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

Lower American River Chinook Salmon Escapement Survey September 1992 - January 1993 [1/]

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1/ A cooperative study of the California Department of Fish and Game, County of Sacramento and East Bay Municipal Utilities District. Conducted under the direction of the technical advisory committee to the Alameda County Superior Court appointed Special Master.

2/ Stream Evaluation Program Technical Report No. 93-2.

INTRODUCTION

An intensive spawning escapement survey was conducted on the lower American River during Fall 1992 to develop a reliable chinook salmon spawning population estimate. Results of the 1991 lower American River chinook redd survey showed the need for a reliable estimate to evaluate the influences of flow and temperature on temporal and longitudinal spawning distribution (Snider and McEwan 1992). 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 spawning population size. A reliable population estimate developed concurrent with redd surveys should allow this distinction. An intensive spawning escapement survey would also provide additional baseline information on spawning completeness, sex and age composition, and behavior relative to habitat conditions and population size.

The Schaefer and the Jolly-Seber methods are used commonly to develop spawning escapement estimates by salmon resource managers along the Pacific Coast. The Schaefer method (Schaefer 1951) is the primary method used by the California Department of Fish and Game. It has been routinely used in the lower American River since 1973 (Rich and Leidy 1985). The Jolly-Seber method (Seber 1982) 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 method for estimating escapement where the population or the stream being surveyed is large (Fisher, Meyer, Reavis, pers. comm.). The primary difference between the two methods involves the assumption of a closed population (i.e., no recruitment or emigration during the survey period). The Jolly-Seber method accounts for recruitment and emigration - the Schaefer model only accounts for recruitment.

Objectives

1) To estimate the lower American River fall run chinook salmon spawning population, including confidence limits.

2) To examine the Jolly-Seber and the Schaefer population estimation methods and recommend future escapement estimation procedures.

3) 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 between 27 September 1992 and 31 January 1993, to estimate the chinook salmon spawning population in the lower American River. Two different mark-recapture sampling procedures (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).

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 Wednesdays, Reach 2 on Thursdays and Reach 3 on Fridays. 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. Carcasses were examined 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 fresh carcasses observed from week 7 through week 14 were tagged with a color-coded hog ring inserted in the upper jaw to identify the week the carcass was tagged. Standard length (SL), fork length (FL) if possible, and sex were determined for each 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, 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.

Table 1. Location of survey reaches, lower American River Chinook Salmon Escapement Survey, September 1992 - January 1993.

Reach	Location	River Mile
1	Sailor Bar to Rossmoor	23.0 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

Previously tagged, (recaptured carcasses with one hog ring) were tagged with a second hog ring. The tag data were collected and the carcass was returned as described above. When carcasses with two hog rings were found, the data from both tags were recorded and the carcass was removed from the survey (chopped in two). Surveys were extended four weeks beyond the last tagging date (week 14) to recover tagged fish to estimate survival rates for the Jolly-Seber method. A Lotus 123 spreadsheet was used to calculate Jolly-Seber estimates.

Length data (SL and FL) were also collected from 20 carcasses taken at the Nimbus Salmon and Steelhead Hatchery. These data were regressed to establish a SL to FL relationship. The relationship between SL and FL was: FL = 1.11(SL) + 0.47

Water clarity (Secchi depth), flow, and water temperature data were obtained from concurrent studies (Snider *et al* 1993).

RESULTS

A total of 366 fresh carcasses and 2,226 non-fresh carcasses were observed (Table 2). Water clarity was consistently high (> 8 ft) and flows were consistently low (relative to mean post-Folsom conditions) through week 13. High visibility (> 8 ft) increases the likelihood of fish capture compared to poor visibility which hinders fish recovery. Lower flows provide better access to the river, therefore increasing carcass catchability rates. Consistent conditions reduce bias (Law 1992) and provide comparable data. Flows increased substantially after week 16 (16 January 1993) - the final recovery portion of the survey - affecting less than 10% of the spawning period (Snider *et al*. 1993).

Temporal Distribution

The temporal distribution of carcasses is bimodal (Figure 2) indicating that two distinct runs were surveyed. The lowest point between the two modes occurred during week 5 (ending 31 October 1992) signifying the break between the two runs occurred about 1 November 1992. Surveys through week 5 (beginning 28 September 1992) yielded three fresh and 127 non-fresh chinook salmon carcasses. The majority of fish were observed during the first week, implying that the peak of the earlier run occurred prior to the first survey week. Early (August-September) chinook salmon runs have been previously noted in creel censuses and coded-wire-tag evaluations (Meyer pers. comm.). Coded wire tag data indicate that the majority of this run is comprised of Feather River Hatchery fish. Between 1982 and 1991, 86% of the coded wire tagged adult chinook were from the Feather River Hatchery (Table 3). Data from the earlier portion of the survey (prior to week 6) was not used to estimate spawning escapement since this study's objective was to estimate fall run chinook salmon spawning escapement and representing the later - post week five counts.

Carcasses from the fall run spawning population were first observed 1 November 1992 during week six (1 fresh, 10 non-fresh), with substantial numbers beginning to appear during week eight (21 fresh, 44 non-fresh). The counts peaked during week 12 (79 fresh, 471 non-fresh). A total of 363 fresh carcasses and 2,099 non-fresh carcasses were counted from the potential spawning population (i.e., after week 5).

Table 2. General survey information, lower American River chinook salmon escapement survey, September 1992 - January 1993.

Week	Date	Flow (cfs)[1/]	Secchi Depth	Carcass Count	
				Fresh	Non-fresh
1	Sep 27-Oct 3, 1992	600	11.5	2	82
2	Oct 4 - 10, 1992	604	9.4	0	34
3	Oct 11 - 17, 1992	603	12.0	1	1
4	Oct 18 - 24, 1992	596	9.6	0	7
5	Oct 25 - 31, 1992	764	10.4	0	3
6	Nov 1 - 7, 1992	505	8.0	1	10
7	Nov 8 - 14, 1992	504	10.0	5	20
8	Nov 15 - 21, 1992	505	11.0	21	44
9	Nov 22 - 28, 1992	505	9.0	34	133
10	Nov 29 - Dec 5, 1992	503	9.5	84	314
11	Dec 6 - 12, 1992	503	9.0	64	372
12	Dec 13 - 19, 1992	503	8.0	79	471
13	Dec 20 - 26, 1992	504	6.0	50	333
14	Dec 27 - Jan 2, 1993	502	2.0	18	183
15	Jan 3 - 9, 1993[2/]	503	5.3	5	179
16	Jan 10 - 16, 1993 [2/]	496	NA	2	28
17	Jan 17 - 23, 1993 [2/]	12,253	NA	0	12
18	Jan 24 - 30, 1993 [2/]	6,674	NA	0	0
Total				366	2,226

[1/] Average flow of Wednesday, Thursday and Friday of that week.
[2/] Recovery survey only - no carcasses were tagged during these weeks.

Table 3. Summary of source of coded wire tagged chinook salmon collected from the lower American River during August and September, 1982 - 1991.

	Number of tags collected		
Hatchery	August	September	Total (%)
Feather River Hatchery	32	52	84 (86)
Mokelumne River Hatchery	5	6	11 (11)
Coleman Fish Hatchery	0	2	2 (2)
Nimbus Fish Hatchery	0	1	1 (1)
Total	37	61	98

Spatial Distribution

Carcasses were relatively evenly distributed between reaches 1 and 2 through week 7 (Table 4). Most of these early carcasses were non-fresh (Figures 3 and 4). Reach 1 contained most of the carcasses (92%) once significant numbers of spawned fish began to appear (week 8 through week 17). The majority of carcasses was collected from above mile 20 (Figure 5).

Size Distribution

The length frequency for all measured carcass data exhibits a bimodal distribution with two distinct distributions centered at 56 cm FL and 87 cm FL (Figure 6). These two distributions represent grilse and adult FL data. The FL representing the break between the two distributions (68 cm FL) was used to distinguish grilse (< 68 cm) from adults (≥ 68 cm). This value is consistent with previous escapement surveys on the lower American River.

