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

Lower American River
Chinook Salmon Escapement Survey
October 1993 - January 1994

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Stream Evaluation Program
Technical Report No. 95-4
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INTRODUCTION

An intensive spawning escapement survey was conducted on the lower American River during fall 1993 to estimate fall-run chinook salmon in-river spawning abundance and distribution. Spawning habitat availability investigations on the lower American River require consistent, reliable estimates of the spawner population to help distinguish habitat versus population influences on temporal and longitudinal spawning distribution (Snider and McEwan 1992, Snider *et a*l. 1993). Changes in spawning activity related to changes in flow and temperature need to be distinguished from changes due to population size. For example, 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 spawning completeness, age and sex composition, and behavior relative to habitat conditions and population size.

The Schaefer (Schaefer 1951) and Jolly-Seber (Seber 1982) models are routinely used to develop spawning escapement estimates throughout the Pacific Coast region. A modification of the Schaefer model is the primary model used by the California Department of Fish and Game. It has been routinely used in the lower American River since 1974 (Rich and Leidy 1985). The Schaefer model always overestimates the escapement population, reportedly up to 5-fold or more at low survival and low catch rates (Law 1992). The Jolly-Seber model typically provides a more accurate escapement estimate for various combinations of capture, tagging and survival rates although it too overestimates the population at low survival and low catch rates (<10%). The Jolly-Seber model is considered by some salmon managers to offer a more accurate escapement estimate (Boydstun 1992, Law 1992, Reavis pers. comm.). However, there is substantial disagreement among California's salmon managers as to the utility of the Jolly-Seber model for estimating escapement where the population or the stream being surveyed is large (Fisher, Meyer, Reavis, pers. comm.). Law (1992) reports that some biologists using the Jolly-Seber model on large streams feel the estimates are “too low”. If catch rates are higher for recaptures than for new recruits, the Jolly-Seber model tends to underestimate the population while the Schaefer model consistently overestimates.

Objectives

- To estimate the fall 1993, in-river fall-run chinook salmon spawning population, including confidence limits, for the lower American River.

- To continue to examine the Jolly-Seber and Schaefer population estimation 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 the chinook salmon run in the lower American River.

METHODS

Weekly carcass surveys were conducted from the week starting 17 October 1993 through the week ending 23 January 1994, to estimate the chinook salmon spawning population in the lower American River. Two different mark-recapture sampling methods (Schaefer and Jolly-Seber) were used to obtain the estimate. The survey was limited to the uppermost 14 miles of the lower American River, from Watt Avenue (river mile 9) to Sailor Bar (river mile 23) (Figure 1). The lowermost nine river miles - downstream of Watt Avenue - were not included in the study since this river portion supports relatively little spawning (Snider and McEwan 1992, Snider *et al.* 1993, Snider and Vyverberg 1995).

The study segment was divided into three reaches (Table 1) to be comparable with data collected in a concurrent redd survey. Sampling was conducted from upstream to downstream. Typically, Reach 1 was surveyed on Mondays, Reach 2 on Tuesdays and Reach 3 on Wednesdays. At least three biologists surveyed for chinook salmon carcasses; one biologist per bank (except when water levels prevented safe footing), and one biologist in a boat, traversing the channel for thorough inspection of the river bottom.

Table 1. Location of survey reaches, lower American River Chinook Salmon Escapement Survey, September 1993 - January 1994.

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 Ave	14.5 to 9.0

Carcasses were inspected for freshness by examining the eyes for clarity and the gills for color. A fish with at least one clear eye, or pink gills (if eye clarity could not be determined), was considered fresh. All but 12 fresh carcasses observed from Week 3 (31 October - 6 November 1993) through Week 14 (16-23 January 1994) were tagged with a color-coded hog ring inserted in the upper jaw to identify the week the carcass was tagged. (The 12, untagged fresh carcasses were encountered immediately above the downstream study boundary where there is no recovery potential). Fork length (FL) and standard length (SL), if possible, and sex were determined for each tagged fresh carcass. Egg retention was checked to determine if the fish had completely spawned (i.e., few eggs remaining), partially spawned (more than 50% retention) or not spawned (nearly full ovaries). Each fresh carcass was then returned to flowing water just upstream from where it was collected, or left in place in the backwater areas, to emulate the disposition of dying salmon. Non-fresh carcasses were counted and cut through the backbone with a machete to remove them from future surveys.

Previously tagged, or recaptured carcasses with one hog ring were tagged with a second hog ring and the tag data were collected. The carcass was then replaced in the river as described above. When carcasses with two hog rings were located, the data from both tags were recorded and the carcass was then chopped through the backbone to remove it from the survey.

Water clarity (Secchi depth), flow, and water temperature data were obtained from concurrent studies (Snider and Vyverberg 1995).

RESULTS

A total of 1,479 fresh carcasses and 10,231 non-fresh carcasses (11,710 total) was observed (Table 2). Water clarity was consistently high (> 8 ft) and flows were consistently moderate (relative to mean post-Folsom conditions) through Week 13 (Figure 2). High visibility (> 8 ft) increases the likelihood of carcass capture and recovery. Lower flows provide better access to the river also increasing carcass catchability rates. Consistent conditions reduce bias (Law 1992) and provide comparable data.

Temporal Distribution

Fresh carcasses were observed during every survey week but Week 14 (Figure 3). Few carcasses (fresh and non-fresh) were observed during the first two weeks. The number of carcasses began to increase beginning in the third week with the peak carcass counts occurring during Weeks 6, 7 and 8 (21 November through 8 December). The fresh and non-fresh carcasses counts during these three weeks totaled 2,615, 3,142 and 2,608, respectively, and accounted for 71% of the total carcass count (11,710).

Table 2. General survey information for the 1993 lower American River chinook salmon spawner escapement survey, October 1993 - January 1994.

Week	Dates	Flow (cfs)[1/]	Secchi depth (ft)[1/]	Water temperature (°F)[1/]	Carcass count	
					Fresh	Non-fresh
1	Oct 17 - 23, 1993	3,752	11	64	1	11
2	Oct 24 - 30, 1993	2,012	12	63	1	13
3	Oct 31 - Nov 6, 1993	2,001	15	62	12	36
4	Nov 7 - 13, 1993	1,752	12.5	59	45	107
5	Nov 14 - 20, 1993	1,750	11	57	261	364
6	Nov 21 - 27, 1993	1,753	10	55	495	2,120
7	Nov 28 - Dec 4, 1993	1,753	9.5	54	365	2,777
8	Dec 5 - 11, 1993	2,284	10	54	195	2,413
9	Dec 12 - 18, 1993	3,684	10	54	68	829
10	Dec 19 - 25, 1993	1,747	11.5	50	23	940
11	Dec 26, 1993 - Jan 1, 1994	1,753	14	50	8	316
12	Jan 2 - 8, 1994	1,753	12	49	3	116
13	Jan 9 - 15, 1994	1,753	12.5	49	2	109
14	Jan 16 - 23, 1994	1,750	na	na	0	80
Total					1,479	10,231

[1/] Average measurements for Monday, Tuesday and Wednesday of that week.

Spatial Distribution

Most carcasses were counted in Reach 1 (63% of all carcasses, 81% of fresh carcasses) (Table 3, Figure 4). The proportion of total carcasses counted in Reaches 1 and 2 varied owing both to movement of carcasses from Reach1 to Reach 2 and beyond, and to relative changes in spawning in Reach 2. The tag recovery rate in Reach 1 remained the lowest throughout the survey. Recovery rates in Reaches 2 and 3 were higher than in Reach 1 and tended to increase as the overall number of tagged carcasses increased (of which most were tagged in Reach 1). The distribution of fresh carcasses better reflects distribution of spawning. Nearly 80% of all fresh carcasses were observed each week in Reach 1, except during Weeks 8 and 10 (Figure 5).

Most fresh carcasses were collected from the upper portion of Reach 1 (above river-mile 20), at Sacramento Bar and Sailor Bar (Figure 6). These two locations accounted for nearly 80% of the total fresh carcass count. Counts within the lower portion of Reach 1 and the upper portion of Reach 2 (river-mile 17 - 19) were comparably lower than upstream. Counts downstream of river-mile 17 were consistently very low (<10%).

