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 1999–April 2000

by

Bill Snider
Bob Reavis
and
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Stream Evaluation Program
Technical Report No. 00-9
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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 1999–2000 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 forth year a late-fall-run escapement survey was undertaken 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, during a period when survey conditions can be reduced by high flows and reduced water transparency. Suitable survey conditions may last from only a few days to several months. Late-fall-run surveys were initiated in January 1996 (the 1995-96 season) but high flows caused their early termination. No survey was attempted during the 1996–97 season due high flows and extremely poor visibility. Surveys were conducted during 1997–98 and 1998–99.

Weekly surveys were conducted from 27 December 1999 through 25 April 2000. The surveys covered a 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. Flows ranged from 4,000 cubic feet per second (cfs) during week 4 (18–20 January 2000) to 41,700 cfs in week 10 (28 February–2 March 2000). Water transparency ranged from 5 ft during weeks 8–10 (14 February–2 March) to 15 ft during week 2 (3–5 January). Water temperature ranged from 48º F in week 9 (22-24 February) to 54º F in week 16 (10-12 April).

We observed 2,554 late-fall-run carcasses (365 fresh and 2,189 decayed). We measured (length) and sexed 324 fresh carcasses. Based on the fresh carcass measurements, 27% of the spawner population were male adults (>2-years old), 49% were female adults, 20% were male grilse (2-years old), and 4% were female grilse. Examination of 152 fresh female carcasses for egg retention showed that 148 (97%) had completely spawned, 1 (1%) still contained a substantial number of eggs, and 3 (2%) were unspawned.

Survey conditions (flow and water transparency) were good in January, marginal in February through mid-March, and good in mid-March through April. During the first 4 weeks of the survey, flow ranged between 4,000 and 5,000 cfs and water clarity was $\geq$7 ft, providing good survey conditions. In week 8 (14-16 February 2000) flows increased to 32,900 cfs and water clarity decreased to 5 ft adversely affecting survey conditions through week 12 (18 March 2000). The number of carcasses observed decreased from 234 in week 7 to only 7 in week 8. Less than 5% of the total number of carcasses observed during the survey were seen after week 7 (117 out of 2,554).

The estimated total spawner escapement (adults and grilse) was 8,552 (2,059 grilse and 6,493 adults) using the Petersen model; it was 7,827 (1,884 grilse and 5,943 adults) using the Schaefer model ; and it was 6,231 (1,500 grilse and 4,731 adults) using the Jolly-Seber model.

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 1999–2000 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 forth 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 was first attempted in 1996, but was severely hampered by high flows. Extremely high flow conditions prevented a late-fall-run survey in 1997. Complete surveys were carried out in 1998 and 1999 (Snider *et al.* 1998 and Snider *et al.* 1999).

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 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 “catch” 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 Central Valley streams. The 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 ≥10% (Boydstun 1994, Law 1994). Still, there has been considerable disagreement about model use among fishery managers responsible for estimating spawner escapement for California streams. They have believed that population estimates obtained by the Jolly-Seber model are too low. Law (1994) states that both the Schaefer and Jolly-Seber 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 2000 late-fall-run salmon spawner escapement survey was conducted from 27 December 1999 through 25 April 2000. 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 1999–April 2000.

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. The observers attempted to locate and collect carcasses as the boat traversed the river between the channel margins. Observed carcasses were collected and 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 making them unavailable for recovery. Tagged carcasses were released into running water for recapture. Data collected to estimate population size included the numbers tagged, chopped, and recovered. All carcasses were also examined for eye clarity and gill color to determine freshness. Carcasses were considered fresh if either eye was clear or if the 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 (CWT). The heads were collected from marked carcasses to recover and read the CWTs.

Our objective was to estimate the late-fall-run salmon natural escapement in the upper Sacramento River using the more accepted Schaefer or Jolly-Seber models. During the 2000 survey, there were no recoveries of tagged fresh carcasses from 9 of the 15 weeks when tag groups were released (these results are used in Schaefer model), and no recoveries of either fresh or decayed carcasses in 7 of the 15 groups (these results are used in the Jolly-Seber model). To account for these periods, the results for these weeks were grouped to calculate an estimates using these two models. An escapement estimate was also calculated using the Petersen model to provide comparisons to previous years when results didn't allow calculations with the other models due to lack of tag recoveries.

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

1. Petersen model (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.

2. 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.

3. Jolly-Seber model (as described by Boydstun 1994): $E = N_1 + D_1 + D_2 ... + D_j$

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.

Flow measurements for each survey day were obtained from the gauge located near Keswick Dam and 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 2,554 carcasses was observed (Table 2). Mean[1/] flow ranged from 4,000 cfs during week 4 (18–20 January 2000) to 41,700 cfs during week 10 (28 February –2 March 2000). Flows exceeded 30,000 cfs from weeks 8 through 11 (14 February–through 8 March 2000) (Table 2, Figure 2). Mean temperature ranged from 48˚ F during week 9 (22–24 February 2000) to 54˚ F during week 16 (10–12 April 2000) (Table 2, Figure 2). Mean water transparency (Secchi depth) ranged from 15 ft during week 2 (3–5 January 2000) to 5 ft in weeks 8–10 (14 February–2 March 2000) (Table 2, Figure 2).

Temporal Distribution

Most carcasses (83%, n = 2,109) were observed during the first month of the survey (27 December 1999–28 January 2000) (Table 2, Figure 3). Thirteen percent (n = 344) were observed during the second month (31 January–24 February 2000), 2% (n = 41) were observed in the third month (28 February–March 29 2000), and 2% (n = 60) in the last month of the survey. Spawning appeared to be concentrated in January, however, relatively high flow conditions and poor visibility likely reduced the number of carcasses observed from early February through mid-March.

1/ Mean of daily measurements for week.

Table 2. General survey information for the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1999 – April 2000.

Week	Survey dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (°F)[2/]	Carcass count[3/]		
					Fresh	Decayed	Total
1	Dec 27–29 (1999)	5,300	14	52	78	375	453
2	Jan 3–5	5,000	15	52	104	558	662
3	Jan 10–12	4,400	11	52	58	403	461
4	Jan 18–20	4,000	7	51	14	179	193
5	Jan 24–26	11,100	10	50	49	291	340
6	Jan 31–Feb 2	16,100	10	50	9	85	94
7	Feb 7–9	12,200	8	50	33	201	234
8	Feb 14–16	32,900	5	51	1	6	7
9	Feb 22–24	36,700	5	48	1	8	9
10	Feb 28–Mar 2	41,700	5	50	0	2	2
11	Mar 6–8	34,800	6	49	1	4	5
12	Mar 13–15	19,900	6	50	0	4	4
13	Mar 20–22	9,700	7	50	0	11	11
14	Mar 27–29	6,000	8	52	0	19	19
15	Apr 3–5	4,900	12	52	4	12	16
16	Apr 10–12	8,500	10	54	5	14	19
17	Apr 17–19	8,300	9	52	1	8	9
18	Apr 24–25	8,900	9	53	7	9	16
	Totals				365	2,189	2,554

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.

Spatial Distribution

The majority of carcasses were observed in Reach 1 (60%, n = 1,537); 28% were observed in Reach 2 (n = 719), and 12% (n = 298) 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 and Age Composition

Mean size of all measured carcasses was 79.5 cm FL (n = 324) (Table 4). Size ranged from 45 to 108 cm FL. Male salmon (n = 154) averaged 77.1 cm FL (range: 45–108 cm FL) (Figure 5). Female salmon (n = 170) averaged 81.7 cm FL (range: 62–99 cm FL) (Figure 6). The weekly mean size for males ranged from 71.4 to 94.0 cm FL (Table 4 and Figure 7). Weekly mean size for females ranged from 80.0 to 94.5 cm FL (Table 4, 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 (Table 5, Figures 5 and 6). Both male and female grilse were defined as salmon ≤70 cm FL. Male grilse (n = 66) averaged 58.3 cm FL (range: 45–70 cm FL, SD = 6.3); male adults (n = 88) averaged 91.3 cm FL (range: 71–108 cm FL, SD = 8.4). Female grilse (n = 12) averaged 67.9 cm FL (range: 62–70 cm FL, SD = 2.7); female adults (n = 158) averaged 82.7 FL (range: 71–99 cm FL, SD = 6.0).

Grilse comprised 24% (n = 78) of the 324 measured carcasses (Table 6). Nearly 36% (28) of all grilse were observed during the first week; 86% were observed during the first 3 weeks (27 December 1999–12 January 2000) (Figure 9). Adults comprised 76% (n = 246) of the carcasses measured.

Sex Composition

Males comprised 36% (n = 88) and females comprised 64% (n = 158) (Table 7) of the fresh adult carcasses examined. Males comprised 85% (n = 66) and females comprised 15% (n = 12) of the fresh grilse examined. Males comprised 48% (n = 154) of all fresh carcasses measured and females comprised 52% (n = 170).