Grilse comprised 29% (104) of the measured fresh carcasses, adults comprised 71% (256) (Table 5), six fresh carcasses were not measured. Grilse were present from week 9 through week 14 (Figure 7). Grilse composition ranged from 6% (week 14) to 58% (week 9) during that period. Grilse size ranged from 46 cm FL to 67 cm FL. Adult size ranged from 69 cm FL to 113 cm FL.

Sex Composition

Males comprised 59% of the fresh carcasses examined during the spawning run, beginning in week 6 (Table 6). Sixty percent (127) of the 211 male carcasses measured were adults and 40% (84) were grilse (Table 6). The majority of the 148 female carcasses measured were adults (128 or 86%); 20 female grilse were counted.

Table 4. Chinook salmon carcass distribution summary, lower American River chinook salmon escapement survey, September 1992 - January 1993.

	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	2	-	38	0	-	44	0	0	0
2	0	0	28	0	0	3	0	0	3
3	0	0	0	1	0	1	0	0	0
4	0	0	6	0	0	1	0	0	0
5	0	0	3	0	0	0	0	0	0
6	1	0	6	0	0	4	0	0	0
7	1	0	9	4	0	10	0	0	1
8	18	0	32	2	0	10	1	0	2
9	26	5	99	6	1	27	2	0	7
10	68	10	255	15	1	48	1	0	11
11	49	19	298	15	1	72	0	0	2
12	65	33	394	14	8	77	0	0	0
13	45	40	281	5	14	52	0	0	0
14	17	25	157	1	3	26	0	0	0
15	5	19	157	0	0	14	0	0	8
16	2	6	25	0	0	1	0	0	2
17	0	0	12	0	0	0	0	0	0
Total	299	157	1800	63	28	390	4	0	36

1/ Number of fresh carcasses

2/ Number of tagged carcasses recovered

Table 5. Size composition of chinook salmon carcasses, lower American River chinook salmon escapement survey, September 1992 - January 1993.

Week	Size Range (FL in cm)	Number Measured	Grilse (<68 cm)		Adult (≥68 cm)	
			Number	Percent	Number	Percent
1	80-83	2	0	0	2	100
2	No fresh carcasses measured					
3	79	1	0	0	1	100
4	No fresh carcasses measured					
5	No fresh carcasses measured					
6	88	1	0	0	1	100
7	70-95	5	0	0	5	100
8	50-97	21	9	42	12	58
9	46-107	34	20	58	14	42
10	47-103	81	33	40	48	60
11	47-103	64	20	33	44	67
12	46-113	76	17	22	59	78
13	49-100	50	4	8	46	92
14	55-104	18	1	6	17	94
15	77-89	5	0	0	5	100
16	84-105	2	0	0	2	100
17	No fresh carcasses measured					
Total	46-113	360[1/]	104	29	256	71

1/ Six fresh carcasses were not measured.

Table 6. Sex composition[1/] of chinook salmon carcasses, lower American River chinook salmon escapement survey, September 1992 - January 1993.

	Grilse				Adult				Total			
	Male		Female		Male		Female		Male		Female	
Week	N	%	N	%	N	%	N	%	N	%	N	%
1	-	-	-	-	1	50	1	50	1	50	1	50
2	No fresh carcasses surveyed											
3	-	-	-	-	1	100	0	0	1	100	0	0
4	No fresh carcasses surveyed											
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	0	0	1	100	0	0	1	100
7	-	-	-	-	4	80	1	20	4	80	1	20
8	7	78	2	12	7	59	5	41	14	67	7	33
9	17	85	3	15	10	72	4	18	27	79	7	21
10	30	81	3	19	26	55	22	45	56	69	25	31
11	13	65	7	35	28	64	16	36	41	64	23	36
12	12	71	5	29	30	51	29	49	42	55	34	45
13	4	100	0	0	14	31	32	69	18	36	32	64
14	1	100	0	0	3	17	14	83	4	22	14	78
15	-	-	-	-	2	50	2	50	2	50	2	50
16	-	-	-	-	1	50	1	50	1	50	1	50
17	No fresh carcasses surveyed											
Total	84	81	20	19	127	50	128	50	211	59	148	41

1/ Sex was not identified for seven fresh carcasses.

The ratio of males to females changed significantly as the run continued past week 8 (Figure 8). Males outnumbered females early - by as much as 4:1 during week 9 - largely due to the early presence of male grilse. The grilse sex composition ranged from 65% male (week 11) to 100% male (week 13) (Figure 9). Females outnumbered males late, after week 12 . The adult sex composition ranged from 80% male (week 7) to 78% female (week 14).

Spawning Success

Ninety-two percent of the female carcasses investigated for egg retention had successfully spawned (Table 7). Three percent were found partially spawned and five percent were unspawned.

The first two fresh female carcasses observed were unspawned (week 1 and week 6). Seven unspawned females were subsequently found during weeks 9, 12, 13 and 14 (Figure 10). Two female grilse and five adults were found unspawned. The first completely spawned female was found during week 7. Partially spawned females were found during week 8 (3 females), week 13 and 14 (1 female each).

Population Estimates

A total of 350 carcasses were tagged from week 8 through week 14, of which 185 were subsequently recovered (Table 8). Application of the Schaefer model to the data yielded an escapement estimate of 4,472 fish (Table 9). The Jolly-Seber model yielded an estimate of 3,710 fish (Tables 10 and 11).

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

DISCUSSION

Escapement estimates derived from both the Schaefer and Jolly-Seber methods were significantly lower than the previous 25 year (1967 - 1991)[1] mean of 32,307 fish (Table 13 and Figure 11). Grilse composition (29%) was the highest measured during the same period. Prespawning mortality (5%) was substantially lower than that reported for chinook salmon in the Klamath River basin (Zuspan *et al* 1991).

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[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.

Table 7. Spawning completion (egg retention) summary, lower American River chinook salmon escapement survey, September 1992 - January 1993.

Week	Number of Females Examined	Spawned		Unspawned		Partially Spawned	
		Number	Percent	Number	Percent	Number	Percent
1	1	0	0	1	100	0	0
2	0	-	-	-	-	-	-
3	0	-	-	-	-	-	-
4	0	-	-	-	-	-	-
5	0	-	-	-	-	-	-
6	1	0	0	1	100	0	0
7	1	1	100	0	0	0	0
8	7	4	57	0	0	3	43
9	7	6	86	1	14	0	0
10	25	25	100	0	0	0	0
11	23	23	100	0	0	0	0
12	34	33	97	1	3	0	0
13	32	29	91	2	6	1	3
14	14	12	86	1	7	1	7
15	2	2	100	0	0	0	0
16	1	1	100	0	0	0	0
17	0	-	-	-	-	-	-
Total	148	136	92	7	5	5	3

Table 8. Summary of tags and recaptures of chinook salmon carcasses by week.

Week of Tagging	Number Tagged	Number Recaptured									
		Week of Recapture									Total Recaptured
		9	10	11	12	13	14	15	16	17	
8	21	6	2								8
9	34		9	4	3	1					17
10	84			16	11	3					30
11	64				27	19	5	3			54
12	79					31	7	6	3		47
13	50						16	6	3	0	25
14	18							4	0	0	4
Total	350	6	11	20	41	54	28	19	6	0	185

Table 9. Chinook salmon spawning escapement estimates using the Schaefer and Jolly-Seber methods for the lower American River during Fall 1992.

Method	Age Group	Estimate
Schaefer	Grilse	1,485
	Adult	2,987
	Total	4,472
Jolly-Seber	Grilse	1,224
	Adult	2,486
	Total	3,710

Table 10. Population estimate matrix using Schaefer Method with only fresh carcasses tagged and all captured untagged carcasses removed.

Week of Recovery	Week of Tagging							Totals
	8	9	10	11	12	13	14	
9	303							303
10	129	664						793
11		181	946					1127
12		85	408	453				946
13		16	62	178*	406			662
14	42			47	92	248		429
15			27	36	84	145	183	475
16	9				26	25		60
17								0
Sum	483	946	1443	714	608	418	183	4795
Tagged	0	-34	-81	-64	-76	-50	-18	-323
							Population Estimate=	4,472

* Example:

(# recovered week i x (T_i/m) x (c_i/*m*) = estimate for week i

Calculation for tagging week = 11 and recovery week = 13 (from Table 8) is 19 x 1.18 x 7.94 = 178

T = total tagged, m = total tagged in i^{th} period, c = total fish encountered, *m* = total encountered in i^{th} period

Table 11. Population estimate matrix using Jolly-Seber method with tagged fresh carcasses marked in weeks 7 - 14 and all captured untagged carcasses removed.