Size Distribution

A total of 1,465 fresh carcasses was measured (Table 4). The mean FL was 71.4 cm. Size ranged from 33.5 to 107 cm. Male salmon averaged 75.4 cm FL (range; 33.5-107 cm FL). Female salmon averaged 73.5 cm Fl (range: 49-95 cm FL).

Length frequency distributions were used to define a general size criteria distinguishing grilse (2-year-old salmon) and adult (>2 year-old salmon) for both sexes (Figures 7 and 8). Male grilse were defined as salmon $\leq$70 cm FL; female grilse were $\leq$60 cm FL. Male grilse averaged 60.9 cm FL (range: 33.5-70 cm FL, SD=5.7); male adults averaged 84.4 cm FL (range: 71-107 cm FL, SD=7.6). Female grilse averaged 56.0 cm FL (range: 49-60 cm FL, SD=3.0); female adult averaged 75.0 cm FL (range: 61-95 cm FL, SD=6.8).

Mean weekly size for each sex was primarily influenced by the proportion of grilse:adults. Mean weekly adult sizes were fairly constant for both sexes although higher deviations from the mean appeared to coincide with the smaller sample sizes that occurred before and after the peak counts (Figures 9 and 10).

Grilse comprised 23% (332) of the 1,465 measured fresh carcasses (Table 5). Both male and female grilse first appeared during Week 4 (Table 6) and were simultaneously present through Week 10 (Figure 11). Two grilse were observed after Week 10, one female in Week 12 and one male in Week 13. Between Weeks 4 and 10, grilse composition was fairly constant ranging from 20 to 28% of the total count (mean: 23%). The largest number of grilse was counted during Week 6 (121).

Table 3. Summary of chinook salmon carcass distribution during the 1993 lower American River chinook salmon spawner escapement survey, October 1993 - January 1994.

	Reach 1			Reach 2			Reach 3		
	Fresh		Non-fresh	Fresh		Non-fresh	Fresh		Non-fresh
Week	M[1/]	R[2/]	Count	M	R	Count	M	R	Count
1	0	-	5	1	-	6	0	-	0
2	1	0	8	0	0	3	0	0	2
3	10	0	28	1	0	5	1	0	3
4	39	1	79	6	0	25	0	0	3
5	202	7	235	54	3	104	5	1	25
6	392	56	1,366	88	21	686	15	2	68
7	299	153	1,586	59	47	1,074	7	5	117
8	178	167	1,685	13	22	635	4	6	93
9	53	26	408	14	14	288	1	5	133
10	15	42	476	6	22	330	2	5	134
11	6	15	177	1	8	117	1	1	22
12	3	6	78	0	2	34	0	0	4
13	0	2	67	0	1	32	0	0	12
14	0	2	31	0	1	48	0	0	1
Total	1,198	477	6,229	243	141	3,387	36	25	617

1/ Number of fresh carcasses tagged
2/ Number of tagged carcasses recovered

Table 4. Size and sex statistics for all fresh chinook salmon carcasses measured during the 1993 lower American River chinook salmon spawner escapement survey, October 1993 - January 1994.

	All salmon			Male salmon			Female salmon		
		Length (FL in mm)			Length (FL in cm)			Length (FL in cm)	
Week	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
1	1	78.0	-	1	78.0	-	0	-	-
2	1	71.5	-	0	-	-	1	74.5	-
3	12	82.7	78-98	6	88.3	83-98	6	77.5	77-82
4	45	73.8	57-96	23	94.5	57-96	22	73.1	57-88
5	257	76.1	33.5-104	147	77.4	33.5-104	110	74.0	57-95
6	496	74.2	45-105	246	74.7	45-105	247	73.7	49-95
7	352	75.1	47-107	174	76.1	47-107	178	74.2	52-94
8	197	72.0	49-103	75	73.1	49-103	122	71.0	50-93
9	69	71.7	51-102	26	70.1	21-102	43	72.6	52-86.5
10	23	75.9	49.5-100	10	79.8	58-100	13	72.9	49.5-93
11	7	82.4	69-92	0	-	-	7	82.4	69-92
12	3	77.0	56-95	1	95	-	2	68.0	56-80
13	2	69.0	59-79	1	59	-	1	79.0	-
14	0	-	-	0	-	-	0	-	-
Total	1,465	71.4	33.5-107	713	75.4	33.5-107	752	73.5	49-95

Table 5. Age composition (grilse and adult) of fall-run chinook salmon measured during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

	Adults	Grilse
Week	Number (%)	Number (%)
1	1 (100)	0 (0)
2	1 (100)	0 (0)
3	12 (100)	0 (0)
4	35 (78)	10 (22)
5	205 (80)	52 (20)
6	375 (76)	121 (24)
7	280 (80)	72 (20)
8	146 (74)	51 (26)
9	50 (72)	19 (28)
10	18 (78)	5 (22)
11	7 (100)	0 (0)
12	2 (67)	1 (33)
13	1 (50)	1 (50)
14	0 (0)	0 (0)
Total	1,133 (77)	332 (23)

Table 6. Sex composition of chinook salmon grilse and adult carcasses measured during the 1993 lower American River chinook salmon spawner escapement survey, October 1993 - January 1994.

	Grilse[1/]				Adult			
	Male		Female		Male		Female	
Week	Number	%	Number	%	Number	%	Number	%
1	0	-	0	-	1	100	0	0
2	0	-	0	-	0	0	1	100
3	0	-	0	-	6	50	6	50
4	8	80	2	20	15	42	20	58
5	47	90	5	10	100	49	105	51
6	101	83	20	17	148	39	227	61
7	64	89	8	11	110	39	170	61
8	35	69	16	31	40	27	106	73
9	14	74	5	26	12	24	38	76
10	2	40	3	60	8	44	10	66
11	0	-	0	-	0	0	7	100
12	0	0	1	100	1	50	1	50
13	1	100	0	0	0	0	1	100
14	0	-	0	-	0	-	0	-
Total	272	82	60	18	441	39	692	61

.1/ Grilse were defined as males $\leq$70 cm and females $\leq$60 cm based upon length frequency distribution data (Figures 7 and 8),

Sex Composition

Males comprised 49% (713) of the 1,465 fresh carcasses examined (Table 4). Sixty-two percent (272) of the 713 male carcasses and 8% (60) of the female carcasses were grilse (Table 6).

The ratio of males to females was fairly constant during the majority of the survey (Weeks 4 - 10). Males slightly dominated the counts early (up to 57% during Week 5); females dominated the counts later (up to 62% in Weeks 8 and 9). (Figure 12). The adult sex composition during this same period was dominated by females ranging from 51% in Week 5 to 76% in Week 9. The grilse sex composition ranged from 40% male (Week 10) to 90% male (Week 5).

Spawning Success

Ninety-four percent (708) of the female carcasses investigated for egg retention had completely spawned (Table 7). Three percent were partially spawned and three percent were unspawned. Ninety-four percent of female adults had completely spawned; 3% were partially spawned and 3% were unspawned. Ninety-two percent of 55 female grilse had completely spawned; 2% were partially spawned and 6% were unspawned.

The frequency of unspawned and partially spawned female salmon decreased as the season progressed and the number of females increased (Table 7). The first fresh female carcass, observed during Week 2, was unspawned; 50% of the fresh female carcasses observed during Week 3 were unspawned and 40% of the females observed during Week 4 were either partially spawned or unspawned.

Population Estimates

A total of 1,474 carcasses were tagged from Week 3 through Week 12, of which 643 were subsequently recovered (Table 8). Using the Schaefer method, the spawner escapement estimate was 26,786 (Table 9). Using the Jolly-Seber method, the spawner escapement estimate was 20,820.

Grilse and adult population estimates were determined using their respective percentage composition in the fresh carcass sample.

	Schaefer Method	Jolly-Seber Method
Total estimate	26,786	20,820
Adult estimate	20,624	16,031
Grilse estimate	6,162	4,789

Table 7. Spawning completion (egg retention) summary for adult female chinook salmon measured during the lower American River spawner escapement survey, October 1993 - January 1994.

