CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Water and Aquatic Habitat Conservation Branch
Stream Evaluation Program

Upper Sacramento River
Fall-Run Chinook Salmon Escapement Survey
September - December 1998

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Stream Evaluation Program
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2/ Stream Evaluation Program Technical Report 99-2.

SUMMARY

A fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during fall-winter 1998 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 fourth 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 *et. al.* 1997; Snider *et. al.* 1998a; and Snider *et. al.* 1998b).

The survey was conducted from 28 September through 17 December 1998. 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). Flows averaged 8,400 cubic feet per second (cfs) during survey week 1 (28 September - 1 October 1998); decreased to 6,000 cfs in weeks 4, 5, and 6 (19 October - 5 November); and then gradually increased to 23,400 cfs during week 11 (7 - 11 December). Mean weekly water temperature ranged from 51° F during weeks 9 and 10 (23 November - 3 December) to 55° F during weeks 2, 3, and 4 (5 - 22 October).

We examined 3,726 fall-run carcasses (fresh and decayed) of which 1,111 fresh carcasses were measured, sexed, and aged. Based upon this sample, 86% of the population were adult salmon (>2-years old) and 14% were grilse (2-years old); 31% were adult males, 55% were adult females, 6% were male grilse and 7% were female grilse (38% male; 62% female). Carcasses were observed during every week of the survey. Peak carcass recovery occurred during weeks 4 through 7 (19 October -13 November) which indicated that peak spawning likely occurred from 5 - 31 October 1997.

We examined 678 females for egg retention. Of these, 647 (96%) had completely spawned; 9 (1%) still contained a substantial number of eggs; and 22 (3%) were unspawned.

Two known (adipose clipped) hatchery produced fall-run spawners were observed. The minimum estimated proportion of hatchery produced spawners was 0.4% adult and 2.7% grilse.

The spawner population was estimated using two different mark-recapture models, the Schaefer and Jolly-Seber models. Per the Schaefer model, 893 fresh adult carcasses were marked and 237 (27%) were subsequently recaptured yielding an escapement estimate of 14,211 total salmon (12,506 adult and 1,705 grilse). Per the Jolly-Seber model, 2,671 fresh and decayed carcasses were marked and 651 (24%) were subsequently recaptured yielding an estimate of 8,559 total salmon (7,532 adults and 1,027 grilse). Both estimates are considerably less than the mean annual fall-run chinook salmon escapement estimate (67,015 grilse and adult) for 1956 through 1998. Escapement estimates from the four most recent annual carcass surveys have ranged from 14,211 to 28,890 with a mean of 23,960 and standard deviation of 5,723.

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 1998 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), PL. 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 DFG to conduct studies to determine flow needs of salmon in the upper Sacramento River.

The primary charge of 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 routinely 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 later recapture. This protocol was initially used in the Central Valley in 1973 to estimate the Yuba River escapement (Taylor 1974). Fall-run carcass surveys were also conducted in 1995, 1996, and 1997(Snider et. al. 1997; Snider *et. al*. 1998; and Snider *et. al*. 1998) in the upper Sacramento River.

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 (e.g., Feather and American rivers) 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.)[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.

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), Snider *et. al*. (1997), and Snider *et. al*. (1998); 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 by first capturing, tagging, and releasing live salmon at Fremont Weir (RM 82.5), then later recovering them as carcases 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 then 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-

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

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 8 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 (Figure 1).

Objectives

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

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

- To determine egg-retention rate, and 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 1998 spawner escapement surveys began immediately following the initial observation of spawning activity and then were conducted weekly from 28 September through 17 December 1998. 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 1998.

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 North St. Bridge	292.0-284.0 (8.0)
4	North St. Bridge to Cottonwood Bridge	284.0-273.0 (11.0)

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 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"; 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 to simulate conditions of a naturally dying or dead fish. Data collected included number tagged, number chopped, and number 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 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.

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 (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.

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 day surveyed 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

A total of 3,726 carcasses was observed (Table 2). Mean weekly flow ranged from 6,000 to 8,400 cfs during weeks 1 through 7 (28 September - 13 November); then generally increased; and peaked at 23,400 cfs during week 11 (Table 2, Figure 2). Mean weekly temperature ranged from 51° F during weeks 9 and 10 (23 November - 3 December) up to 55° F during weeks 2, 3, and 4 (5-22 October) (Table 2, Figure 2). Water clarity (Secchi depth) ranged from 5 feet in week 9 (23-25 November) up to 13 feet in weeks 4, 5, and 6 (19 October - 5 November) (Table 2, Figure 2)

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Temporal Distribution

The temporal distribution of carcasses indicates that spawning occurred from early September through early December. The number of observed carcasses steadily increased from 85 in week 1 (28 September - 1 October) to a peak 677 in week 6 (2-5 November). The highest number of fresh carcasses was observed during week 4 (19-22 October), followed by week 5 then week 6. Correspondingly, the highest numbers of decayed carcasses were observed from week 4 through week 7 (Table 2, Figure 3). These results indicate that most spawning activity occurred between weeks 2 and 5 (5-29 October) and the peak of spawning activity likely occurred during weeks 3, 4 and 5. This observation is based upon an estimated 2 week delay between spawning and mortality, when fresh carcasses become available to be surveyed (Snider and Vyverberg 1995).

Spatial Distribution

The spatial distribution of all observed carcasses was 29% in Reach 1, 36% in Reach 2, 23% in Reach 3, and 12% in Reach 4 (Table 3 and Figure 4).

Size Distribution

A total of 1,111 carcasses was measured (Table 4). Mean adult size was 80.3 cm FL. Size ranged from 43 to 110 cm FL. Male salmon (n=422) averaged 84.6 cm FL (range: 43 - 110 cm FL) (Figure 5). Female salmon (n=689) averaged 77.9 cm FL (range: 49 - 98 cm FL) (Figure 6). The weekly mean size for males ranged from 68.5 to 90.0 cm FL (Figure 7). Weekly mean size for females ranged from 68.8 to 82.6 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 grilse (n=73) were defined as salmon $\leq$ 71 cm FL, and female grilse (n=82) were defined as salmon $\leq$ 67 cm FL (Table 5). Male grilse averaged 62.4 cm FL (range: 43 - 71 cm FL, SD=6.7); male adults (n=349) averaged 89.3 cm FL (range: 72 - 110 cm FL, SD=9.1). Female grilse averaged 61.8 cm FL (range: 49 - 67 cm FL, SD=4.1); female adults (n=607) averaged 79.8 FL (range: 68 - 98 cm FL, SD=6.8).

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

Week	Dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (°F)[2/]	Carcass count[3/]		
					Fresh	Decayed	Total
1	Sep 28 - Oct 1	8,400	11	54	40	45	85
2	Oct 5 - 8	7,800	12	55	79	73	152
3	Oct 13 - 16	6,200	12	55	136	178	314
4	Oct 19 - 22	6,000	13	55	209	375	584
5	Oct 26 - 29	6,000	13	52	188	479	667
6	Nov 2 - 5	6,000	13	53	163	514	677
7	Nov 9 - 13	8,000	11	54	124	416	540
8	Nov 16 - 19	13,300	9	54	101	246	347
9	Nov 23 - 25	14,800	5	51	18	60	78
10	Nov 30 - Dec 3	14,700	6	51	26	95	121
11	Dec 7 - 11	23,400	7	53	15	20	35
12	Dec 14 - 17	15,300	7	52	43	83	126
				Totals	1,142	2,584	3,726

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 by reach of carcasses (adults and grilse) observed during the upper Sacramento River fall-run chinook salmon escapement survey, September- December 1998.

Week	Reach 1 (RM 298.5-295.0)		Reach 2 (RM 295.0-292.0)		Reach 3 (RM 292.0-284.0)		Reach 4 (RM 284.0-273.0)	
	M[1/]	C[2/]	M	C	M	C	M	C
1	25	3	41	0	9	1	6	0
2	56	0	36	10	16	16	13	5
3	92	14	110	17	39	15	19	8
4	135	11	184	8	123	16	101	6
5	164	7	262	29	93	19	85	8
6	138	13	239	32	131	24	82	18
7	140	22	152	46	91	39	47	3
8	181	21	51	6	60	7	12	9
9	3	0	3	1	47	18	4	2
10	16	1	50	5	40	7	2	0
11	0	11	0	8	0	12	0	4
12	0	28	0	44	0	46	0	8
Totals	950	131	1,128	206	649	220	371	71

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 1998.