The female to male ratio for adult spawners was nearly 1.8 to 1 (158:88) (Table 7, Figure 10). Females made up at least 53% of the weekly adult population. The female to male ratio for grilse was 0.2 to 1. Males comprised at least 80% of the weekly grilse population during the first 5 weeks of the survey when 95% of all grilse were observed (Figure 11).

Table 3. Distribution of carcasses (adults and grilse) observed during the upper Sacramento River late-fall-run chinook salmon escapement survey, December 1999–April 2000.

Week	Reach 1		Reach 2		Reach 3	
	M[1/]	C[2/]	M	C	M	C
1	248	4	114	20	59	8
2	275	105	156	70	40	16
3	282	85	35	18	27	14
4	94	25	34	14	16	10
5	193	64	34	18	27	4
6	6	7	46	8	22	5
7	75	15	76	44	18	6
8	4	1	2	0	0	0
9	1	1	1	3	0	3
10	0	0	0	1	0	1
11	4	0	0	0	0	1
12	1	1	0	0	1	1
13	0	2	0	3	4	2
14	6	3	2	4	1	3
15	6	2	5	2	1	0
16	0	12	0	5	0	2
17	0	4	0	2	0	3
18	0	11	0	2	0	3
Total	1,195	342	505	214	216	82

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 1999 – April 2000.

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	71	75.2	50–104	43	71.4	50–104	28	82.9	64–94
2	81	77.5	45–105	47	75.7	45–105	34	80.0	65–95
3	53	80.3	58–105	27	79.9	58–105	26	80.7	62–92
4	14	80.7	62–92	4	79.0	62–88	10	81.4	72–92
5	45	80.6	54–98	15	81.1	54–98	30	80.3	69–92
6	9	86.7	56–107	2	81.5	56–107	7	88.1	78–95
7	33	82.5	48–99	10	86.1	48–99	23	80.9	69–89
8	1	85.0	-	0	-	-	1	85.0	-
9	0	-	-	0	-	-	0	-	-
10	0	-	-	0	-	-	0	-	-
11	1	85.0	-	0	-	-	1	85.0	-
12	0	-	-	0	-	-	0	-	-
13	0	-	-	0	-	-	0	-	-
14	0	-	-	0	-	-	0	-	-
15	4	85.8	82–90	1	89.0	-	3	84.7	82–90
16	4	90.8	66–108	2	87.0	66–108	2	94.5	90–99
17	1	86.0	-	1	86.0	-	0	-	-
18	7	88.3	69–98	2	94.0	90–98	5	86.0	69–94
Total	324	79.5	45–108	154	77.1	45–108	170	81.7	62–99

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 1999 – April 2000.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	12	158	66	88
Mean FL (cm)	67.9	82.7	58.3	91.3
Range FL (cm)	62–70	71–99	45–70	71–108
S D	2.7	6.0	6.3	8.4

Table 6. Age composition[1/] (grilse and adult) of carcasses measured during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1999 – April 2000.

	Adults		Grilse	
Week	Number	Percent	Number	Percent
1	43	61	28	39
2	55	68	26	32
3	40	75	13	25
4	13	93	1	7
5	40	89	5	11
6	8	89	1	11
7	31	94	2	6
8	1	100	0	0
9	0	-	0	-
10	0	-	0	-
11	1	100	0	0
12	0	-	0	-
13	0	-	0	-
14	0	-	0	-
15	4	100	0	0
16	3	75	1	25
17	1	100	0	0
18	6	86	1	14
Total(mean)	246	(76)	78	(24)

1/ Based on length-frequency distributions grilse are defined as ≤70 cm FL and adult >70 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 1999 – April 2000.

	Adults				Grilse[1/]			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	16	37	27	63	27	96	1	4
2	26	47	29	53	21	81	5	19
3	17	42	23	58	10	77	3	13
4	3	23	10	77	1	100	0	0
5	11	28	29	72	4	80	1	20
6	1	12	7	88	1	100	0	0
7	9	29	22	71	1	50	1	50
8	0	0	1	100	0	-	0	-
9	0	-	0	-	0	-	0	-
10	0	-	0	-	0	-	0	-
11	0	0	1	100	0	-	0	-
12	0	-	0	-	0	-	0	-
13	0	-	0	-	0	-	0	-
14	0	-	0	-	0	-	0	-
15	1	25	3	75	0	-	0	-
16	1	33	2	67	1	100	0	0
17	1	100	0	0	0	-	0	-
18	2	33	4	67	0	0	1	100
Total (mean)	88	(36)	158	(64)	66	(85)	12	(15)

1/ Based on length-frequency distributions, grilse are defined as ≤70 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 1999–April 2000.

Week	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	28	23	22(96)	0(0)	1(4)
2	34	34	34(100)	0(0)	0(0)
3	26	23	23(100)	0(0)	0(0)
4	10	10	10(100)	0(0)	0(0)
5	30	20	20(100)	0(0)	0(0)
6	7	7	7(100)	0(0)	0(0)
7	23	23	23(100)	0(0)	0(0)
8	1	1	1(100)	0(0)	0(0)
9	0	0	0(0)	0(0)	0(0)
10	0	0	0(0)	0(0)	0(0)
11	1	1	1(100)	0(0)	0(0)
12	0	0	0(0)	0(0)	0(0)
13	0	0	0(0)	0(0)	0(0)
14	0	0	0(0)	0(0)	0(0)
15	3	3	2(67)	0(0)	1(33)
16	2	2	2(100)	0(0)	0(0)
17	0	0	0(0)	0(0)	0(0)
18	5	5	3(60)	1(20)	1(20)
Total (mean)	170	152	148(97)	1(1)	3(2)

Spawning Success

A total of 152 female carcasses was examined for egg retention (Table 8). Ninety-seven percent (n = 148) had completely spawned; 1% (n = 1) had only partially spawned; and 2% (n = 3) had not spawned.

Population Estimates

An adult escapement estimate of 6,493 adults was calculated from the fresh carcass data using the adjusted Petersen model described above (Table 9). The adult estimate was then divided by 0.76 (the portion of adults based on fresh carcass subsample) yielding a total population estimate of 8,552 (6,493 adult and 2,059 grilse). A total of 2,052 adult carcasses (does not include recaptures) were observed. Of these, 266 fresh carcasses were tagged and 87 (33%) were later recovered. These data were used to estimate the spawner population using the Petersen model.

An adult escapement estimate of 5,943 was also calculated from the fresh carcass data using the Schaefer model (Tables 10 and 11). In order to use the Schaefer model, we grouped tagging periods 7-15 and recovery periods 6-14 and 15-16 to provide at least one recovery in each recovery period. The adult estimate was divided by 0.76 for a total escapement estimate of 7,827 late-fall-run spawners (includes 1,884 grilse).

An estimate of 4,731 adults was calculated using the Jolly-Seber model (Table 12) and both fresh and decayed carcass data. In order to use the Jolly-Seber model, we grouped tagging periods 7-15 and tagging periods 7-14 to provide at least one recovery in each recovery period. The adult estimate was also divided by 0.76 for a total escapement estimate of 6,231 late-fall-run spawners (includes 1,500 grilse). A total of 2,052 adult carcasses were observed. Of these, 1,549 fresh and decayed carcasses were tagged and 408 (26%) were later recovered.

The population estimates of the late-fall-run chinook salmon spawner population in the upper Sacramento River from ACID Dam (River mile 298.5) to Anderson River park (River mile 282.0) are as follows:

	Petersen model	Schaefer model	Jolly-Seber model
Total estimate	8,552	7,827	6,231
Adult estimate	6,493	5,943	4,731
Grilse estimate	2,059	1,884	1,500

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 1999–April 2000.

Week	Date	Number observed	Number tagged	Number recovered (Original tagging period)
1	Dec 27–29	294	46	–
2	Jan 3–5	471	69	24(1)
3	Jan 10–12	381	44	16(2), 2(1)
4	Jan 18–20	173	14	11(3),3(2),1(1)
5	Jan 24–26	309	47	5(4),4(3),2(2),1(1)
6	Jan 31–Feb 2	93	8	5(5)
7	Feb 7–9	219	32	5(6),6(3)
8	Feb 14–16	6	1	0
9	Feb 22–24	8	0	0
10	Feb 28–Mar 2	2	0	0
11	Mar 6–8	4	1	0
12	Mar 13–15	4	0	0
13	Mar 20–22	11	0	0
14	Mar 27–29	19	0	0
15	Apr 3–5	16	4	0
16	Apr 10–12	17	0	0
17	Apr 17–19	9	0	1(15)
18	Apr 24–25	16	0	1(15)
Totals		2,052	266	87

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.

Capture-recapture data matrix										
	Tagging period $_{(i)}$								Carcasses	
Recovery period$_{(j)}$	1	2	3	4	5	6	7-15	Tags recovered $R_{(j)}$	counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
1	24							24	789[2/]	32.88
2	2	16						18	399	22.17
3	1	3	11					15	188	12.53
4	1	2	4	5				12	321	26.75
5					5			5	98	19.60
6–14[1/]					6	5		11	300	27.27
15-16[1/]							1	1	27	27.00
17							1	1	17	17.00
$R_{(i)}$	28	21	15	5	11	5	2	(Tagged carcasses recovered)		
$T_{(i)}$	46	69	44	14	47	8	38	(Total carcasses tagged)		
$T_{(i)}/R_{(i)}$	1.64	3.29	2.10	2.80	4.27	1.60	19.00	(Ratio)		

1/ Tagging and recovery periods were grouped to account for weeks when no tags were recovered.
2/ Includes carcasses observed during first week of tagging.