Week	# female adults	Spawned		Unspawned		Partially spawned	
		Number	Percent	Number	Percent	Number	Percent
1	0	0	0	0	0	0	0
2	1	0	0	1	100	0	0
3	5	2	40	3	60	0	0
4	20	12	60	2	10	6	30
5	105	100	95	2	2	3	3
6	227	215	95	9	4	3	1
7	170	167	98	3	2	0	0
8	106	104	98	1	1	1	1
9	38	34	90	0	0	4	10
10	10	9	90	0	0	1	10
11	7	7	100	0	0	0	0
12	1	1	100	0	0	0	0
13	1	1	100	0	0	0	0
Total	691	652	94	21	3	18	3

Table 8. Summary of tagging and recapture of chinook salmon carcasses by week during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

Week of tagging	Number tagged	Number recaptured											
		Week of recapture											Total recaptured
		4	5	6	7	8	9	10	11	12	13	14	
3	12	1											1
4	45		11	4	1								16
5	261			75	25	1	1	2					104
6	495				179	56	1	8	2				246
7	365					138	14	9	2				163
8	195						29	25	8	2		1	65
9	68							25	5	2			32
10	23								7		2	2	11
11	7									4			4
12	3										1		1
Total	1474	1	11	79	205	195	45	69	24	8	3	3	643

Table 9. Population estimate matrix using Schaefer Method with only fresh carcasses tagged and all captured untagged carcasses removed.

Week of recovery	Week of tagging										Totals
	3	4	5	6	7	8	9	10	11	12	
5		1,789									1,789
6		384	6,419								6,803
7		46	1,024	5,881							6,951
8			36	1,620	4,442						6,098
9			53	42	656	1,821					2,572
10			75	241	301	1,122	795				2,534
11				53	60	319	141	195			768
12						95	67		111		273
13								159		114	273
14						83		116			199
Total	0	2,219	7,607	7,837	5,459	3,440	1,003	470	111	114	28,260
Tagged	12	45	261	495	365	195	68	23	7	3	(1,474)
										Population Estimate	26,786

DISCUSSION

Escapement estimates derived from both the Schaefer and Jolly-Seber methods were lower than the previous 26 year (1967 - 1992)[1] mean of 31,236 fish (Table 10). Grilse composition (23%) was higher than the average measured during the same 26 year period (12%). Pre-spawning mortality (3%) was lower than that measured in 1992.

Table 10. Chinook salmon escapement estimates, lower American River, 1967 - 1993.

Year	Grilse	Adults	Total
1967[1/]	3,132	14,868	18,000
1968[1/]	2,777	23,423	26,200
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
Average	3,719	28,412	31,072

[1/] Expanded Direct Count
[2/] Schaefer Method
[3/] Petersen Method

[1] Prior to 1974, estimates were derived from expanded direct counts; those made since 1974 were derived using expanded direct counts, Petersen, Schaefer and Jolly-Seber methods. The Schaefer method was used most often. The expanded direct count method involves multiplying the number of observed carcasses by an estimated capture efficiency based upon survey conditions such as flow and turbidity. For example, the estimate for a survey with a 20% capture efficiency would be obtained by multiplying the carcass count by 5. A 20% efficiency was considered high.

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FIGURES

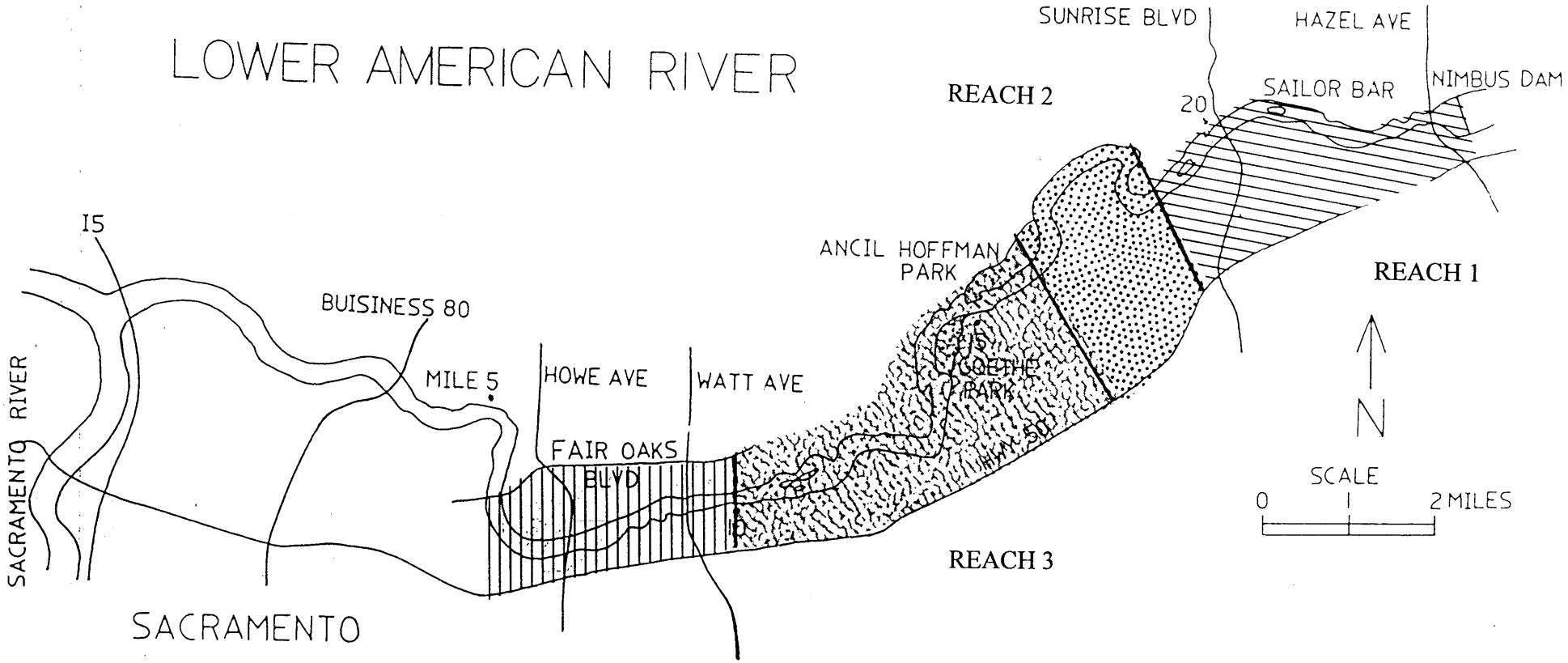

Figure 1. Location of lower American River spawner escapement survey reaches.