	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	39	67.4	49-96	13	68.5	49-96	26	68.8	54-90
2	79	74.6	53-98	37	77.0	53-98	42	72.5	56-89
3	131	79.2	43-103	54	83.4	43-103	77	76.3	52-92
4	193	82.2	49-108	82	86.8	54-108	111	78.9	53-97
5	187	82.7	49-106	66	88.3	49-106	121	79.7	56-98
6	159	81.0	58-106	56	84.6	58-106	103	79.1	59-94
7	132	81.2	49-105	46	86.1	49-105	86	78.6	59-97
8	97	79.7	52-110	31	86.9	52-110	66	76.3	52-98
9	16	78.5	60-109	4	83.0	60-109	12	77.0	60-97
10	25	85.2	50-104	9	90.0	50-104	16	82.6	68-92
11	14	81.1	56-100	5	88.8	56-100	9	75.3	63-98
12	39	80.9	49-101	19	81.2	62-101	20	80.7	49-98
Total (mean)	1,111	(80.3)	43-110	422	(84.6)	43-110	689	(77.9)	49-98

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 1998.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	82	607	73	349
Mean FL (cm)	61.8	79.8	62.4	89.3
Range FL (cm)	49-67	68-98	43-71	72-110
Standard Deviation	4.1	6.8	6.7	9.1

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

	Adults		Grilse	
Week	Number	Percent	Number	Percent
1	13	33	26	67
2	49	62	30	38
3	113	86	18	14
4	175	91	18	9
5	176	94	11	6
6	142	89	17	11
7	124	94	8	6
8	85	88	12	12
9	12	74	4	25
10	24	96	1	4
11	11	79	2	21
12	32	82	7	18
Total(mean)	956	(86)	155	(14)

Grilse comprised 155 (14%) of the 1,111 measured carcasses (Table 6). The greatest number of grilse (30) was observed in the second week (5-8 October) (Figure 9). Adults comprised 956 (86%) of the measured carcasses. The greatest number of adults (176) was also observed during Week 5 (26 -29 October).

Sex Composition

Males comprised 37% (n=349) of the fresh adult carcasses examined, while females comprised 63% (n=607) (Table 7). Males comprised 47% of the grilse (n=73); females comprised 53% (n=82). Females comprised 62% (n=689) of the all fresh carcasses; males comprised 38% (n=422). The female to male ratio for adult spawners was nearly 1.9:1 (607:349) (Table 7 and Figure 10). Females dominated the adult population throughout the survey period. The grilse population was also mostly female (Figure 11).

Spawning Success

There were 678 females examined for egg retention (Table 8). Of these, 647 (96%) had completely spawned, 9 (1%) had only partially spawned, and 22 (3%) had not spawned. At least 73% of the females checked each week had completely spawned.

Population Estimates

Only fresh carcass data were used to calculate the Schaefer estimate. A total of 893 fresh adult carcasses was tagged and 237 (27%) were subsequently recaptured. Both fresh and decayed carcass data were used to calculate the Jolly-Seber estimate. A total of 2,671 fresh and decayed adult carcasses was tagged, and 651 (24%) were subsequently recaptured.

An estimate of 12,506 adult spawners was calculated using the Schaefer model (Tables 9 and 10). Since adults made up 88% of the total escapement based on carcasses measured (Table 6), a total escapement estimate of 14,211 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.88. An adult escapement estimate of 7,532 was calculated using the Jolly-Seber model (Table 11). This estimate was similarly expanded by dividing by 0.88 resulting in a total escapement estimate of 8,559 spawners.

The 1998 population estimates for salmon spawning in the upper Sacramento River from Cottonwood Creek to ACID Dam are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	14,211	8,559
Adult estimate	12,506	7,532
Grilse estimate	1,705	1,027

The estimated 1998 escapement (14,211) is considerably less than the 1956 -1998 average (67,015) for the section of stream from RBDD to Keswick Dam (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.

Hatchery Produced Spawners

Two adipose-clipped (hatchery produced) carcasses were collected. No CWTs were found. Both carcasses were female; one was 60 cm FL and one was 83 cm FL.

Table 7. Sex composition of fall-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, September - December 1998.

	Adults				Grilse*			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	4	31	9	69	9	35	17	65
2	23	47	26	53	14	47	16	53
3	45	40	68	60	9	50	9	50
4	71	40	104	60	11	61	7	39
5	61	35	115	65	5	45	6	55
6	48	34	94	66	8	47	9	53
7	42	34	82	66	4	50	4	50
8	27	32	58	68	4	33	8	67
9	2	17	10	83	2	50	2	50
10	8	33	16	67	1	100	0	0
11	4	36	7	64	1	100	0	0
12	14	44	18	56	5	71	2	29
Total (mean)	349	(37)	607	(63)	73	(47)	82	(53)

* Based on length-frequency distributions, male grilse are defined as salmon $\leq$ 71 cm FL and female grilse as salmon $\leq$ 67 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 1998.

Week	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	26	26	25(96)	1(4)	0(0)
2	42	42	40(95)	1(2)	1(2)
3	77	75	74(99)	1(1)	0(0)
4	111	110	105(95)	2(2)	3(3)
5	121	119	115(97)	0(0)	4(3)
6	103	101	96(95)	1(1)	4(4)
7	86	84	80(95)	1(1)	3(4)
8	66	65	62(95)	0(0)	3(5)
9	12	11	8(73)	1(9)	2(18)
10	16	16	16(100)	0(0)	0(0)
11	9	9	8(89)	1(10)	0(0)
12	20	20	18(90)	0(0)	2(10)
Totals (means)	689	678	647(96)	9(1)	22(3)

Table 9. Weekly summary of tagging and recapture of fresh adult chinook salmon carcasses during the upper Sacramento River escapement survey, September - December 1998.

Schaefer model capture-recapture data matrix

Week of recovery $_{(j)}$	Week of tagging $_{(i)}$ 1	2	3	4	5	6	7	8	9	10	Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
2	13										13	167*	12.85
3	1	7									8	261	32.63
4	1	3	24								28	542	19.36
5		2	6	42							50	649	12.98
6			6	18	40						64	663	10.36
7			1	5	14	30					80	634	12.68
8					3	4	12				19	314	16.53
9								3			3	64	21.33
10									2		2	107	53.50
11											0	31	0.00
12											0	112	0.00
$R_{(i)}$	15	12	37	65	57	34	12	3	2	0	(Tagged fish recovered)		
$T_{(i)}$	17	35	90	188	175	147	116	87	14	24	(Total fish tagged)		
$T_{(i)}/R_{(i)}$	1.13	2.92	2.43	2.89	3.07	4.32	9.67	29.0	7.00	0.00	(Ratio)		

Includes carcasses counted during week 1

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 1998.

Population estimate

Week of recovery$_{(j)}$	Week of tagging $_{(i)}$										Totals
	1	2	3	4	5	6	7	8	9	10	
2	189										189
3	37	666									703
4	22	169	1,130								1,321
5		76	189	1,577							1,842
6			151	539	1,272						1,963
7			31	183	545	1,645					2,404
8					152	286	1,917				2,355
9								1,856			1,856
10									749		749
11											0
12											0
Subtotals	248	911	1,502	2,299	1,969	1,930	1,917	1,856	749	0	13,382
Tags		-35	-90	-188	-175	-147	-116	-87	-14	-24	-876
								Population estimate -			12,506

Table 11. Weekly summary of tagging and recapture of both fresh and decayed adult chinook salmon carcasses during the upper Sacramento River escapement survey, September - December 1998.

Jolly-Seber capture-recapture data matrix

Week of recovery$_{(j)}$	Week of tagging$_{(i)}$										Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$
	1	2	3	4	5	6	7	8	9	10		
2	21										21	175*
3	4	18									22	275
4	2	3	64								69	583
5		2	18	110							130	729
6			8	40	120						168	767
7			2	10	41	94					147	631
8					6	15	54				75	370
9						1	3	10			14	75
10								2	3		5	110
11										0	0	31
12										0	0	112
Tags recovered$_{(i)}$	27	23	92	160	167	110	57	12	3	0	<- Tagged fish recovered	
Carcasses Tagged$_{(i)}$	46	76	205	483	548	527	382	264	46	94	<- Total fish tagged	

* Includes carcasses examined during Week 1.

Table 12. Annual fall-run chinook salmon escapement estimates (adults and grilse) for upper Sacramento River from RBDD to Keswick Dam, 1956 - 1998.

Year	Totals *	Year	Totals
1956	84,716	1978	32,235
1957	47,300	1979	47,758
1958	99,300	1980	21,961
1959	249,600	1981	26,261
1960	210,000	1982	17,731
1961	134,700	1983	26,226
1962	115,500	1984	36,898
1963	135,200	1985	51,647
1964	140,500	1986	67,958
1965	98,900	1987	76,039
1966	107,900	1988	65,204
1967	78,100	1989	48,512
1968	95,600	1990	32,225
1969	114,600	1991	19,272
1970	65,950	1992	26,912
1971	52,247	1993	33,923
1972	33,559	1994	31,017
1973	40,424	1995	28,030(26,548)**
1974	45,590	1996	30,194(28,890)
1975	52,248	1997	95,505(26,191)
1976	43,612	1998	4,824(14,211)
1977	15,784	Mean = 67,015***	

* Estimates for years 1968 through 1985 were based on ladder counts made at RBDD during the entire run. Estimates for years after 1985 were based on ladder counts made at RBDD during a portion of the run.

