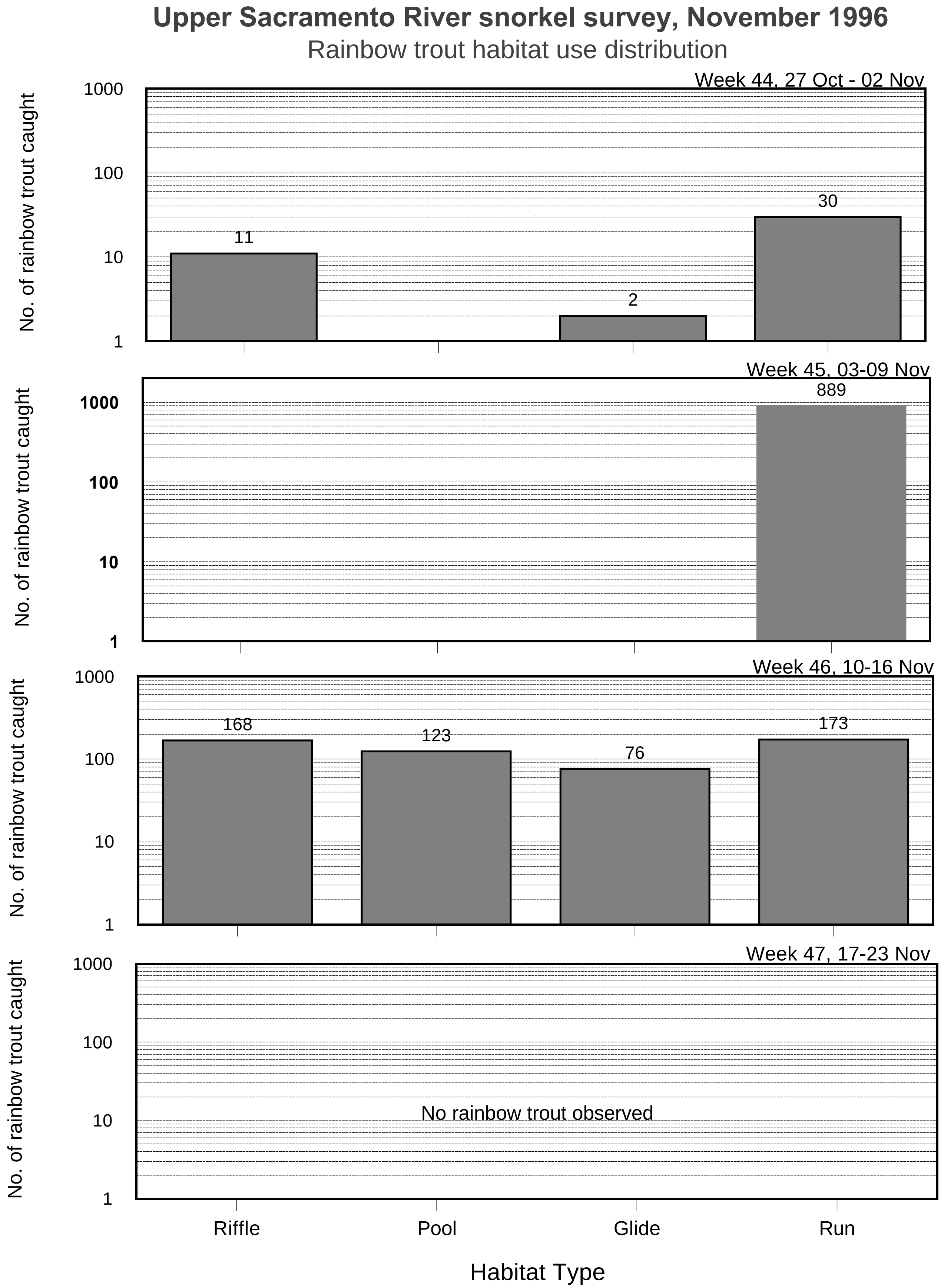


Figure 23. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 27 October - 23 November 1996.

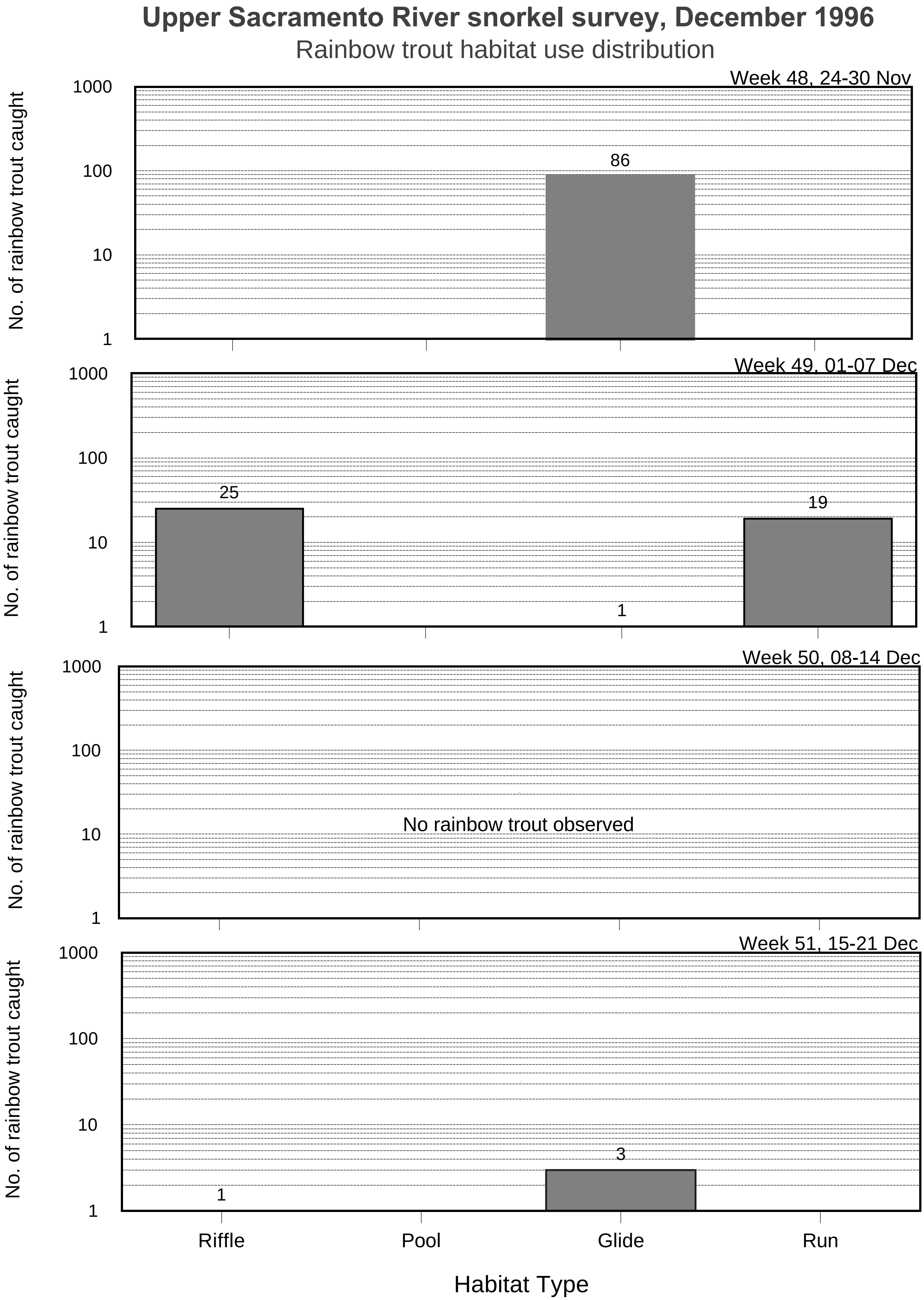


Figure 24. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 24 November - 21 December 1996.

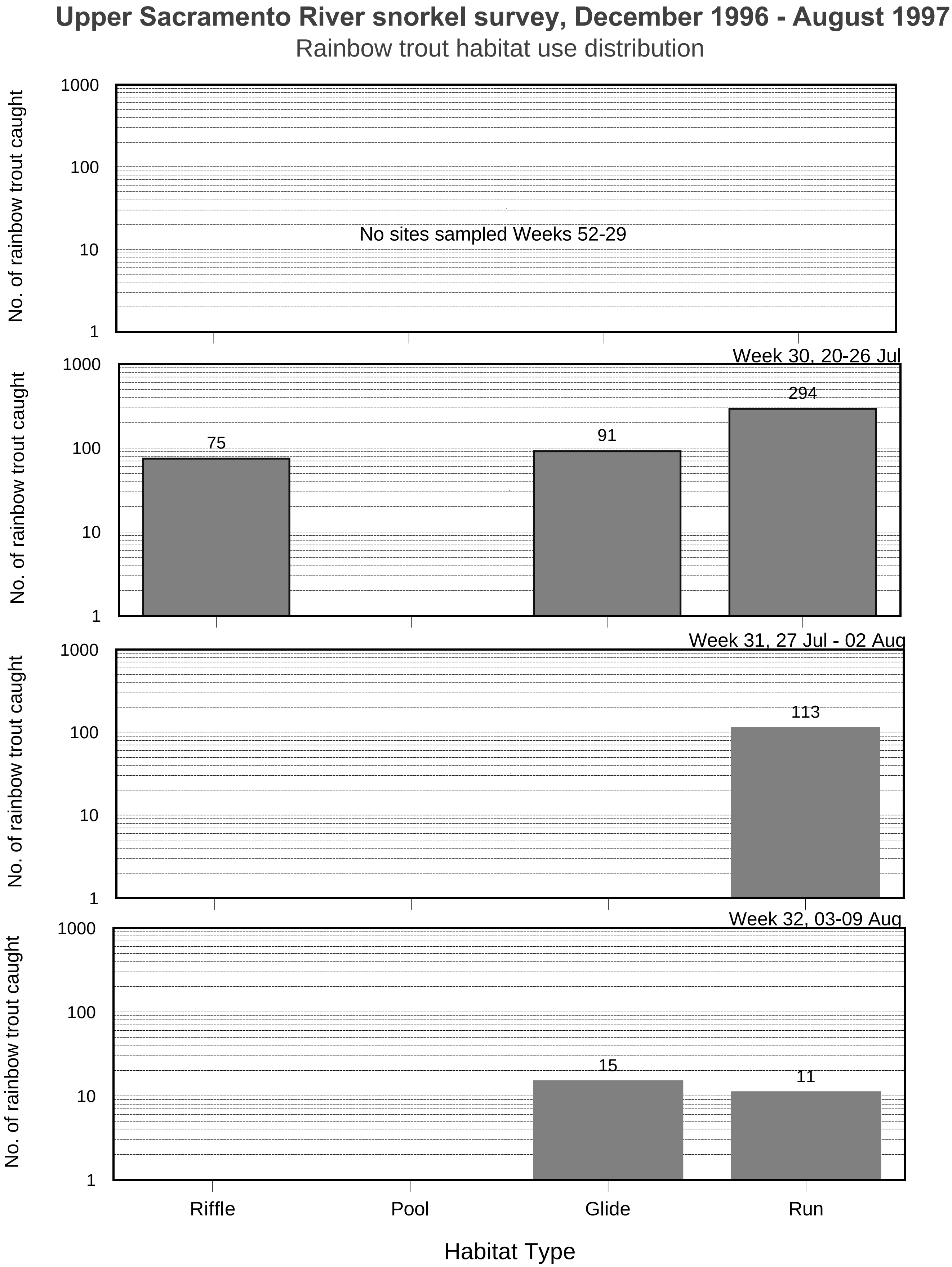


Figure 25. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 20 July - 09 August 1997.

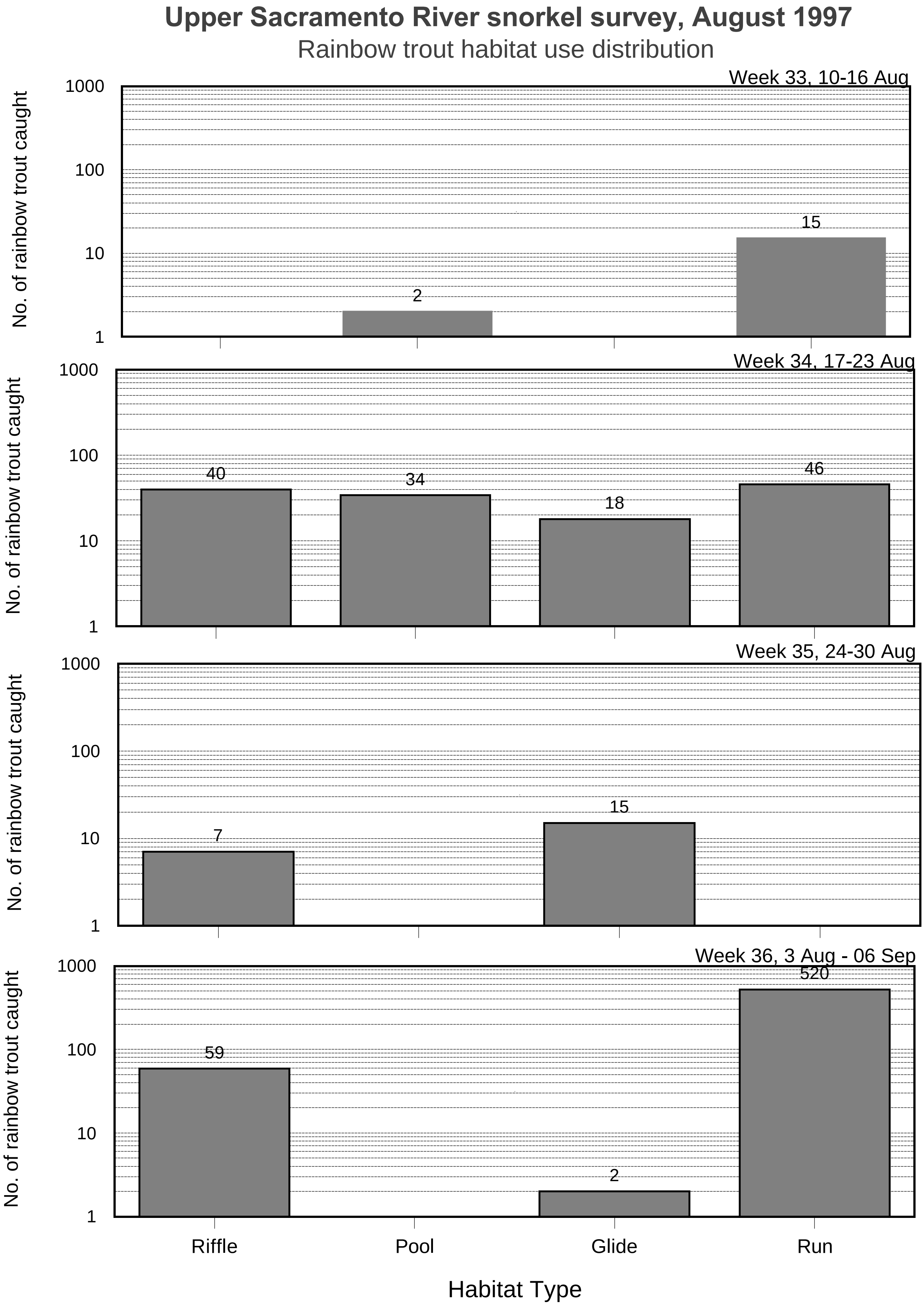


Figure 26. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 10 August - 06 September 1997.

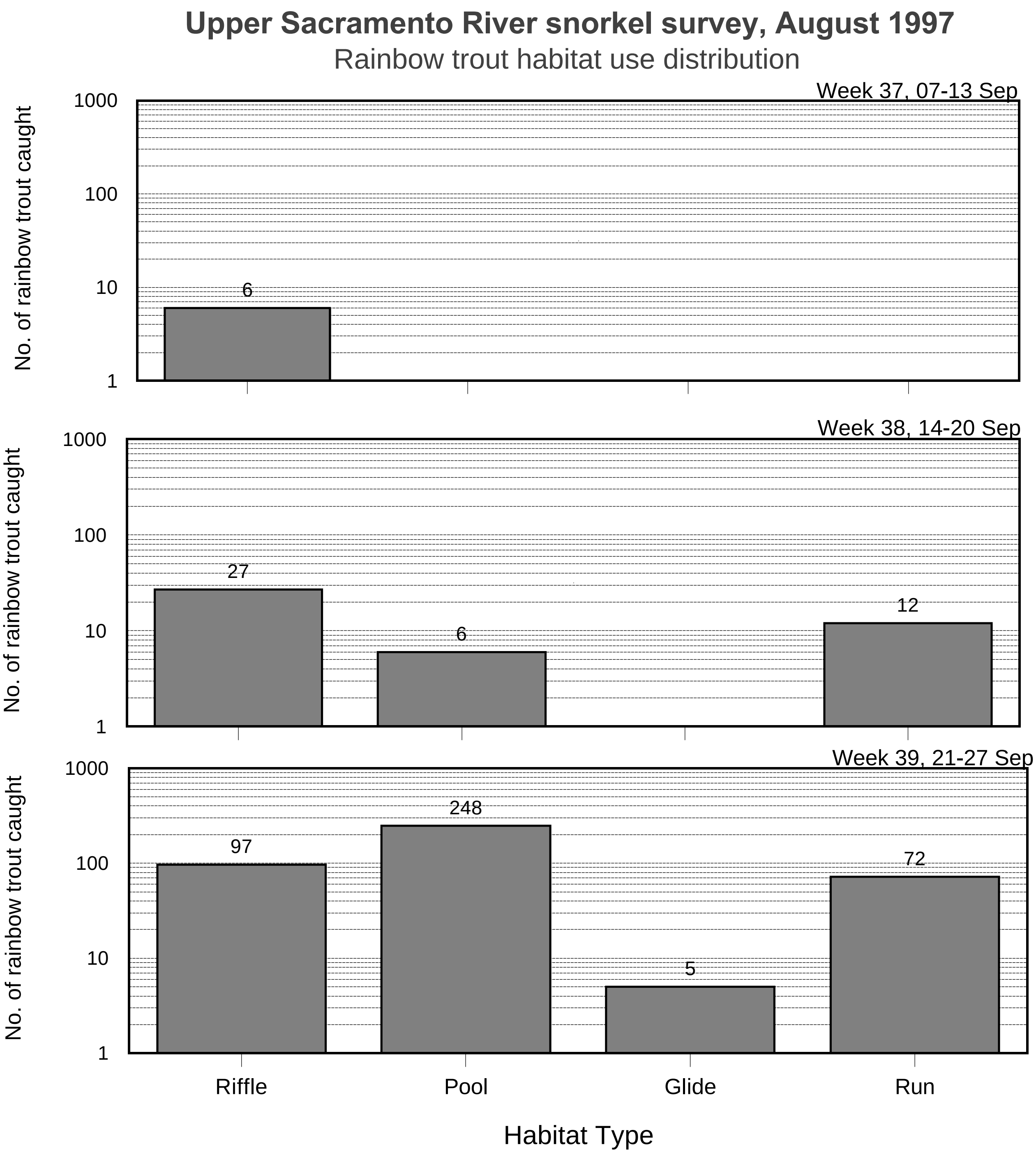


Figure 27. Weekly habitat use distribution of rainbow trout observed during the upper Sacramento River snorkel survey, 07-27 September 1997.

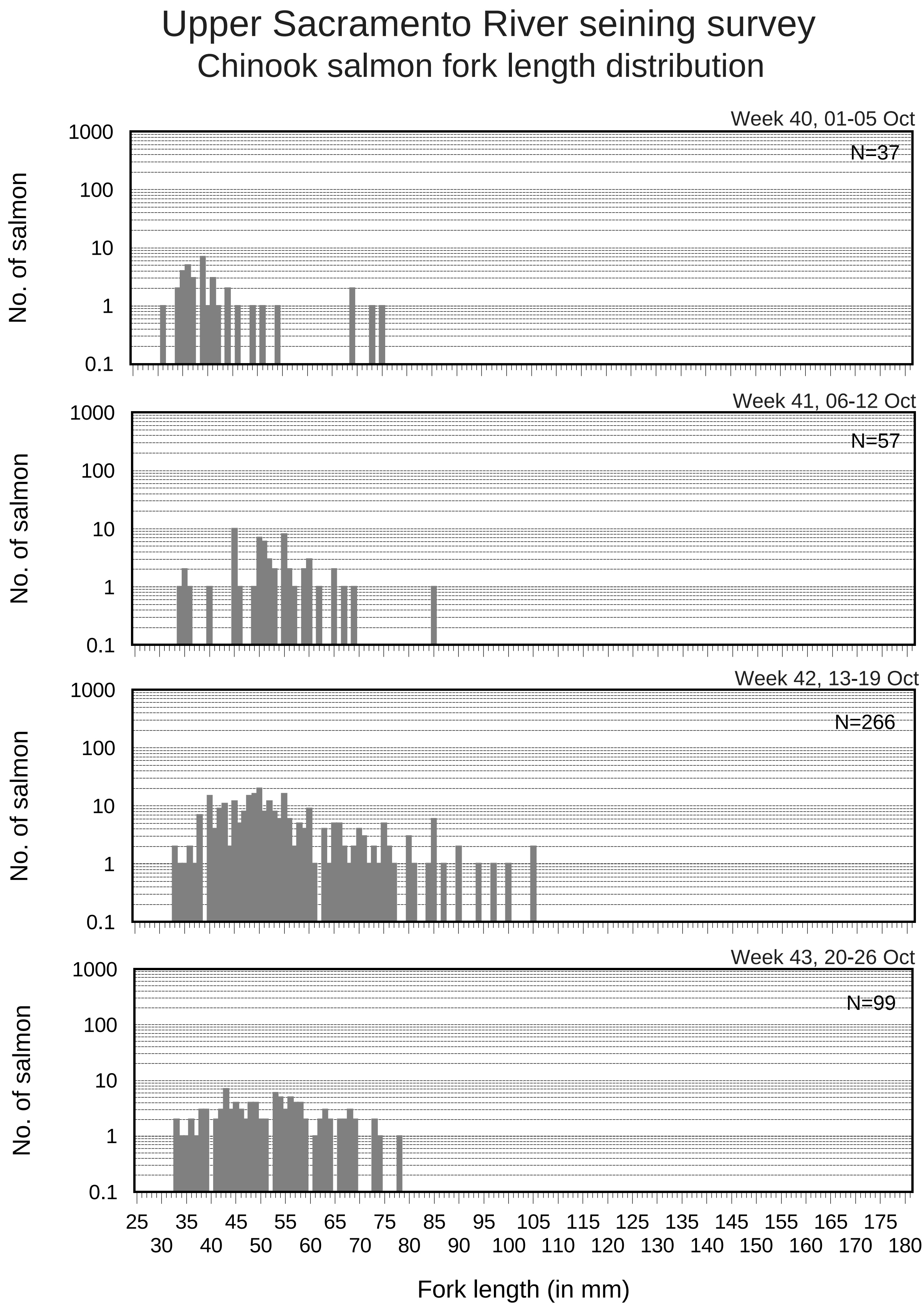


Figure 28. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 01-26 October 1996.

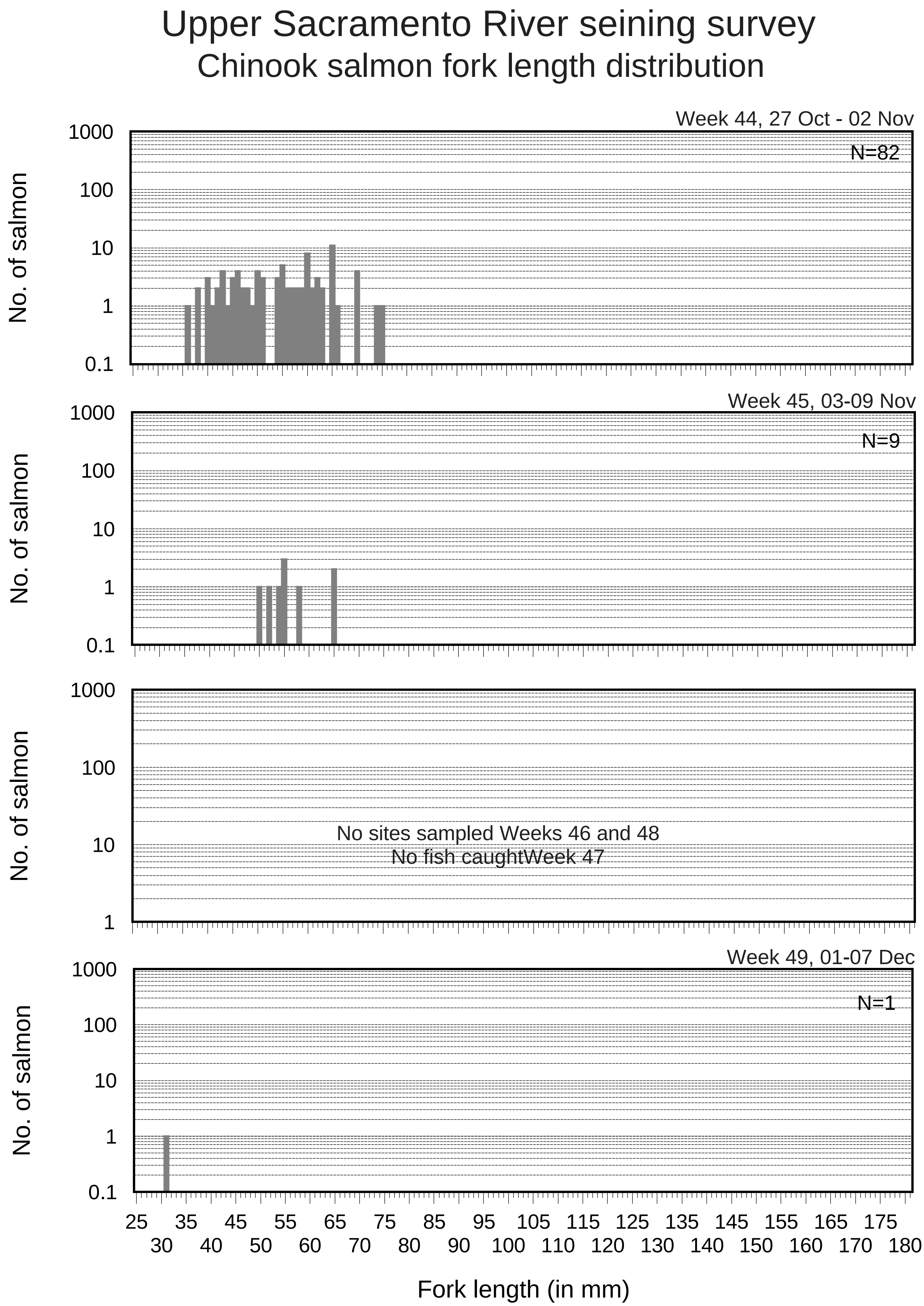


Figure 29. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 27 October - 07 December 1996.

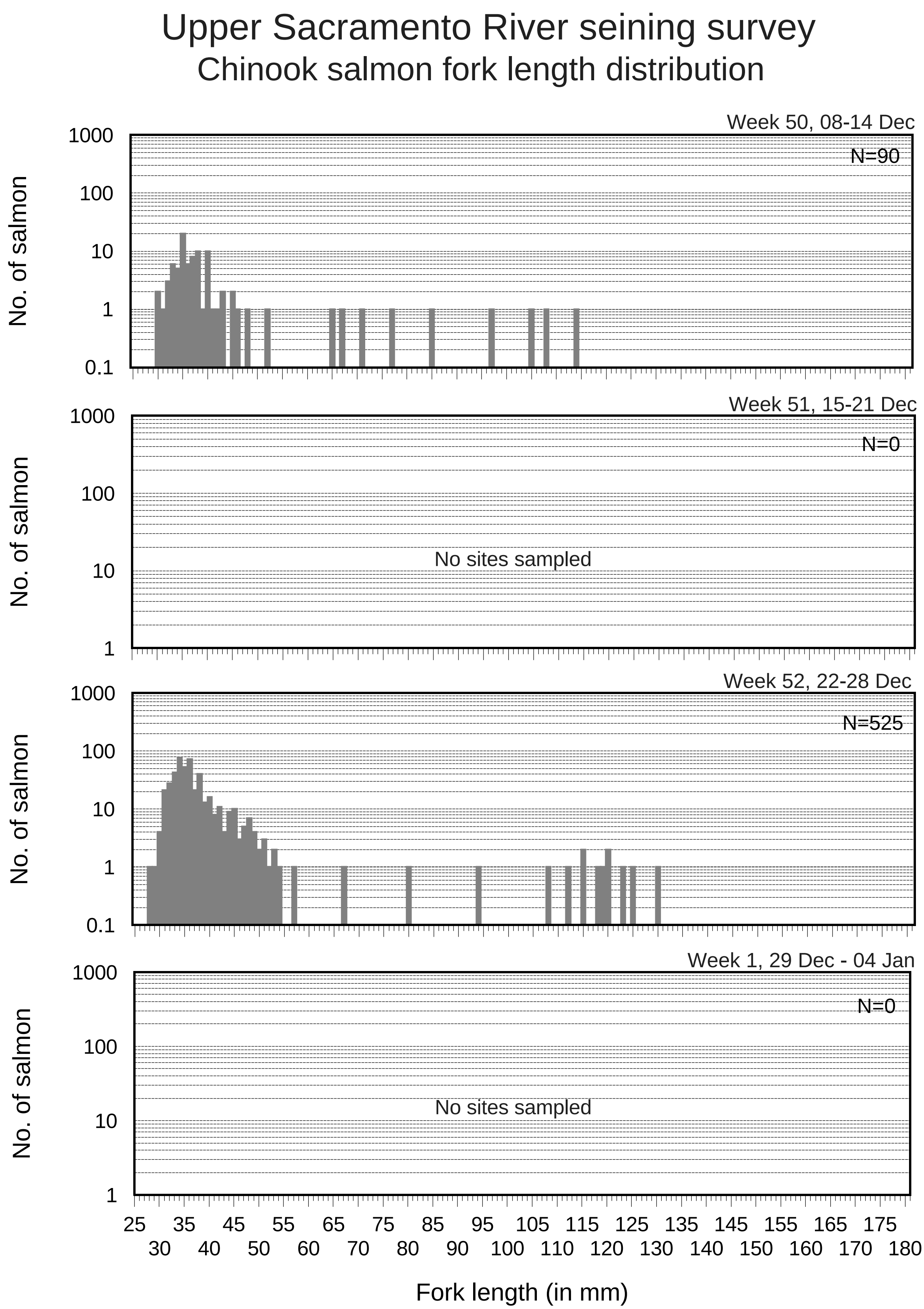


Figure 30. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 08 December 1996 - 04 January 1997.

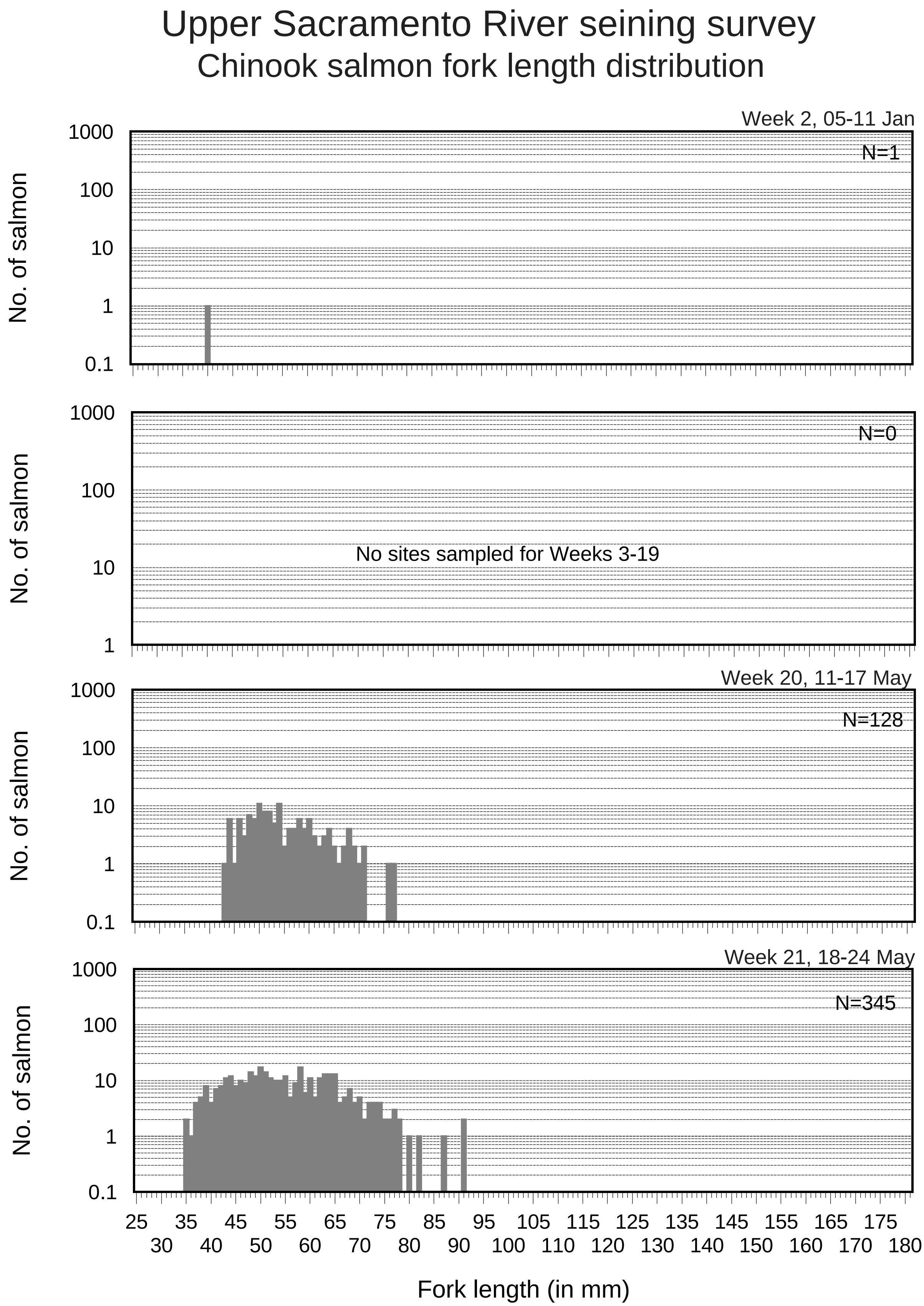


Figure 31. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 05 January - 24 May 1997.

