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

1997 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey April - August 1997

by

Bill Snider
Bob Reavis
and
Scott Hill

Stream Evaluation Program
Technical Report No. 98-1
January 1998

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

1997 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey April - August 1997[1/,2/]

by

Bill Snider
Bob Reavis
and
Scott Hill

January 1998

1/ This was a cooperative investigation with U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office and was supported by funding provided by the U.S. Fish and Wildlife Service, Central Valley Anadromous Fish Restoration Program as part of a cooperative agreement with the California Department of fish and Game pursuant to the Central Valley Project Improvement Act (P.L. 102-575).

2/ Stream Evaluation Program Technical Report No. 98-1

SUMMARY

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

The survey was conducted from 30 April 1997 through 29 August 1997. It covered the uppermost 14 miles of the Sacramento River accessible to migrating salmon, from river mile 288 (RM 288) upstream to Keswick Dam (RM 302).

Flow ranged from 9,000 cubic feet per second (cfs) to 11,000 cfs through mid-June, then between 14,000 and 15,000 cfs into early August. Secchi depths (water clarity) were between 3 and 4 ft through mid-June, increased to over 6 ft by the end of June and eventually maintained between 6 and 10 ft thereafter. Water temperature increased from 49 °F during the first week of spawning to 52 °F by mid-June and essentially remained at 52 °F for the remainder of the survey.

Temporal distribution of carcasses suggests that most spawning (~70%) occurred from early June into early July. The peak in fresh carcasses occurred during early July.

We collected 239 carcasses (105 fresh and 134 decayed) and measured 190. Ninety-two percent (174) were adult salmon and 8% (16) were grilse; 21% were adult males, 70% were adult females, 4% were male grilse and 5% were female grilse. Overall, 25% of the measured carcasses were male and 75% were female; 24% of the adults were male and 76% were female.

Ninety-six percent of 140 females checked for egg retention were completely spawned.

Five hatchery-produced winter run were collected, including one caught at Coleman National Fish Hatchery (CNFH), then marked and released into the survey reach.

We shortened the survey reach length and increased survey frequency to increase carcass counts and recapture rates. The result was a 2.5 fold increase in effort within the reach where 90% of the carcasses were collected in 1996. In spite of increased effort, poor visibility made carcass observations difficult. Tags were recovered from only 16 of the 36 tag groups and the recapture rate was 12%. As in 1996, insufficient numbers of tagged fish were recaptured to allow using either the Schaefer or Jolly-Seber models. The Petersen model yielded an estimate of 1,888 adult and 165 grilse winter run (2,053 total).

The 1997 winter-run escapement estimate based on counts made at Red Bluff Diversion Dam (RBDD) (RM 243) was 480 adult and 361 grilse. Based on comparisons of the estimated number of marked, hatchery-produced winter run both passing RBDD and returning to the upper river, the winter-run migration past RBDD was adjusted to 6,125 salmon (3,500 adults and 2,625 grilse). The estimated effective spawner population was between 1,478 and 2,333 females.

INTRODUCTION

A winter-run chinook salmon *Oncorhynchus tshawytscha* escapement survey was conducted in the upper Sacramento River during spring-summer 1997 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality and temporal and spatial distribution of spawning. This was the second consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine salmon habitat requirements in the Sacramento River system (Snider *et al*. 1997). A fundamental component of the investigation is the determination of basic life histories of the various salmon runs in the system as a basis for identifying salmon-habitat relationships at all life stages, including spawning. Also, since spawning habitat investigations can be influenced by spawner abundance as well as habitat availability, it is important that spawner population data be developed concurrent with habitat monitoring to distinguish 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, 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 habitat availability, 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 spawner escapement surveys should be conducted on the upper Sacramento River.

The 1996 and 1997 surveys were the first attempts to use carcass mark-and-recapture techniques to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass mark-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 mark-and-recapture 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.

Evaluation of winter-run spawning in the Sacramento River is an integral part of an agreement between the DFG and the U.S. Fish and Wildlife Service (FWS), Central Valley Anadromous

Fish Restoration Program to evaluate habitat requirements for anadromous salmonids in Central Valley streams. Studies being implemented by the DFG will provide the FWS with reliable scientific information for development of flow recommendations and 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 runs 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.