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 1999–April 2000.

Population estimation

Recovery period$_{(j)}$	Tagging period$_{(i)}$ 1	2	3	4	5	6	7–15[1/]	Totals
1	1,296							1,296
2	73	1,165						1,238
3	21	124	404					549
4	44	176	314	375				908
5					419			419
6–14[1/]					699	218		917
15-16							513	513
17							323	323
Subtotals	1,434	1,465	718	375	1,118	218	836	6,163
Tags		-69	-44	-14	-47	-8	-38	-220
								5,943

1/ Tagging and recovery periods were grouped to account for weeks when no tags were recovered.

Table 12. Upper Sacramento River adult late-fall-run chinook salmon population estimate using the Jolly-Seber model based on tagging fresh carcasses with all captured untagged carcasses removed, December 1998 – April 1999.

Capture-recapture data matrix

Tagging week	Number tagged	Carcasses examined	Recaptures of carcasses in week								Total recoveries
			1	2	3	4	5	6	7-14 1/	8	
1	278	294									
2	336	623	152								152
3	294	465	13	71							84
4	134	222	2	15	32						49
5	234	357	2	3	18	25					48
6	72	115			2	1	19				22
7-14 1/	188	315			1	4	28	13			46
15	12	20							4		4
16		10								1	1
17		17								1	1
18										1	1
Totals	1,548	2,456	169	89	53	30	47	13	4	3	408

1/ Tagging and recovery periods were grouped to account for weeks when no tags were recovered.

The 2000 escapement of 8,552 (using Petersen model) 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 13 and Figure 12). The 1967 through 1992 yearly estimates were based on RBDD ladder counts. Changes in operation of RBDD have eliminated the opportunity to count late-fall run at the dam since 1992.

Coded-wire-tag Recovery Data

Twenty-nine fresh carcasses observed during the survey were marked with adipose fin clips. Of this total, 26 possessed coded-wire tags (Table 14). All tag groups were reared at Coleman National Fish Hatchery and tagged by the FWS. All tag groups were released at the hatchery except 05-42-29 (Benicia), 05-42-30 (Miller Park), 05-50-49 (Georgina Slough), and 05-50-61 (Port Chicago).

CONCLUSIONS AND RECOMMENDATIONS

Poor survey conditions beginning in early February reduced our ability to clearly identify the magnitude and temporal distribution of late-fall-run chinook salmon spawning. The sharp decline in carcass recoveries coincident with the increased flow and decreased water transparency suggests that the reduction in carcasses observed after week 7 was initially due to poor survey conditions rather than a decrease in spawning. The results of juvenile salmon emigration monitoring at Balls Ferry should be evaluated to determine if the trend in emigration of late-fall-run fry corresponds to the sharp decrease in spawning noted in the escapement survey or if it reflects a more gradual decline. This information in combination with the escapement survey results could be used to better define the temporal spawning distribution as well as the relative magnitude of spawning that may have been obscured from the escapement survey during the period of high flows and low visibility.

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Table 13. Summary of late-fall-run chinook salmon escapement estimates (adults and grilse) for the Sacramento River (Keswick Dam to RBDD) from 1956 through 2000. (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 [1/]
1982	1,141	1999	8,683 [1/]
1983	13,274	2000	8,552 [1/]

1/ Estimates based on carcass counts.

Table 14. Summary of coded-wire tags recovered from carcasses observed during the 1999–2000 late-fall-run chinook salmon spawner escapement survey.

Tag #	Brood year	Sex	Length (cm)	Date recovered	River mile recovered
05-50-61	97	M	66	12/27/99	296.5
05-42-36	96	F	75	12/28/99	294
05-50-55	97	M	72	1/3/00	298
05-42-40	96	F	83	1/3/00	298
no tag	-	M	73	1/3/00	298
05-50-55	97	M	75	1/3/00	298
05-50-56	97	F	65	1/3/00	298
no tag	-	F	69	1/3/00	298
05-50-51	97	F	69	1/3/00	298
05-41-26	96	M	90	1/4/00	295
05-50-49	97	M	92	1/4/00	294
05-42-37	96	F	81	1/5/00	287
05-50-52	97	M	61	1/5/00	289
05-41-27	96	F	75	1/10/00	296.5
05-42-36	96	F	76	1/10/00	-
05-41-26	96	F	78	1/10/00	296.5
05-50-49	97	M	84	1/11/00	294
05-42-37	96	F	72	1/18/00	298
05-42-30	96	M	86	1/24/00	296.5
05-42-41	96	F	80	1/24/00	296.5
05-42-29	96	F	73	1/24/00	296.5
05-41-24	96	F	81	1/24/00	297
05-41-27	96	F	75	1/24/00	297
05-41-27	96	F	72	1/24/00	298
05-41-27	96	M	91	1/25/00	296
no tag		F	90	2/1/00	294
05-42-37	96	F	84	2/7/00	296.5
05-50-49	97	M	75	2/7/00	298
05-41-23	96	F	86	4/17/00	-

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APPENDIX

Appendix Table 1. Comparison of results from the 1998 through 2000 upper Sacramento River late-fall-run spawner survey.

Parameter	1998 survey	1999 survey	2000 survey
Survey dates	29 Dec 1997–1 May 1998	28 Dec1998–28 Apr 1999	27 Dec 1999-25 Apr 2000
No. of total carcasses	847	2,206	2,554
No. of fresh carcasses	182	450	365
No. of decayed carcasses	665	1,756	2,189
Tag recovery rate	9.2%	28.4%	32.8%
Estimated population	9,717 (Petersen model)	8,683 (Petersen model)	8,552 (Petersen model)
Adult estimate	8,648	7,467	6,493
Grilse estimate	1,069	1,216	2,059
Adult female estimate	49%	56%	49%
Adult male estimate	40%	30%	27%
Grilse female estimate	7%	9%	4%
Grilse male estimate	4%	5%	20%
Female:male ratio adults	1.2:1	1.9:1	1.8:1
Size criterion (male)	Adult >70cm	Adult >71 cm	Adult >70 cm
Size criterion (female)	Adult >70cm	Adult >71 cm	Adult >70 cm
Spawning success (%)	93%	93%	97%
Spatial distribution (Reach 1,2,3)	62%, 19%, 19%	46%, 32%, 22%	60%,28%,12%
Temporal distribution(Jan, Feb, Mar, Apr)	97%, 2%, 0.3%, 0.7%	57%, 22%, 16%, 5%	83%,13%,2%,2%
Flow range	4,200–52,800 cfs	5,500–29,800 cfs	4,000-41,700 cfs
Temperature range	47–54^{o} F	47–52^{o} F	48–53^{o} F
Visibility range	4–12 ft	5–10 ft	5–15 ft

