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

Lower American River
Chinook Salmon Escapement Survey
October 1995 - January 1996

Prepared by

Bill Snider
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Stream Evaluation Program
Technical Report No. 96-4
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2/ Stream Evaluation Program Technical Report No. 96-4

INTRODUCTION

An intensive fall-run chinook salmon escapement survey was conducted on the lower American River during the fall-winter of 1995 to estimate spawner abundance and distribution. This was the forth consecutive year that the Technical Advisory Committee (TAC) established by the Alameda County Superior Court was intimately involved with the escapement survey (Snider *et al*. 1993, Snider *et al*. 1995, and Snider and Bandner 1996). The primary charge of the TAC - to improve understanding of the relationships between salmon and habitat in the lower American River - requires reliable estimates of the spawner population to help distinguish habitat versus population influences on the temporal and longitudinal spawning distribution (Snider and McEwan 1992, Snider *et al*. 1993, and 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 concurrent with redd surveys should allow 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.

Since the early 1970's, tag-and-recapture data have been collected during the spawner surveys to estimate escapements to several Central Valley tributary streams, including the American River. Three models have been used by the Department of Fish and Game to estimate escapement: Petersen (Ricker 1975), Schaefer (1951) and the Jolly-Seber (Seber 1982). The Petersen model is the most simple but least accurate (Law 1992). It has been used primarily when data are insufficient to allow calculation with other models. It is occasionally used to calculate estimates for smaller tributary streams (e.g. Cosumnes, Merced, Stanislaus, and Tuolumne rivers), and was used to calculate the 1984 American River estimate. A modification of the Schaefer model has been used in "larger" Central Valley tributary streams since 1973 (Taylor 1974). This model has been used to estimate the lower American River escapement starting in 1976. Based on Law's analysis (Law 1992), the Schaefer model will over estimate escapement when carcass "survival" (carry-over from week-to-week) and recovery rates are equivalent to those typically observed on the American River. Similarly, based on Law's (1992) analysis, the Jolly-Seber model will slightly under estimate the lower American River escapement. The Jolly-Seber model is more accurate when model assumptions are meet and recovery rates are $\geq$ 10% (Boydstun 1992 and Law 1992). Still, there is considerable disagreement among fisheries managers responsible for estimating spawner escapement for California streams. They believe that population estimates obtained by this model are too low (Fisher and Meyer, pers. comm.). Law (1992) states the 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.

Objectives

- To estimate the 1995, in-river, fall-run chinook salmon spawning population for the lower American River.

- To continue to examine the Jolly-Seber and Schaefer population models and recommend future escapement estimation procedures.

- 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 lower American River.

METHODS

Lower American River carcass surveys annually begin once spawning activity is observed. In 1995, surveys were conducted from October 23, 1995 through January 5, 1996. The 14-mile-long stream segment from Sailor Bar (river mile 22) downstream to Watt Avenue (river mile 9) was surveyed weekly (Figure 1). This stream segment was further divided into three reaches (Table 1). Surveys were made on Monday, Tuesday, and Wednesday with Thursday surveys if needed. A subsample of "fresh" carcasses was measured and the females were examined to determine the degree of spawning (egg retention).

Since 1988, tag-recapture methods were conducted to provide estimates using both the Schaefer and Jolly-Seber models; separate records were kept for the tag and recapture of fresh and decayed carcasses. The standard Schaefer model protocol was to tag only fresh carcasses. When the Jolly-Seber model was initiated in 1988, the standard protocol was to tag both fresh and decayed carcasses. Fresh carcass data were used to calculate an estimate using the Schaefer model. The combined fresh and decayed carcass data were used to calculate an estimate using the Jolly-Seber model. Estimates derived from the Schaefer model are more directly comparable to previous year's estimates, and therefore provide a consistent indication of population trends. Law's analysis showed that the Schaefer model was most accurate when using fresh carcass data. The Jolly-Seber model was most accurate when using combined fresh and decayed carcass data.

To determine freshness, all carcasses were examined for eye clarity and gill color. A carcass was considered "fresh" if either one eye was clear or the gills were pink, otherwise it was considered "decayed". Fresh and decayed carcasses were distinctly marked: fresh carcasses were tagged in the upper jaw and decayed carcasses in the lower jaw. Tagged carcasses were recorded as adult or grilse and fresh or decayed, then returned to flowing water near the location where they were collected. Untagged carcasses were recorded in the same manner, then chopped through the backbone to remove them from future surveys.

Table 1. Location of survey reaches in the lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

Reach	Location	River mile
1	Sailor Bar to Rossmoor	22.0 to 18.0
2	Rossmoor to Goethe Park Footbridge	18.0 to 14.5
3	Goethe Park Footbridge to Watt Avenue	14.5 to 9.0

Data collected from a subsample of the fresh carcasses included fork length (FL) in centimeters, reach of 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 more than 50% of the eggs remained; and unspent if they were unspawned.

RESULTS AND DISCUSSION

A total of 1,980 fresh carcasses and 19,264 decayed carcasses (adults and grilse) was observed (Table 2). Water clarity ranged from 12.7 feet in late October to 2.5 feet in late December. Flow was a 2,500 cfs throughout the survey period. Temperature ranged from 64^{o}F during the first survey week to 51^{o}F during the last week.

Temporal Distribution

The number of observed carcasses steadily increased from the first week, peaked in the sixth week (November 27-30), and then declined each week afterwards (Table 3 and Figure 2). Few carcasses were observed during the first two weeks or the last week of the survey. Fresh carcasses were observed during every week of the survey.

Spatial Distribution

Most carcasses were observed in Reach 1 (61% of all carcasses and 75% of the fresh carcasses) (Table 3 and Figure 3). At least 69% of fresh carcasses were observed in Reach 1 during all weeks except for the last week of the survey when only one fresh carcass (observed in Reach 2) was seen (Figure 4). Estimates of spawning distribution were affected by the following factors: i) no surveys were conducted in Reach 3 during weeks 4 and 5 which slightly inflated the estimates of the portion of the population spawning in the upper two reaches, and ii) an unknown portion of the carcasses observed in the lower reaches likely drifted downstream after spawning in an upstream reach deflating the estimate for Reach 1.

Table 2. General survey information for the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

Week	Dates	Flow (cfs)	Secchi depth (ft)[1/]	Water temperature (°F)[1/]	Carcass count[2/]	
					Fresh	Decayed
1	Oct 23-25, 1995	2,500	12.7	64	16	60
2	Oct 30-Nov 1, 1995	2,500	10.0	63	73	152
3	Nov 6-8, 1995	2,500	9.0	61	175	526
4	Nov 13-15, 1995	2,500	8.5	59	410	2,119
5	Nov 20-22, 1995	2,500	9.3	60	439	4,344
6	Nov 27-30, 1995	2,500	9.3	59	457	5,610
7	Dec 4-7, 1995	2,500	8.4	59	270	3,733
8	Dec 11-15, 1995	2,500	7.0	57	89	1,665
9	Dec 18-20, 1995	2,500	2.5	54	41	748
10	Dec 27-29, 1995	2,500	4.0	52	9	224
11	Jan 3-5, 1996	2,500	4.7	51	1	83
				Totals	1,980	19,264

1/ Average of measurements made from days surveys were made.
2/ Includes grilse and adults.

Table 3. Summary of fall-run chinook salmon carcass distribution during the 1995 lower American River spawner escapement survey (includes adults and grilse but not tag recoveries), October 1995 - January 1996.

Week	Reach 1				Reach 2				Reach 3			
	Fresh		Decayed		Fresh		Decayed		Fresh		Decayed	
	M[1/]	C[2/]	M[1/]	C[2/]	M[1/]	C[2/]	M[1/]	C[2/]	M[1/]	C[2/]	M[1/]	C[2/]
1	13	0	28	17	1	2	8	0	0	0	3	4
2	53	0	64	20	15	0	47	9	5	0	7	5
3	129	0	225	116	41	0	102	43	5	0	10	30
4	274	0	172	1,077	115	21	103	767	3/	3/	3/	3/
5	334	0	448	2,303	105	0	241	1,352	3/	3/	3/	3/
6	334	0	452	2,577	114	0	251	1,618	9	0	21	691
7	217	0	346	2,017	41	0	163	752	12	0	34	421
8	79	0	243	642	9	0	92	447	1	0	20	221
9	35	0	92	387	6	0	29	106	0	0	17	117
10	0	9	0	123	0	0	0	58	0	0	0	43
11	0	0	0	56	0	1	0	15	0	0	0	12
Totals	1,468	9	2,070	9,335	447	24	1,036	5,167	32[4/]	0[4/]	112[4/]	1,544[4/]

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

Size Distribution

A total of 1,104 carcasses was measured (Table 4). The sample mean FL was 81.0 cm. Size ranged from 48 to 112 cm FL. Male salmon averaged 82.7 cm FL (range: 48 - 112 cm FL). Female salmon averaged 78.4 cm FL (range: 55 - 99 cm FL).