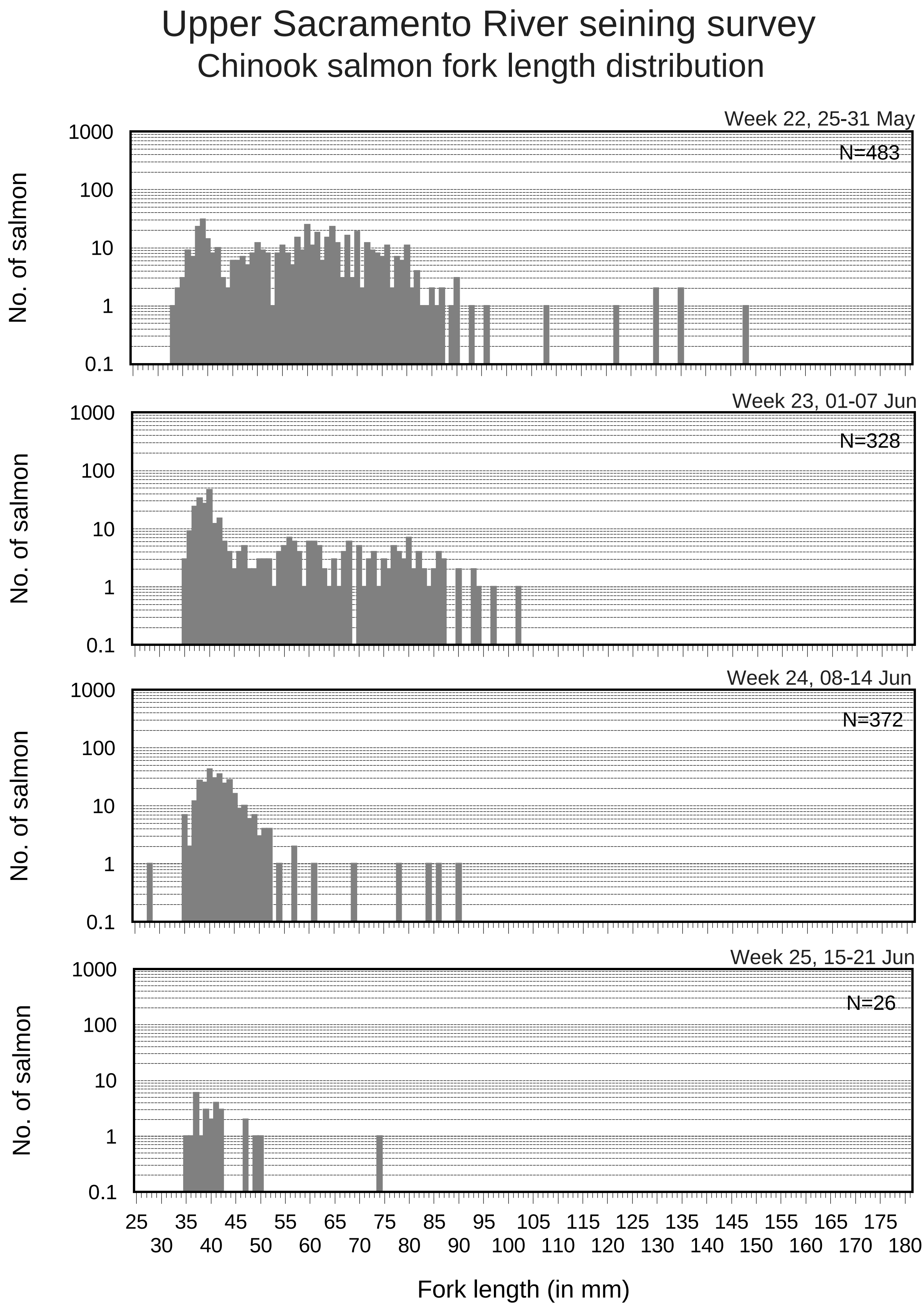


Figure 32. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 25 May - 21 June 1997.

Upper Sacramento River seining survey
Chinook salmon fork length distribution

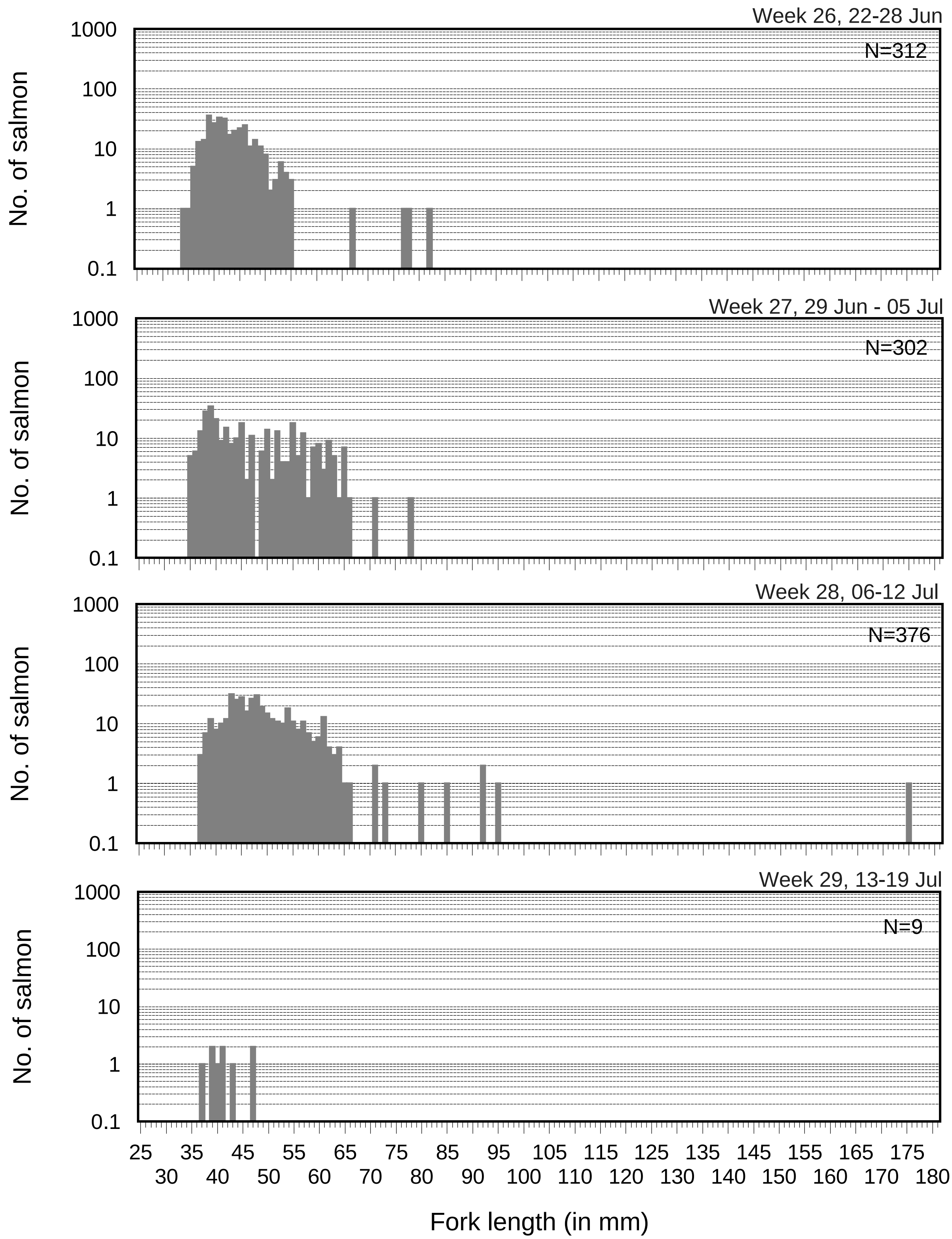


Figure 33. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 22 June - 19 July 1997.

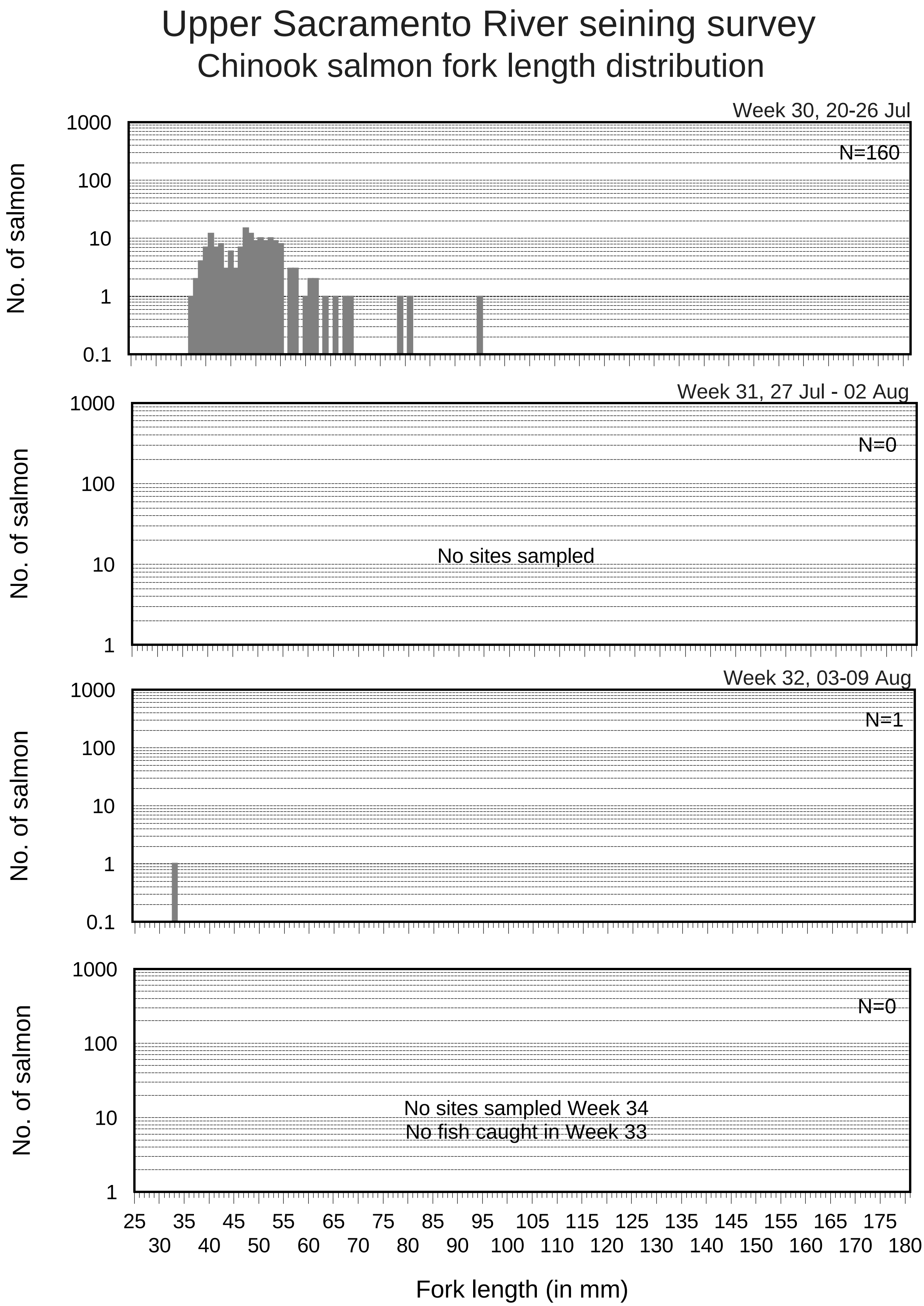


Figure 34. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 20 July - 23 August 1997.

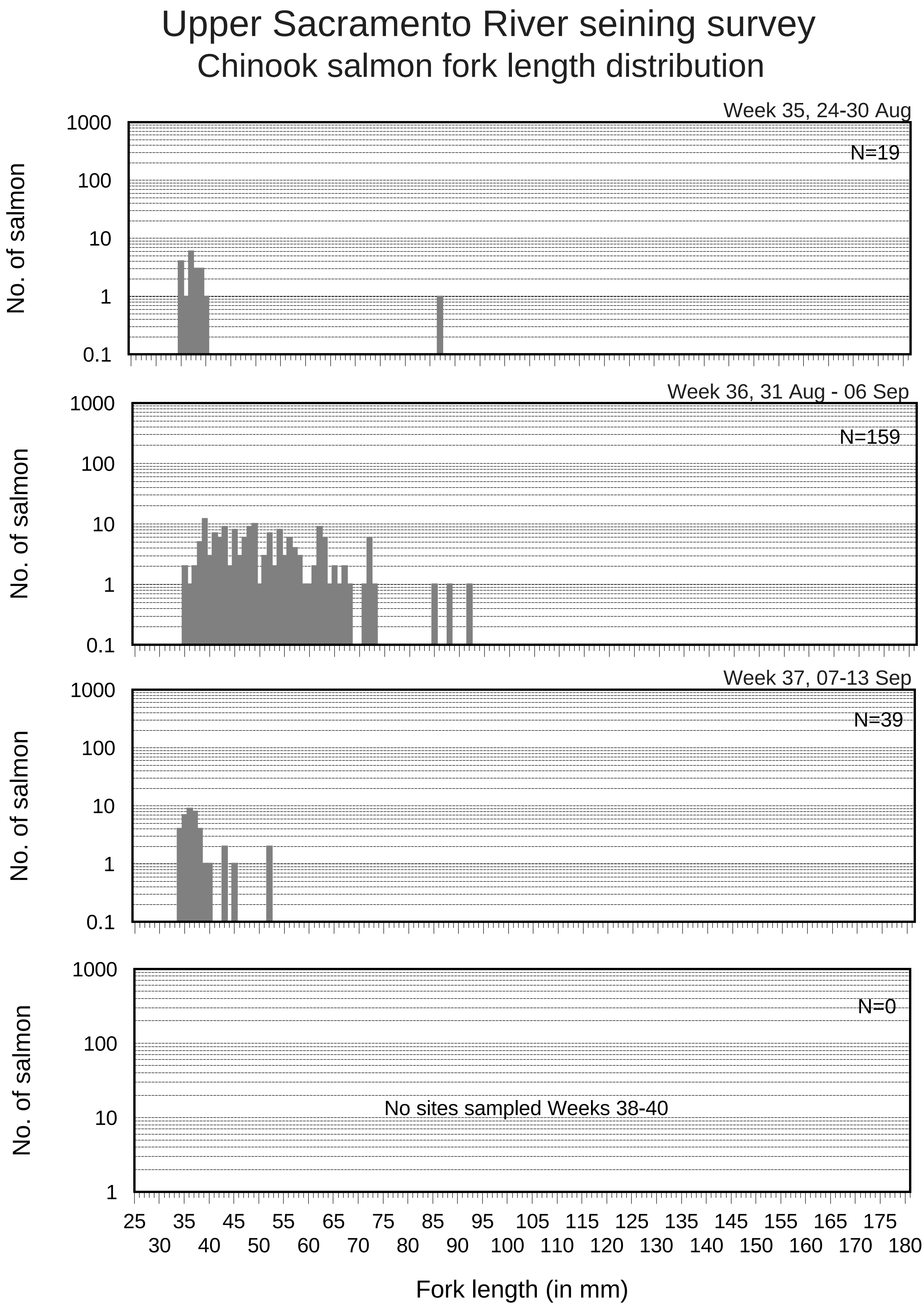


Figure 35. Size distribution of chinook salmon collected by beach seine in the upper Sacramento River, 24 August - 30 September 1997.

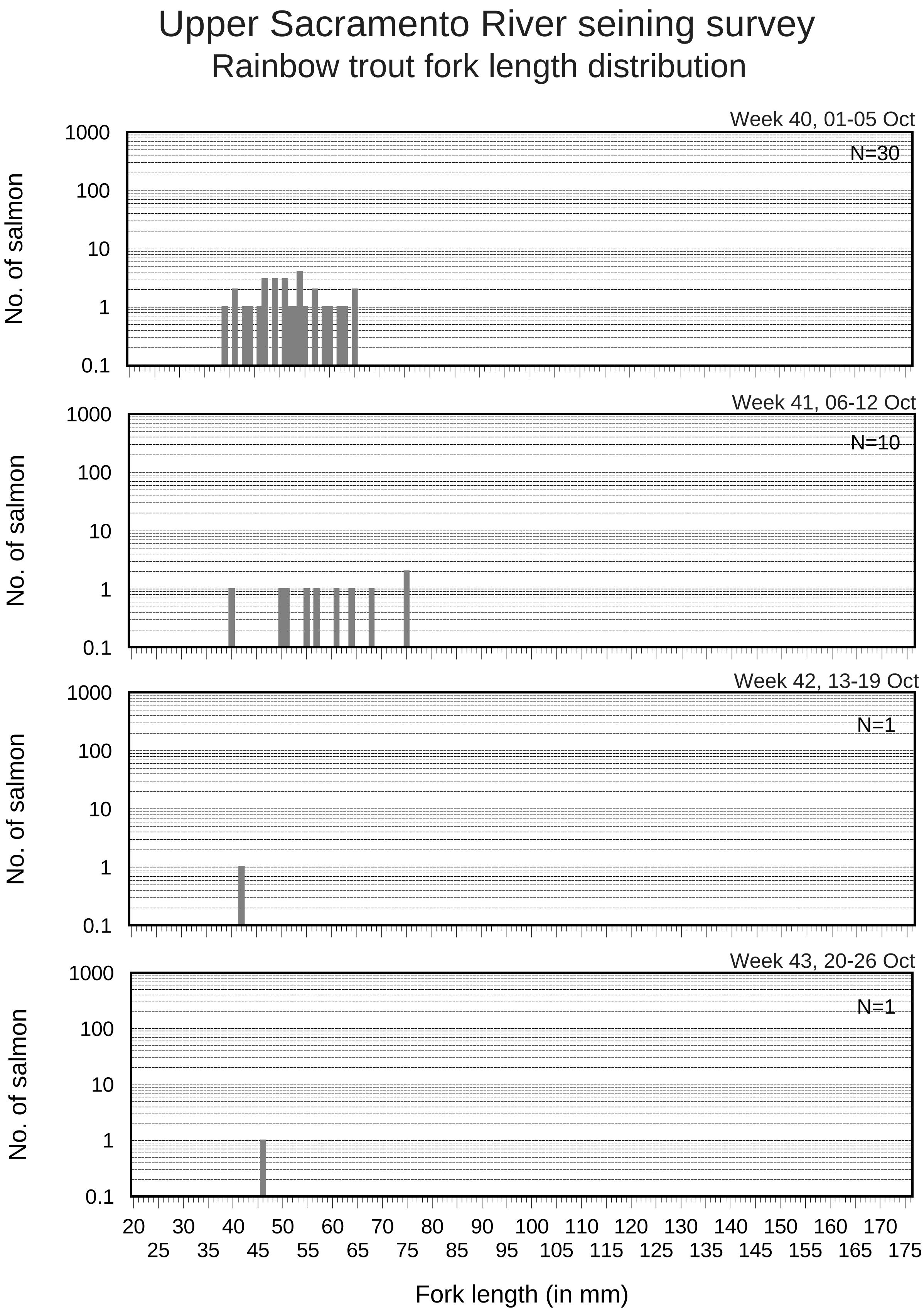


Figure 36. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 01-26 October 1996.

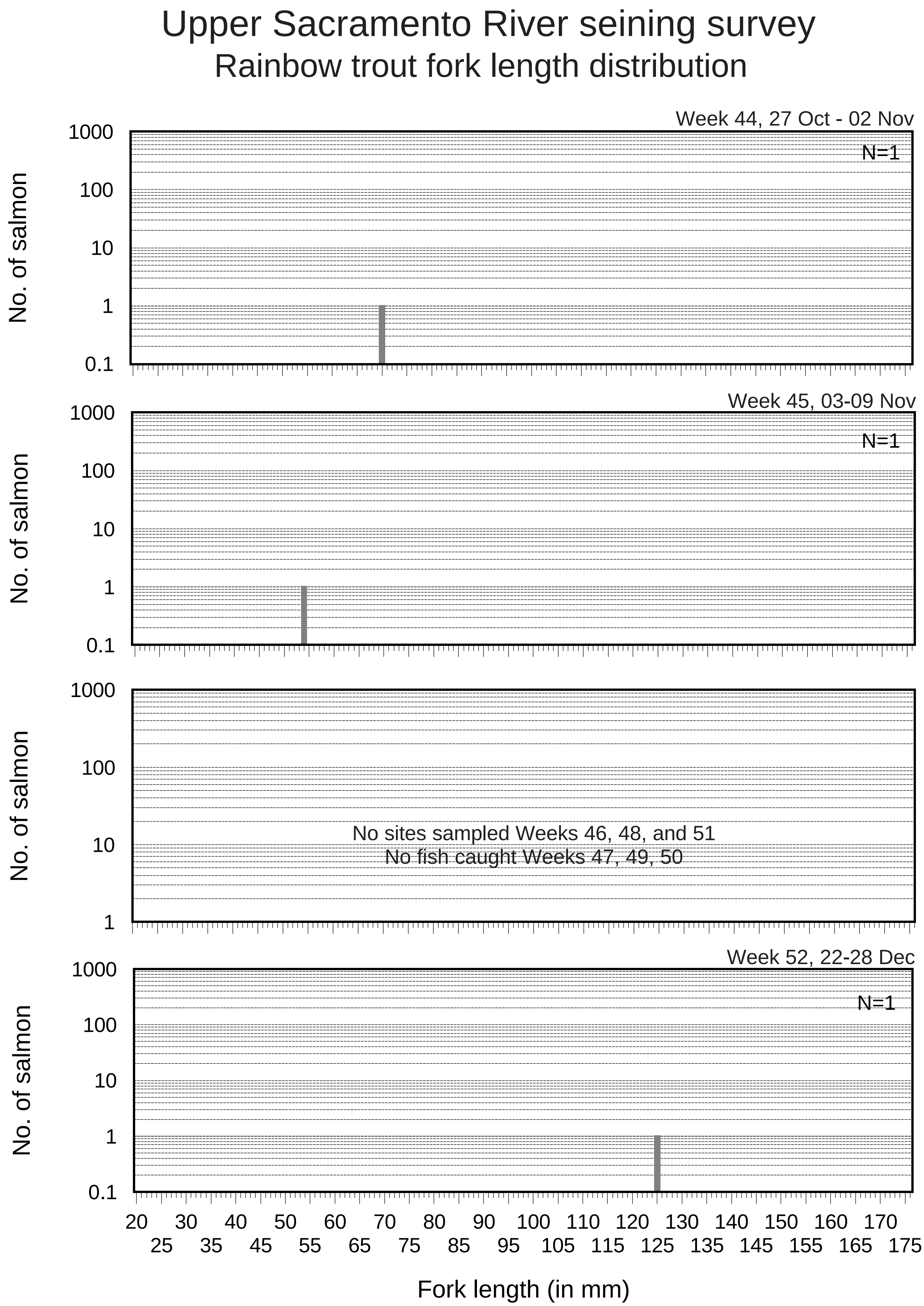


Figure 37. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 27 October - 28 December 1996.

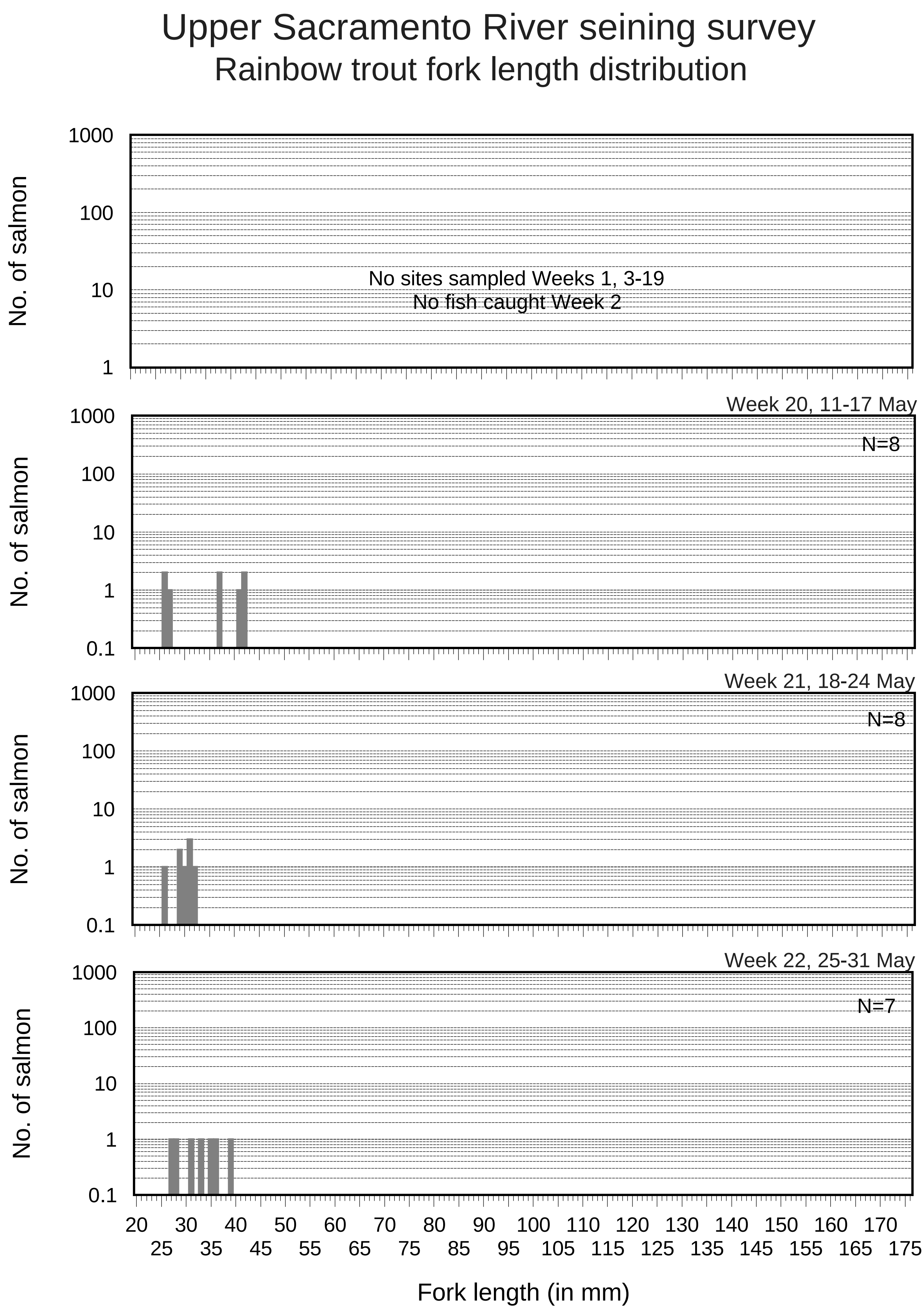


Figure 38. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 29 December 1996 - 31 May 1997.

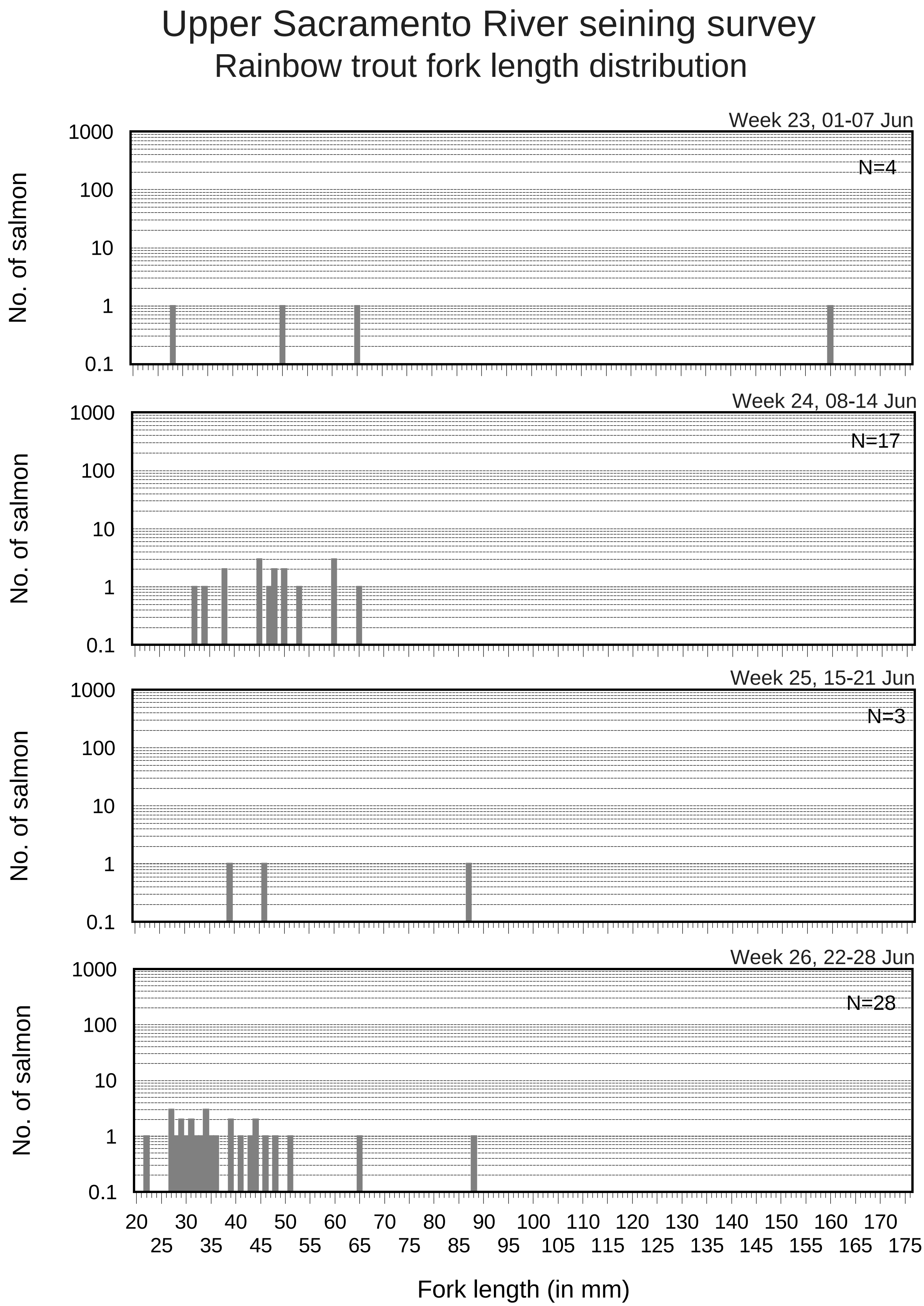


Figure 39. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 01-28 June 1997.

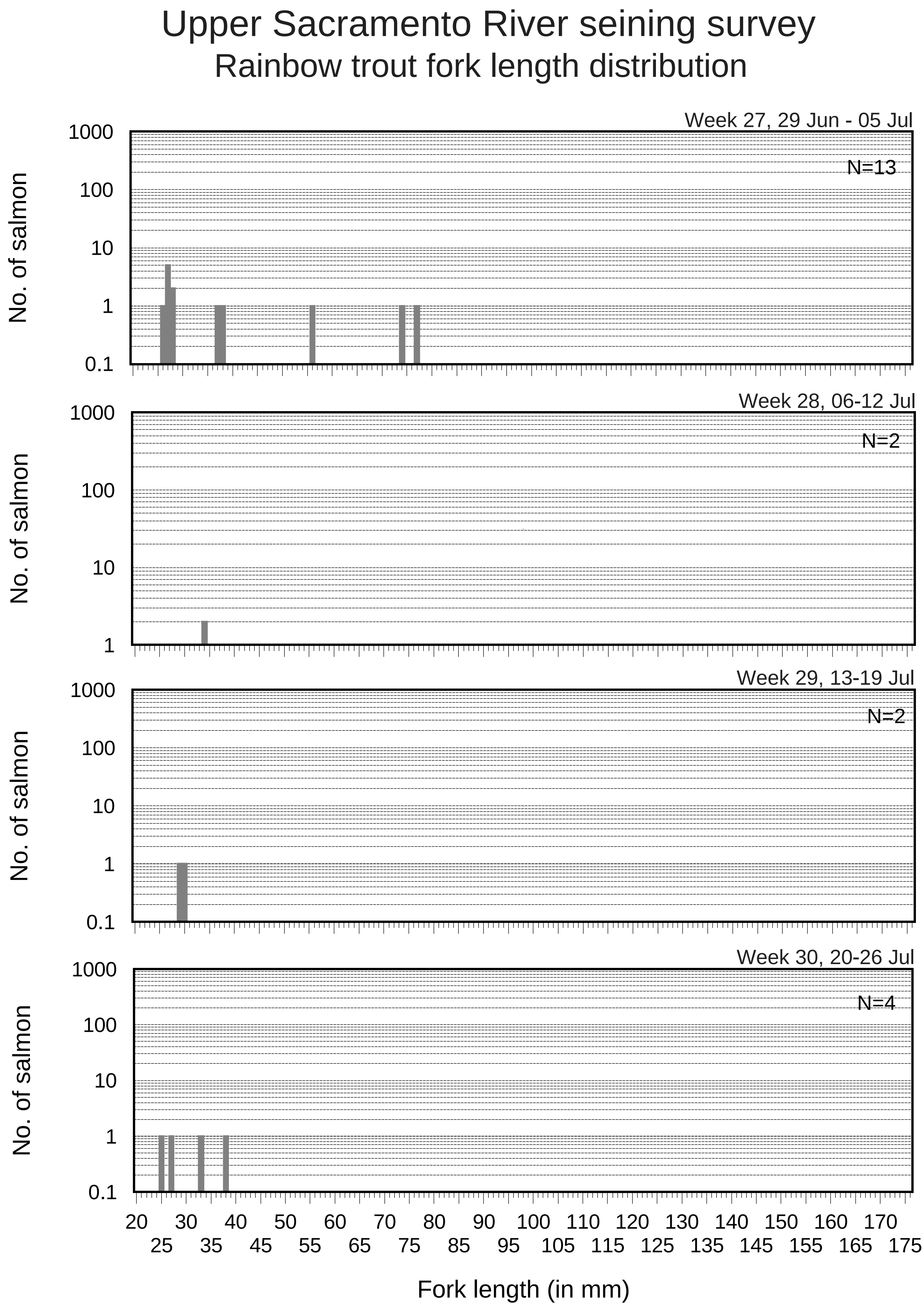


Figure 40. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 29 June - 26 July 1997.