Week	Number Tagged	Carcasses Examined	Number Recaptured (by week tagged)										Total
			8	9	10	11	12	13	14	15	16	17	
8	21	65	0	0	0	0	0	0	0	0	0	0	0
9	34	167	6	0	0	0	0	0	0	0	0	0	6
10	84	398	2	9	0	0	0	0	0	0	0	0	11
11	64	436	0	4	16	0	0	0	0	0	0	0	20
12	79	550	0	3	11	27	0	0	0	0	0	0	41
13	50	383	0	1	3	19	31	0	0	0	0	0	54
14	18	201	0	0	0	5	7	16	0	0	0	0	28
15	0	184	0	0	0	3	6	6	4	0	0	0	19
16	0	30	0	0	0	0	3	3	0	0	0	0	6
17	0	12	0	0	0	0	0	0	0	0	0	0	0
Total	350	2426	8	17	30	54	47	25	4	0	0	0	185

Table 12. Jolly-Seber estimate calculation - Lotus spreadsheet matrix*.

Week (i)	K(i)	b(i)	s(i)	N(i)	B(i)	N(1)	D(i)
8	0	0	0.5185	102	231	141	321.36
9	2	11	0.8726	261	1016	0	1088.02
10	8	34	0.3953	1128	558	0	887.10
11	18	42	1.00	880	678	0	650.34
12	31	94	0.7753	1229	125	0	142.16
13	24	102	1.00	713	337	0	319.63
14	21	109	0.2632	758	89	0	173.93
15	6	26	1.0000	241	-26	0	-25.50
16	0	7	1.000	31	12	0	12.0
17	0	1	1.000	13	0	0	0
						Total	3,710

* i = week (survey period); K_i and b_i= calculation variables - do not represent any specific population variable; s_i = probability of survival from i to i+1; N_i = total number in the population prior to time i; B_i = recruitment in the interval i to i+1; N(1) total population before survey period: $N_1/(s_1)^{½}$; D_i = population estimate for week i; Total population estimate = sum of Di + N(1)

The Schaefer Method estimate was greater than the Jolly-Seber estimate, as expected (Law 1992). The nearly ideal sampling conditions experienced during most of the survey allowed for high capture rates yielding relatively low estimates.

This resulted in the two methods yielding more equivalent values than would be expected under less desirable conditions such as higher, more variable flows or lower visibility that would negatively affect capture rates. If sampling conditions reduce capture efficiency it is expected that the Schaefer estimate would be higher and the difference between the two estimates would be greater. Tagging both fresh and non-fresh carcasses would be expected to increase the Jolly-Seber estimate (Law 1992).

A detailed evaluation of the Schaefer and Jolly-Seber methods is provided by Boydstun (1992) and Law (1992). They both concluded that the Jolly-Seber method was more accurate than the Schaefer method and that the Schaefer method consistently overestimates the actual population. Law found the Schaefer method to consistently lie outside the 90% confidence interval of the actual population. Law also found the Schaefer method to be more acutely affected by changes in capture rates. As such, an estimate using the Schaefer method would be expected to progressively overestimate the population, especially when capture and recovery conditions decrease due to high flows, turbid conditions, etc. Law (1992) observed that such deviations were not significantly affected by increased tagging rates.

Law (1992) also observed that tagging only fresh carcasses resulted in further reductions in the Jolly-Seber estimate - the true population was underestimated in the example given by Law when only fresh carcasses were tagged. The Schaefer method estimate was closer to the true population when only fresh carcasses were tagged. Again, the sensitivity of the two models relative to tagging fresh carcass only was dependent upon capture conditions. Jolly-Seber underestimated the population during poor capture conditions and overestimated during good capture conditions. Schaefer estimates improved by marking fresh carcasses only, particularly at high capture rates.

Criticisms of the Jolly-Seber method deal largely with the typically low estimates compared with Schaefer and the inability to compare the numerous, past Schaefer derived estimates with future Jolly-Seber derived estimates. Both methods can be used concurrently, however, since field applications are very similar. The primary difference in application between the two methods is the required extension of sampling when using Jolly-Seber. This method requires that the population be surveyed for two additional sample periods after the last tagging effort to develop a carcass "survival" estimate.

Both methods require certain assumptions be met that are difficult to achieve in large rivers (Boydstun, Law pers. comm.). We attempted to use the models developed by Law (1992) relating changes in confidence limits for both methods. Law (pers. comm.) recommended against using his models based upon his belief that large rivers do not accommodate the assumptions of either model. Boydstun (pers. comm.) suggested that the capture rates on large rivers is typically too low to use either method correctly, especially since the models were developed for estimating "live" populations. Law (pers. comm.) believes that the assumptions dealing with random mixing of released, tagged carcasses and the maintenance of equal probability of recapture for all carcasses are not achievable in large rivers.

RECOMMENDATIONS

Intensive escapement surveys should be continued to complement redd surveys. Several modifications in the 1992 procedure (listed below) should be implemented in 1993. Also, the two estimate methods should be evaluated further for sensitivity to changes in flow during and between years and various alternative tagging procedures should be considered as to the efficacy of improving the flexibility of the models relative to the various sampling conditions likely to be encountered on a large river such as the lower American River.

1. Tag non-fresh carcasses as well as fresh carcasses

2. Only tag carcasses once: stop tagging recaptured, tagged carcasses.

3. Initiate tagging within a short interval following the first spawning event. All subsequent tagging/recapture surveys should be conducted at intervals equal to the length of this first interval.

4. If the number of carcasses increases to a level that no-longer allows 100% tagging, the tagging should be proportional in each reach (e.g., 1 of 5 tagged for ALL reaches) regardless of any difference in carcass density.

Table 13. Chinook salmon escapement estimates, lower American River, 1967 - 1991.

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
Average	3,718	28,589	32,307

[1/] Expanded Direct Count, [2/] Schaefer Method, [3/] Petersen Method, [4/] Jolly-Seber Method