Length frequency distributions were used to define a general size criterion distinguishing grilse (2-year old salmon) and adult (>2-year old salmon) for both sexes (Figures 5 and 6). Male grilse (n=97) were defined as salmon $\leq$ 70 cm FL; female grilse (n=16) were $\leq$ 65 cm FL (Table 5). Male grilse averaged 60.9 cm FL (range: 48 - 70 cm FL, SD=5.5); male adults (n=506) averaged 86.8 cm FL (range: 71 - 112 cm FL, SD=7.0). Female grilse averaged 60.8 cm FL (range: 55 - 65 cm FL, SD=3.0) ; female adults (n=485) averaged 79.0 FL (range: 66 - 99 cm FL, SD=5.6).

Mean weekly size for females ranged from 70.1 to 79.9 cm FL (Table 4 and Figure 7). The mean weekly size for males ranged from 70.0 to 102.0 cm FL, but it only ranged from 75.1 to 86.9 cm FL for the first 9 weeks when over 99% of the males carcasses were measured (Figure 8).

Grilse comprised 10% (113) of the 1,104 measured carcasses (Table 6). The greatest number of grilse (25) was observed in the third week (November 6-8) (Figure 9). Both male and female grilse were observed throughout most of the survey.

Table 4. Size and sex statistics for fresh fall-run chinook salmon carcasses measured during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

	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	13	74.1	50-90	10	75.1	50-91	3	70.1	62-85
2	80	78.9	50-95	52	79.1	50-95	28	77.4	70-88
3	162	80.0	48-101	101	80.6	48-101	61	79.0	62-89
4	130	80.5	56-109	76	82.6	58-109	54	77.5	56-99
5	191	81.0	53-112	105	83.3	53-112	86	78.3	55-91
6	248	81.1	55-108	124	84.3	55-108	124	77.9	60-96
7	156	82.8	48-110	75	86.9	48-110	81	79.8	66-96
8	74	80.2	55-102	37	82.9	55-102	37	77.4	58-89
9	40	79.5	55-108	19	79.1	56-108	21	79.9	55-99
10	9	74.6	56-87	3	70.0	56-87	6	76.8	63-86
11	1	102.0	-	1	102.0	-	0	-	-
Totals	1,104	81.0	48-112	603	82.7	48-112	501	78.4	55-99

Table 5. Summary of adult and grilse size and numbers by sex for fall-run chinook salmon carcasses measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

	Female		Male	
	Grilse	Adults	Grilse	Adults
Total measured	16	485	97	506
Mean FL (cm)	60.8	79.0	60.9	86.8
Range FL (cm)	55-65	66-99	48-70	71-112
SD	3.0	5.6	5.5	7.0

Sex Composition

Males comprised 55% (603) of the fresh carcasses examined (Table **7**); 506 (84%) were adults and 97 (16%) were grilse. Females comprised 45% (501) of the fresh carcasses examined; 485 (97%) were adults and 16 (3%) were grilse. Male grilse comprised 86% (97) of the grilse observed; female grilse comprised 14% (16).

The ratio of male to female adult spawners was nearly 1:1 (506:485) (Table **7** and Figure 10). Males were more numerous in the early season through the fifth week (November 20-22) and females were more numerous afterwards. The final week was the exception when the only fresh carcass observed was an adult male in Reach 2. Grilse sex composition ranged from 67% male in Week 10 to 100% male in weeks 2 and 7 (Figure 11).

Spawning Success

There were 478 females examined for egg retention (Table 8). Of these, 327 (68%) had completely spawned, 89 (19%) had not spawned, and 62 (13%) had partially spawned. Unspawned females were seen throughout most of the survey season. Substantial portions ($\geq$ 20%) of the females observed in weeks 1,2,3,4,6, and 9 were unspawned.

Table 6. Age composition (grilse and adult) of fall-run chinook salmon carcasses measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

	Adults		Grilse [1/]	
Week	Number	Percent	Number	Percent
1	8	62	5	38
2	70	88	10	12
3	137	85	25	15
4	112	86	18	14
5	175	92	16	8
6	230	93	18	7
7	148	95	8	5
8	70	95	4	5
9	34	85	6	15
10	6	67	3	33
11	1	100	0	0
Totals (average)	991	(90)	113	(10)

1/ Grilse were defined as males $\leq$ 70 cm FL and females $\leq$ 65 cm FL based upon length frequency distribution (figures 5 and 6).

Table 7. Sex composition of fall-run chinook salmon grilse and adults carcasses measured during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

	Adults				Grilse [1/]			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	6	75	2	25	4	80	1	20
2	42	60	28	40	10	100	0	0
3	78	57	59	43	23	92	2	8
4	63	56	49	44	13	72	5	28
5	92	53	83	47	13	81	3	19
6	108	47	122	53	16	89	2	11
7	67	45	81	55	8	100	0	0
8	34	49	36	51	3	75	1	25
9	14	41	20	59	5	83	1	17
10	1	17	5	83	2	67	1	33
11	1	100	0	0	0	0	0	0
Totals (mean)	506	(51)	485	(49)	97	(86)	16	(14)

1/ Grilse were defined as males $\leq$ 70 cm FL and females $\leq$ 65 cm FL base upon length frequency distribution (figures 5 and 6).

Table 8. Spawning completion (egg retention) summary for female fall-run chinook salmon carcasses measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

Week	# females measured	# females checked for egg retention	Number (%) spawned	Number (%) unspawned	Number (%) partially spawned
1	3	2	0 (0)	2 (100)	0 (0)
2	28	18	10 (55)	5 (28)	3 (17)
3	61	61	34 (56)	21 (34)	6 (10)
4	54	49	37 (76)	10 (20)	2 (4)
5	86	84	60 (72)	12 (14)	12 (14)
6	124	121	83 (68)	24 (20)	14 (12)
7	81	80	55 (69)	8 (10)	17 (21)
8	37	36	30 (83)	0 (0)	6 (17)
9	21	21	13 (62)	7 (33)	1 (5)
10	6	6	5 (83)	0 (0)	1 (7)
11	0	0	0	0	0
Totals (means)	501	478	327 (68)	89 (19)	62 (13)

Population Estimates

A total of 1,794 fresh adult carcasses were tagged from Week 2 through Week 10 (Table 9a). There were 7 fresh adult carcasses tagged during Week 1 that were never recovered; these carcasses along with the decayed carcasses observed during weeks 1 and 2 were added to the C_j of the Week 3 recovery period. A total of 569 (32%) of the fresh carcasses tagged from Week 2 through the remainder of the season were subsequently recovered. The fresh carcass data were used in the Schaefer model to estimate an adult spawner escapement of 63,086 adults (Table 9b). Since adults made up 90% of the escapement, a total escapement (adults and grilse) of 70,096 was calculated by dividing the adult estimate by 0.90.

A total of 3,038 decayed adult carcasses was also tagged from Week 1 through Week 10; 1,006 (33%) were subsequently recovered. The tag-recover data from the decayed and fresh carcasses were combined in the Jolly-Seber model yielding an adult escapement of 38,676 (Table 10). This estimate was expanded, as above, resulting in a total escapement estimate of 42,973.

The population estimates for salmon spawning in the American River below the Nimbus Racks are as follows:

	Schaefer model	Jolly-Seber model
Total estimate	70,096	42,973
Adult estimate	63,086	38,676
Grilse estimate	7,010	5,297

In addition to the 70,096 salmon that spawned in the lower American River downstream from Nimbus Hatchery, there were 6,498 fall-run salmon that entered Nimbus Hatchery.
The Schaefer adult escapement estimate was more than double the previous 28 years' (1967 - 1994) mean of 28,621 fish (Table 11 and Figure 12).