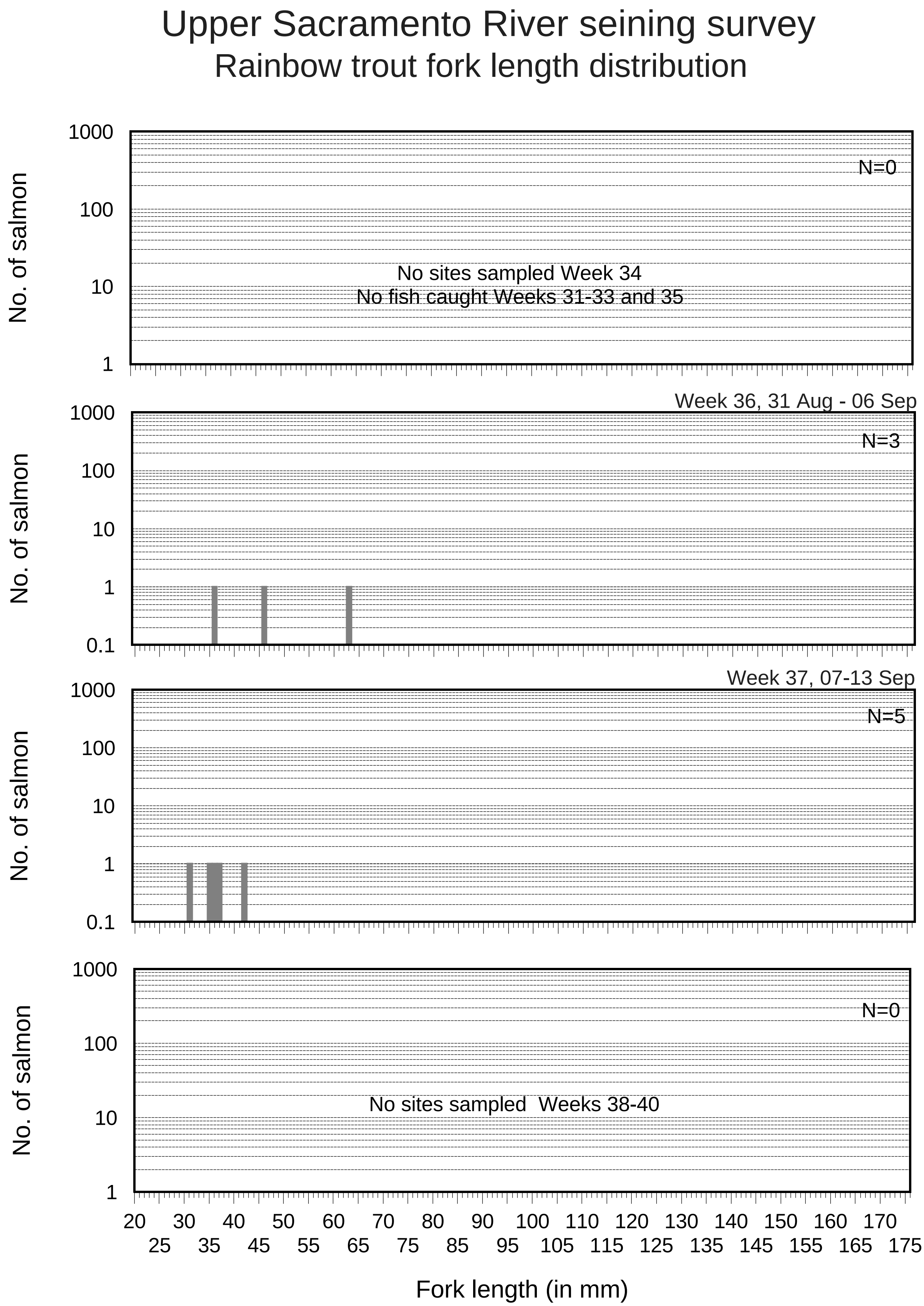


Figure 41. Size distribution of rainbow trout collected by beach seine in the upper Sacramento River, 27 July - 30 September 1997.

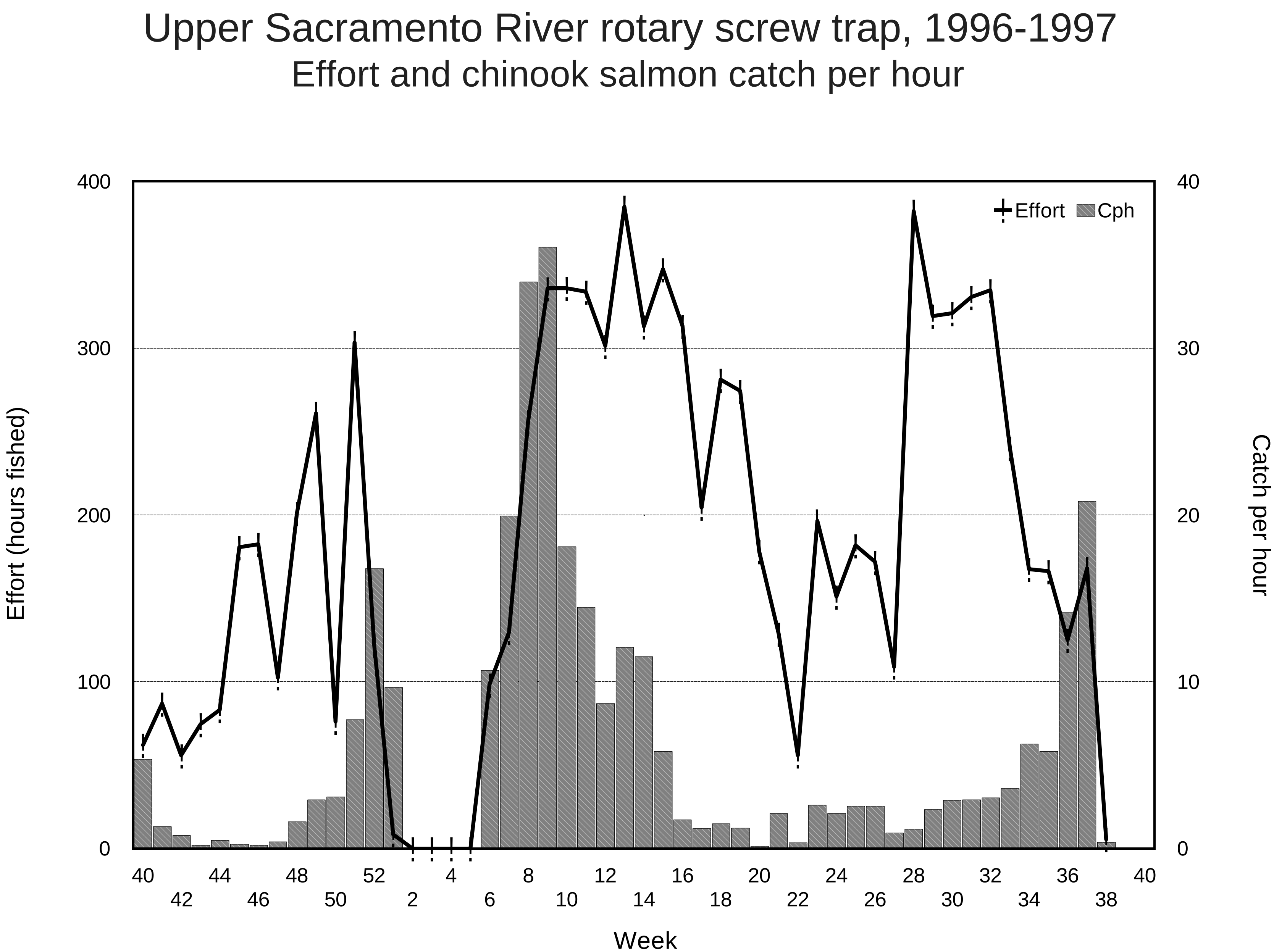


Figure 42. Weekly catch per hour of chinook salmon and hours fished by rotary screw trap in the upper Sacramento River, 01 October 1996 - 15 September 1997.

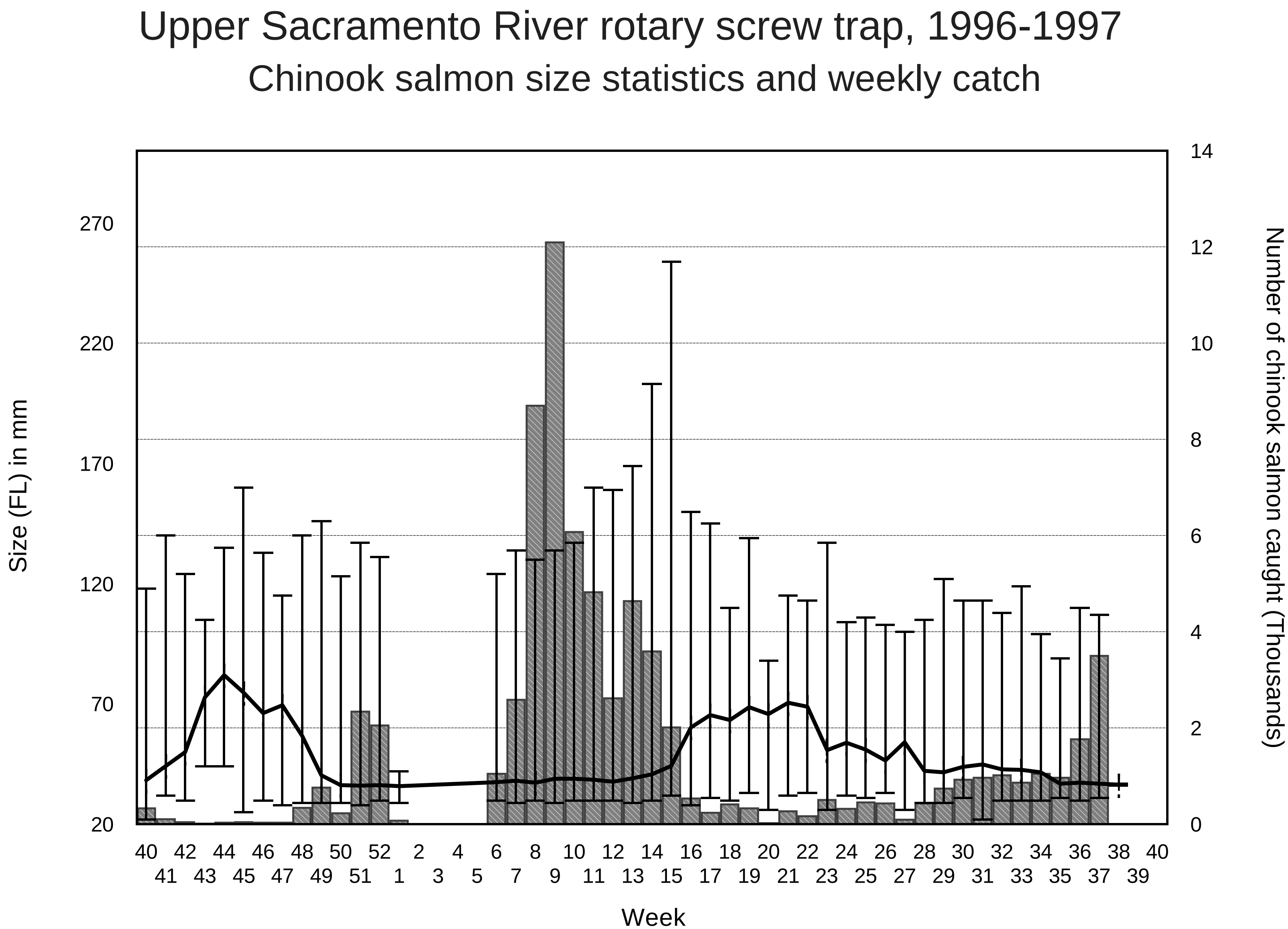


Figure 43. Chinook salmon mean forklength (minimum and maximum) and total caught by rotary screw trap on a weekly basis in the upper Sacramento River, October 1996 - September 1997.

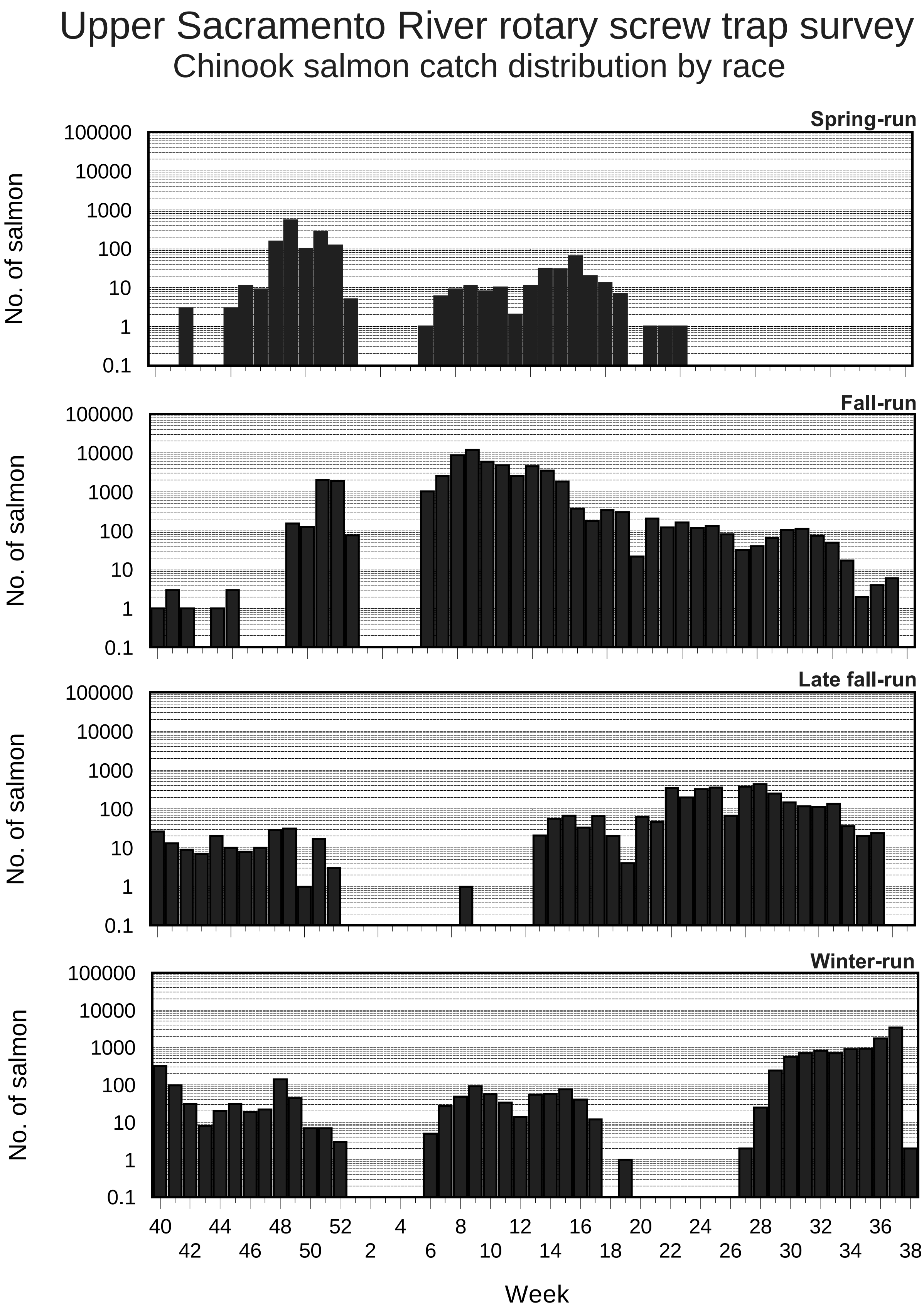


Figure 44. Catch distribution of chinook salmon races collected by rotary screw trap in the upper Sacramento River, 01 October - 15 September 1997.

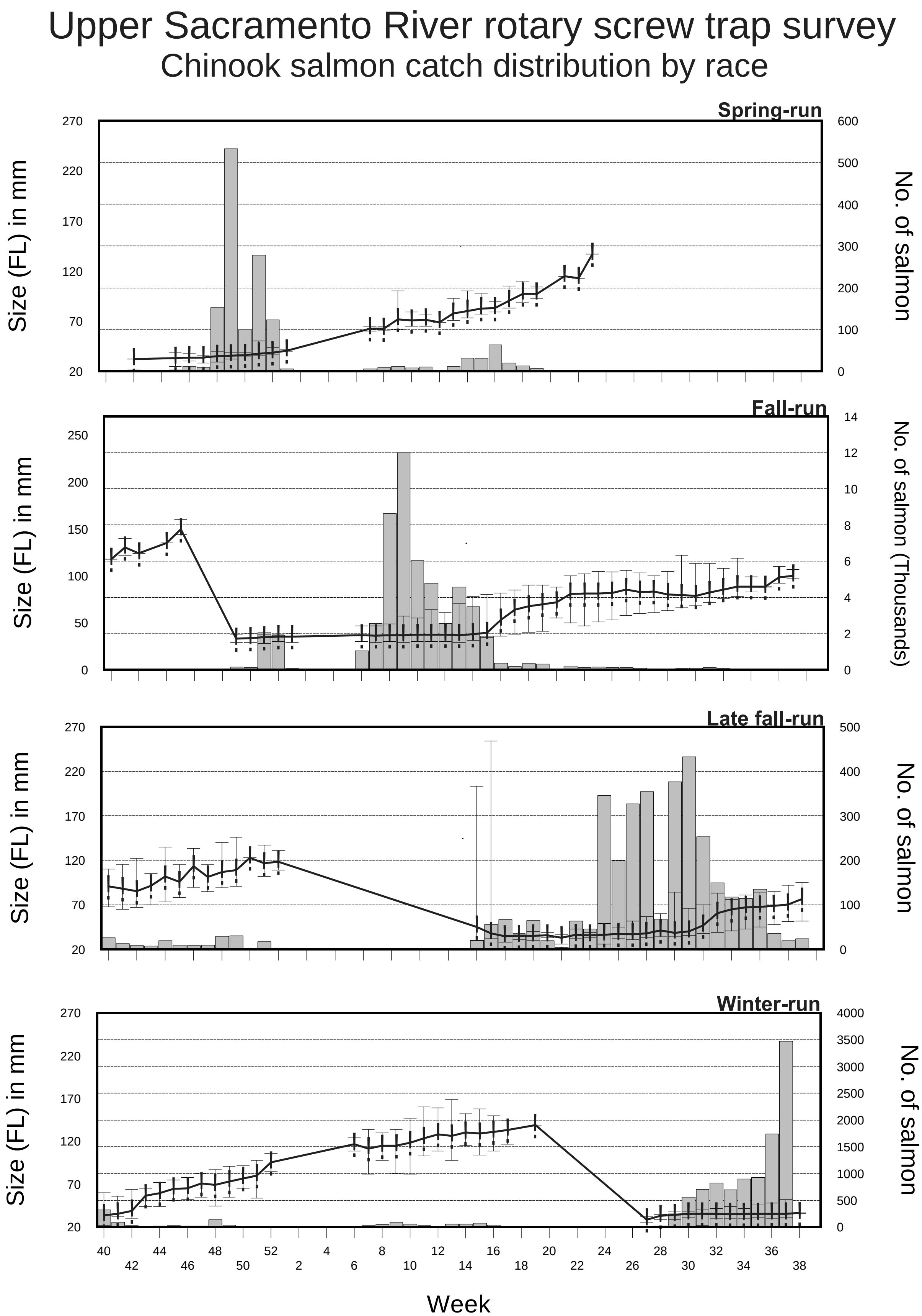


Figure 45. Weekly catch and size statistics for the four races of chinook salmon collected by rotary screw trap in the upper Sacramento River, 01 October - 15 September 1997.

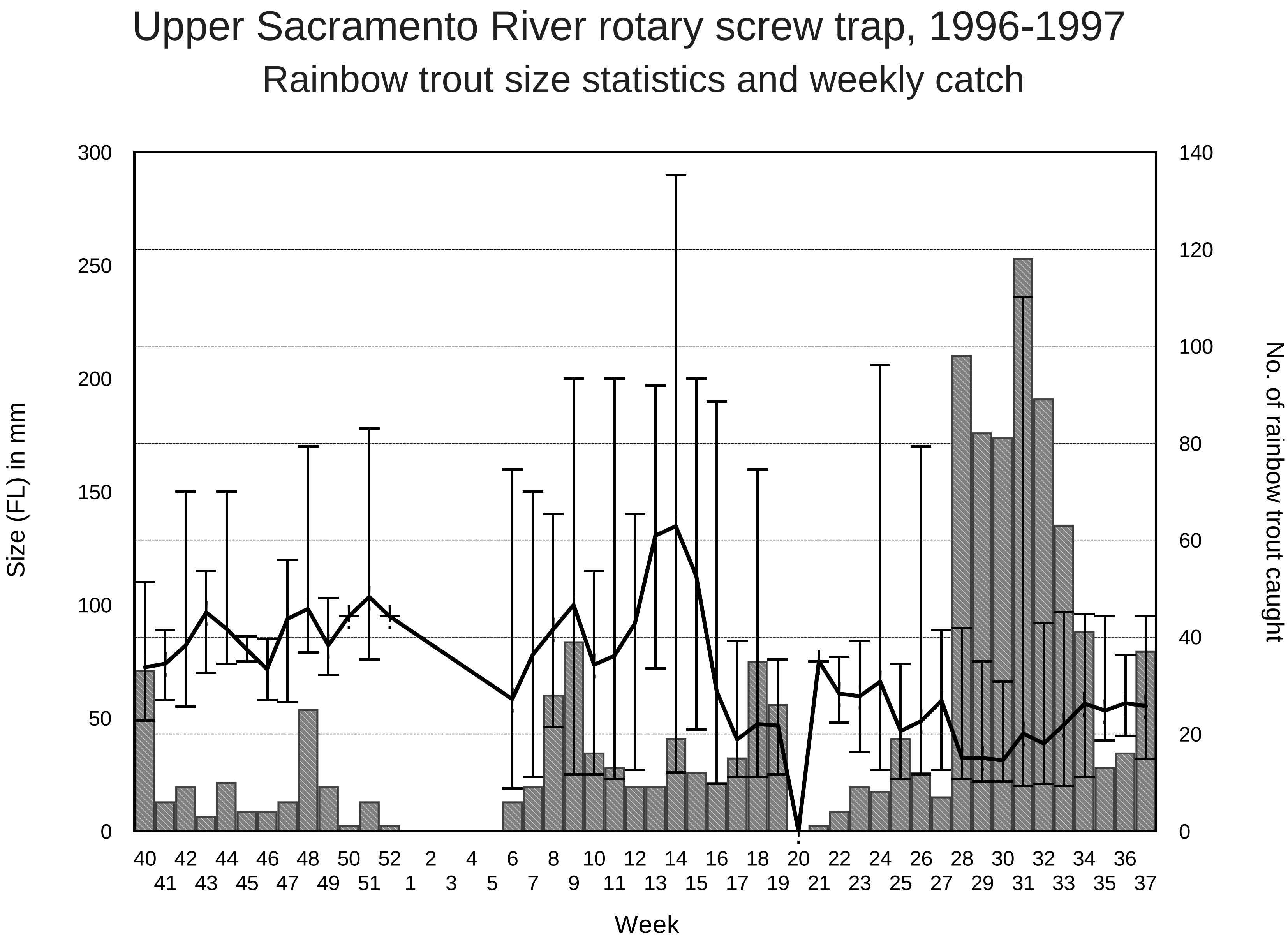


Figure 46. Rainbow trout mean forklength (minimum and maximum) and total caught by rotary screw trap on a weekly basis in the upper Sacramento River, October 1996 - September 1997.

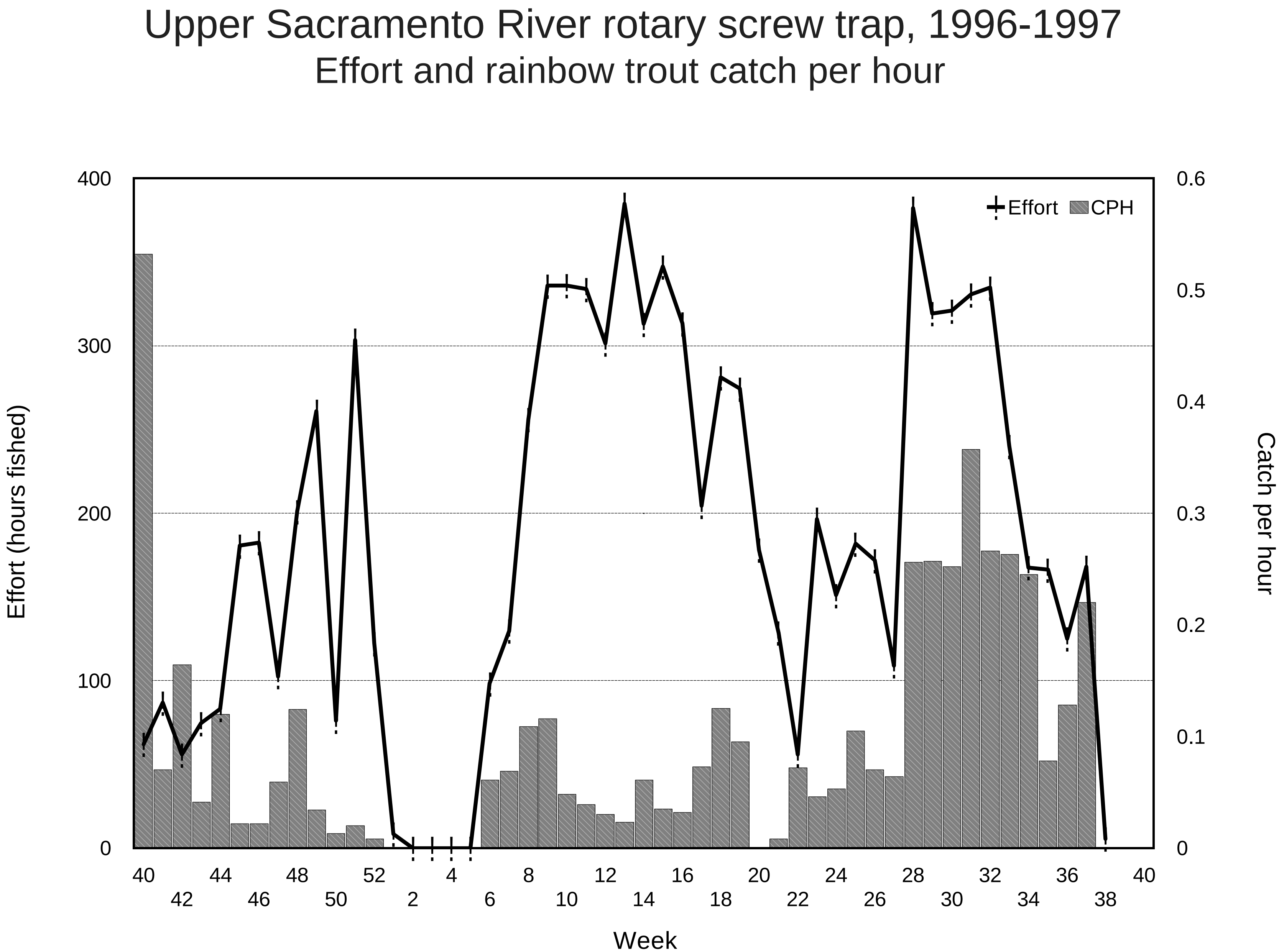


Figure 47. Weekly catch per hour of rainbow trout and hours fished by rotary screw trap in the upper Sacramento River, 01 October 1996 - 15 September 1997.

APPENDIX I

Upper Sacramento River Habitat Type Distribution List

Sacramento River, Habitat Types, Battle Creek (RM 271) to Keswick Dam (RM 302)

Habitat ID #	Habitat Type	Landmark	River Mile
1	BC run		271
2	BC run		
3	BC riffle		
4	BC riffle		
5	BC pool	Barge Hole/Battle Creek	
6	BC riffle		
7	BC glide		
8	FW glide		272
9	BC run		273
10	BC riffle	Cottonwood Creek	
11	FW glide	Redding Island	274
12	FW run		275
13	FW riffle		276
14	FW glide	Balls Ferry Bridge Crossing	
15	FW pool		277
16	FW run	Ash Creek	
17	FW riffle		
18	FW glide	Bear Creek	
19	FW run		278
20	BC run		
21	BC riffle		
22	BC run		
23	BC riffle		
24	FW glide		
25	FW run		
26	FW riffle	Power Line riffle	279
27	FW glide		
28	BC pool	Haas Hole	
29	BC run	Cow Creek	280
30	BC riffle		

Habitat ID #	Habitat Type	Landmark	River Mile
31	BC run		
32	BC riffle		
33	FW glide		
34	BC run	Deschutes Rd Xing/Stillwater Creek	281
35	OC area		
36	BC riffle	Hawes riffle	
37	OC area		
38	BC glide		282
39	FW glide		
40	FW run		
41	BC riffle		
42	FW pool		
43	FW glide		
44	FW pool		283
45	FW glide	North Street Bridge /Churn Creek	284
46	FW run	Hwy 5 Crossing	285
47	FW pool		
48	FW glide		
49	FW run		
50	FW riffle	Lower Plywood riffle	
51	FW glide		286
52	FW run		
53	BC riffle	Upper Plywood Riffle	
54	FW run		
55	FW riffle		
56	FW glide		287
57	FW glide		
58	FW run		
59	BC riffle		
60	BC riffle		
61	SC riffle		
62	BC run		

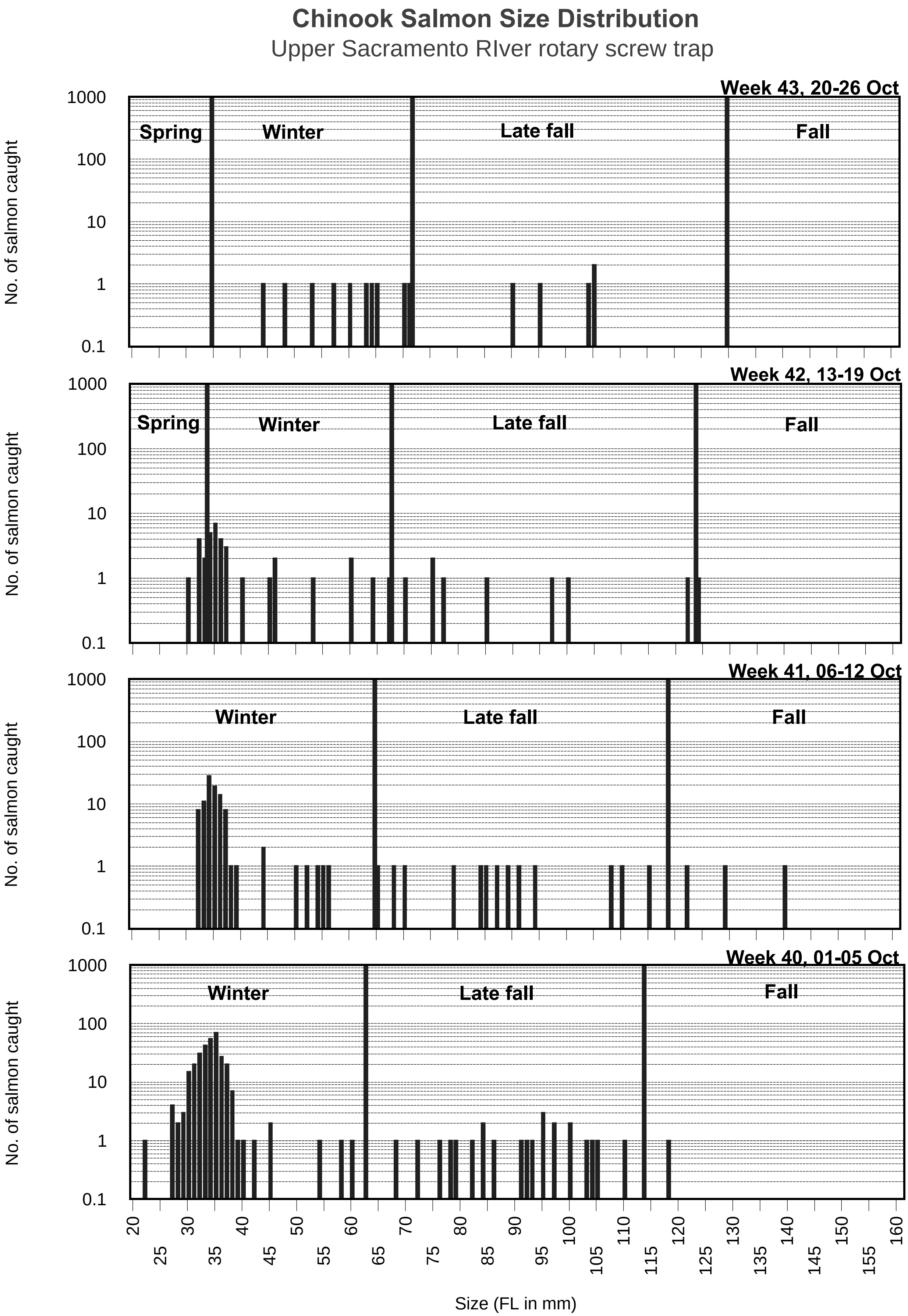
Habitat ID #	Habitat Type	Landmark	River Mile
63	BC run		
64	BC riffle	Joe Deering riffle	
65	OC area		
66	BC riffle		
67	FW glide		
68	BC riffle		
69	BC riffle		
70	BC glide		
71	OC area		289
72	OC area		
73	BC run		
74	OC area		
75	BC riffle		
76	SC riffle		
77	SC pool		
78	SC riffle		
79	OC area		
80	SC pool	Olney Creek	
81	BC glide		290
82	SC run		
83	SC riffle		
84	SC riffle		
85	BC run		
86	BC riffle		
87	BC glide		
88	BC riffle		
89	OC area		
90	FW glide		291
91	FW run		
92	SC riffle		
93	SC run		
94	SC riffle		

Habitat ID #	Habitat Type	Landmark	River Mile
95	OC area		
96	SC run		
97	SC riffle	Tobiasson riffle	
98	BC riffle		
99	FW glide		292
100	FW run	South Bonny View Road Crossing	
101	BC pool		
102	BC riffle		
103	BC riffle	Golf Course riffle	
104	BC run		293
105	FW run		
106	BC run		
107	OC area		
108	BC riffle	Wyndom riffle	
109	FW glide		294
110	BC glide		
111	BC run		
112	BC riffle	Cypress Avenue Bridge Crossing	295
113	BC glide		
114	OC area		
115	BC run		
116	OC area	Kutras Lake	
117	BC riffle		
118	BC pool		
119	BC riffle		
120	FW glide		
121	FW run	Kutras Island	
122	FW run		
123	BC riffle	East Island	
124	BC riffle	Turtle Bay East	
125	BC riffle	West Island	
126	OC area		

