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

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

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

SUMMARY

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

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

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

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

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

INTRODUCTION

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

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

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

Three models have been used by the DFG to estimate escapement using carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1994). It has been used primarily when data are insufficient to allow calculation with the other models. It is occasionally used to calculate estimates for tributary streams with typically small spawner populations (e.g., Cosumnes, Merced, Stanislaus, and Tuolumne rivers). A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. Based on Law's (1994) analysis, the Schaefer model will overestimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed in Central Valley tributaries. Similarly, based on Law's (1994) analysis, the Jolly-Seber model will slightly underestimate Central Valley spawner escapement. This model was first used to estimate escapement in the Central Valley in 1988. The Jolly-Seber model is

more accurate when model assumptions are met and recovery rates are ≥10% (Boydstun 1994, Law 1994). Still, there is considerable disagreement about model use among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by the Jolly-Seber model are too low (Fisher and Meyer, pers. comm.). Law (1994) states that both models could produce low estimates if the basic assumption of equal mixing of tagged carcasses with all carcasses is violated, resulting in the recaptured carcasses constituting a different subpopulation.

Historical Background

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

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

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

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

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

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

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

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

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

Objectives

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

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

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

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

METHODS

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

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

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

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

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

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

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

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

where:

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

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

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

where:

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

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

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

RESULTS AND DISCUSSION

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

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Temporal Distribution

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

Spatial Distribution

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

Size Distribution

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

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

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

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

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

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

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

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

1/ Number of carcasses tagged.

2/ Number of untagged carcasses chopped.

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

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

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

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

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

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

Sex Composition

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

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

Spawning Success

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

Population Estimates

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

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

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

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

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

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

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

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

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

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

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

Schaefer model capture-recapture data matrix

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

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

Population estimate

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

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

Jolly-Seber capture-recapture data matrix

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

* Includes carcasses observed during first week of tagging

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

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

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LITERATURE CITED

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

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

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

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

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

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

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

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

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

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

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

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

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

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

FIGURES

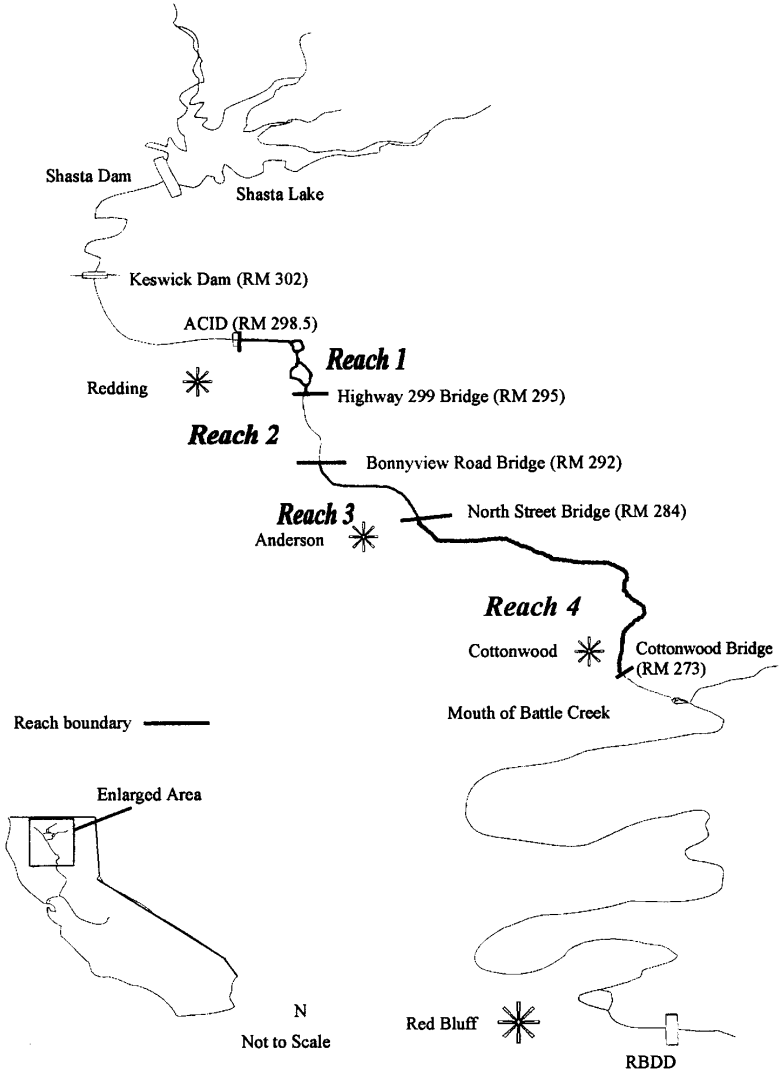

Figure 1. Upper Sacramento River fall-run chinook salmon escapement study location including reach designations, September - December, 1996.