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Table 9a. Summary of tagging and recapture of fresh adult fall-run chinook salmon carcasses by week during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

Schaefer model capture-recapture data matrix

Week of Recovery$_{(j)}$	$R_{(ij)}$ by Week of Tagging $_{(i)}$								Tags recovered $R_{(j)}$	Carcasses counted $C_{(j)}$	Ratio $C_{(j)}/R_{(j)}$
	2	3	4	5	6	7	8	9			
3	13								13	895	68.85
4	3	43							46	2,338	50.83
5		5	110						115	4,641	40.36
6			5	120					125	5,907	47.26
7			3	8	151				162	3,952	24.40
8			1	1	7	56			65	1,702	26.18
9					1	1	27		29	737	25.41
10					2	1	5	2	10	214	21.40
11						2		2	4	78	19.50
Recovery $R_{(i)}$	16	48	119	129	161	60	32	4			
Tagged $M_{(i)}$	62	152	350	416	433	262	83	36			
$M_{(i)}/R_{(i)}$	3.88	3.17	2.94	3.22	2.69	4.37	2.59	9.00			

Table 9b. Lower American River adult chinook salmon population estimate using the Schaefer Model by tagging fresh carcasses only with all captured untagged carcasses removed, October 1995 - January 1996.

	Population estimation (i)								
Week of recovery (j)	Week of tagging								
	2	3	4	5	6	7	8	9	Totals
3	3,468								3,468
4	591	6,921							7,512
5		639	13,057						13,696
6			695	18,287					18,982
7			215	629	9,907				10,752
8			77	84	493	6,403			7,057
9					68	111	1,780		1,959
10					115	93	278	385	871
11						170		351	521
Subtotals	4,059	7,560	14,044	19,001	10,583	6,778	2,057	736	64,818
Tagged		-152	-350	-416	-433	-262	-83	-36	-1,732
				Estimated population of natural spawning adults					63,086

Table 10. Summary of tagging and recapture of adult fall-run chinook salmon carcasses (fresh and decayed) by week during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

Jolly-Seber capture-recapture data matrix

Week of recovery (j)	Week of tagging (i)									Tagged fish recovered R(j)	Total fish recovered C(j)
	1	2	3	4	5	6	7	8	9		
1										0	66
2	19									19	212
3	1	39								40	663
4		5	117							122	2,433
5		1	10	177						188	4,714
6			2	10	323					335	6,117
7			1	6	27	386				420	4,210
8				1	5	20	162			188	1,825
9						9	12	152		173	881
10						5	7	21	42	75	279
11							2	2	11	15	89
R (i)	20	45	130	194	355	420	183	175	53	<-Tagged fish recovered	
M (i)	45	162	451	603	1,076	1,128	788	419	160	<-Total fish tagged	

Table 11. Fall-run chinook salmon escapement estimates, lower American River, 1967 - 1995.

Year	Grilse	Adults	Total
1967[1/]	3,132	14,868	18,000
1968[1/]	2,777	23,423	16,200
1969[1/]	8,208	35,452	43,660
1970[1/]	2,753	25,927	28,680
1971[1/]	5,210	36,470	41,680
1972[1/]	3,352	14,107	17,459
1973[1/]	4,688	77,554	82,242
1974[2/]	1,769	51,827	53,596
1975[1/]	2,699	29,433	32,132
1976[2/]	1,181	21,978	23,159
1977[2/]	4,701	36,904	41,605
1978[2/]	595	12,334	12,929
1979[2/]	896	36,419	37,315
1980[2/]	8,805	25,454	34,259
1981[2/]	2,521	40,941	43,462
1982[1/]	4,323	28,677	33,000
1983[1/]	7,313	19,087	26,400
1984[3/]	2,196	25,251	27,447
1985[2/]	11,392	44,728	56,120
1986[2/]	4,443	44,929	49,372
1987[2/]	2,960	18,185	21,145
1988[4/]	1,905	13,974	15,879
1989[2/]	2,459	14,619	17,078
1990[2/]	1,167	5,541	6,708
1991[2/]	1,506	16,639	18,145
1992[2/]	1,297	3,175	4,472
1993[2/]	6,162	20,624	26,786
1994[2/]	2,927	28,405	31,333
1995[2/]	7,010	63,086	70,096
Average	3,805	28,621	32,426

1/ Expanded direct count
2/ Schaefer method
3/ Petersen method
4/ Jolly-Seber method

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FIGURES

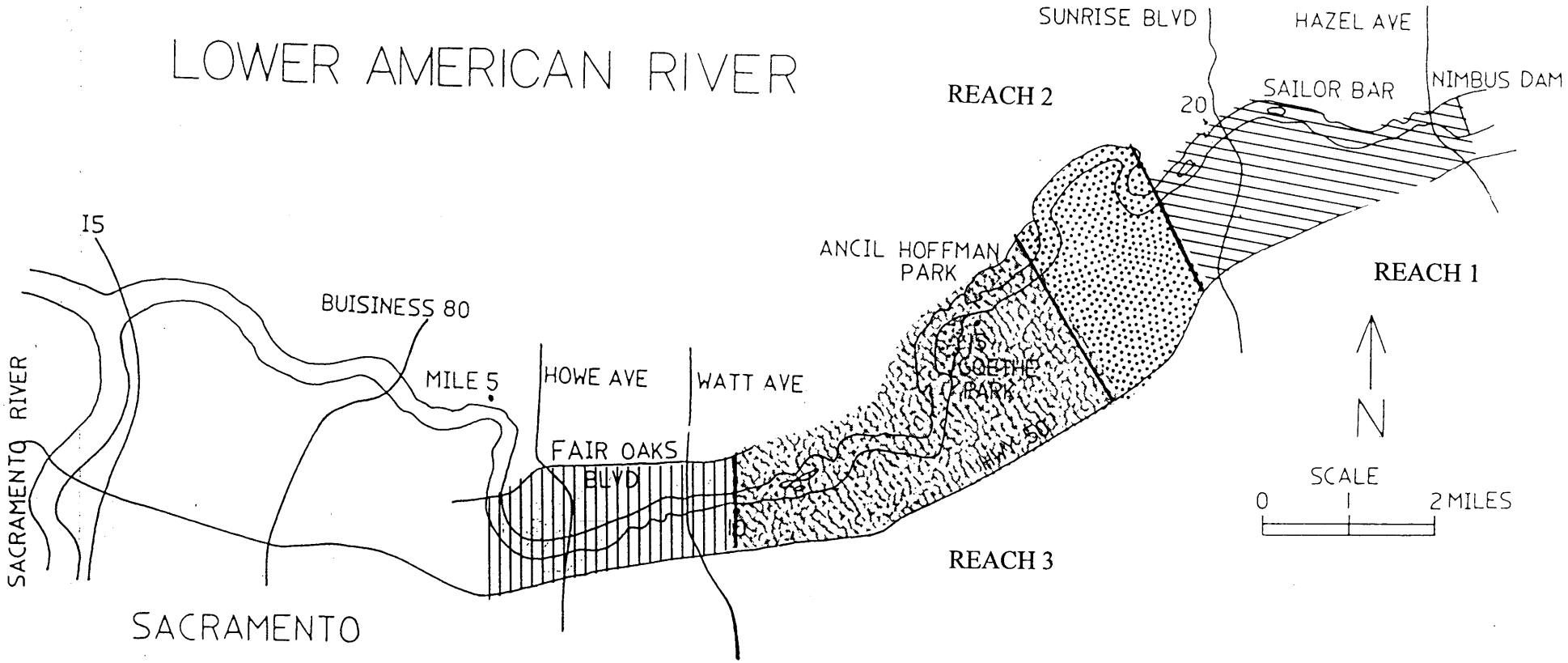

Figure 1. Location of lower American River spawner escapement survey reaches.