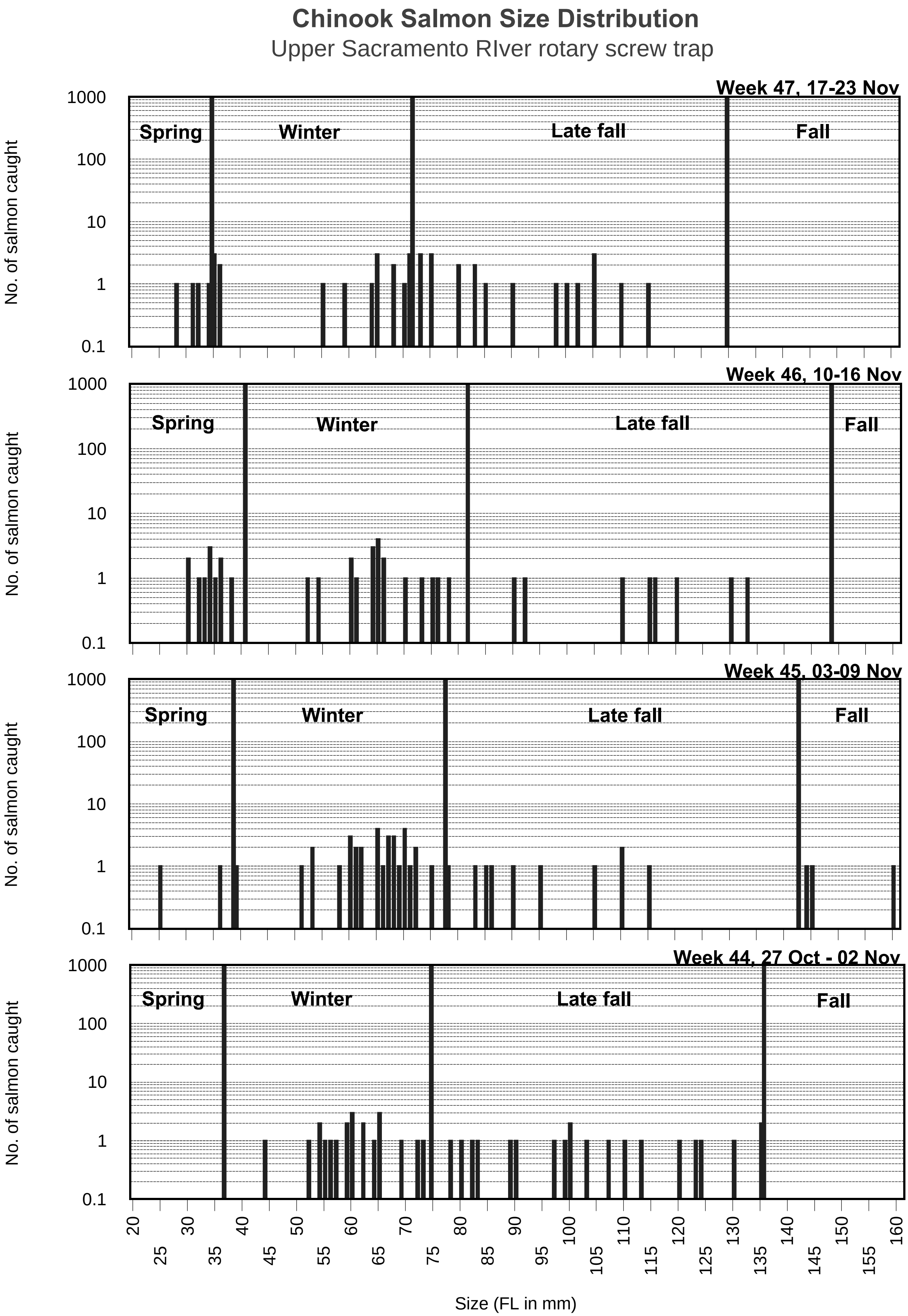
Habitat ID #	Habitat Type	Landmark	River Mile
127	OC area		
128	SC riffle		
129	BC glide	Hwy 299- 44 /Turtle, Bay West	
130	BC pool		
131	BC run		
132	BC riffle	Redding riffle	
133	FW glide	Pumping Plant	
134	FW run		
135	FW riffle		
136	FW glide		298
137	FW run		
138	FW riffle	DWR Gravel Restoration Site	
139	FW pool	ACID Dam/"Lake Redding"	
140	FW glide		
141	run	'boulder run'	300
142	pool		
143	run		301

APPENDIX II

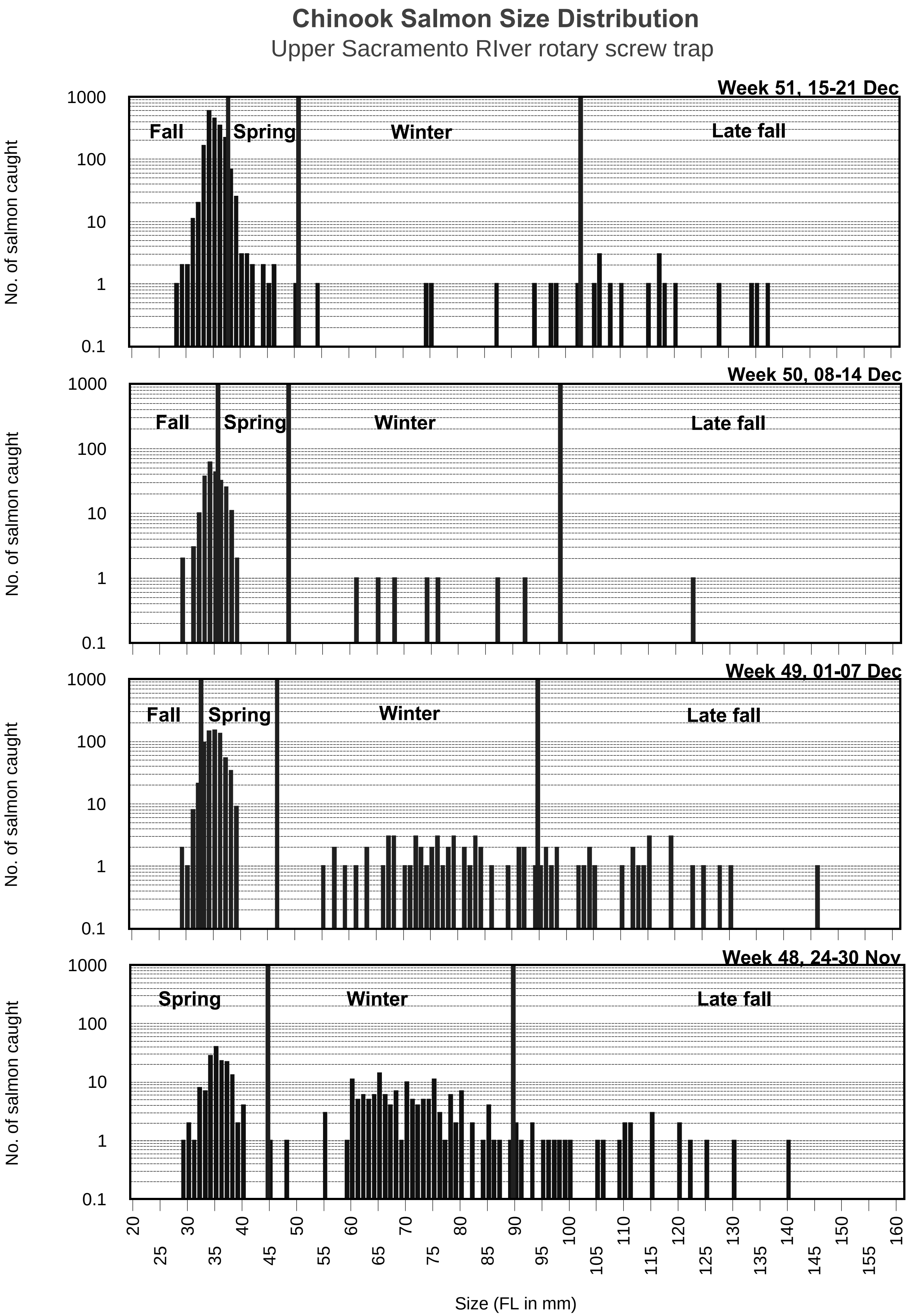
Rotary screw trap catch weekly length distribution
October 1996 - September 1997



II-1. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 01 October - 26 October 1996.



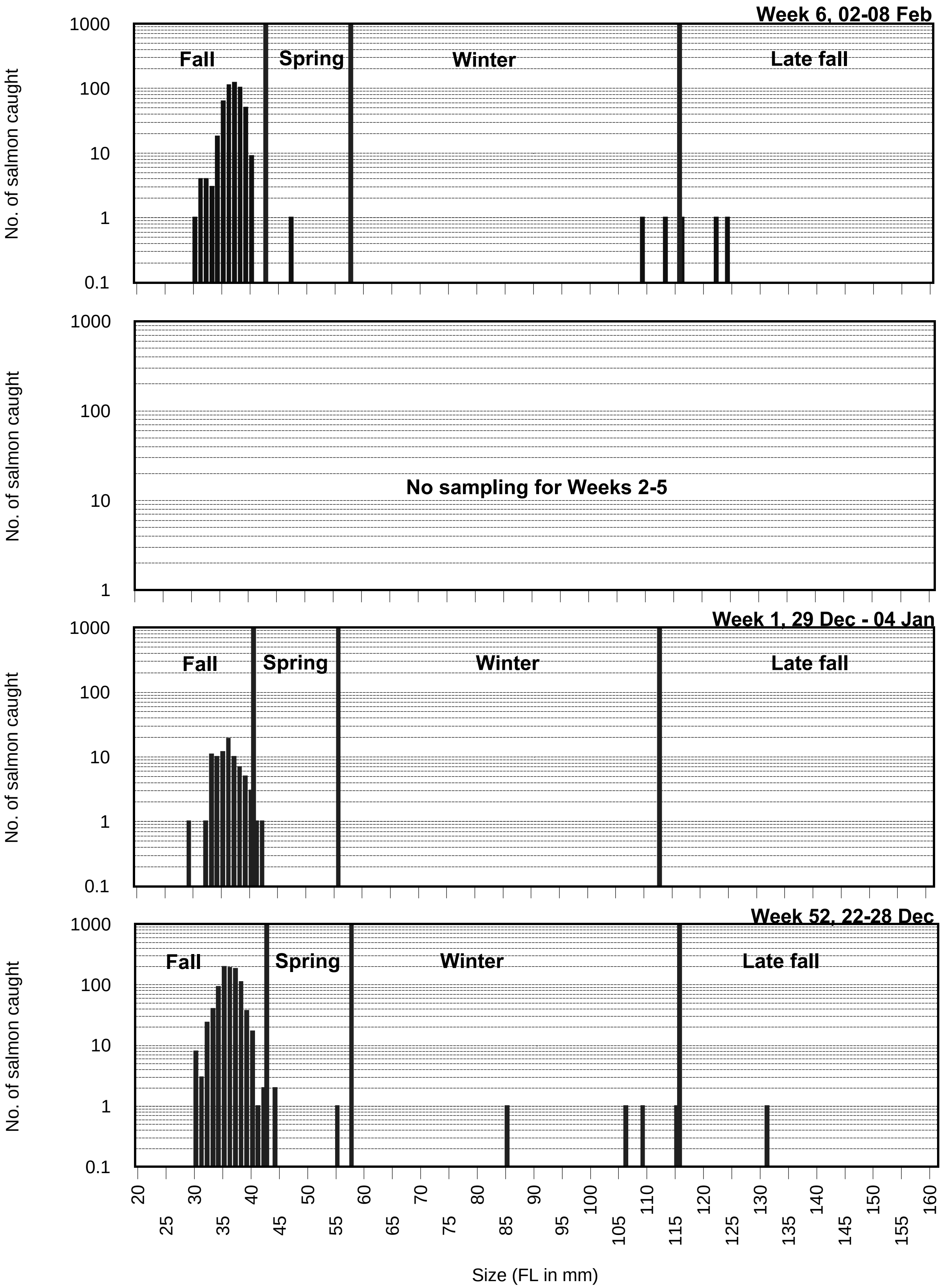
II-2. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 27 October - 23 November 1996.



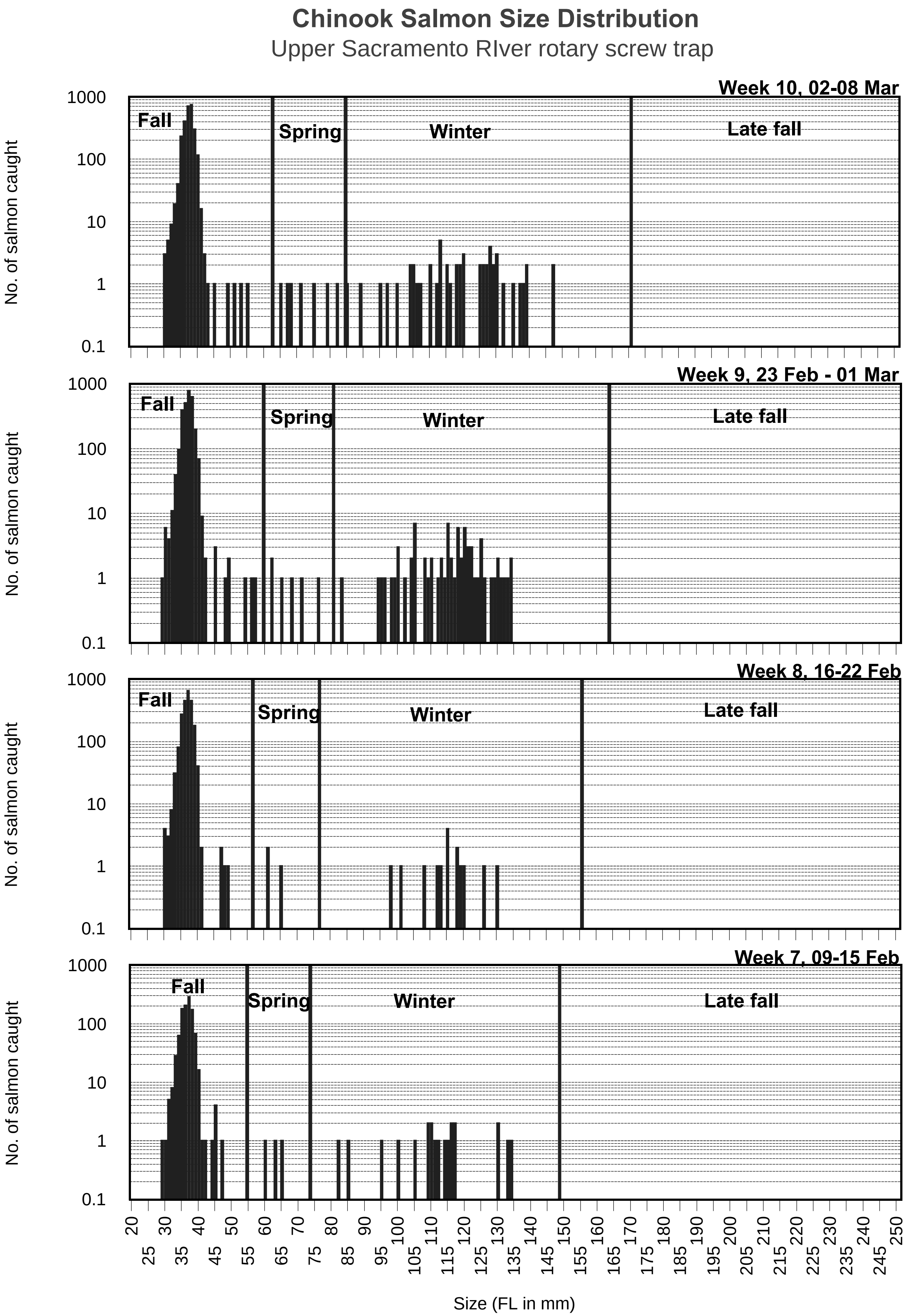
II-3. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 24 November - 21 December 1996.

Chinook Salmon Size Distribution

Upper Sacramento RIver rotary screw trap



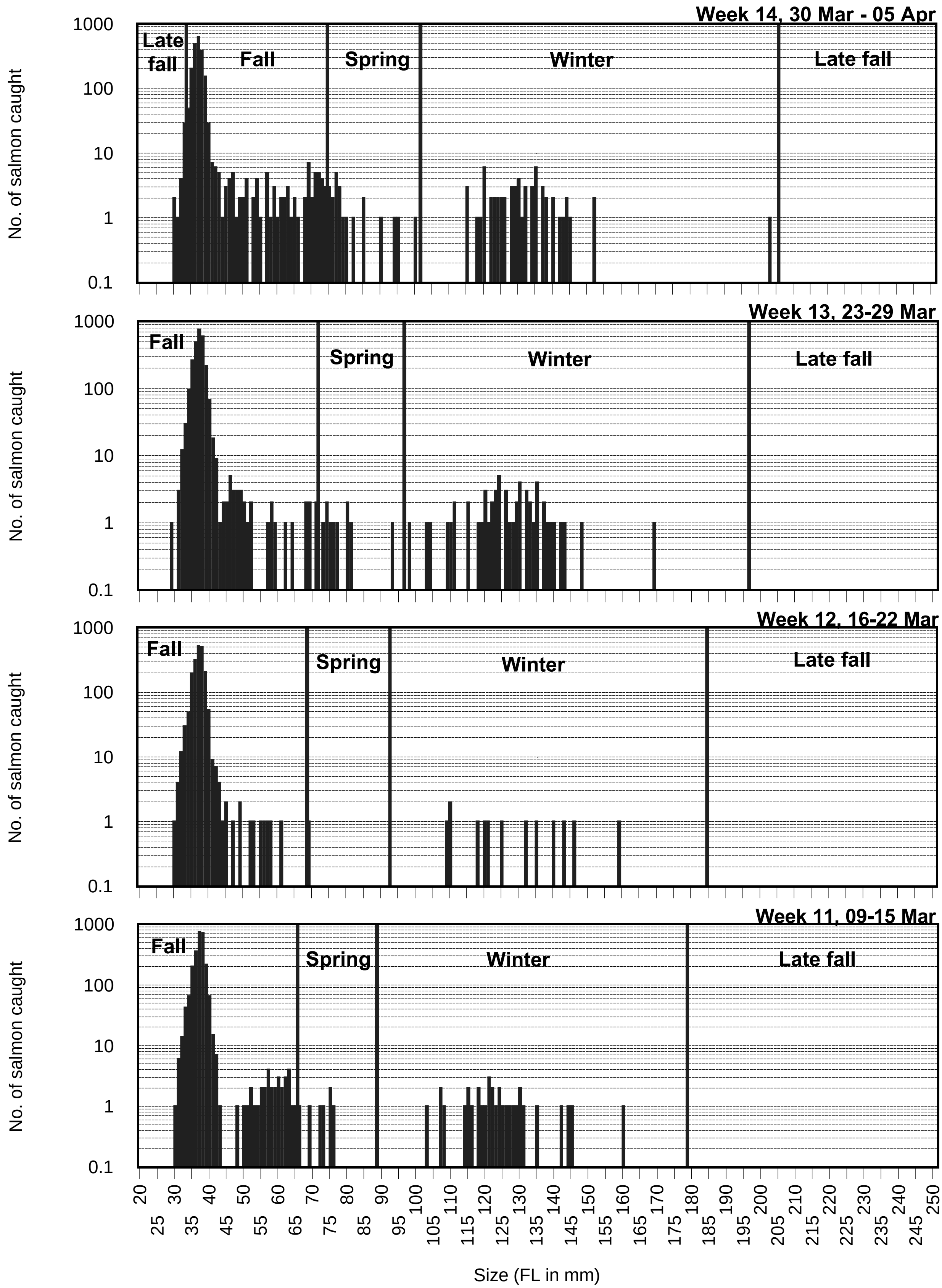
II-4. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 22 December 1996 - 08 February 1997.



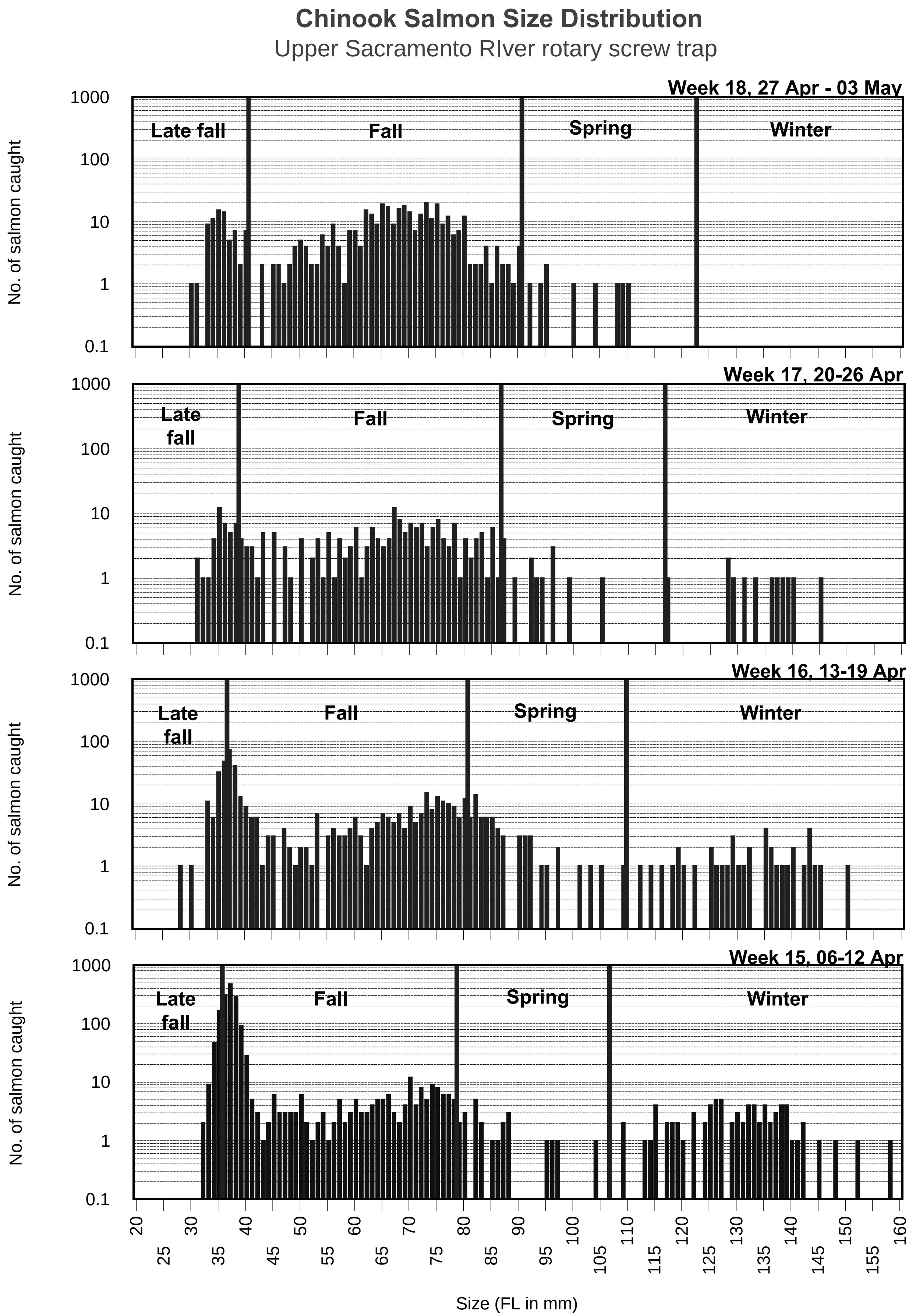
II-5. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 09 February - 08 March 1997.

Chinook Salmon Size Distribution

Upper Sacramento RIver rotary screw trap



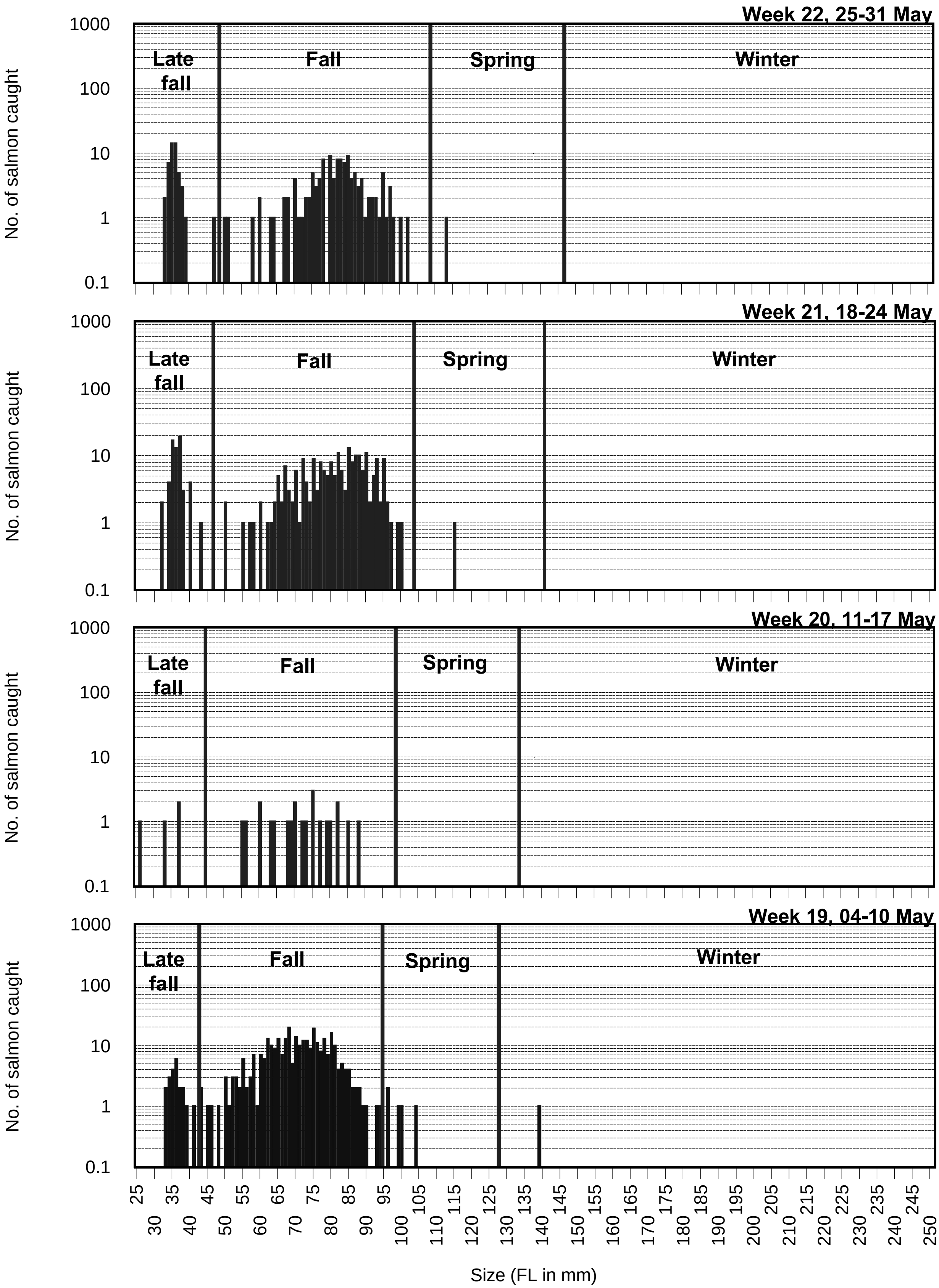
II-6. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 09 March - 05 April 1997.



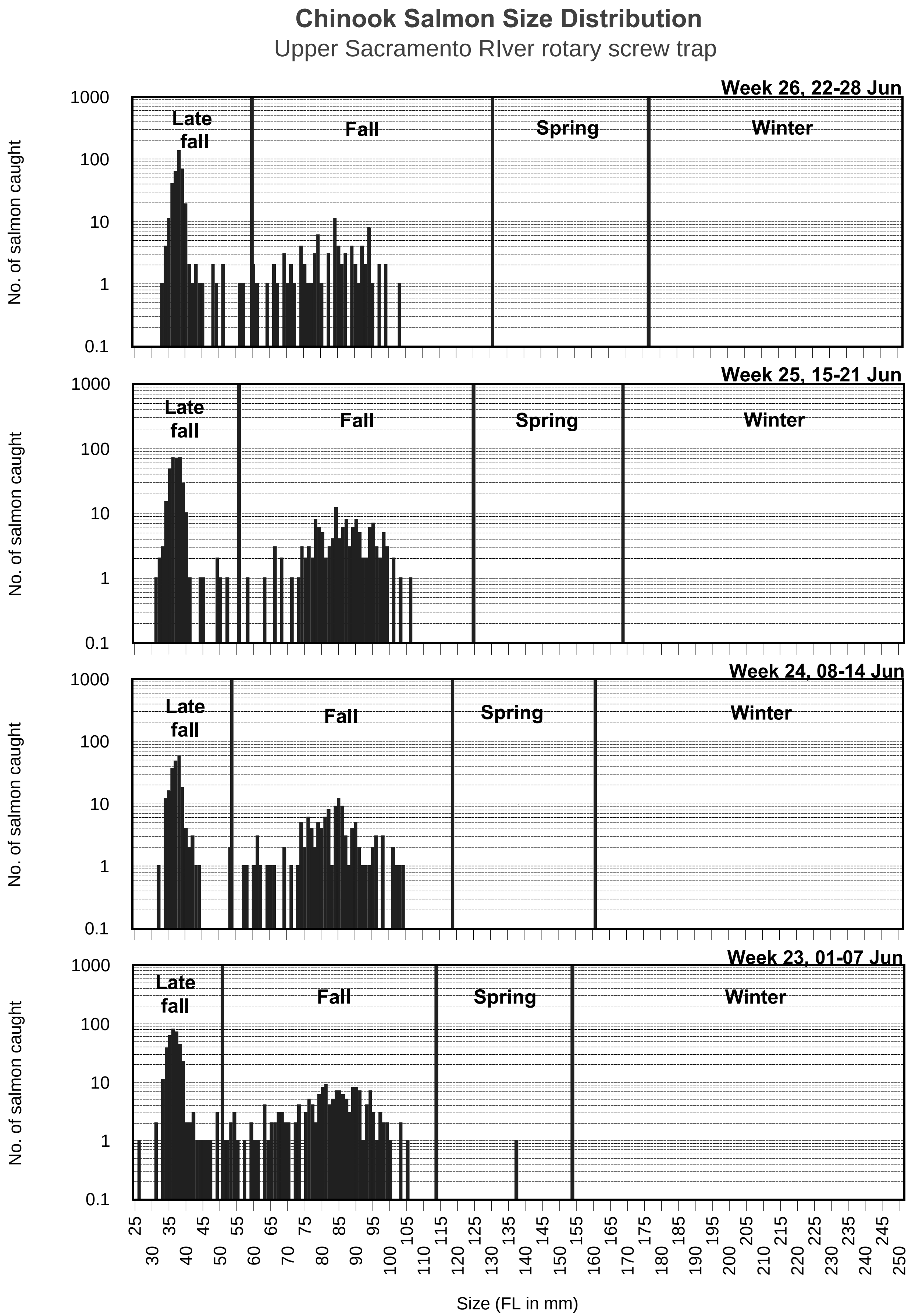
II-7. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 06 April - 03 May 1997.