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FIGURES

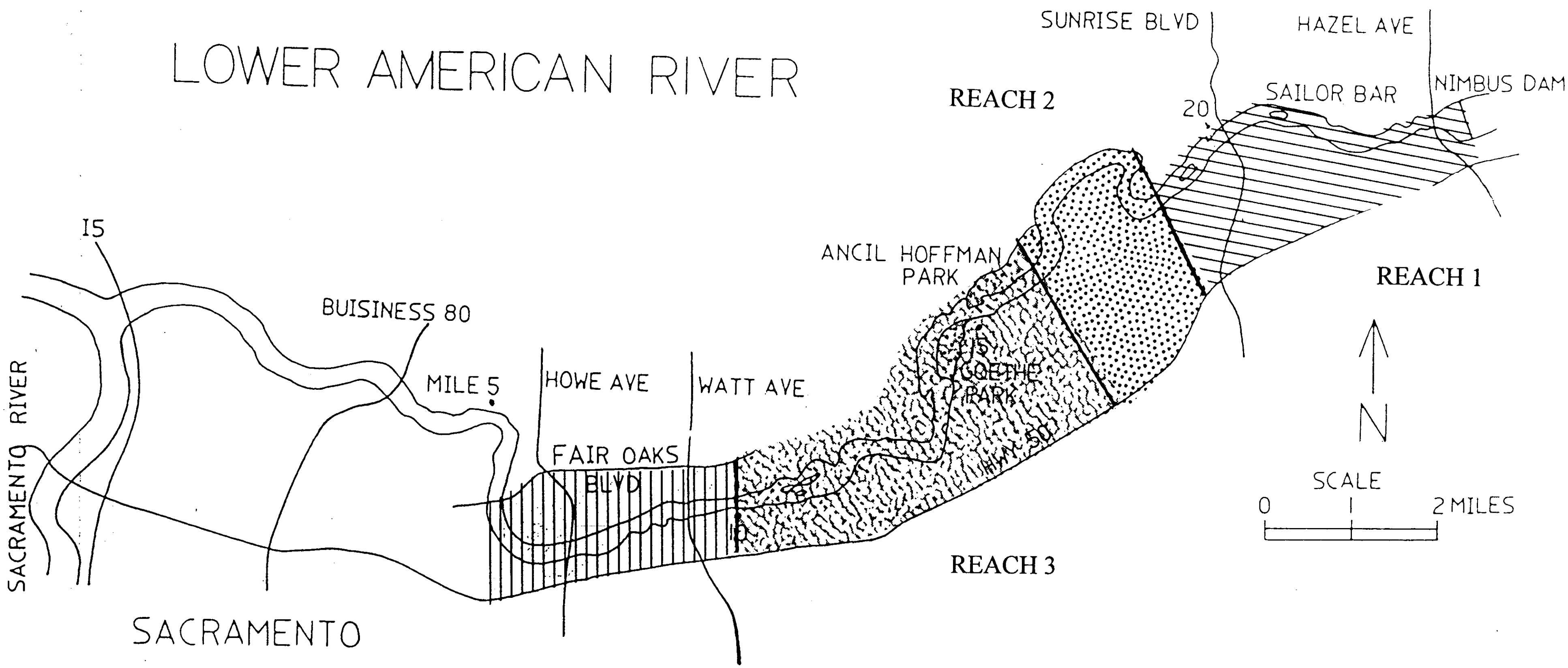

Figure 1. Location of lower American River spawner escapement survey reaches.

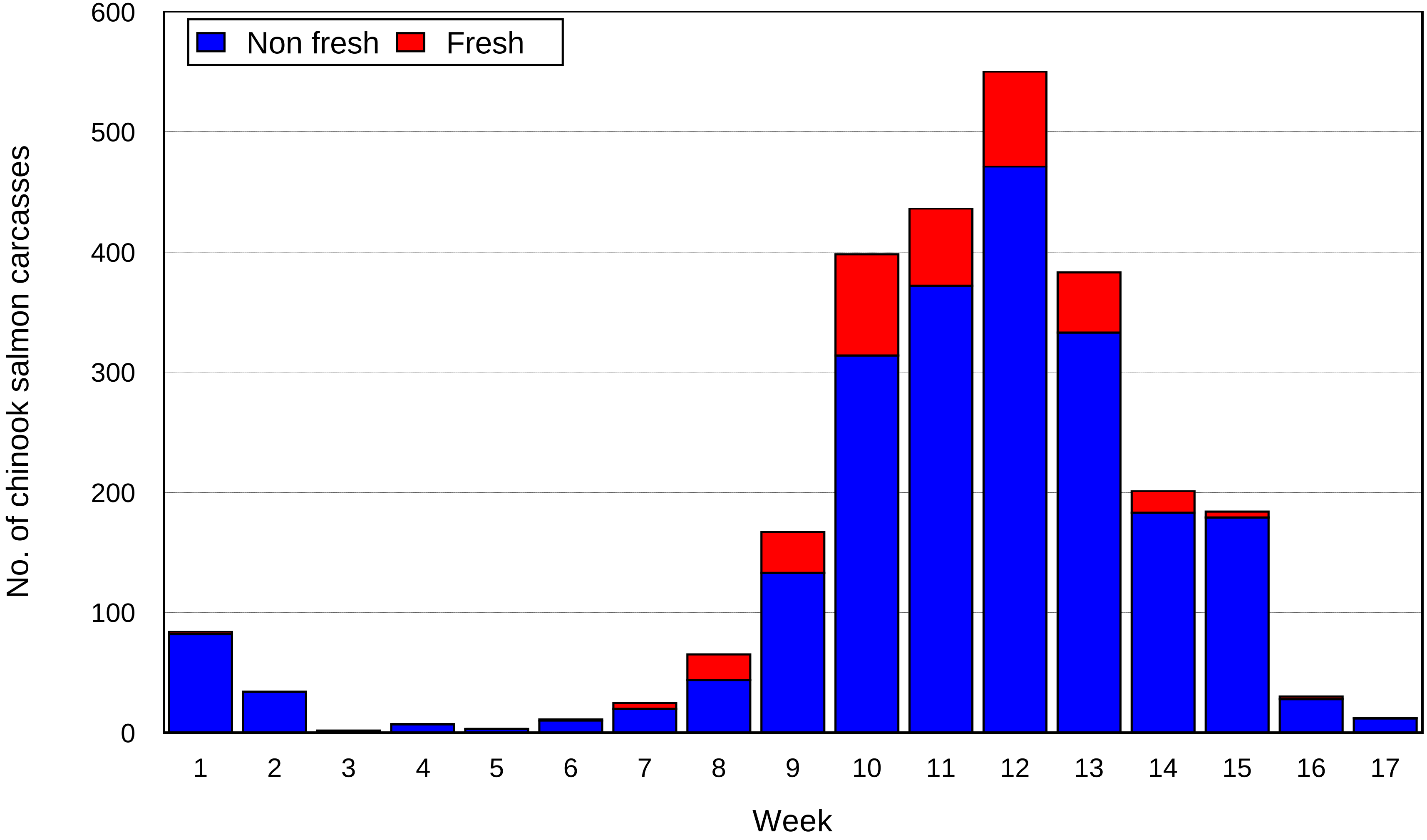

Figure 2. Weekly distribution of fresh and non-fresh carcasses counted during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

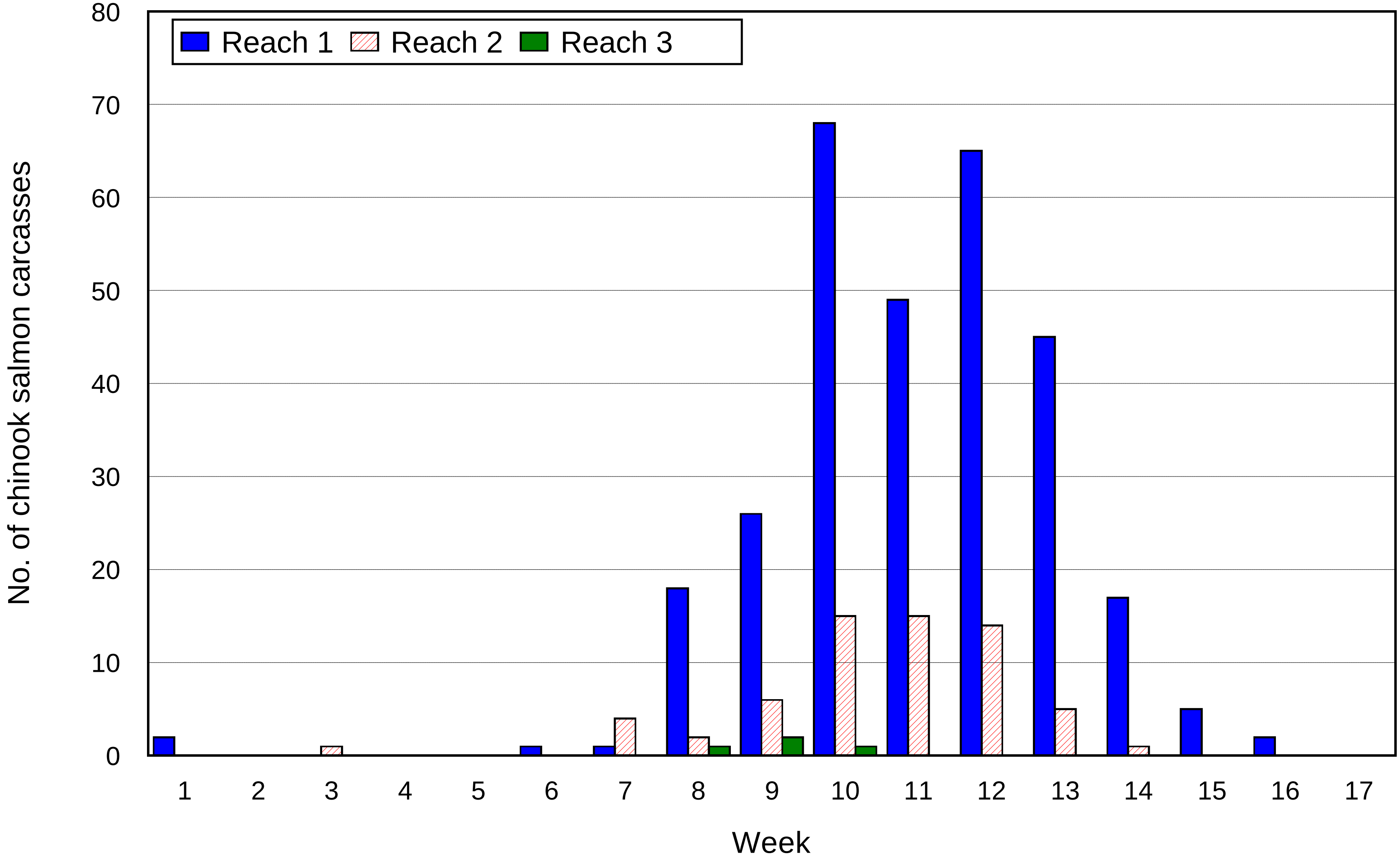

Figure 3. Weekly distribution of fresh carcass counted (by reach) during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

