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

Upper Sacramento River
Fall-Run Chinook Salmon Escapement Survey
September - December 1997

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Stream Evaluation Program
Technical Report No. 98-3
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2/ Stream Evaluation Program Technical Report No. 98-3

SUMMARY

A fall-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during fall-winter 1997 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the third 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. 1998).

The survey was conducted from 29 September through 18 December 1997. It included 25.5 miles of the Sacramento River, from Cottonwood Creek to Anderson-Cottonwood Irrigation District (ACID) dam located just 3.5 miles downstream of Keswick Dam (the upstream limit to migration). Flow decreased from 6,300 cubic feet per second (cfs) during survey period 1 (29 September - 2 October 1997), to 4,900 cfs in survey period 2 (6 - 9 October 1997), and then ranged from 4,200 to 4,600 cfs for the remainder of the survey season. Mean weekly water temperature ranged from 53^{o} F during survey periods 11 and 12 (8 - 18 December 1997) to 57^{o} F during survey period 3 (14 - 17 October 1997).

We examined 7,754 fall-run carcasses (fresh and decayed) of which 1,219 fresh carcasses were measured, sexed, and aged; 1,448 fresh carcasses were observed. Based upon this sample, 90% of the population were adult salmon (>2-years old) and 10% were grilse (2-years old); 37% were adult males, 53% were adult females, 8% were male grilse and 2% were female grilse (45% male; 55% female). Carcasses were observed during every week of the survey. Peak carcass recovery occurred during survey periods 3 through 7 (14 October - 14 November 1997) which indicated that peak spawning likely occurred from 1 - 31 October 1997.

We examined 639 females for egg retention. Of these, 587 (92%) had completely spawned; 20 (3%) still contained a substantial number of eggs; and 32 (5%) were unspawned.

The spawner population was estimated using two different mark-recapture models, the Schaefer and Jolly-Seber models. Per the Schaefer model, 981 fresh adult carcasses were marked and 305 (31%) were subsequently recaptured yielding an escapement estimate of 26,191 total salmon (23,572 adult and 2,619 grilse). Per the Jolly-Seber model, 5,783 fresh and decayed carcasses were marked and 1,494 (26%) were subsequently recaptured yielding an estimate of 19,506 total salmon (17,555 adults and 1,951 grilse). Both estimates are considerably less than the mean annual fall-run chinook salmon escapement estimate (66,779 grilse and adult) for 1956 through 1997. Escapement estimates(Schaefer model) from the recent three annual carcass surveys have been nearly equal ranging from 26,191 to 28,890 with an mean of 27,210 and standard deviation of 1,466.

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 1997 to estimate spawner abundance and distribution. This survey was carried out to fulfill the mandates of Section 3406(b)(1)(B) of the Central Valley Project Improvement Act (CVPIA), P.L. 102-575, which requires the Secretary of the Interior to determine instream flow needs for all Central Valley Project controlled streams and rivers. Flow-need recommendations are to be provided to the Secretary by the U. S. Fish and Wildlife Service (FWS) after consultation with the DFG. In response to this Act, the FWS and the DFG have signed a "Cooperative Agreement" by which the FWS will fund the DFG to conduct studies to determine flow needs of salmon in the upper Sacramento River.

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

Carcass tag-and-recapture surveys have been regularly used to estimate salmon spawner escapements in Central Valley tributary streams (e.g., American, Yuba, and Feather rivers). During these surveys, carcasses are tagged and released into running water for later 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. Fall-run carcass surveys were also conducted in 1995 and 1996 (Snider et. al. 1997; Snider et. al. 1998).

Three models have been used by the DFG to estimate escapement using carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for tributary streams with typically small spawner populations (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. Based on Law's (1994) analysis, the Schaefer model will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis,

the Jolly-Seber model will slightly underestimate Central Valley spawner escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is more accurate when model assumptions are met and recovery rates are $\geq$ 10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.)[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 carcasses on the spawning grounds in the upper Sacramento River (Fry 1961).

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

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

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

- **1986 - present** The DFG's Inland Fisheries Division (IFD) annually estimates fall-run escapement using both counts made at RBDD and aerial redd surveys. The dam's gates are now typically open between mid-September and mid-May of the following year improving fish passage but eliminating direct counts at the ladders during up to 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 1997 upper Sacramento River fall-run chinook salmon escapement survey were:

- To estimate the 1997, in-river, fall-run chinook salmon spawning population for the upper Sacramento River upstream of Cottonwood Creek.

- To evaluate egg-retention, 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 1997 spawner escapement surveys began immediately following the initial observation of spawning activity and then were conducted weekly from 29 September through 18 December 1997. 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 1997.

Reach	Location	River mile (length)
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. Data collected to estimate population size 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: $E = N_{ij} = R_{ij}(T_iC_j/R_iR_j) - T_i$

where:

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

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

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

where:

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

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

Flow measurements for each day surveyed were obtained from the Keswick gauge operated by the 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 7,754 carcasses was observed (Table 2). Flow averaged 6,300 cubic feet per second (cfs) during the first survey period, 4,900 cfs during the second survey period, and ranged from 4,200 to 4,600 cfs during survey periods 4 through 12 (Table 2, Figure 2). Mean temperature ranged from 53° F during survey periods 11 and 12 to 57° F during survey period 3 (Table 2, Figure 2). Water clarity (Secchi depth) ranged from 5 ft (Survey period 8) to 12 ft (survey periods 3 and 4) (Table 2, Figure 2)

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Temporal Distribution

The number of carcasses observed increased steadily from survey period 1 through 5 (29 September - 30 October), and then declined thereafter (Table 2 and Figure 3).

Spatial Distribution

The distribution of the total carcasses observed per reach was 28% in Reach 1, 34% in Reach 2, 24% in Reach 3, and 14% in Reach 4 (Table 3 and Figure 4).

Size Distribution

A total of 1,219 carcasses was measured (Table 4). Mean adult size was 81.6 cm FL. Size ranged from 42 to 112 cm FL. Male salmon (n = 548) averaged 84.4 cm FL (range: 42 - 112 cm FL) (Figure 5). Female salmon (n = 671) averaged 79.2 cm FL (range: 58 - 98 cm FL) (Figure 6). The weekly mean size for males ranged from 64.4 to 87.1 cm FL (Figure 7). Weekly mean size for females ranged from 77.4 to 84.6 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=94) were defined as salmon $\leq$ 72 cm FL, and female grilse (n=22) were defined as salmon $\leq$ 66 cm FL (Table 5). Male grilse averaged 61.7 cm FL (range: 42 - 72 cm FL, SD=8.0); male adults (n=454) averaged 89.0 cm FL (range: 73 - 112 cm FL, SD=8.2). Female grilse averaged 63.8 cm FL (range: 58 - 66 cm FL, SD=2.1); female adults (n=649) averaged 79.7 FL (range: 67 - 98 cm FL, SD=6.8).

Grilse comprised 116 (10%) of the 1,219 measured carcasses (Table 6). The greatest number of grilse (22) was observed in the fifth survey period (27 - 30 October) (Figure 9). Adults comprised 1,103 (90%) of the measured carcasses. The greatest number of adults (221) was observed during Survey period 3 (14 - 17 October).

Table 2. General survey information for the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997.

Survey period	Dates	Flows (cfs)[1/]	Secchi depth (ft)[2/]	Water temperature (^{O}F)[2/]	Carcass count[3/]	
					Fresh	Decayed
1	Sep 29 - Oct 2	6,300	10	54	14	16
2	Oct 6 - 9	4,900	9	54	108	123
3	Oct 14 - 17	4,500	12	57	312	791
4	Oct 20 - 23	4,300	12	56	280	938
5	Oct 27 - 30	4,400	11	57	247	1,415
6	Nov 3 - 6	4,600	10	56	139	1,197
7	Nov 10 - 14	4,600	9	56	103	824
8	Nov 17 - 20	4,600	5	54	48	305
9	Nov 24 - 26	4,200	7	55	57	246
10	Dec 1 - 4	4,200	9	54	49	190
11	Dec 8 - 11	4,200	9	53	38	138
12	Dec 15 - 18	4,200	8	53	53	123
				Totals	1,448	6,306

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

Table 3. Distribution of carcass (adults and grilse) observed during the upper Sacramento River fall-run chinook salmon escapement survey, September- December 1997.