Results of the carcass survey may be used for comparison and possible augmentation of data collected on winter-run migration at the RBDD. Similarly, the survey could augment weekly winter-run redd surveys. The FWS, Northern Central Valley Fish and Wildlife Office and CNFH could also use the results to evaluate their winter-run escapement augmentation program using winter run spawned and reared at CNFH (USFWS 1996, Croci and Hamelberg 1997).

Objectives

The objectives of the 1997 winter-run chinook salmon spawner escapement survey were:

- To estimate the 1997, in-river, winter-run chinook salmon population for the upper Sacramento River based on a carcass mark-recapture survey and augment estimates that are based on RBDD counts.

- To continue examination of 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) to eventually identify winter-run spawning habitat requirements in the upper Sacramento River.

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. Winter run typically spawn from mid-April through mid-August.

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. Fisher (1993) concludes this run may also have historically spawned in reaches of the Sacramento and Pit rivers that were also cut off with the construction of Shasta Dam. Winter run status since the construction of Shasta Dam has been described by Slater (1963), Hallock and Fisher (1985), and Fisher (1993). Since Shasta Dam has blocked winter run's access to most of its historic spawning habitat, winter run now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River. Due to a drastically declining population, winter run were listed as endangered by the California Fish and Game Commission in 1989, and as threatened by the National Marine Fisheries Service (NMFS) in 1990 and then as endangered in 1994.

The NMFS (1996) has developed a winter-run extinction model that identifies population conditions corresponding to an acceptable low probability of population extinction. Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over any 13 consecutive years is at least 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 three 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 annual escapement will be estimated with a precision of +/- 25%.

Since 1969, winter-run escapement estimates have been based upon counts of salmon using fishways that provide passage around RBDD. Counts can only be made when the diversion is in operation, when all the gates are down, and all fish migrating to areas upstream of RBDD use the fishways located in the center and on the east and west ends of the dam. From 1969 through 1985, 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 using a combination of actual daytime counts (east and west fishways) and counts made from daytime video recordings of fish using the center fishway. The daytime counts were expanded using weekly nighttime count data.

Beginning in 1986, operation of RBDD was modified to accommodate winter-run migration. Now the diversion operates only during an abbreviated portion of the historic winter-run migration, typically from mid-May through mid-September. The number of winter-run spawners migrating upstream of RBDD is now based upon an expansion of the number of fish counted once the gates are closed. Fish passing RBDD during this period are counted applying essentially the same methods used when counts covered the entire migration (pre-1986). Fish using the east and west ladders are counted directly through viewing facilities from 0600 to 2000 h seven days per week. Fish using the center ladder are counted by video taping fish passage from 0600 to 2000 h each day seven days per week. The video tapes are reviewed to identify and count fish that had passed. Once a week, the DFG determines night passage at the east and west ladders by extending the direct counts from 2000 to 2200 h and then video taping passage from 2200 to 0600 h the next morning. These tapes are also reviewed to identify and count fish that had passed. The single night count is used to "correct" the weekly, daytime counts to represent night passage for all other nights of the week. The DFG also operates a fish trap located in the east fish ladder. The trap is usually operated seven days a week through July then five days a week through mid-September from 0600 to 1500 h, when water temperatures are $\leq 60^{o}$ F. Trapped fish are identified to species or, if a salmon, to run. Fish are measured and checked for marks (e.g., adipose fin clips).

Escapement is estimated by expanding the abbreviated season-long count, assuming it is proportionate to historic, complete 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.

METHODS

The FWS, Northern Central Valley Fish and Wildlife Office and the DFG's Stream Evaluation Program jointly conducted a carcass mark-and-recapture survey to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 30 April 1997 through 29 August 1997. Methods were similar to those used in the 1996 winter-run escapement survey (Snider *et al*. 1997) with the exception that changes in the survey reach and survey frequency were made to improve on the low collection rates observed in 1996.