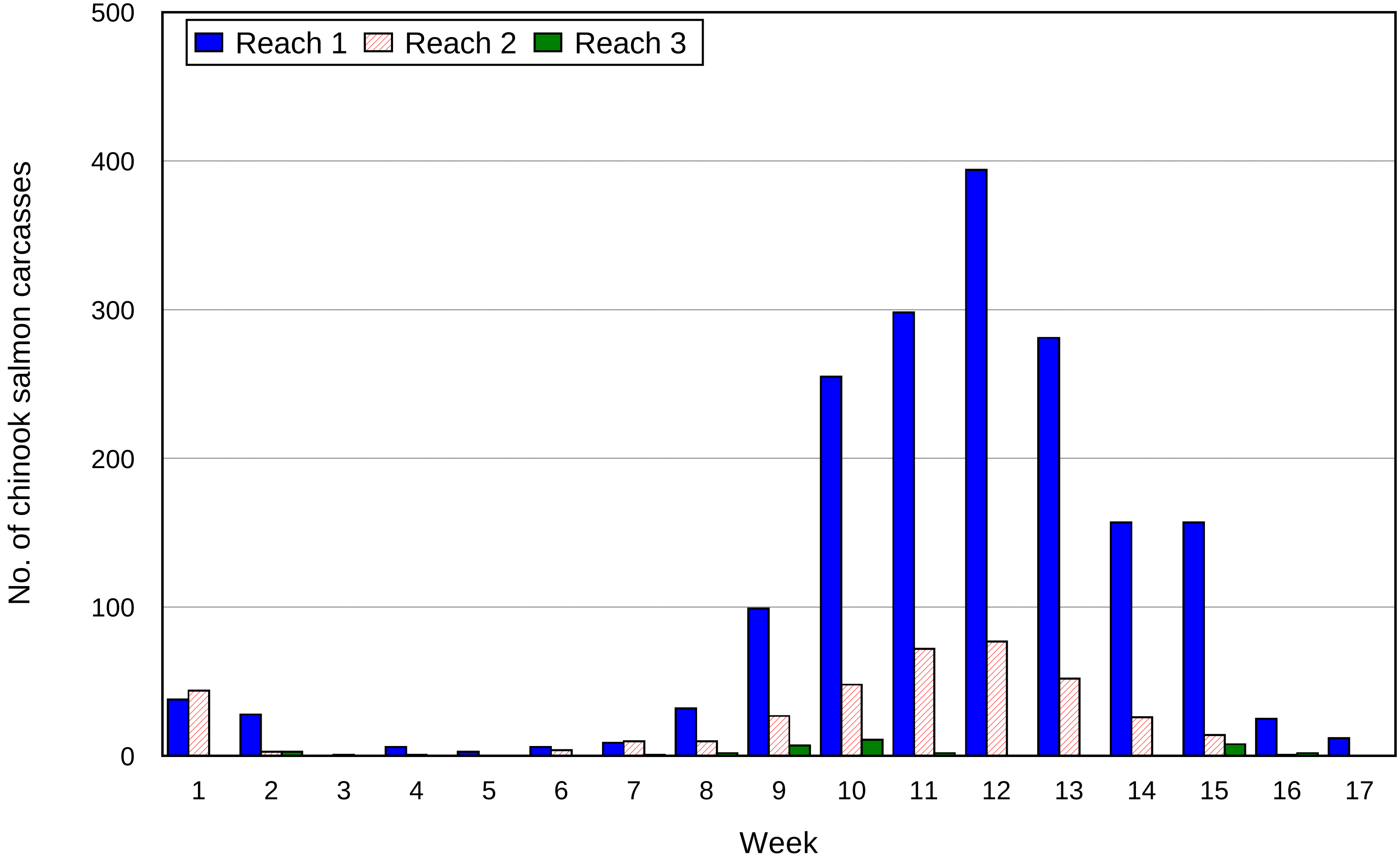

Figure 4. Weekly distribution of non-fresh carcasses counteds, by reach, during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

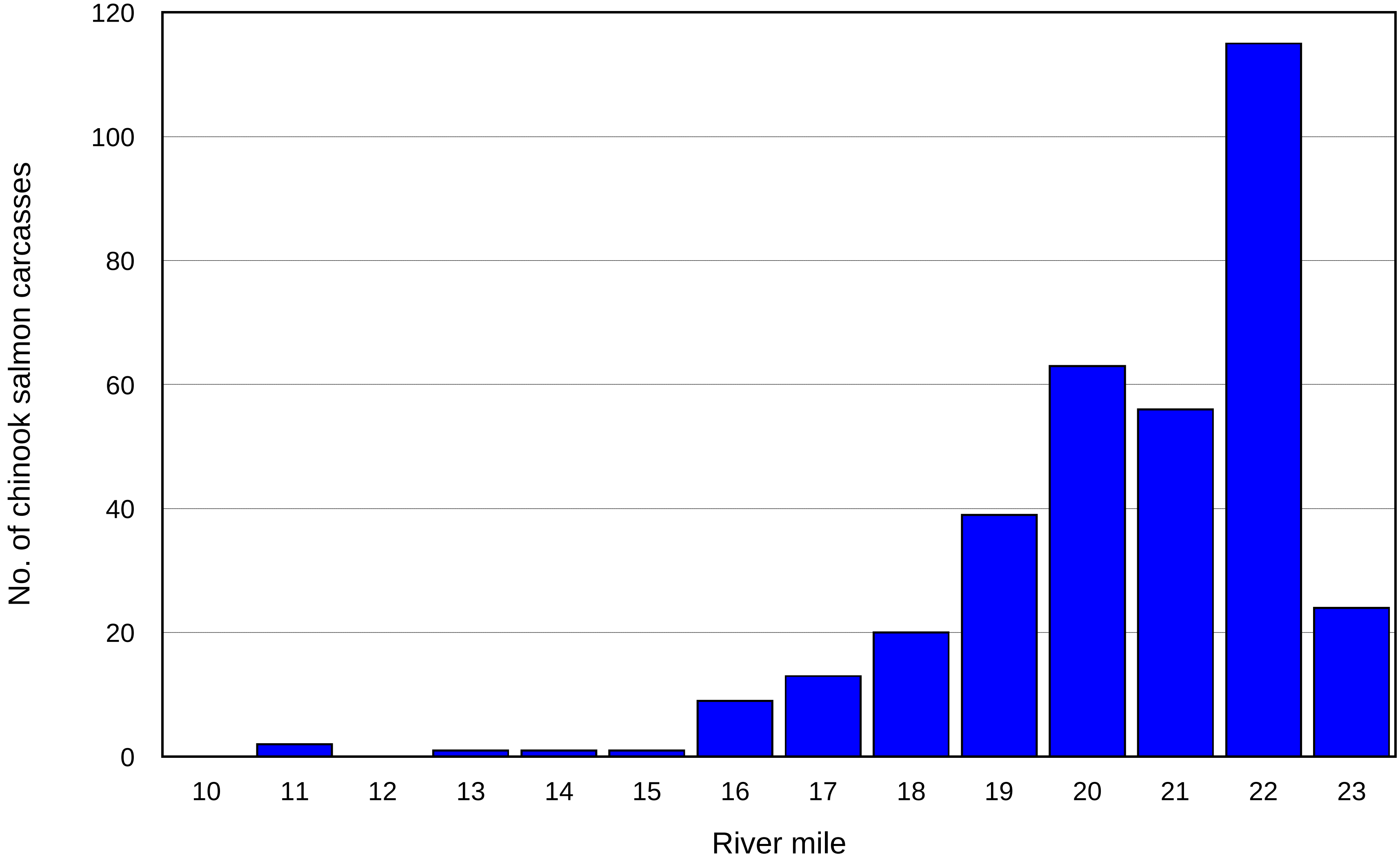

Figure 5. Spatial distribution of all carcasses (fresh and non fresh) counted, per river mile, during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