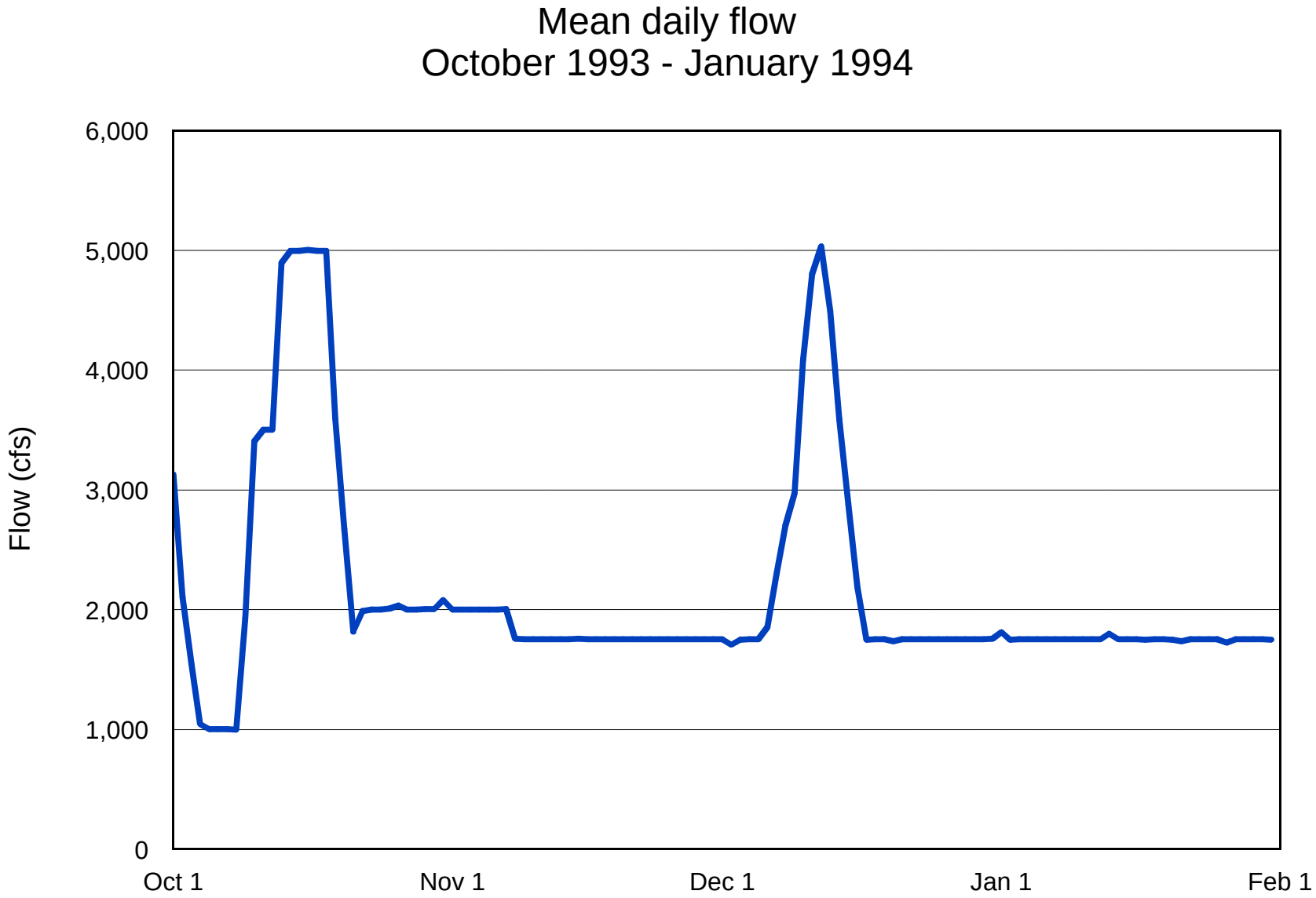

Figure 2. Mean daily flow measured at Nimbus Dam during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

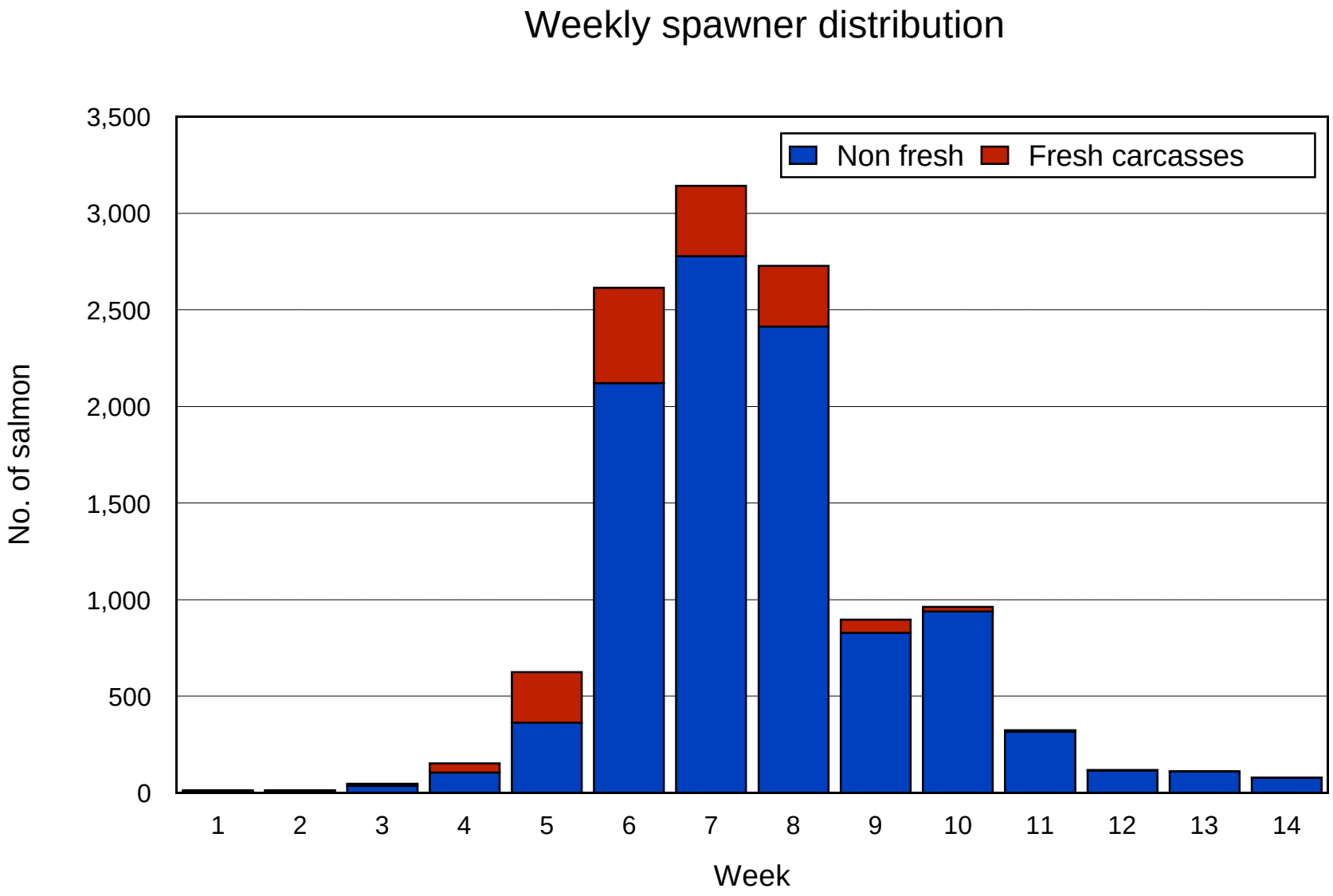

Figure 3. Weekly spawner carcass distribution observed during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