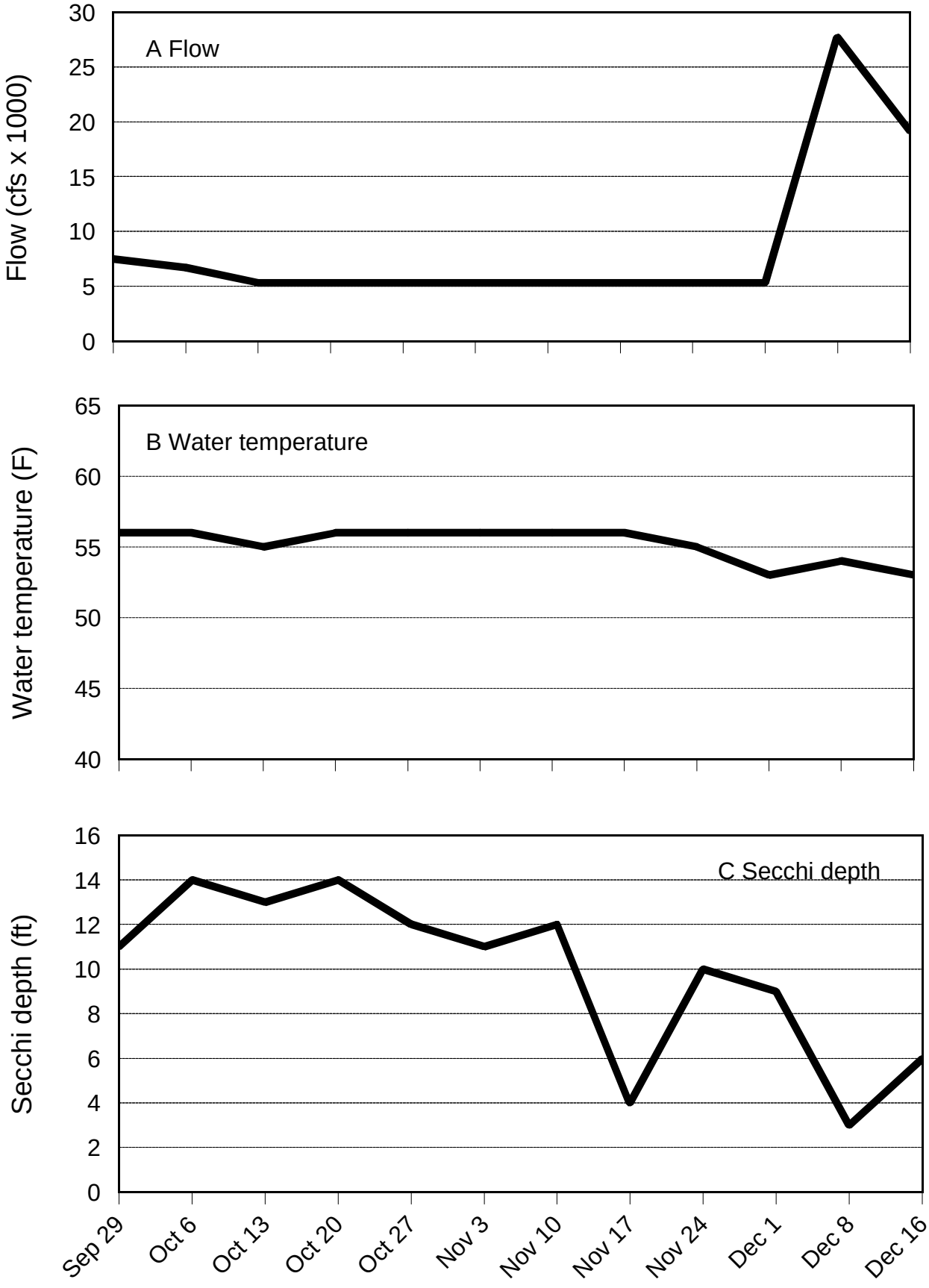

Figure 2. Mean daily flow (A) measured at Keswick Dam, water temperature (B) and secchi depth (C) during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1996.