In 1996, the survey reach extended 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Figure 1), which is considered the primary spawning area for winter run in the upper Sacramento River. However, 90% of winter-run spawning in 1996 occurred in the uppermost 14 stream miles. This prompted us to shorten the survey reach to the 14 stream miles between Keswick Dam and the Redding Water Treatment Plant (RM 288) to increase sampling efficiency. Sampling effort was also increased in 1997. The shortened reach was surveyed about 2.5 times as often as it was in 1996.

The study reach was divided into the following two reaches:

1. Keswick Dam to Cypress Street Bridge - RM 302 to RM 295,

2. Cypress Street Bridge to Redding Water Treatment Plant - RM 295 to RM 288.

The upper reach was surveyed on the first day and the lower reach on the second day of each two-day survey period. Then one day was skipped and the cycle repeated. Most of the survey effort was conducted by boat (two boats and two observers 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 effort was primarily concentrated in areas where carcasses were known to collect. Most observed carcasses were collected using a gaff or gig for measurement and tagging, as described below.

Flow measurements from the Keswick gauge were obtained from the U.S. Geological Survey. Water temperatures and Secchi disk (water clarity) readings were measured daily by the survey crew.

Population Estimates

The winter-run spawner population was estimated using a mark-and-recapture (tag-and-recovery) method. Most collected carcasses were tagged except those in an advanced state of decay. Carcasses not tagged were counted then cut in two (chopped). All chopped carcasses were disregarded in subsequent surveys. Carcasses were tagged by attaching a small colored plastic ribbon to the upper or lower jaw with a hog ring. The tag color was used to show 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 was noted during tagging to accommodate the various population estimators. The Schaefer model uses only fresh carcass data, and the Jolly-Seber model uses both fresh and decayed carcass data. This approach is consistent with procedures used on other Central Valley streams. All tagged carcasses were returned to flowing water near where they were collected in an attempt to simulate “natural” carcass dispersion. Recovered, previously tagged carcasses were examined for tag color, location of tag (upper or lower jaw), and age (size). The pertinent data were recorded and the carcass was chopped.

Size/age Distribution and Sex Composition

Fork length (FL), sex, and date of collection were recorded for all measurable carcasses. Some carcasses were too deteriorated to allow accurate measurements. The length-frequency distribution of each sex was used to define the length separating adults (>2 years old) and grilse (2 year olds).

Carcasses were also checked for adipose fin clips, indicating the fish was of hatchery origin and possessed a coded-wire tag (CWT). CWTs were collected from clipped carcasses.

Spawning Success

All measurable female carcasses were checked for egg retention. Females were classified as spent if few eggs remained, as partially spent if a substantial amount (50% or more) of eggs still remained in the body cavity, and unspent if they appeared to be completely unspawned.

Temporal Distribution

Fresh carcasses were assumed to become available to sampling within two weeks of spawning completion, based upon observations made in the American River (Snider and Vyverberg 1995). The total number of fresh carcasses observed for both survey reaches for each survey period was used to describe temporal spawning distribution.

Spatial Distribution

The total number of fresh carcasses observed in each survey reach was used to define season-long geographic distribution of spawning activity. Flow likely carried some carcasses from the upstream reach, where spawning occurred, to the downstream reach, where recovery occurred, potentially biasing the spatial distribution of spawning toward the downstream reach. Using only fresh carcasses, versus fresh and decayed carcasses, should substantially reduce the bias.

RESULTS

General

A total of 105 fresh and 134 decayed carcasses were observed during the 19-week survey (Table 1). Mean flow for each of the 41 survey periods ranged from 8,000 to 15,000 cfs (Table 2, Figure 2). Mean survey-period temperature ranged from 49 ^{o}F to 53 ^{o}F (Table 1, Figure 2). Secchi depth readings ranged from 3 to 10 ft (Table 1) and generally increased as the survey season progressed (Figure 2).

Population Estimates

The Jolly-Seber and Schaefer models were not used to estimate escapement since tagged carcasses were recovered from only 16 of the 36 tag groups. These models require that tags be recovered from each tag group.

The adult spawner population was therefore estimated using the adjusted, Peterson formula (Ricker 1975)[1], by combining the season-long totals for number of adult carcasses observed, Table

---

[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.

