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

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Stream Evaluation Program
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2/ Stream Evaluation Program Technical Report No. 97-2.
3/ California Department of Fish and Game, Stream Flow and Habitat Evaluation Program.
4/ U. S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office.

SUMMARY

A winter-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey was conducted in the upper Sacramento River during spring-summer 1996 to acquire data on spawner abundance, age and sex composition, pre-spawning mortality and temporal and spatial distribution of spawning. The survey is part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system.

The survey was conducted from 29 April through 5 September 1996. The survey included 31 miles of the river, extending from the mouth of Battle Creek to Keswick Dam, the upstream limit of migration.

We collected 118 winter run carcasses; 52 were fresh, and 66 were decayed. The winter run spawner population comprised 11% male adults, 71% female adults and 18% male grilse (two-year-old salmon). The peak of spawning occurred during the eleventh and twelfth weeks of our survey (8-18 July), and more than 90% of spawning occurred within the 14-mile-long reach immediately downstream of Keswick Dam.

We attempted to estimate winter run escapement using a mark and recapture technique on carcasses. This was the first time such a technique has been applied in the upper Sacramento River to estimate winter run escapement. A total of 82 carcasses was tagged and released; 13 tagged carcasses were recovered. Initially, we intended to use three different mark-recapture models to estimate escapement: the Schaefer, Jolly-Seber and Peterson models. The first two models require that tagged fish from each group of weekly tagged fish be recaptured during subsequent weeks. Unfortunately, no tags were recovered from 10 of the 15 tag groups. As a result we could only use the Peterson estimate which allows combining all tagging and recovery data. The winter run escapement estimate using this model was 820 fish.

A comparison of our estimate with estimates made for winter run passing upstream of Red Bluff Diversion Dam (RBDD) (940 fish) and season-long redd counts indicated that in 1996 the winter run spawner population and spawning activity were very low. Further, a sensitivity evaluation of the RBDD data using data collected on hatchery-produced, adipose-clipped winter run returning to Battle Creek suggested that both the RBDD and our escapement estimates are liberal and that the actual escapement of in-river produced winter run was probably less than 650 fish.

Our data indicate that the male to female adult ratio was 1:6.4, while the RBDD data indicate a ratio of 1:1.3. The discrepancy could reflect an inherent difference in the availability of male and female carcasses. The male salmon age structure was substantially different from criteria used by the National Marine Fisheries Service (NMFS 1996) in their extinction model. The percentage of grilse was high, while the age 3 composition was low. Female age composition was comparable to the NMFS criteria. These data indicate that there may be a serious sex-ratio and age-composition problem facing winter run accompanying the low populations.

We recommend continuing the carcass surveys with increased survey effort. We also recommend further investigation into the apparent anomalies in sex and age composition .

INTRODUCTION

A winter-run chinook salmon (*Oncorhynchus tshawytscha*) escapement survey was conducted in the upper Sacramento River during spring-summer 1996 to acquire data on spawner abundance, age and sex composition, pre-spawning mortality and temporal and spatial distribution of spawning. The survey is part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system. A fundamental component of the investigation is the determination of basic life histories of the various races of salmon in the system as a basis for identifying salmon-habitat relationships at all life stages, including spawning. Also, inasmuch as investigations into spawner habitat relationships can be influenced by spawner abundance as well as habitat availability, it is important that data on the spawner population be developed concurrent with habitat monitoring to enable distinction of the influences of these two factors on habitat use.

Escapement surveys conducted concurrently with redd surveys have been successfully used in the lower American River to identify relationships between spawning habitat availability and flow (Snider and McEwan 1992, Snider *et al*. 1993, and Snider and Vyverberg 1995). The investigations on the lower American River strongly suggest that relationships between water temperature and temporal distribution of spawning and emergence, spawner abundance and pre-spawning mortality, flow and spatial distribution, spawner abundance and habitat use as well as innate variability in expressed life history attributes can all influence the interpretation of salmon-habitat investigations. Thus, based upon our experiences in evaluating salmon-habitat relationships on the lower American River, we concluded that similar information should be developed on the upper Sacramento River.

This survey was the first attempt to use mark and recapture techniques on carcasses to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass tag-and-recapture surveys are routinely used to estimate escapement to Sacramento Valley tributary streams (e.g., American, Yuba, and Feather rivers and Battle Creek). This method was initially used in the Central Valley to estimate the 1973 Yuba River escapement (Taylor 1974). Three models have been used by the California Department of Fish and Game (DFG) to estimate escapement from carcass tag-and-recovery data: Petersen (Ricker 1975), Schaefer (1951) and the Jolly-Seber (Seber 1982). The Petersen model is the simplest but least accurate (Law 1992) and 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). A modified Schaefer model has been used in "larger" Central Valley tributary streams since 1973 when it was first used to estimate the Yuba River escapement. The Jolly-Seber model was first used in the Central Valley in 1988 to estimate escapement in the Feather, Yuba, American, Stanislaus, Tuolumne, and Merced rivers.

Since 1971, winter run escapement estimates have been based upon counts of salmon using fishways that provide passage around Red Bluff Diversion Dam (RBDD; river mile 243). Counts can only be made when the diversion is in operation, when all the diversion gates are down, and all fish migrating to areas upstream of RBDD must use the fishways located in the center and on the east and west ends of the dam. Between 1971 and 1986, RBDD was typically operated throughout the entire winter run migration period allowing a complete accounting of winter run escapement. Salmon using the fishways were counted from a combination of actual daytime counts (east and west fishways) and from counts made from daytime video recordings of fish using the center fishway. The daytime counts were expanded using weekly nighttime count data.

Beginning in 1987, operation of RBDD was modified to accommodate winter run migration. Presently, the diversion operates from approximately 15 May through 15 September. Based upon complete season counts made prior to 1987, on average, only about 15% of the winter run spawner population passed RBDD after 15 May (range: 4.7-24.3%). Fish counts are now based upon an expansion of the number of fish caught in a trap located in the east fishway. The trap is usually operated five days a week from 0600 to 1500. Collected fish are identified to species or, if a salmon, to run. (Fish are also measured and checked for marks). The number of winter run counted is expanded to a weekly count based upon historic proportionate use of the three traps. Escapement is estimated by expanding the weekly “count” assuming it is proportionate to historic, season-long counts. The count is divided by the mean proportion of the total population that passed RBDD (when counts were season-long) based on the date the diversion is placed in operation (e.g., 15% for 15 May).