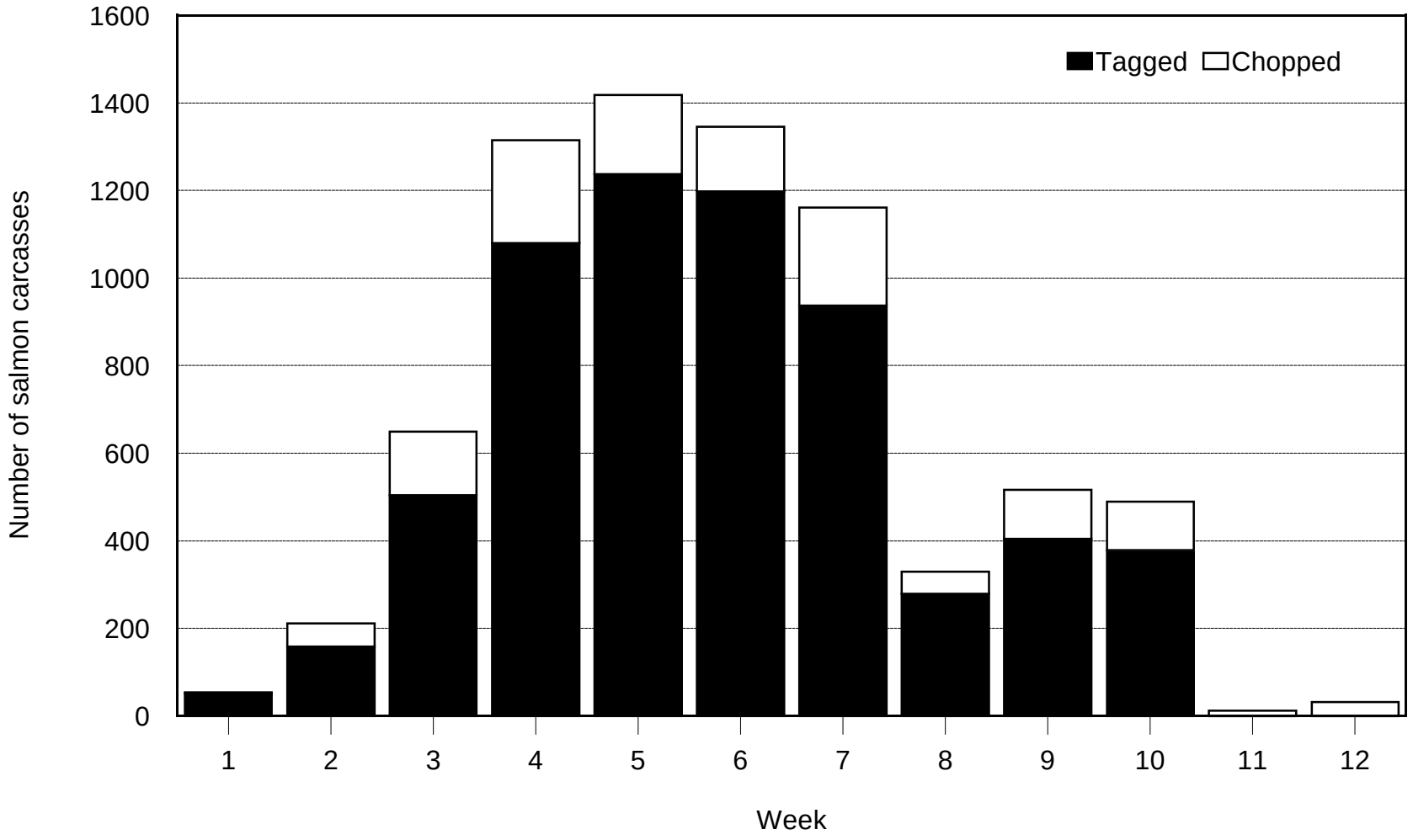

Figure 3. Weekly distribution of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1996.