Chinook Salmon Size Distribution

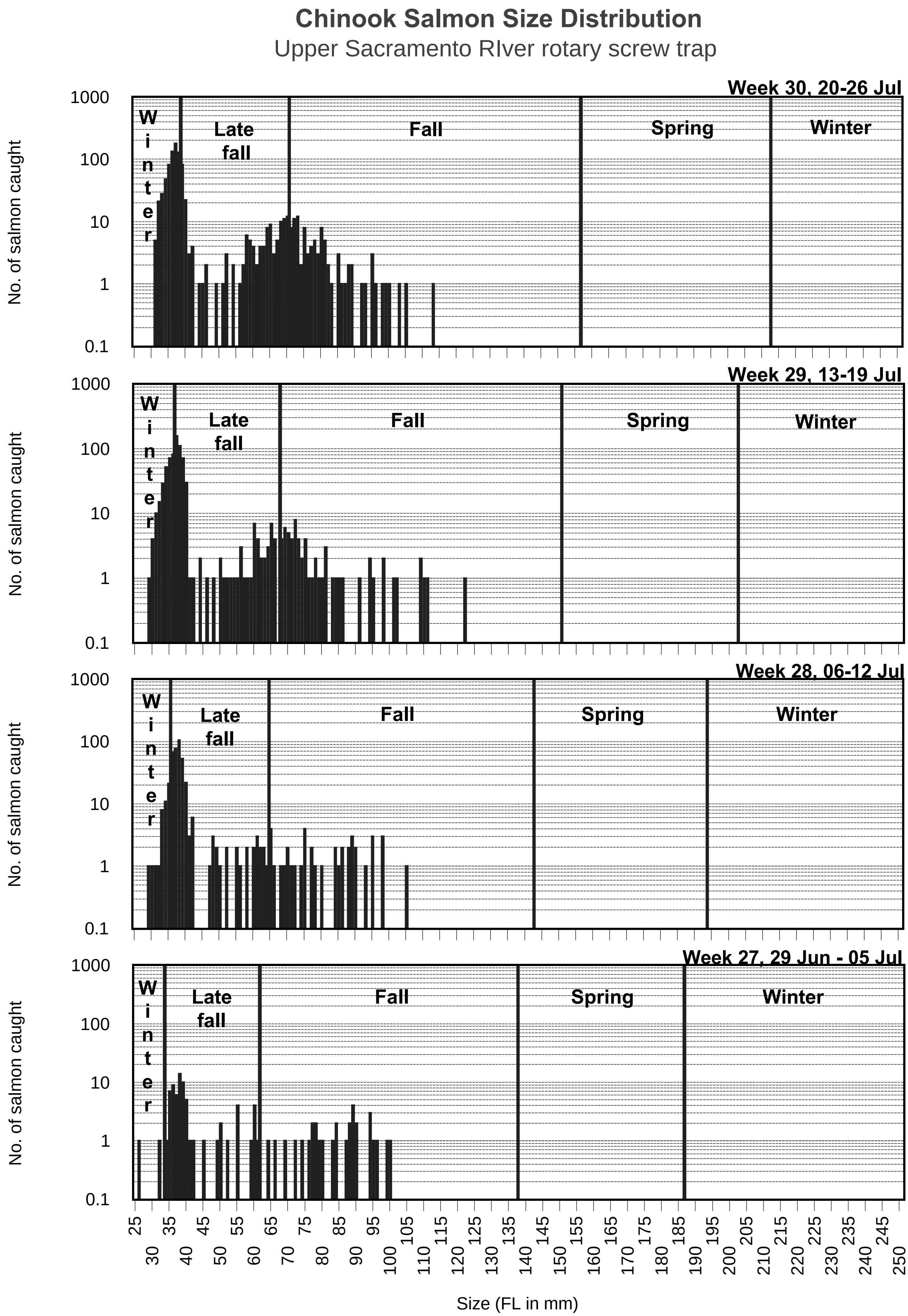
Upper Sacramento RIver rotary screw trap



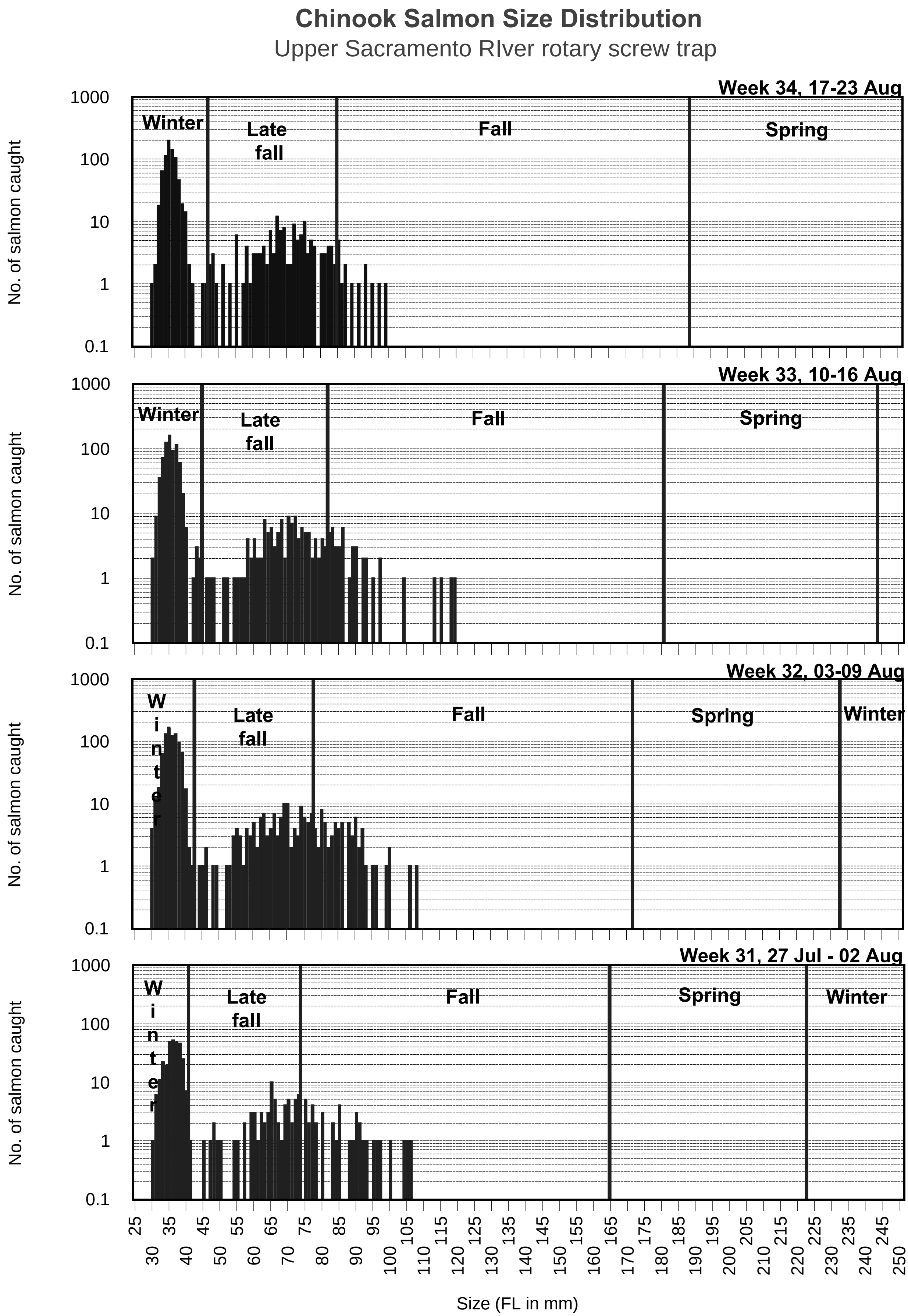
II-8. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 04-31 May 1997.



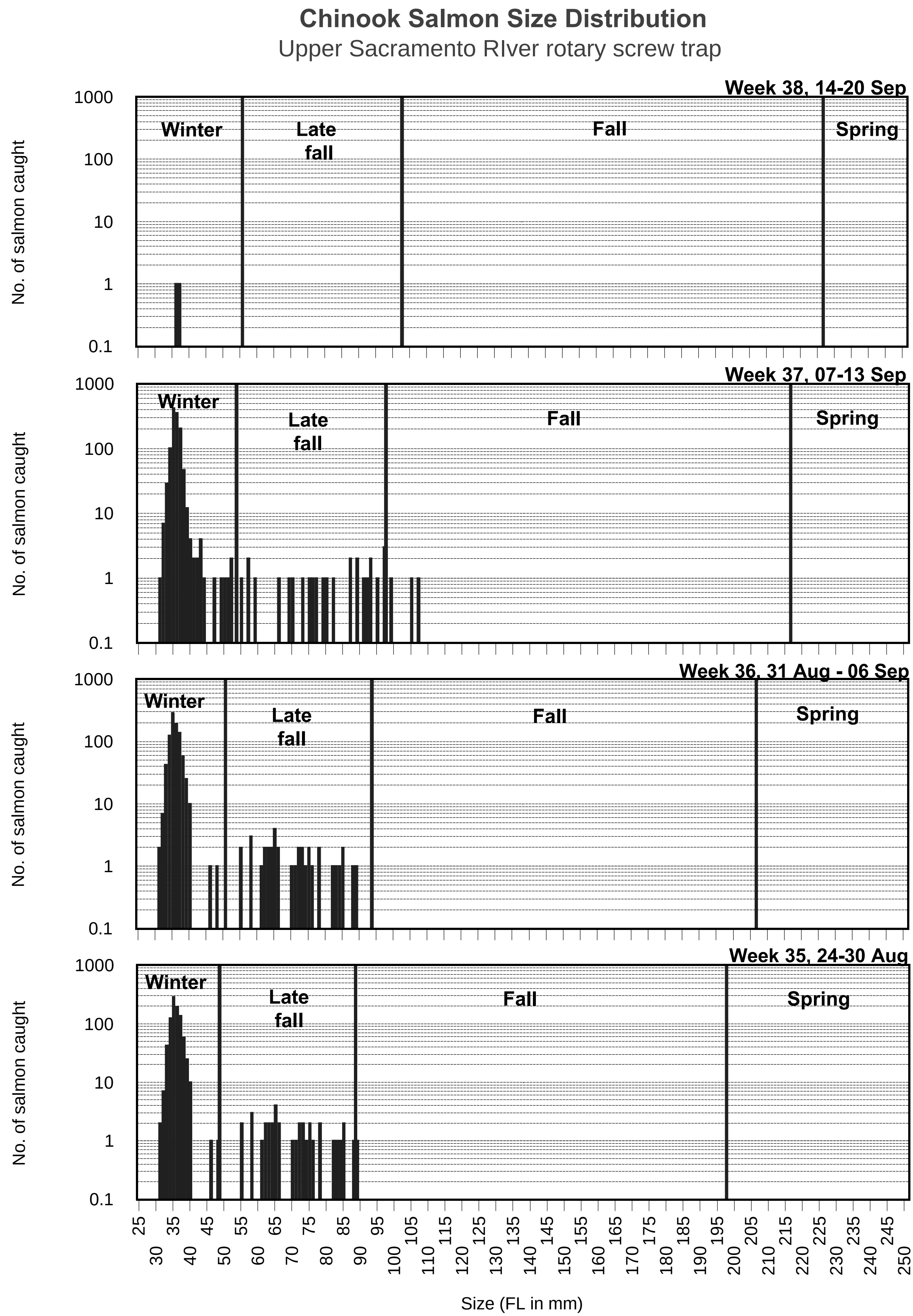
II-9. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 01-28 June 1997.



II-10. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 29 June - 26 July 1997.



II-11. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 27 July - 23 August 1997.



II-12. Size distribution of chinook salmon caught by rotary screw traps in the upper Sacramento River, 24 August - 20 September 1997.

APPENDIX III

Upper Sacramento River Fall-Run Chinook Salmon Escapement Survey
September - December 1996

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

1996 Upper Sacramento River Fall-Run Chinook Salmon Escapement Survey September - December 1996[1/,2/]

by

Bill Snider
Bob Reavis
and
Scott Hill

October 1997

1/ This work was supported by funding provided by U.S. Fish and Wildlife, Service Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of fish and Game pursuant to the Central Valley Project Improvement Act (P.L. 102-575).

2/ Stream Evaluation Program Technical Report No. 97-4.

SUMMARY

A fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during fall-winter 1996 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the second consecutive year a fall-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system (Snider and Reavis 1997).

The survey was conducted from 30 September through 19 December 1996. It included 25.5 miles of the Sacramento River, from Cottonwood Creek to Anderson-Cottonwood Irrigation District (ACID) dam located just 3.5 miles downstream of Keswick dam (the upstream limit to migration). Flow varied from 7,500 cubic feet per second (cfs) during survey week 1 (30 September - 3 October 1996), 6,700 cfs in survey week 2 (7-10 October 1996), 5,300 during survey weeks 3 through 10 (15 October-5 December 1996), 27,700 cfs in survey week 11 (9-13 December 1996), and 19,100 cfs in survey week 12 (16-19 December 1996). Mean weekly water temperature ranged from 56^{o} F during the first weeks of spawning to 53^{o} F by the end of the survey.

We collected 7,534 fall run carcasses (fresh and decayed) of which 1,192 were measured (fresh). Based upon the measured carcasses, 79% were adult salmon and 21% were grilse (two-year-old salmon); 27% were adult males, 52% were adult females, 19% were male grilse and 2% were female grilse (46% male; 54% female). Carcasses were observed during every week of the survey. Peak carcass recovery occurred during weeks 3 through 5 (15 October 1996-1 November 1996) which indicated that peak spawning likely occurred from 1 through 23 October 1996.

We examined 632 females for egg retention. Of these, 552 (87%) had completely spawned and 80 (13%) still contained a substantial number of eggs.

The spawner population was estimated using two different mark-recapture models, the Schaefer and Jolly-Seber models. Per the Schaefer model, 1,001 fresh carcasses were marked and 322 (32%) were subsequently recaptured yielding an estimate of 25,890 total salmon (20,453 adult and 5,437 grilse). Per the Jolly-Seber model, 5,316 fresh and decayed carcasses were marked and 1,379 (26%) were subsequently recaptured yielding an estimate of 20,544 total salmon (16,320 adults and 4,314 grilse). Both estimates are considerably less than the mean annual fall-run chinook salmon escapement estimate (68,724 grilse and adult) for 1956 through 1996.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Evaluation Program (STEP) conducted an intensive fall-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey on the upper Sacramento River during the fall of 1996 to estimate spawner abundance and distribution. This survey was carried out to fulfill the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, which requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with the DFG. In response to this Act, the FWS and the DFG have signed a "Cooperative Agreement" by which the FWS will fund the DFG to conduct studies to determine flow needs of salmon in the upper Sacramento River.

The primary charge of the STEP - to improve understanding of the relationships between salmon and habitat in the upper Sacramento River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and spatial spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, Snider and Vyverberg 1995). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. Spawning density, redd superimposition, habitat use, and other parameters can be affected by both changes in habitat conditions (flow dependent) and spawner population size. A reliable population estimate developed concurrently with redd surveys allows this distinction. An intensive spawning escapement survey also provides additional baseline information on egg retention (pre-spawning mortality), age and sex composition, and behavior relative to habitat conditions and population size.

Carcass tag-and-recapture surveys have been regularly used to estimate salmon spawner escapements in Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). During these surveys, carcasses are tagged and released into running water for recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). This is the second year a carcass tag-and-recapture survey was conducted in the upper Sacramento River; the first recapture survey was conducted in fall 1995 (Snider and Reavis 1997).

Three models have been used by the DFG to estimate escapement using carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for tributary streams with typically small spawner populations (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. Based on Law's (1994) analysis, the Schaefer model will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis, the Jolly-Seber model will slightly underestimate Central Valley spawner escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are $\geq$10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.). Law (1994) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

Historical Background

The history of efforts to enumerate spawner escapement in the upper Sacramento River has been described by Needham *et. al*. (1943), Fry (1961), Menchen (1970), and Snider and Reavis (1997); therefore, it is only briefly reviewed here.

- 1937-1942 Spawner escapement estimates were first made by counting salmon moving through the fish ladder at the ACID dam at river mile (RM) 298.5, near Redding. Annual counts were normally made from April through October or early November, when the dam was installed for irrigation.

- 1943-1945 Salmon were counted at a weir located near Balls Ferry Bridge (RM 278.5).

- 1945-1952, The FWS estimated escapement using "ground level spawning area surveys" (Fry 1961).

- 1950-1955 The DFG estimated spawner escapement using salmon that were captured, tagged and released at Fremont Weir (RM 82.5) then recovered on the spawning grounds in the upper Sacramento River (Fry 1961).

- 1956-1968 The DFG estimated escapement using carcass counts and aerial redd counts. Experienced personnel estimated the proportion of salmon observed, based upon survey conditions and previous years' experience and expanded the “counts” accordingly.

- 1969-1985 Estimates were based on season-long counts of salmon moving through the fish ladders at Red Bluff Diversion Dam (RBDD) (RM 243). Aerial redd counts were used to determine the proportions of the run spawning above and below RBDD.

■1986 - present   The DFG's Inland Fisheries Division (IFD) annually estimates fall-run escapement using both counts made at RBDD and aerial redd surveys. The dam's gates are now typically open between mid-September and mid-May of the following year improving fish passage but eliminating direct counts at the ladders during up to eight months of the year. The number of fall-run spawners migrating upstream of RBDD is now based upon an expansion of the number of fish counted when the gates are lowered and fish are forced to migrate through fish ladders passing over the diversion.

When monitoring stocks over a long period, as is the case for the Central Valley salmon escapement surveys, the sampling design should assure the data be collected in a consistent manner and represent the population as a whole (Ney 1993). Lack of these attributes from the Central Valley surveys should not reflect on persons who made population estimates, but on logistic limitations. Annual budgets for temporary employees needed to conduct the escapement surveys were often reduced or eliminated resulting in estimates based on less data. In addition, population estimates were often based on counts made upstream of substantial areas of fall run spawning activity, e.g., ACID dam, Balls Ferry, and RBDD.

Objectives

The objectives of the 1996 upper Sacramento River fall-run chinook salmon escapement survey were:

- To estimate the 1996, in-river, fall-run chinook salmon spawning population for the upper Sacramento River upstream of Cottonwood Creek.

- To evaluate egg-retention, sex and age composition of fall-run chinook salmon spawning in the upper Sacramento River.

- To augment redd surveys to provide baseline information on spawning distribution, spawning habitat availability, instream flow requirements, and the status of chinook salmon in the upper Sacramento River.

METHODS

The 1996 spawner escapement surveys began immediately following the initial observation of spawning activity and then were conducted weekly from 30 September through 19 December 1996. The 25.5-mile-long stream segment from ACID dam (RM 298.5) downstream to the mouth of Cottonwood Creek (RM 273.0; Figure 1) was divided into four reaches (Table 1); each reach was surveyed one day per week.

Table 1. Location of survey reaches during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1996.

Reach	Location	River mile
1	ACID Dam to Cypress St. Bridge	298.5 - 295.0
2	Cypress St. Bridge to Bonnyview Bridge	295.0 - 292.0
3	Bonnyview Bridge to North St. Bridge	292.0 - 284.0
4	North St. Bridge to Cottonwood Bridge	284.0 - 273.0

Surveys were primarily conducted using two boats with two observers per boat. The observers attempted to locate and collect carcasses as each boat traversed the river between the center of the channel and one of the channel margins. Collected carcasses were checked for completeness (i.e., with the head intact) and previous tags. Complete, untagged carcasses were usually tagged using color-coded hog-rings to distinguish the week of tagging. Carcasses that were not tagged were chopped in half. Chopped carcasses included: I) those previously tagged, ii) those on shore in a "leathery condition"; iii) those in Reach 4 (the most downstream reach) that would likely wash out of the survey area and never be recovered; and, iv) carcasses in excess of the number that crews could tag during a day. Tagged carcasses were released into running water for recapture. Data acquired weekly for estimating population size included number tagged, number chopped, and number recovered (by week of tagging).

All carcasses were also examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or gills were pink. Data collected from a subsample of the fresh carcasses included gender, fork length (FL) in centimeters, reach of the stream that each carcass was observed, and egg retention for females. Females were classified as spent if few eggs were remaining, partially spent if more than 50% of the eggs remained, and unspent if the ovaries were nearly full of eggs.

To be consistent with the standard protocol that has been used on most Central Valley streams, escapement estimates were determined using fresh carcass data to calculate a Schaefer model estimate, and both fresh and decayed carcass data to calculate a Jolly-Seber model estimate.

The formulas used to derive the escapement estimates (E) are as follows:

Schaefer model: $E = N_{ij} = R_{ij}(T_iC_j/R_iR_j) - T_i$

where:

N_{ij} = Population size in tagging period *I* recovery period *j*,
R_{ij} = number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
T_i = number of carcasses tagged in the *i*th tagging period,
C_j = number of carcasses recovered and examined in the *j*th recovery period,
R_i = total recaptures of carcasses tagged in the *i*th tagging period, and
R_j = total recaptures of tagged carcasses in the *j*th recovery period.

This model differs from the original in that the number of tags applied after the first week is subtracted from the population estimate to account for sampling with replacement. Schaefer's original model was based on sampling without replacement while in salmon survey conditions, sampling occurs with replacement.

Jolly-Seber model: $E = N_1 + D_1 + D_2 ... + D_j$

where:

N_1 = Number of carcasses in the population in period 1, the first period of spawning and dying, and
D_i = number of carcasses that joined the population between periods *I* and *I*+1, with j as the last survey period.

Calculation of the basic quantities used in the Jolly-Seber model has been described in detail by Boydstun (1994).

Flow measurements for each day surveyed were obtained from the Keswick gauge operated by the US Geological Survey. Water temperature (grab sample) and water visibility (Secchi depth) were measured daily by the survey crew.

RESULTS AND DISCUSSION

A total of 7,534 carcasses was observed (Table 2). Flow averaged 7,500 cubic feet per second (cfs) during the first week, 6,700 cfs during the second week, 5,300 cfs during weeks 3 though 10, 27,700 cfs during week 11, and 19,100 cfs during week 12 (Table 2, Figure 2). Average weekly temperature ranged from 53 /F during weeks 10 and 12 to 56 /F during weeks 1, 2, 5, 6, 7, and 8 (Table 2, Figure 2). Water clarity (Secchi depth) was generally high. It exceeded 10 ft until late in the survey when flow increased (Table 2, Figure 2)
.

Temporal Distribution

The number of carcasses observed increased steadily from week 1 through 5 (September 30 - November 1), and then declined thereafter (Table 2 and Figure 3).

Spatial Distribution

The distribution of the total carcasses observed per reach was 23% in Reach 1, 37% in Reach 2, 26% in Reach 3, and 14% in Reach 4 (Table 3 and Figure 4).

Size Distribution

A total of 1,192 carcasses was measured (Table 4). Mean adult size was 80.7 cm FL. Size ranged from 36 to 113 cm FL. Male salmon (n = 553) averaged 78.5 cm FL (range: 36 - 113 cm FL) (Figure 5). Female salmon (n = 639) averaged 82.6 cm FL (range: 45 - 107 cm FL) (Figure 6). The weekly mean size for males ranged from 52.0 to 91.4 cm FL (Figure 7). Weekly mean size for females ranged from 80.3 to 87.0 cm FL (Table 4 and Figure 8).

Length-frequency distributions were used to define a general size criterion distinguishing grilse (2-year-old salmon) and adults (>2-year-old salmon) for each sex (Figures 5 and 6). Male (n = 230) grilse were defined as salmon ≤73 cm FL, and female grilse (n = 21) were defined as salmon ≤64 cm FL (Table 5). Male grilse averaged 57.3 cm FL (range: 36 - 73 cm FL, SD=7.4); male adults (n=323) averaged 93.5 cm FL (range: 74 - 113 cm FL, SD=7.9). Female grilse averaged 56.3 cm FL (range: 45 - 64 cm FL, SD=5.3); female adults (n = 618) averaged 83.5 FL (range: 65 - 107 cm FL, SD=6.9).

Grilse comprised 251 (21%) of the 1,192 measured carcasses (Table 6). The greatest number of grilse (63) was observed in the fourth week (October 21-24) (Figure 9). Adults comprised 941 (79%) of the measured carcasses. The greatest number of adults (198) was also observed during week 4.

Table 2. General survey information for the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1996.

Week	Dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (^{O}F)[2/]	Carcass count[3/]	
					Fresh	Decayed
1	Sep 30 - Oct 3	7,500	11	56	30	24
2	Oct 7 - 10	6,700	14	56	110	102
3	Oct 15 - 18	5,300	13	55	240	409
4	Oct 21 - 24	5,300	14	55	366	949
5	Oct 28 - Nov 1	5,300	12	56	270	1,148
6	Nov 4 - 7	5,300	11	56	180	1,165
7	Nov 12 - 15	5,300	12	56	147	1,014
8	Nov 18 - 21	5,300	4	56	49	281
9	Nov 25 - 27	5,300	10	55	74	442
10	Dec 2 - 5	5,300	9	53	70	420
11	Dec 9 - 13	27,700	3	54	5	7
12	Dec 16 - 19	19,100	6	53	5	27
				Totals	1,546	5,988

1/ Weekly average discharge during days sampled as measured at Keswick Dam by U.S. Bureau of Reclamation.
2/ Weekly average of daily measurements taken by survey crews.
3/ Includes both adults and grilse.

Table 3. Distribution of carcasses (adults and grilse) observed during the upper Sacramento River fall run chinook escapement survey, September - December 1996.

Week	Reach 1		Reach 2		Reach 3		Reach 4	
	M[1/]	C[2/]	M	C	M	C	M	C
1	23	0	13	0	11	2	5	0
2	48	15	57	16	33	12	21	10
3	144	7	128	108	177	17	55	13
4	281	15	489	52	179	148	131	20
5	336	16	312	47	366	86	223	32
6	192	17	500	71	290	31	216	28
7	188	47	393	81	208	65	148	31
8	99	6	92	10	60	21	28	14
9	93	28	147	36	88	32	77	15
10	127	35	172	52	72	23	8	1
11	0	4	0	2	0	2	0	4
12	0	7	0	13	0	8	0	4
Total	1,531	197	2,303	488	1,484	447	912	172

1/ Number of carcasses tagged.
2/ Number of untagged carcasses chopped.

Table 4. Size and sex statistics for fresh fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1996.

Week	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
1	12	91.4	83-101	12	91.4	83-101	0	-	-
2	96	82.9	45-105	41	84.8	45-101	55	81.3	54-99
3	189	81.2	46-107	89	80.6	46-107	100	81.8	51-98
4	261	79.7	36-111	136	77.2	36-111	125	82.5	56-107
5	201	80.0	45-112	80	76.8	45-112	121	83.8	48-98
6	132	79.9	45-105	65	76.7	45-105	67	83.0	54-94
7	145	80.1	40-112	72	79.7	40-112	73	80.4	45-95
8	8	85.1	68-112	2	91.0	70-112	6	84.5	68-94
9	74	83.5	45-110	20	78.4	45-110	54	85.4	63-100
10	67	76.9	47-113	33	70.4	47-113	34	83.2	50-95
11	5	81.0	59-105	2	82.0	59-105	3	80.3	70-87
12	2	69.5	52-87	1	52.0	52.0	1	87.0	87.0
Total (mean)	1,192	(80.7)	36-113	553	(78.5)	36-113	639	(82.6)	45-107

Table 5. Summary of adult and grilse sizes and numbers by sex for carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1996.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	21	618	230	323
Mean FL (cm)	56.3	83.5	57.3	93.5
Range FL (cm)	45-64	65-107	36-73	74-113
Standard Deviation	5.3	6.9	7.4	7.9

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1996.

Week	Adults		Grilse	
	Number	Percent	Number	Percent
1	12	100	0	0
2	86	90	10	10
3	158	84	31	16
4	198	76	63	24
5	158	79	43	21
6	101	77	31	23
7	108	74	37	26
8	7	88	1	12
9	64	86	10	14
10	44	66	23	34
11	4	80	1	24
12	1	50	1	50
Total(mean)	941	(79)	251	(21)

Sex Composition

Males comprised 46% (n = 553) of the fresh carcasses examined; 323 (58%) were adults and 230 (42%) were grilse (Table 7). Females comprised 54% (n = 639) of the fresh carcasses examined, 618 (97%) were adults, and 21 (3%) were grilse.

The female to male ratio for adult spawners was nearly 2:1 (618:323) (Table 7 and Figure 10). Females dominated the adult population throughout the survey period; the grilse population was mostly males (Figure 11). Females comprised 66% of the adult population, and males comprised 92% (230) of the grilse population.

Spawning Success

There were 632 females examined for egg retention (Table 8). Of these, 552 (87%) had completely spawned, 69 (11%) had only partially spawned, and 11 (2%) had not spawned. At least 82% of the females checked per week had completely spawned.

Population Estimates

Fresh carcass data were used to calculate the Schaefer estimate. Both fresh and decayed carcass data were used to calculate the Jolly-Seber estimate. A total of 1,001 fresh carcasses was tagged and 322 (32%) were subsequently recaptured. A total of 5,316 fresh and decayed adult carcasses was tagged, and 1,379 (26%) were subsequently recaptured.

An estimate of 20,453 adult spawners was calculated using the Schaefer model (Tables 9 and 10). Since adults made up 79% of the total escapement based on carcasses measured (Table 6), a total escapement estimate of 25,890 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.79. An adult escapement estimate of 16,230 was calculated using the Jolly-Seber model (Table 11). This estimate was also expanded by dividing by 0.79 resulting in a total escapement estimate of 20,544 spawners.

The population estimates for salmon spawning in the upper Sacramento River from ACID Dam to Cottonwood Creek are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	25,890	20,544
Adult estimate	20,453	16,230
Grilse estimate	5,437	4,314

The 1996 escapement of 25,890 is considerably less than the 1956-1996 average of 68,724 for the section of stream from Keswick Dam to RBDD (Table 12 and Figure 12). Since most fall-run chinook salmon spawn between Cottonwood Creek and ACID dam, with very little spawning taking place upstream of ACID dam, the inclusion of the uppermost 3.5 miles of river (ACID dam to Keswick Dam) would have added little to the survey.

Table 7. Sex composition of fall-run chinook salmon grilse[1/] and adults carcasses measured during the upper Sacramento River escapement survey, September - December 1996.

Week	Adults				Grilse			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
1	12	100	0	0	0	0	0	0
2	32	37	54	63	9	90	1	10
3	60	38	98	62	29	94	2	6
4	76	38	122	62	60	95	3	5
5	43	27	115	73	37	86	6	14
6	34	34	67	66	31	100	0	0
7	41	38	67	62	31	84	6	16
8	1	14	6	86	1	100	0	0
9	11	17	53	86	9	90	1	10
10	12	27	32	73	21	91	2	9
11	1	25	3	75	1	100	0	0
12	0	0	1	100	1	100	0	0
Total (mean)	323	(34)	618	(66)	230	(92)	21	(8)

1/ Based on length-frequency distributions, male grilse are defined as males ≤73 cm FL and female grilse as females ≤64 cm FL.

Table 8. Spawning completion (egg retention) summary for female fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1996.

Week	No. females measured	No. females checked for egg retention	No. spawned (%)	No. partially spawned (%)	Number unspawned (%)
1	0	0	0(0)	0(0)	0(0)
2	55	55	52(95)	3(5)	0(0)
3	100	100	84(84)	12(12)	4(4)
4	125	123	109(89)	13(10)	1 (1)
5	121	119	104(87)	14(12)	1(1)
6	67	66	59(89)	7(11)	0(O)
7	73	72	59(82)	10(14)	3(4)
8	6	6	6(100)	0(0)	0(0)
9	54	53	46(87)	6(11)	1(2)
10	34	34	29(85)	4(12)	1(3)
11	3	3	3(100)	0(0)	0(0)
12	1	1	1 (100)	0(0)	0(0)
Total (mean)	639	632	552(87)	69(11)	11(2)

Table 9. Summary of tagging and recapture of fresh adult fall-run chinook salmon carcasses by week during the upper Sacramento River escapement survey, September - December 1996.

Schaefer model capture-recapture data matrix

Week of recovery $_{(j)}$	Week of tagging $_{(I)}$										Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
	1	2	3	4	5	6	7	8	9	10			
2	3										3	251	83.67
3	1	9									10	584	58.40
4		5	35								40	1,169	29.23
5		4	10	43							69	1,275	18.48
6		1	7	12	55						72	1,229	17.07
7				6	21	35					55	1,014	18.44
8				1	8	4	19				29	356	12.28
9						6	9	6			22	481	21.86
10						1	1	6	14		22	472	21.45
11										0			
12										0			
$R_{(I)}$	4	19	52	84	62	46	29	12	14	0	<- Tagged fish recovered		
$T_{(I)}$	26	57	132	241	191	131	70	73	50	30	<- Total fish recovered		
$T_{(I)}/R_{(I)}$	6.50	3.00	2.54	2.87	3.08	2.85	2.41	6.08	3.57	0.00	<- Ratio		

Table 10. Upper Sacramento River adult fall-run chinook salmon population estimate using the Schaefer model based on tagging fresh carcasses with all captured untagged carcasses removed, September - December 1

Population estimate

Week of recovery (j)	Week of tagging (I)										Totals
	1	2	3	4	5	6	7	8	9	10	
2	1,632										1,632
3	380	1,577									1,956
4		438	2,597								3,035
5		222	469	2,916							3,607
6		51	303	1,028	2,261						3,644
7				423	682	1,838					2,942
8					227	140	563				940
9					67	374	475	789			1,714
10						61	52	783	1,073		1,969
11									0	0	0
12									0	0	0
Subtotal	2,011	2,288	3,369	4,267	3,237	2,412	1,090	1,581	1,073	0	21,428
Tagged		-57	-132	-241	-191	-131	-70	-73	-50	-30	-975
								Population estimate -			20,453

Table 11. Summary of tagging and recapture of fresh and decayed carcasses by week during the upper Sacramento River escapement survey, September - December, 1996.

Jolly-Seber capture-recapture data matrix

Week of recovery (j)	Week of tagging (I)										Tags recovered $R_{(j)}$	Total fish recovered $C_{(j)}$
	1	2	3	4	5	6	7	8	9	10		
2	8										8	256*
3	3	18									21	595
4	1	12	114								127	1,256
5	1	4	29	198							232	1,427
6		1	9	89	288						387	1,544
7				17	57	224					298	1,257
8					11	17	76				104	395
9					1	10	51	28			90	549
10						1	4	21	82		108	503
11								1	1	1	3	13
12										1	1	25
$R_{(j)}$	13	35	152	304	357	252	131	50	83	2		
$M_{(j)}$	49	144	436	937	1,053	1,026	766	247	355	303		

* Includes carcasses observed during first week of tagging

Table 12. Annual fall-run chinook salmon escapement estimates (adults and grilse) for upper Sacramento River from Keswick Dam to Red Bluff Diversion Dam, 1956 - 1995. (Data for years prior to 1995 provided by Frank Fisher, DFG, Red Bluff).

Year	Total	Year	Total
1956	84,716	1976	43,612
1957	47,300	1977	15,784
1958	99,300	1978	32,235
1959	249,600	1979	47,758
1960	210,000	1980	21,961
1961	134,700	1981	26,261
1962	115,500	1982	17,731
1963	135,200	1983	26,226
1964	140,500	1984	36,898
1965	98,900	1985	51,647
1966	107,900	1986	67,958
1967	78,100	1987	76,039
1968	95,600	1988	65,204
1969	114,600	1989	48,512
1970	65,950	1990	32,225
1971	52,247	1991	19,272
1972	33,559	1992	26,912
1973	40,424	1993	33,923
1974	45,590	1994	31,017
1975	52,248	1995	26,548

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LITERATURE CITED

Boydstun, L.B. 1994. Evaluation of the Schaefer and Jolly-Seber methods for the fall-run chinook salmon, *Oncorhynchus tshawytscha,* spawning run into Bogus Creek, Upper Klamath River, Calif. Fish & Game 80(1):1-13.

Fry, D.H., 1961. King salmon spawning stocks of California Central Valley, 1940-1959. Calif. Fish & Game, 47(1):55-71.

Law, P.M.W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif. Fish & Game 80(1):14-28.

Menchen, R.S. (Editor). 1970. King (chinook) salmon spawning stocks in California's Central Valley, 1969. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 70-14, 26 p.

Ney, J.J. 1993. Practical Use of biological statistic, *in* Kohler and Hubert (Editors). 1993. Inland fisheries management in North American. American Fisheries Society. Bethesda, Maryland. pp 137-158.

Needham, P.R., H.A. Hanson, and L.P. Parker. 1943. Supplementary Report on investigations of fish-salvage problems in relation to Shasta Dam. Special Scientific Rpt. No. 26, U.S. Dept. of Interior, USF&WS, 150 p.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dep of Environ., Fish. And Mar. Serv. Bull.191. 382 p.

Schaefer, M.B. 1951. Estimation of the size of animal population by marking experiments. USF&WS Bull. 52:189-203.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. 2nd. MacMillan, New York, N.Y. 654 p.

Snider, B. and D. McEwan. 1992. Chinook salmon and steelhead trout redd survey: Lower American River, 1991 - 1992, Final report. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow and Habitat Evaluation Program.

Snider, B. and B. Reavis. 1997. Upper Sacramento River fall-run chinook salmon escapement survey, September - December 1995. Final report. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow and Habitat Evaluation Program.

Snider, B., K. Urquhart, D. McEwan, and M. Munos. 1993. Chinook salmon redd survey, lower American River, Fall 1992. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow & Habitat Evaluation Program.

Snider, B. And K. Vyverberg. 1995. Chinook salmon redd survey, lower American River, Fall, 1993. Calif. Dept. Fish & Game, Envir. Serv. Div., Stream Flow & Habitat Evaluation Program.

Taylor, S.N. (Editor). 1974. King (chinook) salmon spawning stocks in California's Central Valley, 1973. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 74-12. 32 p.

FIGURES

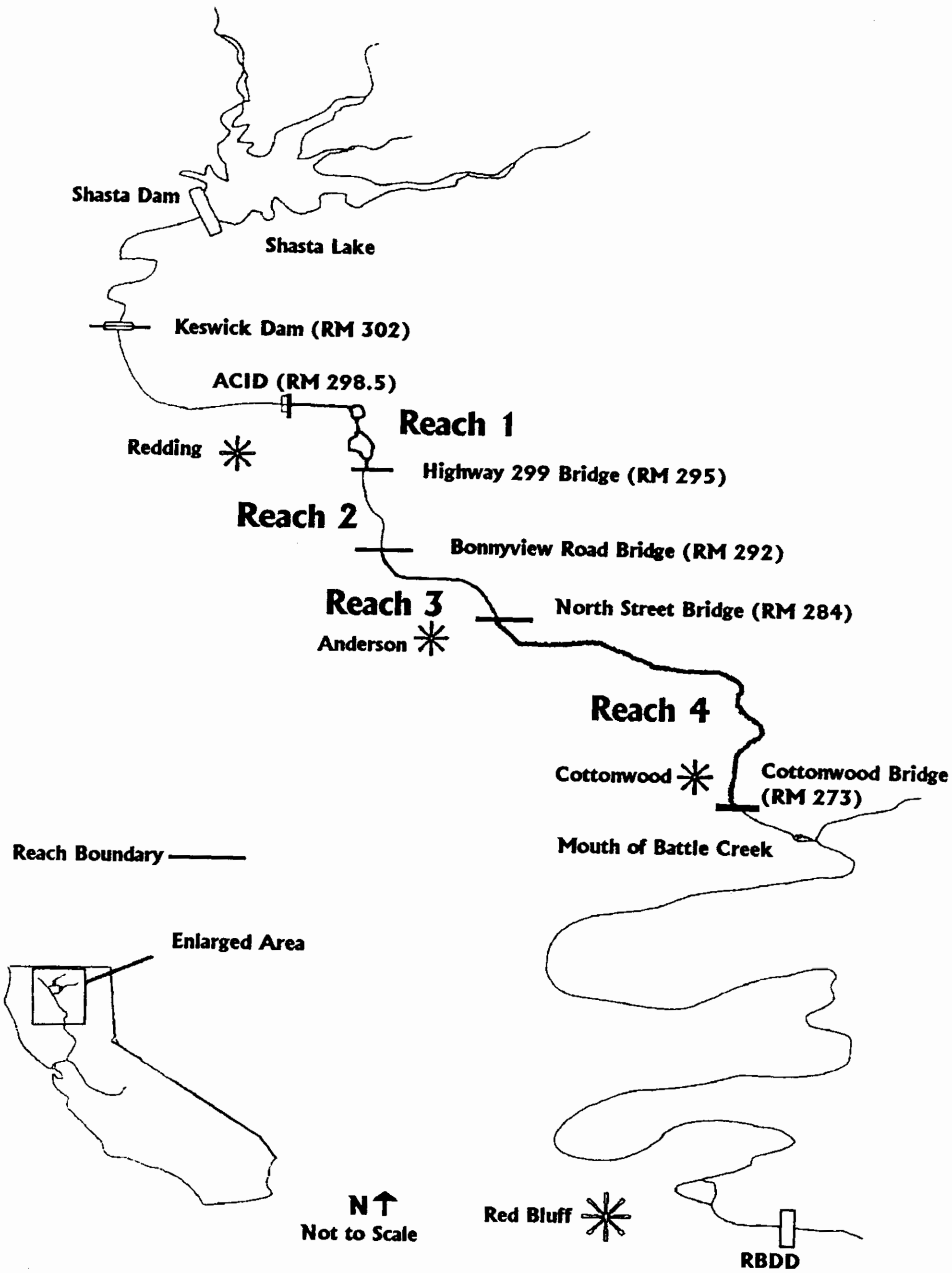

Figure 1. Upper Sacramento River fall-run chinook salmon escapement study location including reach designations, September - December, 1996.

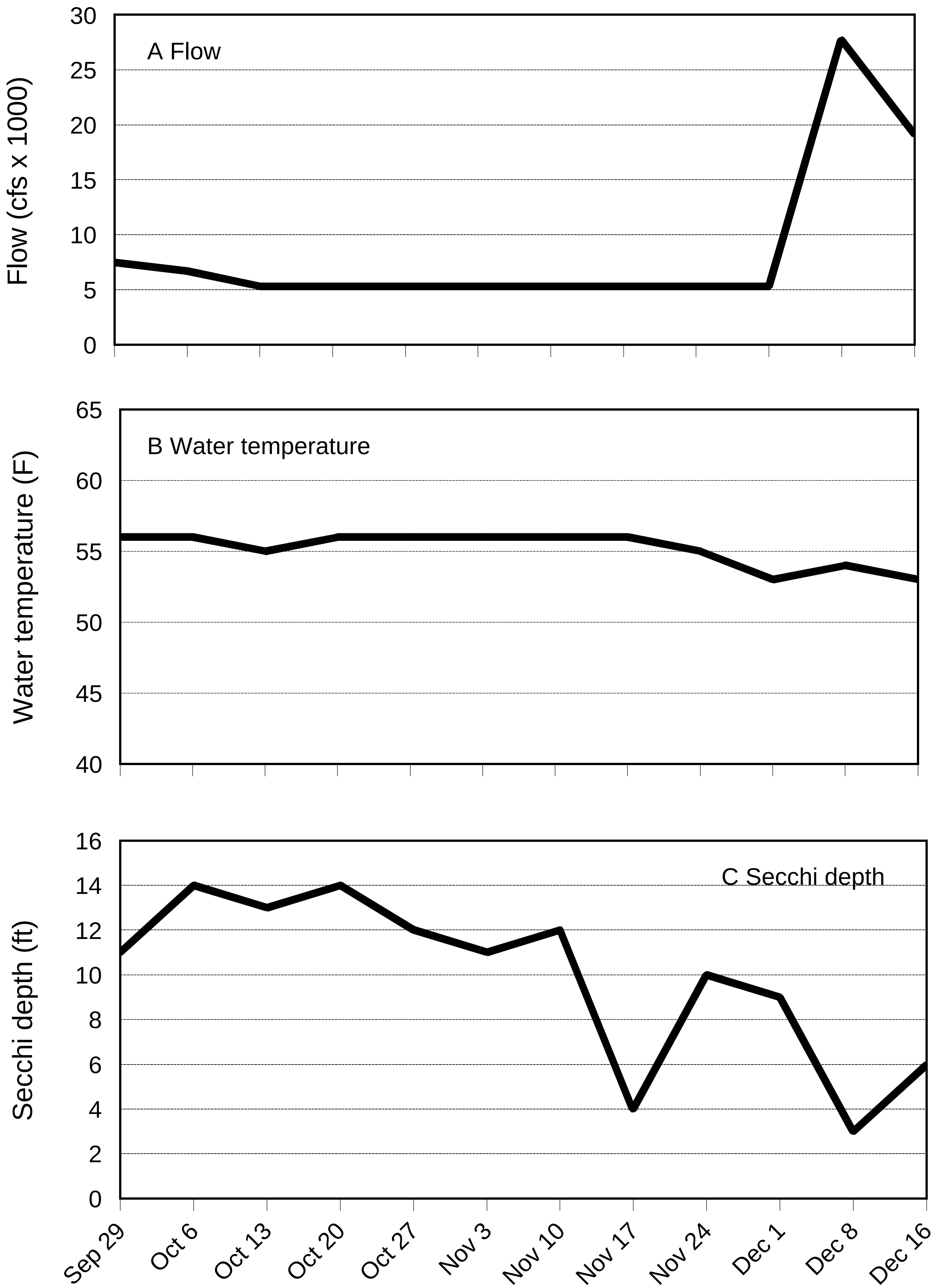

Figure 2. Mean daily flow (A) measured at Keswick Dam, water temperature (B) and secchi depth (C) during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1996.

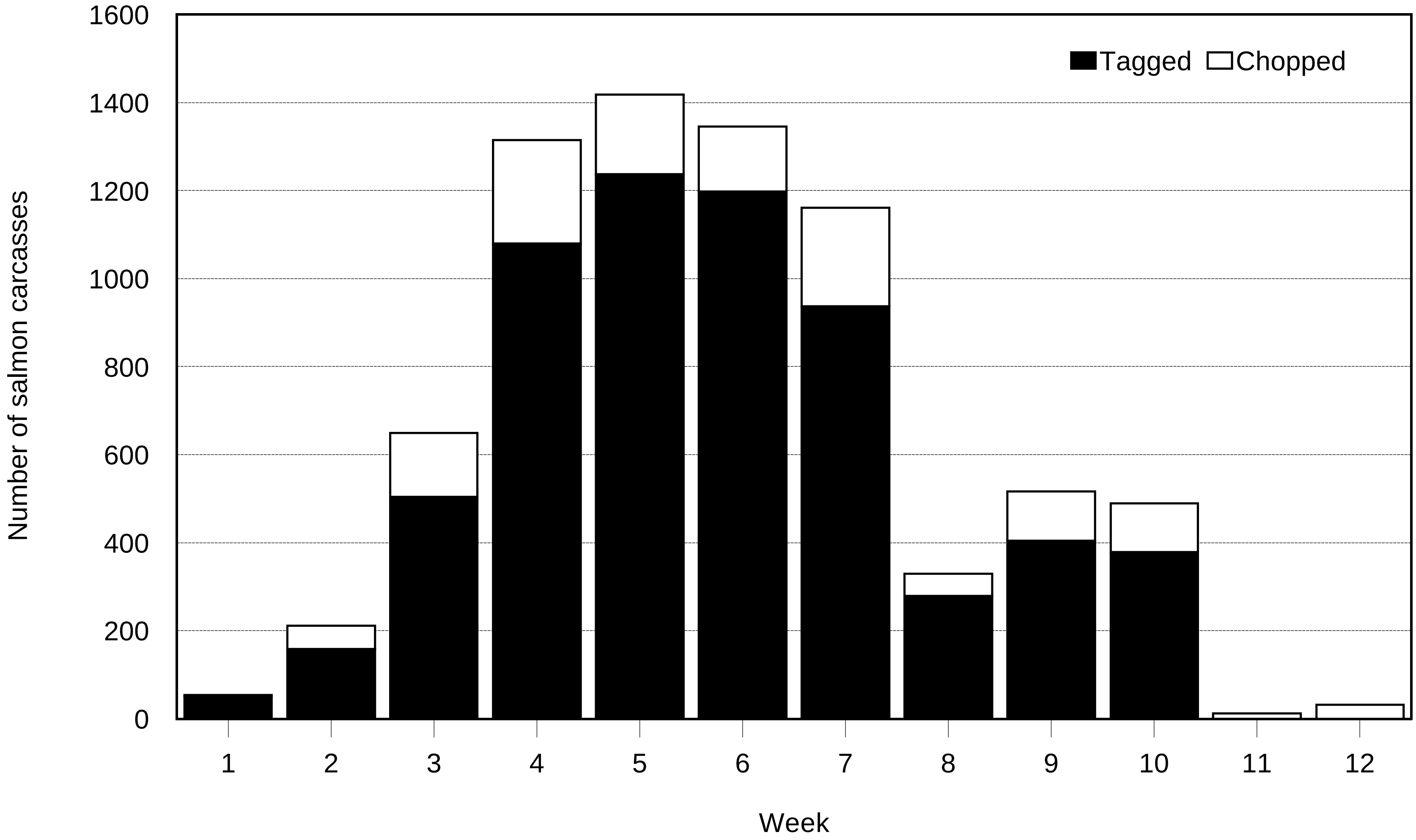

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1996.

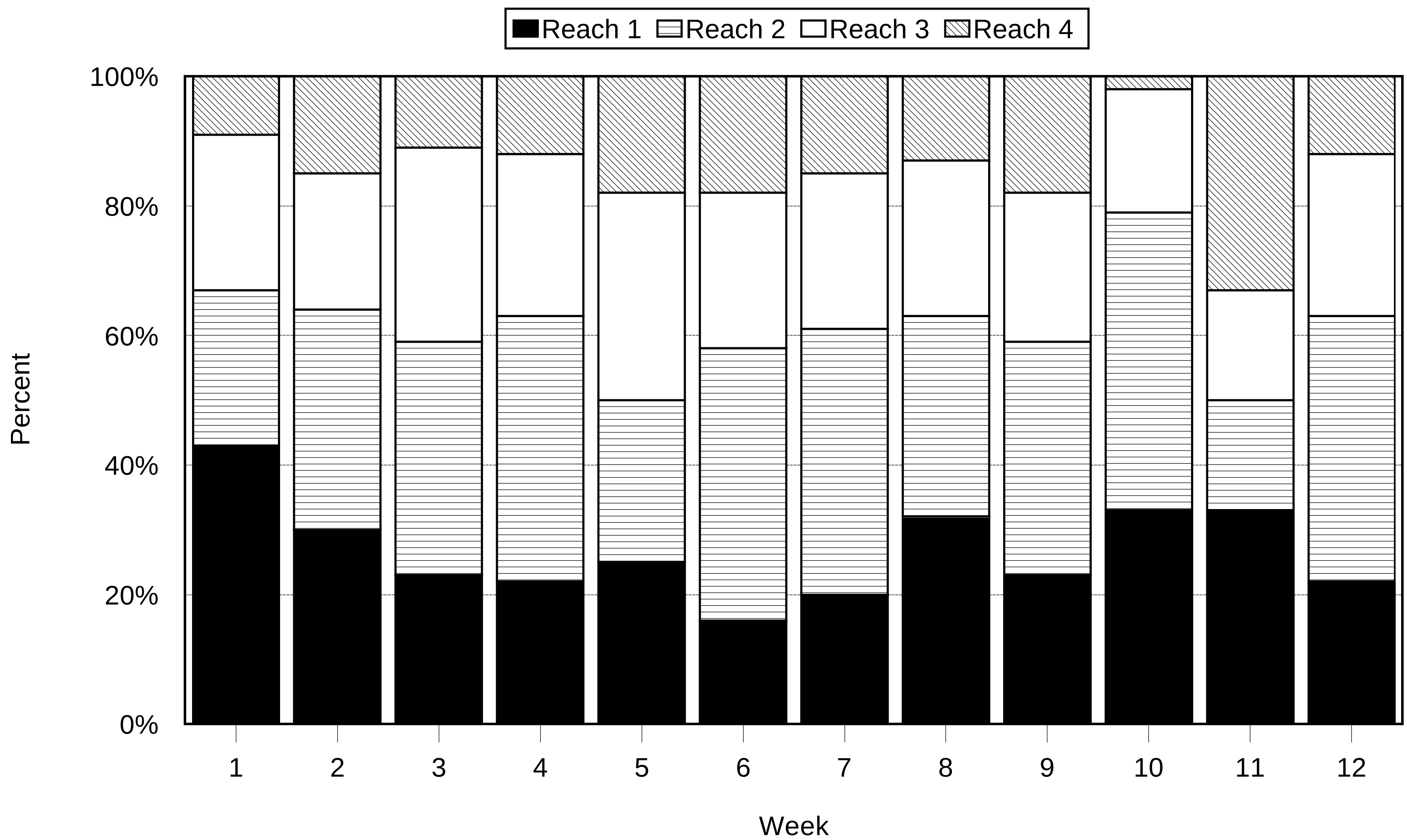

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1996.

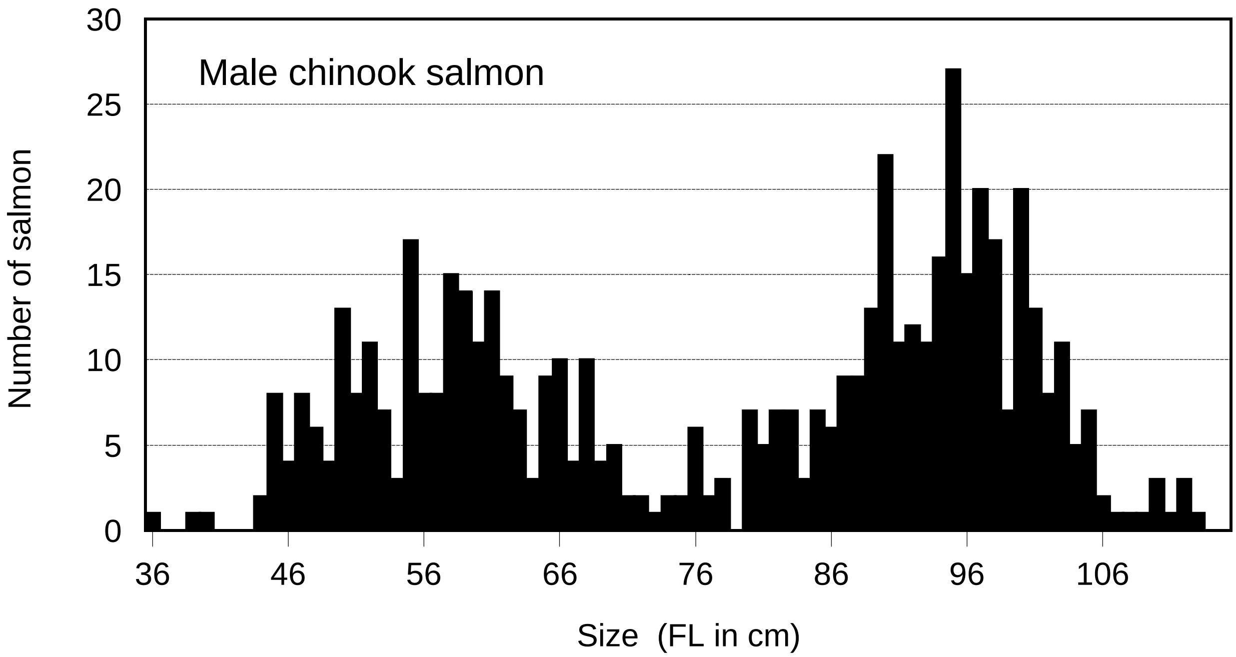

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1996.

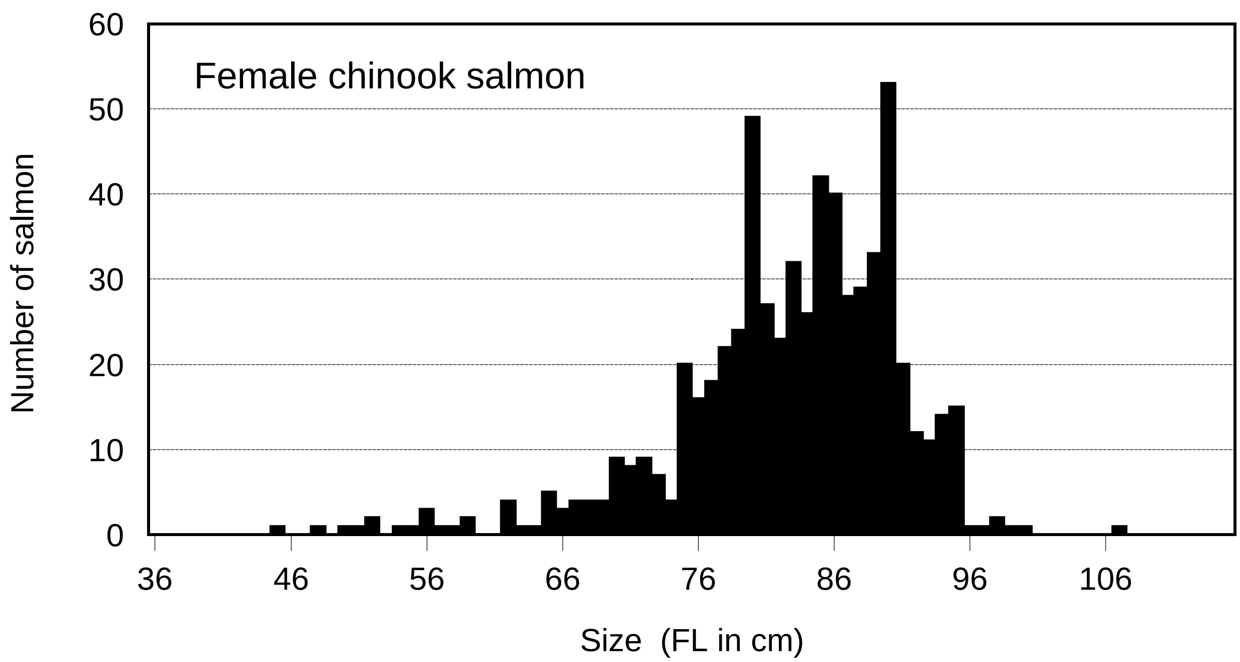

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1996.

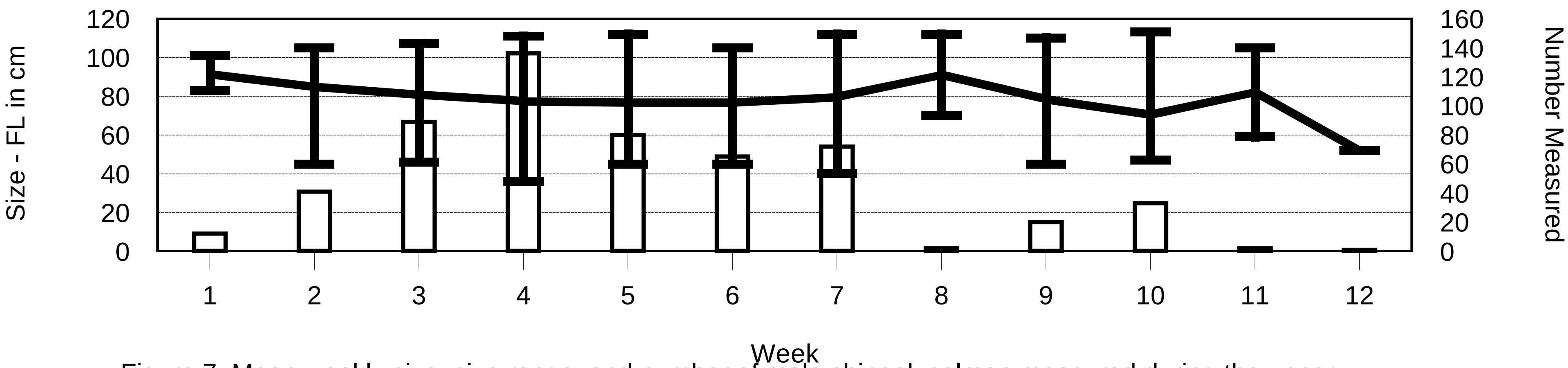

Figure 7. Mean weekly size, size range, and number of male chinook salmon measured during the upper Sacramento River spawner escapement survey, September - December 1996.

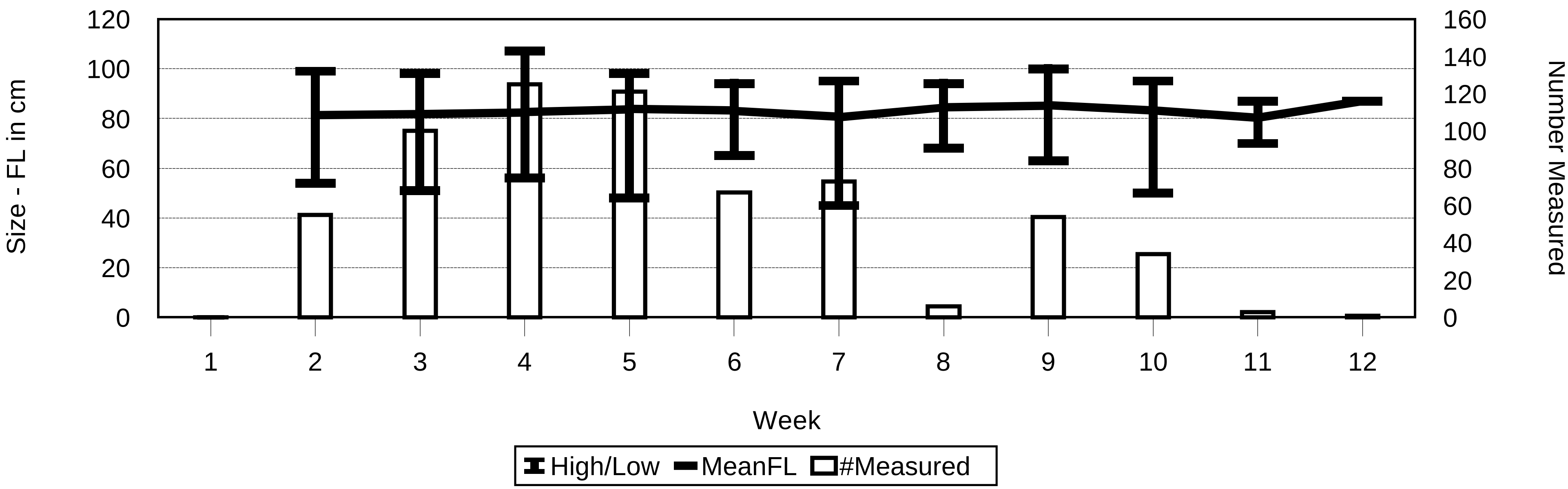

Figure 8. Mean weekly size, size range, and number of female chinook salmon measured during the upper Sacramento River spawner escapement survey, September - December 1996.

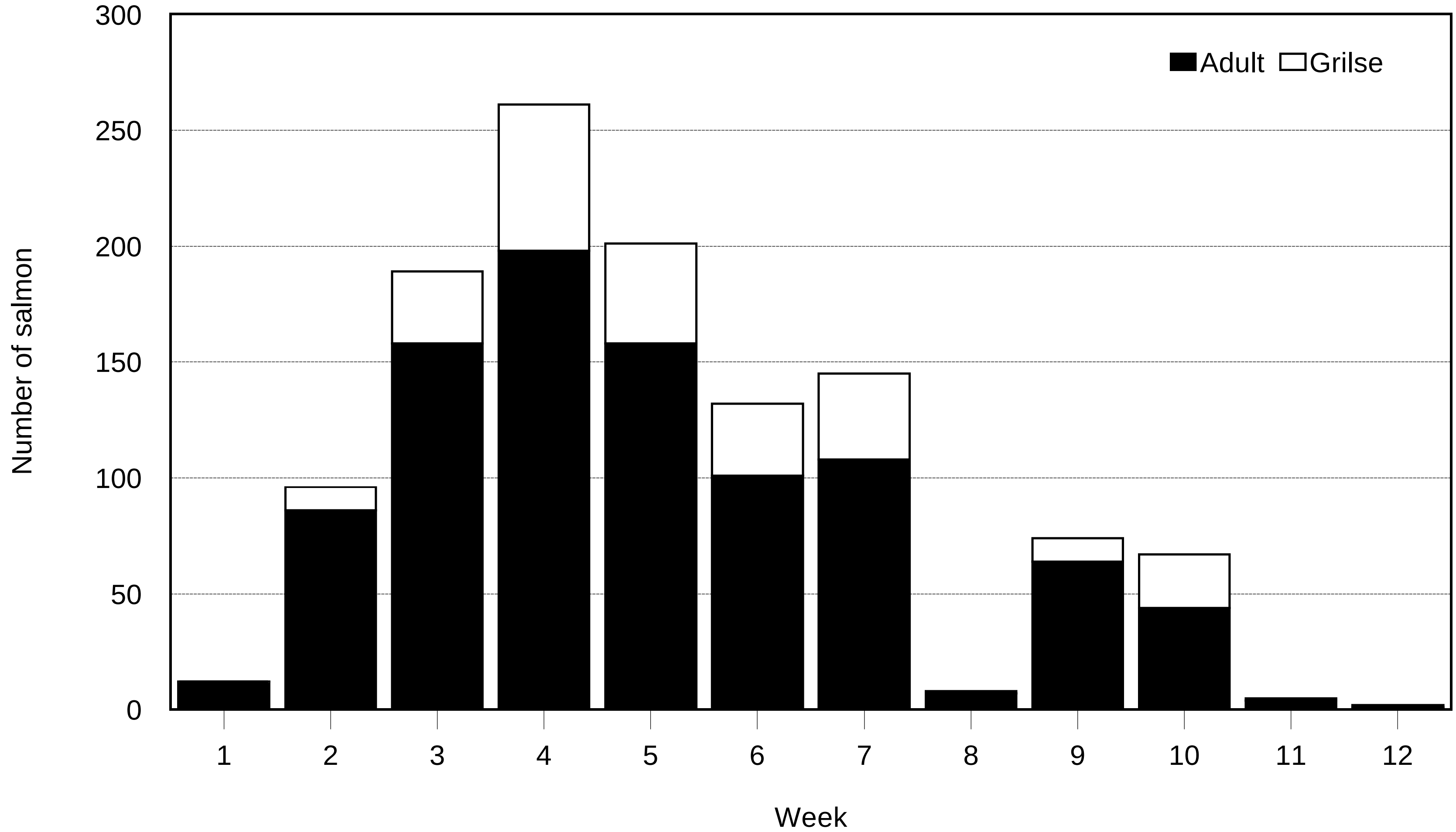

Figure 9. Age compostion of chinook salmon measured during the upper Sacramento River chinook salmon spawner escapement survey, September - December 1996.

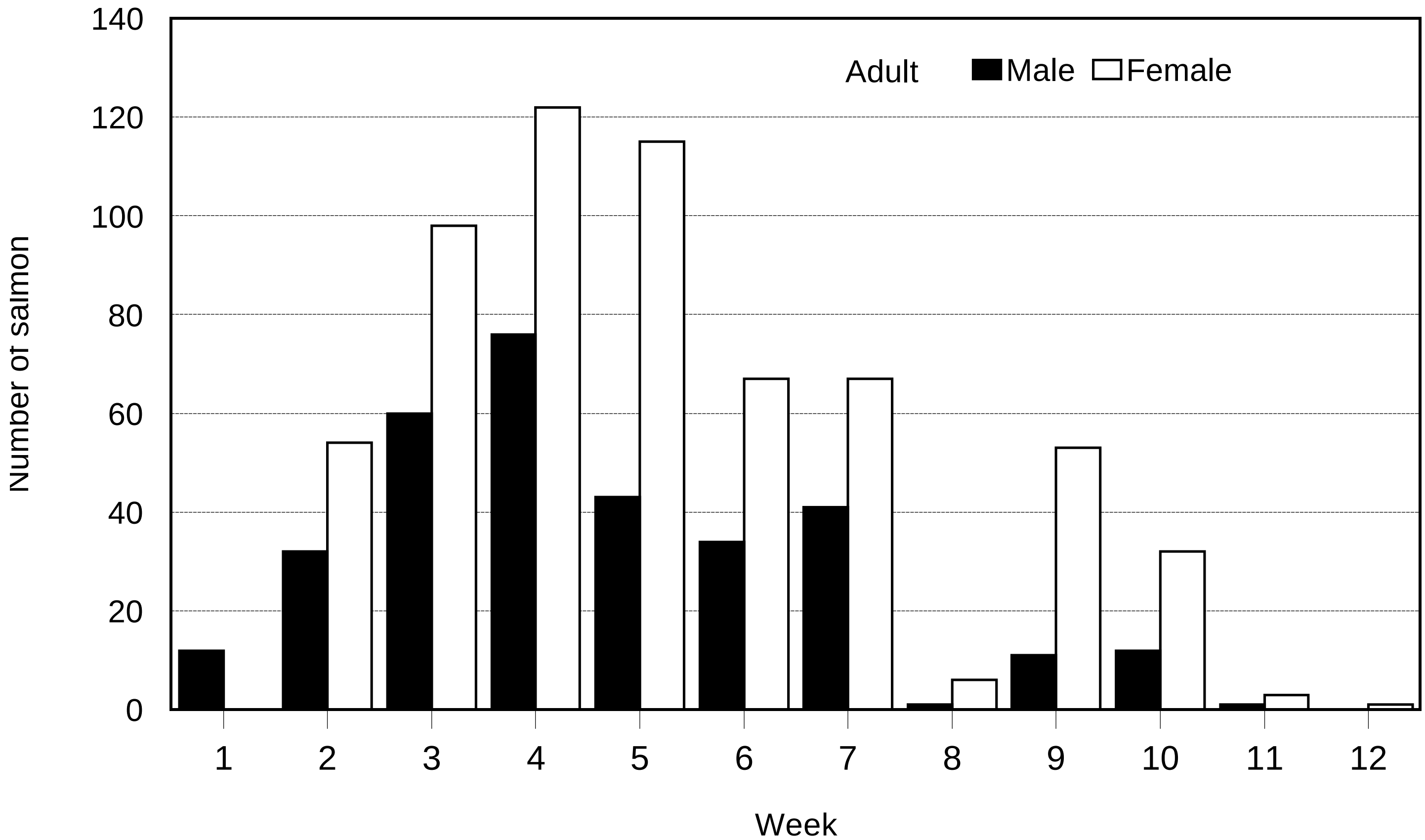

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the upper Sacramento River chinook salmon spawner escapement survey, September - December 1996.