** Results of carcass surveys, not used in calculating mean.

*** Average was calculated using annual escapements estimates from the 1956 through1998 period.

DISCUSSION

Carcass surveys have been annually conducted on the Sacramento River since 1995 to acquire data on the river's fall-run chinook spawning population. Our purpose was to determine if this method would provide reliable information on abundance and age and sex composition of the spawner population, temporal and spatial distribution of spawning and pre spawning mortality (egg retention), and if these data in combination with results of other investigations (e.g., redd surveys and RBDD fish counts) could be used to identify any influences of flow, temperature, channel morphology, and other habitat conditions on the functioning of the river's fall-run population. Results obtained during the four survey years (1995-1998) are inconclusive, however it appears that this approach will provide the targeted information needed to improve our understanding of the dynamics of the river's fall-run population, and ultimately its relationship with manageable habitat conditions.

C Fall-run spawner escapement estimates have been very consistent during the four survey years (Table 13). The estimates for the first three years were essentially identical ranging from 25,890 to 26,246 salmon (mean=26,209, SD=268). Tag recovery rates were also nearly equal during the first three years (mean=32%. SD=0.82). The population estimate decreased in 1998 to 14,211 as did the recovery rate (24%).

Since flows and water clarity were noticeably different in 1998, when both total estimate and recovery rate were lower than during the first three survey years, we evaluated the relationship between recovery rate and flow, water clarity and number of fish tagged to identify any biases potentially associated with these variables. No relationships were observed between weekly tag recovery rates and flow (r^2=0.07), water clarity (r^2=0.02) or number of fish tagged (r^2=0.24).

Escapement estimates were also made for the reach from RBDD to Keswick using fish counts made at RBDD and redd distribution data. Escapement estimates for this reach were similar to the carcass survey based estimates in 1995 (28,030 v. 26,546) and 1996 (30,184 v. 25,890), but were considerably different in 1997 (95,505 v. 26,191) and 1998 (5,386 v. 14,211).

The differences may be due to the difference in the survey reach lengths. The RBDD count based estimate includes 31.5 miles not covered in the carcass survey (3.5 miles upstream of the carcass survey reach, from ACID to Keswick Dam, and 28 miles downstream from the survey reach from Cottonwood Creek to RBDD). Redd survey data, however, indicate that few salmon spawn upstream of ACID and downstream of Cottonwood Creek. The carcass survey results also indicate that spawning activity decreases moving downstream, less than 12% of the observed carcasses were found in the lower 11 miles (43%) of the survey reach. Comparison of the 1995 and 1996 results suggest that from 86 to 95% of spawning occurs within the carcass survey reach. A

Table 13. Comparison of results of carcass surveys conducted on the upper Sacramento River fall-run chinook salmon spawner population from 1995 through 1998.

	1995	1996	1997	1998
Total estimate	26546	25890	26191	14211
% Adult	91	79	90	86
% Grilse	9	21	10	14
% Female adult	66.4	65.7	59	63.5
% Male adult	33.6	34.3	41	36.5
% Female all	62	54	55	63
% Male all	38	46	45	37
Tag recovery rate (%)	33	32	31	24
Spawning success	94	87	92	96
Reach 1 %	40	23	28	29
Reach 2 %	21	37	34	36
Reach 3 %	23	26	24	23
Reach 4 %	16	14	14	12
Peak carcass count (all)	6 11/5-11	5 10/28-11/1	5 10/27-30	6 11/2-5
Flow range	4800-6500	6700-27700	4200-6300	6200-23400
Temperature range	53-57	53-56	53-57	51-55
Grilse size criteria (male)	64	73	72	71
Grilse size criteria (female)	64	64	66	67

similar comparison suggests that only 27% of spawning occurred in the carcass survey reach in 1997. Since the carcass based survey was nearly 3-fold the RBDD based estimate, no such comparison could be made. However, since we observed 3,726 carcasses in 1998, nearly 70% of the redd based estimate, it is extremely likely that the RBDD based method drastically underestimated spawner escapement.

- Age composition of the spawner population varied from 91% to 79% adults (Table 13). There was no relationship observed between percent grilse and the estimated adult population for the subsequent year.

- Sex composition varied only slightly during the four survey years (Table 13). The percentage of female adults ranged from 59% (1997) to 66.4% (1995) (mean=63.7, SD=2.9). The total percentage of female (grilse and adult) ranged from 54% (1996) to 63% (1998) (mean=58.5, SD=4.0).

- Spatial spawning distribution (based upon location of fresh carcass collection) varied slightly within Reaches 1 and 2 and was fairly consistent in Reaches 2 and 4 (Table 13). The majority of spawning occurred within Reaches 1 and 2, accounting for at least 60% of all spawning (mean=62%, SD=1.9) Spawning distribution within these two reaches was predominantly within Reach 2, nearly twice as much spawning was observed in Reach 1 versus 2 in 1995, the only year when spawning was greater in Reach 1. Spawning within Reach 3 was very consistent (mean=24, SD=1.2). Similarly, spawning in Reach 4 was also very consistent (mean=14%, SD=1.4).

- Spawning consistently peaked during the last week of October and first week of November. Fresh and decayed carcasses were also observed during the first survey week (typically the first week of October) of each year.

- Spawning success, measured as percentage of completely spent female carcasses, ranged from 87% to 96%. The lowest spawning success was measured in 1996 when the overall population was highest; the highest success was measured in 1998 when overall population was lowest.

- The contribution of hatchery produced salmon to the fall-run spawner population appears to be very low. Only two adipose clipped fish were observed, on grilse and one adult. These two fish were likely produced at Coleman National Fish Hatchery (CNFH) then marked, tagged and released into the upper Sacramento River system. (The majority of adipose clipped salmon that return to the upper Sacramento River are from CNFH). Since 7% of the fall-run production at CNFH are typically marked, one adipose clipped fish potentially represents about 14 CNFH produced fish (i.e., 1 marked and 13 unmarked). The estimated, minimum proportion of hatchery produced spawners was 0.4% adults and 2.7% grilse.

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FIGURES

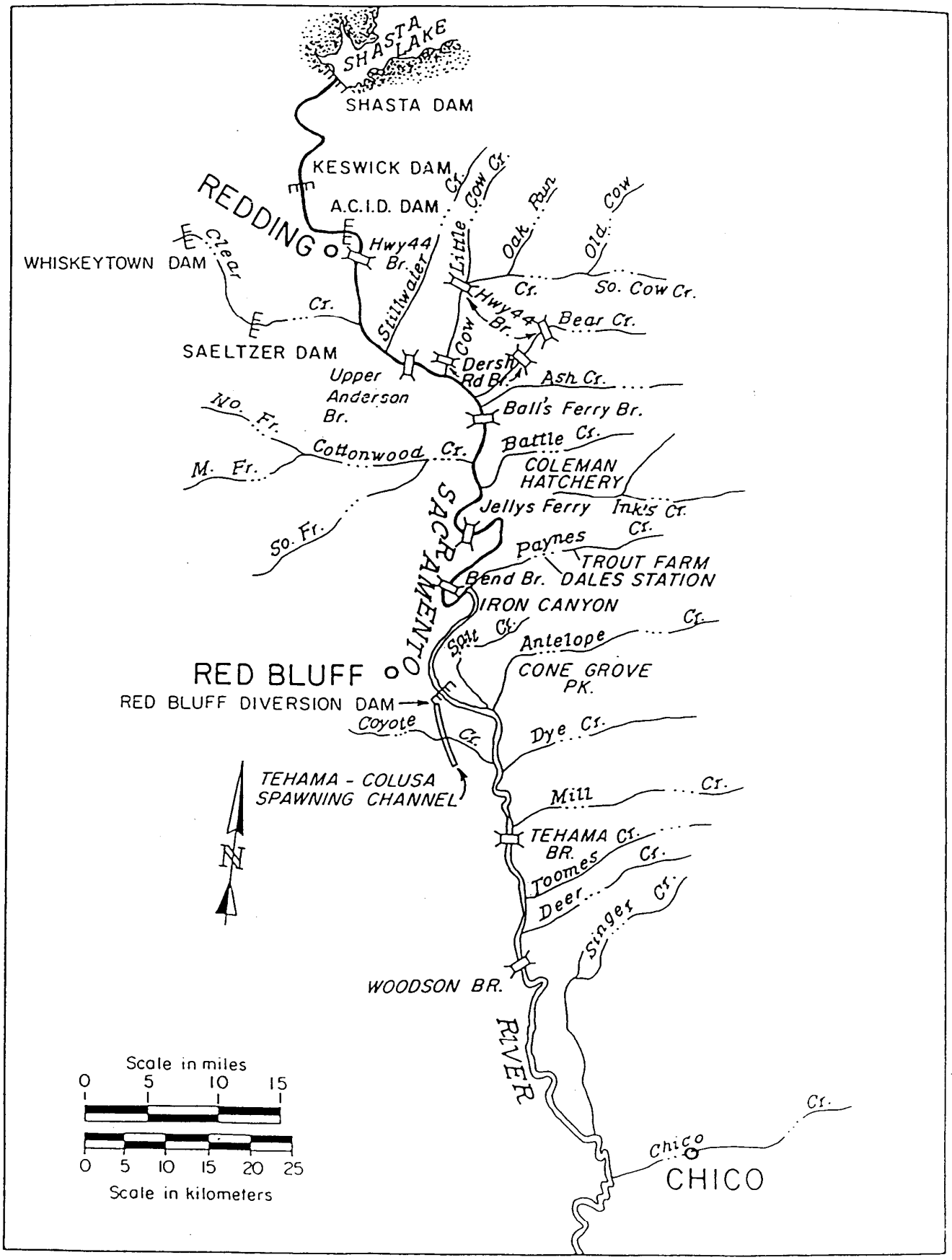

Figure 1. Upper Sacramento River.