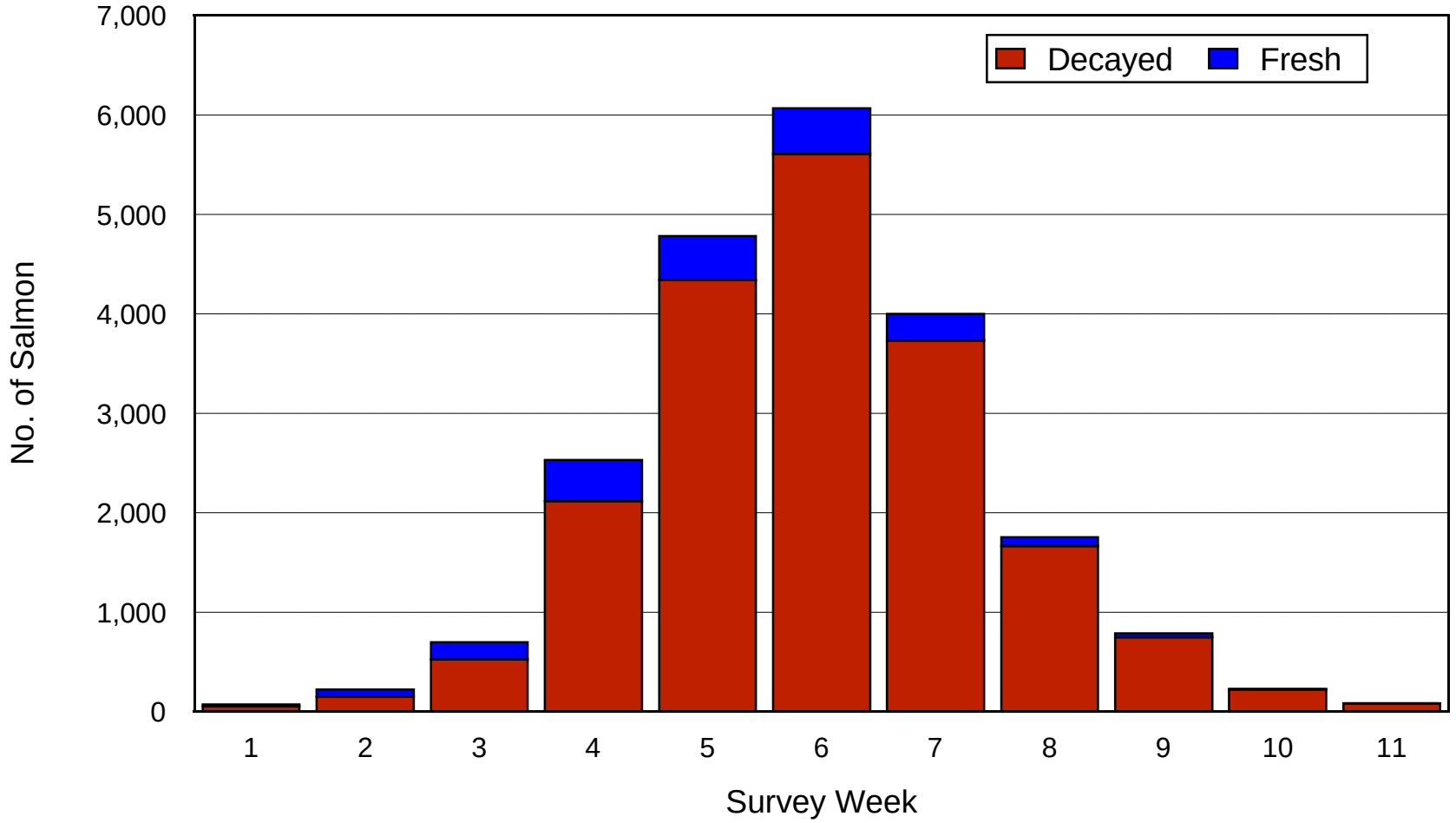

Figure 2. Weekly spawner carcass distribution observed during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

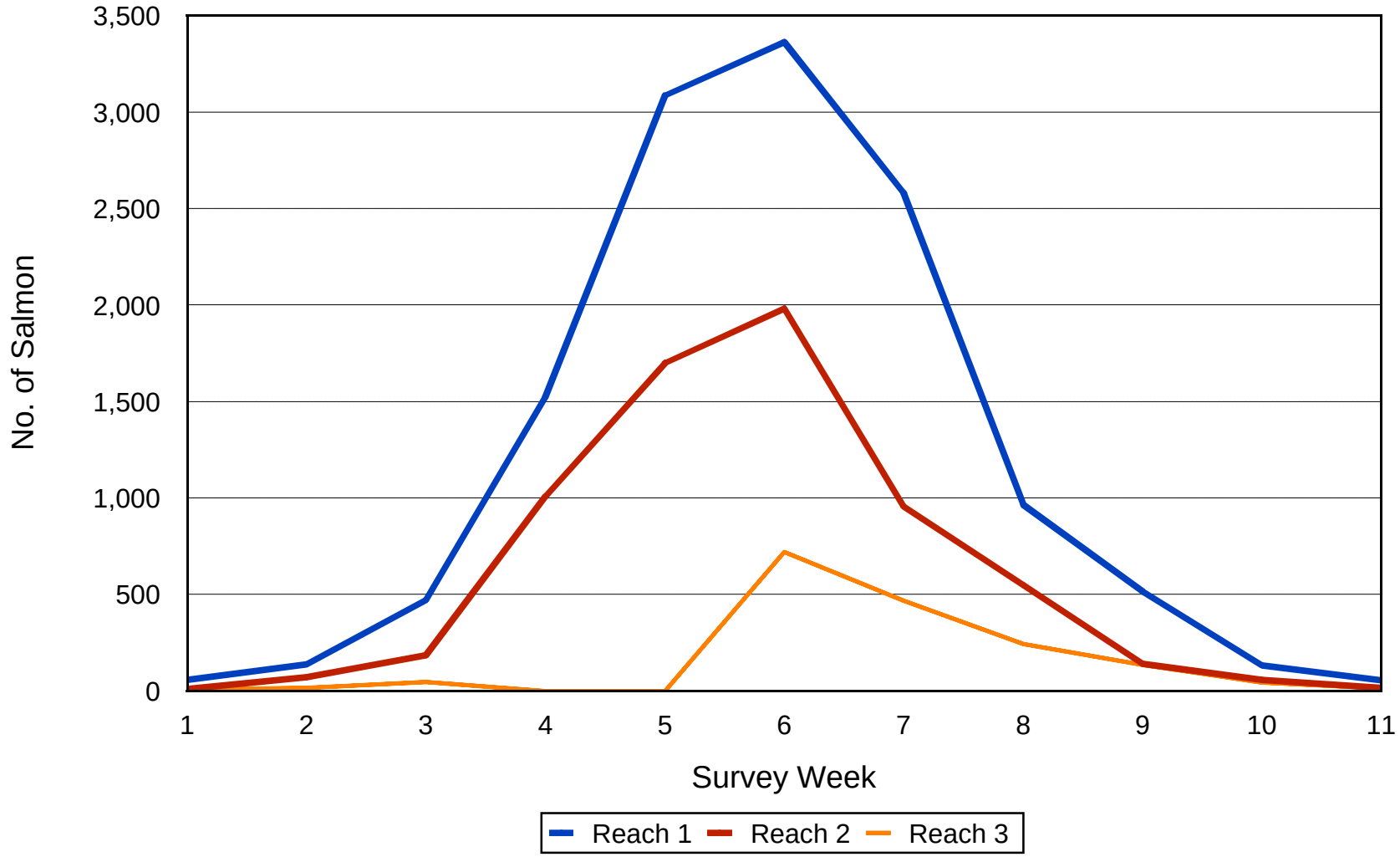

Figure 3. Weekly carcass distribution (totals by reach) observed during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996