1. Summary of mean flow, mean water temperature, Secchi depths and carcass counts during each survey period of the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (°F)[2/]	Secchi depth (ft)	Carcass count[3/] Fresh	Decayed
1	Apr 30 - May 1	8,600	49	3.2	1	4
2	May 3 - 4	8,000	50	3.0	1	8
3	May 6 - 7	8,800	50	3.0	0	6
4	May 9 - 10	9,200	50	3.3	0	1
5	May 12 - 13	9,800	51	3.2	1	1
6	May 15 - 16	10,100	50	3.3	2	1
7	May 18 - 19	9,500	50	3.2	0	0
8	May 21 - 22	10,200	50	3.2	2	1
9	May 24 - 25	10,500	50	3.3	1	1
10	May 27 - 28	10,200	51	4.4	0	4
11	May 30 - 31	9,800	51	4.0	0	2
12	Jun 2 - 3	10,500	51	3.8	1	3
13	Jun 5 - 6	10,400	52	3.7	3	1
14	Jun 8 - 9	11,000	51	4.2	1	1
15	Jun 11 - 12	12,200	52	4.1	2	4
16	Jun 14 - 15	14,600	52	4.7	2	1
17	Jun 17- 18	15,000	52	5.8	5	1
18	Jun 20 - 21	14,700	52	5.4	3	3
19	Jun 23 - 24	14,500	52	6.9	6	3
20	Jun 26 - 27	14,700	52	5.9	4	1
21	Jun 29 - 30	14,900	52	4.4	5	1
22	Jul 2 - 3	14,800	53	7.0	5	6
23	Jul 5 - 6	14,500	52	6.8	6	4
24	Jul 8 - 9	14,800	52	6.8	3	3
25	Jul 11 - 12	14,800	52	7.0	10	2
26	Jul 14 - 15	14,900	54	6.8	3	8
27	Jul 17 - 18	14,800	52	7.1	8	14
28	Jul 20 - 21	15,000	52	6.4	6	5
29	Jul 23 - 24	14,900	52	6.6	7	4
30	Jul 26 - 27	14,800	52	7.9	4	4
31	Jul 29 - 30	14,500	52	6.6	4	2
32	Aug 1 - 2	14,300	52	7.0	1	8
33	Aug 4 - 5	14,200	52	8.9	1	7
34	Aug 7 - 8	12,200	52	9.2	3	5
35	Aug 10 - 11	12,800	52	10.0	2	4
36	Aug 13 - 14	11,900	52	9.3	1	4
37	Aug 16 - 17	10,000	52	9.2	1	1
38	Aug 19- 20	10,000	52	9.9	0	0
39	Aug 22 - 23	14,700	52	9.5	0	0
40	Aug 25- 26	14,500	52	8.7	0	2
41	Aug 28 - 29	8,000	52	9.2	0	3
				Totals	105	134

1/ Mean flow measured at Keswick Dam during survey period.
2/ Mean water temperature measured by survey crew during survey period.
3/ Includes grilse and adults; does not include tag recoveries.

Table 2. Summary of tagging and recapture of winter-run chinook salmon carcasses (fresh and decayed) observed during upper Sacramento River escapement survey, April - August 1997.

Tagging period	Date	Number observed		Number tagged		Number recovered	Original tagging period
		Adults	Grilse	Adults	Grilse		
1	4/30-5/1	5	0	5	0	0	
2	5/3-4	9	0	6	0	0	
3	5/6-7	6	0	6	0	0	
4	5/9-10	1	0	1	0	0	
5	5/12-13	2	0	2	0	0	
6	5/15-16	3	0	3	0	1	5
7	5/18-19	0	0	0	0	0	
8	5/21-22	3	0	3	0	0	
9	5/24-25	2	0	2	0	0	
10	5/28-29	4	0	3	0	0	
11	5/30-31	2	0	2	0	0	
12	6/2-3	4	0	3	0	0	
13	6/5-6	4	0	4	0	0	
14	6/8-9	2	0	2	0	0	
15	6/11-12	6	0	3	0	0	
16	6/14-15	3	0	3	0	0	
17	6/17-18	6	0	5	0	0	
18	6/20-21	6	0	5	0	0	
19	6/23-24	9	0	8	0	1	18
20	6/26-27	5	0	5	0	1	19
21	6/29-30	6	0	6	0	0	
22	7/2-3	10	1	8	1	2	18,21
23	7/5-6	9	1	8	1	2	21,22
24	7/8-9	6	0	6	0	0	
25	7/11-12	10	2	10	2	3	20,23,24
26	7/14-15	10	1	8	1	0	
27	7/17-18	22	0	17	0	1	26
28	7/20-21	8	3	8	2	1	26
29	7/23-24	10	1	9	1	3	22,27,28
30	7/26-27	6	2	4	2	1	29
31	7/29-30	5	1	4	1	2	29,30
32	8/1-2	9	0	6	0	2	29,31
33	8/4-5	7	1	3	1	0	
34	8/7-8	7	1	4	0	0	
35	8/10-11	5	1	4	1	0	
36	8/13-14	4	1	0	1	0	
37	8/16-17	2	0	1	0	1	34
38	8/19-20	0	0	0	0	0	
39	8/22-23	0	0	0	0	0	
40	8/25-26	1	1	0	0	0	
41	8/28-29	2	1	0	0	1	33
Totals		221	18	177	14	22*	