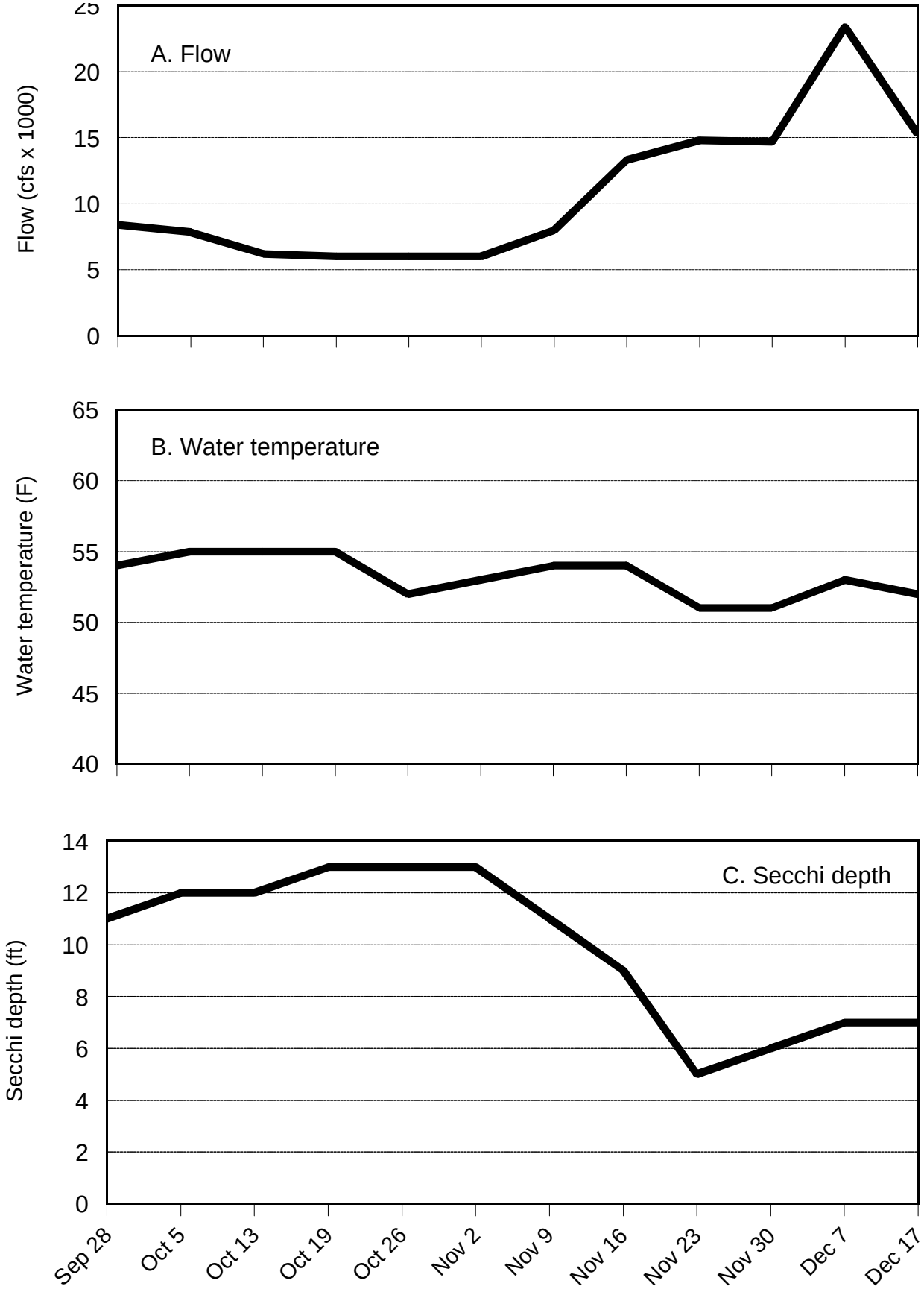

Figure 2. Mean daily flow at Keswick Dam (A), water temperature (B), and Secchi depth (C), measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

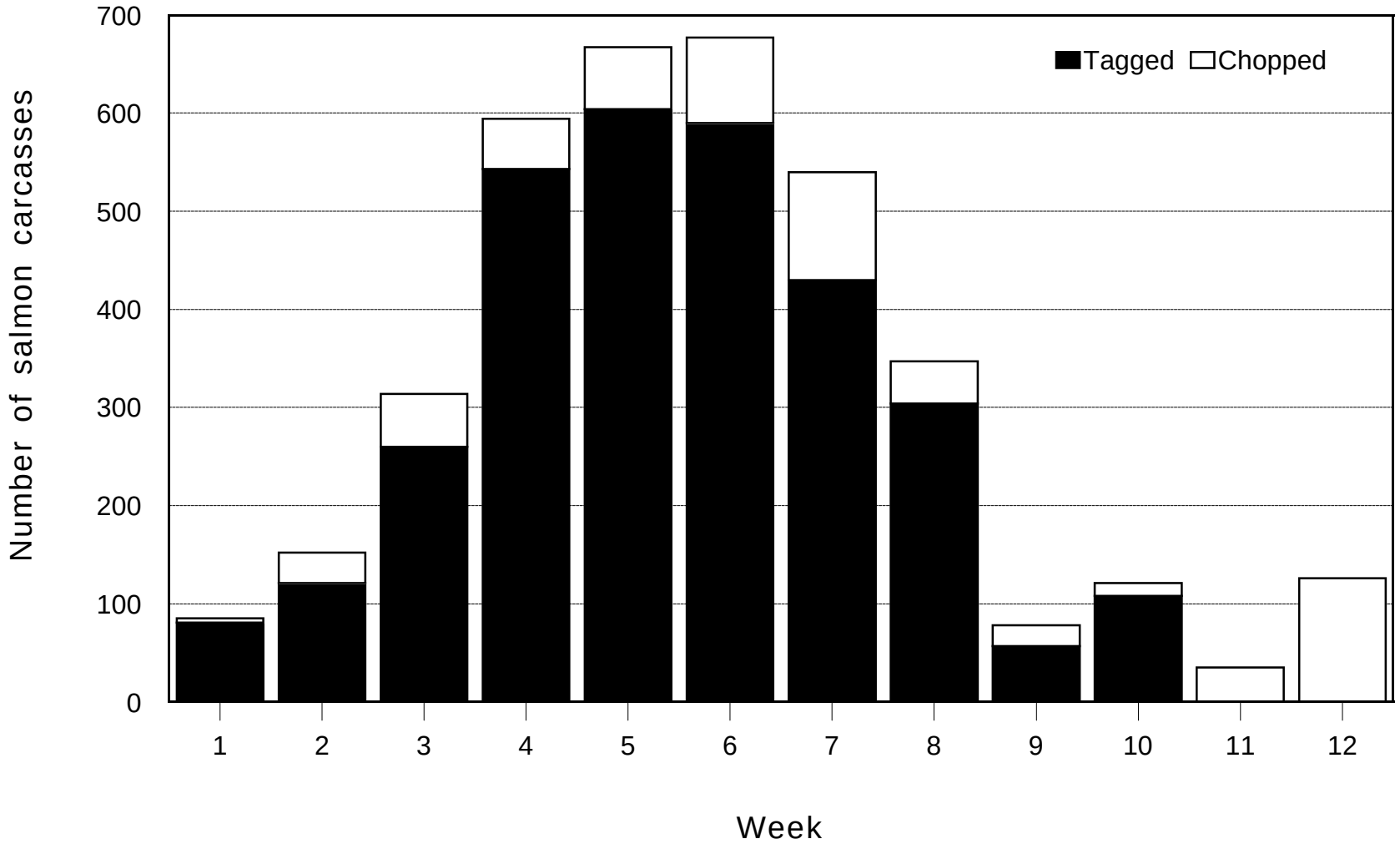

Figure 3. Weekly distribution of both fresh and decayed carcasses (adult and grilse) observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