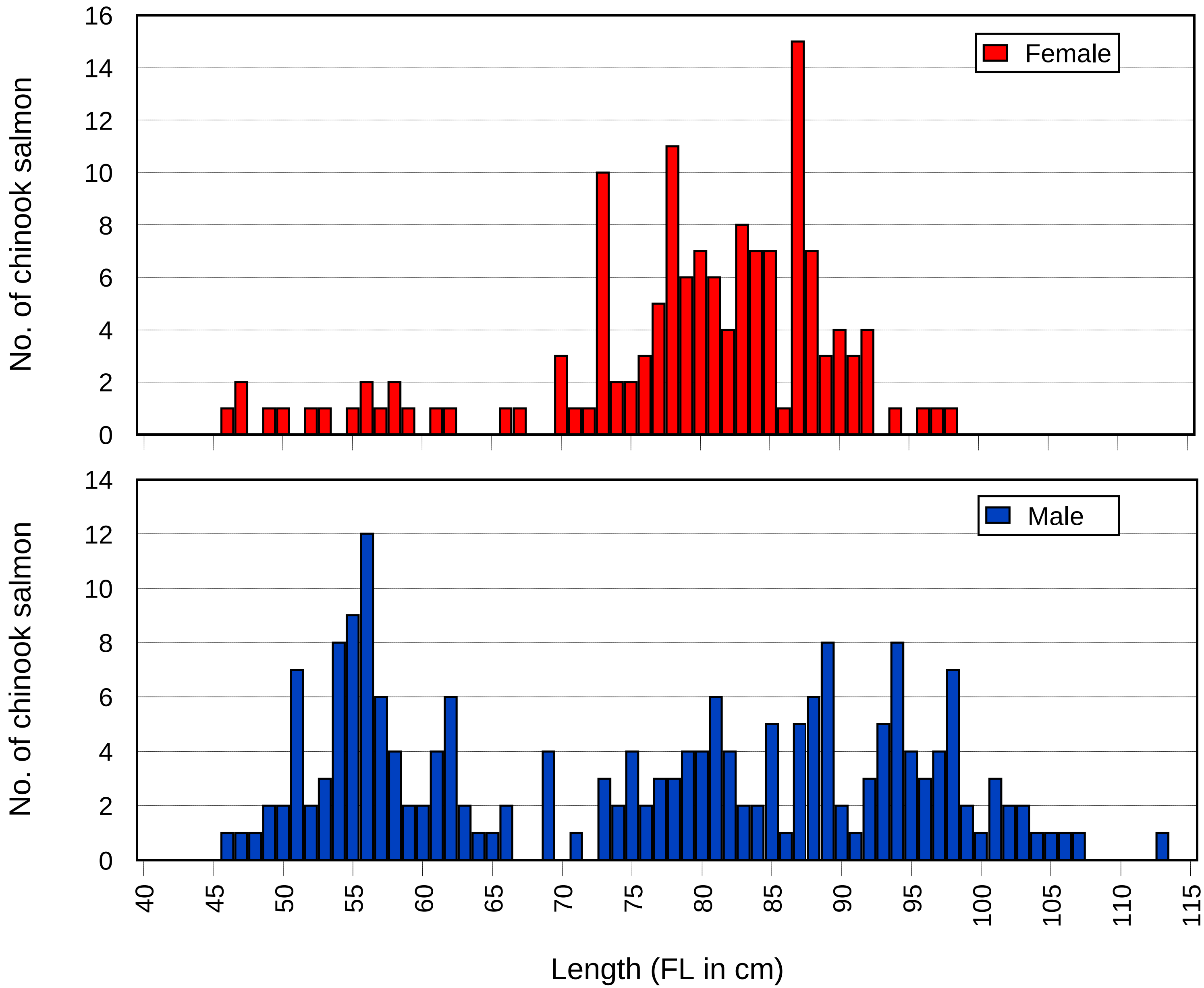

Figure 6. Length frequency distributions for male and female chinook salmon carcasses measured during the 1992 lower American River fall-run chinook salmon spawner escapement survey, 27 September 1992 - 30 January 1993.

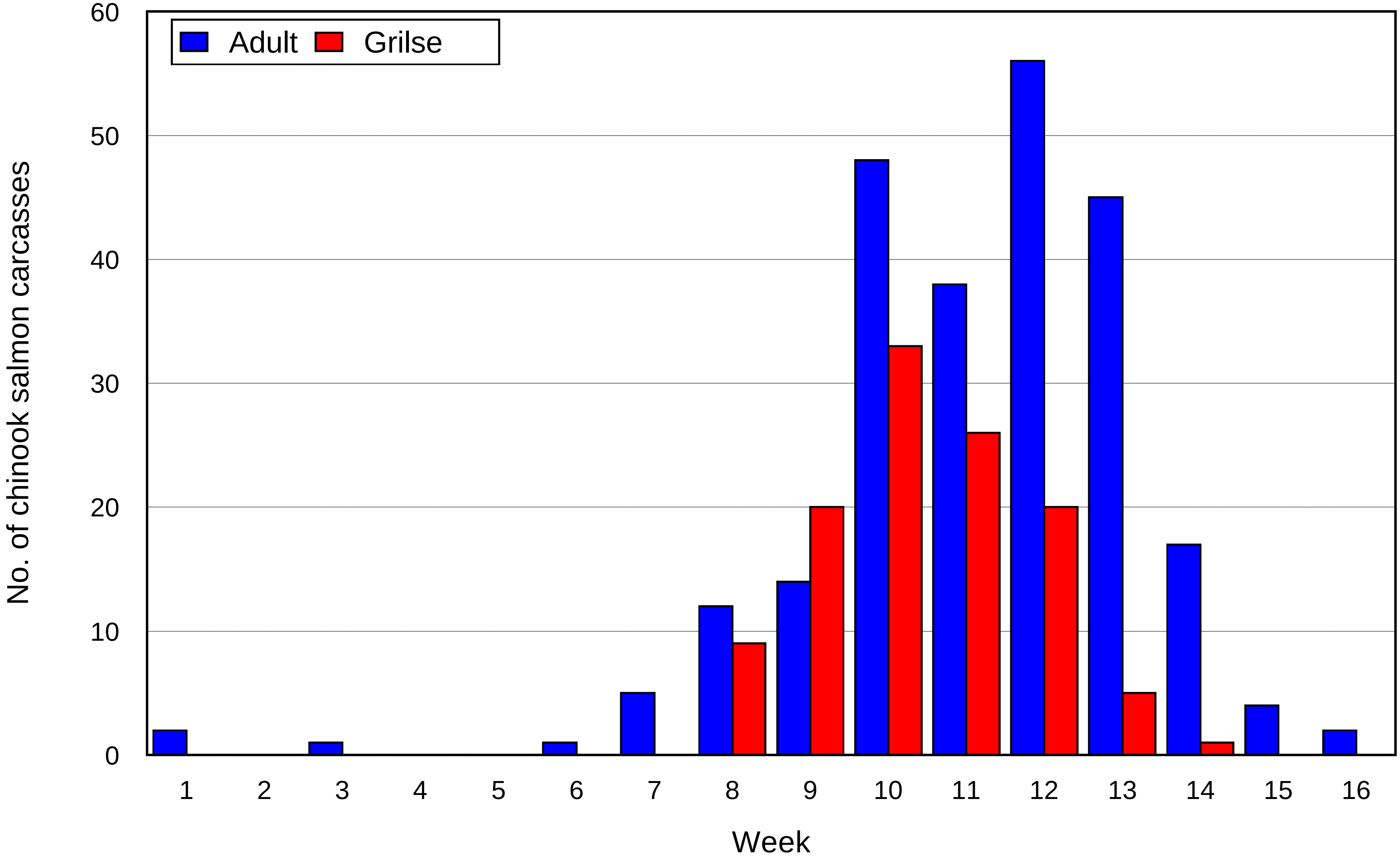

Figure 7. Weekly distribution of carcasses counted (both adult-sized and grilse-sized) during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