* All were adults, no grilse were recovered.

tagged and recovered. Fresh and decayed adult carcasses were combined yielding a total of 177 adult carcasses tagged (Table 2), 22 recovered, and 243 adult carcasses examined (including the 22 tag recoveries). The adult spawner estimate was 1,888.

The total population (grilse and adult) was calculated by dividing the adult estimate by 0.92, the estimated proportion of adults. The total population estimate was 2,053. The estimated grilse population was 165.

Size/age Distribution and Sex Composition

A total of 190 carcasses was measured (Table 3). Mean FL was 76.1 cm (range: 49-104 cm FL). Male salmon (n = 48) averaged 81.3 cm FL (range: 50-104 cm FL). Female salmon (n = 142) averaged 74.3 cm FL (range: 49-104 cm FL). Monthly mean size ranged from 67.0 to 92.0 cm FL for males, and from 71.4 to 83.8 cm FL for females (Table 3). On average, larger salmon of both sexes spawned early followed by progressively smaller fish (Table 3, Figure 4).

Length-frequency distributions were used to define a general size criterion to distinguish grilse (2-year-old salmon) and adults (>2-year-old salmon) for both sexes. There was an 11 cm separation between male grilse and adults that clearly divided the two age groups (Figure 3). The break in female length distribution was not as evident (Figure 3). Grilse were defined as ≤64 cm FL for both sexes (Table 4). The female size distribution indicates that female adults may have been less than 64 cm FL, perhaps as small as 60 cm FL. We plan to verify the age/length relationship for the 1997 spawner population using scales and otoliths taken from most measured carcasses. In this report, the same length was used for both sexes to distinguish grilse and adults.

Male grilse averaged 53.6 cm FL (SD = 2.9; range: 50-59 cm FL). Female grilse averaged 59.9 cm FL (SD = 4.6; range 49-63 cm FL) (Table 4). Adults were defined as >64 cm FL. Male adults averaged 86.1 cm FL (SD = 9.1; range: 70-104 cm FL). Female adults averaged 75.3 cm FL (SD = 6.0; range 66-104 cm FL).

Ninety-two percent (n = 174) of the carcasses measured were adults and 8% (n = 16) were grilse (Table 5). At least 86% of the carcasses observed each month were adults. The greatest fraction (14%) of grilse was observed in August.

The grilse sample comprised 56% (n = 9) females and 44% (n = 7) males (Table 6). The adult sample comprised 76% (n = 133) females and 24% (n = 41) males. The ratio of male:female adult spawners was 1:3.2. The grilse sample comprised 56% (n = 9) females and 46% (n = 6) males. The overall sex ratio, including grilse, was 1:3.

Spawning Success

Ninety-six percent (n = 135) of the 140 females examined for egg retention had completely spawned. Three percent (n = 4) had partially spawned, and 1% (n = 1) had not spawned. The unspawned and partially-spawned females were observed on or before 12 June.