FIGURES

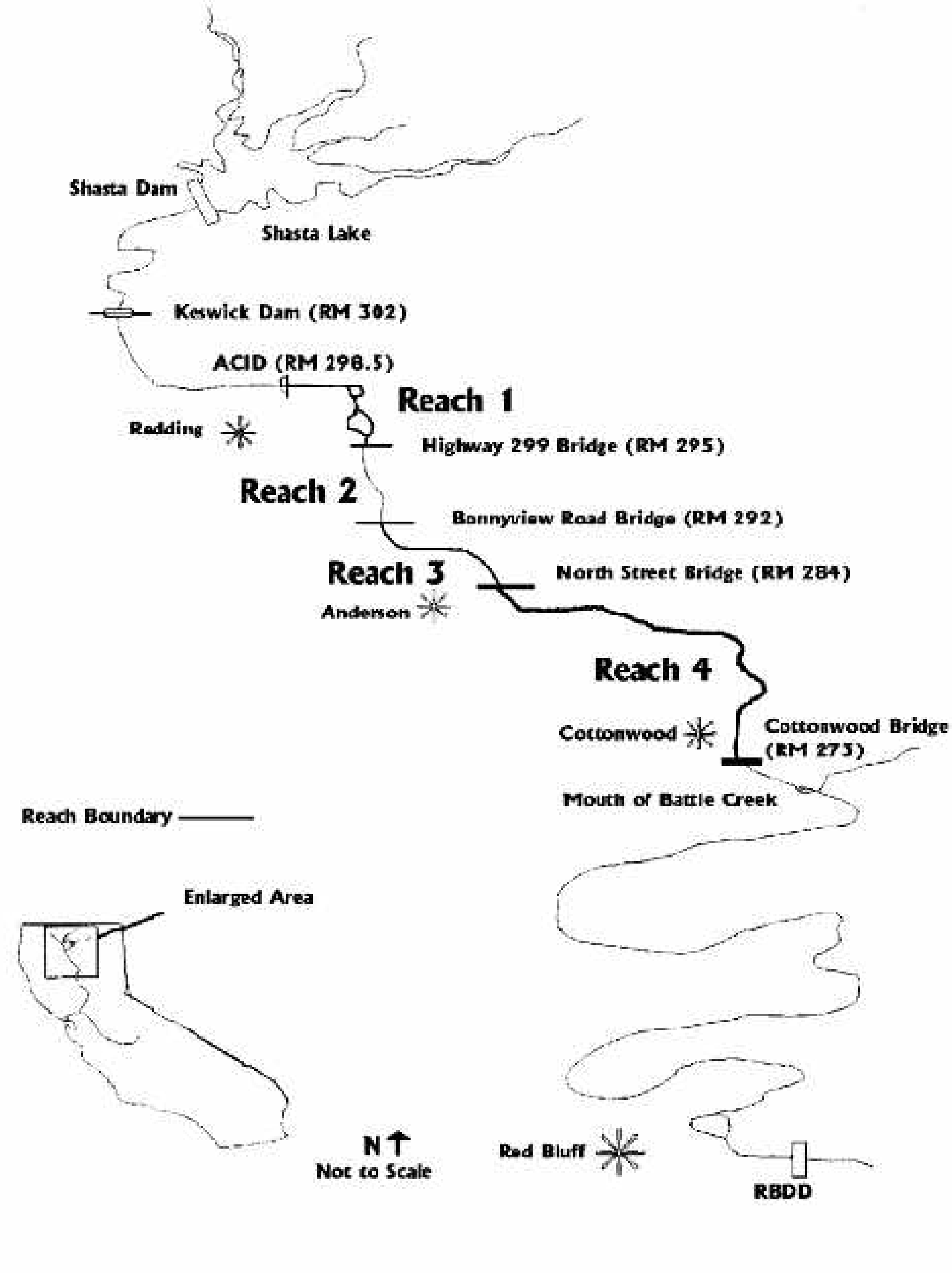

Figure 1. Upper Sacramento River late-fall-run Chinook salmon spawner escapement survey location, including reach designations, December 1999 - April 2000.

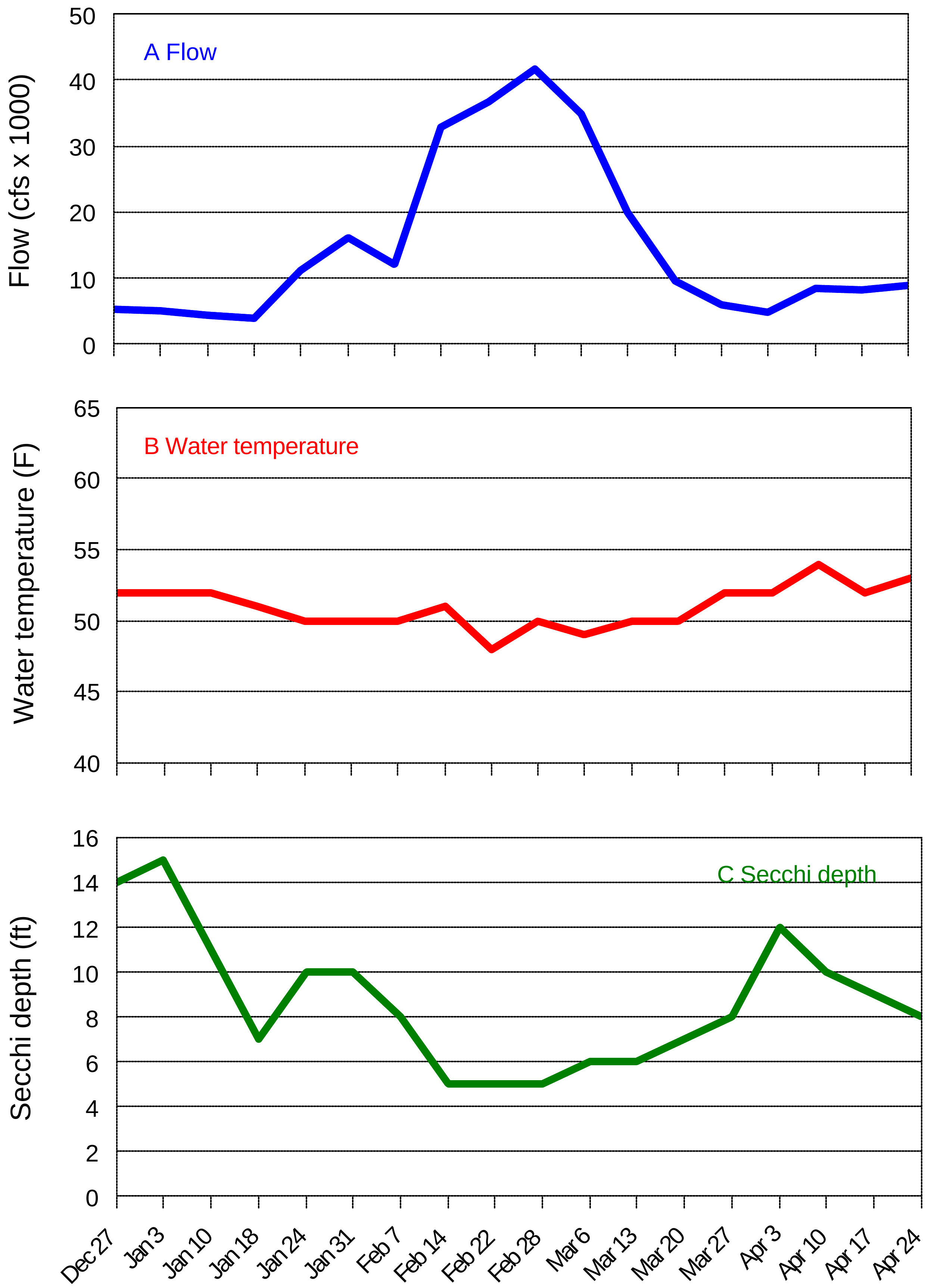

Figure 2. Mean daily flow (A) measured at Keswick Dam, water temperature (B) and Secchi depth (C) during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1999 - April 2000.

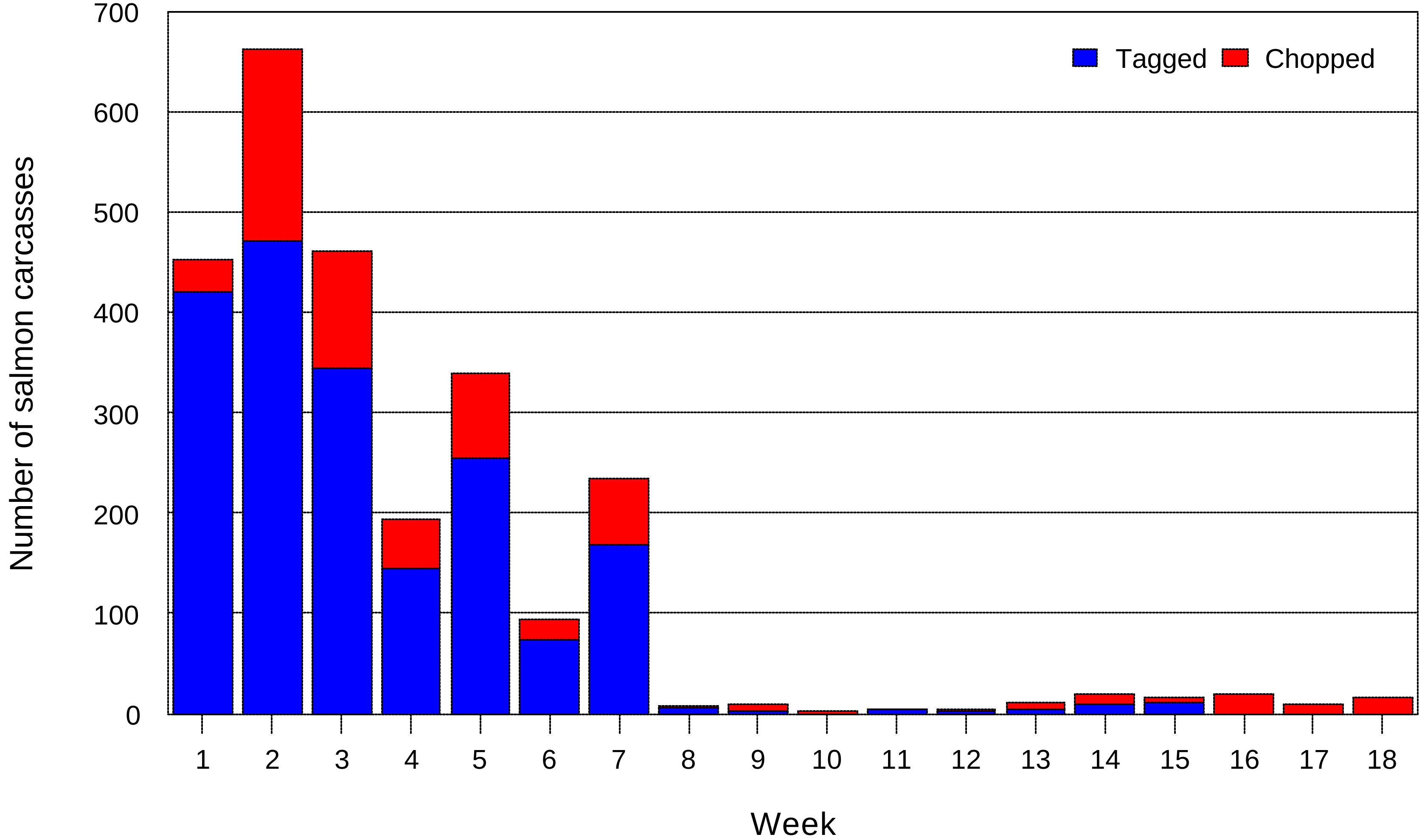

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1999 - April 2000.