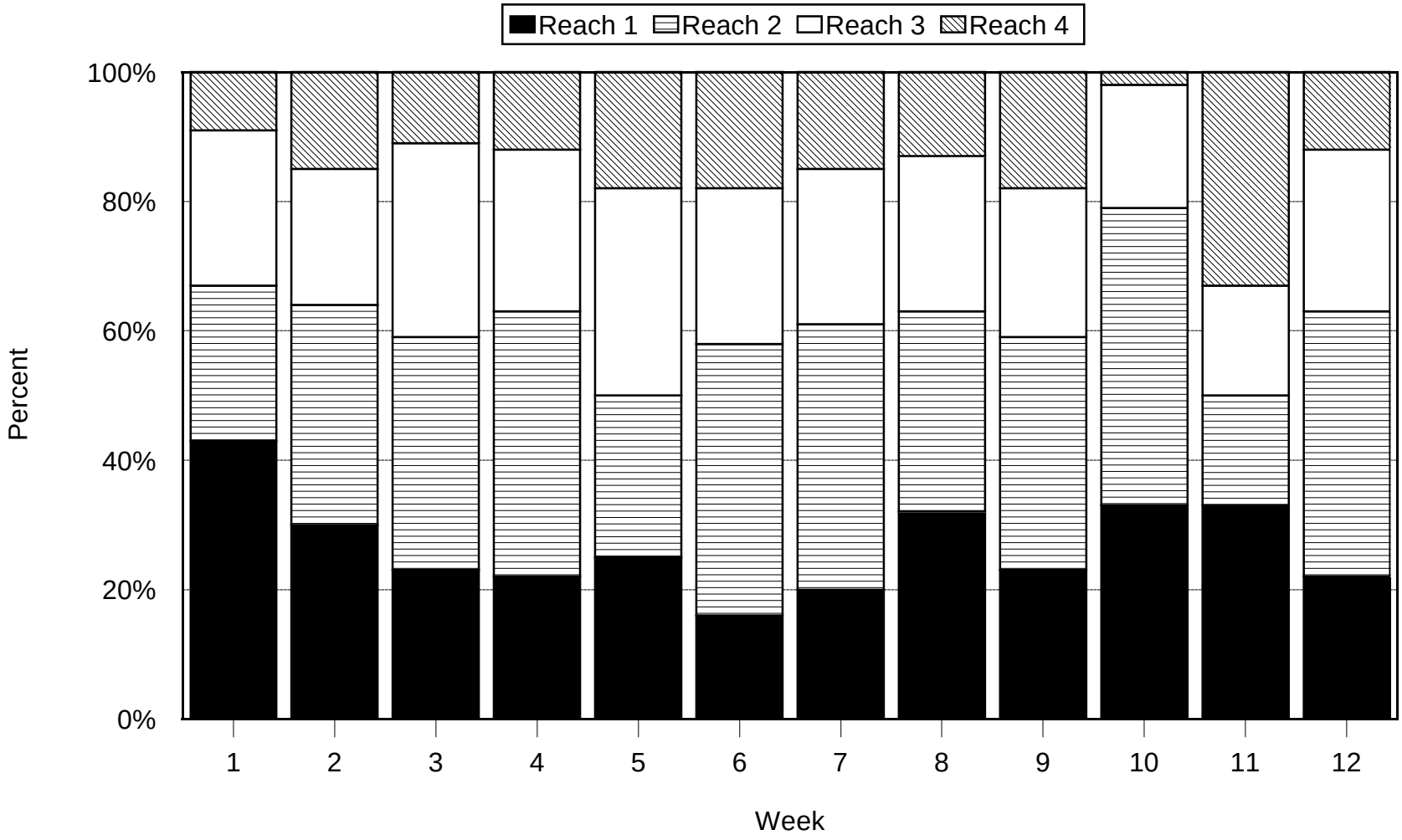

Figure 4. Weekly distribution (%) by reach of both fresh and decayed carcasses observed during the upper Sacramento River fall-run chinook salmon spawner escapement survey, September - December 1996.

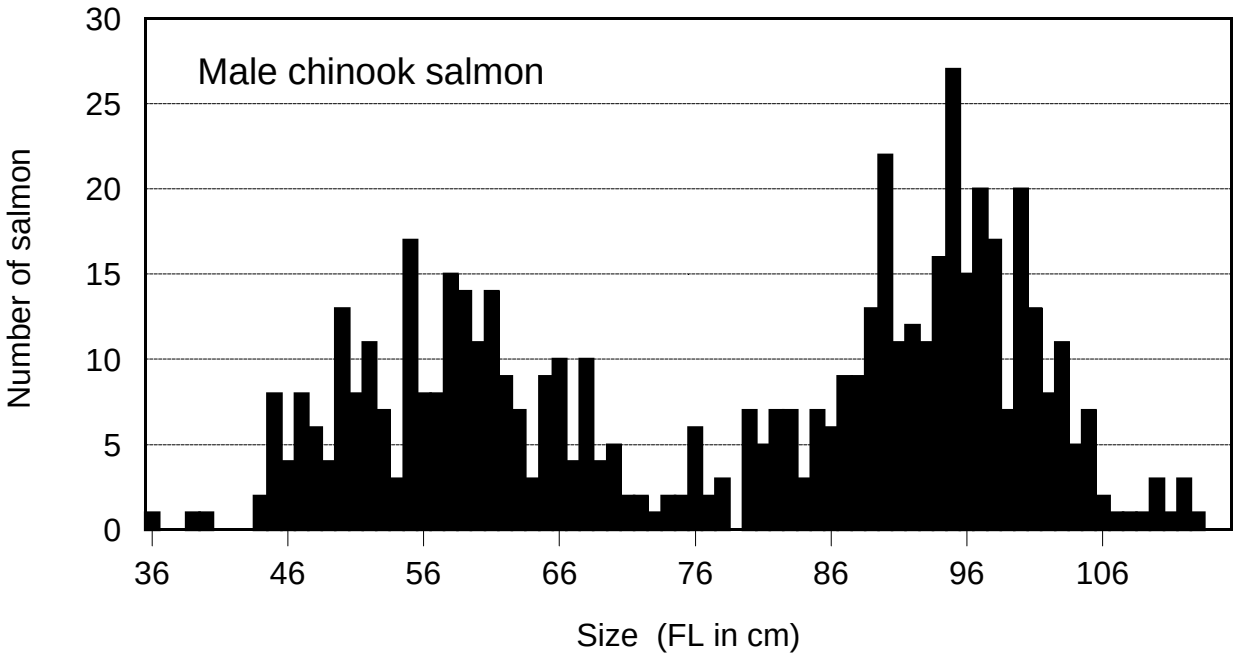

Figure 5. Size (FL in cm) distribution of male chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1996.