Spatial Distribution

Based upon fresh carcass data, spawning was evenly distributed between the two reaches with 48% (n = 50) of the fresh carcasses found in Reach 1 and 52% (n = 55) of the fresh carcasses found in Reach 2 (Table 7). Thirty-seven percent (n = 50) of the decayed carcasses were found in Reach 1; 63% (n = 84) of the decayed carcasses were found in Reach 2. The ratios of fresh:decayed carcasses were 1:1 in Reach 1 and 1:1.5 in Reach 2.

Temporal Distribution

Fresh carcasses were observed from survey period 1 (30 April-1 May 1997) through survey period 37 (16-17 August 1997) (Table 1, Figure 4). The number of fresh carcasses increased gradually through survey period 16 (15 June 1997), averaging less than 3 carcasses per week. A sharp increase in the rate of fresh carcass collection began in survey period 17 (17-18 June 1997) and continued through survey period 29 (23-24 July 1997) (Figure 5). Nearly 70% of all fresh carcasses were observed during this five week period. The peak of fresh carcass recovery occurred during survey period 25 (11-12 July 1997) (Figure 5).

Assuming that fresh carcasses become available for observation approximately two weeks after spawning, spawning occurred from mid-April into early August. Peak spawning occurred from the first week in June through the first week in July.

Hatchery-produced Winter-run Chinook Salmon

Five carcasses from hatchery-produced winter run (indicated by a clipped adipose fin) were observed in the survey reach. One of the adipose-clipped fish was also marked with a tag indicating it was one of 68 salmon that had been collected at CNFH, tagged then released into the Sacramento River to spawn. All five adipose-clipped fish were females (Table 8). One had not completely spawned indicating a 20% pre-spawning mortality. Size ranged from 63 cm FL to 78 cm FL (mean = 72 cm FL),

Table 3. Size and sex statistics for carcasses measured during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

	All salmon			Male salmon			Female salmon		
		Length (FL in cm)			Length (FL in cm)			Length (FL in cm)	
Month	Number measured	Mean	Range	Number measured	Mean	Range	Number measured	Mean	Range
May[1/]	27	88.1	71-104	14	92.0	75-104	13	83.8	71-104
June	47	77.0	49-93	11	80.5	55-93	36	75.9	49-90
July	95	73.4	51-98	20	76.5	51-98	75	72.6	57-84
August	21	70.8	50-86	3	67.0	50-81	18	71.4	60-86
Total (overall)	190	(76.1)	(49-104)	48	(81.3)	(50-104)	142	(74.3)	(49-104)

1/ Includes data gathered on 30 April 1997.

Table 4. Summary of adult and grilse size and number by sex for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, April - August 1997.

	Female		Male	
	Grilse*	Adults	Grilse*	Adults
Total measured	9	133	7	41
Mean	59.9	75.3	53.6	86.1
Range FL (cm)	49-63	66-104	50-59	70-104
Standard deviation	4.6	6.0	2.9	9.1

* Grilse were defined as salmon $\leq$64 cm FL.

Table 5. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, April - August 1997.

Survey period	Adults		Grilse	
	Number	%	Number	%
May**	27	100	0	0
June	45	96	2	4
July	84	88	11	12
August	18	86	3	14
Total (overall)	174	(92)	16	(8)

** Includes data gathered on 30 April

Table 6. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, April - August 1997.

Month	Adults				Grilse			
	Male		Female		Male		Female	
	Number	%	Number	%	Number	%	Number	%
May[1/]	14	52	13	48	0	-	0	-
June	10	22	35	78	1	50	1	50
July	15	18	69	82	5	45	6	55
August	1	6	16	94	1	33	2	67
Total (overall)	41	(24)	133	(76)	7	(44)	9	(56)

1/ Includes data gathered on 30 April

Table 7. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997. Includes adults, grilse, fresh and decayed carcasses but not tag recoveries.