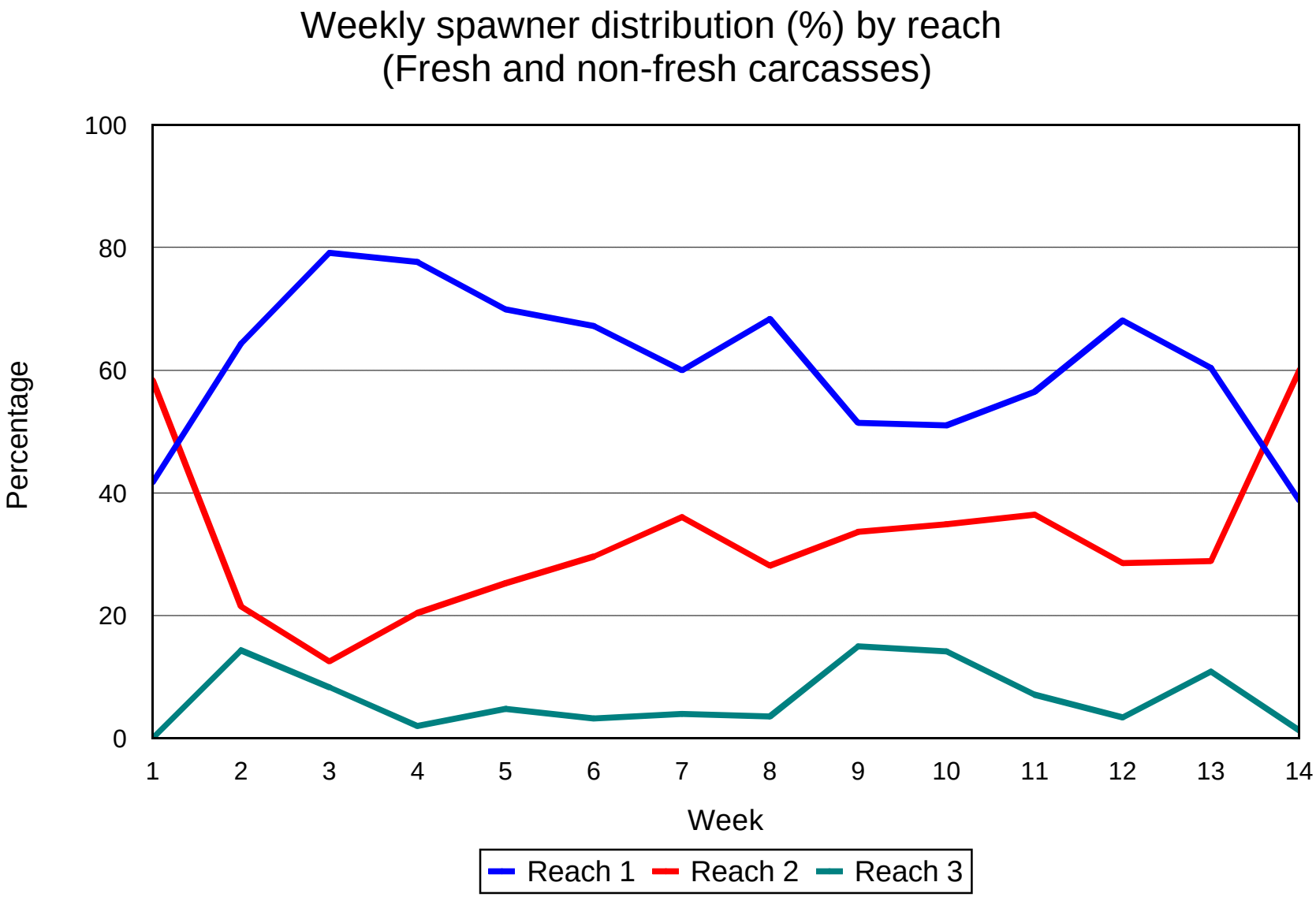

Figure 4. Weekly spawner carcass distribution, by reach (%), observed during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

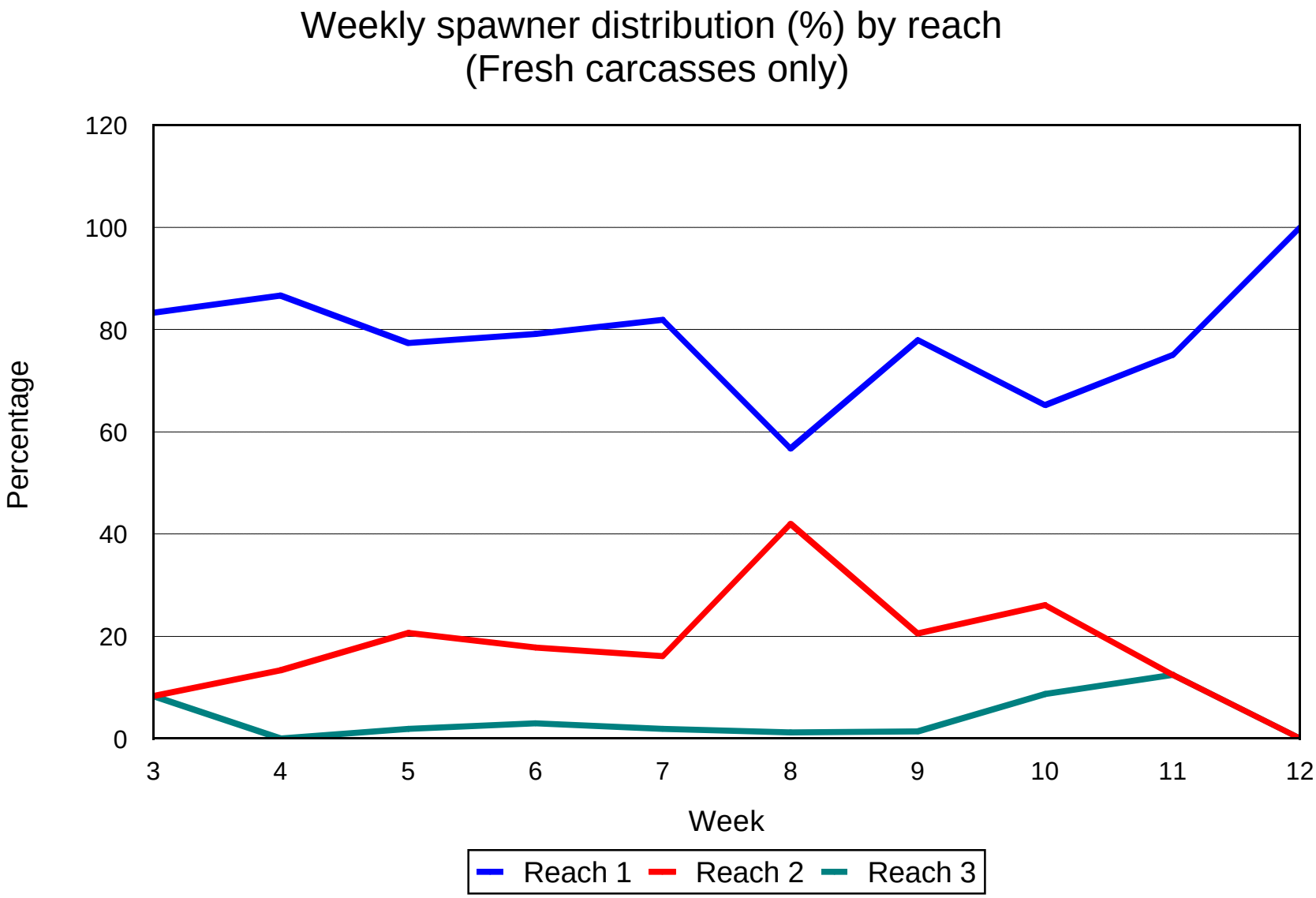

Figure 5. Weekly spawner carcass distribution, by reach (%), for fresh carcasses observed during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

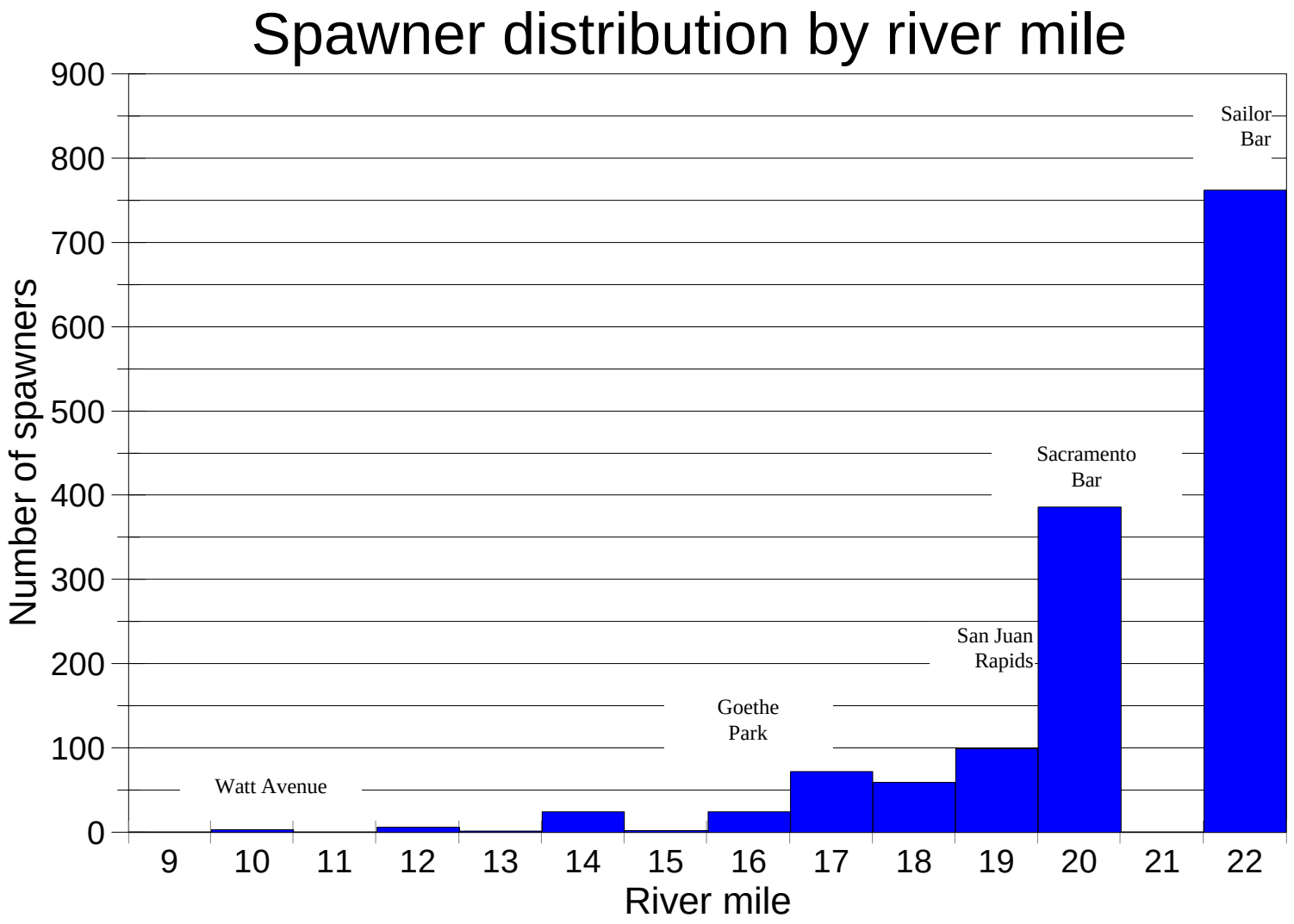

Figure 6. Spawner carcass distribution by river mile observed during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