Survey period	Reach 1		Reach 2		Reach 3		Reach 4	
	M[1/]	C[2/]	M	C	M	C	M	C
1	11	0	11	0	7	0	1	0
2	35	12	104	17	42	15	6	0
3	248	11	424	20	244	18	126	12
4	234	11	504	20	239	29	164	17
5	332	27	564	47	345	73	256	18
6	344	64	262	66	288	46	218	48
7	224	84	156	54	160	87	130	32
8	99	82	68	53	26	3	16	6
9	92	35	53	27	49	37	8	2
10	75	28	26	24	44	19	13	10
11	0	84	0	44	0	36	0	12
12	0	83	0	48	0	34	0	11
Total	1,694	521	2,172	420	1,444	397	938	168

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 1997.

Survey period	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	14	69.9	42-105	9	64.4	42-105	5	79. 6	71-88
2	108	82.1	49-105	67	84.0	49-105	41	78.9	65-98
3	238	82.4	54-111	111	85.7	54-111	127	79.5	64-98
4	205	82.4	45-112	86	87.1	45-112	119	79.0	64-94
5	195	80.0	51-108	83	83.5	51-108	112	77.4	59-94
6	135	80.9	51-100	46	84.3	51-100	89	79.1	63-95
7	89	80.9	52-103	29	84.8	52-103	60	79.0	62-95
8	48	80.3	58-101	19	84.6	60-101	29	77.4	58-98
9	52	82.1	53-105	26	83.5	53-105	26	80.7	66-95
10	48	82.0	44-106	22	83.0	44-106	26	81.0	67-92
11	38	84.4	44-109	23	84.2	44-109	15	84.6	71-94
12	49	82.5	55-107	27	82.0	55-107	22	83.2	62-93
Total (mean)	1,219	(81.6)	42-112	548	(84.4)	42-112	671	(79.2)	58-98

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 1997.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Number	22	649	94	454
Mean FL (cm)	63.8	79.7	61.7	89.0
Range FL (cm)	58-66	67-98	42-72	73-112
SD	2.1	6.8	8.0	8.2

Table 6. Age composition (grilse and adult) of carcasses measured during the upper Sacramento River fall-run chinook salmon escapement survey, September - December 1997.

	Adults		Grilse	
Survey period	Number	Percent	Number	Percent
1	8	57	6	43
2	96	89	12	11
3	221	93	17	7
4	195	95	10	5
5	173	89	22	11
6	124	92	11	8
7	84	94	5	6
8	44	92	4	8
9	44	85	8	15
10	41	85	7	15
11	33	87	5	13
12	40	82	9	18
Total(mean)	1,103	(90)	116	(10)

Sex Composition

Males comprised 41% (n = 454) of the fresh adult carcasses examined, while females comprised 59% (n=649)(Table 7). Of the fresh grilse observed, males comprised 81% (n=94) and females comprised 19% (n=22). Females comprised 55% (n=671) of the all fresh carcasses examined and males comprised 45% (n=548).

The female to male ratio for adult spawners was nearly 1.4:1 (649:454) (Table 7 and Figure 10). Females dominated the adult population throughout the survey period; the grilse population was mostly males (Figure 11).

Spawning Success

There were 639 females examined for egg retention (Table 8). Of these, 587 (92%) had completely spawned, 20 (3%) had only partially spawned, and 32 (5%) had not spawned. At least 73% of the females checked per week had completely spawned.

Population Estimates

Fresh carcass data were used to calculate the Schaefer estimate. A total of 981 fresh adult carcasses was tagged and 305 (31%) were subsequently recaptured. Both fresh and decayed carcass data were used to calculate the Jolly-Seber estimate. A total of 5,783 fresh and decayed adult carcasses was tagged, and 1,494 (26%) were subsequently recaptured.

An estimate of 23,572 adult spawners was calculated using the Schaefer model (Tables 9 and 10). Since adults made up 90% of the total escapement based on carcasses measured (Table 6), a total escapement estimate of 26,191 spawners (adults and grilse) was calculated by dividing the adult estimate by 0.9. An adult escapement estimate of 17,555 was calculated using the Jolly-Seber model (Table 11). This estimate was also expanded by dividing by 0.9 resulting in a total escapement estimate of 19,506 spawners.

The 1997 population estimates for salmon spawning in the upper Sacramento River from ACID Dam to Cottonwood Creek are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	26,191	19,506
Adult estimate	23,572	17,555
Grilse estimate	2,619	1,951

The 1997 escapement of 26,191 is considerably less than the 1956 -1997 average of 66,779 for the section of stream from Keswick Dam to RBDD (Table 12 and Figure 12). Since most fall-run chinook salmon spawn between Cottonwood Creek and ACID dam, with very little spawning taking place upstream of ACID dam, the inclusion of the uppermost 3.5 miles of river (ACID dam to Keswick Dam) would have added little to the survey.

Table 7. Sex composition of fall-run chinook salmon grilse and adults carcasses measured during the upper Sacramento River escapement survey, September - December 1997.

Survey period	Adults				Grilse*			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
1	3	38	5	62	6	100	0	0
2	57	59	39	41	10	83	2	17
3	99	45	122	55	12	71	5	29
4	78	40	117	60	8	80	2	20
5	65	38	108	62	18	82	4	18
6	38	31	86	69	8	73	3	17
7	26	31	58	69	3	60	2	40
8	17	39	27	61	2	50	2	50
9	19	43	25	57	7	88	1	12
10	15	37	26	63	7	100	0	0
11	18	55	15	45	5	100	0	0
12	19	48	21	52	8	89	1	11
Total (mean)	454	(41)	649	(59)	94	(81)	22	(19)

C Based on length-frequency distributions, male grilse are defined as $\leq$ 72 cm FL and females grilse as $\leq$ 66 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 1997.

Survey period	No. females measured	No. females checked for egg retention	Number spawned (%)	Number partially spawned (%)	Number unspawned (%)
1	5	5	5(100)	0(0)	0(0)
2	41	41	37(90)	2(5)	2(5)
3	127	124	117(94)	2(2)	5(4)
4	119	113	100(89)	7(6)	6(5)
5	112	110	99(90)	6(5)	5(5)
6	89	86	80(93)	3(3)	3(3)
7	60	55	53(96)	0(0)	2(4)
8	29	27	26(96)	0(0)	1(4)
9	26	25	24(96)	0(0)	1(4)
10	26	20	19(95)	0(0)	1(5)
11	15	11	8(73)	0(0)	3(27)
12	22	22	19(86)	0(0)	3(14)
Total (mean)	671	639	587(92)	20(3)	32(5)

Table 9. Summary of tagging and recapture of fresh adult chinook salmon carcasses by survey period during the upper Sacramento River escapement survey, September - December 1997

Schaefer model capture-recapture data matrix

Period of recovery (j)	Period of tagging$_{(i)}$										Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
	1	2	3	4	5	6	7	8	9	10			
2	1										1	227*	227.00
3	1	16									17	1,071	63.00
4		5	65								70	1,212	17.31
5		1	17	46							64	1,623	25.36
6			6	15	56						77	1,317	17.10
7				4	12	18					34	854	25.12
8					1	4	13				18	327	18.17
9						1	5	3			9	273	30.33
10								2	3		5	208	41.60
11									2	7	9	165	18.33
12										1	1	157	157.00
$R_{(i)}$	2	22	88	65	69	23	18	5	5	8	<- Tagged fish recovered		
$T_{(i)}$	8	65	252	232	185	90	64	28	29	28	<- Total fish tagged		
$T_{(i)}/R_{(i)}$	4.00	2.95	2.86	3.57	2.68	3.91	3.56	5.60	5.80	3.50	<- Ratio		

* Included carcasses observed during Survey period 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 1997.