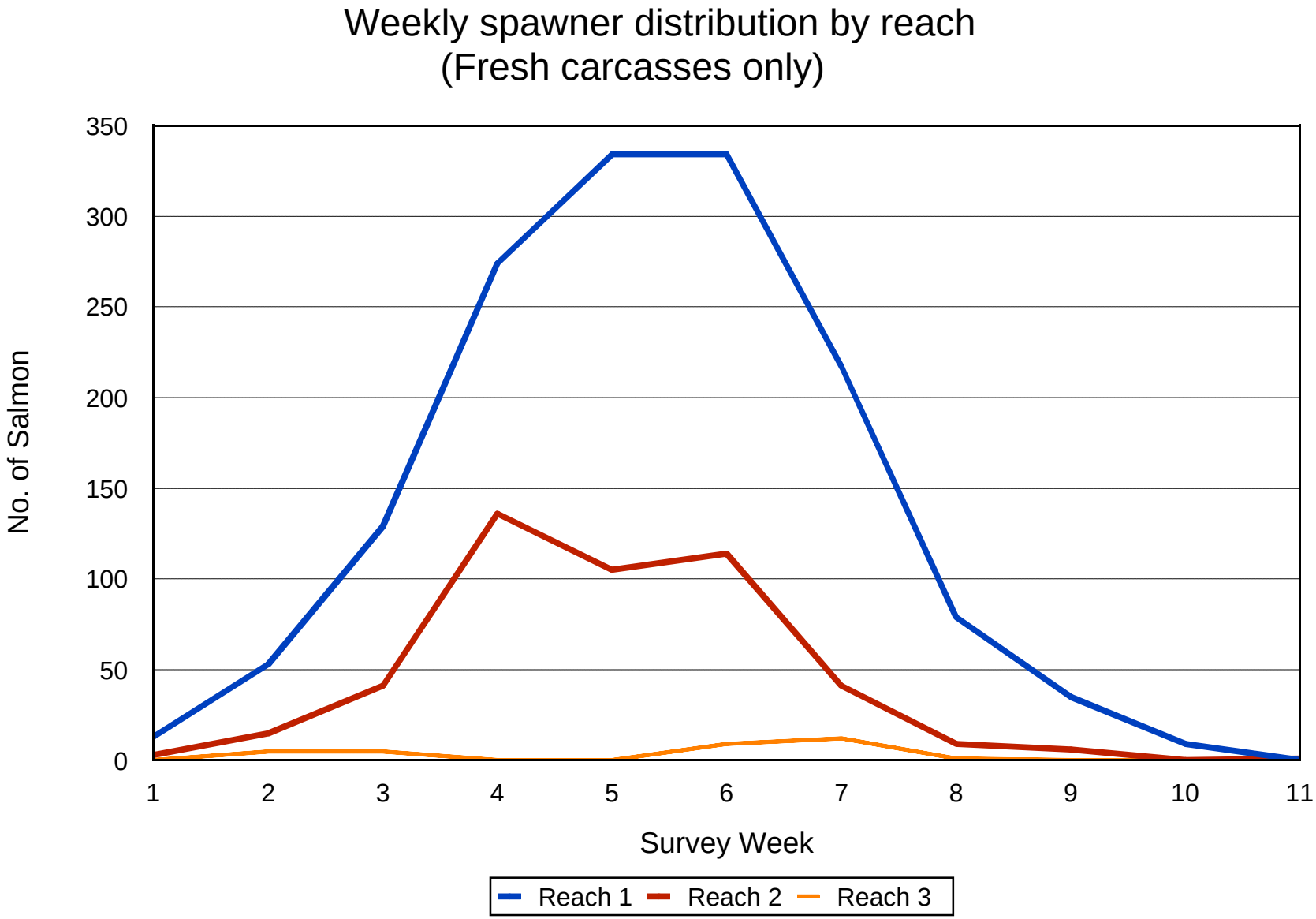

Figure 4. Weekly spawner carcass distribution (totals by reach) for fresh carcasses observed during the 1995 lower American River chinook salmon spawner escapement survey, October 1995 - January 1996.

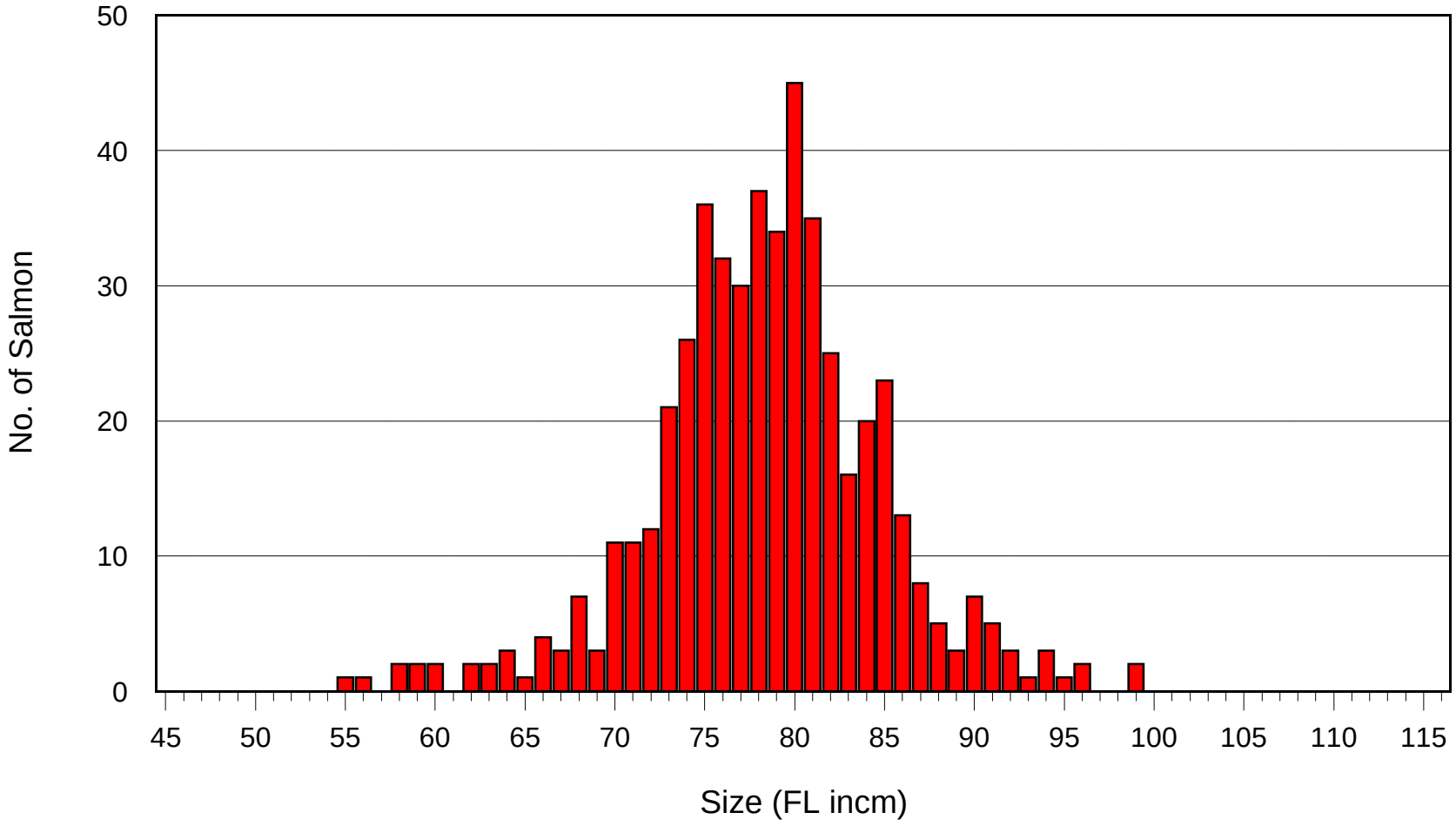

Figure 5. Size (FL in cm) distribution of female chinook salmon carcasses observed during the lower American River spawner escapement survey, October 1995 - January 1996.

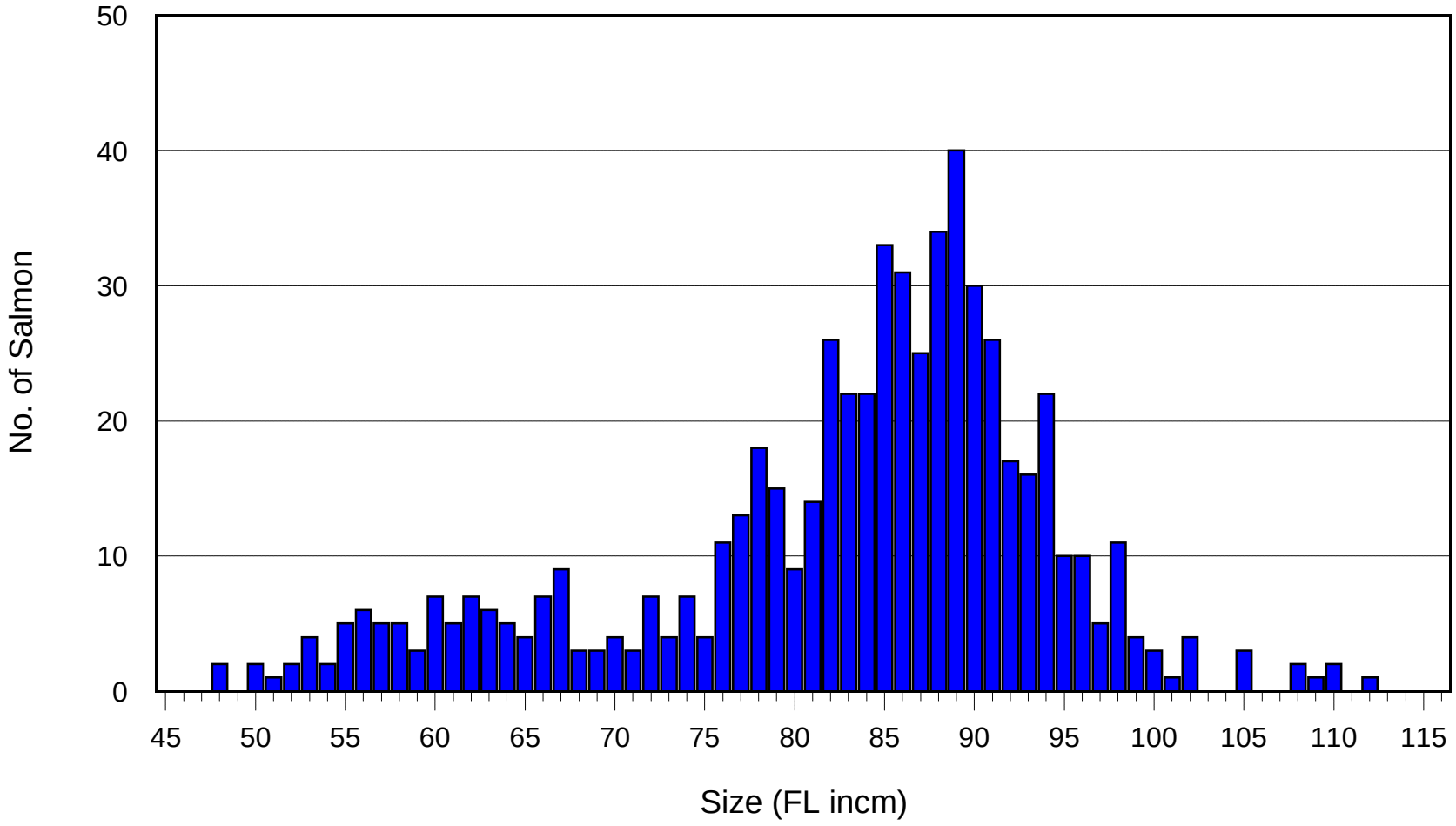

Figure 6. Size (FL in cm) distribution of male chinook salmon carcasses observed during the lower American River spawner escapement survey, October 1995 - January 1996.

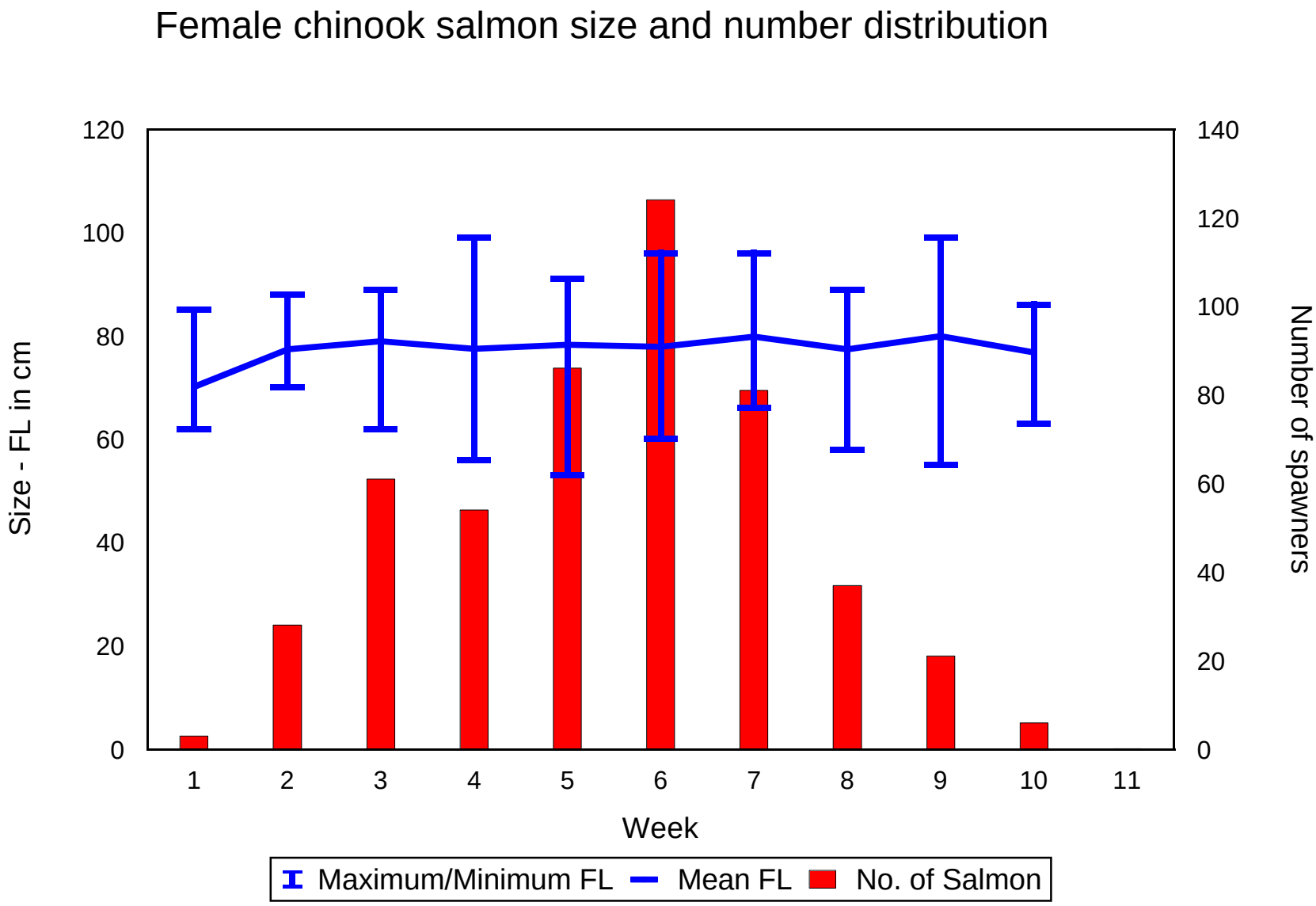

Figure 7. Mean size, size range and number of female chinook measured weekly during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

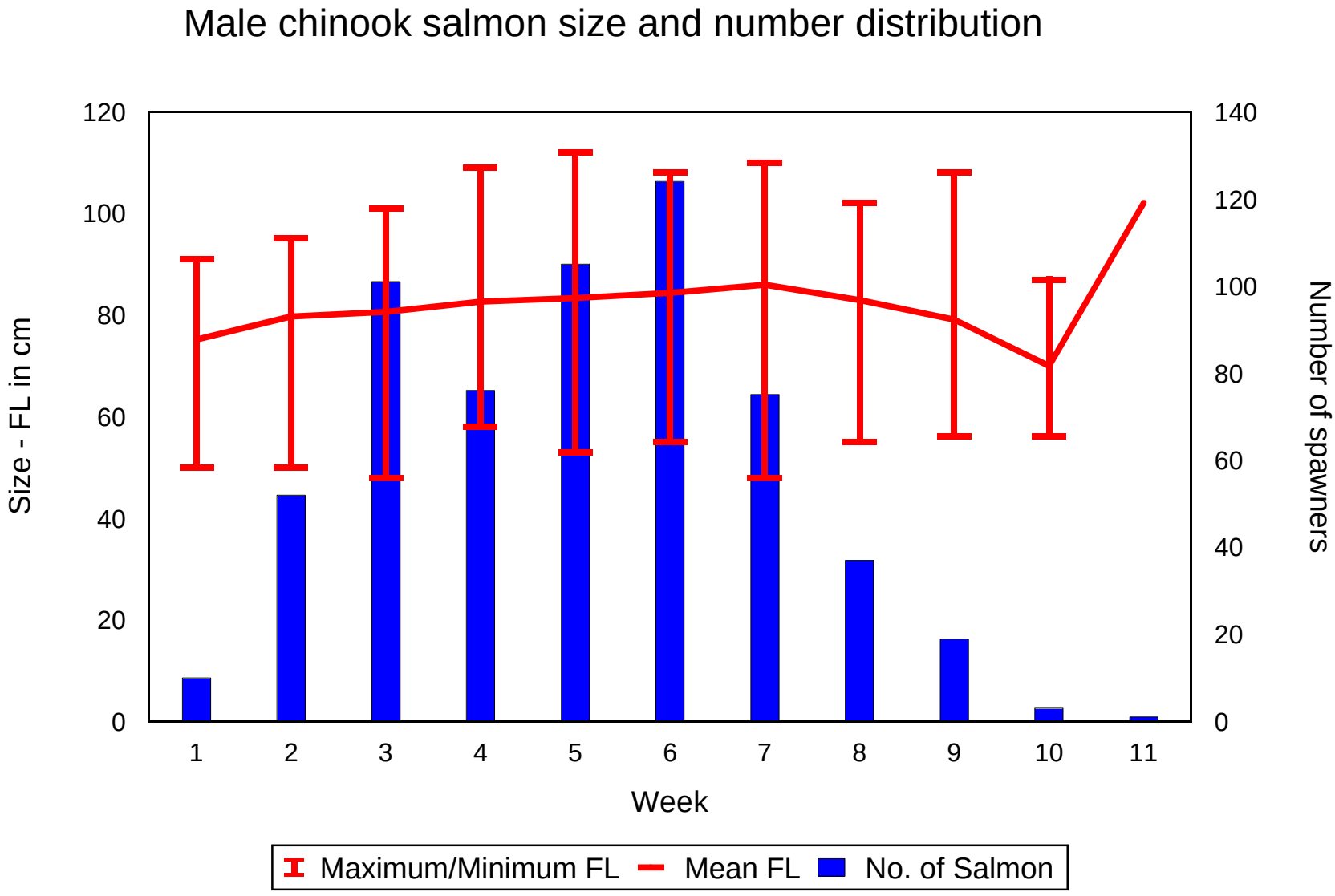

Figure 8. Mean size, size range and number of male chinook salmon measured weekly during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

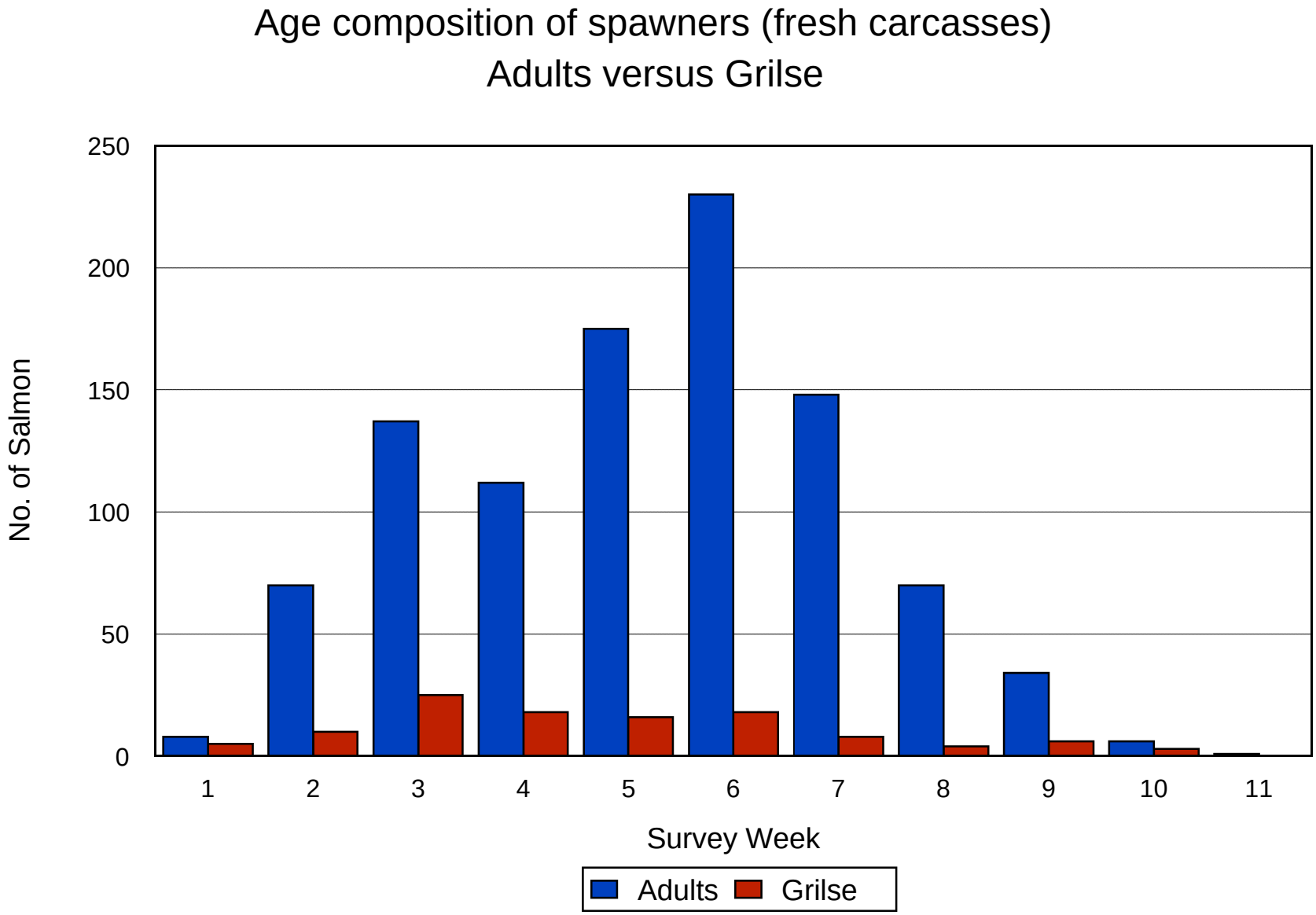

Figure 9. Age composition of chinook salmon measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996

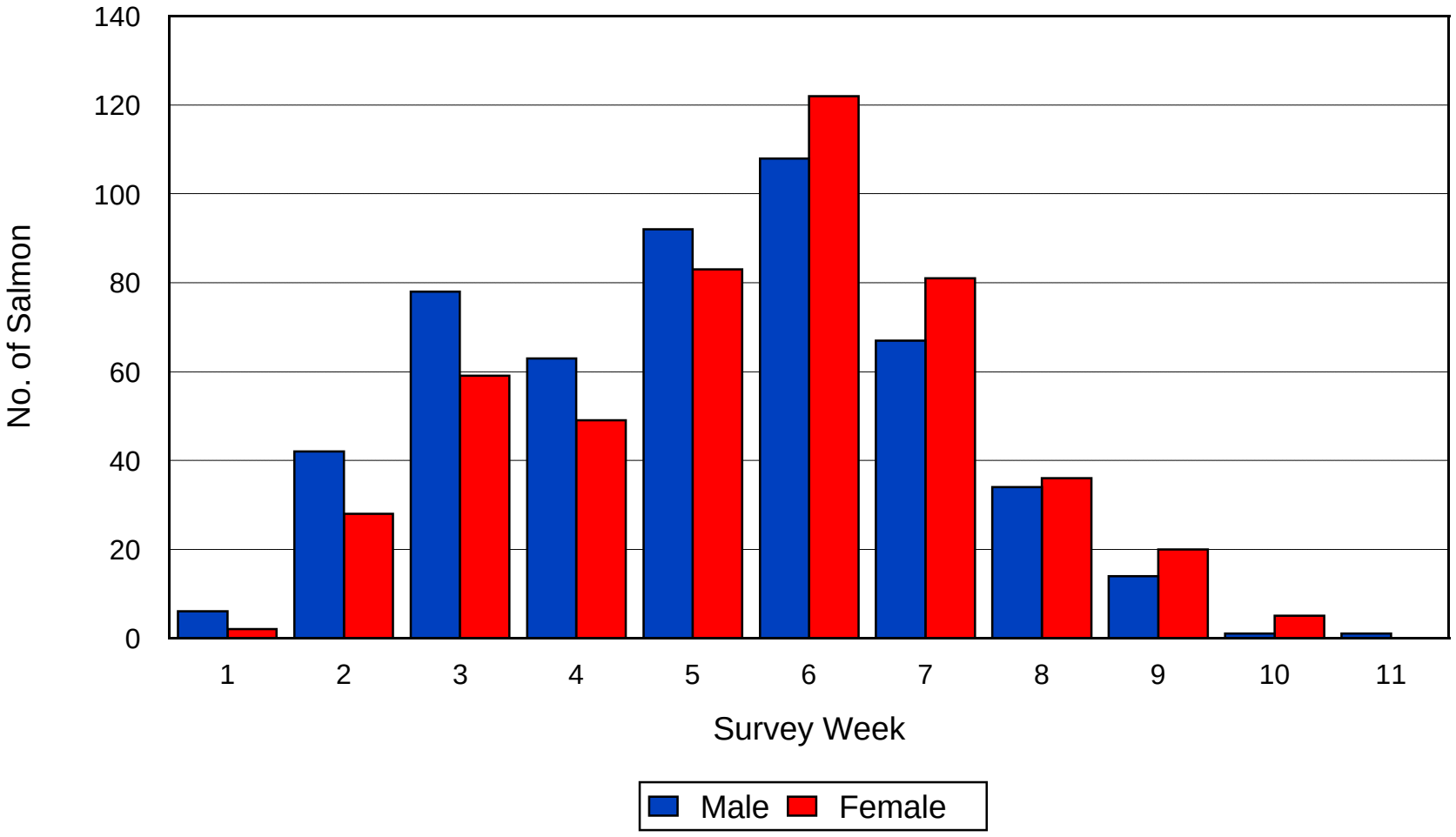

Figure 10 Weekly distribution of the sex of adult-sized chinook salmon measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

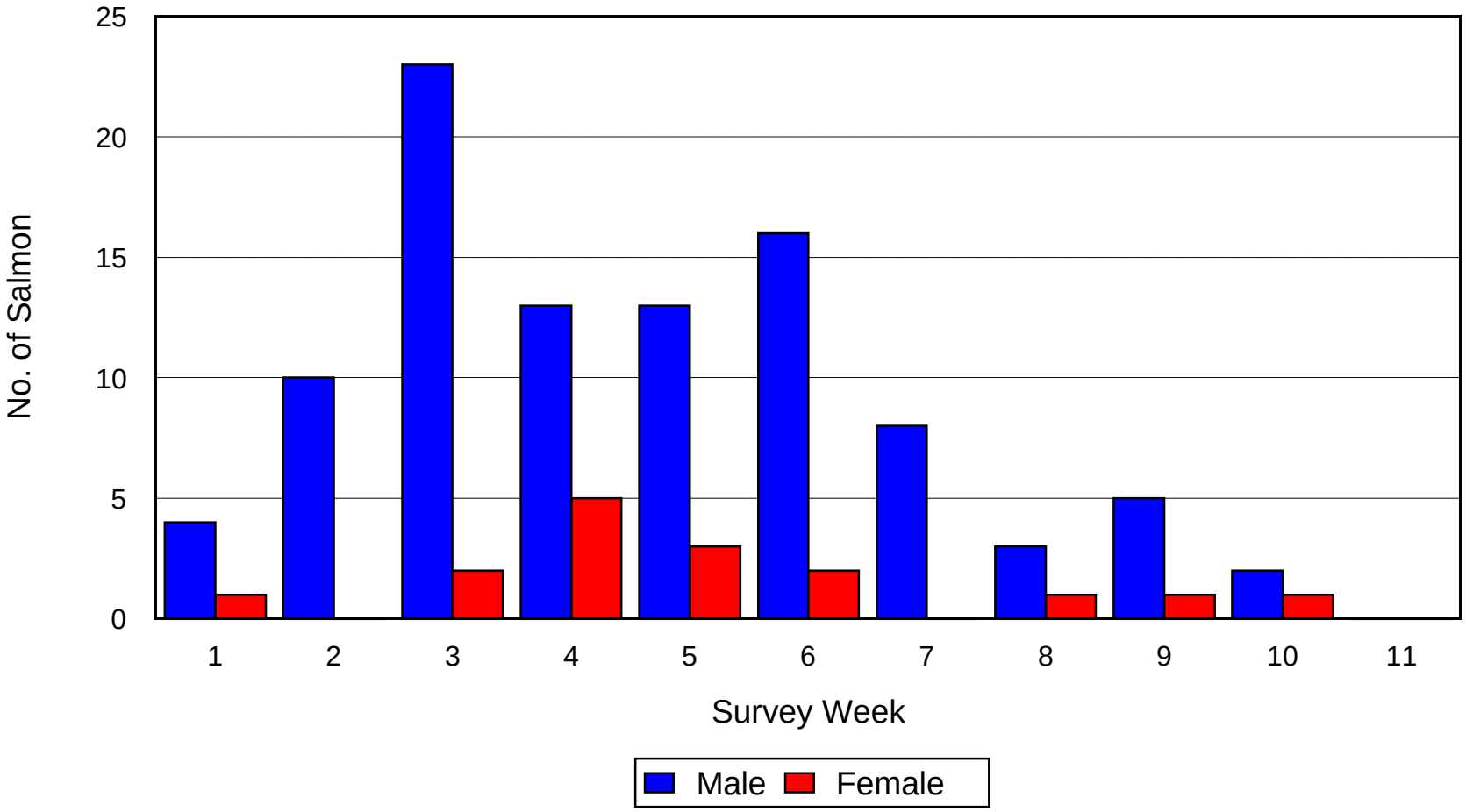

Figure 11. Weekly distribution of the sex of grilse-sized chinook salmon measured during the 1995 lower American River spawner escapement survey, October 1995 - January 1996.

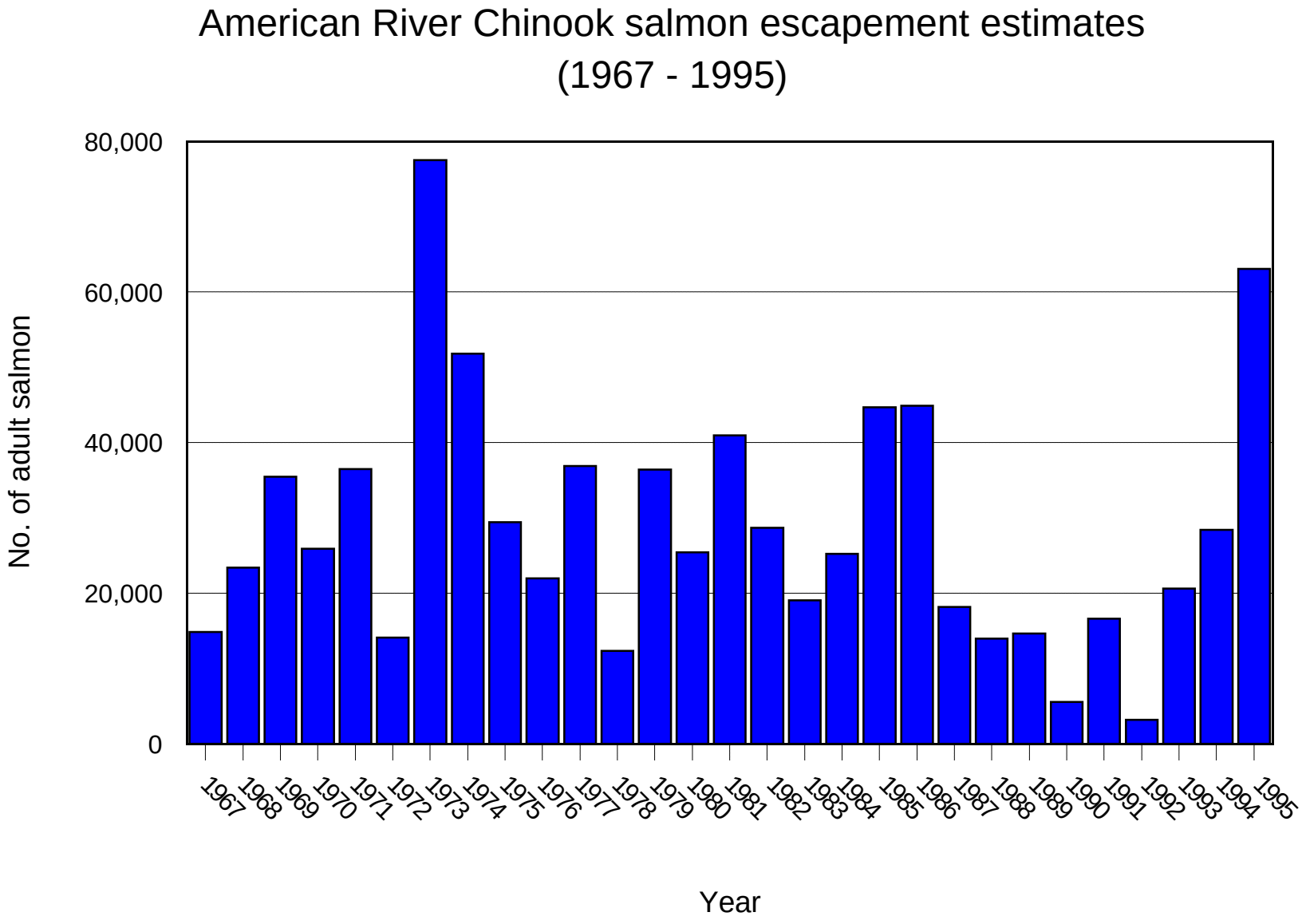

Figure 12. Summary of adult escapement estimates for fall-run chinook salmon in the lower American River, 1967 - 1995.