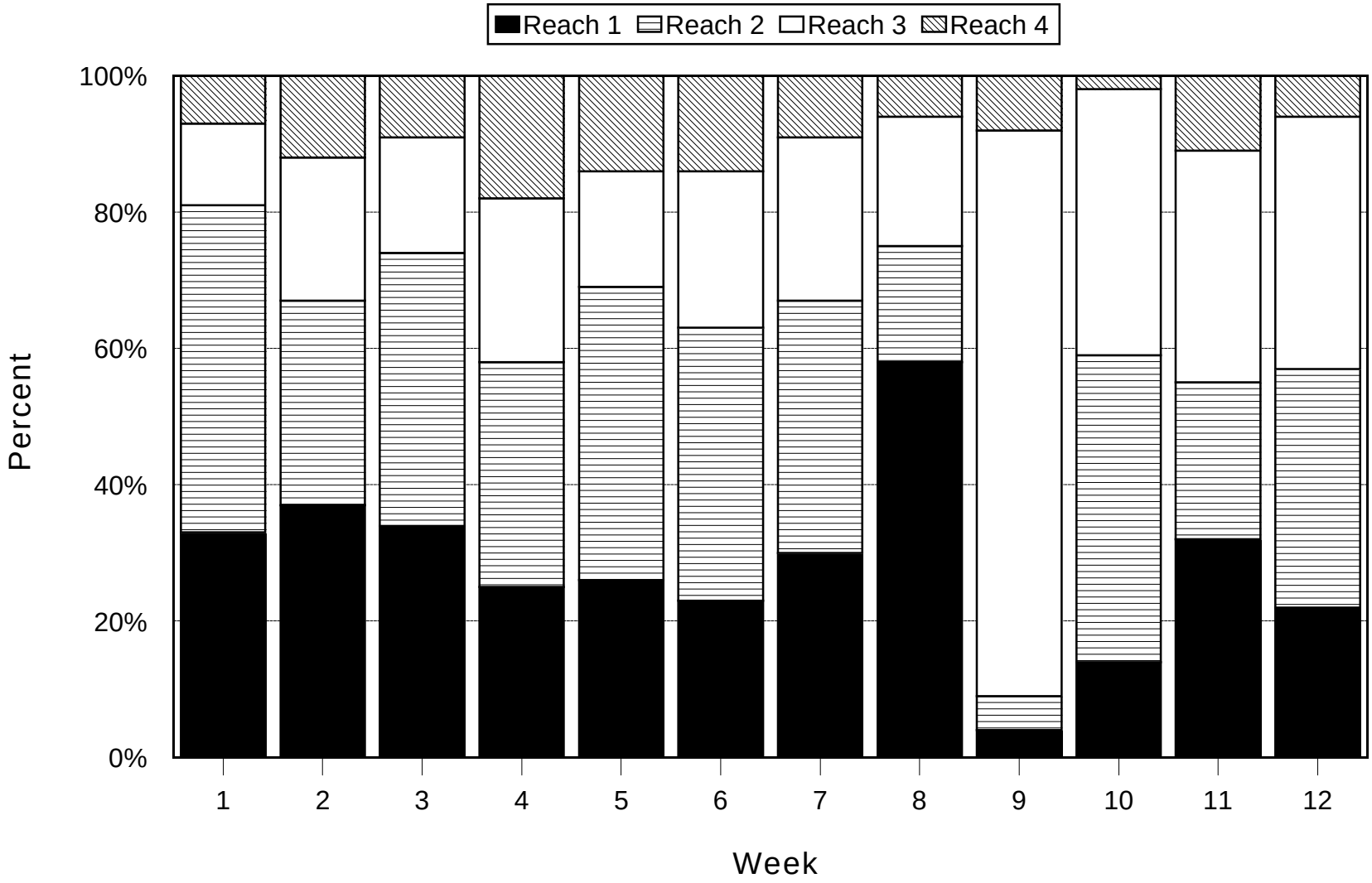

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

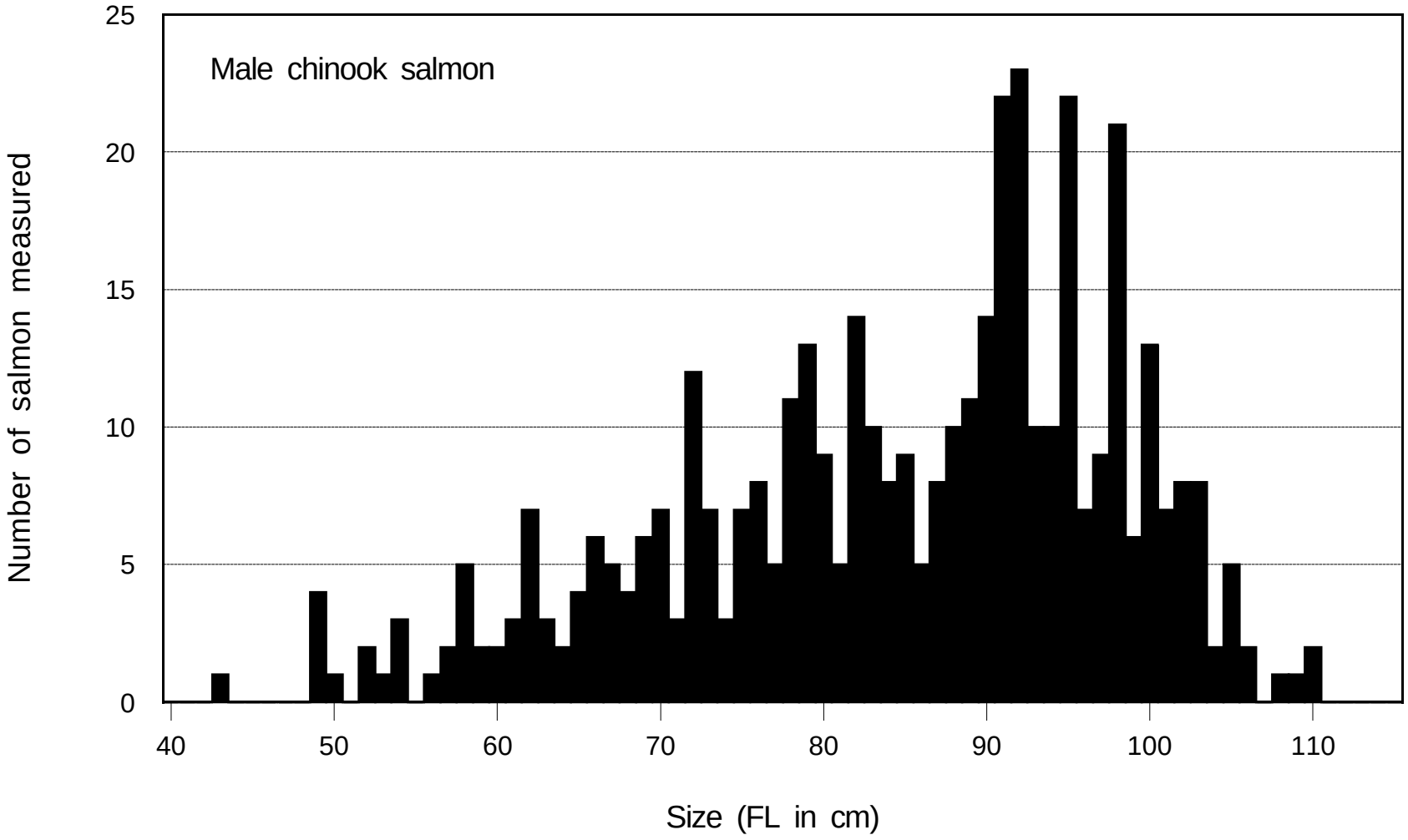

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1998.