Population estimate

Period of recovery$_{(j)}$	Period of tagging $_{(i)}$										Totals
	1	2	3	4	5	6	7	8	9	10	
2	908										908
3	252	2,978									3,230
4		256	3,223								3,479
5		75	1,235	4,164							5,473
6			294	916	2,568						3,778
7				359	808	1,769					2,936
8					49	284	840				1,173
9						119	539	510			1,168
10								466	724		1,190
11									213	449	662
12										550	550
Subtotals	1,160	3,309	4,751	5,438	3,425	2,172	1,379	976	937	999	24,545
Tags		-65	-252	-232	-185	-90	-64	-28	-29	-28	-973
										Population estimate -	23,572

Table 11. Summary of tagging and recapture of fresh and decayed adult chinook salmon carcasses by survey period during the upper Sacramento River escapement survey, September - December 1997.

Jolly-Seber capture-recapture data matrix

Period of recovery$_{(j)}$	Period of tagging $_{(i)}$										Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$
	1	2	3	4	5	6	7	8	9	10		
2	4										4	233*
3	2	27									29	1,090
4		11	238								249	1,391
5		1	77	292							370	1,929
6			18	54	301						373	1,613
7				12	52	169					233	1,053
8				1	4	29	78				112	421
9					1	5	22	38			66	330
10							1	6	20		27	230
11									7	18	25	181
12									1	5	6	162
Tags recovered$_{(i)}$	6	39	333	359	358	203	101	44	28	23	<- Tagged fish recovered	
Carcasses Tagged$_{(i)}$	22	169	1,002	1,070	1,405	1,034	590	184	172	135	<- Total fish tagged	

* Includes carcasses examined during Survey period 1.

Table 12. Annual fall--run chinook salmon escapement estimates (adults and grilse) for upper Sacramento River from Keswick Dam to RBDD Diversion Dam, 1956 - 1994. (Data for years prior to 1995 provided by Frank Fisher, DFG, Red Bluff).

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

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FIGURES

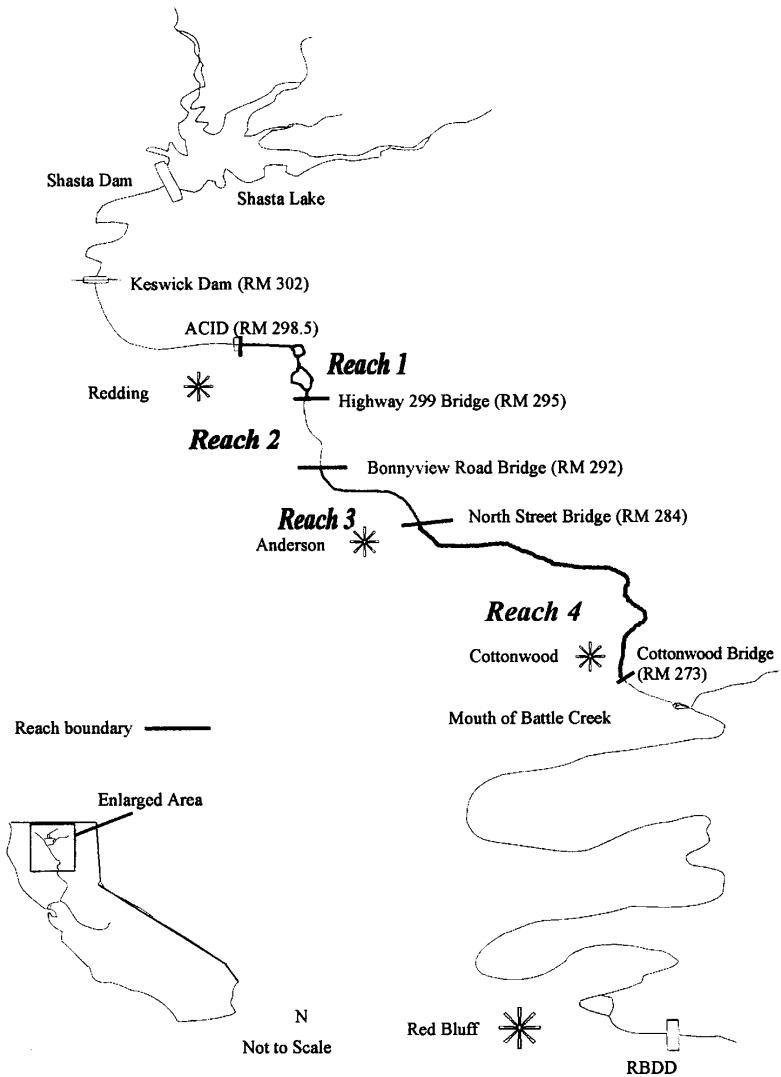

Figure 1. Location of sampling reaches in the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

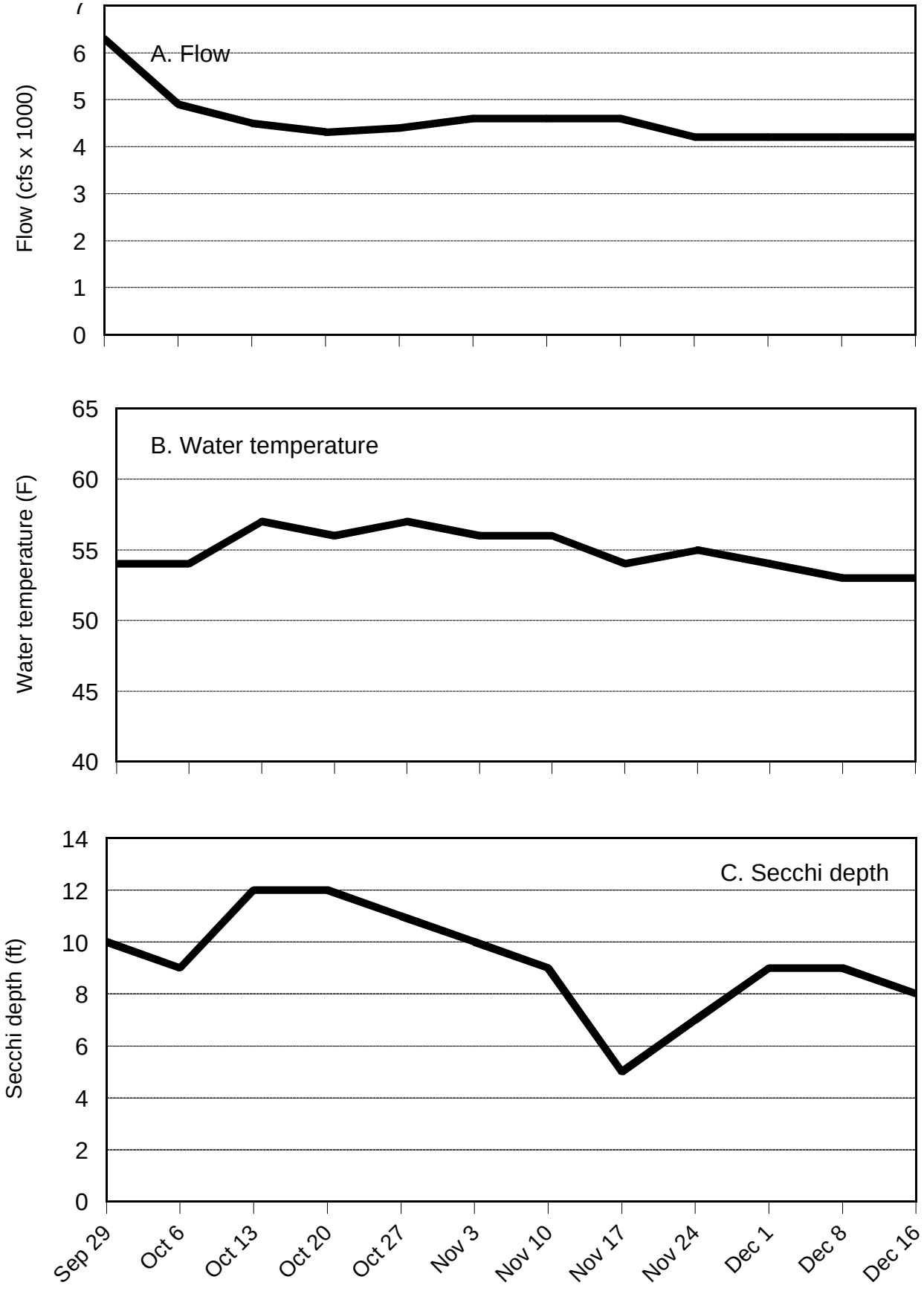

Figure 2. Mean daily flow (A), water temperature (B), and secchi depth (C), measured at Keswick Dam during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