Results of the carcass survey may be used for comparison and possible augmentation of data collected on winter run escapement at the RBDD. Similarly, the survey could augment weekly surveys of winter run redds. The U.S. Fish and Wildlife Service (FWS), Northern Central Valley Fish and Wildlife Office and Coleman National Fish Hatchery (CNFH) could also use the survey data to evaluate their program aimed at augmenting winter run escapement with winter run spawned and reared at CNFH (USFWS 1996, Croci and Hamelberg 1997).

Objectives

- To estimate the 1996, in-river, winter-run chinook salmon population for the upper Sacramento River based on a carcass tag-recovery study and augment estimates that are based on RBDD counts.

- To examine the feasibility of using mark-recapture techniques (i.e., Peterson, Jolly-Seber, and Schaefer population models) to estimate winter run escapement in the upper Sacramento River, and recommend future escapement estimating procedures.

- To obtain baseline information on spawning distribution (spatial and temporal), environmental conditions at time of spawning, and spawning population (size, sex composition, and spawning success).

Background

Winter run are one of four chinook salmon runs present in California's Central Valley; the other three runs are fall, late-fall, and spring. Winter run generally leave the ocean and enter fresh water to begin their upstream migration from December through June. The peak of the run normally passes RBDD in March and April. They spawn from mid-April through mid-August with most of the spawning occurring in May and June.

The earliest references to winter run salmon have been summarized by Fisher (1993). In 1874, Livingston Stone noted winter run in the McCloud River (a tributary to the Sacramento River that presently drains into Shasta Lake). Stone was charged with establishing an egg-taking station to provide a source of salmon eggs to the eastern states. To carry out this charge, he established Baird Hatchery on the McCloud River near its confluence with the Sacramento River. Fisher (1993) concludes this run may also have historically spawned in the upper Sacramento River above Shasta Dam as well as in the Pit River and Battle Creek. Their status since the construction of Shasta Dam has been described by Slater (1963), Hallock and Fisher (1985), and Fisher (1993). Due to a drastically declining population, winter run were listed by the California Fish and Game Commission in 1989 as endangered and by the NMFS as threatened in 1990 and then as endangered in 1994.

The NMFS (1996) has developed an extinction model for winter run that they have used to identify population conditions that indicate when *the probability of the population going extinct are at an acceptable level.* Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over any 13 consecutive years is 10,000 females. This population level assumes that the male:female ratio is 1:1 and that the age structure is comparable to that observed by Hallock and Fisher (1985) over 3 brood years. The assumed age structure is 50% 2-year olds, 44% 3-year olds and 6% 4-year olds for males and 89% 3-year olds and 11% 4-year olds for females. The population criteria also assume that managers will be able to estimate the escapement each year with a precision of 25%.

The DFG entered an agreement with the FWS, Central Valley Anadromous Fish Restoration Program in 1995 to evaluate habitat requirements for anadromous salmonids using Central Valley streams. Various studies have been developed and are being implemented by the DFG to provide the FWS with reliable scientific information. The information is to be used by the DFG and the FWS to develop flow recommendations to satisfy requirements of the Central Valley Project Improvement Act, Section 3406(b)(1)(B). The Sacramento River was selected for intensive fish-habitat investigations due to the significant influence the Central Valley Project has upon flow, temperature and ultimately fish habitat in the river. Furthermore, the upper Sacramento River is the only stream reach in the Central Valley that supports all four chinook salmon races and steelhead. The exclusive occurrence of winter-run chinook salmon - a federally and state listed species - and the presence of rapidly disappearing steelhead, presently being considered for federal listing, underscore the significance of habitat in this stream reach.

METHODS

The FWS, Northern Central Valley Fish and Wildlife Office and the DFG's Stream Flow and Habitat Evaluation Program jointly conducted a carcass mark-and-recapture study to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The study was carried out from 29 April 1996 through 5 September 1996. The segment of stream studied is located between Keswick Dam (river mile 302) and the mouth of Battle Creek (river mile 271) (Figure 1). This segment of river is the primary spawning area for winter run in the upper Sacramento River, although a few are occasionally observed downstream of the mouth of Battle Creek.

The survey segment was divided into the following four reaches:

1. Keswick Dam to Hwy. 299 Bridge - river mile 302 to 297,

2. Hwy. 299 Bridge to Bonnyview Bridge - river mile 297 to 292,

3. Bonnyview Bridge to North Street Bridge (City of Anderson) River - river mile 292 to 283, and

4. North Street Bridge to mouth of Battle Creek - river mile 283 to 271.

Typically, one day per week was spent surveying each reach. Most of the survey effort was conducted by boat (two boats and two persons per boat). Each boat was generally used to survey along one shoreline out to the middle of the river. There were several short stretches of river that were surveyed on foot. Survey efforts were usually more concentrated in areas where carcasses were known to collect.

Population estimates

A carcass tag-and-recovery study was used to estimate winter run escapement in the mainstem Sacramento River above Battle Creek. A gaff or gig was used to collect carcasses. We tagged all collected carcasses except those that were in an advanced state of decay. (Untagged carcasses were chopped in half). Carcasses were tagged with a small colored plastic ribbon attached to the upper or lower jaw with a hog ring. The tag color was used to identify the week the carcass was tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the upper jaw. Decayed carcasses were tagged in the lower jaw. Carcass condition (fresh versus decayed) was recorded to accommodate the different models used to estimate escapement: the Schaefer model uses only fresh carcass data; the Jolly-Seber model uses both fresh and decayed carcass data. This approach is consistent with the procedures used for other Central Valley streams. All tagged carcasses were returned to flowing water near the location where they were originally recovered. This method of depositing the tagged carcass is assumed to allow the