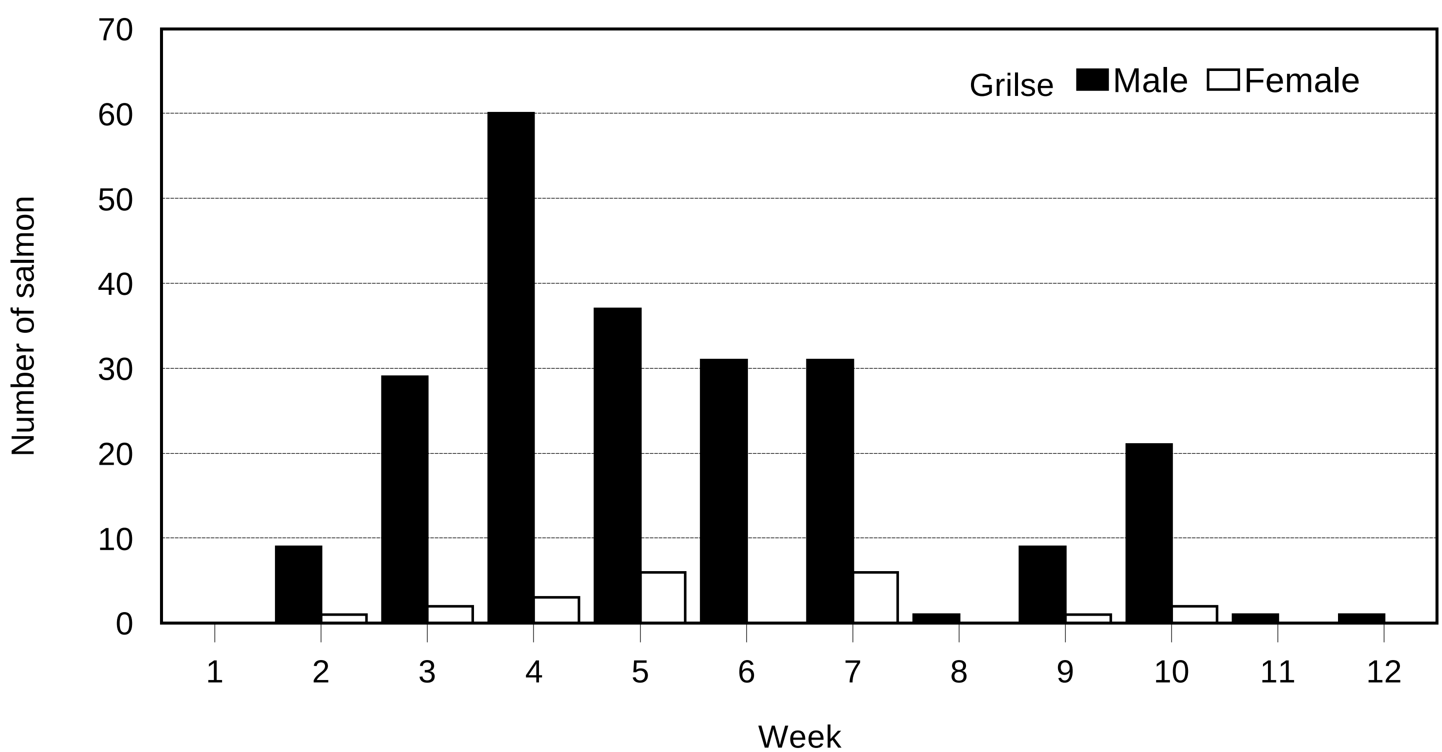

Figure 11. Weekly distribution of the sex of grilse-sized fall-run chinook salmon measured during the upper Sacramento River spawner escapement survey, October - December 1995.

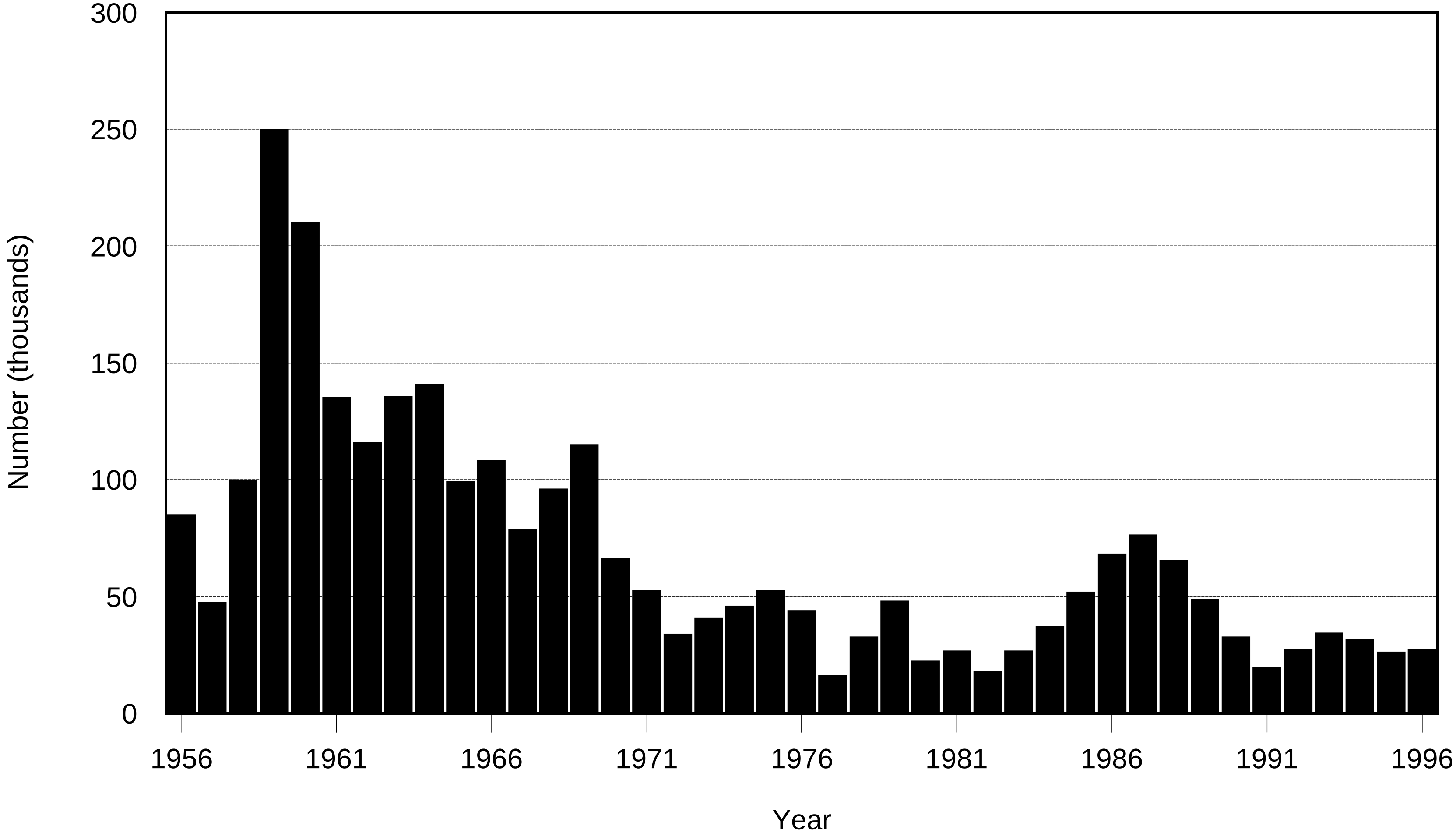

Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1996).

APPENDIX IV

Upper Sacramento River winter-run chinook salmon escapement survey
April - August 1997

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

1997 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey April - August 1997[1/,2/]

by

Bill Snider
Bob Reavis
and
Scott Hill

January 1998

1/ This was a cooperative investigation with U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office and was supported by funding provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of fish and Game pursuant to the Central Valley Project Improvement Act (P.L. 102-575).

2/ Stream Evaluation Program Technical Report No. 98-1

SUMMARY

A winter-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during spring-summer 1997 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the second consecutive year a winter run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system (Snider *et al*. 1997).

The survey was conducted from 30 April 1997 through 29 August 1997. It covered the uppermost 14 miles of the Sacramento River accessible to migrating salmon, from river mile 288 (RM 288) upstream to Keswick Dam (RM 302).

Flow ranged from 9,000 cubic feet per second (cfs) to 11,000 cfs through mid-June, then between 14,000 and 15,000 cfs into early August. Secchi depths (water clarity) were between 3 and 4 ft through mid-June, increased to over 6 ft by the end of June and eventually maintained between 6 and 10 ft thereafter. Water temperature increased from 49 ^{o}F during the first week of spawning to 52 ^{o}F by mid-June and essentially remained at 52 ^{o}F for the remainder of the survey.

Temporal distribution of carcasses suggests that most spawning (~70%) occurred from early June into early July. The peak in fresh carcasses occurred during early July.

We collected 239 carcasses (105 fresh and 134 decayed) and measured 190. Ninety-two percent (174) were adult salmon and 8% (16) were grilse; 21% were adult males, 70% were adult females, 4% were male grilse and 5% were female grilse. Overall, 25% of the measured carcasses were male and 75% were female; 24% of the adults were male and 76% were female.

Ninety-six percent of 140 females checked for egg retention were completely spawned.

Five hatchery-produced winter run were collected, including one caught at Coleman National Fish Hatchery (CNFH), then marked and released into the survey reach.

We shortened the survey reach length and increased survey frequency to increase carcass counts and recapture rates. The result was a 2.5 fold increase in effort within the reach where 90% of the carcasses were collected in 1996. In spite of increased effort, poor visibility made carcass observations difficult. Tags were recovered from only 16 of the 36 tag groups and the recapture rate was 12%. As in 1996, insufficient numbers of tagged fish were recaptured to allow using either the Schaefer or Jolly-Seber models. The Petersen model yielded an estimate of 1,888 adult and 165 grilse winter run (2,053 total).

The 1997 winter-run escapement estimate based on counts made at Red Bluff Diversion Dam (RBDD) (RM 243) was 480 adult and 361 grilse. Based on comparisons of the estimated number of marked, hatchery-produced winter run both passing RBDD and returning to the upper river, the winter-run migration past RBDD was adjusted to 6,125 salmon (3,500 adults and 2,625 grilse). The estimated effective spawner population was between 1,478 and 2,333 females.

INTRODUCTION

A winter-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during spring-summer 1997 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the second consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system (Snider *et al*. 1997). A fundamental component of the investigation is the determination of basic life histories of the various salmon runs in the system as a basis for identifying salmon-habitat relationships at all life stages, including spawning. Also, since spawning habitat investigations can be influenced by spawner abundance as well as habitat availability, it is important that spawner population data be developed concurrent with habitat monitoring to distinguish the influences of these two factors on habitat use.

Escapement surveys conducted concurrently with redd surveys have been successfully used in the lower American River to identify relationships between spawning habitat availability and flow (Snider and McEwan 1992, Snider *et al*. 1993, Snider and Vyverberg 1995). The investigations on the lower American River strongly suggest that relationships between water temperature and temporal distribution of spawning and emergence, spawner abundance and pre-spawning mortality, flow and habitat availability, spawner abundance and habitat use as well as innate variability in expressed life history attributes can all influence the interpretation of salmon-habitat investigations. Thus, based upon our experiences in evaluating salmon-habitat relationships on the lower American River, we concluded that spawner escapement surveys should be conducted on the upper Sacramento River.

The 1996 and 1997 surveys were the first attempts to use carcass mark-and-recapture techniques to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass mark-and-recapture surveys are routinely used to estimate escapement to Sacramento Valley tributary streams (e.g., American, Yuba, and Feather rivers and Battle Creek). This method was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974). Three models have been used by the California Department of Fish and Game (DFG) to estimate escapement from carcass mark-and-recapture data: Petersen (Ricker 1975), Schaefer (1951) and the Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1992) and has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to calculate estimates for smaller tributary streams (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modified Schaefer model has been used in “larger” Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. The Jolly-Seber model was first used in the Central Valley in 1988 to estimate escapement in the Feather, Yuba, American, Stanislaus, Tuolumne, and Merced rivers.

Evaluation of winter-run spawning in the Sacramento River is an integral part of an agreement between the DFG and the U.S. Fish and Wildlife Service (FWS), Central Valley Anadromous

Fish Restoration Program to evaluate habitat requirements for anadromous salmonids in Central Valley streams. Studies being implemented by the DFG will provide the FWS with reliable scientific information for development of flow recommendations and satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B). The Sacramento River was selected for intensive fish-habitat investigations due to the significant influence the Central Valley Project has upon flow, temperature and ultimately fish habitat in the river. Furthermore, the upper Sacramento River is the only stream reach in the Central Valley that supports all four chinook salmon runs and steelhead. The exclusive occurrence of winter-run chinook salmon - a federally and state listed species - and the presence of rapidly disappearing steelhead, presently being considered for federal listing, underscore the significance of habitat in this stream reach.

Results of the carcass survey may be used for comparison and possible augmentation of data collected on winter-run migration at the RBDD. Similarly, the survey could augment weekly winter-run redd surveys. The FWS, Northern Central Valley Fish and Wildlife Office and CNFH could also use the results to evaluate their winter-run escapement augmentation program using winter run spawned and reared at CNFH (USFWS 1996, Croci and Hamelberg 1997).

Objectives

The objectives of the 1997 winter-run chinook salmon spawner escapement survey were:

- To estimate the 1997, in-river, winter-run chinook salmon population for the upper Sacramento River based on a carcass mark-recapture survey and augment estimates that are based on RBDD counts.

- To continue examination of the feasibility of using mark-recapture techniques (i.e., Peterson, Jolly-Seber, and Schaefer population models) to estimate winter-run escapement in the upper Sacramento River, and recommend future escapement estimating procedures.

- To obtain baseline information on spawning distribution (spatial and temporal), environmental conditions at time of spawning, and spawning population (size, sex composition, and spawning success) to eventually identify winter-run spawning habitat requirements in the upper Sacramento River.

Background

Winter run are one of four chinook salmon runs present in California's Central Valley; the other three runs are fall, late-fall, and spring. Winter run generally leave the ocean and enter fresh water to begin their upstream migration from December through June. The peak of the run

normally passes RBDD in March and April. Winter run typically spawn from mid-April through mid-August.

The earliest references to winter-run salmon have been summarized by Fisher (1993). In 1874, Livingston Stone noted winter run in the McCloud River, a tributary to the Sacramento River that presently drains into Shasta Lake. Fisher (1993) concludes this run may also have historically spawned in reaches of the Sacramento and Pit rivers that were also cut off with the construction of Shasta Dam. Winter run status since the construction of Shasta Dam has been described by Slater (1963), Hallock and Fisher (1985), and Fisher (1993). Since Shasta Dam has blocked winter run's access to most of its historic spawning habitat, winter run now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River. Due to a drastically declining population, winter run were listed as endangered by the California Fish and Game Commission in 1989, and as threatened by the National Marine Fisheries Service (NMFS) in 1990 and then as endangered in 1994.

The NMFS (1996) has developed a winter-run extinction model that identifies population conditions corresponding to an acceptable low probability of population extinction. Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over any 13 consecutive years is at least 10,000 females. This population level assumes that the male:female ratio is 1:1 and that the age structure is comparable to that observed by Hallock and Fisher (1985) over three brood years. The assumed age structure is 50% 2-year olds, 44% 3-year olds and 6% 4-year olds for males and 89% 3-year olds and 11% 4-year olds for females. The population criteria also assume that annual escapement will be estimated with a precision of +/- 25%.

Since 1969, winter-run escapement estimates have been based upon counts of salmon using fishways that provide passage around RBDD. Counts can only be made when the diversion is in operation, when all the gates are down, and all fish migrating to areas upstream of RBDD use the fishways located in the center and on the east and west ends of the dam. From 1969 through 1985, RBDD was typically operated throughout the entire winter-run migration period allowing a complete accounting of winter-run escapement. Salmon using the fishways were counted using a combination of actual daytime counts (east and west fishways) and counts made from daytime video recordings of fish using the center fishway. The daytime counts were expanded using weekly nighttime count data.

Beginning in 1986, operation of RBDD was modified to accommodate winter-run migration. Now the diversion operates only during an abbreviated portion of the historic winter-run migration, typically from mid-May through mid-September. The number of winter-run spawners migrating upstream of RBDD is now based upon an expansion of the number of fish counted once the gates are closed. Fish passing RBDD during this period are counted applying essentially the same methods used when counts covered the entire migration (pre-1986). Fish using the east and west ladders are counted directly through viewing facilities from 0600 to 2000 h seven days per week. Fish using the center ladder are counted by video taping fish passage from 0600 to 2000 h each day seven days per week. The video tapes are reviewed to identify and count fish that had passed. Once a week, the DFG determines night passage at the east and west ladders by extending the direct counts from 2000 to 2200 h and then video taping passage from 2200 to 0600 h the next morning. These tapes are also reviewed to identify and count fish that had passed. The single night count is used to "correct" the weekly, daytime counts to represent night passage for all other nights of the week. The DFG also operates a fish trap located in the east fish ladder. The trap is usually operated seven days a week through July then five days a week through mid-September from 0600 to 1500 h, when water temperatures are $\leq 60^{o}$ F. Trapped fish are identified to species or, if a salmon, to run. Fish are measured and checked for marks (e.g., adipose fin clips).

Escapement is estimated by expanding the abbreviated season-long count, assuming it is proportionate to historic, complete season-long counts. The count is divided by the mean proportion of the total population that passed RBDD (when counts were season-long) based on the date the diversion is placed in operation.

METHODS

The FWS, Northern Central Valley Fish and Wildlife Office and the DFG's Stream Evaluation Program jointly conducted a carcass mark-and-recapture survey to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 30 April 1997 through 29 August 1997. Methods were similar to those used in the 1996 winter-run escapement survey (Snider *et al*. 1997) with the exception that changes in the survey reach and survey frequency were made to improve on the low collection rates observed in 1996.

In 1996, the survey reach extended 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Figure 1), which is considered the primary spawning area for winter run in the upper Sacramento River. However, 90% of winter-run spawning in 1996 occurred in the uppermost 14 stream miles. This prompted us to shorten the survey reach to the 14 stream miles between Keswick Dam and the Redding Water Treatment Plant (RM 288) to increase sampling efficiency. Sampling effort was also increased in 1997. The shortened reach was surveyed about 2.5 times as often as it was in 1996.

The study reach was divided into the following two reaches:

1. Keswick Dam to Cypress Street Bridge - RM 302 to RM 295,

2. Cypress Street Bridge to Redding Water Treatment Plant - RM 295 to RM 288.

The upper reach was surveyed on the first day and the lower reach on the second day of each two-day survey period. Then one day was skipped and the cycle repeated. Most of the survey effort was conducted by boat (two boats and two observers per boat). Each boat was generally used to survey along one shoreline out to the middle of the river. There were several short stretches of river that were surveyed on foot.
Survey effort was primarily concentrated in areas where carcasses were known to collect. Most observed carcasses were collected using a gaff or gig for measurement and tagging, as described below.

Flow measurements from the Keswick gauge were obtained from the U.S. Geological Survey. Water temperatures and Secchi disk (water clarity) readings were measured daily by the survey crew.

Population Estimates

The winter-run spawner population was estimated using a mark-and-recapture (tag-and-recovery) method. Most collected carcasses were tagged except those in an advanced state of decay. Carcasses not tagged were counted then cut in two (chopped). All chopped carcasses were disregarded in subsequent surveys. Carcasses were tagged by attaching a small colored plastic ribbon to the upper or lower jaw with a hog ring. The tag color was used to show the week the carcass was tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the upper jaw; decayed carcasses were tagged in the lower jaw. Carcass condition was noted during tagging to accommodate the various population estimators. The Schaefer model uses only fresh carcass data, and the Jolly-Seber model uses both fresh and decayed carcass data. This approach is consistent with procedures used on other Central Valley streams. All tagged carcasses were returned to flowing water near where they were collected in an attempt to simulate "natural" carcass dispersion. Recovered, previously tagged carcasses were examined for tag color, location of tag (upper or lower jaw), and age (size). The pertinent data were recorded and the carcass was chopped.

Size/age Distribution and Sex Composition

Fork length (FL), sex, and date of collection were recorded for all measurable carcasses. Some carcasses were too deteriorated to allow accurate measurements. The length-frequency distribution of each sex was used to define the length separating adults (>2 years old) and grilse (2 year olds).

Carcasses were also checked for adipose fin clips, indicating the fish was of hatchery origin and possessed a coded-wire tag (CWT). CWTs were collected from clipped carcasses.

Spawning Success

All measurable female carcasses were checked for egg retention. Females were classified as spent if few eggs remained, as partially spent if a substantial amount (50% or more) of eggs still remained in the body cavity, and unspent if they appeared to be completely unspawned.

Temporal Distribution

Fresh carcasses were assumed to become available to sampling within two weeks of spawning completion, based upon observations made in the American River (Snider and Vyverberg 1995). The total number of fresh carcasses observed for both survey reaches for each survey period was used to describe temporal spawning distribution.

Spatial Distribution

The total number of fresh carcasses observed in each survey reach was used to define season-long geographic distribution of spawning activity. Flow likely carried some carcasses from the upstream reach, where spawning occurred, to the downstream reach, where recovery occurred, potentially biasing the spatial distribution of spawning toward the downstream reach. Using only fresh carcasses, versus fresh and decayed carcasses, should substantially reduce the bias.

RESULTS

General

A total of 105 fresh and 134 decayed carcasses were observed during the 19-week survey (Table 1). Mean flow for each of the 41 survey periods ranged from 8,000 to 15,000 cfs (Table 2, Figure 2). Mean survey-period temperature ranged from 49 ºF to 53 ºF (Table 1, Figure 2). Secchi depth readings ranged from 3 to 10 ft (Table 1) and generally increased as the survey season progressed (Figure 2).

Population Estimates

The Jolly-Seber and Schaefer models were not used to estimate escapement since tagged carcasses were recovered from only 16 of the 36 tag groups. These models require that tags be recovered from each tag group.

The adult spawner population was therefore estimated using the adjusted, Peterson formula (Ricker 1975)[1], by combining the season-long totals for number of adult carcasses observed, Table

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[1]

$$N = \frac{(M+1)\,(C+1)}{(R+1)}$$

Where,

N = estimated spawning population for survey period,
M = number of carcasses marked during survey,
C = total number of carcasses examined during survey, and
R = number of marked carcasses recovered during survey.

1. Summary of mean flow, mean water temperature, Secchi depths and carcass counts during each survey period of the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

Survey period	Dates	Mean flow (cfs)1/	Mean water temperature (°F)2/	Secchi depth (ft)	Carcass count3/ Fresh	Decayed
1	Apr 30 - May 1	8,600	49	3.2	1	4
2	May 3 - 4	8,000	50	3.0	1	8
3	May 6 - 7	8,800	50	3.0	0	6
4	May 9 - 10	9,200	50	3.3	0	1
5	May 12 - 13	9,800	51	3.2	1	1
6	May 15 - 16	10,100	50	3.3	2	1
7	May 18 - 19	9,500	50	3.2	0	0
8	May 21 - 22	10,200	50	3.2	2	1
9	May 24 - 25	10,500	50	3.3	1	1
10	May 27 - 28	10,200	51	4.4	0	4
11	May 30 - 31	9,800	51	4.0	0	2
12	Jun 2 - 3	10,500	51	3.8	1	3
13	Jun 5 - 6	10,400	52	3.7	3	1
14	Jun 8 - 9	11,000	51	4.2	1	1
15	Jun 11 - 12	12,200	52	4.1	2	4
16	Jun 14 - 15	14,600	52	4.7	2	1
17	Jun 17- 18	15,000	52	5.8	5	1
18	Jun 20 - 21	14,700	52	5.4	3	3
19	Jun 23 - 24	14,500	52	6.9	6	3
20	Jun 26 - 27	14,700	52	5.9	4	1
21	Jun 29 - 30	14,900	52	4.4	5	1
22	Jul 2 - 3	14,800	53	7.0	5	6
23	Jul 5 - 6	14,500	52	6.8	6	4
24	Jul 8 - 9	14,800	52	6.8	3	3
25	Jul 11 - 12	14,800	52	7.0	10	2
26	Jul 14 - 15	14,900	54	6.8	3	8
27	Jul 17 - 18	14,800	52	7.1	8	14
28	Jul 20 - 21	15,000	52	6.4	6	5
29	Jul 23 - 24	14,900	52	6.6	7	4
30	Jul 26 - 27	14,800	52	7.9	4	4
31	Jul 29 - 30	14,500	52	6.6	4	2
32	Aug 1 - 2	14,300	52	7.0	1	8
33	Aug 4 - 5	14,200	52	8.9	1	7
34	Aug 7 - 8	12,200	52	9.2	3	5
35	Aug 10 - 11	12,800	52	10.0	2	4
36	Aug 13 - 14	11,900	52	9.3	1	4
37	Aug 16 - 17	10,000	52	9.2	1	1
38	Aug 19- 20	10,000	52	9.9	0	0
39	Aug 22 - 23	14,700	52	9.5	0	0
40	Aug 25- 26	14,500	52	8.7	0	2
41	Aug 28 - 29	8,000	52	9.2	0	3
				Totals	105	134

1/ Mean flow measured at Keswick Dam during survey period.
2/ Mean water temperature measured by survey crew during survey period.
3/ Includes grilse and adults; does not include tag recoveries.

Table 2. Summary of tagging and recapture of winter-run chinook salmon carcasses (fresh and decayed) observed during upper Sacramento River escapement survey, April - August 1997.

Tagging period	Date	Number observed		Number tagged		Number recovered	Original tagging period
		Adults	Grilse	Adults	Grilse		
1	4/30-5/1	5	0	5	0	0	
2	5/3-4	9	0	6	0	0	
3	5/6-7	6	0	6	0	0	
4	5/9-10	1	0	1	0	0	
5	5/12-13	2	0	2	0	0	
6	5/15-16	3	0	3	0	1	5
7	5/18-19	0	0	0	0	0	
8	5/21-22	3	0	3	0	0	
9	5/24-25	2	0	2	0	0	
10	5/28-29	4	0	3	0	0	
11	5/30-31	2	0	2	0	0	
12	6/2-3	4	0	3	0	0	
13	6/5-6	4	0	4	0	0	
14	6/8-9	2	0	2	0	0	
15	6/11-12	6	0	3	0	0	
16	6/14-15	3	0	3	0	0	
17	6/17-18	6	0	5	0	0	
18	6/20-21	6	0	5	0	0	
19	6/23-24	9	0	8	0	1	18
20	6/26-27	5	0	5	0	1	19
21	6/29-30	6	0	6	0	0	
22	7/2-3	10	1	8	1	2	18,21
23	7/5-6	9	1	8	1	2	21,22
24	7/8-9	6	0	6	0	0	
25	7/11-12	10	2	10	2	3	20,23,24
26	7/14-15	10	1	8	1	0	
27	7/17-18	22	0	17	0	1	26
28	7/20-21	8	3	8	2	1	26
29	7/23-24	10	1	9	1	3	22,27,28
30	7/26-27	6	2	4	2	1	29
31	7/29-30	5	1	4	1	2	29,30
32	8/1-2	9	0	6	0	2	29,31
33	8/4-5	7	1	3	1	0	
34	8/7-8	7	1	4	0	0	
35	8/10-11	5	1	4	1	0	
36	8/13-14	4	1	0	1	0	
37	8/16-17	2	0	1	0	1	34
38	8/19-20	0	0	0	0	0	
39	8/22-23	0	0	0	0	0	
40	8/25-26	1	1	0	0	0	
41	8/28-29	2	1	0	0	1	33
Totals		221	18	177	14	22*	

* All were adults, no grilse were recovered.

tagged and recovered. Fresh and decayed adult carcasses were combined yielding a total of 177 adult carcasses tagged (Table 2), 22 recovered, and 243 adult carcasses examined (including the 22 tag recoveries). The adult spawner estimate was 1,888.

The total population (grilse and adult) was calculated by dividing the adult estimate by 0.92, the estimated proportion of adults. The total population estimate was 2,053. The estimated grilse population was 165.

Size/age Distribution and Sex Composition

A total of 190 carcasses was measured (Table 3). Mean FL was 76.1 cm (range: 49-104 cm FL). Male salmon (n = 48) averaged 81.3 cm FL (range: 50-104 cm FL). Female salmon (n = 142) averaged 74.3 cm FL (range: 49-104 cm FL). Monthly mean size ranged from 67.0 to 92.0 cm FL for males, and from 71.4 to 83.8 cm FL for females (Table 3). On average, larger salmon of both sexes spawned early followed by progressively smaller fish (Table 3, Figure 4).

Length-frequency distributions were used to define a general size criterion to distinguish grilse (2-year-old salmon) and adults (>2-year-old salmon) for both sexes. There was an 11 cm separation between male grilse and adults that clearly divided the two age groups (Figure 3). The break in female length distribution was not as evident (Figure 3). Grilse were defined as ≤64 cm FL for both sexes (Table 4). The female size distribution indicates that female adults may have been less than 64 cm FL, perhaps as small as 60 cm FL. We plan to verify the age/length relationship for the 1997 spawner population using scales and otoliths taken from most measured carcasses. In this report, the same length was used for both sexes to distinguish grilse and adults.

Male grilse averaged 53.6 cm FL (SD = 2.9; range: 50-59 cm FL). Female grilse averaged 59.9 cm FL (SD = 4.6; range 49-63 cm FL) (Table 4). Adults were defined as >64 cm FL. Male adults averaged 86.1 cm FL (SD = 9.1; range: 70-104 cm FL). Female adults averaged 75.3 cm FL (SD = 6.0; range 66-104 cm FL).

Ninety-two percent (n = 174) of the carcasses measured were adults and 8% (n = 16) were grilse (Table 5). At least 86% of the carcasses observed each month were adults. The greatest fraction (14%) of grilse was observed in August.

The grilse sample comprised 56% (n = 9) females and 44% (n = 7) males (Table 6). The adult sample comprised 76% (n = 133) females and 24% (n = 41) males. The ratio of male:female adult spawners was 1:3.2. The grilse sample comprised 56% (n = 9) females and 46% (n = 6) males. The overall sex ratio, including grilse, was 1:3.

Spawning Success

Ninety-six percent (n = 135) of the 140 females examined for egg retention had completely spawned. Three percent (n = 4) had partially spawned, and 1% (n = 1) had not spawned. The unspawned and partially-spawned females were observed on or before 12 June.

Spatial Distribution

Based upon fresh carcass data, spawning was evenly distributed between the two reaches with 48% (n = 50) of the fresh carcasses found in Reach 1 and 52% (n = 55) of the fresh carcasses found in Reach 2 (Table 7). Thirty-seven percent (n = 50) of the decayed carcasses were found in Reach 1; 63% (n = 84) of the decayed carcasses were found in Reach 2. The ratios of fresh:decayed carcasses were 1:1 in Reach 1 and 1:1.5 in Reach 2.

Temporal Distribution

Fresh carcasses were observed from survey period 1 (30 April-1 May 1997) through survey period 37 (16-17 August 1997) (Table 1, Figure 4). The number of fresh carcasses increased gradually through survey period 16 (15 June 1997), averaging less than 3 carcasses per week. A sharp increase in the rate of fresh carcass collection began in survey period 17 (17-18 June 1997) and continued through survey period 29 (23-24 July 1997) (Figure 5). Nearly 70% of all fresh carcasses were observed during this five week period. The peak of fresh carcass recovery occurred during survey period 25 (11-12 July 1997) (Figure 5).

Assuming that fresh carcasses become available for observation approximately two weeks after spawning, spawning occurred from mid-April into early August. Peak spawning occurred from the first week in June through the first week in July.

Hatchery-produced Winter-run Chinook Salmon

Five carcasses from hatchery-produced winter run (indicated by a clipped adipose fin) were observed in the survey reach. One of the adipose-clipped fish was also marked with a tag indicating it was one of 68 salmon that had been collected at CNFH, tagged then released into the Sacramento River to spawn. All five adipose-clipped fish were females (Table 8). One had not completely spawned indicating a 20% pre-spawning mortality. Size ranged from 63 cm FL to 78 cm FL (mean = 72 cm FL),

Table 3. Size and sex statistics for carcasses measured during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

	All salmon			Male salmon			Female salmon		
		Length (FL in cm)			Length (FL in cm)			Length (FL in cm)	
Month	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
May[1/]	27	88.1	71-104	14	92.0	75-104	13	83.8	71-104
June	47	77.0	49-93	11	80.5	55-93	36	75.9	49-90
July	95	73.4	51-98	20	76.5	51-98	75	72.6	57-84
August	21	70.8	50-86	3	67.0	50-81	18	71.4	60-86
Total (overall)	190	(76.1)	(49-104)	48	(81.3)	(50-104)	142	(74.3)	(49-104)

1/ Includes data gathered on 30 April 1997.

Table 4. Summary of adult and grilse size and number by sex for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, April - August 1997.

	Female		Male	
	Grilse*	Adults	Grilse*	Adults
Total measured	9	133	7	41
Mean	59.9	75.3	53.6	86.1
Range FL (cm)	49-63	66-104	50-59	70-104
Standard deviation	4.6	6.0	2.9	9.1

* Grilse were defined as salmon ≤64 cm FL.

Table 5. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, April - August 1997.

Survey period	Adults		Grilse	
	Number	%	Number	%
May**	27	100	0	0
June	45	96	2	4
July	84	88	11	12
August	18	86	3	14
Total (overall)	174	(92)	16	(8)

** Includes data gathered on 30 April

Table 6. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, April - August 1997.

Month	Adults				Grilse			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
May[1/]	14	52	13	48	0	-	0	-
June	10	22	35	78	1	50	1	50
July	15	18	69	82	5	45	6	55
August	1	6	16	94	1	33	2	67
Total (overall)	41	(24)	133	(76)	7	(44)	9	(56)

1/ Includes data gathered on 30 April

Table 7. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997. Includes adults, grilse, fresh and decayed carcasses but not tag recoveries.

	Reach 1		Reach 2	
Survey period	Fresh	Decayed	Fresh	Decayed
1	1	4	0	0
2	0	3	1	5
3	0	1	0	5
4	0	1	0	0
5	0	0	1	1
6	0	1	2	0
7	0	0	0	0
8	2	1	0	0
9	0	0	1	1
10	0	1	0	3
11	0	1	0	1
12	0	0	1	3
13	1	0	2	1
14	0	0	1	1
15	1	0	1	4
16	1	0	1	1
17	2	0	3	1
18	1	1	2	2
19	3	1	3	2
20	1	0	3	1
21	4	0	1	1
22	2	3	3	3
23	4	2	2	2
24	2	2	1	1
25	2	0	8	2
26	0	2	3	6
27	4	5	4	9
28	3	1	3	4
29	4	1	3	3
30	2	1	2	3
31	3	1	1	1
32	1	3	0	5
33	1	4	0	3
34	2	2	1	3
35	2	4	0	0
36	1	1	0	3
37	0	1	1	0
38	0	0	0	0
39	0	0	0	0
40	0	0	0	2
41	0	2	0	1
Totals	50	50	55	84

Table 8. Summary of statistics for adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

Date collected	Sex	FL (cm)	Spawning completed
16 May	Female	71	No
16 May	Female	70	Yes
5 June	Female	78	Yes
18 July	Female	78	Yes
26 July	Female	63	Yes
Mean (range)		72 (63-78)	80%

DISCUSSION

The results of two years of carcass surveys cannot, by themselves, address the issues of habitat availability relative to flow and other attributes of physical habitat. Several more years of survey are needed. These data should then be compared with redd survey data to identify salmon spawning habitat requirements. The low population level may also reduce the efficacy of the population surveys in evaluating habitat needs. If the population is so low relative to habitat availability, little can be determined with these data alone, especially relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1996). However, if habitat is limiting at these low populations, habitat-flow relationships should be identifiable. Other studies that will augment this component of the overall investigation may include aerial photographic surveys of redds, physical habitat modeling, and focused evaluation of the hydraulic and substrate attributes of spawning habitat.

Population Estimates

One of the goals for the 1997 survey was to increase the recovery rate experienced in 1996 by increasing the survey effort. The overall tag recovery rate, however, was only 12% in 1997 versus 15% in 1996. Similarly, we were not able to recover tags from 20 of the 36 tag groups, thus only allowing use of the relatively weak Petersen model to estimate the spawner population. Law (1994) found that the Petersen model consistently showed substantially larger overestimation than either the Schaefer or Jolly-Seber models. When both fresh and decayed carcasses are used, he found that the Petersen model overestimated the known population by as much as 151% and by as much as 83% when only fresh carcasses were used. We used both fresh and decayed carcasses to derive the estimate of 1,888 adult winter run. Using just fresh carcasses, the estimate is 1,354. As such, it is highly likely that our total escapement estimate of 2,053 winter run is an overestimate of the true population.

Possible reasons for low tag recoveries include poor visibility, higher flows and low spawner population. Poor visibility early in the survey certainly limited carcass recovery. Secchi readings were less than 4 ft through most of May and did not reach 6 ft until late June. Tag recoveries were extremely low through mid-June and then showed a sharp increase concurrent with improved water clarity (Figure 6). For example, by the third week of June, when water clarity finally increased to 6 feet, we had tagged nearly 40% of the carcasses that eventually would be tagged during the survey but we had only recovered about 13% of the number eventually recovered. The recovery rate was less than 5%. Within two weeks, the number tagged increased about two-fold while the number recovered increased 5-fold and the recovery rate increased to almost 10%.

Even though flow increased between May and July when recovery rates increased apparently due to improved water clarity, higher flows likely increase the rate that tagged carcasses are swept out of the study area, decreasing the probability of recovery. Recovery rates during the 1995 and 1996 upper Sacramento River fall-run chinook salmon escapement surveys were about 32% and flow was around 5,000 cfs (Snider and Reavis 1997). In contrast, recovery rates were less than 16% during the 1996 and 1997 winter-run escapement surveys and flow was typically between 9,000 and 15,000 cfs.

The total number of carcasses tagged during the 1995 and 1996 fall-run escapement surveys were nearly 40 times as many as were tagged during the 1996 and 1997 winter-run surveys.

Effective Spawner Population

The effective spawner population is defined as the estimated number of females that spawned, assuming there were enough males to service all the redds. Since 75% of the carcasses used to estimate escapement were female, the estimated female population based on the carcass survey was 1,540 (including grilse-sized females). Prespawning mortality was 4% yielding an estimated effective spawner population of 1,478.

Sex Composition

The ratio of males:females observed during the carcass surveys was 1:3 during 1997, compared to 1:6.4 during 1996. The sex ratio varied throughout the survey ranging from 1:0.9 in May (n = 27), 1:3.2 in June (n = 47), 1:2.6 in July (n = 95) and 1:6.0 in August (n = 21).

The following are possible explanations for the observed difference in sex composition:

1. The recovery rate of males is less than for females. In a carcass survey and weir count conducted on Bogus Creek, a tributary to the Klamath River, the recovery rate of adult males was 11% less the rate for females (Boydstun 1994).

2. If a high portion of the male population leaves the ocean as 2-year olds, the male to female ratio of that age class remaining in the ocean is reduced significantly. Based on

the age composition criteria used in the NMFS model, 50% of the returning males would be grilse. Assuming an initial sex ratio of 1:1, this alone would result in a male to female ratio of nearly 1 to 2. As the proportion of males returning as 2 year olds increases (x), the ratio of male to female adults for that age class decreases to 1:(1/1-x) (e.g., if x = 0.5, the ratio is 1:2; if x = 0.7, the ratio is 1:3.3, *etc.*).

3. A combination of the above two factors would produce an even greater disparity between adult males and females.

Comparison with Red Bluff Diversion Dam Winter-run Escapement Estimates

Results of the salmon counts at RBDD indicated an estimated 841 in-river produced winter run , including 480 adult and 361 grilse migrated to the upper Sacramento River (DFG unpubl. data). RBDD data also indicate that an estimated 40 hatchery-produced winter run migrated to the upper Sacramento River. The male to female ratio for adults was 1 to 1.44.

An estimated 256 hatchery-produced winter run returned to Battle Creek (S. Croci, FWS, unpubl. data). An additional 34 hatchery-produced winter run were estimated to have spawned in the Sacramento River survey area, yielding a hatchery-produced winter-run escapement estimate of 290.

Escapement of hatchery-produced winter run based on RBDD counts was 40. This was less than 15% of the estimate based on carcass survey and Battle Creek counts. The RBDD estimate was based on the expansion of a count of 7 adipose clipped fish and the assumption that the counting period accounted for 17.45% of the total migration. If we assume that the actual number of hatchery-produced winter run migrating past RBDD was 290 as described above, then the proportion of the run counted at RBDD was 7/290, or 2.4%. This proportion lies within the range observed between 1969 and 1985 (Figure 7).

The above analysis therefore suggests that a substantial portion (~97%) of the hatchery-produced winter-run population passed RBDD before counts began in early May. Assuming the timing of the in-river produced winter-run migration was comparable, the estimate of the in-river produced adult escapement, using the RBDD count (84 adults) is 3,500 winter run.

This analysis indicates that the number of in-river produced adult winter run migrating upstream of RBDD was about 200% greater than the estimated number that spawned (3,500 v 1,888). Knowing that the Petersen estimate is high suggests that the disparity between the two estimates is even greater. If we take into account that the sex ratios indicate that the estimated number of males in the carcass survey may be biased, a comparison of the effective spawner population derived from RBDD and carcass survey estimates should reduce the bias. The effective spawner population estimated using the RBDD data and 4% prespawning mortality is 2,333 versus 1,478 using the carcass survey data. Part of this difference can be explained by the fact that some portion of the population migrating past RBDD dies, or otherwise does not reach the spawning area investigated in our survey. The RBDD estimate should exceed the number of fish expected to spawn in the survey area.

RECOMMENDATIONS

- The mark and recapture carcass surveys should be continued.

- Investigate the discrepancies between the sex ratios observed during the carcass survey and the fish trapped at RBDD.

  One of the principle questions that needs to be addressed is whether there is a difference in the availability of male and female carcasses to our sampling procedures. One possible explanation for the low male to female ratio observed in 1996 and 1997 is due to post- spawning behavior differences. Males may move downstream or to areas unavailable to sampling (e.g., deep pools), while females stay on the redd until they die and therefore are more susceptible to sampling. An effort should be made to determine if the ratio of male to female carcasses in deep (pool) areas is different from that observed in our surveys. This could be done several times throughout the spawning season using video surveillance or diving.

- Further evaluate the age composition of winter-run adults.

  The length at age criteria used to identify the age of female and male winter run should be verified using scales and otoliths collected from the sampled carcasses.

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LITERATURE CITED

Boydstun, L. B. 1994. Analysis of two mark-recapture methods to estimate the fall chinook salmon (*Oncorhynchus tshawytscha*) spawning run in Bogus Creek, California. Calif. Fish & Game 80(1):1-13.

Croci, S. J. and S. Hamelberg. 1997. Evaluation of the Sacramento River winter chinook salmon (*Oncorhynchus tshawytscha*) propagation program in 1996. USFWS Report. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office, Red Bluff, CA

Fisher, F. W. 1993. Historical review of winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River, California. Dept. Fish & Game Inland Fish Div. Office rept.

Hallock, R .J. and F. W. Fisher. 1985. Status of Winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River. Dept. Fish & Game Anad. Fish Br. Office rept.

Law, P. M. W. 1994. A simulation study of salmon carcass survey by capture-recapture method. Calif. Fish & Game 80(1):14-28.

NMFS (National Marine Fisheries Service). 1996. Recommendations for the recovery of the Sacramento River winter-run chinook salmon. Nat. Marine Fish. Serv. Southwest Region, Long Beach CA. 228 p.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Canada Dept. of Environ., Fish. and Mar. Serv. Bull. 191. 382 p.

Schaefer, M. B. 1951. Estimation of the size of animal populations by marking experiments. USF&WS Bull. 52:189-203.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. 2nd. MacMillan, New York, N.Y. 654 p.

Slater, D. W. 1963. Winter-run chinook salmon in the Sacramento River, California with notes on water temperature requirements for spawning. U.S.Fish & Wildlife Serv. Spec. Sci. Rept. - Fisheries No.461 9 pp.

Snider, B. and D. McEwan. 1992. Chinook salmon and steelhead trout redd survey, lower American River, 1991 - 1992, Final report. Calif. Dept. Fish & Game, Stream Evaluation Program, Envir. Serv. Div.

Snider, B., K. Urquhart, D. McEwan, and M. Munos. 1993. Chinook salmon redd survey, lower American River, Fall 1992. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B. and K. Vyverberg. 1995. Chinook salmon redd survey, lower American River, Fall 1993. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, S. Hamelberg, S. Croci, S. Hill, and E. Kohler. 1997. 1996 Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

Taylor, S. N. (Editor). 1974. King (chinook) salmon spawning stocks in California's Central Valley, 1973. Calif. Dept. Fish & Game, Anad. Fish. Admin. Rep. No. 74-12. 32 p.

USFWS. 1996. Escapement of hatchery-origin winter chinook salmon (*Oncorhynchus tshawytscha*) to the Sacramento River, California in 1995, with on spring chinook salmon in Battle Creek. U.S. Fish and Wildlife Service, Norther Central Valley Fish and Wildlife Office, Red Bluff, CA.

FIGURES

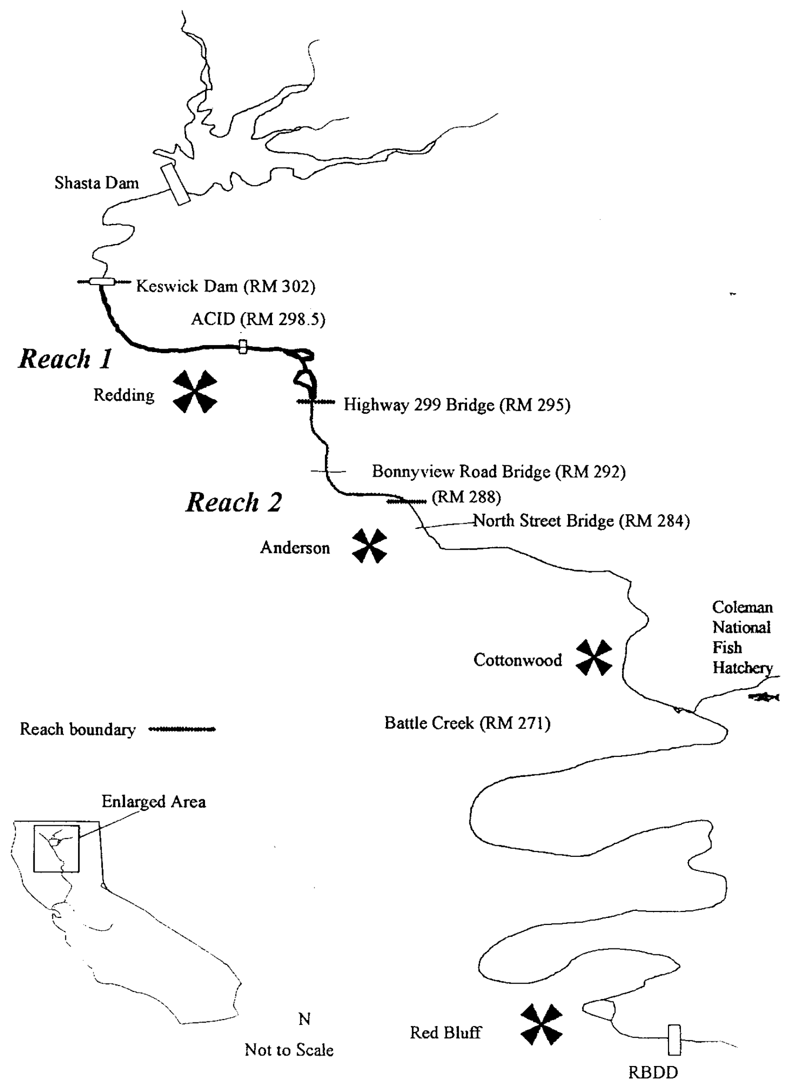


Figure 1. Upper Sacramento River winter-run chinook salmon escapement study location including reach designations, April - August 1997.

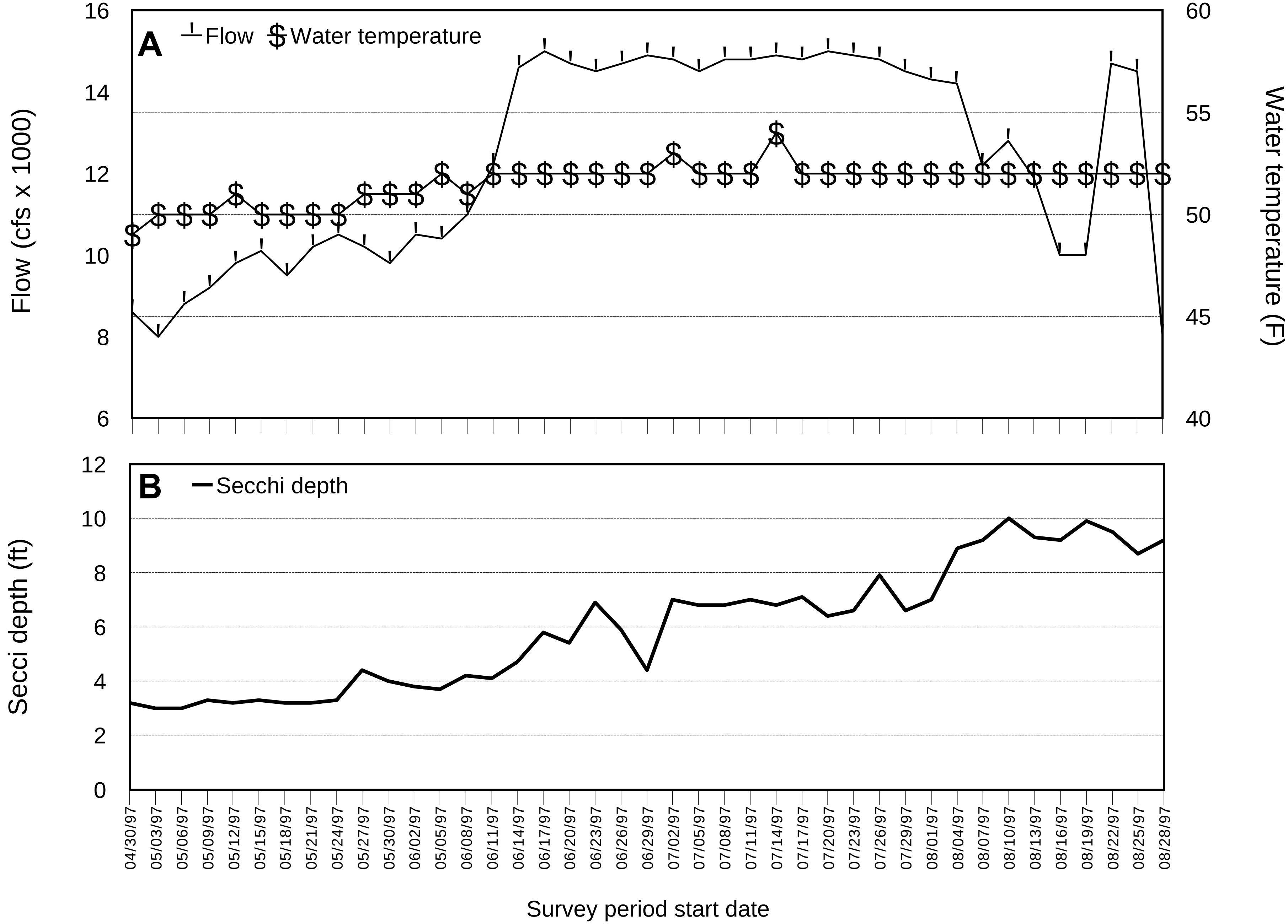


Figure 2. Mean flow and water temperature (A) and Secchi depth (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

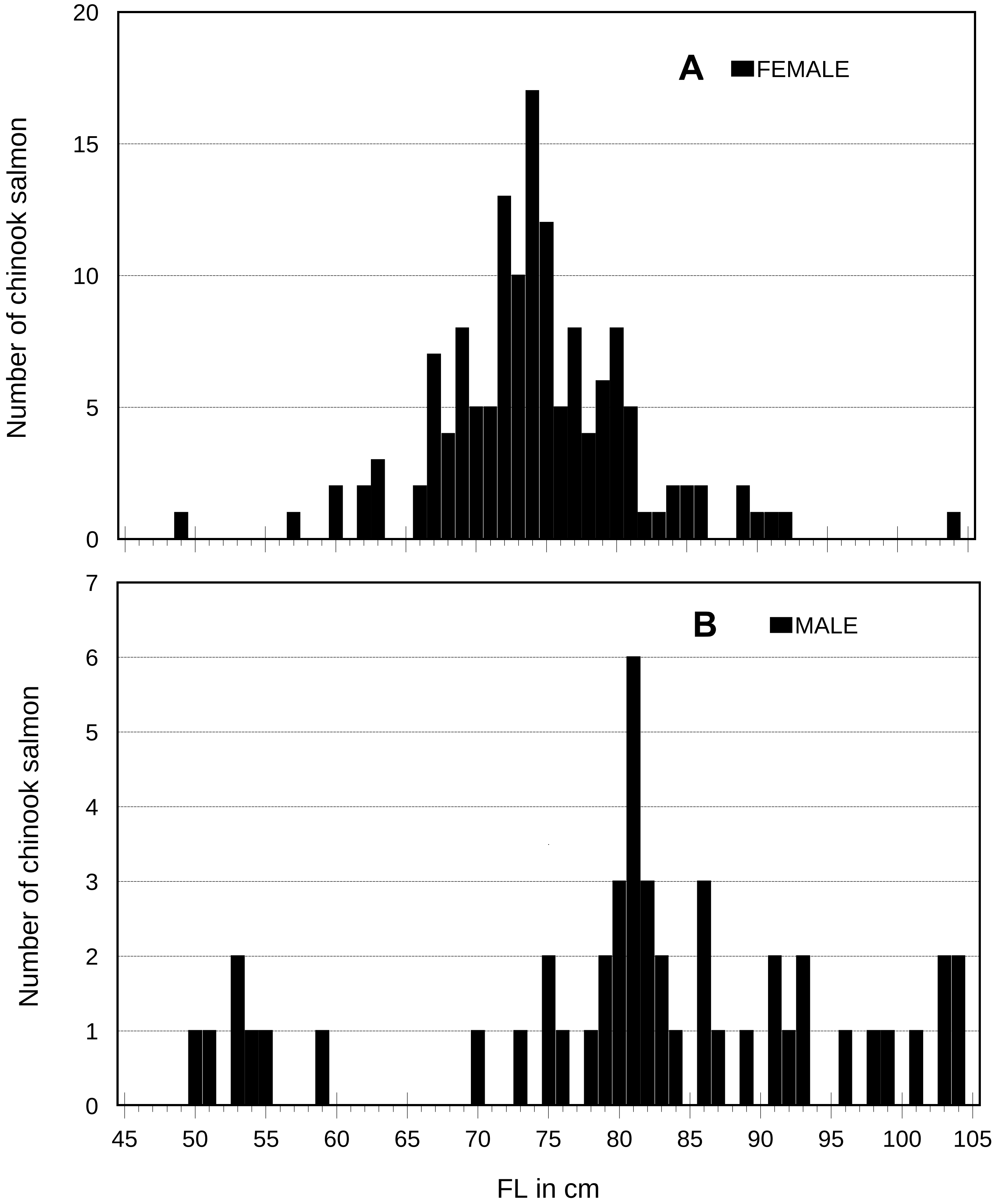


Figure 3. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

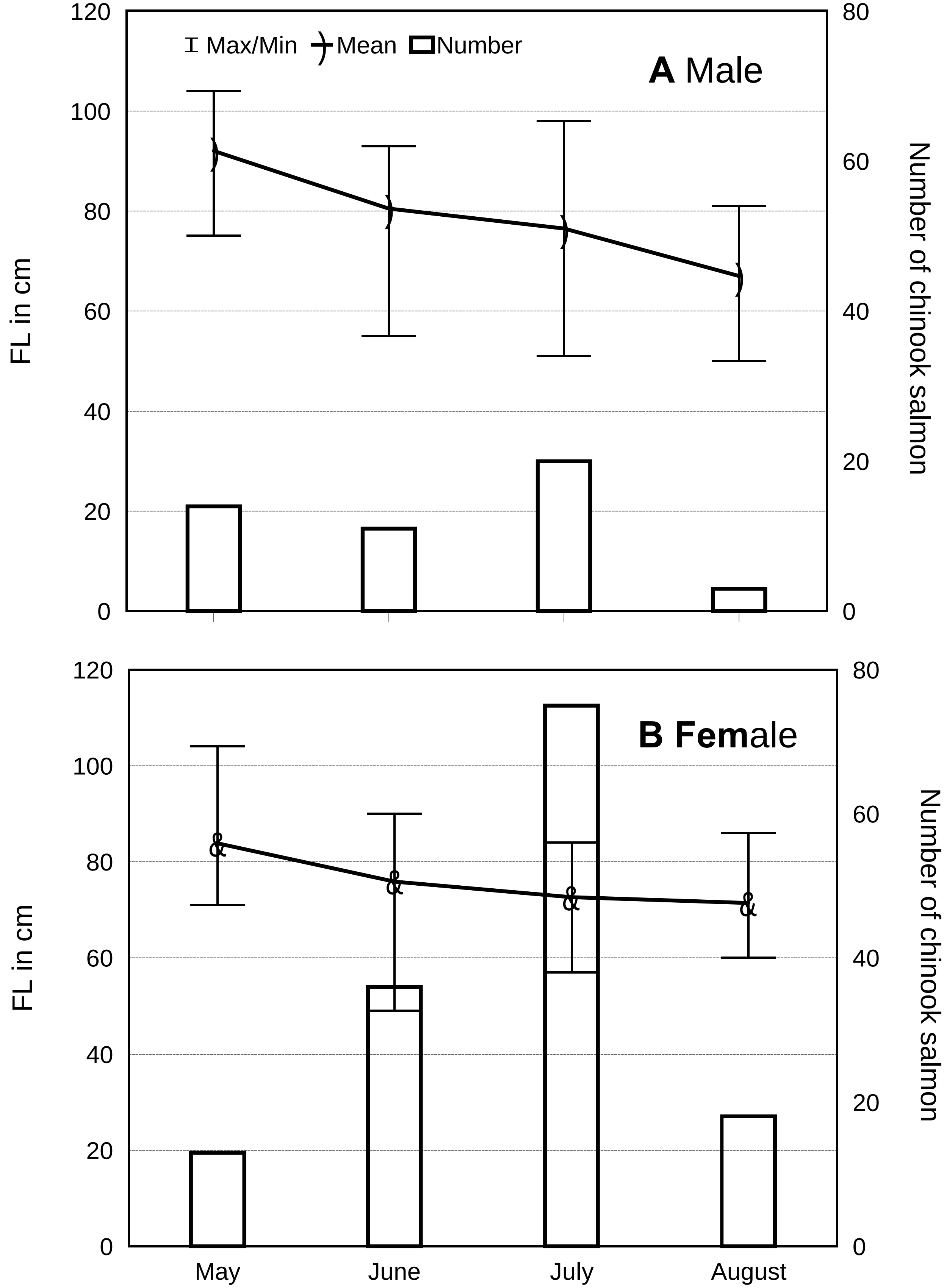


Figure 4. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

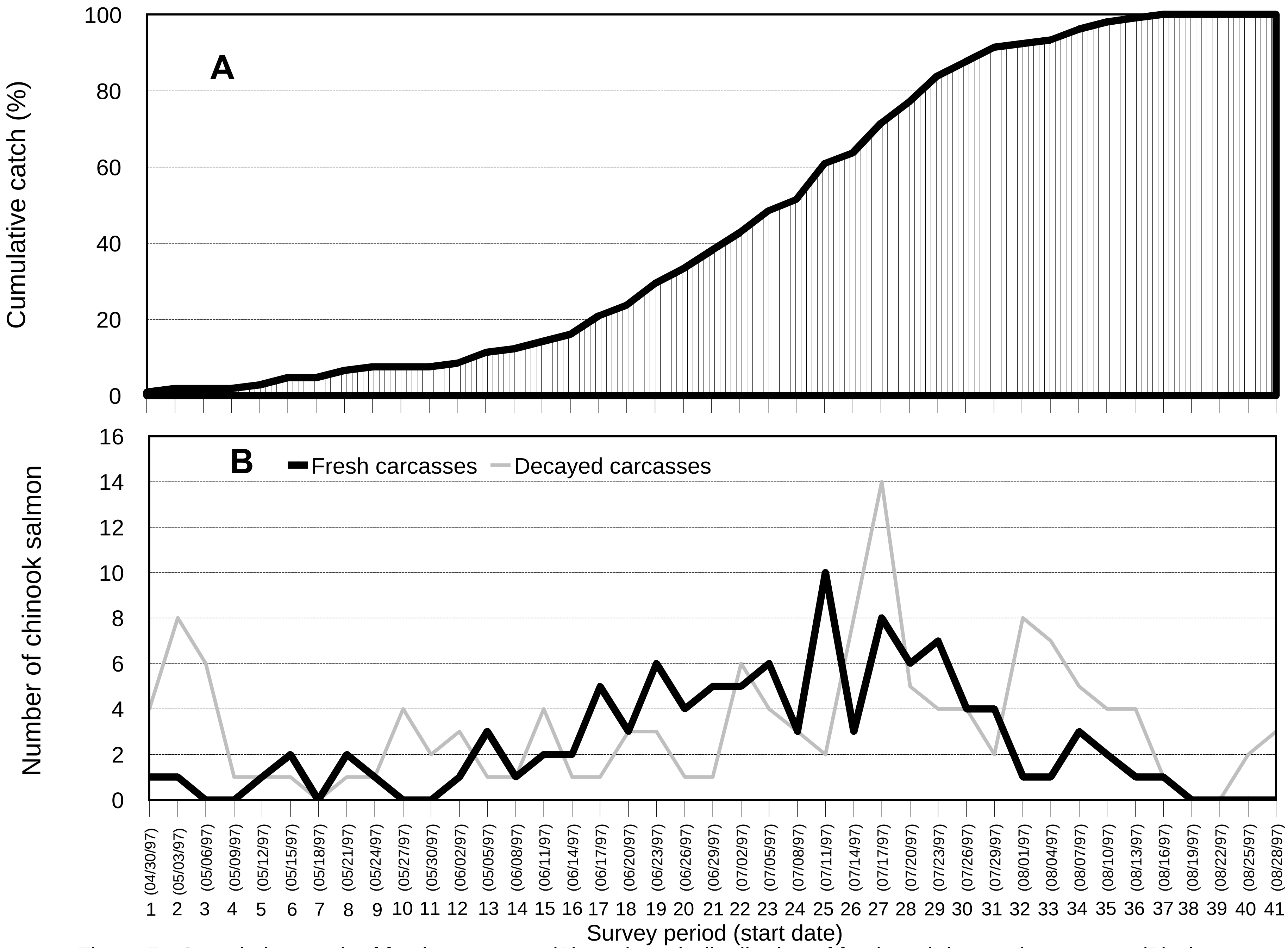


Figure 5. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B) , by survey period, during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

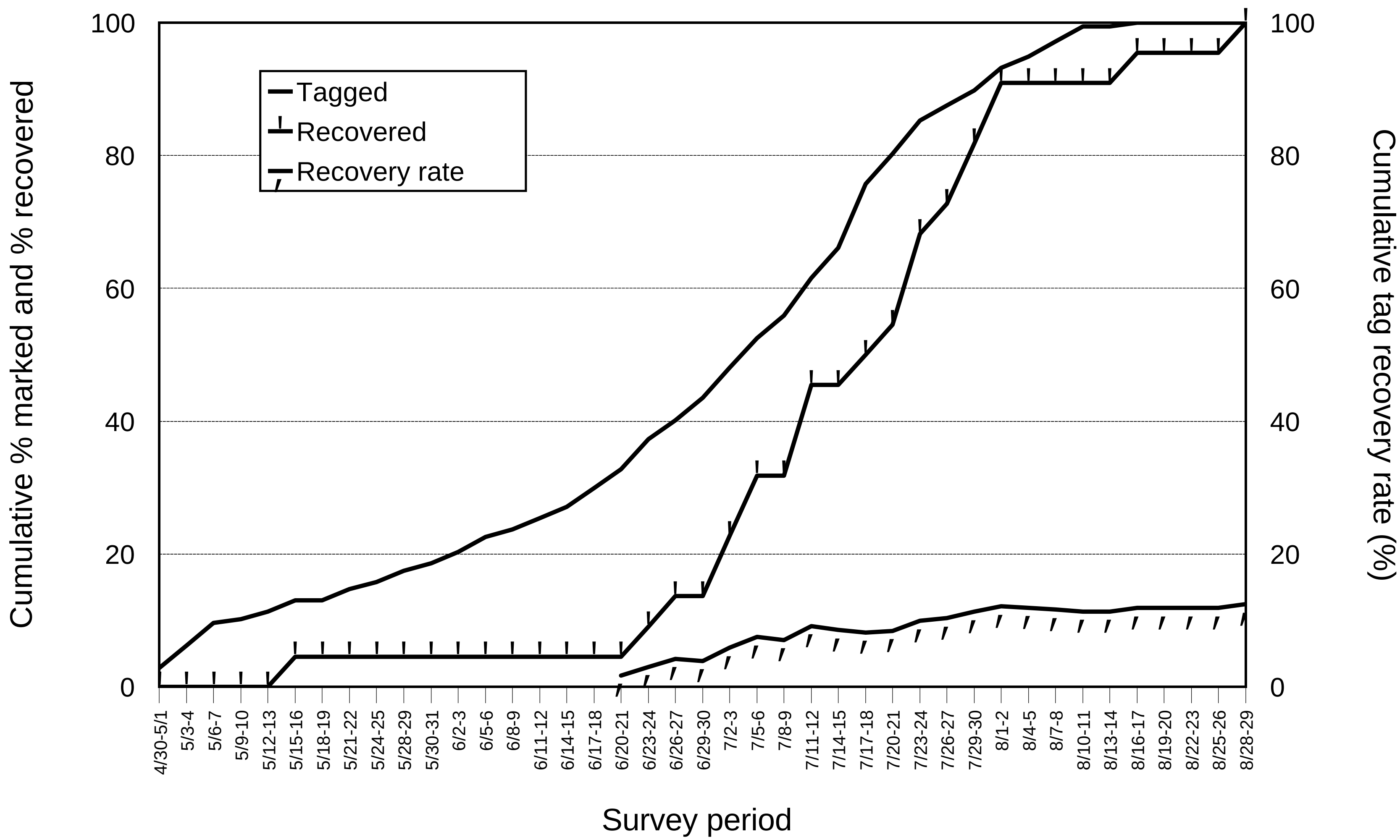
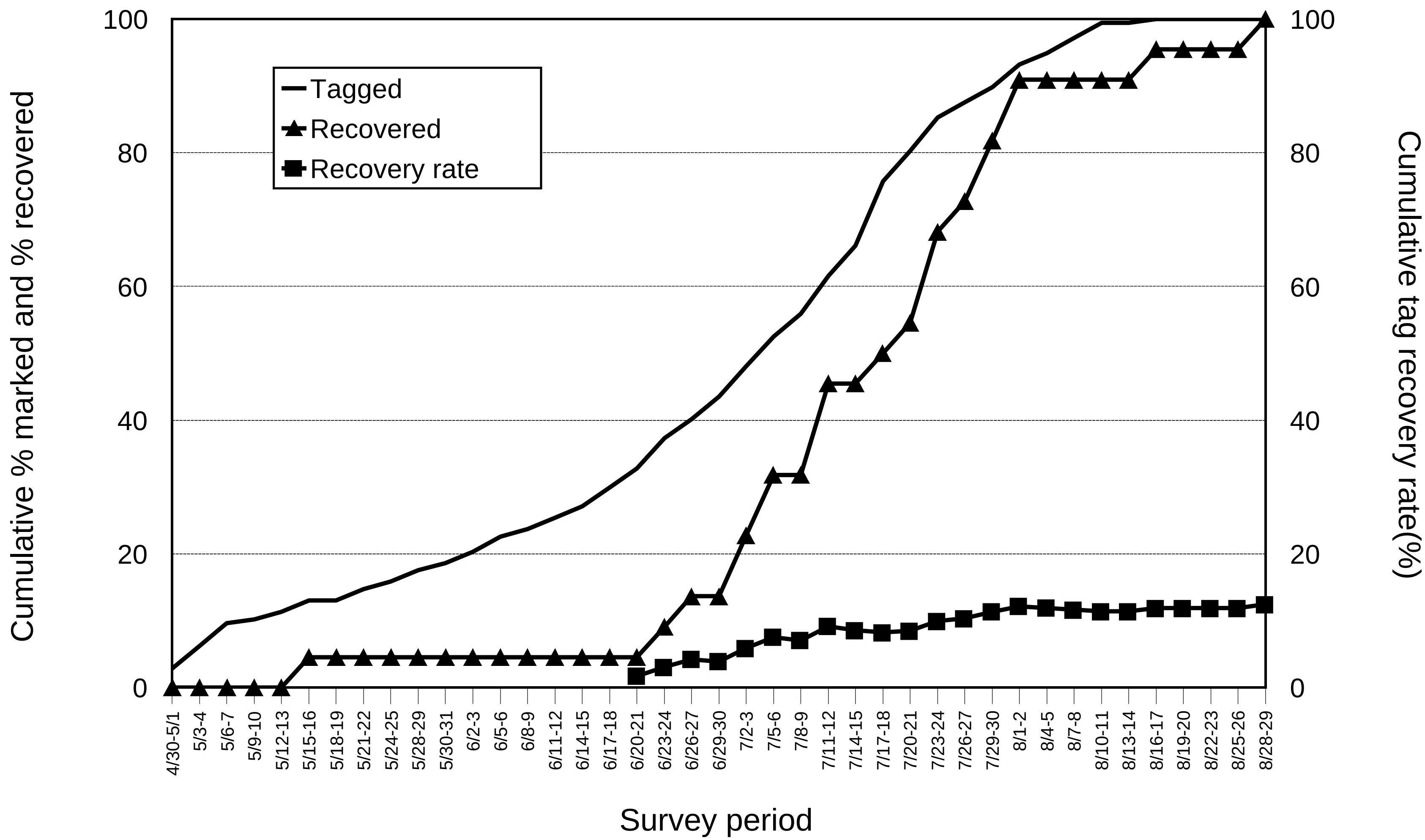


Figure 6. Comparison of temporal distribution of tagging versus recovering of tagged carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

Figure 7. Percentage of the total migration of winter-run chinook salmon passing Red Bluff Diversion Dam after Week 19 (1969 through 1985).



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