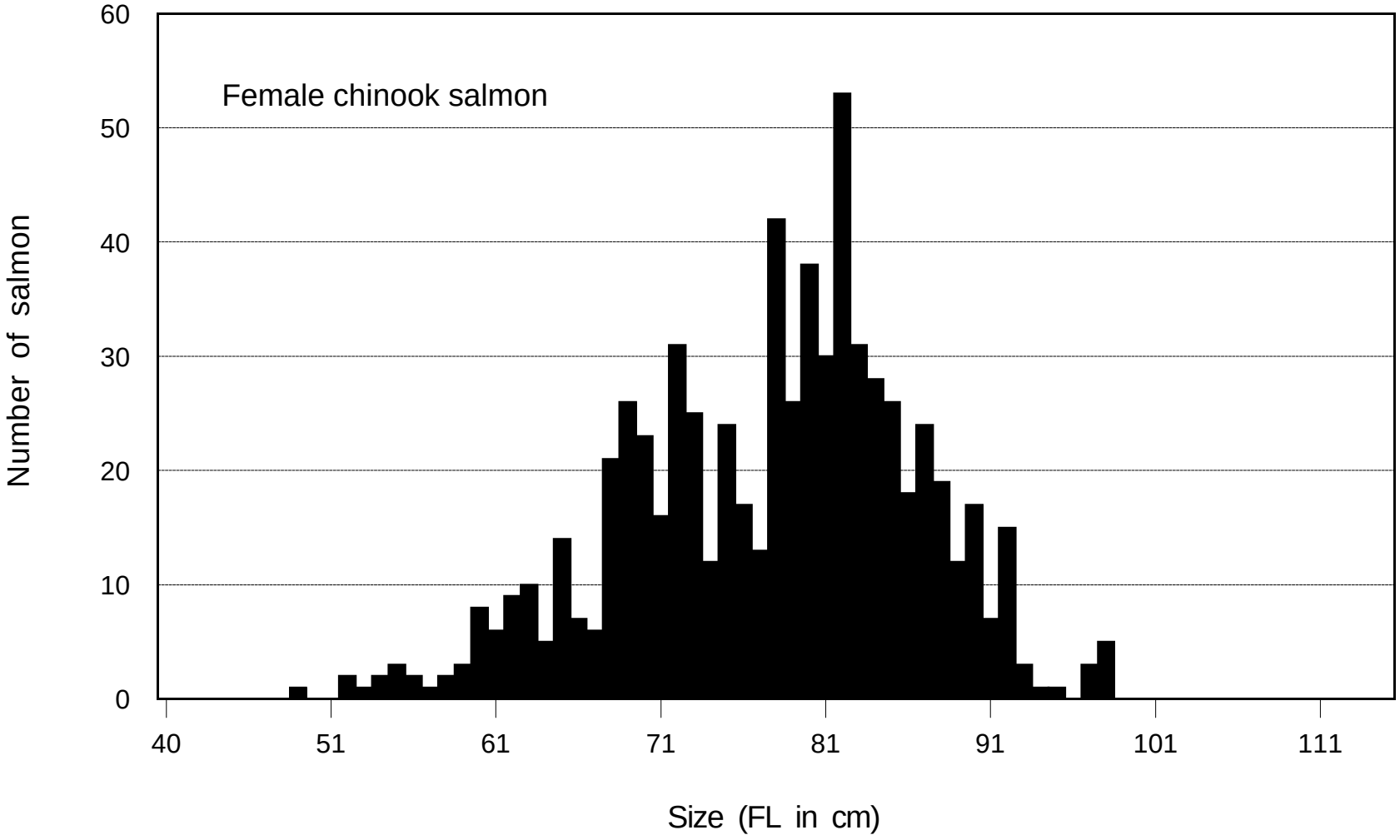

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1998.

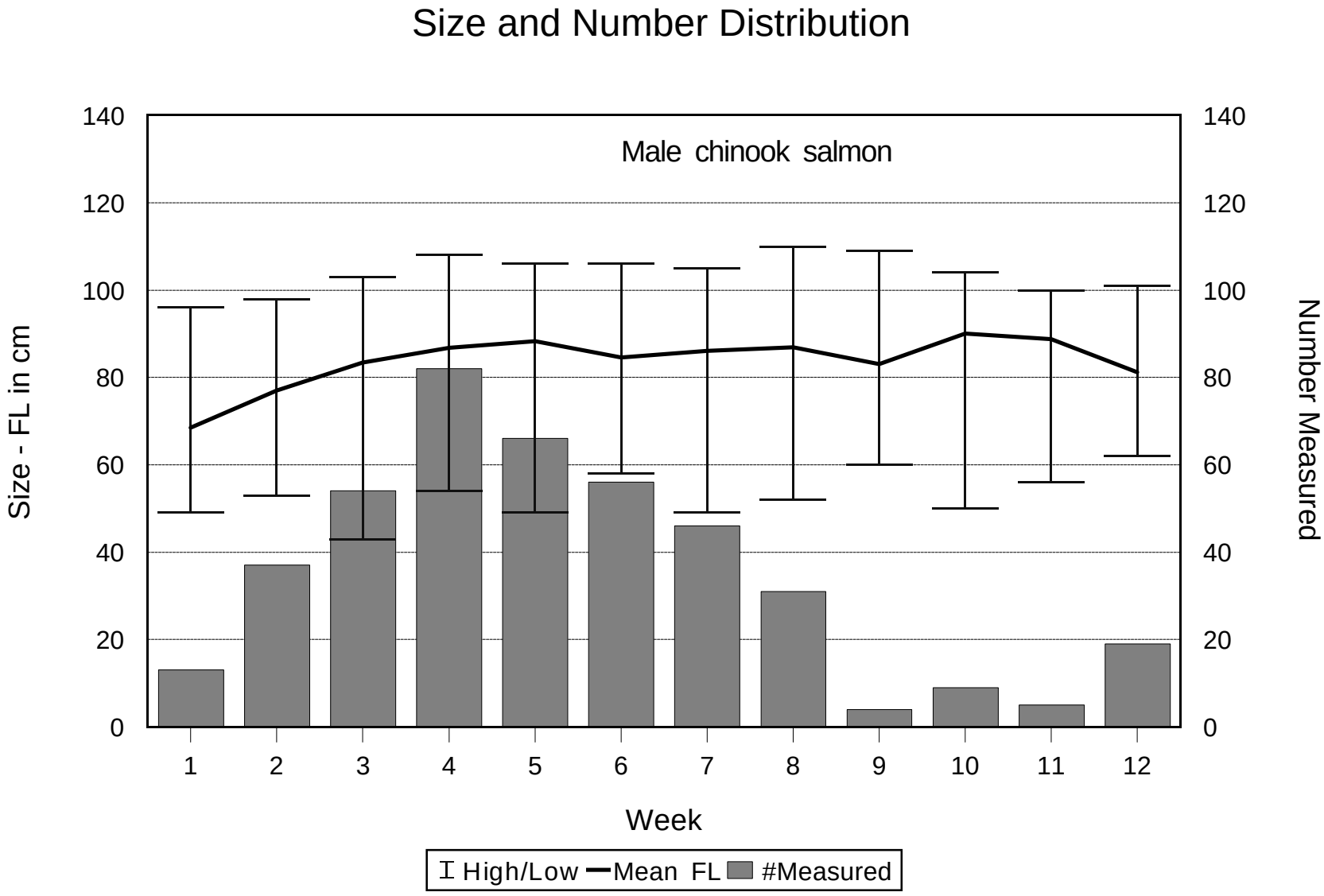

Figure 7. Weekly mean size, size range, and number of male chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