	Reach 1		Reach 2	
Survey period	Fresh	Decayed	Fresh	Decayed
1	1	4	0	0
2	0	3	1	5
3	0	1	0	5
4	0	1	0	0
5	0	0	1	1
6	0	1	2	0
7	0	0	0	0
8	2	1	0	0
9	0	0	1	1
10	0	1	0	3
11	0	1	0	1
12	0	0	1	3
13	1	0	2	1
14	0	0	1	1
15	1	0	1	4
16	1	0	1	1
17	2	0	3	1
18	1	1	2	2
19	3	1	3	2
20	1	0	3	1
21	4	0	1	1
22	2	3	3	3
23	4	2	2	2
24	2	2	1	1
25	2	0	8	2
26	0	2	3	6
27	4	5	4	9
28	3	1	3	4
29	4	1	3	3
30	2	1	2	3
31	3	1	1	1
32	1	3	0	5
33	1	4	0	3
34	2	2	1	3
35	2	4	0	0
36	1	1	0	3
37	0	1	1	0
38	0	0	0	0
39	0	0	0	0
40	0	0	0	2
41	0	2	0	1
Totals	50	50	55	84

Table 8. Summary of statistics for adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

Date collected	Sex	FL (cm)	Spawning completed
16 May	Female	71	No
16 May	Female	70	Yes
5 June	Female	78	Yes
18 July	Female	78	Yes
26 July	Female	63	Yes
Mean (range)		72 (63-78)	80%

DISCUSSION

The results of two years of carcass surveys cannot, by themselves, address the issues of habitat availability relative to flow and other attributes of physical habitat. Several 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

One of the goals for the 1997 survey was to increase the recovery rate experienced in 1996 by increasing the survey effort. The overall tag recovery rate, however, was only 12% in 1997 versus 15% in 1996. Similarly, we were not able to recover tags from 20 of the 36 tag groups, thus only allowing use of the relatively weak Petersen model to estimate the spawner population. Law (1994) found that the Petersen model consistently showed substantially larger overestimation than either the Schaefer or Jolly-Seber models. When both fresh and decayed carcasses are used, he found that the Petersen model overestimated the known population by as much as 151% and by as much as 83% when only fresh carcasses were used. We used both fresh and decayed carcasses to derive the estimate of 1,888 adult winter run. Using just fresh carcasses, the estimate is 1,354. As such, it is highly likely that our total escapement estimate of 2,053 winter run is an overestimate of the true population.
Possible reasons for low tag recoveries include poor visibility, higher flows and low spawner

population. Poor visibility early in the survey certainly limited carcass recovery. Secchi readings were less than 4 ft through most of May and did not reach 6 ft until late June. Tag recoveries were extremely low through mid-June and then showed a sharp increase concurrent with improved water clarity (Figure 6). For example, by the third week of June, when water clarity finally increased to 6 feet, we had tagged nearly 40% of the carcasses that eventually would be tagged during the survey but we had only recovered about 13% of the number eventually recovered. The recovery rate was less than 5%. Within two weeks, the number tagged increased about two-fold while the number recovered increased 5-fold and the recovery rate increased to almost 10%.

Even though flow increased between May and July when recovery rates increased apparently due to improved water clarity, higher flows likely increase the rate that tagged carcasses are swept out of the study area, decreasing the probability of recovery. Recovery rates during the 1995 and 1996 upper Sacramento River fall-run chinook salmon escapement surveys were about 32% and flow was around 5,000 cfs (Snider and Reavis 1997). In contrast, recovery rates were less than 16% during the 1996 and 1997 winter-run escapement surveys and flow was typically between 9,000 and 15,000 cfs.

The total number of carcasses tagged during the 1995 and 1996 fall-run escapement surveys were nearly 40 times as many as were tagged during the 1996 and 1997 winter-run surveys.

Effective Spawner Population

The effective spawner population is defined as the estimated number of females that spawned, assuming there were enough males to service all the redds. Since 75% of the carcasses used to estimate escapement were female, the estimated female population based on the carcass survey was 1,540 (including grilse-sized females). Prespawning mortality was 4% yielding an estimated effective spawner population of 1,478.

Sex Composition

The ratio of males:females observed during the carcass surveys was 1:3 during 1997, compared to 1:6.4 during 1996. The sex ratio varied throughout the survey ranging from 1:0.9 in May (n = 27), 1:3.2 in June (n = 47), 1:2.6 in July (n = 95) and 1:6.0 in August (n = 21).

The following are possible explanations for the observed difference in sex composition:

1. The recovery rate of males is less than for females. 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 the rate for females (Boydstun 1994).