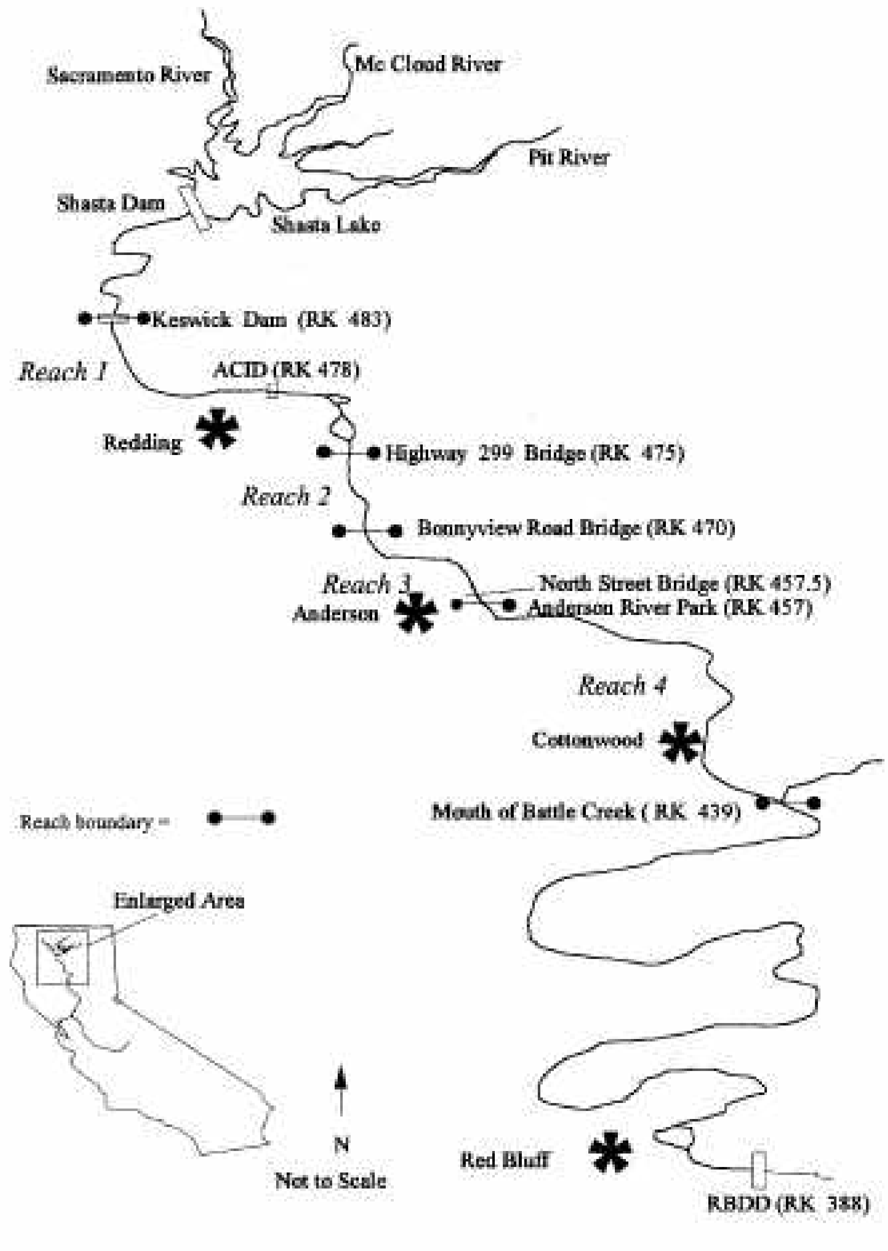

Figure 1. Upper Sacramento River chinook salmon escapement study location including reach designations.

carcass to mimic the manner that naturally dying fish disperse in the stream. Recovered carcasses were examined for tag color and location of tag (upper or lower jaw). The pertinent data were recorded and the carcass was chopped in half. All chopped carcasses were disregarded in subsequent surveys.

Size/age distribution and sex composition

Fork length (FL), sex, and date observed were recorded for all carcasses except those that were so badly deteriorated as to preclude an accurate measurement. The length frequency distribution was then used to define the length cutoff between adults (>2 years old) and grilse (2 years old). Initially, adults were defined as fish $\geq$ 65 cm FL and grilse as fish < 65 cm FL. After later examination of the length frequency distribution, male adults were slightly redefined as salmon > 65 FL and grilse $\leq$ 65 cm FL. Similarly, all males > 95 cm FL and females > 85 cm FL were considered 4-year old fish.

Temporal distribution

Weekly totals of both fresh and decayed carcasses were tabulated for the entire study segment. The totals were used to define temporal distribution (weekly) of winter run spawning activity above Battle Creek. Carcasses were assumed to be found within two weeks of spawning completion based upon observations made in the American River (Snider and Vyverberg 1995).

Spatial distribution

Weekly totals of both fresh and decayed carcasses were calculated for each of the four reaches. The totals were used to generally identify geographic distribution of spawning activity. Flow likely carried some carcasses from the reach where spawning occurred to a downstream reach where recovery occurred, potentially biasing the spatial distribution of spawning toward downstream reaches.

Spawning success

Primarily, fresh female carcasses were examined for eggs. Females were classified as spent if few eggs remained in the body cavity; as partially spent if a substantial amount of eggs still remained; and unspent if they appeared to be completely full of eggs (unspawned).

Flow measurements were obtained from the US Geological Survey Keswick gauge. Water temperatures were measured daily by the survey crew.

RESULTS

General

A total of 118 carcasses, including 52 fresh and 66 decayed carcasses, was collected during the 19-week survey. Carcasses were collected during each week, except in the last survey week, (3-5 September; Table 1). The highest carcass count was in week 12 (15-18 June). Mean weekly flow ranged from 7,200 cfs in week 2 (6-9 May) to 16,200 cfs in week 4 (20-23 May). Flow was consistently high (12,000 to 15,000 cfs) after week 3 (Table 1). Mean weekly water temperature was typically less than 56 ^{o}F, except during week 10 (1-3 July) when it reached 59 ^{o}F.

Population estimates

A total of 86 carcasses was tagged from week 1 through week 15 (Table 2). No carcasses were tagged in week 4). We recovered 13 tagged carcasses. There were 131 carcasses examined (including the 13 tag recoveries). There were no tag recoveries for 10 of the 15 weekly tag groups (Table 2). As a result, neither the Jolly-Seber nor the Schaefer models could be used. Both of these models require tag recoveries in the weeks following their release. The weekly tag data were therefore combined (fresh and decayed carcasses as well as grilse and adults) and a population estimate was calculated using the adjusted Peterson formula[1/] as described by Ricker (1975). The estimated winter-run chinook salmon escapement using the Peterson model was 820 salmon.

Size/age distribution and sex composition

A total of 82 carcasses was measured (Table 3). The sample mean fork length (FL) was 74 cm (SD=10.9). Size ranged from 47 to 99 cm FL. Male salmon (n=24) averaged 67 cm FL (SD=14.7; range: 47 - 99 cm FL). Female salmon (n=58) averaged 77 cm FL (SD=7.2; range: 65 - 93 cm FL). The weekly mean size for males ranged from 53 to 99 cm FL, and from 73 to 88 cm FL for females.

1/

$$N = \frac{(M+1)(C+1)}{(R+1)}$$

Where, *N* = estimated spawning population for survey period,
M = number of carcasses marked during survey,
C = total number of carcasses examined during survey, and
R = number of marked carcasses recovered during survey.

Table 1. Weekly summaries of mean flow, mean water temperature, and carcass totals collected during the upper Sacramento River winter-run chinook salmon escapement survey, April - September 1996.

Week	Dates	Mean Weekly Flow (cfs)[1/]	Mean Weekly Water Temperature (°F)[2/]	Carcass Count[3/]	
				Fresh	Decayed
1	29 Apr - 2 May	7,900	54	2	3
2	6 - 9 May	7,200	54	4	0
3	13 - 16 May	9,200	53	2	4
4	20 - 23 May	16,200	52	0	1
5	28 - 31 May	13,500	53	1	4
6	3 - 6 Jun	14,900	54	3	1
7	10 - 13 Jun	14,200	54	0	3
8	17 - 20 Jun	13,400	54	5	4
9	24 - 27 Jun	12,400	54	2	7
10	1 - 3 Jul	14,600	59	6	1
11	8 - 11 Jul	15,000	56	10	4
12	15 - 18 Jul	13,600	55	7	11
13	22 - 25 Jul	14,200	54	7	6
14	29 Jul - 1 Aug	15,000	55	2	9
15	5 - 8 Aug	14,800	55	0	4
16	12 - 15 Aug	15,000	55	0	1
17	19 - 22 Aug	15,000	55	0	2
18	26 - 29 Aug	14,200	55	1	1
19	3 - 5 Sep	11,000	55	0	0
			Totals	52	66

1/ Average flow as measured at Keswick Dam during days surveys were conducted.
2/ Average temperature as recorded by survey crew on days surveys were conducted.
3/ Includes grilse and adults (does not include tag recoveries).

Length frequency distributions were used to define a general size criteria distinguishing grilse (2-year-old salmon) and adults (>2-year-old salmon) for both sexes. Male grilse were defined as ≤65 cm FL (Figure 2). They averaged 58 cm FL (SD=5; range: 47-65 cm FL). There was a 11-cm separation between male grilse and adults that clearly divides these two groups. Male adults were defined as > 65 cm FL. They averaged 80 cm FL (SD=9.0; range: 76-99 cm FL). The length frequency distribution of females did not show a size separation which suggests there were no grilse (Figure 3). As a result, all females were classified as adults. Female adults averaged 77 cm FL (SD=7.0; range 65-93 cm FL).

Of the carcasses measured and sexed (n=82), 82% (n=67) were adults and 18% (n=15) were grilse (Table 4). The grilse portion of this sample was comprised entirely of males, while the adult portion comprised 87% (n=58) females and 13% (n=9) males. The ratio of male to female adult spawners was 1:6.4. All females were classified as adults, while 63% (n=15) of the males were grilse and 37% (n=9) were adults. Adult females were always more numerous during the survey than adult males except for week 15 (Figure 4). Combining adult and grilse males, females outnumbered males in all weeks except 14 and 15 (Figure 5).

Length frequency data were also used to distinguish 3-year-old and 4-year-old salmon (Figures 2 and 3). Although very few large fish were available for the analysis, the female length distribution was distinctly bimodal with the second mode occurring in the 86-90 mm FL range. The male length distribution did not exhibit a distinctive distribution for larger fish; however a size separation did occur at 90 mm FL. Four-year olds were identified as females >85 cm FL and males >90 cm FL.

Based upon the size criteria derived from the length frequency data for males and females, the age composition of the spawning population was: 63% 2-year olds, 29% 3-year olds and 8% 4-year olds for males, and 83% 3-year olds and 17% 4-year olds for females.

Temporal distribution

Weekly carcass totals (fresh and decayed) for the 31-mile study segment ranged from 1 to 9 carcasses from 29 April to 3 July (weeks 1 through 10) (Table 1). They ranged from 11 to 18 from 8 July through 1 August (weeks 11 through 14) which was the peak period for the study. After 1 August, the number of carcasses observed declined with the last one observed during the week of 26 August (week 18).

Spatial distribution

The greatest concentration of winter run carcasses was observed in Reach 1: 56% (n=29) of the fresh carcasses and 46% (n=30) of the decayed carcasses (Table 5). In Reach 2, 33% (n=17) of the fresh and 43% (n=29) of the decayed carcasses were seen; in Reach 3, 9% (n=5) of the fresh and 9% (n=6) of the decayed carcasses were observed; and in Reach 4, 2% (n=1) of the fresh and 2% (n=1) of the decayed carcasses were observed. The ratio of fresh:decayed carcasses progressively decreased moving downstream through Reach 3: 1:1.03 in reach 1, 1:1.71 in Reach 2 to 1:1.20 in Reach 3.

Spawning success

There were 55 females examined for egg retention. Of these, 94% (n=52) had completely spawned, 4% (n=2) had partially spawned, and 2% (n=1) had not spawned. The one unspawned female (FL=75 cm) was observed on 5 May. The two partially-spent females were observed 13 May (FL=86 cm) and 9 July (FL=76 cm).

Table 2. Summary of tag and recapture data by week during the upper Sacramento River winter-run chinook salmon escapement survey, April - September 1996. Data includes adults, grilse, fresh, and decayed carcasses.

Week of Recovery	Week of tagging																	Number tags recovered	Total carcasses observed
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
1	-																	-	5
2	1																	1	5
3		0																0	6
4			0															0	1
5				0														0	5
6					0													0	4
7						0												0	3
8							0											0	9
9								0										0	9
10									0									0	7
11										1								1	15
12											8							8	26
13												1						1	14
14													2					2	13
15														0				0	4
16															0			0	1
17																0		0	2
18																	0	0	2
19																	0	0	0
Recovered	1	0	0	0	0	0	0	0	0	1	8	1	2	0	0	0	0	13	131
Tagged	3	4	4	0	3	3	1	7	6	7	13	16	8	7	3	0	1	86	

Table 3. Size and sex statistics for winter run chinook salmon carcasses measured during upper Sacramento River escapement survey, April - September 1996.

Week	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm) Mean(sd)	Range	Number measured	Length (FL in cm) Mean(sd)	Range	Number measured	Length (FL in cm) Mean(sd)	Range
1	3	86(6.7)	80-93	0	-	-	3	86(6.7)	80-93
2	4	88(4.4)	83-92	0	-	-	4	88(4.4)	83-92
3	4	87(9.6)	75-98	1	98	98	3	84(7.8)	75-90
4	0	-	-	0	-	-	-	-	-
5	3	87(12.8)	74-99	1	99	99	2	81(11.0)	74-89
6	3	86(8.2)	77-93	0	-	-	3	86(8.2)	77-93
7	1	86	86	0	-	-	1	86	86
8	5	73(4.6)	68-79	0	-	-	5	73 (4.6)	68-79
9	5	72(10.2)	59-84	2	62(3.5)	59-64	3	78(5.5)	73-84
10	7	71(8.1)	55-78	1	55	55	6	74(3.9)	69-78
11	12	71(10.1)	54-87	4	68(16.2)	54-87	8	73(6.2)	65-84
12	16	72(6.6)	57-83	4	67(11.1)	57-83	12	73(4.1)	66-80
13	8	63(11.3)	47-75	4	53(5.7)	47-60	4	73(2.4)	70-75
14	7	68(9.6)	53-78	4	64(10.4)	53-78	3	75(2.9)	72-77
15	3	77(0.6)	77-78	3	77(0.6)	77-78	0	-	-
16	0	-	-	0	-	-	0	-	-
17	1	77	77	0	-	-	1	77	77
Totals	82		47-99	24		47-99	58		65-93
Averages		74(10.9)			67(14.7)			77(7.2)	

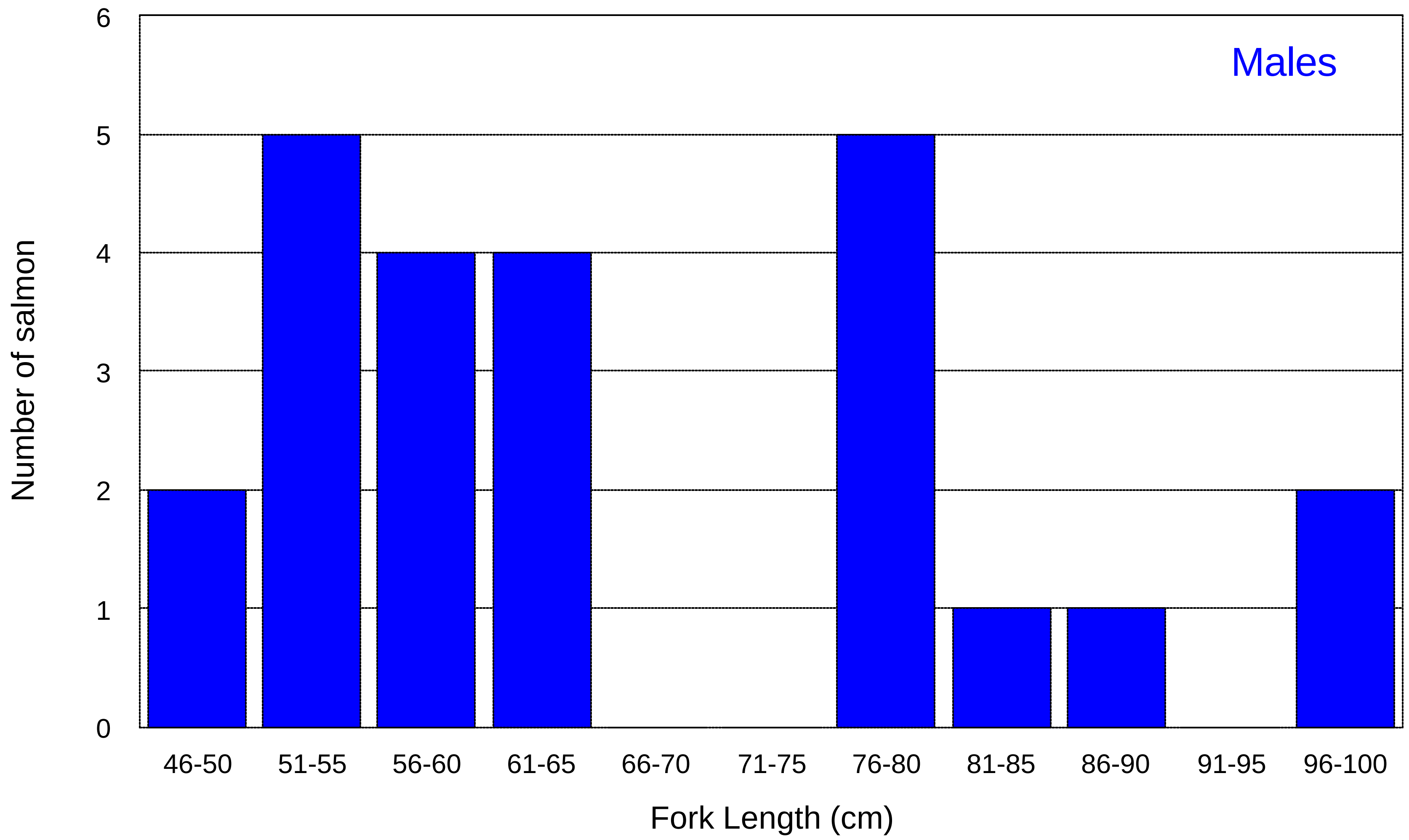

Figure 2. Size (FL in cm) distribution of male winter-run Chinook salmon measured during the upper Sacramento River escapement survey, April - September 1996.

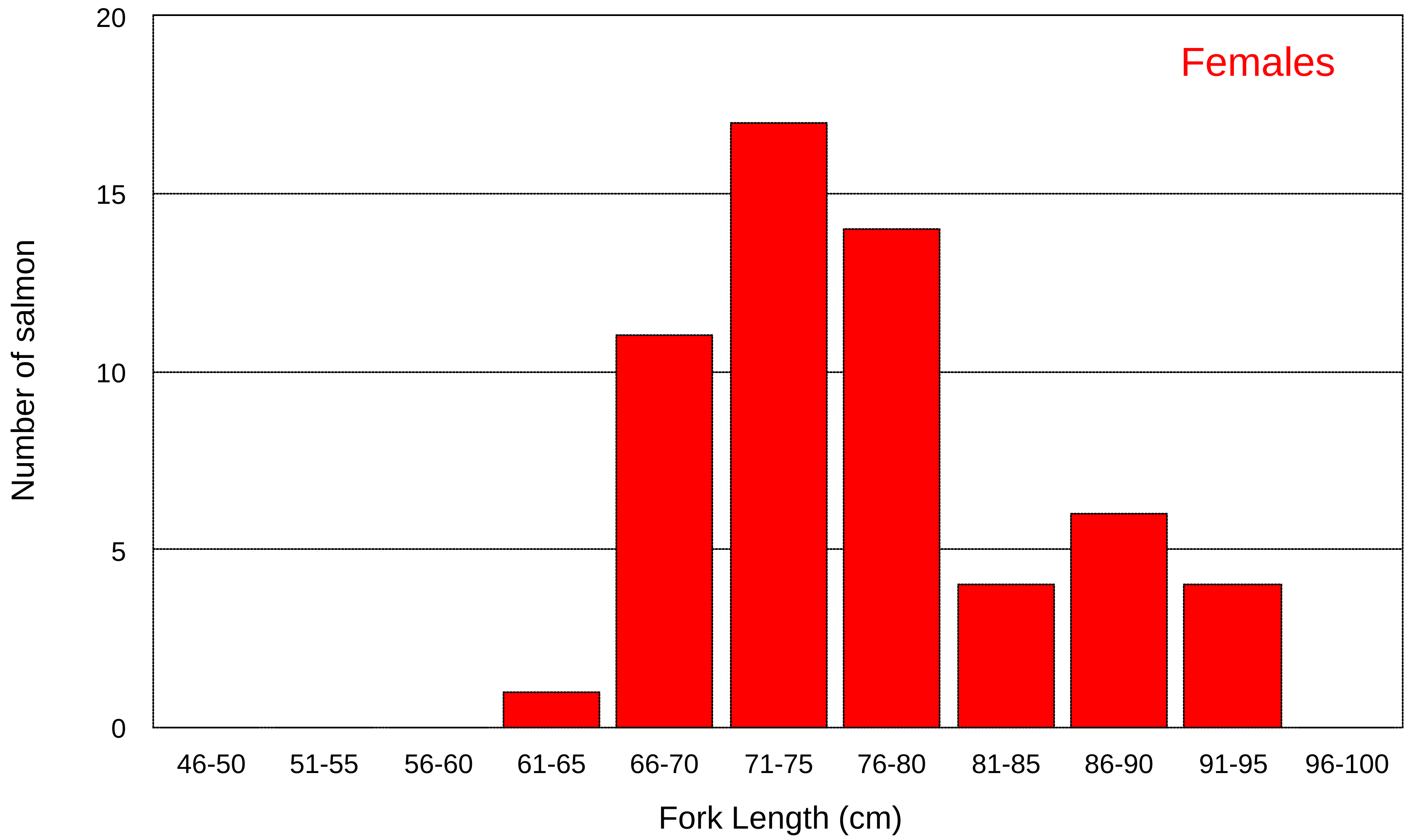

Figure 3. Size (FL in cm) distribution of female winter-run Chinook salmon measured during the upper Sacramento River escapement survey, April - September 1996.

Table 4. Sex composition of winter run chinook salmon grilse and adult carcasses measured during the upper Sacramento River escapement survey, April - September 1996.

	Adults			Grilse[1/]
	Male	Female	Total	Male
Week	Number(%[2/])	Number(%[2/])	Number(%[3/])	Number(%[3/])
1	0(0)	3(100)	3(100)	0(0)
2	0(0)	4(100)	4(100)	0(0)
3	1(25)	3(75)	4(100)	0(0)
4	0(0)	0(0)	0(0)	0(0)
5	1(33)	2(67)	3(100)	0(0)
6	0(0)	3(100)	3(100)	0(0)
7	0(0)	1(100)	1(100)	0(0)
8	0(0)	5(100)	5(100)	0(0)
9	0(0)	3(100)	3(60)	2(40)
10	0(0)	6(100)	6(86)	1(14)
11	2(20)	8(80)	10(83)	2(17)
12	1(8)	12(92)	13(81)	3(19)
13	0(0)	4(100)	4(50)	4(50)
14	1(25)	3(75)	4(57)	3(43)
15	3(100)	0(0)	3(100)	0(0)
16	0(0)	0(0)	0(0)	0(0)
17	0(0)	1(100)	1(100)	0(0)
Totals	9(13)	58(87)	67(82)	15(18)

1/ Grilse were defined as males $\leq$ 65 cm FL. No females were classified as grilse.
2/ Percent of adult population.
3/ Percent of total population.

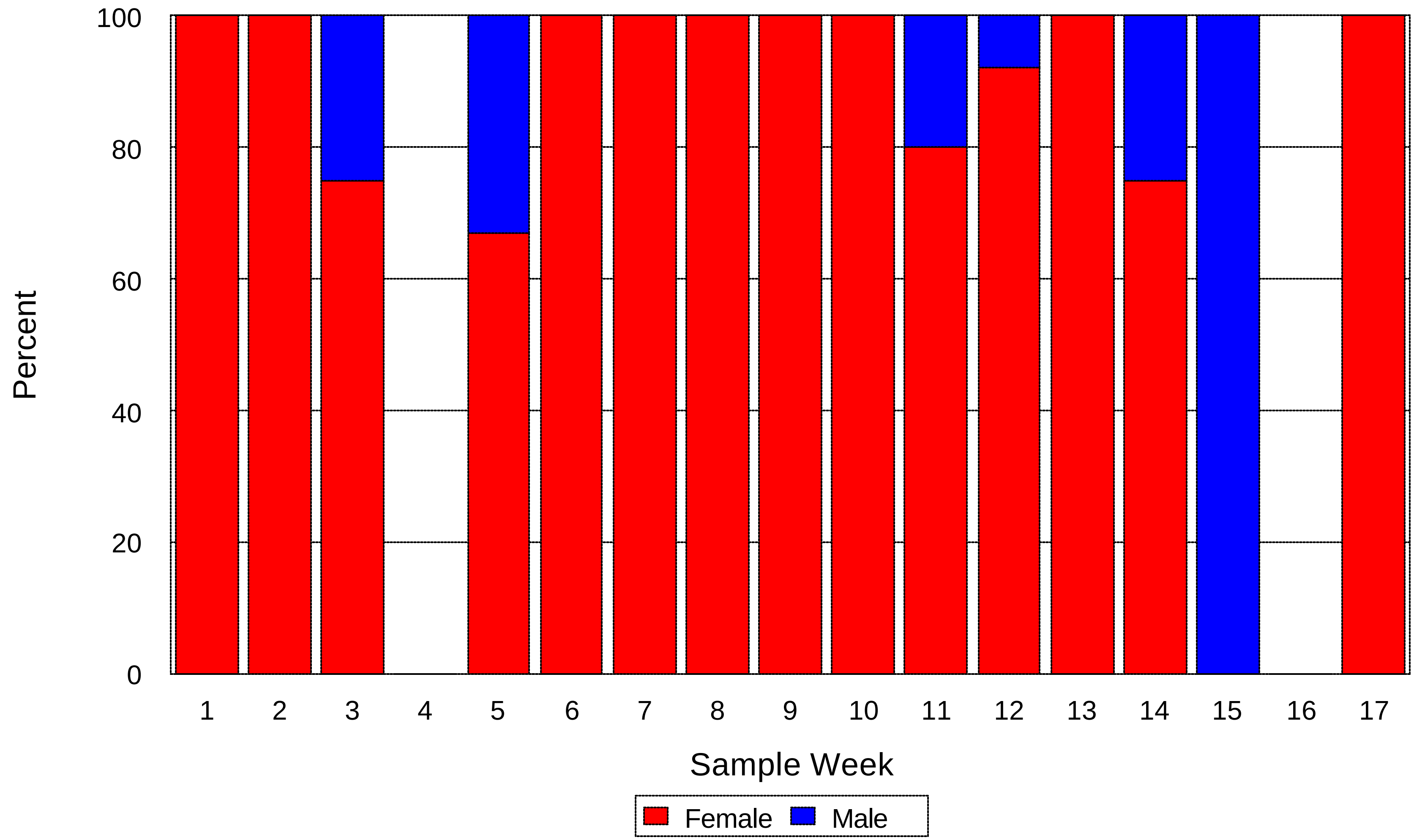

Figure 4. Weekly sex composition of adult chinook salmon measured during the upper Sacramento River winter-run Chinook salmon escapement survey, 29 April - 5 September 1996.

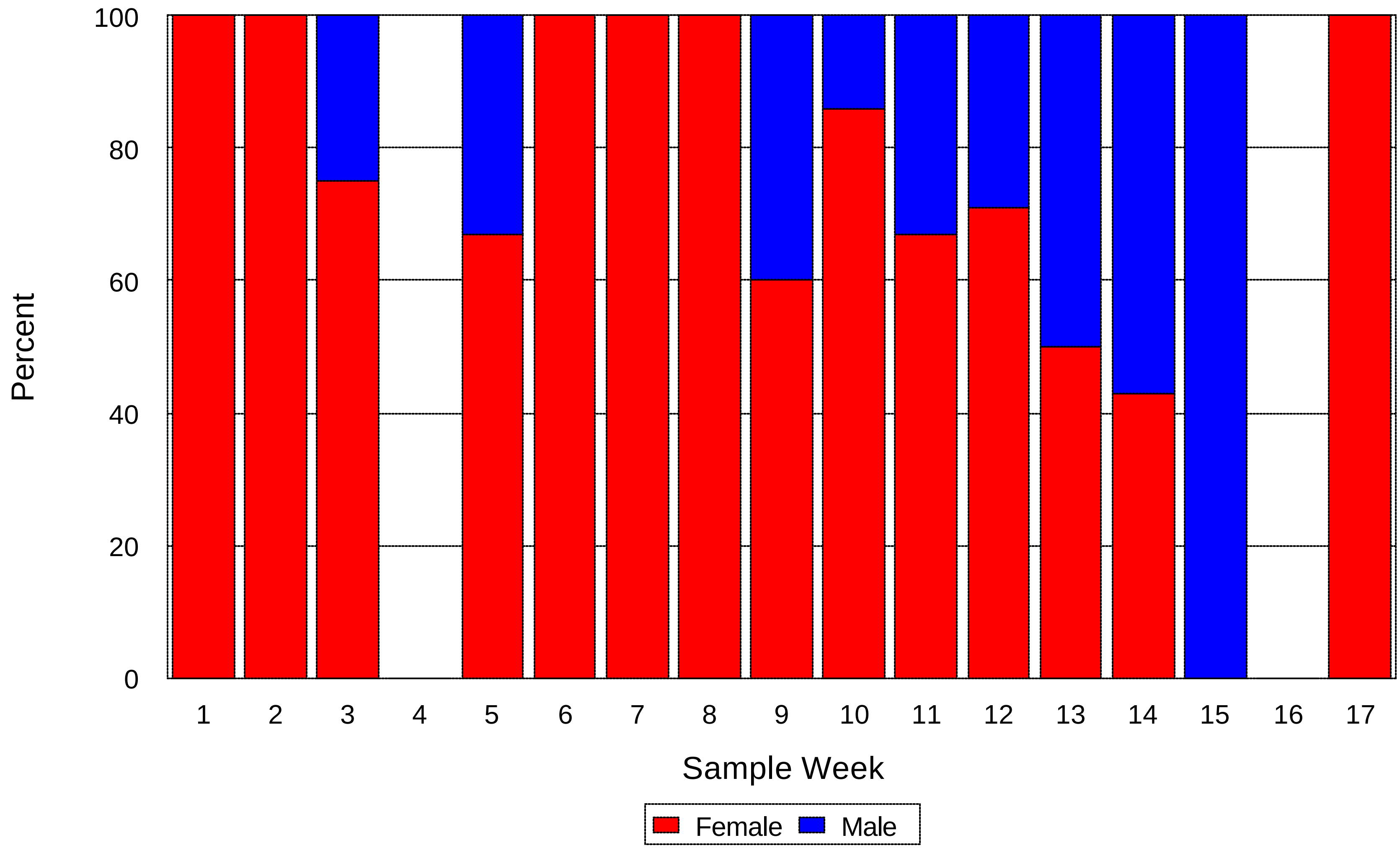

Figure 5. Weekly sex composition of all Chinook salmon (grilse and adults) measured during the upper Sacramento River winter-run chinook salmon escapement survey, 29 April - 5 September 1996.

Table 5. Summary of winter run chinook salmon carcass distribution during the upper Sacramento River escapement survey (includes adults, grilse, fresh and decayed carcasses but not tag recoveries), April - September 1996.

	Reach 1		Reach 2		Reach 3		Reach 4	
Week	Fresh	Decayed	Fresh	Decayed	Fresh	Decayed	Fresh	Decayed
1	0	2	1	1	1	0	0	0
2	3	0	1	0	0	0	0	0
3	2	1	0	1	0	2	0	0
4	0	1	0	0	0	0	0	0
5	1	1	0	3	0	0	0	0
6	1	0	2	1	0	0	0	0
7	0	1	0	2	0	0	0	0
8	4	1	1	2	0	1	0	0
9	1	5	1	1	0	1	0	0
10	4	0	1	1	1	0	0	0
11	4	2	5	2	0	0	1	0
12	4	7	2	3	1	1	0	0
13	4	2	2	3	1	1	0	0
14	1	3	0	6	1	0	0	0
15	0	3	0	1	0	0	0	0
16	0	0	0	1	0	0	0	0
17	0	1	0	0	0	0	0	1
18	0	0	1	1	0	0	0	0
19	0	0	0	0	0	0	0	0
Totals	29(56[1])	30(46[2])	17(33[1])	29(43[2])	5(9[1])	6(9[2])	1(2[1])	1(2[2])

1/ Percent of all fresh carcasses.

2/ Percent of all decayed carcasses.

DISCUSSION

The results of one year's carcass survey cannot, by themselves address the issues of habitat availability relative to flow and other attributes of physical habitat. At least two more years of survey are needed. These data should then be compared with redd survey data to identify salmon spawning habitat requirements. The low population level may also reduce the efficacy of the population surveys in evaluating habitat needs. If the population is so low relative to habitat availability, little can be determined with these data alone, especially relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1996). However, if habitat is limiting at these low populations, habitat flow relationships should be identifiable. Other studies that will augment this component of the overall investigation may include aerial photographic surveys of redds, physical habitat modeling, and focused evaluation of the hydraulic and substrate attributes of spawning habitat.

Population Estimates

The Schaefer and Jolly-Seber models could not be used due to a lack of recoveries from 10 of the 15 week-tag groups. The apparent reason for the lack of recoveries is the small numbers of carcasses collected and then tagged during most weeks. The low number of collected carcasses likely represents the low number of winter run spawning in the mainstem rather than being due solely to the difficult sampling conditions, primarily high flow, in the upper Sacramento River.

The winter run escapement estimate and redd count made by the DFG's Inland Fisheries Division (IFD) staff support the assumption that the spawner population was low and spawning activity was extremely limited. IFD estimated that 940 in-river produced and 356 hatchery-produced (1,296 total) winter run migrated upstream of RBDD. They also counted only 44 redds between Keswick Dam and Jelly's Ferry during their weekly, aerial-redd survey conducted throughout the winter run spawning period (late April to early August).

The FWS estimated that 237 winter run migrated into Battle Creek based on a carcass survey and video recordings made in a fishway at the barrier at CNFH. This estimate was made from data collected independently from RBDD data. It is considered a more accurate estimate of hatchery-origin winter run chinook salmon as it accounts for complete migration and spawn timing (Croci and Hamelberg 1997). The estimate of winter run escapement to Battle Creek is assumed to represent the entire escapement of hatchery-produced salmon since all hatchery (CNFH) produced winter run released into the Sacramento River are marked (adipose clipped), and no marked fish were recovered in the mainstem carcass survey and only marked fish were observed in Battle Creek.

A sensitivity analysis of the RBDD estimates can therefore be made by comparing the escapement for hatchery-produced fish made at RBDD and in Battle Creek. The RBDD escapement estimate for hatchery fish was 356, based on the expansion of a count of 55 adipose clipped winter run, and the assumption that the counting period accounted for 15.43% of the total migration (e.g., estimated escapement = n counted/mean percentage of winter run passing RBDD, 1971-1986, or 356=55/.1543) This estimate is about 50% greater than the “actual” escapement of hatchery-produced fish measured in Battle Creek (237). If the RBDD count (55 fish) is expanded to equal the “actual” escapement (i.e., 237=55/proportion of run counted), the estimated proportion of fish passing RBDD during the 1996 RBDD counting period is 23.2%. This proportion lies within the range observed during the 1971 through 1986 season-long counts made at RBDD (4.7 to 24.3%).

This sensitivity analysis suggests that a smaller portion of the hatchery-produced winter run migration passed RBDD before the counts were started in 1996 (about 85% versus 77%). The run timing may have been later than the average winter run migration timing observed between 1971 and 1986. If we assume the same relationship holds for migration timing of in-river produced fish, the RBDD count of in-river produced winter run (145 fish) yields an estimated escapement of 625.

The observation that the RBDD estimate was liberal in 1996 is supported by conclusions made by Law (1992) in his comparison of Schaefer, Jolly-Seber and Peterson models. After comparing the three models, Law states: “...the Petersen model consistently showed substantially larger overestimation of total population than either the Schaefer model or the Jolly-Seber model.” As such, we can assume that our escapement estimate of 820 derived using the Peterson model is liberal.

The results of all the escapement survey efforts strongly suggest winter-run chinook salmon population numbers are perilously low in the upper Sacramento River. Since carcass survey population estimates derived from the Peterson model almost always overestimate the actual population, escapement of in-river produced winter run was probably less than 820, and possibly as low as 625 in 1996.

Sex composition

The adult sex ratio observed during the carcass study differed substantially from the sample observed at RBDD. The sex ratio of males:females for the winter run observed at RBDD was 1:1.3 while the ratio for the carcass survey was 1:6.4. The reason for this large discrepancy is unknown, but is of great concern. One possible explanation is the inherent difference in recovery rates for male and female salmon carcasses aggravated by the difficult sampling conditions experienced in the upper Sacramento River. In a carcass survey and weir count conducted on Bogus Creek, a tributary to the Klamath River, the recovery rate of adult males was 11% less than the rate for females (Boydstun 1994).

Another explanation is that males migrate earlier than females thus potentially biasing the RBDD estimate of male winter run.

Age Composition

A comparison of the age composition of male and female winter run in the 1996 spawner population shows that male composition was substantially different from the assumed age distribution used by NMFS (1996) (Table 6). The female composition in 1996 was comparable to the NMFS age distribution.

Table 6. Comparison of the age composition criteria used in the NMFS extinction model and the age composition of male and female winter run collected during the 1996 upper Sacramento River winter-run chinook salmon escapement survey.

Age	Males (%)		Females (%)	
	NMFS Criteria	1996 composition	NMFS Criteria	1996 composition
2	50	63	0	0
3	44	29	89	83
4	6	8	11	17

RECOMMENDATIONS

- The mark and recapture carcass surveys should be continued. Survey effort should be increased to attempt to increase the number of carcasses tagged and potentially increase the recovery rate to meet the requirements of the Schaefer and Jolly-Seber models.

  In response to the low tag recovery rates observed in 1996, we have increased survey frequency and decreased the survey segment length in 1997. (The 1997 carcass surveys are now underway.) Keswick Dam is still the upstream end of the survey section, but the study segment is now restricted to the first 14 miles downstream of the dam, instead of 31 miles. We collected more than 90% of the winter run carcasses within this segment in 1996. This 14-mile segment has been further divided into two reaches. The upper reach is surveyed during one day and the lower reach the next day. Then one day is skipped and the cycle is repeated. The weekly frequency of the 1997 surveys is two to two and one-half times greater than the 1996 surveys.

- Investigate the discrepancies between the sex ratios observed during the carcass survey and the fish trapped at RBDD.

  To determine if the difference in sex ratios is due to a difference in availability of males and females to carcass surveys, the DFG plans to tag fall-run chinook salmon captured at RBDD during July, August, and September as surrogates for winter run. Adult spawners will be tagged with Floy tags as they pass over RBDD. The tags will later be observed during the carcass survey during October, November, and December. The recovery rate of each sex will be compared.

Historic RBDD data should be analyzed to determine if there are differences in timing of male and female migrations of winter run past RBDD.

Determine the sex composition of emigrating juvenile winter run. Fish should be sampled using non-invasive techniques of sex determination as part of the emigration surveys presently being conducted at Cow Creek, RBDD, Knights Landing, and Chipps Island.

Further evaluate the age composition of winter run adults.

The length at age criteria used to identify the age of female and male winter run should be verified using scales and otoliths collected from the sampled carcasses.

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