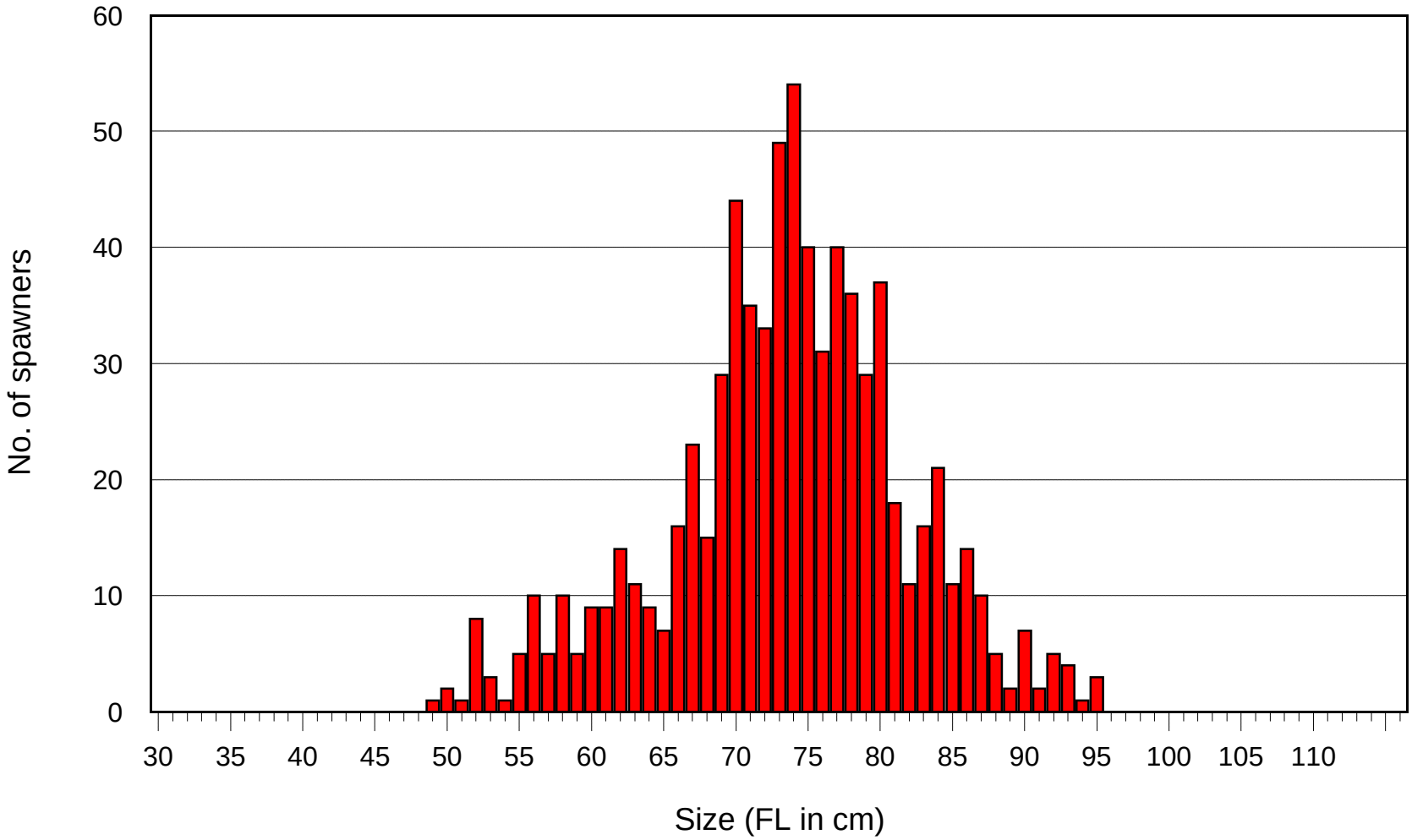

Figure 7. Size (FL) distribution of female chinook salmon carcasses observed during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

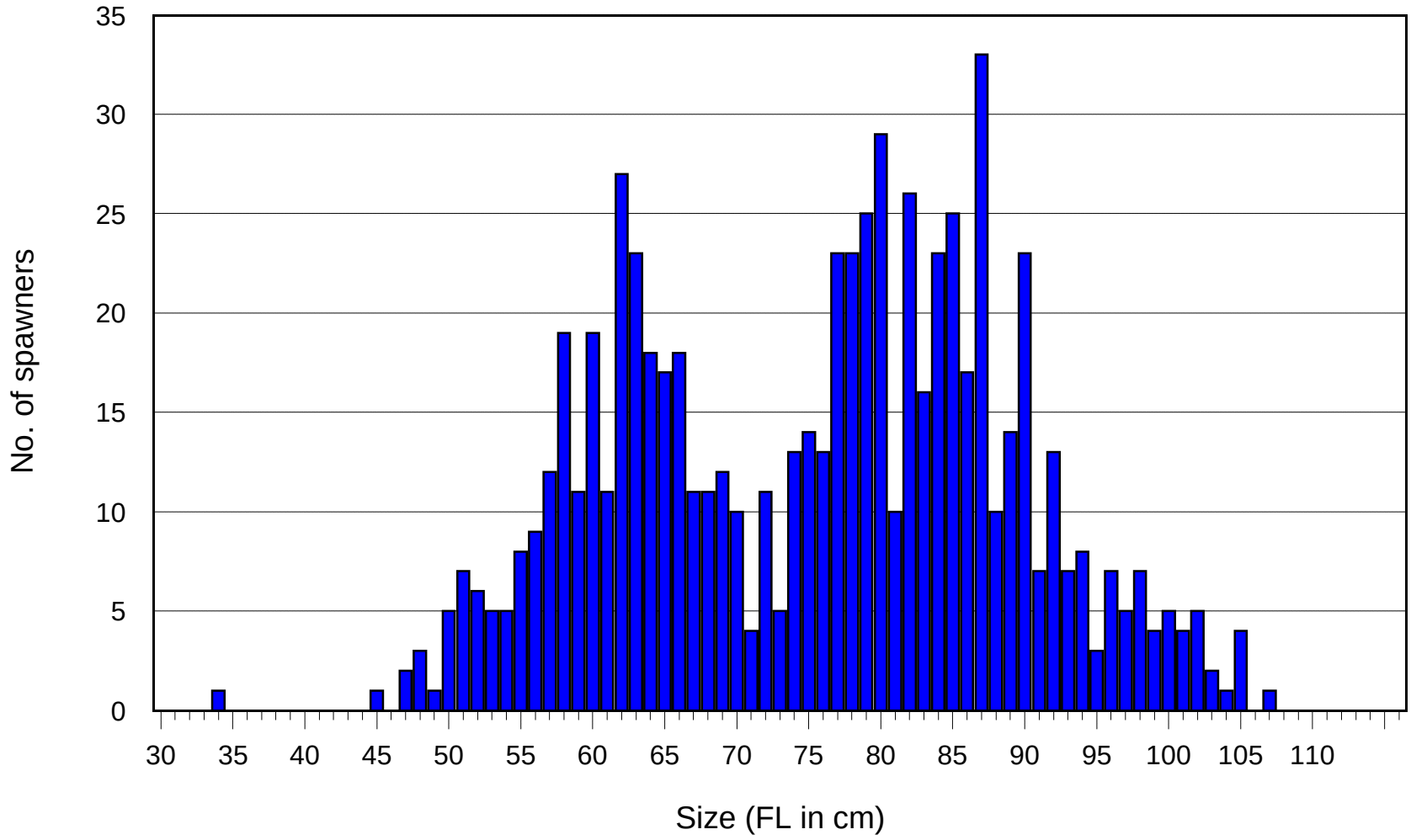

Figure 8. Size (FL) distribution of male chinook salmon carcasses observed during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

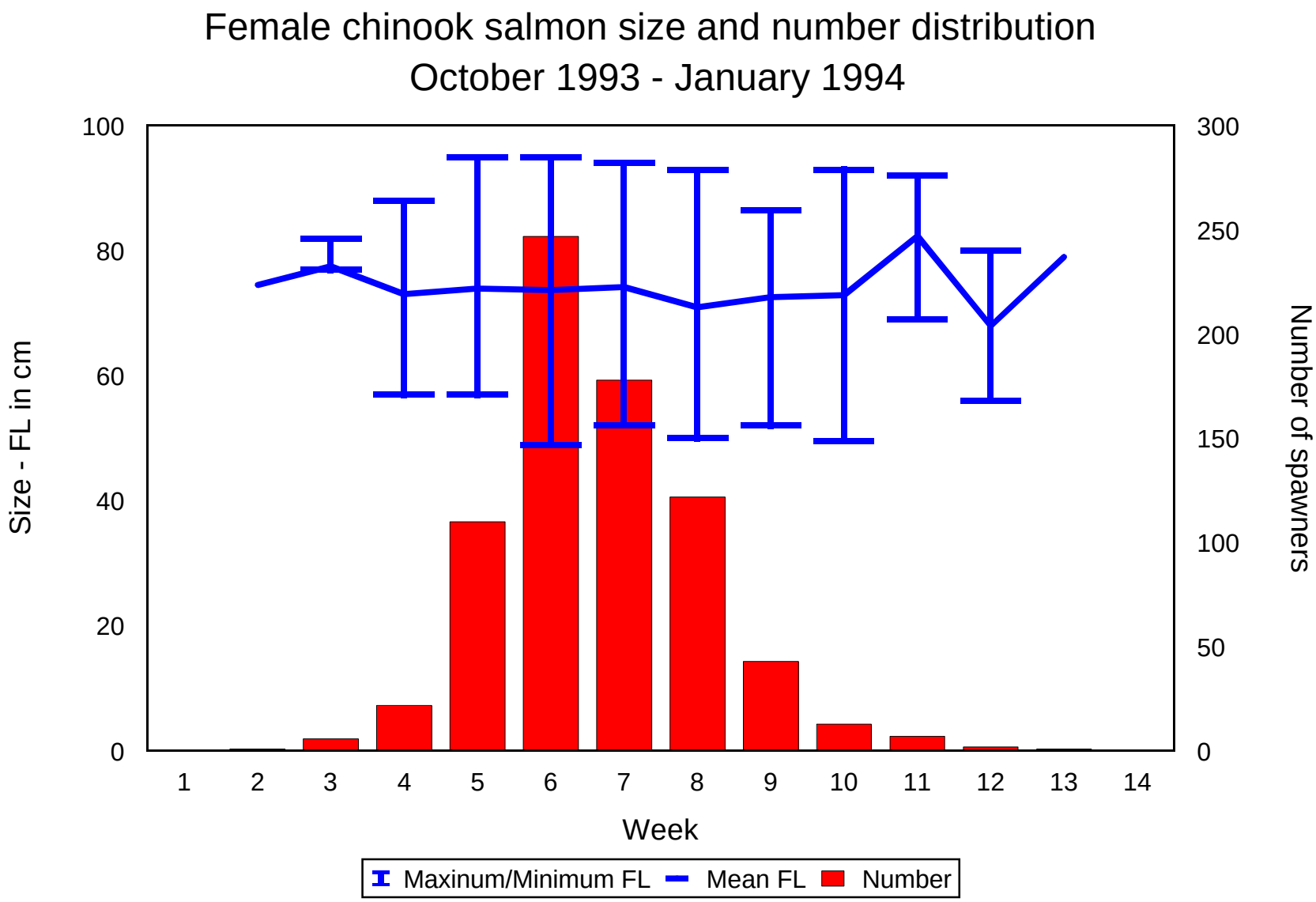

Figure 9. Mean size, size range and number of female chinook salmon measured weekly during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

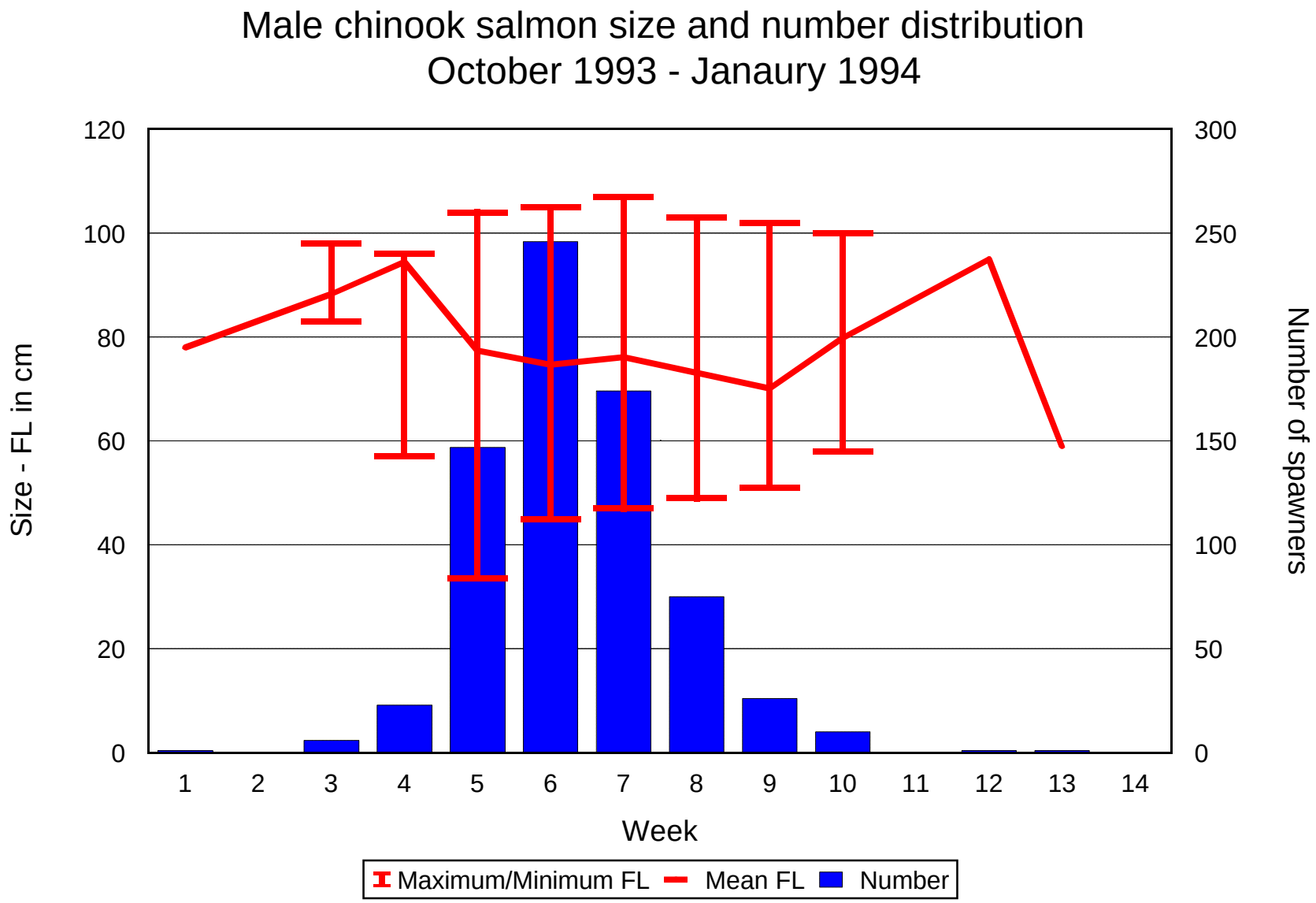

Figure 10. Mean size, size range and number of male chinook salmon measured weekly during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

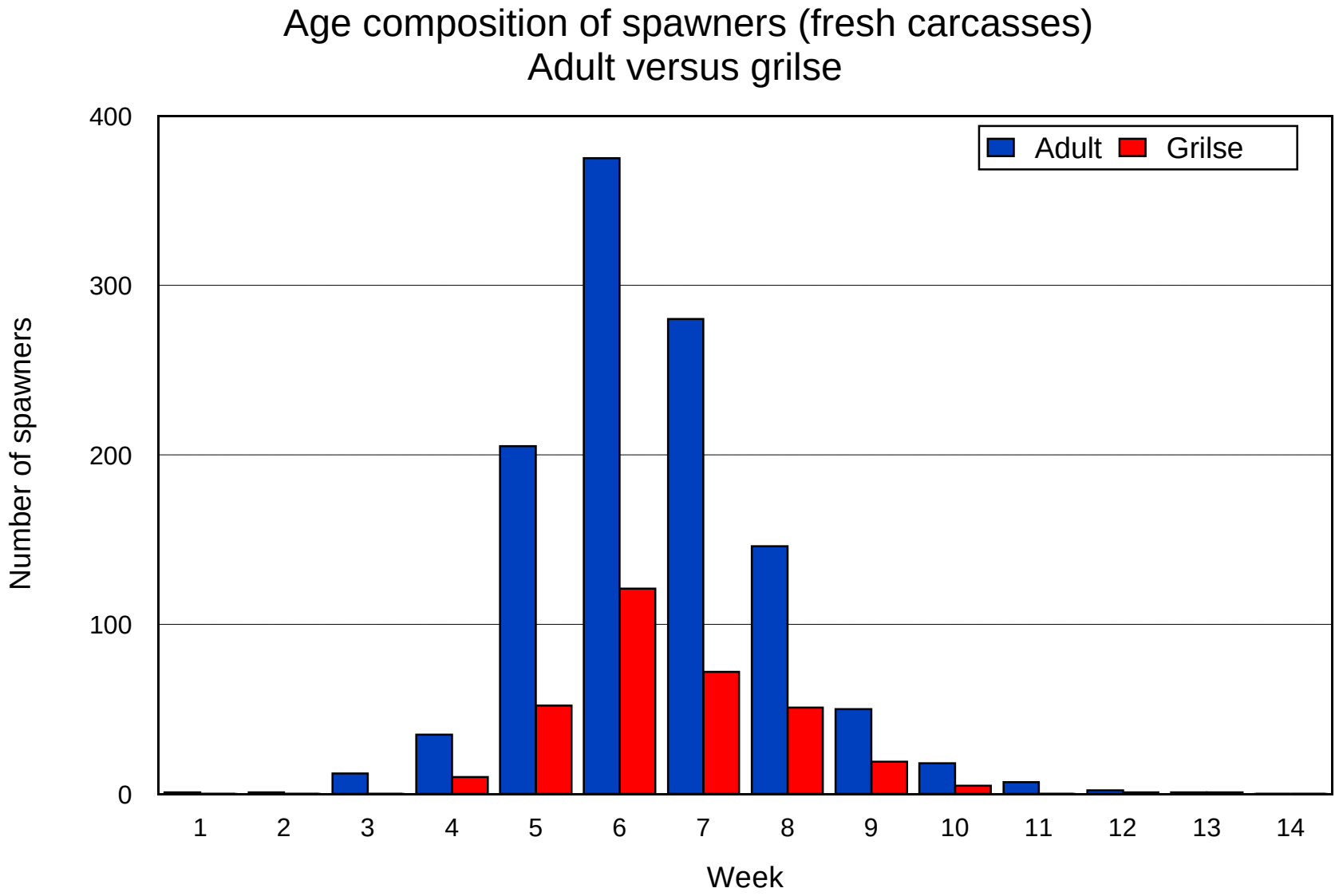

Figure 11. Age composition of chinook salmon measured during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.

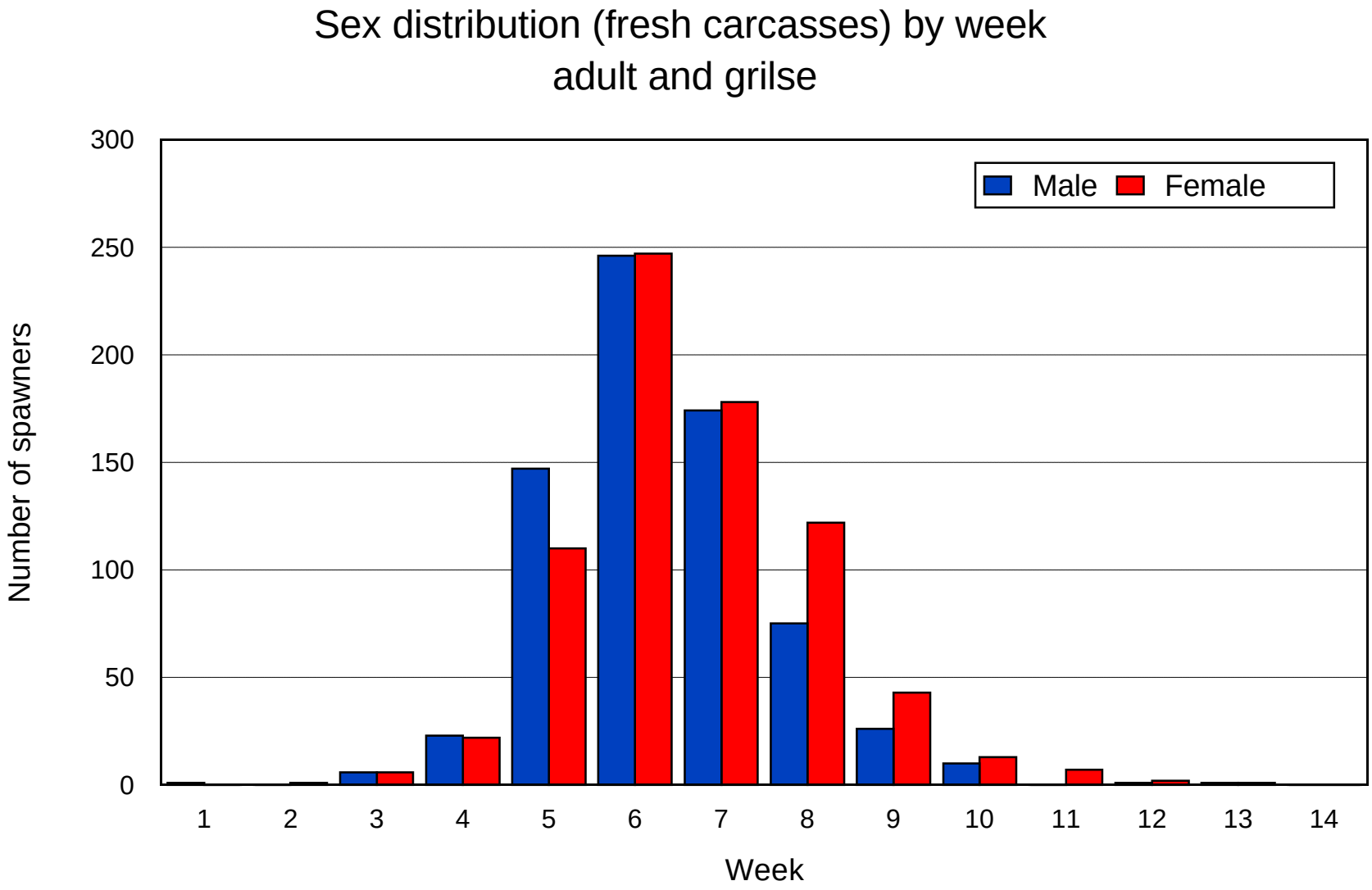

Figure 12. Weekly distribution of the sex of chinook salmon measured during the 1993 lower American River spawner escapement survey, October 1993 - January 1994.