2. If a high portion of the male population leaves the ocean as 2-year olds, the male to female ratio of that age class remaining in the ocean is reduced significantly. Based on

the age composition criteria used in the NMFS model, 50% of the returning males would be grilse. Assuming an initial sex ratio of 1:1, this alone would result in a male to female ratio of nearly 1 to 2. As the proportion of males returning as 2 year olds increases (x), the ratio of male to female adults for that age class decreases to 1:(1/1-x) (e.g., if x = 0.5, the ratio is 1:2; if x = 0.7, the ratio is 1:3.3, *etc.*).

3. A combination of the above two factors would produce an even greater disparity between adult males and females.

Comparison with Red Bluff Diversion Dam Winter-run Escapement Estimates

Results of the salmon counts at RBDD indicated an estimated 841 in-river produced winter run , including 480 adult and 361 grilse migrated to the upper Sacramento River (DFG unpubl. data). RBDD data also indicate that an estimated 40 hatchery-produced winter run migrated to the upper Sacramento River. The male to female ratio for adults was 1 to 1.44.

An estimated 256 hatchery-produced winter run returned to Battle Creek (S. Croci, FWS, unpubl. data). An additional 34 hatchery-produced winter run were estimated to have spawned in the Sacramento River survey area, yielding a hatchery-produced winter-run escapement estimate of 290.

Escapement of hatchery-produced winter run based on RBDD counts was 40. This was less than 15% of the estimate based on carcass survey and Battle Creek counts. The RBDD estimate was based on the expansion of a count of 7 adipose clipped fish and the assumption that the counting period accounted for 17.45% of the total migration. If we assume that the actual number of hatchery-produced winter run migrating past RBDD was 290 as described above, then the proportion of the run counted at RBDD was 7/290, or 2.4%. This proportion lies within the range observed between 1969 and 1985 (Figure 7).

The above analysis therefore suggests that a substantial portion (~97%) of the hatchery-produced winter-run population passed RBDD before counts began in early May. Assuming the timing of the in-river produced winter-run migration was comparable, the estimate of the in-river produced adult escapement, using the RBDD count (84 adults) is 3,500 winter run.

This analysis indicates that the number of in-river produced adult winter run migrating upstream of RBDD was about 200% greater than the estimated number that spawned (3,500 v 1,888). Knowing that the Petersen estimate is high suggests that the disparity between the two estimates is even greater. If we take into account that the sex ratios indicate that the estimated number of males in the carcass survey may be biased, a comparison of the effective spawner population derived from RBDD and carcass survey estimates should reduce the bias. The effective spawner population estimated using the RBDD data and 4% prespawning mortality is 2,333 versus 1,478 using the carcass survey data. Part of this difference can be explained by the fact that some portion of the population migrating past RBDD dies, or otherwise does not reach the spawning area investigated in our survey. The RBDD estimate should exceed the number of fish expected to spawn in the survey area.

RECOMMENDATIONS

- The mark and recapture carcass surveys should be continued.

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

  One of the principle questions that needs to be addressed is whether there is a difference in the availability of male and female carcasses to our sampling procedures. One possible explanation for the low male to female ratio observed in 1996 and 1997 is due to post- spawning behavior differences. Males may move downstream or to areas unavailable to sampling (e.g., deep pools), while females stay on the redd until they die and therefore are more susceptible to sampling. An effort should be made to determine if the ratio of male to female carcasses in deep (pool) areas is different from that observed in our surveys. This could be done several times throughout the spawning season using video surveillance or diving.

- 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.

ACKNOWLEDGMENTS

Survey data were gathered by: Vina Free, Marco Campbell, Ed Kohler, Steve Croci, Julie Zerr and Kevin Niemela with the FWS; Jon Ferguson, John Galos, Jason Kindopp, Jeffery Jahn, Scott Monday, Patrick Garrison and Warren Nichols with the DFG; and Rebecca O'Flaherty with who worked for both agencies. Data were processed and summarized by Katherine Taylor of DFG. We thank those individuals for their efforts, as well as Frank Fisher for providing logistical and technical support and Jim Smith (FWS) for facilitating a cooperative investigation.

LITERATURE CITED

Boydstun, L. B. 1994. