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

Upper Sacramento River Late-Fall-Run Chinook Salmon Escapement Survey December 1998–April 1999

by

Bill Snider
Bob Reavis
and
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Stream Evaluation Program
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2/ Stream Evaluation Program Technical Report 99-3.

TABLE OF CONTENTS

Summary

A late-fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during the winter and spring period of 1998–1999 to acquire data on spawner abundance, age population, pre-spawning mortality, and temporal and spatial distribution of spawning. This was the third year a late-fall-run escapement survey was conducted as part of a multi-year investigation by the Department of Fish and Game (DFG) to determine salmon habitat requirements in the Sacramento River system.

Late-fall-run spawning occurs from winter through early spring when survey conditions can be affected by high flows or reduced water clarity. Suitable survey conditions may last from only a few days to several months. During the first survey year, initiated in January 1996, high flows and extremely poor visibility forced suspension of the survey in late January. Survey conditions were substantially better during the winter-spring period of 1997–98 allowing a season-long survey.

Weekly surveys were conducted from 28 December 1998 through 28 April 1999. The surveys covered the 16.5-mile long section of the Sacramento River between Anderson-Cottonwood Irrigation District (ACID) Dam, at river mile (RM) 298.5, and Anderson River Park (RM 282.0). ACID Dam is located 3.5 miles downstream of Keswick Dam, the upstream limit to salmon migration. Flow ranged from 5,500 cubic feet per second (cfs) during weeks 2 and 3 (4–13 January 1999) and weeks 14 and 15 (29 March–7 April 1999), to 29,800 cfs in week 11 (8–10 March 1999). Water clarity ranged from 5 ft during week 4 (11–3 January) to 10 ft during weeks 3, 5, and 6 (11–13 and 26–28 January and 1–3 February 1999). Water temperature ranged from 47^{o} F in week 11 (8–10 March 1999) to 52^{o} F in week 18 (26–28 April 1999).

We observed 2,206 late-fall-run carcasses (450 fresh and 1,756 decayed). We measured (length) and sexed 435 fresh carcasses. Based on the fresh carcass measurements, 30% of the spawner population were male adults (>2-years old), 56% were female adults, 5% were male grilse (2-years old), and 9% were female grilse. Examination of 275 fresh female carcasses for egg retention showed that 267 (93%) had completely spawned, three (1%) still contained a substantial number of eggs, and five (2%) were unspawned.

Water clarity and flow conditions were more favorable for a tag recapture study in 1998–99 than during 1997–98. During 1997–98 water clarity equaled or exceeded 5 ft during only one-third of the weeks. Water clarity equaled or exceeded 5 ft during the entire 1998–99 survey. Similarly, during 1997–98, flows exceeded 20,000 cfs for one-half the season. In 1998–99, flows only exceeded 20,000 cfs for one-fifth of the season.

The total spawner escapement of 8,683 (1,216 grilse and 7,467 adults) was estimated using the Petersen formula, and 9,577 (1,341 grilse and 8,236 adults) using the Schaefer formula.

INTRODUCTION

The California Department of Fish and Game's (DFG) Stream Evaluation Program (STEP) conducted an intensive late-fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey on the upper Sacramento River during the winter-spring period of 1998–99 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 DFG have signed a "Cooperative Agreement" by which the FWS will fund DFG to conduct studies to determine flow needs of salmonids in the upper Sacramento River.

The primary charge of STEP - to improve understanding of the relationships between anadromous salmonids and habitat in the upper Sacramento River - requires reliable estimates of spawner populations 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 routinely used to estimate fall-run chinook 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 subsequent recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). This is the third year a carcass tag-and-recapture survey was conducted in the upper Sacramento River to estimate late-fall-run escapement. A late-fall-run spawner escapement survey attempted in 1996 was severely hampered by high flows. A complete survey was carried out in 1998 (Snider *et al.* 1998). Extremely high flow conditions prevented a late-fall-run survey in 1997.

Three models have been used by the DFG to estimate escapement based on 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 small spawner populations (e.g., recent upper Sacramento River winter-run populations) (Snider *et al.* 1999). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate escapement in the

Yuba River.

Based on Law's (1994) analysis, the Schaefer and Petersen models 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 spawner escapement in the Central Valley. This Jolly-Seber model was first used to estimate escapement in the Central Valley in 1988. It 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 fishery 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.)[1/]. 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.

METHODS

The 1999 late-fall-run salmon spawner escapement survey was conducted from 28 December 1998 through 28 April 1999. The 16.5-mile-long stream segment from ACID Dam (RM 298.5) downstream to Anderson River Park (RM 282) was divided into three reaches (Figure 1 and Table 1). Each reach was surveyed once per week.

Table 1. Location of reaches surveyed during the upper Sacramento River late fall-run chinook salmon escapement survey, December 1998–April 1999.

Reach	Location	River mile (length in miles)
1	ACID Dam to Cypress St. Bridge	298.5–295.0 (3.5)
2	Cypress St. Bridge to Bonnyview Bridge	295.0–292.0 (3.0)
3	Bonnyview Bridge to Anderson River Park	292.0–282.0 (10.0)

Surveys were primarily conducted using one boat with two observers per boat. The observers attempted to locate and collect carcasses as the boat traversed the river between the channel margins. Collected carcasses were checked for completeness (i.e., with the head intact) and previous tags. Complete, untagged carcasses were usually tagged by attaching a colored ribbon (to indicate week tagged) to the jaw using a hog ring. Carcasses that were not tagged were chopped in half. Chopped carcasses included: i) those previously tagged, ii) those on shore in a "leathery condition"; and, iii) those in the lower end of Reach 3 (the most downstream reach) that would likely wash out of the survey area and never be recovered. Tagged carcasses were

1/ Personal communication with Frank Fisher (DFG-Inland Fisheries Division, Red Bluff) and Fred Meyer (DFG Region 2, Sacramento, retired).

released into running water for recapture. Data collected to estimate population size included the numbers tagged, chopped, and recovered. All carcasses were 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, as partially spent if a substantial amount of the eggs remained, and unspent if the ovaries appeared nearly full of eggs. Carcasses were also examined for adipose-fin marks indicating presence of a coded-wire tag.

Our objective was to estimate the late-fall-run salmon natural escapement in the upper Sacramento River, preferably using the more accepted Schaefer or Jolly-Seber models. Since there were no recoveries from four of the 16 weeks that tag groups were released, the results for these weeks were lumped to calculate an estimate using the Schaefer model. The Petersen model was also used.

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

1. Schaefer model (as described by Taylor 1974): $E = N_{ij} = R_{ij}(T_iC_j/R_iR_j)-T_i$

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.

2. Petersen formula (3.7) as described by Ricker (1975):

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

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

Flow measurements for each survey day were obtained from the Keswick gauge operated by the

U.S. Geological Survey. Water temperature (grab sample) and water visibility (Secchi depth) were measured daily by the survey crew.

RESULTS AND DISCUSSION

A total of 2,206 carcasses was observed (Table 2). Mean[2/] flow ranged from 5,500 cfs during weeks 2 and 3 (4–13 January 1999) and weeks 14 and 15 (29 March–7 April 1999) to 29,800 cfs during week 11 (8–10 March). Flow was greater than 20,000 cfs during 22 percent of the survey weeks (Table 2, Figure 2). Mean temperature ranged from 47° F during week 11 (8–10 March) to 52° F during week 18 (26–28 April) (Table 2, Figure 2). Mean water clarity (Secchi depth) ranged from 5 ft in week 4 (19–21 January) to 10 ft during weeks 3, 5, and 6 (12–13 January and 26 January–3 February) (Table 2, Figure 2).

Temporal Distribution

Most carcasses were observed between 28 December 1998 and 28 January 1999 (57%). Twenty-two percent of the carcasses were observed during February, 16% during March, and 5% during April (Table 2 and Figure 3). Spawning appeared to be concentrated in first two weeks of January, however, the relatively high flow conditions that occurred from mid-February through mid-March may have restricted our ability to observe carcasses after the end of January.

Spatial Distribution

The majority of carcasses were observed in Reach 1 (46%, n = 1,017); 32% were observed in Reach 2 (n = 699), and 22% (n = 490) in Reach 3 (Table 3 and Figure 4). The spatial distribution may not accurately define spawning distribution since an unknown proportion of carcasses likely drifted downstream.

Size Distribution

Mean size of all measured carcasses was 84.4 cm FL (n = 435) (Table 4). Size ranged from 34 to 105 cm FL. Male salmon (n = 151) averaged 92.4 cm FL (range: 34 – 105 cm FL) (Figure 5). Female salmon (n = 284) averaged 82.1 cm FL (range: 52 – 102 cm FL) (Figure 6). The weekly mean size for males ranged from 82.0 to 101.5 cm FL (Figure 7). Weekly mean size for females ranged from 73.0 to 88.3 cm FL (Table 4 and Figure 8).

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 each sex (Figures 5 and 6). Both male (n = 22) and female (n = 40) grilse were defined as salmon $\leq$71 cm FL (Table 5). Male grilse averaged 63.3 cm FL (range: 34–70 cm FL, SD = 9.1); male adults (n = 129) averaged 94.0 cm

2/ Mean of daily measurements for week.

Table 2. General survey information for the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1998 – April 1999.

Week	Survey dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (°F)[2/]	Carcass count[3/]		
					Fresh	Decayed	Total
1	Dec 28 –30 (1998)	6,000	6	48	72	340	412
2	Jan 4–6	5,500	9	49	58	184	242
3	Jan 1–13	5,500	10	48	51	168	219
4	Jan 19–21	19,100	5	49	38	139	177
5	Jan 26–28	11,700	10	49	42	170	212
6	Feb 1–3	7,200	10	48	60	227	287
7	Feb 9 – 11	15,000	9	48	19	100	119
8	Feb 16–19	26,200	8	48	4	16	20
9	Feb 22–26	23,600	8	48	16	50	66
10	Mar 1–4	27,800	8	48	12	34	46
11	Mar 8–10	29,800	7	47	5	20	25
12	Mar 15–17	14,700	8	49	18	73	91
13	Mar 22–24	6,200	7	48	19	104	123
14	Mar 29–31	5,500	8	48	17	51	68
15	Apr 4–7	5,500	8	49	7	17	24
16	Apr 12–14	9,300	8	50	7	25	32
17	Apr 19–21	9,000	9	51	3	23	26
18	Apr 26– 28	9,000	9	52	2	15	17
	Totals				450	1,756	2,206

1/ Mean flow during days sampled as measured at Keswick Dam by U.S. Geological Survey.
2/ Mean of daily measurements taken by survey crews.
3/ Includes both adults and grilse.

FL (range: 72–105 cm FL, SD = 8.3). Female grilse (n = 40) averaged 66.6 cm FL (range: 52–71 cm FL, SD = 4.4); female adults (n = 244) averaged 83.3 FL (range: 72–102 cm FL, SD = 5.9).

Grilse comprised 14% (n = 62) of the 435 measured carcasses (Table 6). Nearly 25% (15) of the grilse were observed during the first week; 50% of all grilse was observed during the first three weeks (28 December 1998–13 January 1999) (Figure 9). Adults comprised 86% (n = 373) of the carcasses measured.

Sex Composition

Males comprised 35% (n = 129) and females comprised 65% (n = 244)(Table 7) of the fresh adult carcasses examined. Males also comprised 35% (n = 22) and females comprised 65% (n = 40) of the fresh grilse examined. Males comprised 35% (n = 151) of all fresh carcasses measured and females comprised 65% (n = 284).

The female to male ratio for adult spawners was nearly 1.9 to1 (244:129) (Table 7 and Figure 10). Females made up at least 57% of the adult population, except during the third week. The female to male ratio for grilse also was 1.9 to1. Most grilse (94%) were observed during the first third of the season (Figure 11).

Spawning Success

A total of 275 female carcasses was examined for egg retention (Table 8). Ninety-seven percent (n = 267) had completely spawned, 1% (n = 3) had only partially spawned, and 2% (n = 5) had not spawned.

Population Estimates

An adult escapement estimate of 7,467 adults was calculated from fresh carcass data using the adjusted Petersen formula described above (Table 9). The adult estimate was then divided by 0.86 (the portion of adults based on fresh carcass subsample) yielding a total population estimate of 8,683 (7,467 adult and 1,216 grilse).

An estimate of 8,236 adults was calculated using the Schaefer formula (Tables 10 and 11). In order to use the Schaefer formula, we grouped fresh carcass results from weeks 7–11 to account for weeks 8–11 when no tags were recovered. This adult estimate was also divided by 0.86 for a total escapement estimate of 9,577 late-fall-run spawners (includes 1,341 grilse).

The 1999 escapement of 8,683 (using Petersen formula) is less than the 1967–1992 average of 14,159 for the section of stream from Keswick Dam to Red Bluff Diversion Dam (RBDD) (Table 12 and Figure 12). The estimates for the 1967 through 1992 period were based on RBDD ladder counts. Changes in operation of RBDD have eliminated the opportunity to count late-fall run since 1992.

Table 3. Distribution of carcasses (adults and grilse) observed during the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1998–April 1999.

Week	Reach 1		Reach 2		Reach 3	
	M[1/]	C[2/]	M	C	M	C
1	167	17	95	23	93	17
2	145	15	45	19	16	2
3	92	18	57	28	16	8
4	93	24	34	10	13	3
5	101	18	42	19	29	3
6	35	33	42	43	102	32
7	29	19	16	2	38	15
8	2	1	9	2	1	5
9	11	5	30	8	9	3
10	14	4	10	3	8	7
11	8	2	6	2	6	1
12	28	10	23	15	4	11
13	23	19	27	34	14	6
14	20	7	16	7	8	10
15	9	3	5	6	1	0
16	17	7	4	2	2	0
17	0	10	0	11	0	5
18	0	11	0	4	0	2
Total	794	223	461	238	360	130

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

Table 4. Size and sex statistics for fresh carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	All salmon			Male salmon			Female salmon		
		Length (FL in cm)			Length (FL in cm)			Length (FL in cm)	
Week	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
1	63	82.8	57–105	26	89.3	57–105	37	78.3	60–97
2	58	82.5	34–105	22	84.4	34–105	36	80.9	62–93
3	50	81.8	45–103	28	83.2	45–103	22	80.0	63–99
4	38	85.2	70–105	15	91.9	70–105	23	80.8	70–94
5	41	83.7	63–104	13	91.6	63–104	28	80.1	63–100
6	60	84.6	52–105	23	95.3	63–105	37	78.5	52–95
7	18	85.2	62–101	7	93.0	73–101	11	80.3	62–93
8	4	85.2	82–89	1	82.0	–	3	86.3	83–89
9	16	86.5	65–104	4	91.0	65–104	12	85.0	75–92
10	12	87.9	77–102	2	101.5	99–102	10	85.4	77–102
11	4	90.8	81–98	1	98.0	–	3	88.3	81–98
12	17	81.8	75–100	1	100.0	–	16	80.9	75–94
13	18	82.3	71–92	2	89.0	86–92	16	81.4	71–92
14	17	88.4	79–102	3	99.3	98–102	14	86.0	79–101
15	7	85.6	79–97	1	97.0	–	6	83.7	79–94
16	7	86.1	78–92	2	91.5	91–92	5	84.0	78–91
17	3	85.3	80–90	0	–	–	3	85.3	80–90
18	2	73.0	62–84	0	–	–	2	73.0	62–84
Total (mean)	435	(84.4)	34–105	151	(92.4)	34–105	284	(82.1)	52–102

Table 5. Summary of adult and grilse sizes and numbers by sex for carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	40	244	22	129
Mean FL (cm)	66.6	83.3	63.3	94.0
Range FL (cm)	52–71	72–102	34–70	72–105
S D	4.4	5.9	9.1	8.3

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	Adults		Grilse	
Week	Number	Percent	Number	Percent
1	48	76	15	24
2	48	83	10	17
3	39	78	11	22
4	35	92	3	8
5	31	76	10	24
6	51	85	9	15
7	17	94	1	6
8	4	100	0	0
9	15	94	1	6
10	12	100	0	0
11	4	100	0	0
12	17	100	0	0
13	17	94	1	6
14	17	100	0	0
15	7	100	0	0
16	7	100	0	0
17	3	100	0	0
18	1	50	1	50
Total(mean)	373	(86)	62	(14)

* Based on length-frequency distributions grilse are defined as $\leq$71 cm FL

Table 7. Sex composition of grilse and adults carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 – April 1999.

	Adults				Grilse[a/]			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	20	42	28	58	6	40	9	60
2	17	35	31	65	5	50	5	50
3	21	54	18	46	7	64	4	36
4	14	40	21	60	1	33	2	67
5	12	39	19	61	1	10	9	90
6	22	43	29	57	1	11	8	89
7	7	41	10	59	0	–	1	100
8	1	25	3	75	0	–	0	–
9	3	20	12	80	1	100	0	0
10	2	17	10	83	0	–	0	–
11	1	25	3	75	0	–	0	–
12	1	6	16	94	0	–	0	–
13	2	12	15	88	0	0	1	100
14	3	18	14	82	0	–	0	–
15	1	14	6	86	0	–	0	–
16	2	29	5	71	0	–	0	–
17	0	0	3	100	0	–	0	–
18	0	0	1	100	0	0	1	100
Total (mean)	129	(35)	244	(65)	22	(35)	40	(65)

a/ based on length-frequency distributions, grilse are defined as ≤71 cm FL

Table 8. Summary of spawning completion (egg retention) determined from fresh female salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998–April 1999.

Week	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	37	36	36(100)	0(0)	0(0)
2	36	34	30(88)	0(0)	4(12)
3	22	22	21(95)	1(5)	0(0)
4	23	23	22(96)	0(0)	1(4)
5	28	28	28(100)	0(0)	0(0)
6	37	36	36(100)	0(0)	0(0)
7	11	11	11(100)	0(0)	0(0)
8	3	0	–	–	–
9	12	12	12(100)	0(0)	0(0)
10	10	10	9(90)	1(10)	0(0)
11	3	3	2(67)	1(33)	0(0)
12	16	16	16(100)	0(0)	0(0)
13	16	16	16(100)	0(0)	0(0)
14	14	14	14(100)	0(0)	0(0)
15	6	6	6(100)	0(0)	0(0)
16	5	3	3(100)	0(0)	0(0)
17	3	3	3(100)	0(0)	0(0)
18	2	2	2(100)	0(0)	0(0)
Total (mean)	284	275	267(93)	3(1)	5(2)

Table 9. Summary of tagging and recapture of fresh adult carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998–April 1999.

Week	Date	Number observed	Number tagged	Number recovered (Original tagging period)
1	Dec 28–30	373	66	–
2	Jan 4–6	227	54	24(1)
3	Jan 11–13	188	43	9(2), 6(1)
4	Jan 19–21	167	38	8(3),4(2),4(1)
5	Jan 26–28	191	40	1(4),2(3),1(2),1(1)
6	Feb 1–3	253	55	22(5), 5(4), 2(3),1(2)
7	Feb 9–11	102	18	6(6),1(3)
8	Feb 16–19	20	4	0
9	Feb 22–26	64	15	0
10	Mar 1–4	44	12	0
11	Mar 8–9	23	4	0
12	Mar 15–17	86	17	3(9)
13	Mar 22–24	118	18	9(12),1(10)
14	Mar 29–31	64	17	2(2)
15	Apr 5–7	24	7	1(14)
16	Apr 12–14	31	7	1(14)
17	Apr 19–21	26	0	1(16),2(15),1(13)
18	Apr 26–28	16		0
Totals		2,017	415	118

Table 10. Upper Sacramento River adult late-fall-run chinook salmon population estimate using the Schaefer model based on tagging fresh carcasses with all captured untagged carcasses removed, December 1998 – April 1999.

Recovery period$_{(j)}$	Tagging period $_{(i)}$												Tags recovered	Carcasses counted	Ratio
	1	2	3	4	5	6	7–11[a/]	12	13	14	15	16	$R_{(j)}$	$C_{(j)}$	$C_{(j)}/R_{(j)}$
1	24												24	624	26.00
2	6	9											15	203	13.53
3	4	4	8										16	183	11.44
4	1	1	2	1									5	196	39.20
5		1	2	5	22								30	283	9.43
6			1			6							7	260	37.14
7–11[a/]							3						3	89	29.67
12							1	9					10	128	12.80
13									2				2	66	33.00
14										1			1	25	25.00
15										1	0		1	32	32.00
16									1		2	1	4	30	7.50
17													0	16	0.00
18													0		0.00
$R_{(i)}$	35	15	13	6	22	6	4	9	3	2	2	1	(Tagged carcasses recovered)		
$T_{(i)}$	66	54	43	38	40	55	53	17	18	17	7	7	(Total carcasses tagged)		
$T_{(i)}/R_{(i)}$	1.83	3.60	3.31	6.33	1.82	9.17	13.2	1.89	6.00	8.50	3.50	7.00	(Ratio)		

a/ Tagging and recovery periods were lumped to account for weeks when no tags were recovered.

Table 11. Upper Sacramento River adult late-fall-run salmon population estimate using the Schaefer model based on tagging fresh carcasses with all the captured untagged carcasses removed, December 1998–April 1999.

Recovery period$_{(j)}$	Tagging period$_{(i)}$												
	1	2	3	4	5	6	7–11[a/]	12	13	14	15	16	Totals
1	1,177												1,177
2	153	438											591
3	86	165	303										554
4	74	141	259	248									722
5		34	62	299	377								772
6			123			2,043							2,166
7–11[a/]							1,179						1,179
12							170	218					388
13									396				396
14										213			213
15										272			272
16									45		53	53	151
17													0
18													0
Subtotals	1,190	778	747	547	377	2,043	1,349	218	441	485	53	53	8,581
Tags		-54	-43	-38	-40	-55	-53	-17	-18	-17	-7	-7	-345
										Populations estimate -			8,236

a/ Tagging and recovery periods were lumped to account for weeks when no tags were recovered.

Table 12. Summary of late-fall-run chinook salmon escapement estimates (adults and grilse) for the Sacramento River (Keswick Dam to RBDD) from 1956 through 1999. (Data provided by Frank Fisher, DFG, Red Bluff).

Year	Total	Year	Total
1967	37,208	1984	5,907
1968	34,733	1985	7,660
1969	37,178	1986	6,710
1970	19,190	1987	14,443
1971	14,323	1988	10,683
1972	31,553	1989	9,875
1973	22,204	1990	6,921
1974	6,445	1991	6,531
1975	16,663	1992	10,371
1976	15,280	1993	no est.
1977	9,090	1994	no est.
1978	8,880	1995	no est.
1979	8,740	1996	no est.
1980	7,747	1997	no est.
1981	1,597	1998	9,717[a/]
1982	1,141	1999	8,683[a/]
1983	13,274		

a/ Based on carcass counts.

Coded-wire-tag Recovery Data

Five fresh carcasses observed during the survey were marked with adipose fin clips. Four of the five marked fish possessed coded-wire tags (Table 13).

Table 13. Summary of coded-wire tags recovered from carcasses observed during the 1998–99 late-fall-run chinook salmon spawner escapement survey.

Tag #	Brood year	Sex	Length (cm)	Date recovered	River mile recovered
No tag		Female	45	1/11/99	298
054109	95	Female	77	1/26/99	296.5
054118	95	Male	100	1/26/99	296.5
054241	96	Female	62	2/1/99	297
053621*	94	Female	81	3/24/99	286

* Read four times to assure accuracy

CONCLUSIONS AND RECOMMENDATIONS

1. The numbers of carcasses observed per week may have been affected by high flows and low visibility. An increase in flow and reduction in water clarity during week 4 likely depressed carcass counts; in week 5 flow decreased and clarity increased resulting in increased carcass counts. Similarly in weeks 7 through 12, flows increased and clarity decreased resulting in reduced counts.

2. Law (1994) concluded the Petersen model consistently and substantially overestimated the total population compared to either the Schaefer or Jolly-Seber models. In our survey, the Petersen formula produced a lower estimate. The higher Schaefer estimate is likely due to our grouping the weeks when tag recoveries were absent. A low recovery rate applied to this grouping resulted in a high proportion of the Schaefer estimate occurring during these weeks (Tables 10 and 11).

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APPENDIX

Appendix Table 1. Comparison of results from the 1998 and 1999 upper Sacramento River late-fall-run spawner survey.

Parameter	1998 survey	1999 survey
Survey dates	29 Dec 1997–1 May 1998	28 Dec1998–28 Apr 1999
No. of total carcasses	847	2,206
No. of fresh carcasses	182	450
No. of decayed carcasses	665	1,756
Tag recovery rate	9.2%	28.4%
Estimated population	9,717 (Petersen model)	8,683 (Petersen model)
Adult estimate	8,648	7,467
Grilse estimate	1,069	1,216
Adult female estimate	49%	56%
Adult male estimate	40%	30%
Grilse female estimate	7%	9%
Grilse male estimate	4%	5%
Female:male ratio adults	1.2:1	1.9:1
Size criterion (male)	Adult >70cm	Adult >71 cm
Size criterion (female)	Adult >70cm	Adult >71 cm
Spawning success (%)	93%	93%
Spatial distribution (Reach 1,2,3)	62%, 19%, 19%	46%, 32%, 22%
Temporal distribution(Jan, Feb, Mar, Apr)	97%, 2%, 0.3%, 0.7%	57%, 22%, 16%, 5%
Flow range	4,200–52,800 cfs	5,500–29,800 cfs
Temperature range	47–54º F	47–52º F
Visibility range	4–12 ft	5–10 ft

FIGURES

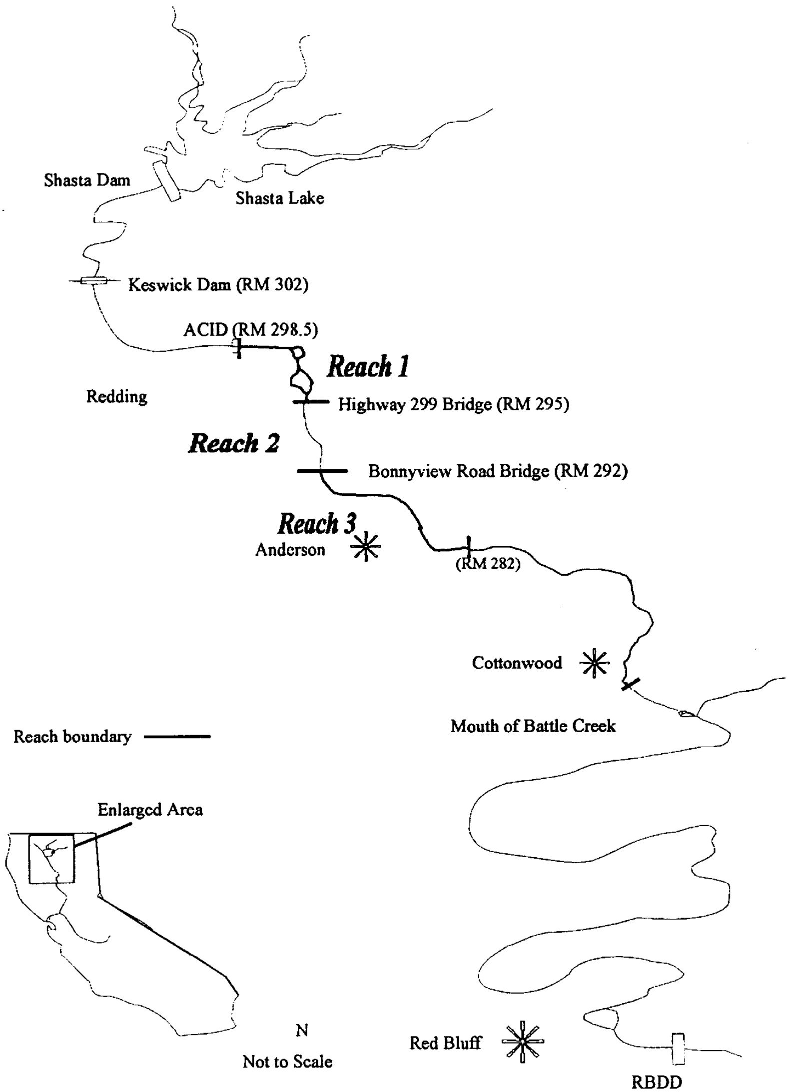

Figure 1. Locatoin of the reaches surveyed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

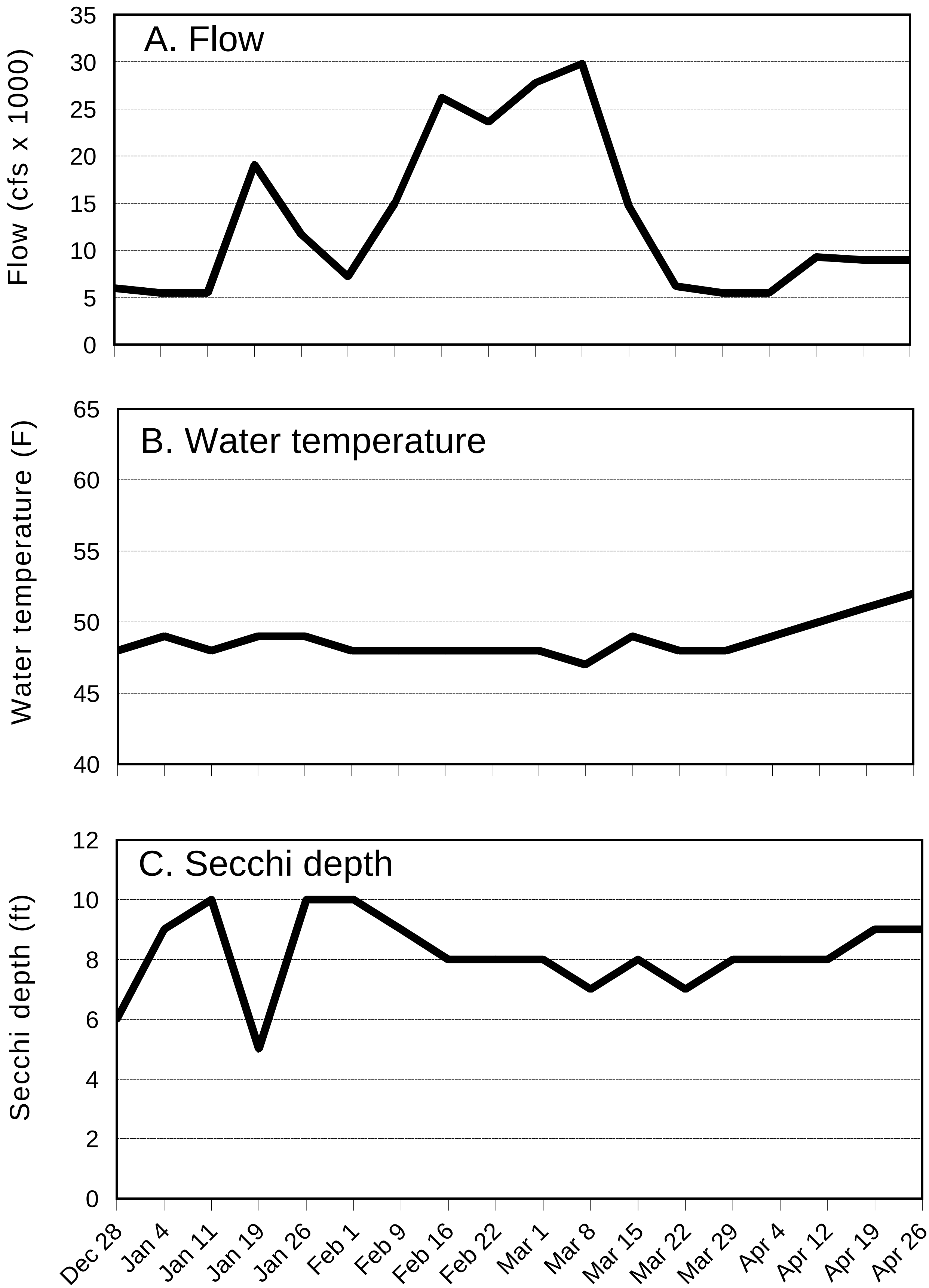

Figure 2. Mean daily flow (A) measured at Keswick Dam, water temperature (B) and secchi depth (C) during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

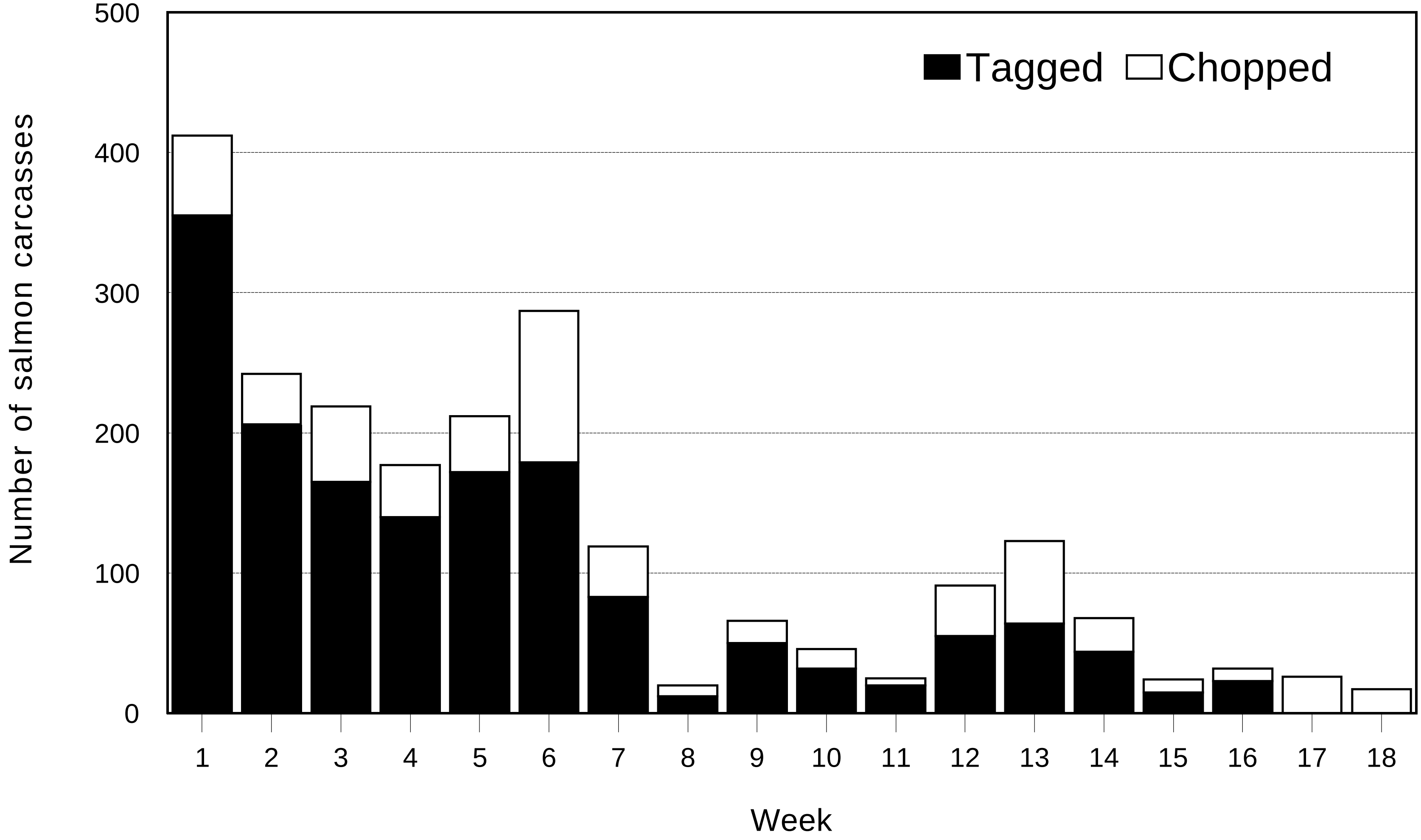

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

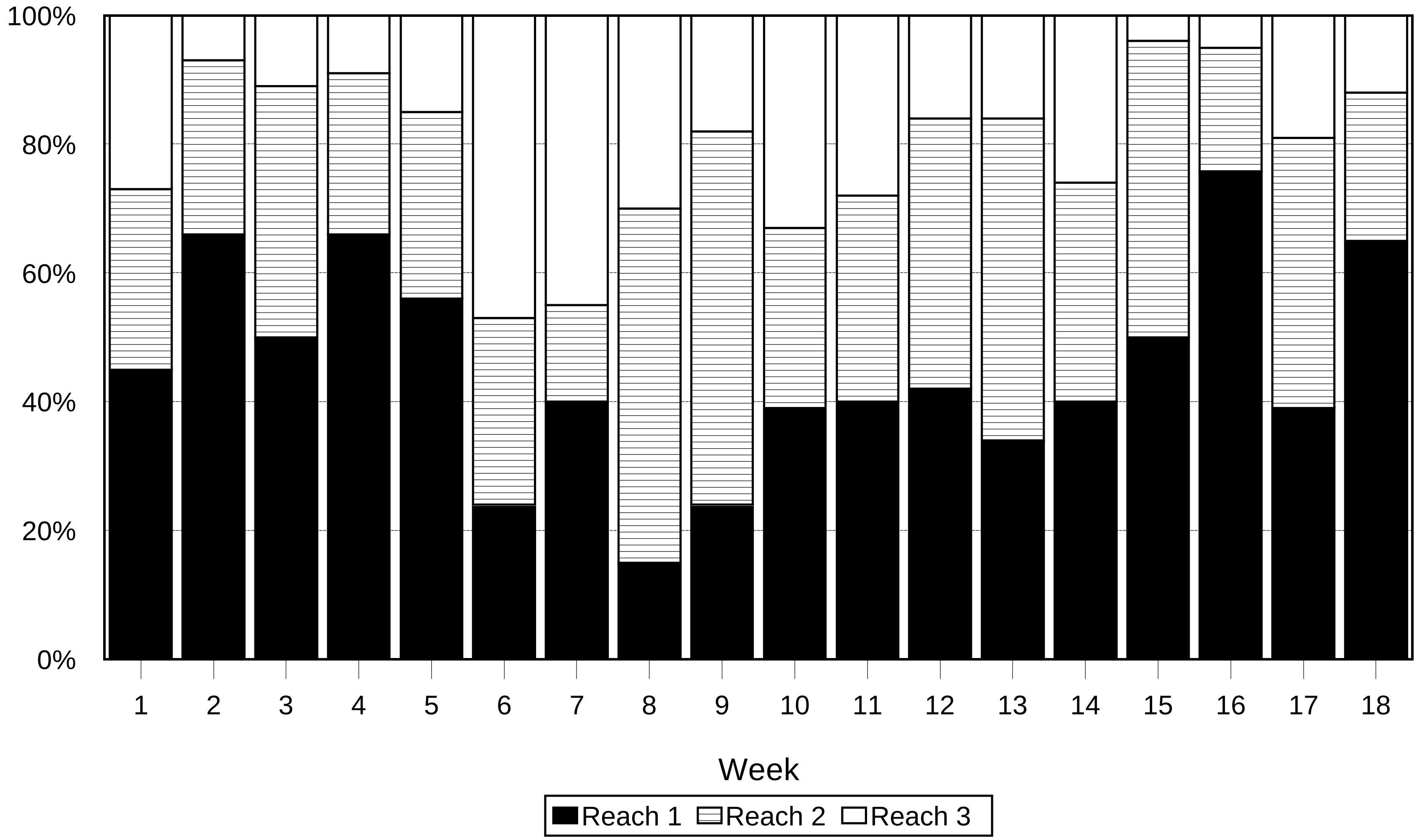

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

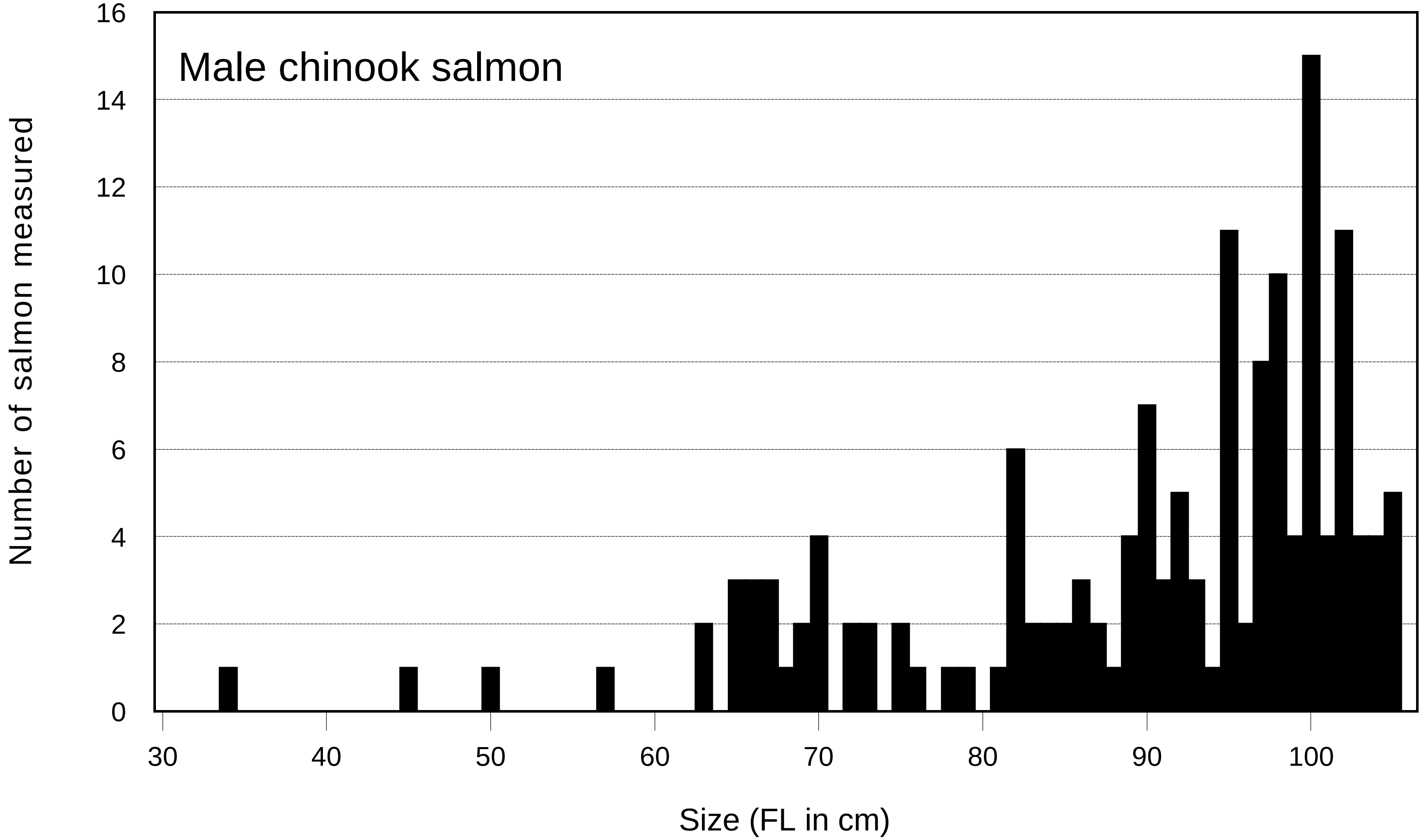

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

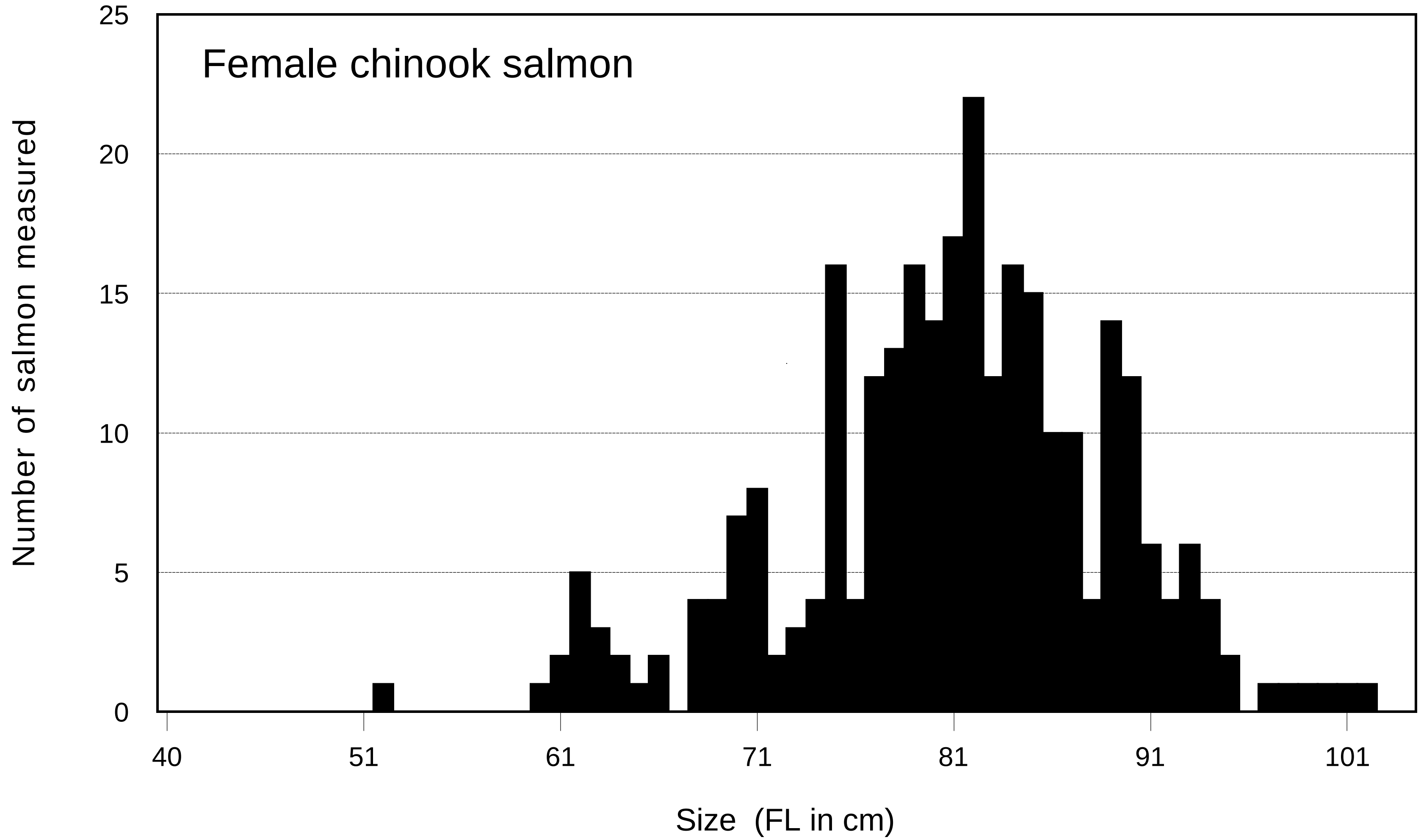

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

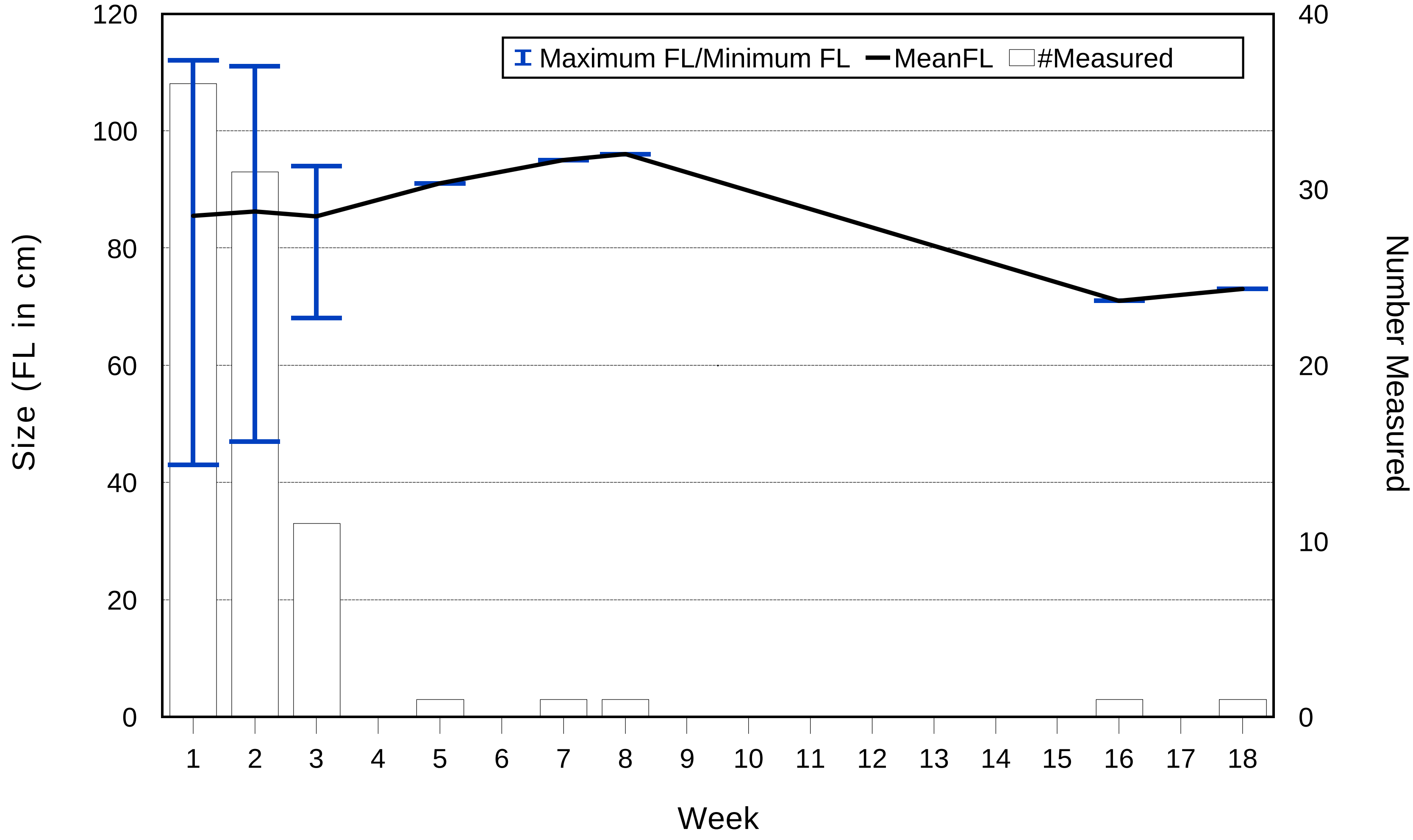

Figure 7. Mean weekly size, size range, and number of male chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

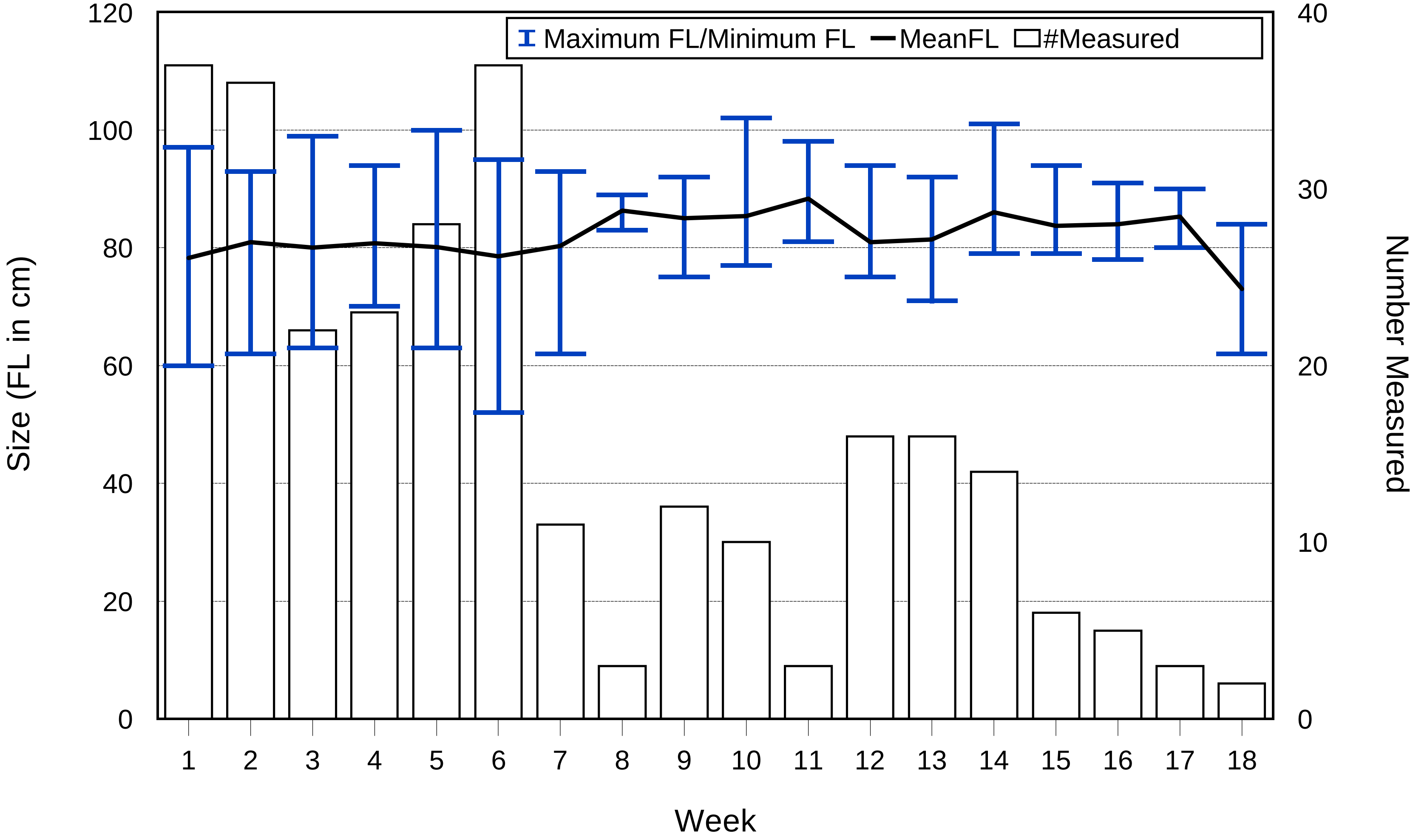

Figure 8. Mean weekly size, size range, and number of female chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

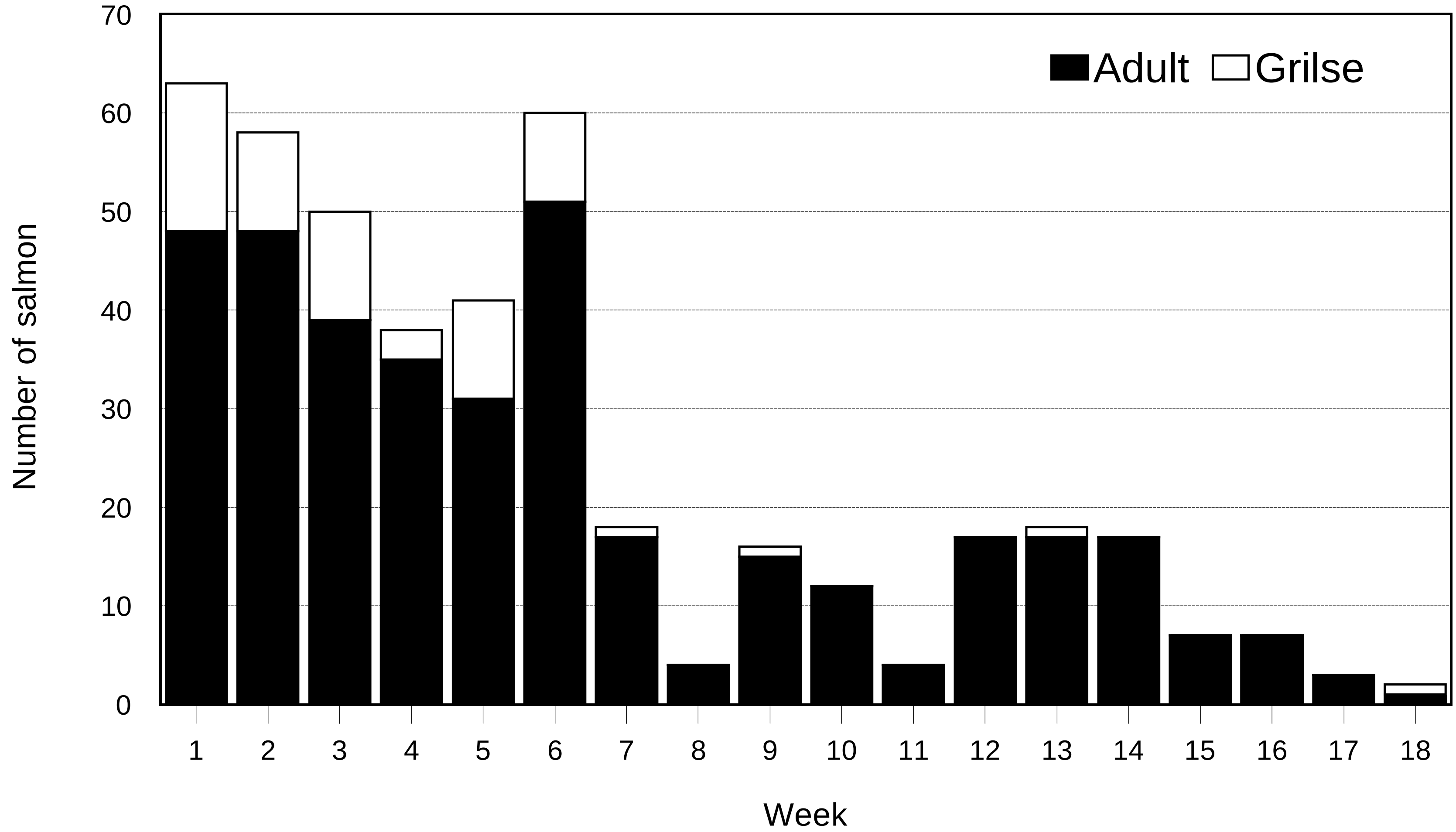

Figure 9. Weekly age compostion of chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

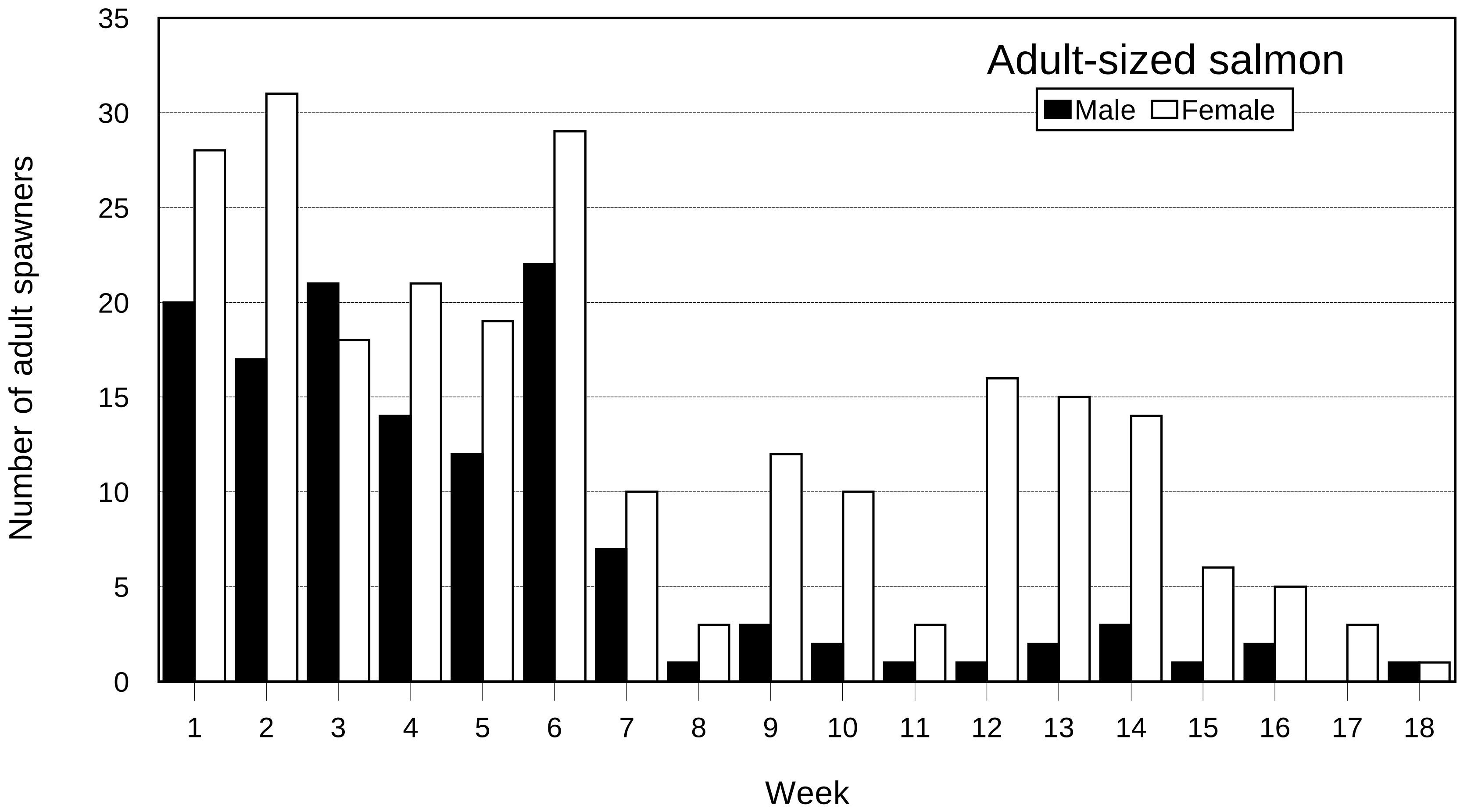

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

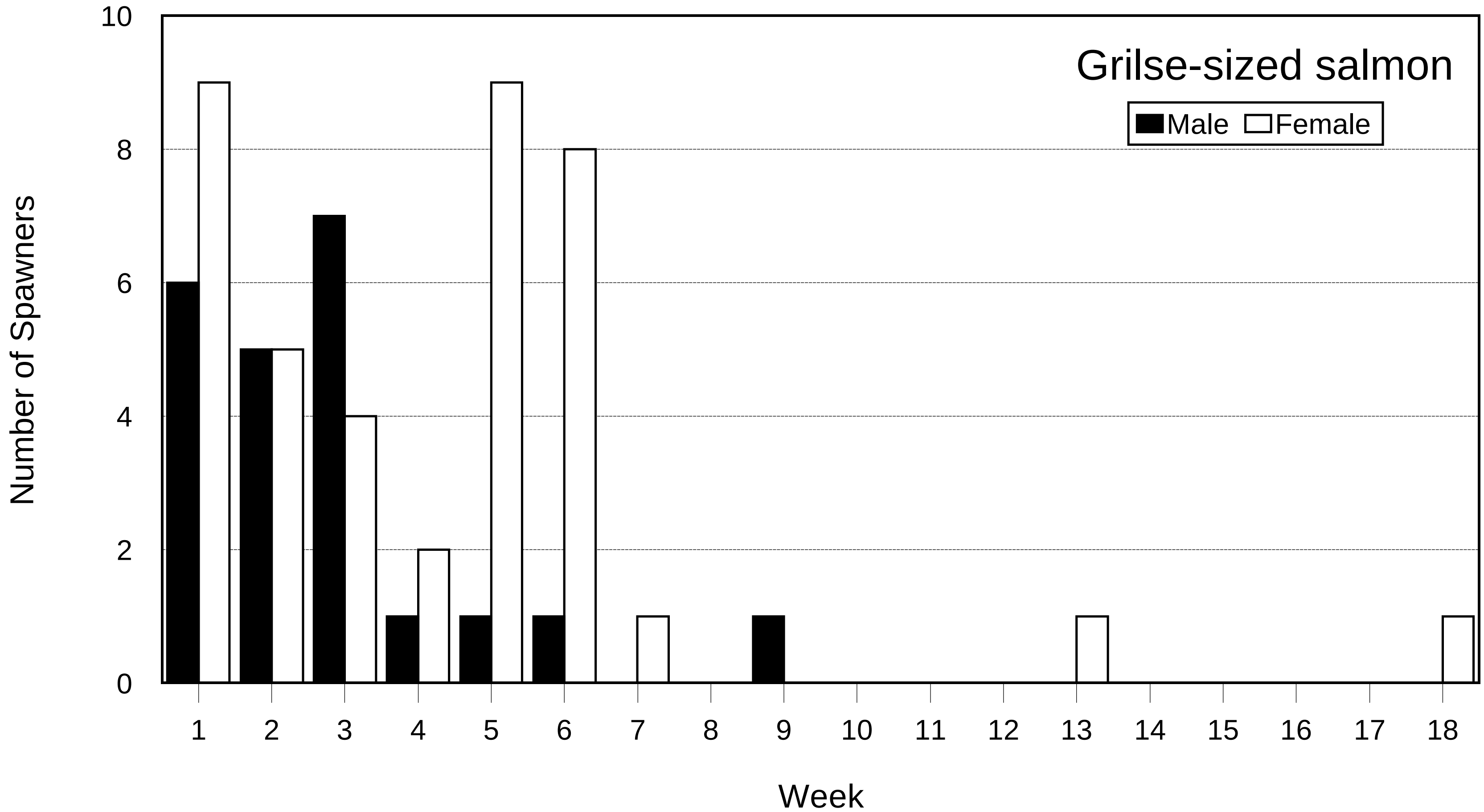

Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1998 - April 1999.

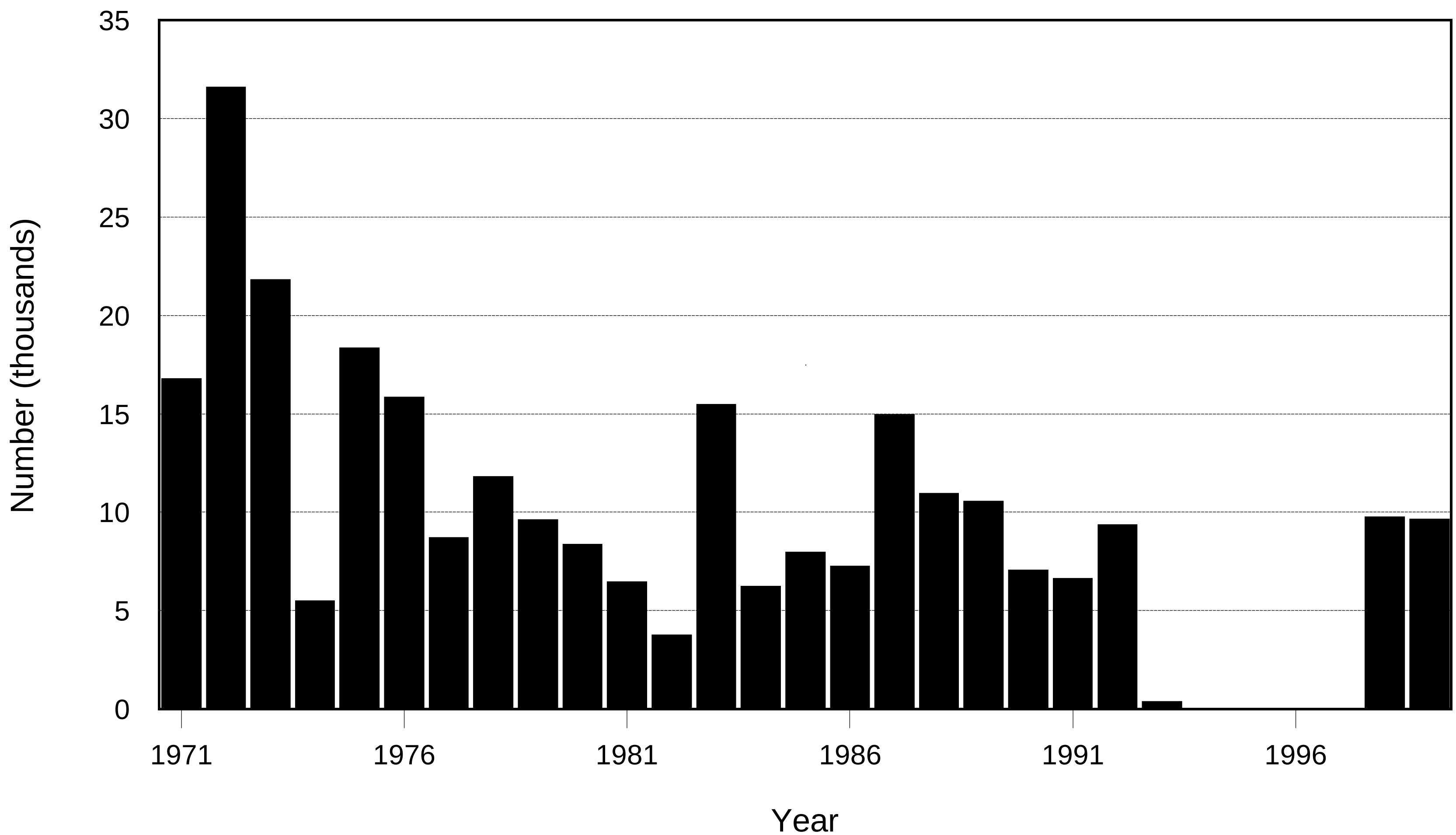

Figure 12. Summary of late-fall-run chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1971 - 1999).