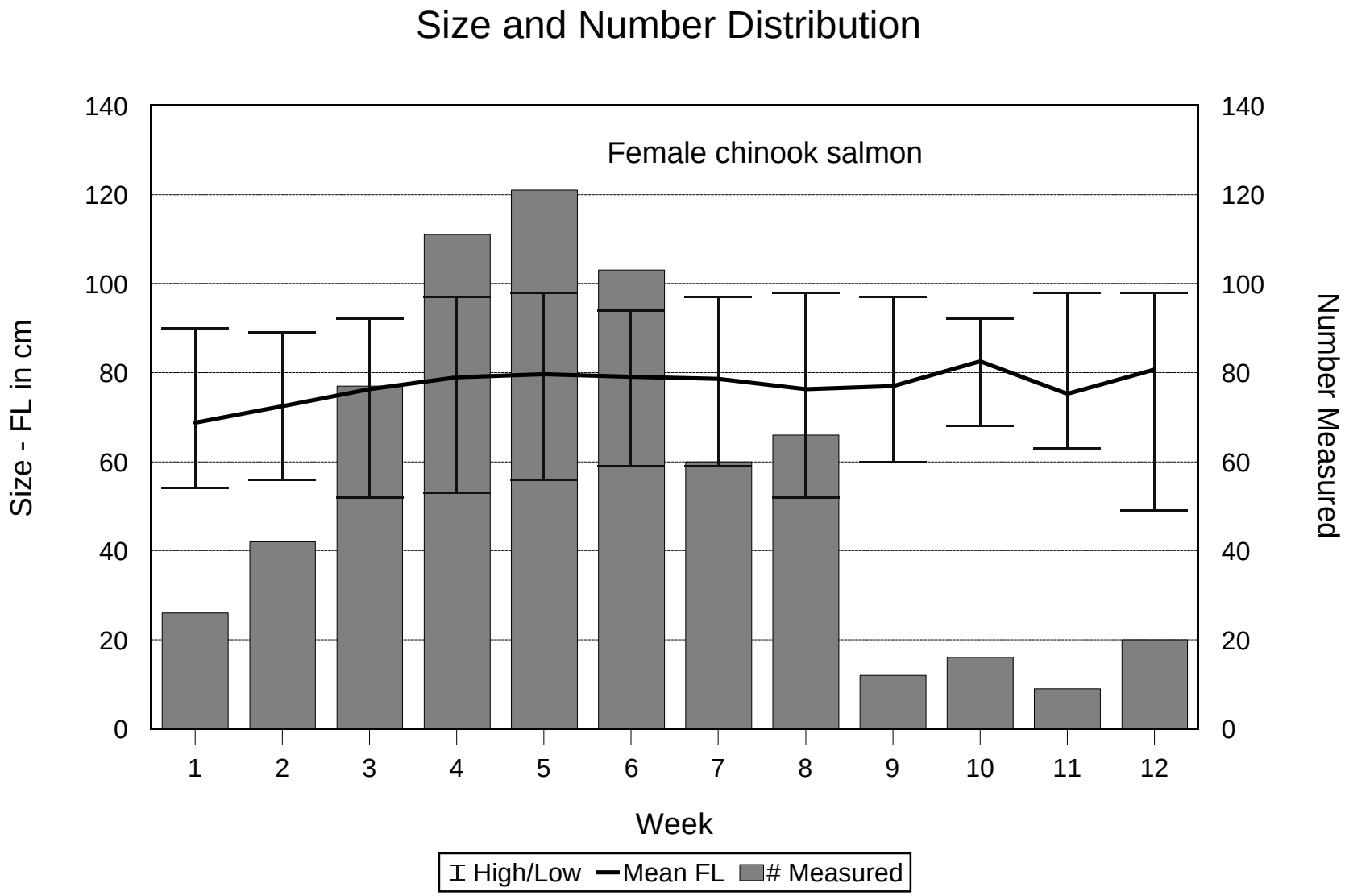

Figure 8. Weekly mean size, size range, and number of female chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

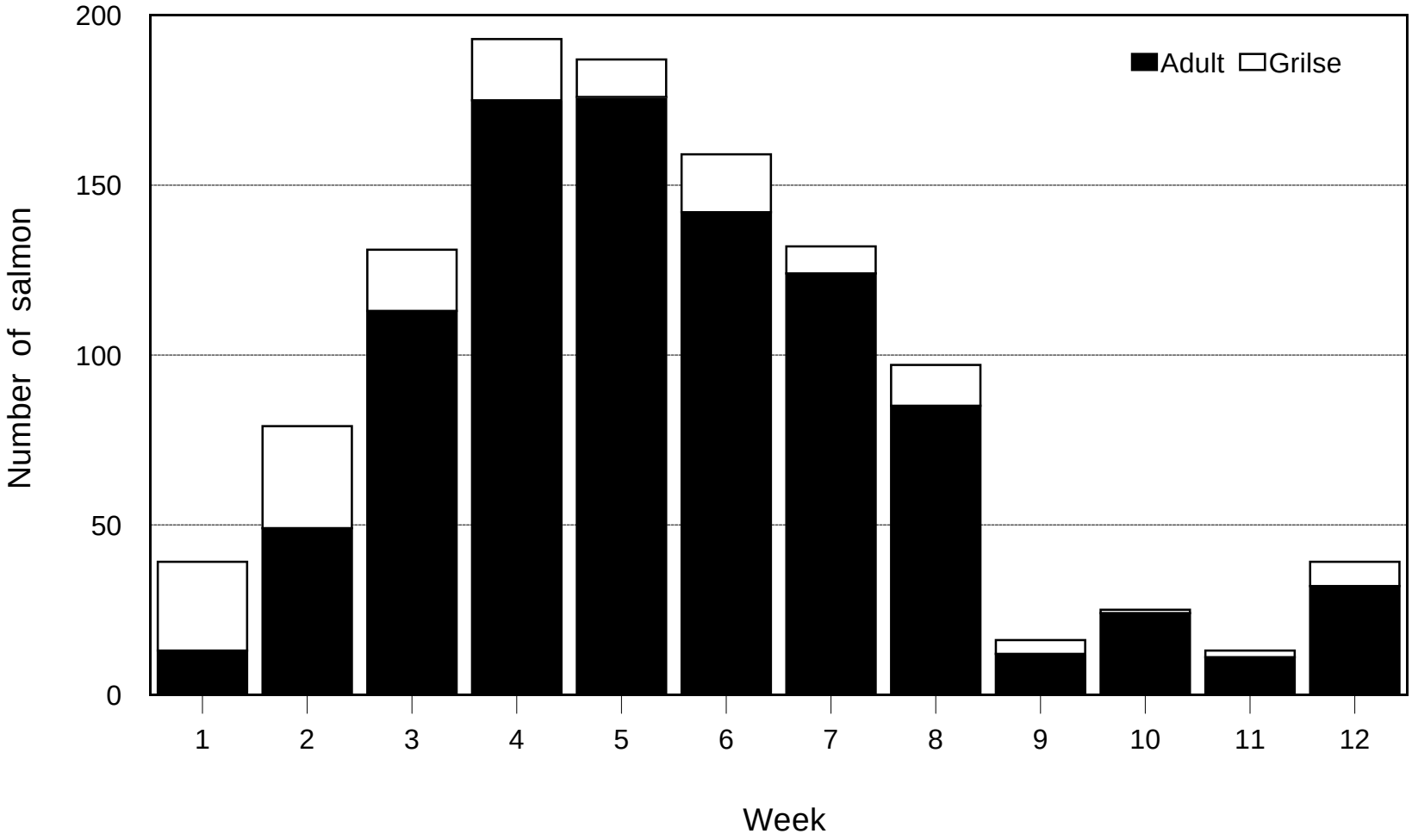

Figure 9. Adult and grilse compostion of chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

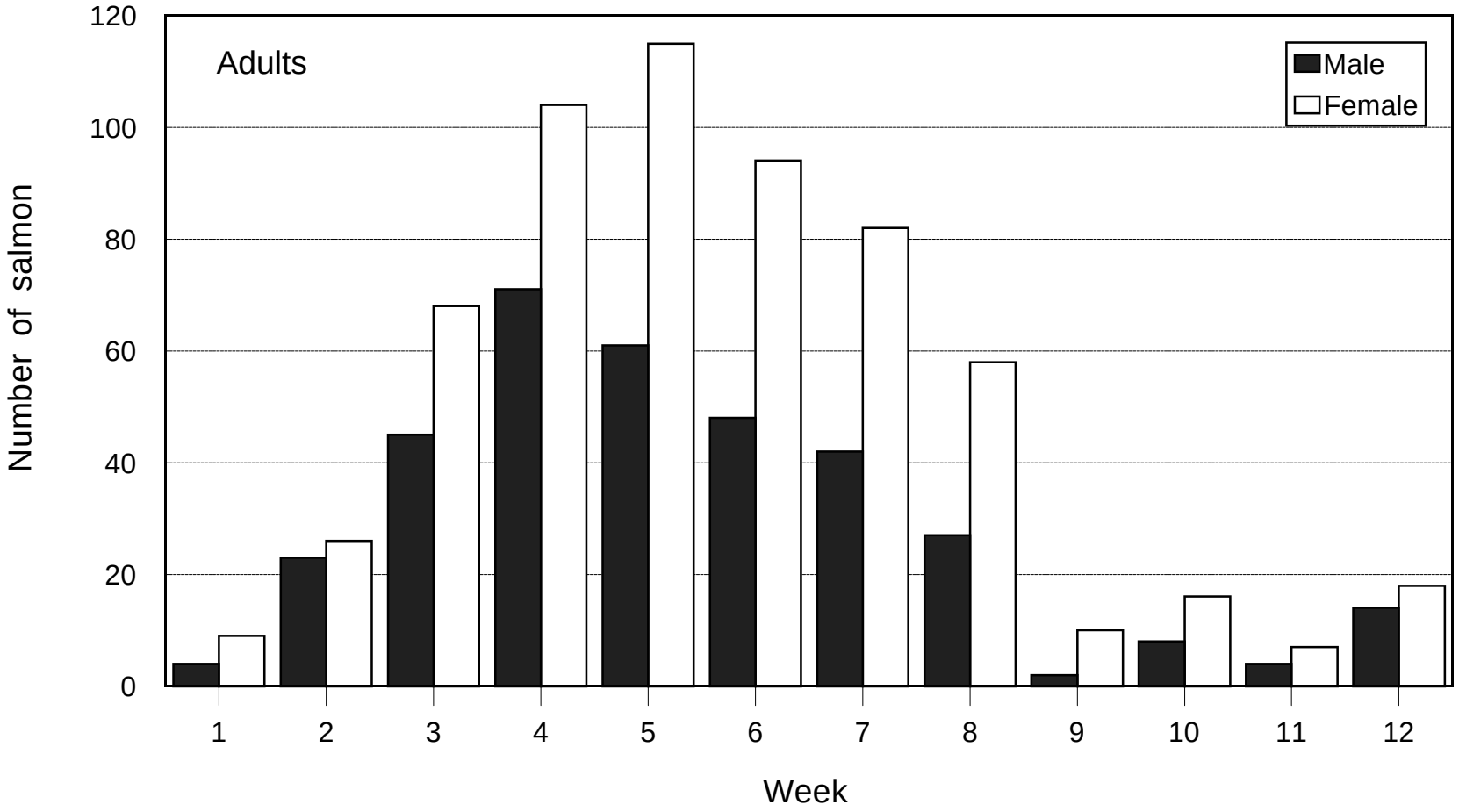

Figure 10. Weekly gender (sex) distribution of adult-sized chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1998.

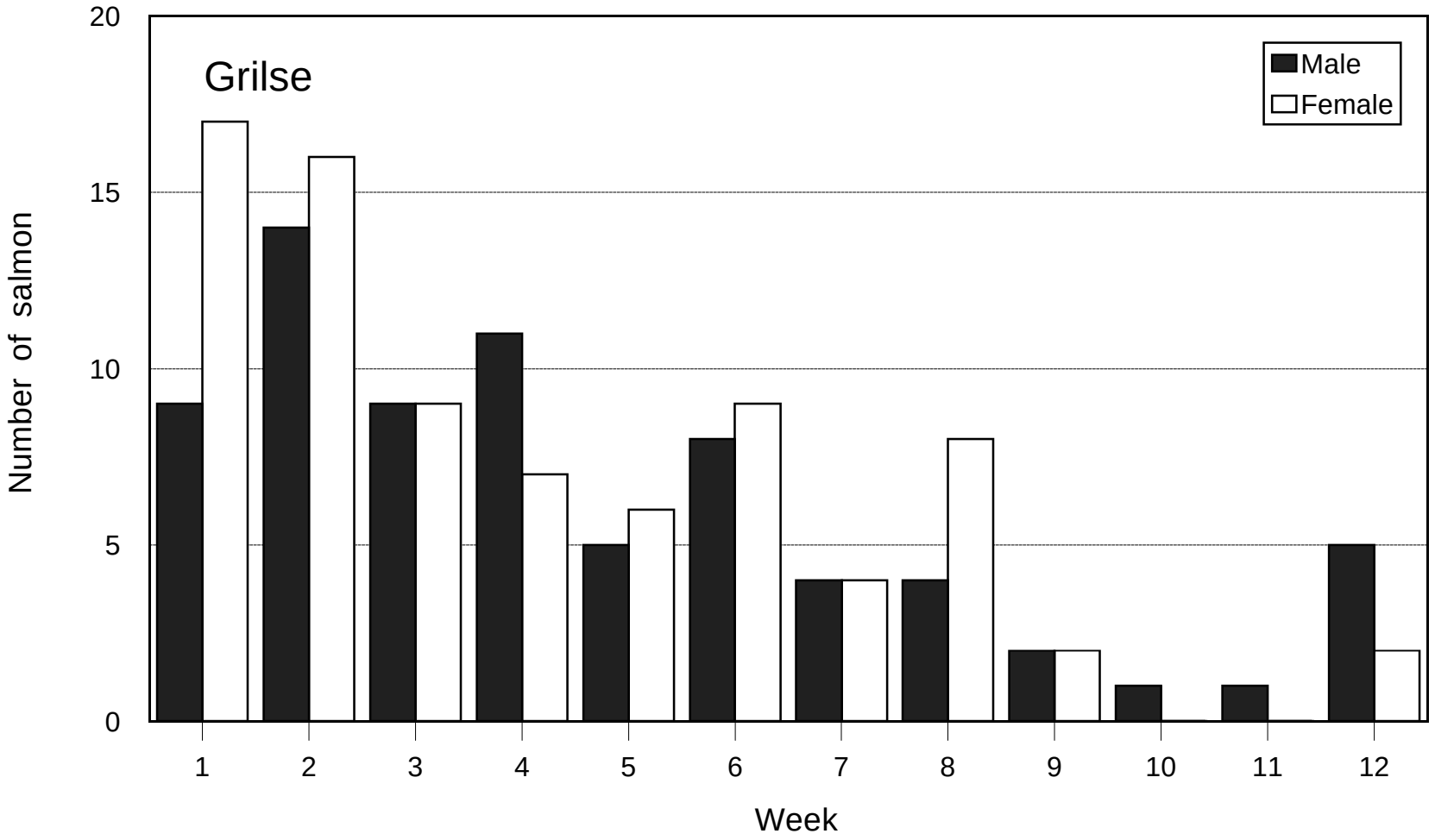

Figure 11. Weekly gender (sex) distribution of grilse-sized chinook salmon measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1998.

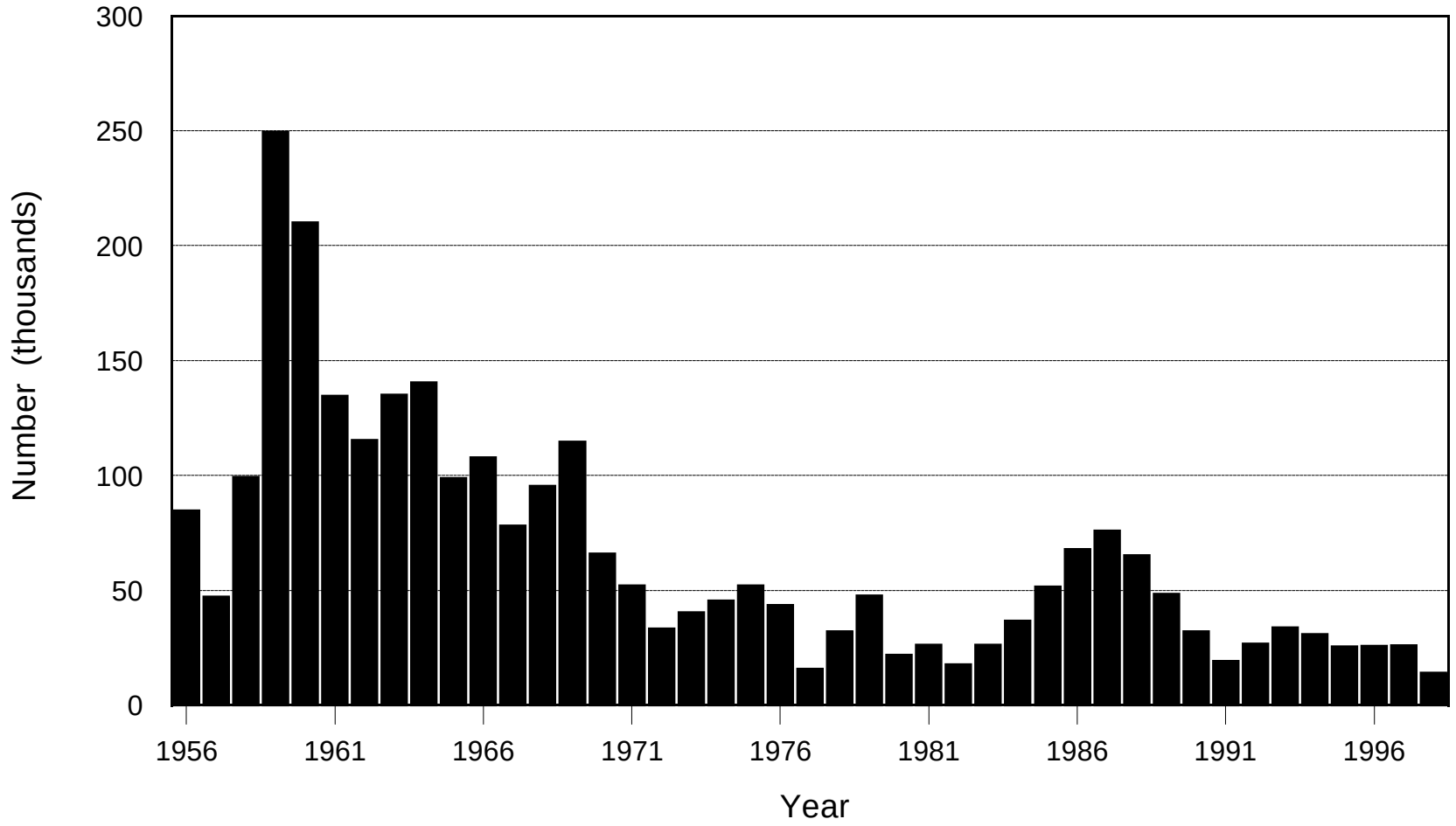

Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1998).