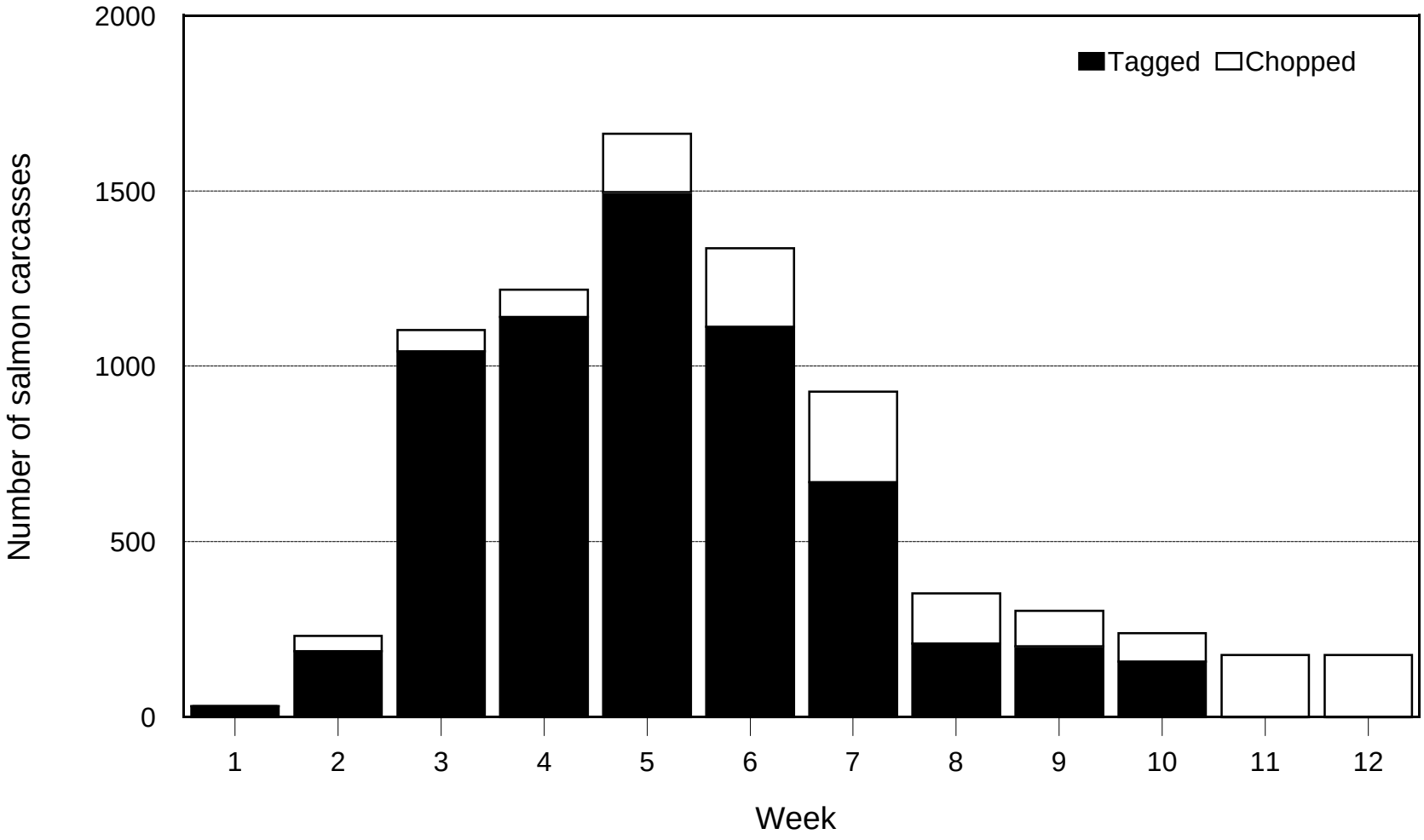

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

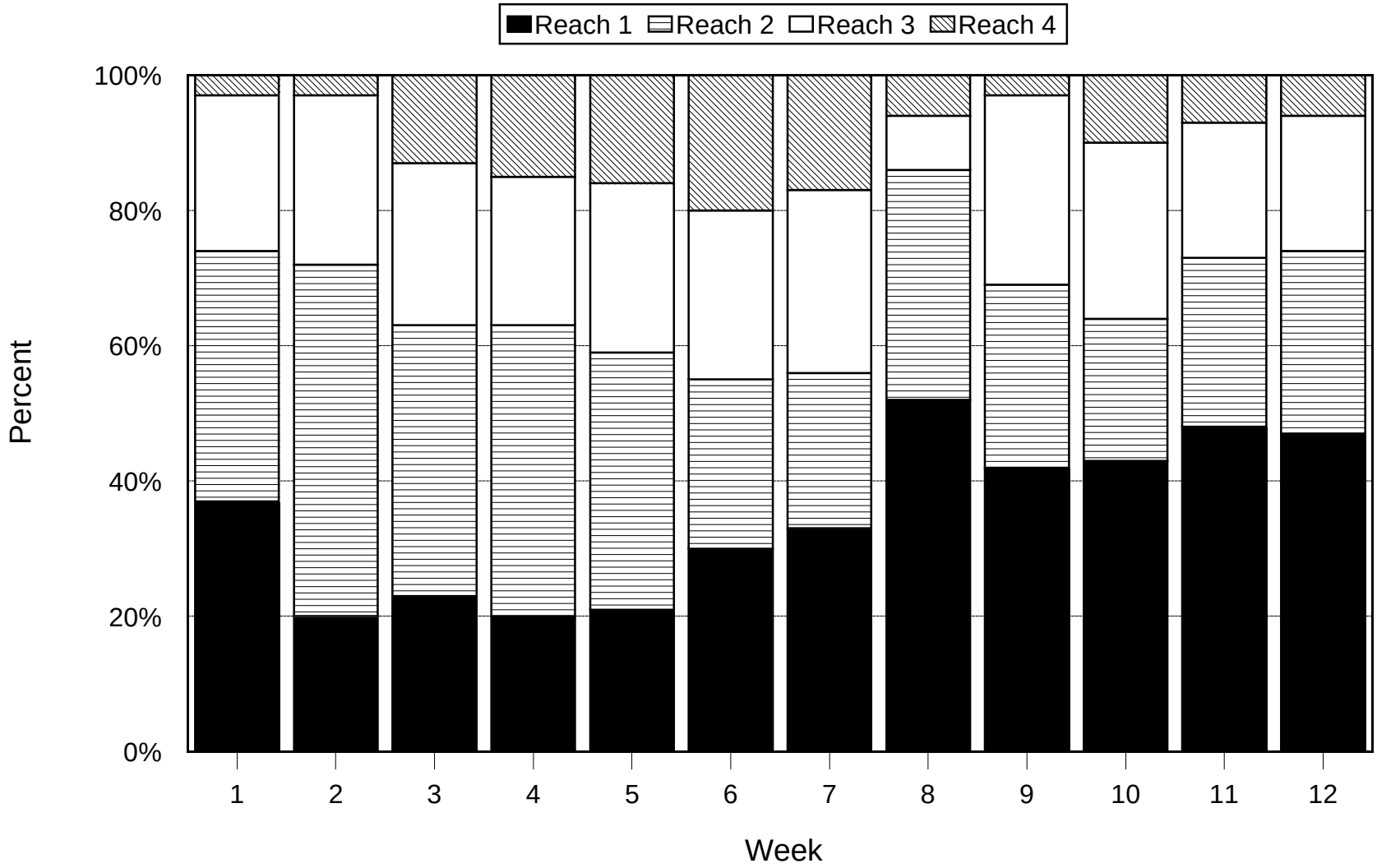

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

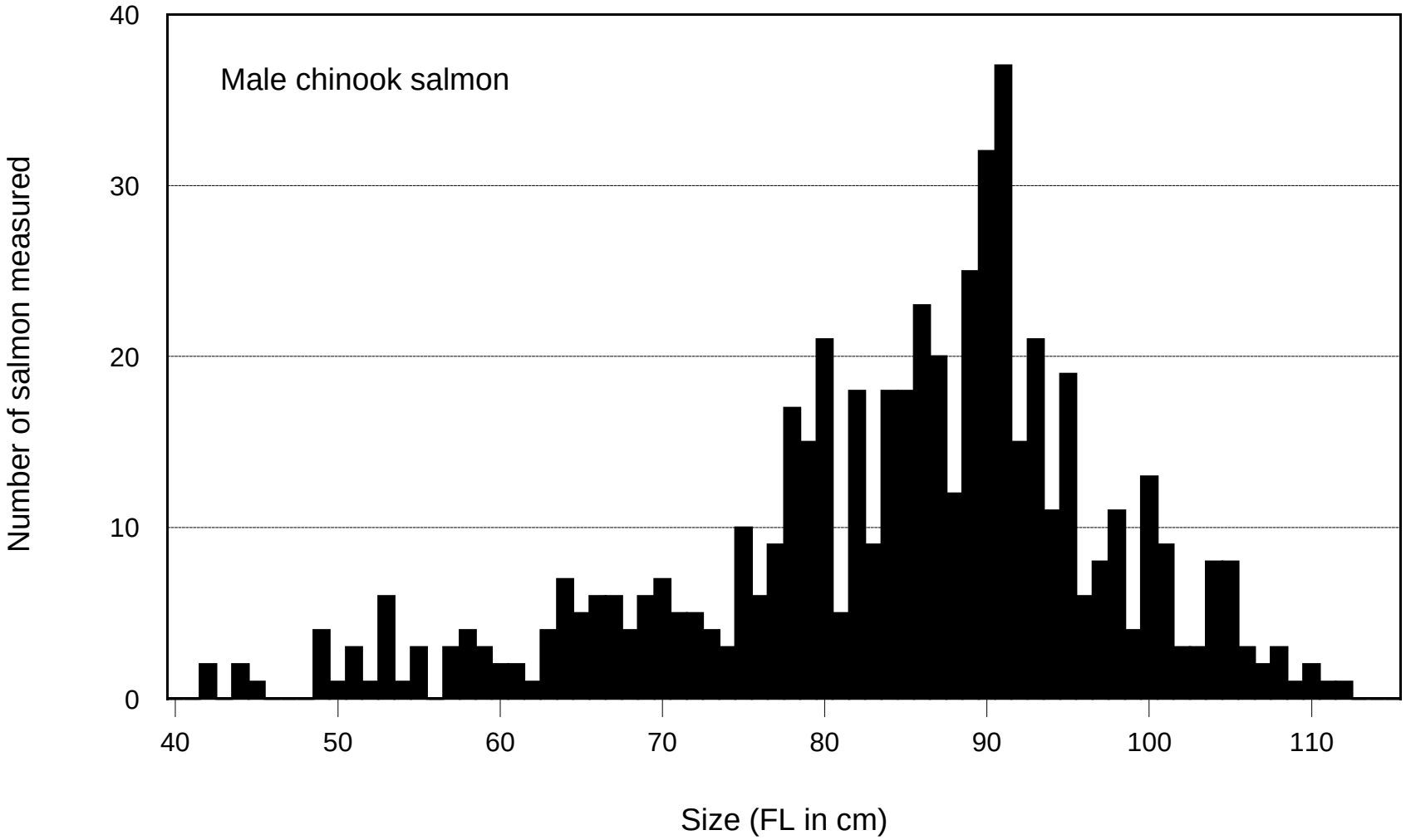

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1997.

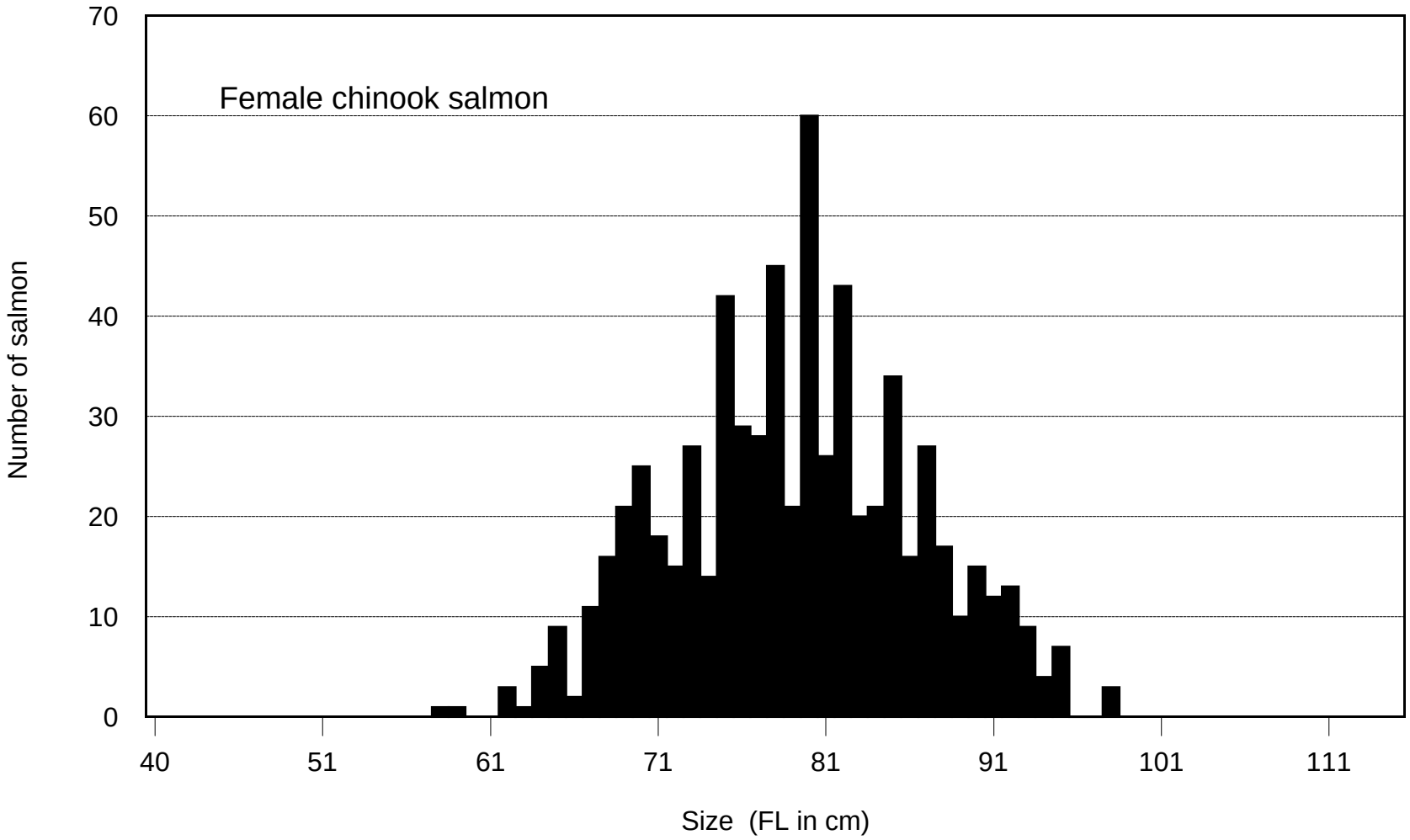

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1997.

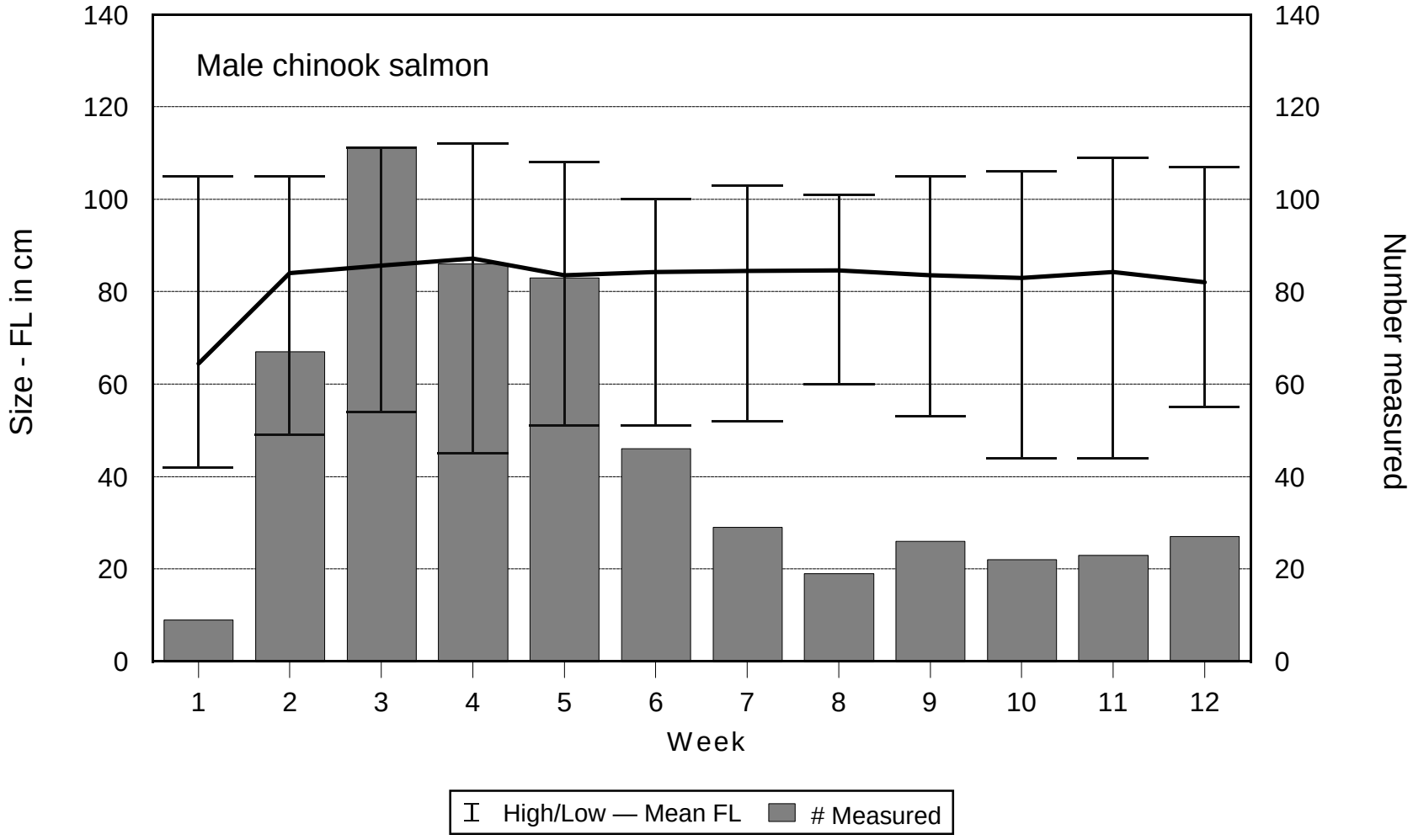

Figure 7. Mean size, size range, and number of male chinook salmon measured weekly during the 1997 upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

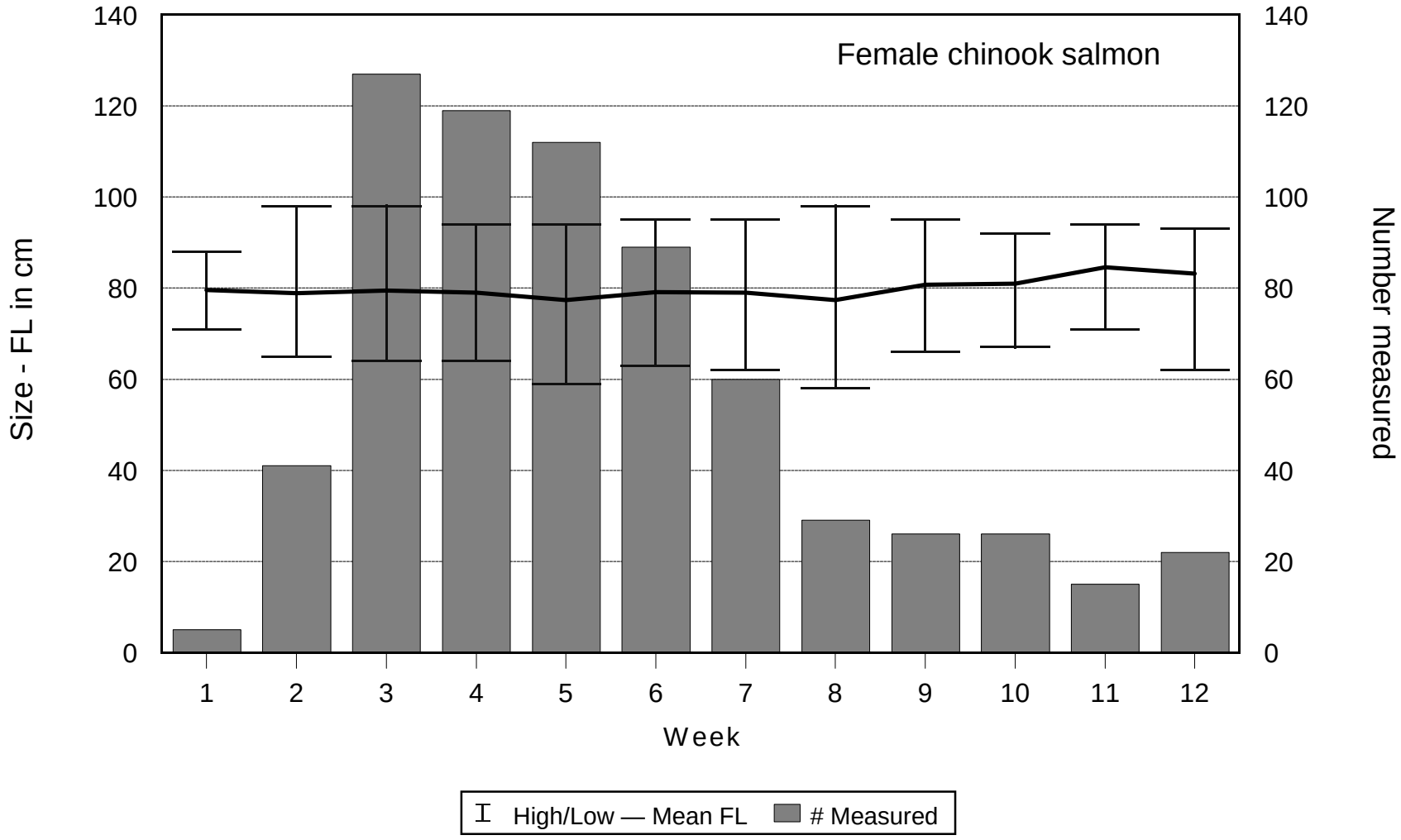

Figure 8. Mean size, size range, and number of female chinook salmon measured weekly during the 1997 upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

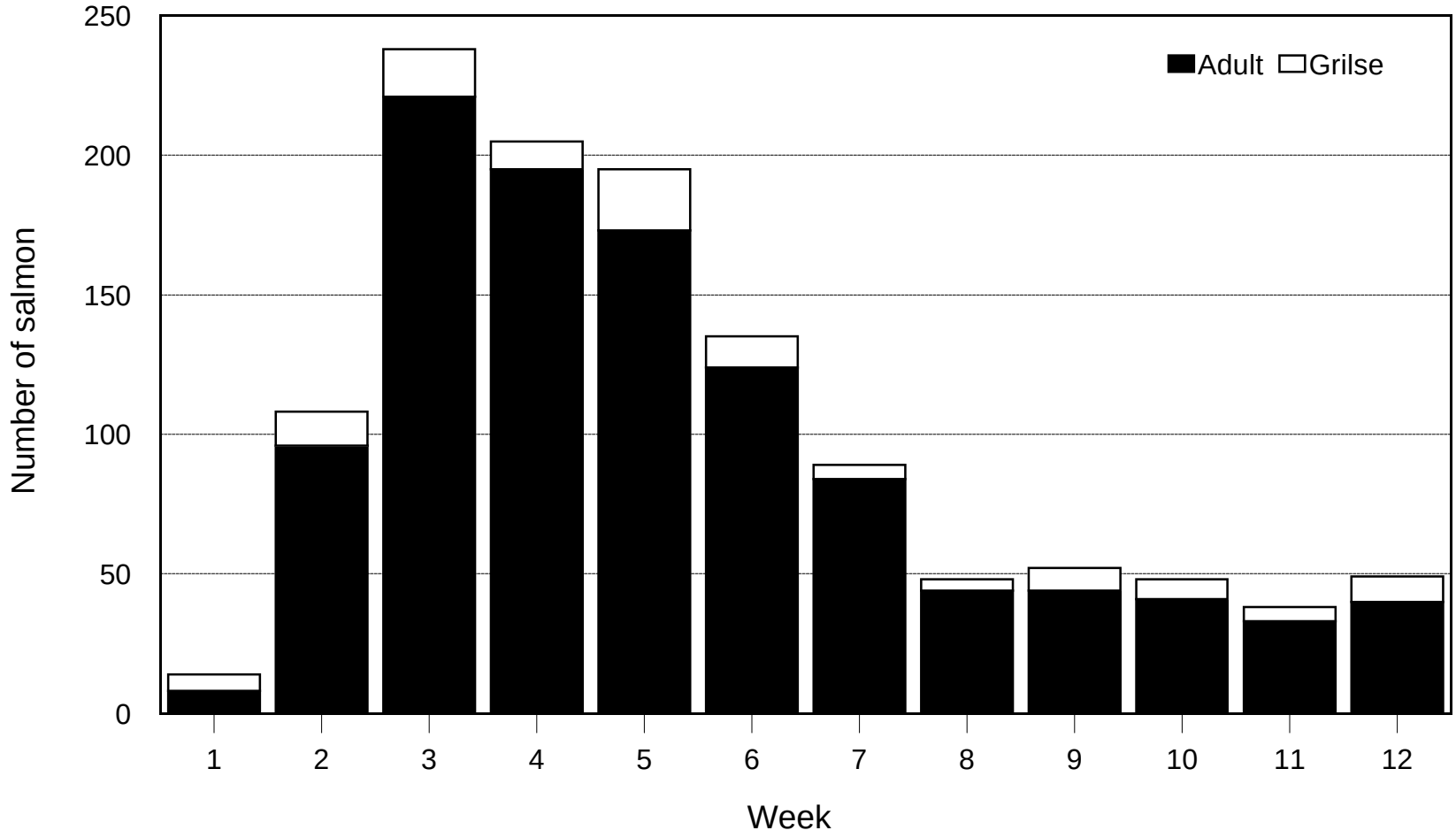

Figure 9. Age compostion of chinook salmon measured during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

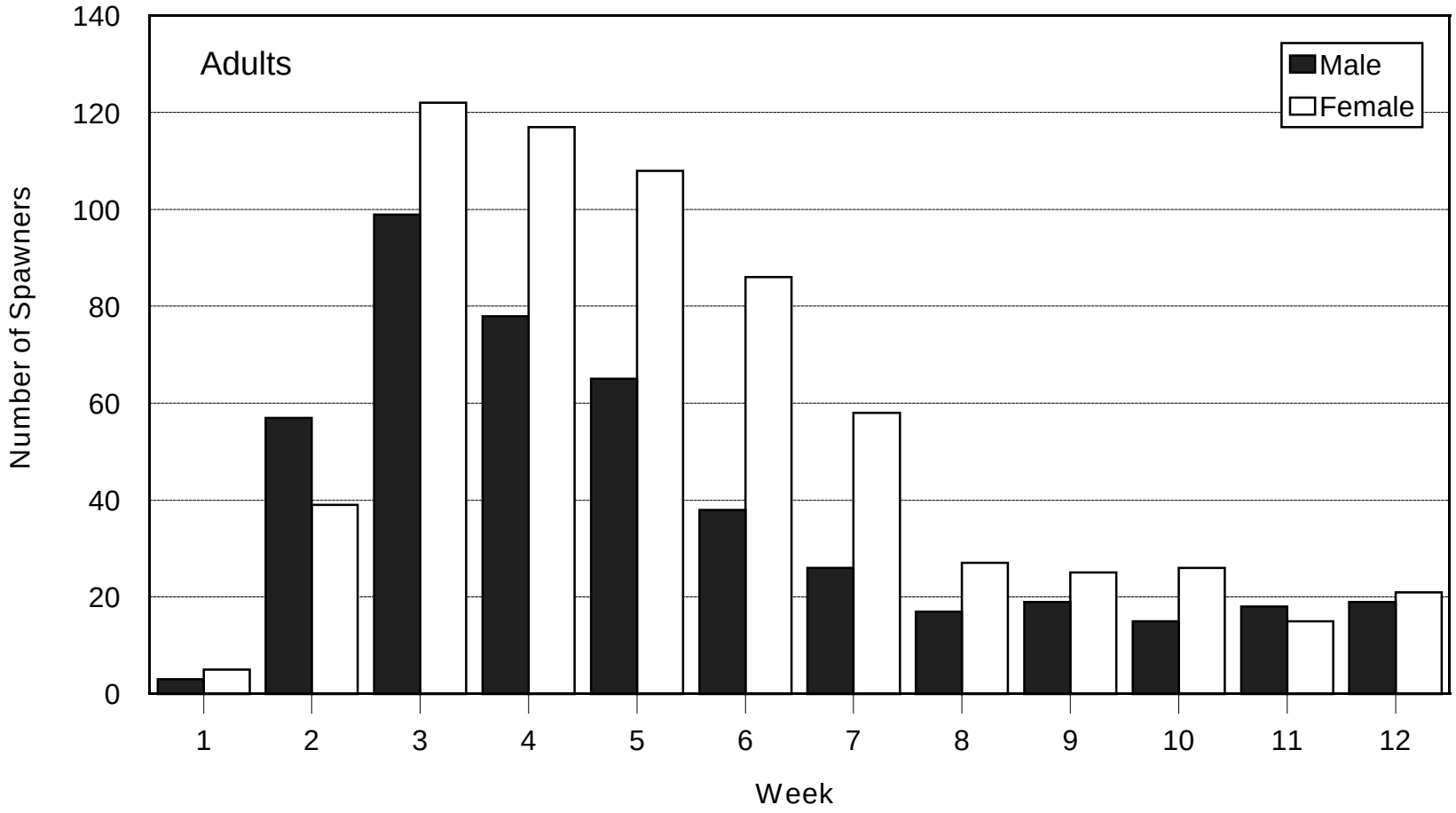

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the 1996 upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1997.

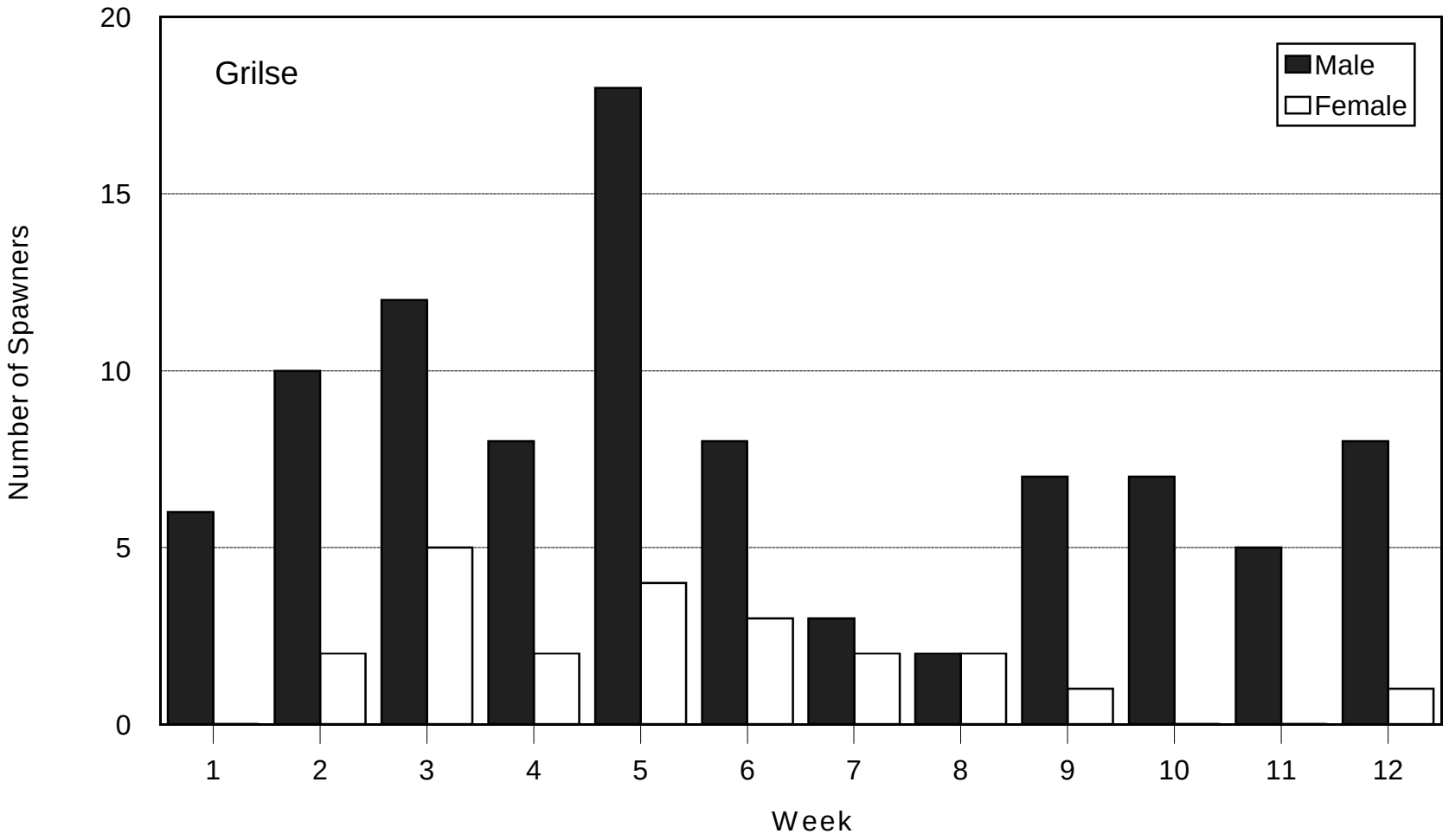

Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1997.

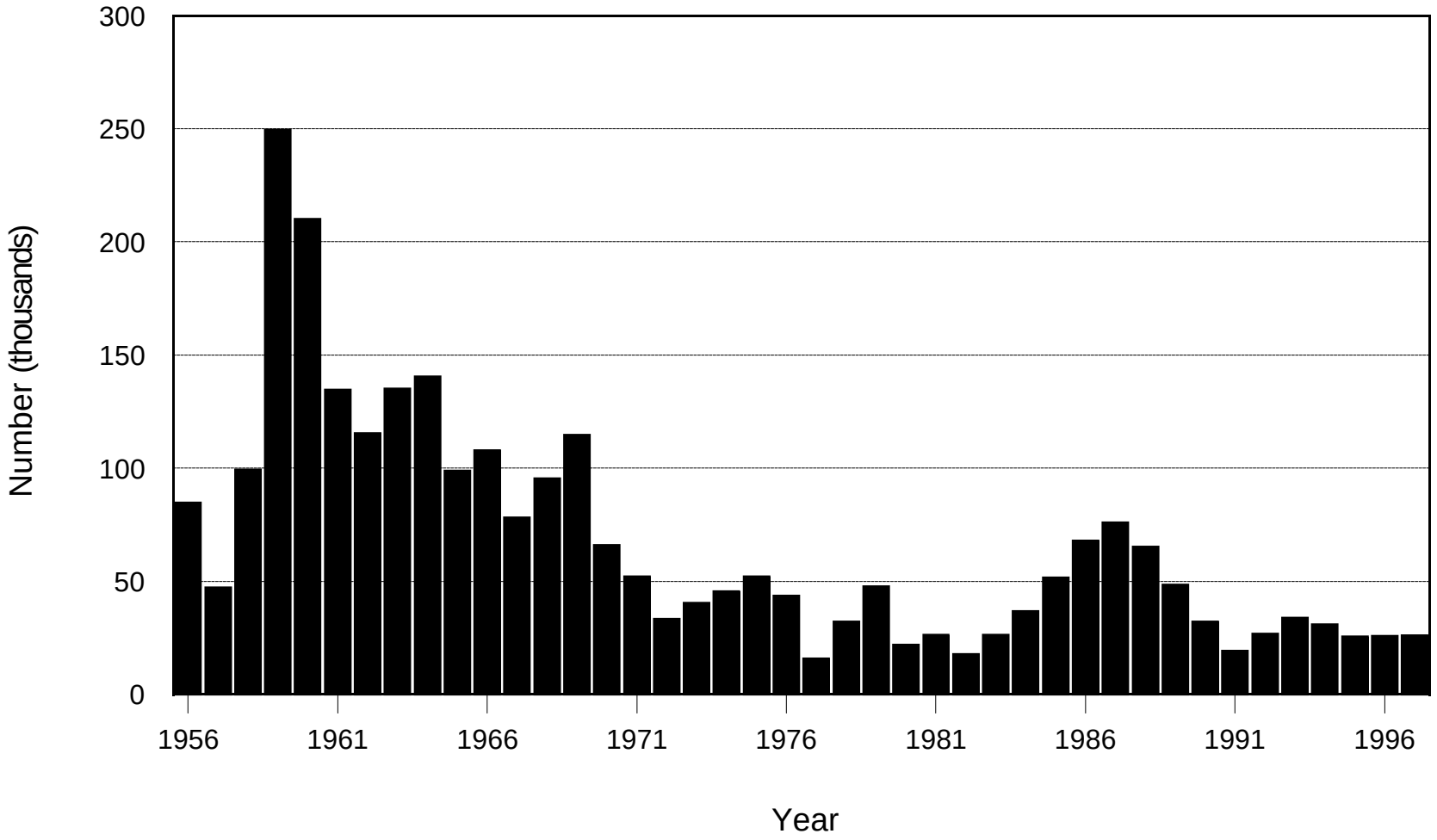

Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1997).