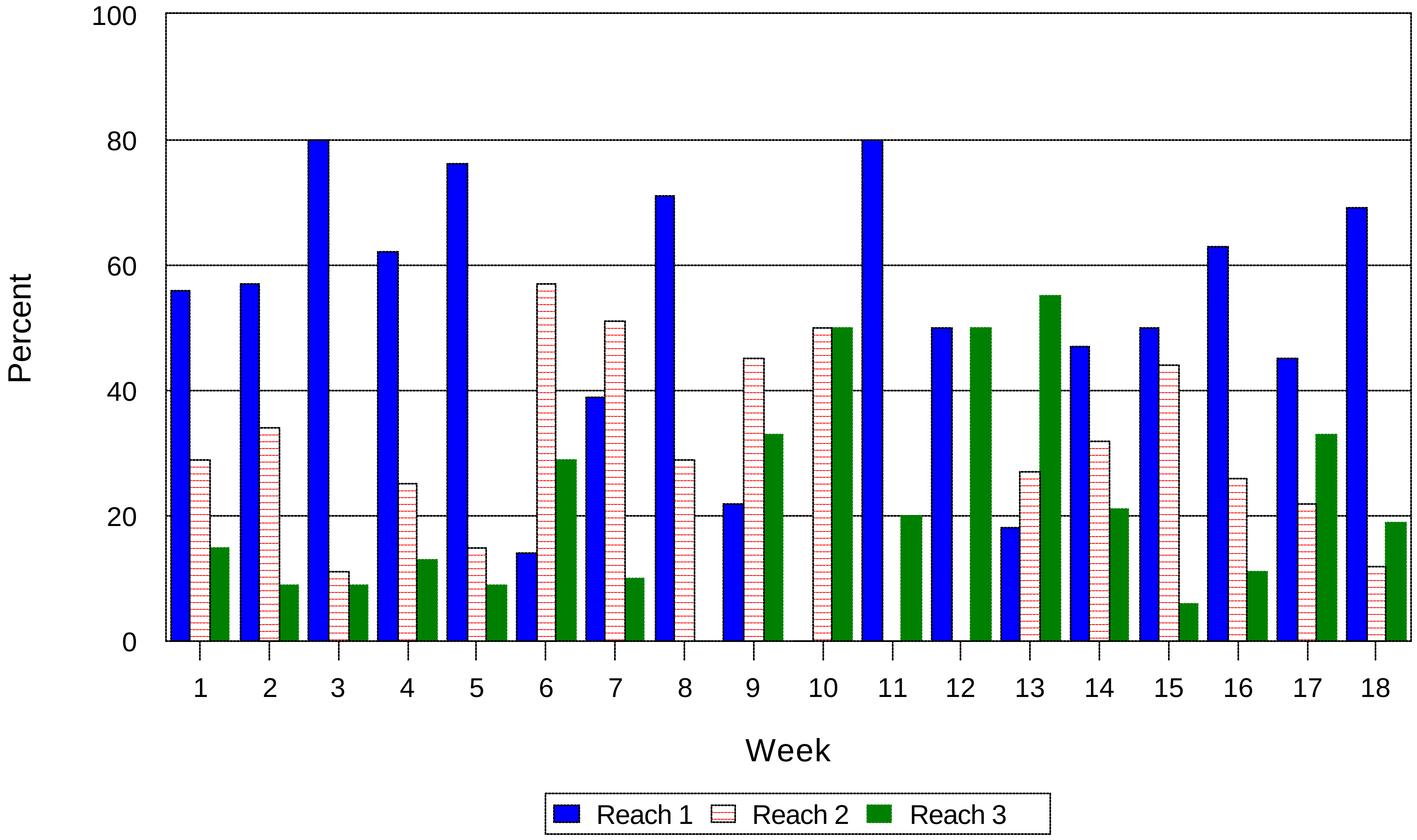

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River late-fall-run chinook salmon spawner escapement survey, December 1999 - April 2000.

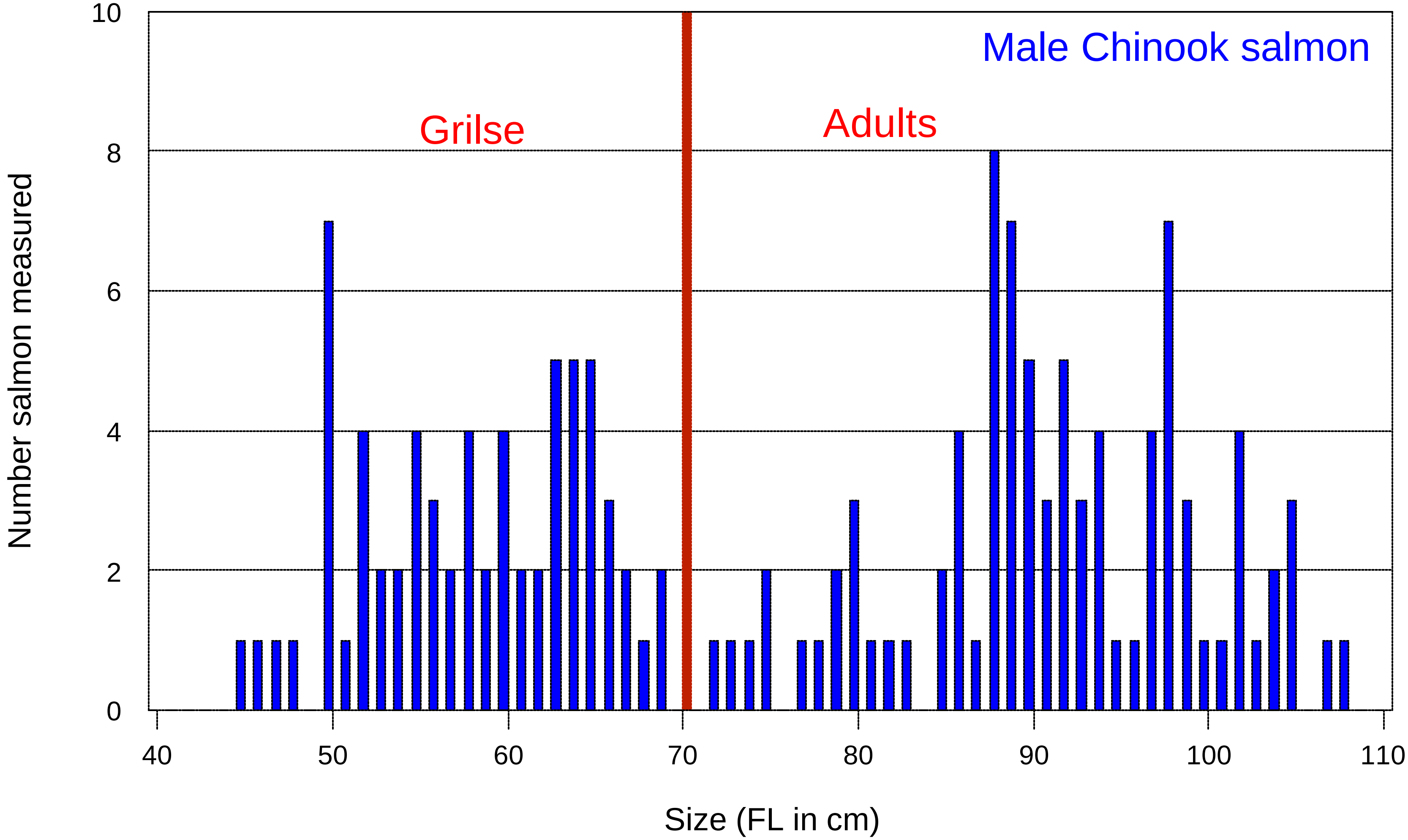

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River late-fall-run spawner escapement survey, December 1999 - April 2000.

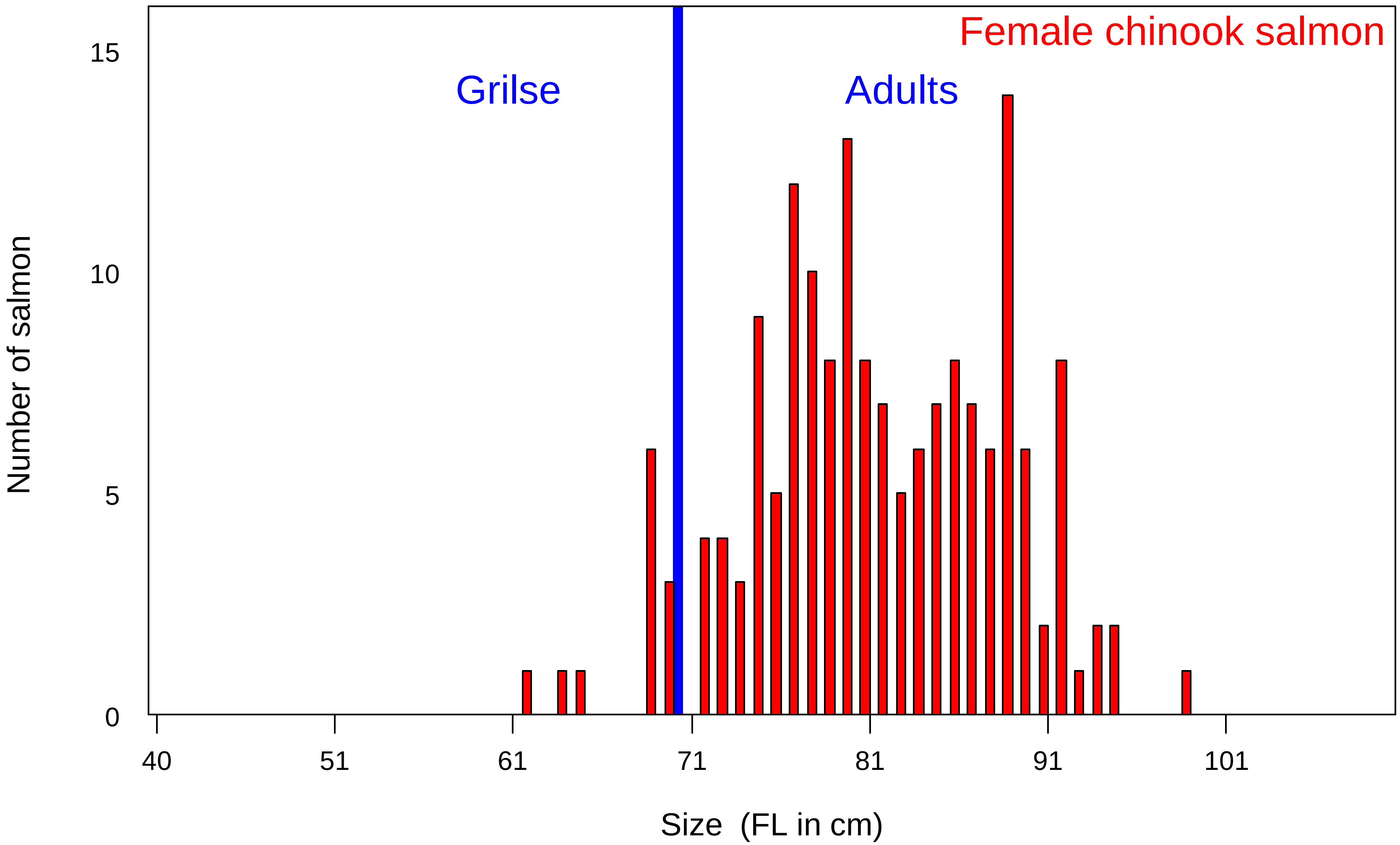

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River late-fall-run spawner escapement survey, December 1999 - April 2000.

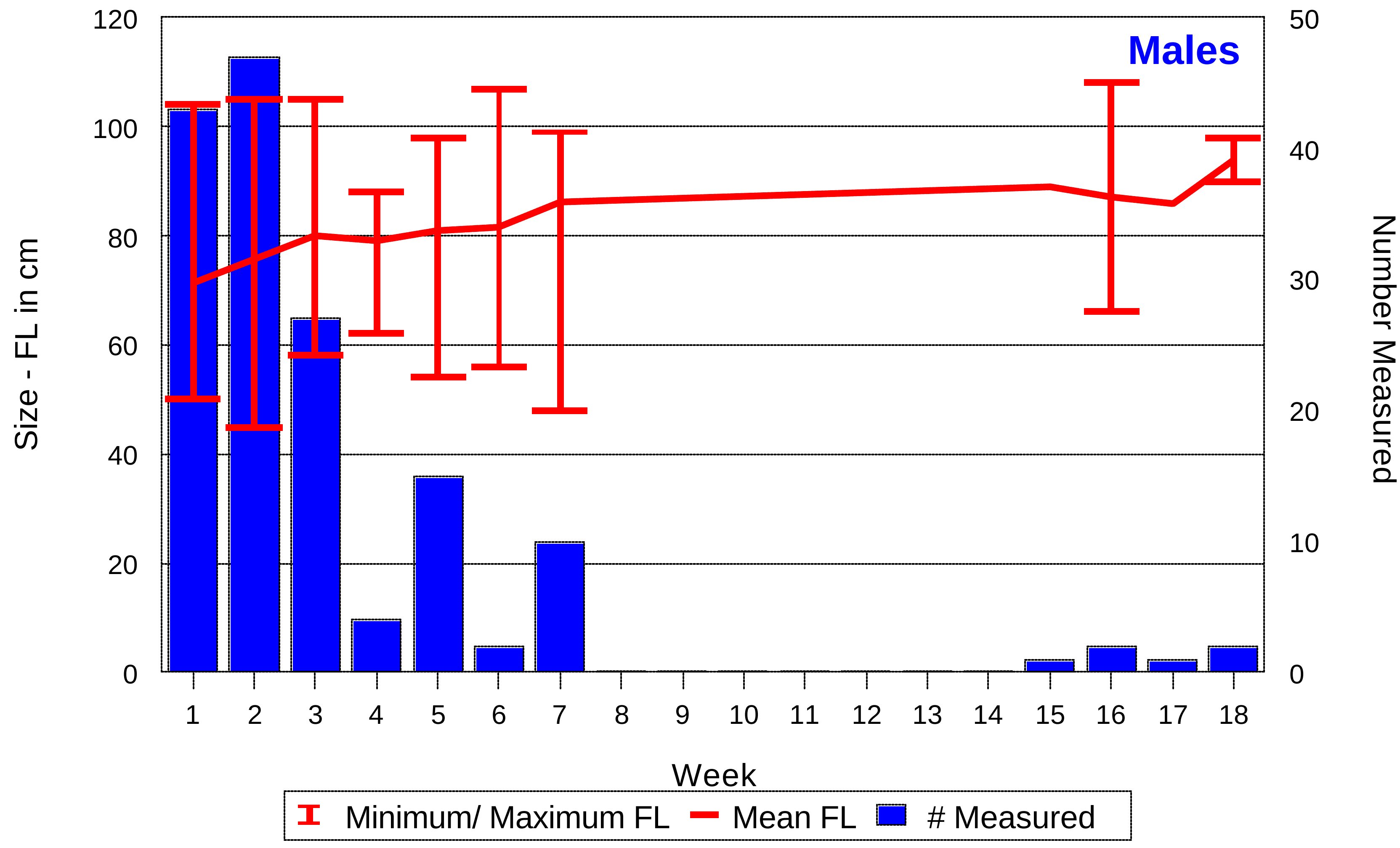

Figure 7. Mean size, size range, and number of male chinook salmon measured weekly during the upper Sacramento River late-fall-run spawner escapement survey, December 1999 - May 2000.

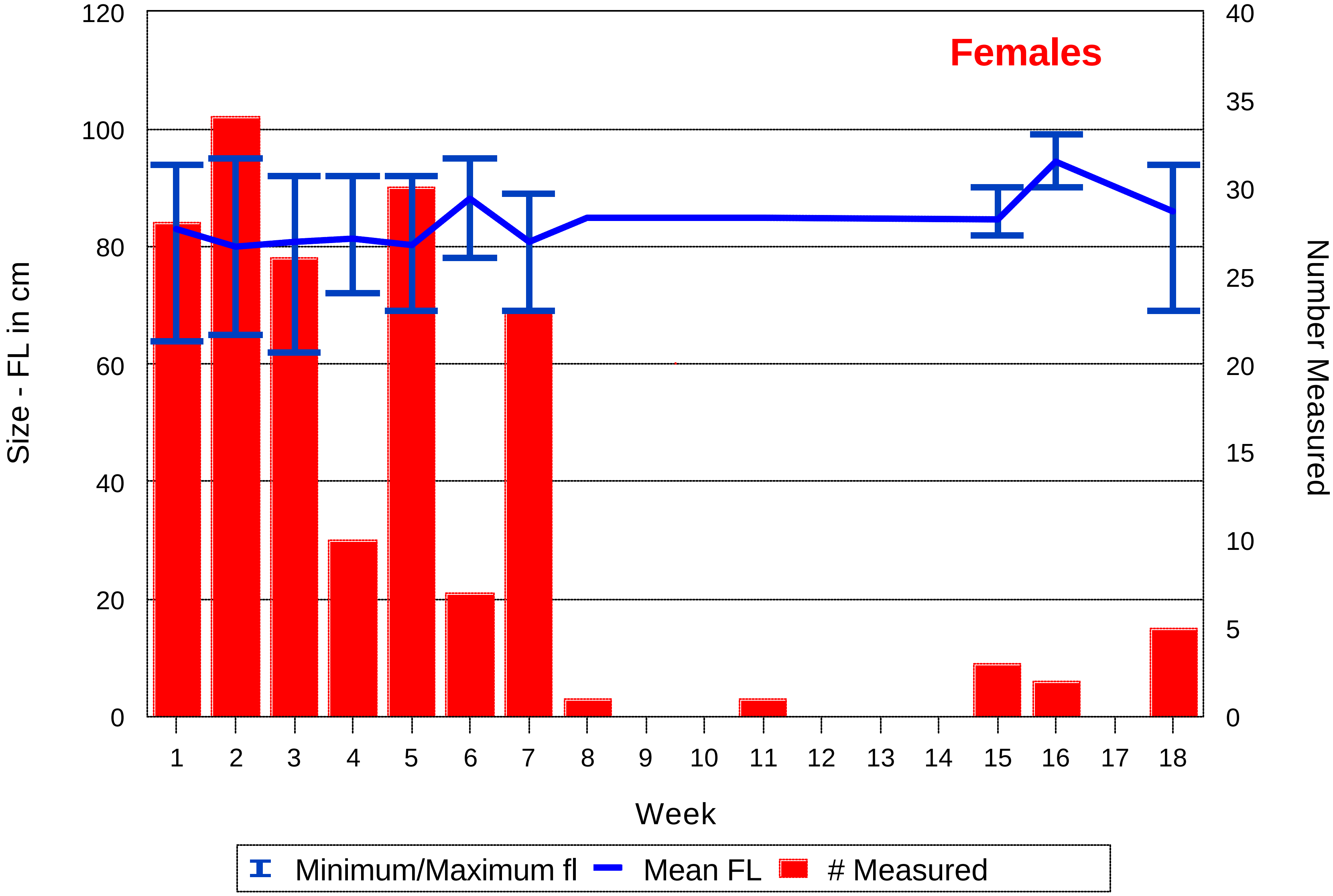

Figure 8. Mean size, size range, and number of female chinook salmon measured weekly during the upper Sacramento River late-fall-run spawner escapement survey, December 1999 - April 2000.

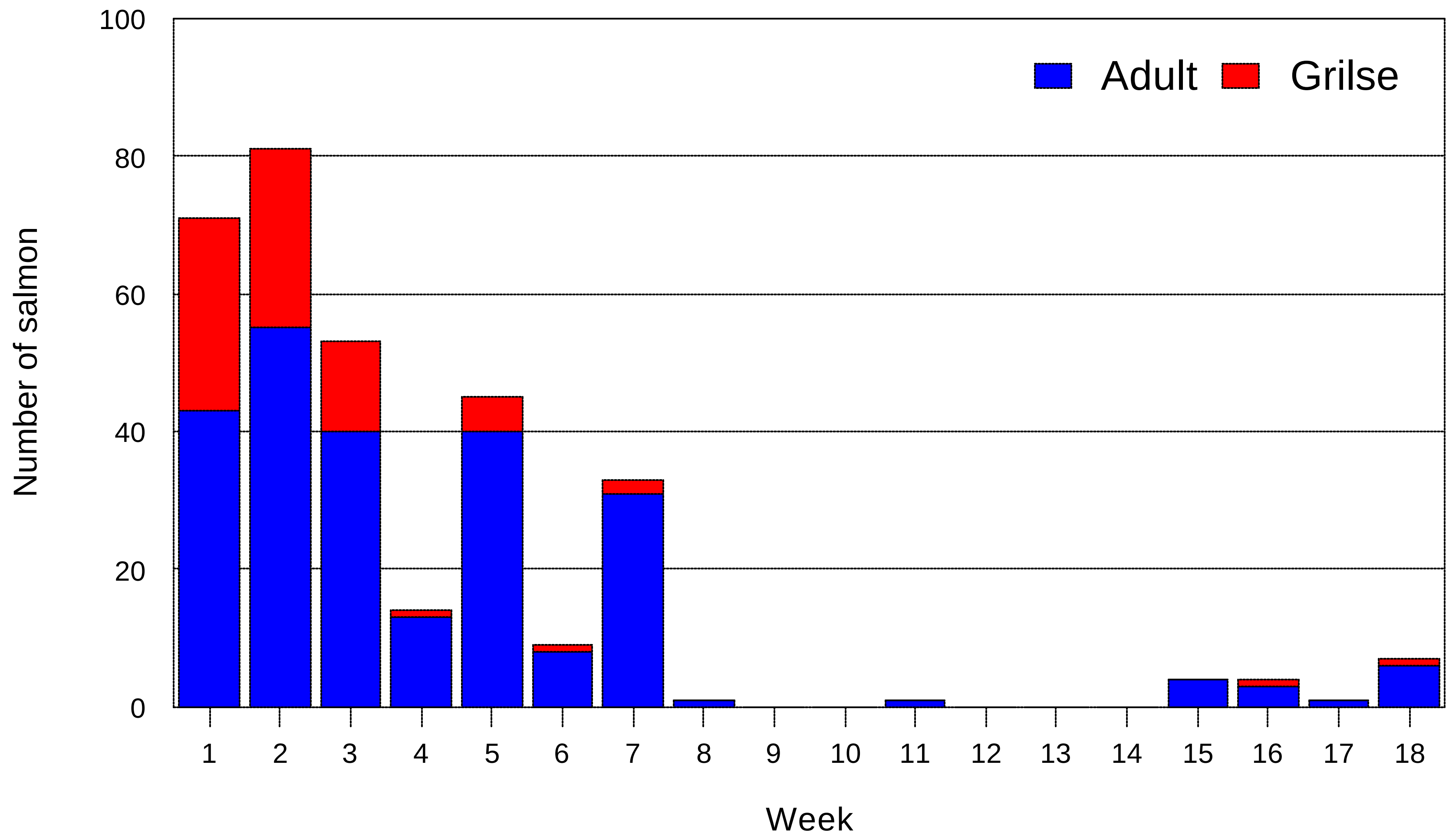

Figure 9. Age compostion of chinook salmon measured during the upper Sacramento River late-fall-run spawner escapement survey, December 1999 - April 2000.

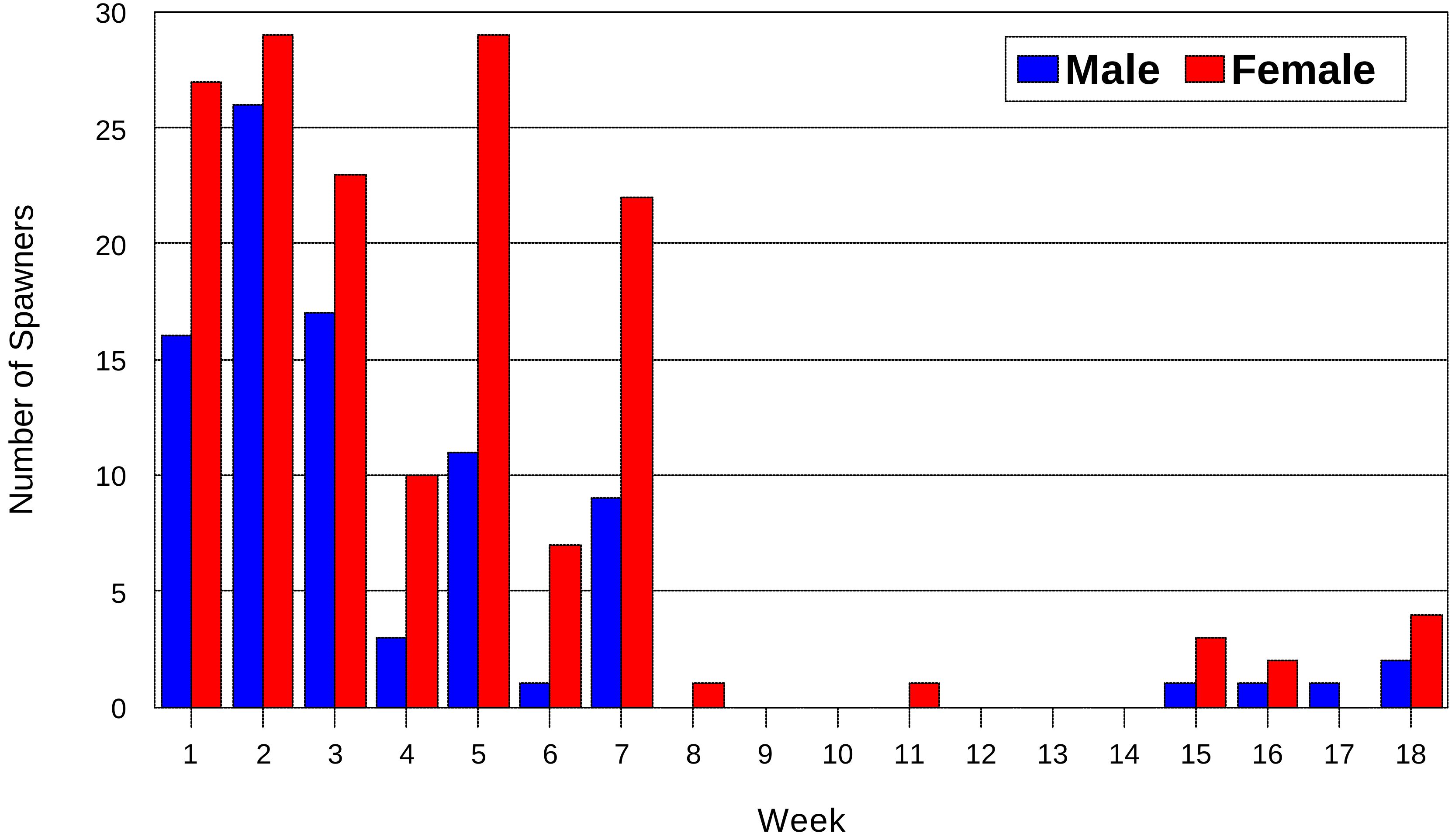

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the upper Sacramento River late-fall-run escapement survey, December 1999 - April 2000.

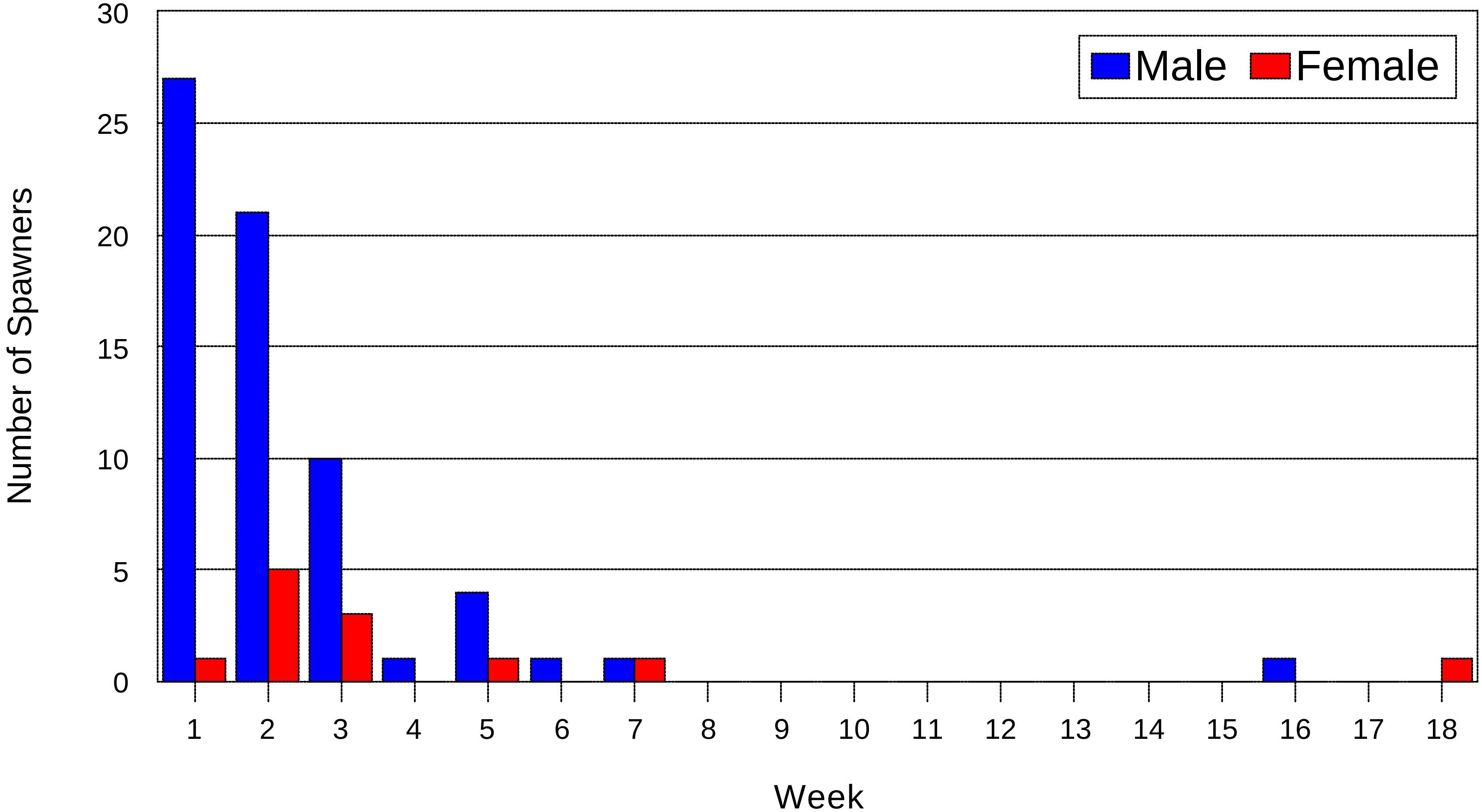

Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the upper Sacramento River late-fall-run spawner escapement survey, December 1999 - April 2000.

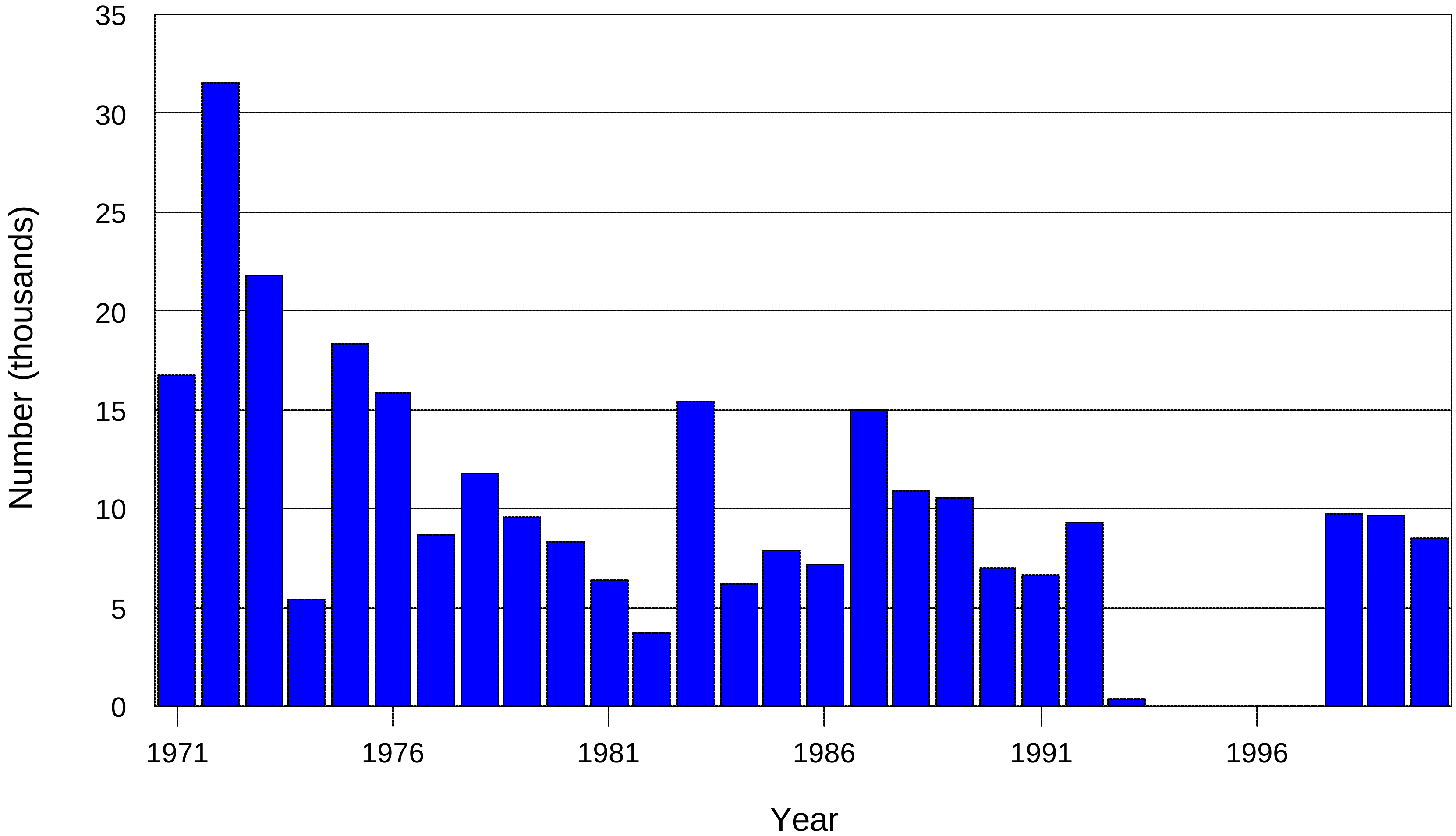

Figure 12. Summary of late-fall-run chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1971 - 2000).