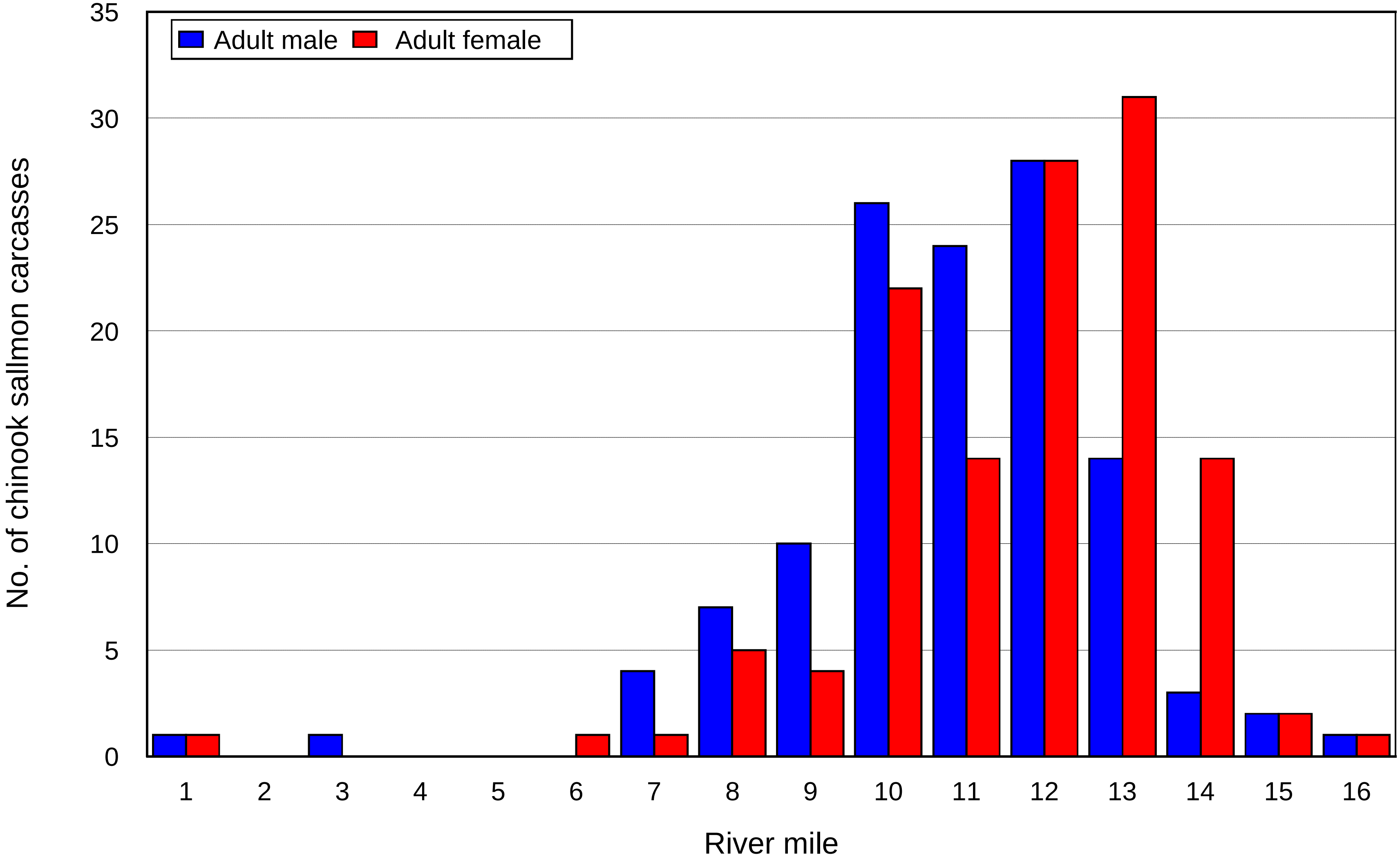

Figure 8. Weekly distribution of the sex of adult-sized carcasses counted during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

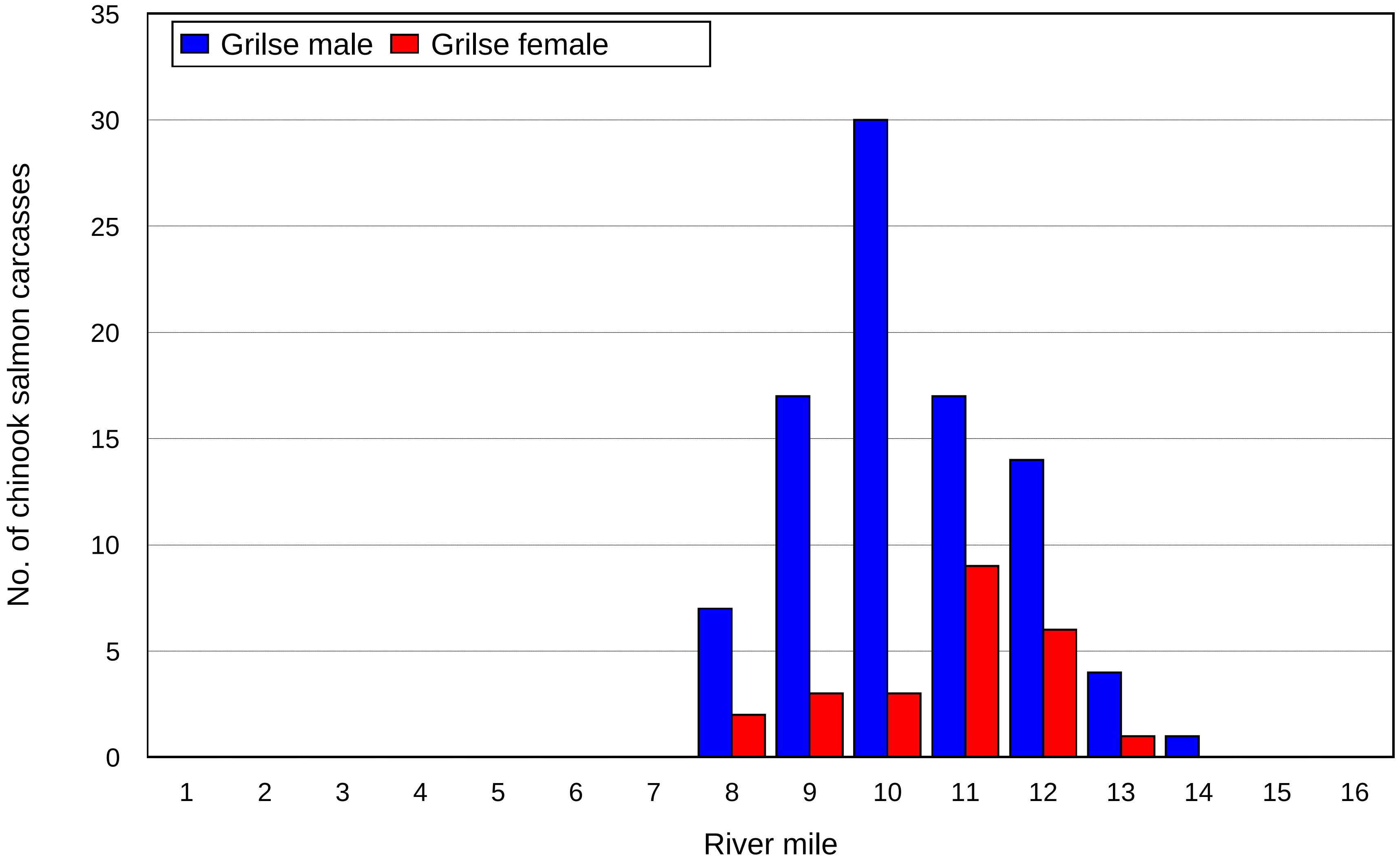

Figure 9. Weekly distribution of the sex of grilse-sized carcasses measured during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