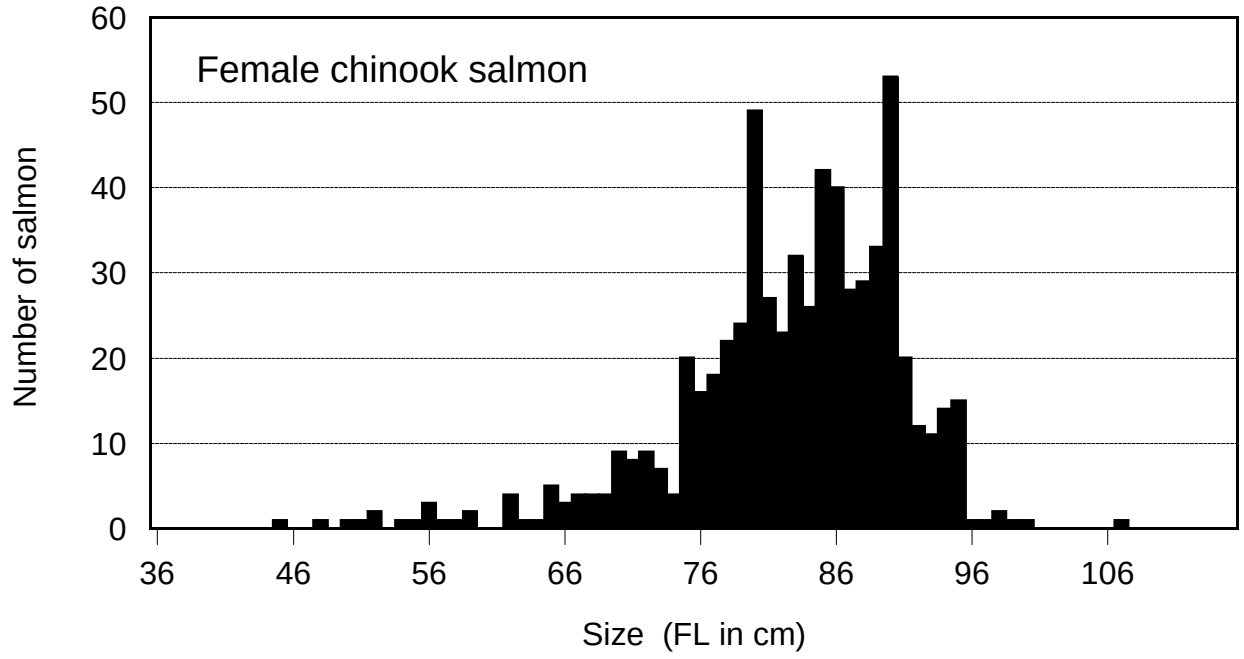

Figure 6. Size (FL in cm) distribution of female chinook salmon carcasses measured during the upper Sacramento River fall-run spawner escapement survey, September - December 1996.

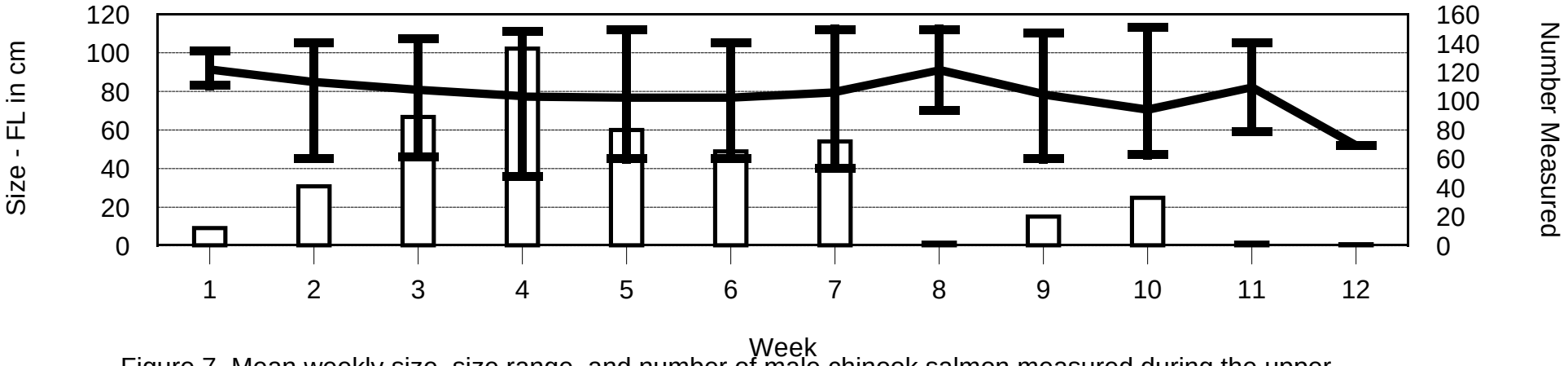

Figure 7. Mean weekly size, size range, and number of male chinook salmon measured during the upper Sacramento River spawner escapement survey, September - December 1996.

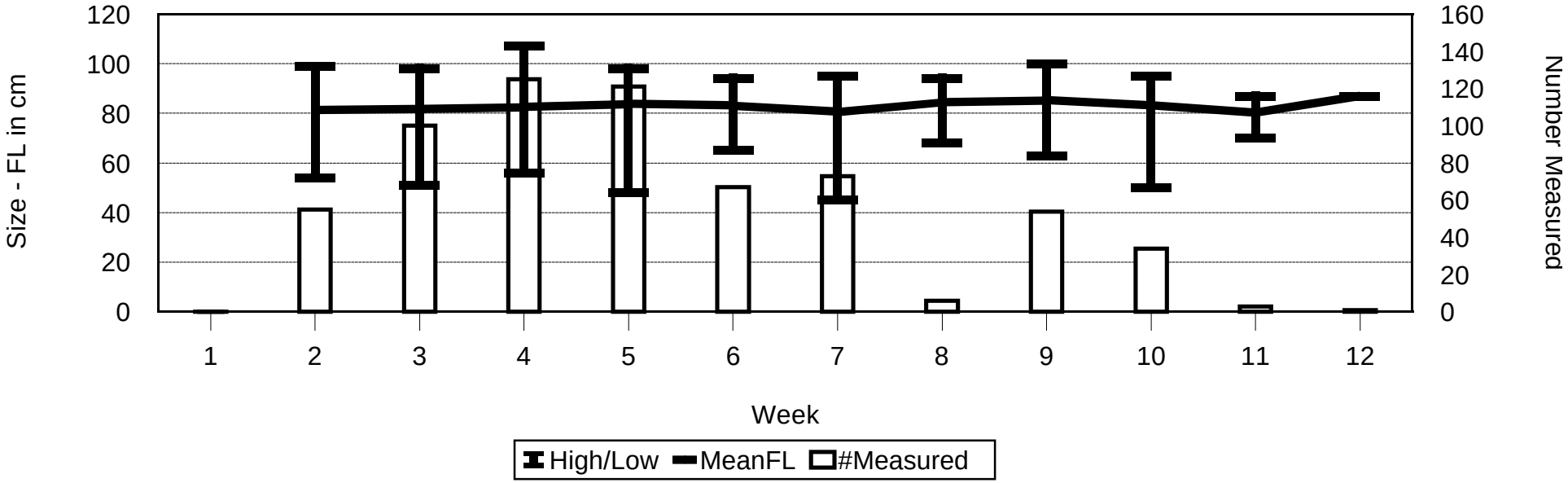

Figure 8. Mean weekly size, size range, and number of female chinook salmon measured during the upper Sacramento River spawner escapement survey, September - December 1996.

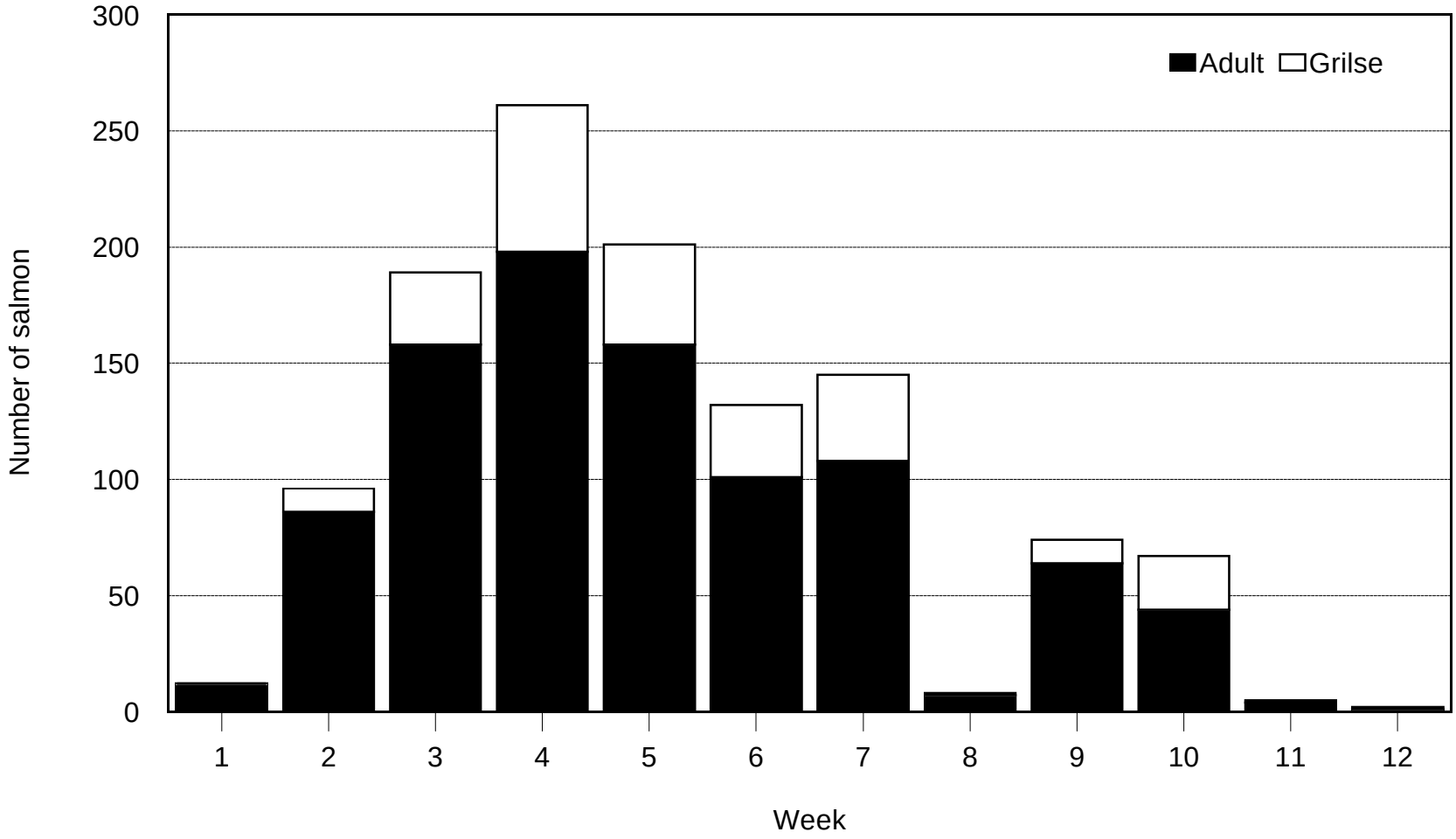

Figure 9. Age compostion of chinook salmon measured during the upper Sacramento River chinook salmon spawner escapement survey, September - December 1996.

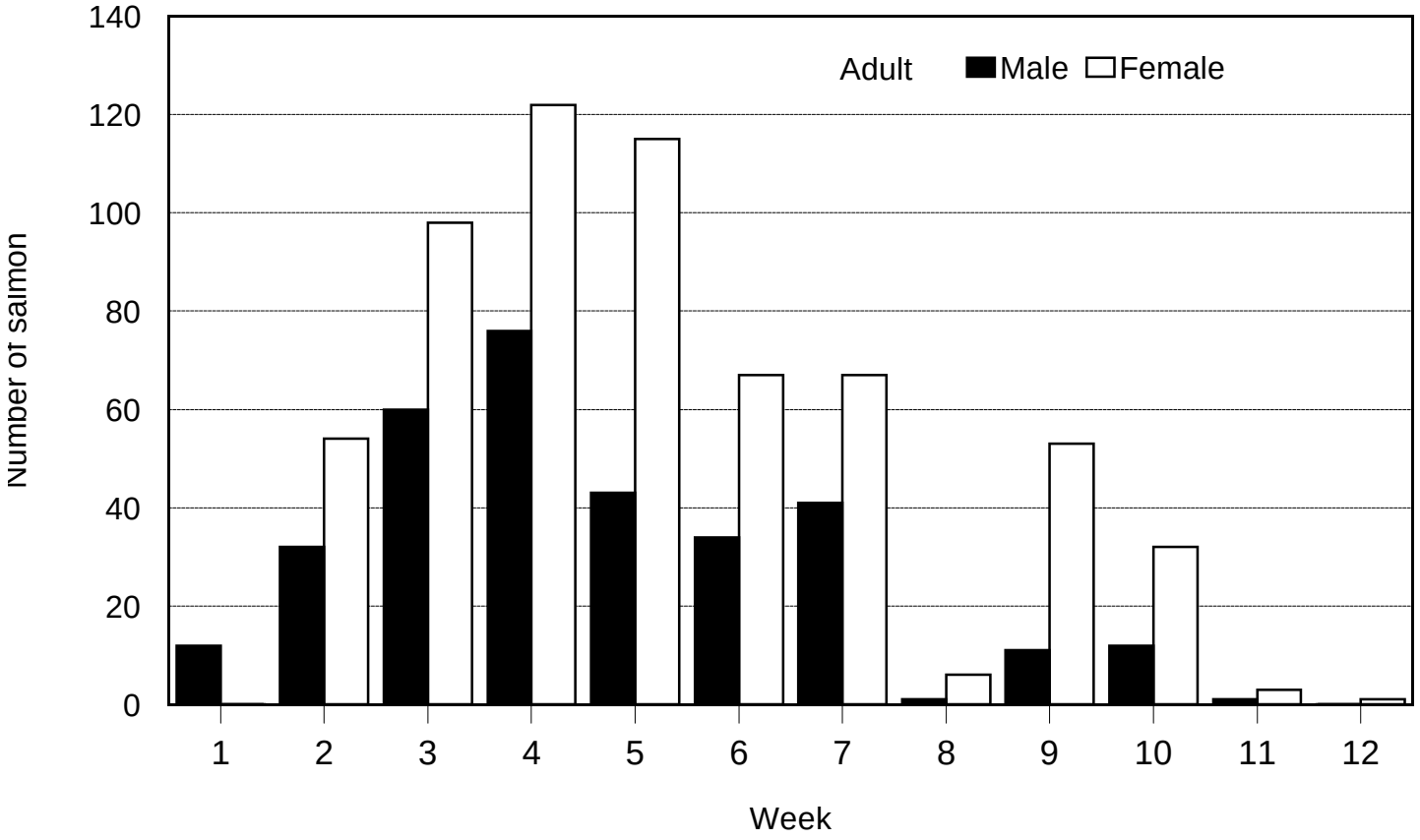

Figure 10. Weekly distribution of the sex of adult-sized chinook salmon measured during the upper Sacramento River chinook salmon spawner escapement survey, September - December 1996.

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

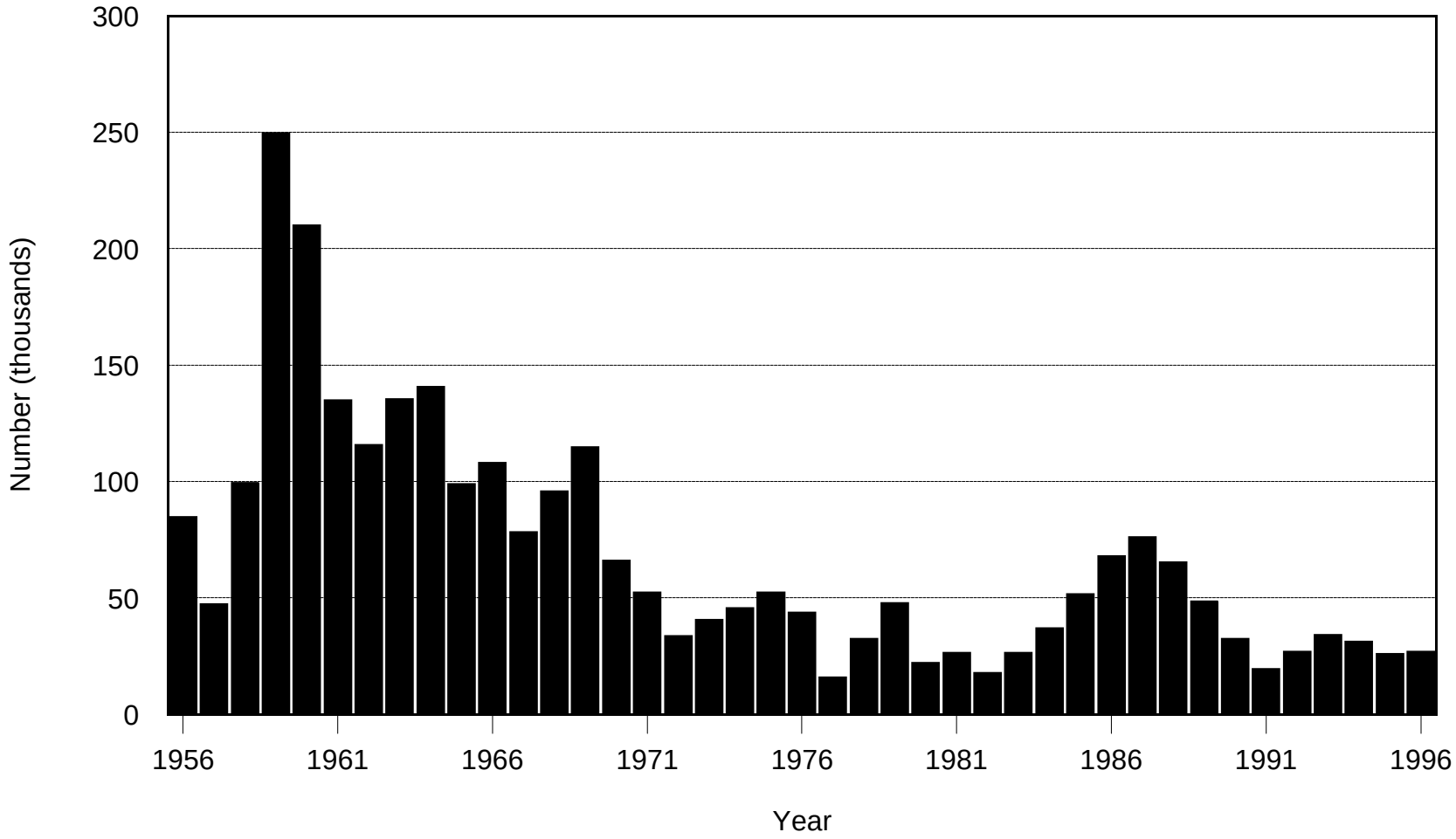

Figure 12. Summary of chinook salmon escapement (adults and grilse) in the mainstem Sacramento River from Keswick Dam downstream to Red Bluff Diversion Dam excluding tributaries (1956 - 1996).