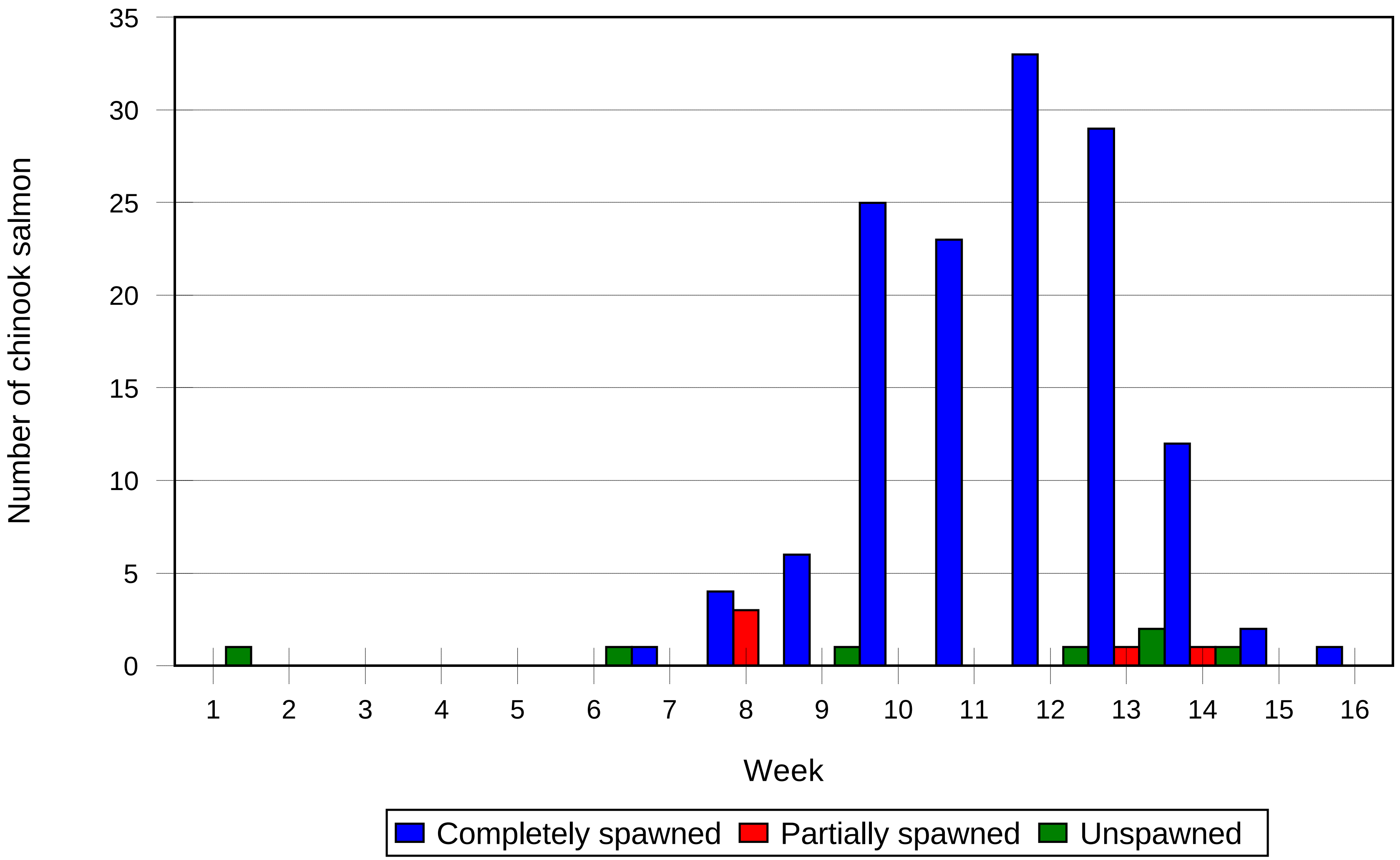

Figure 10. Weekly summary of spawning completion (egg retention) of female salmon measured during the 1992 lower American River fall-run chinook salmon escapement survey, 27 September 1992 - 30 January 1993.

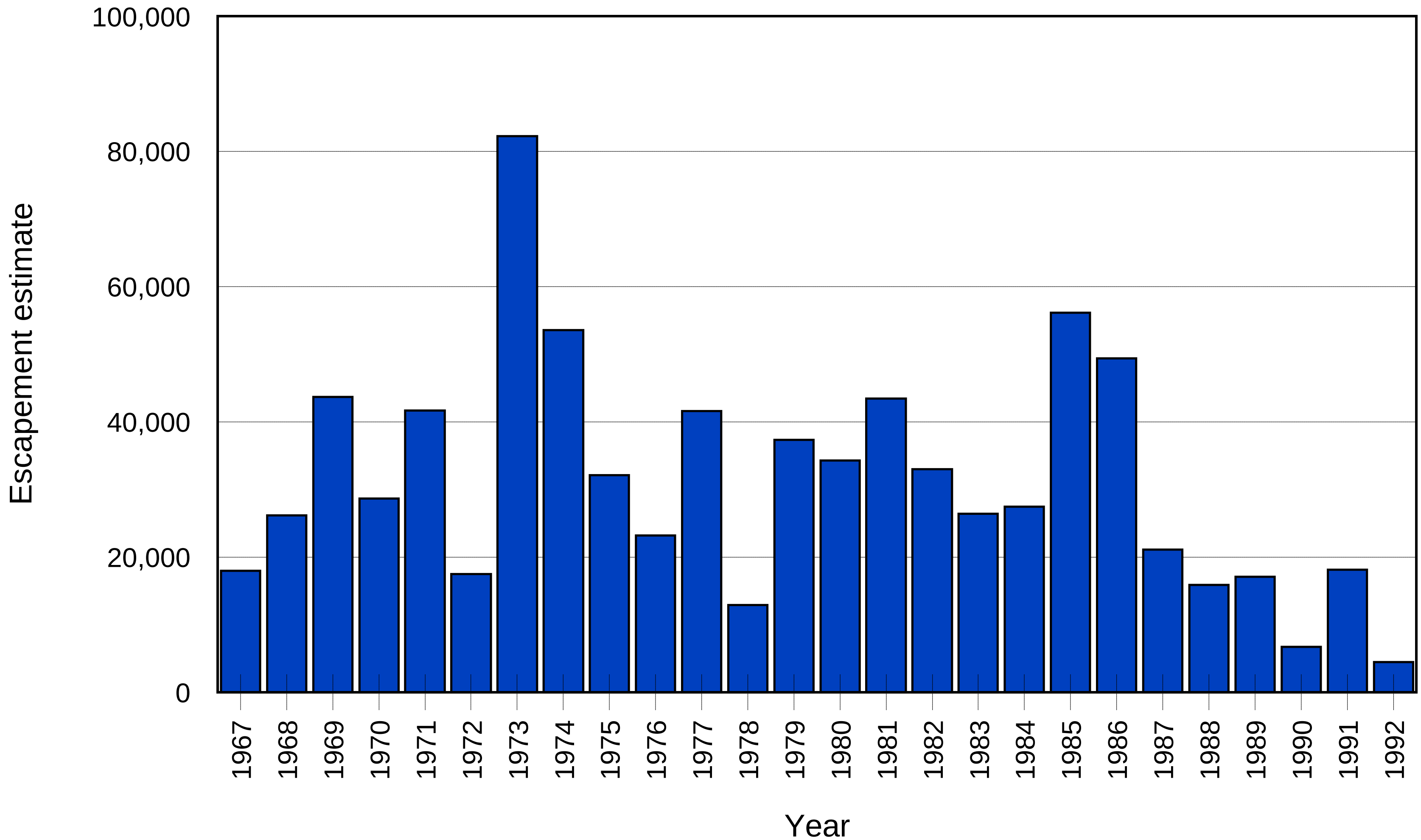

Figure 11. Comparison of annual fall-run chinook salmon escapement estimates made on the lower American River, 1967 - 1992.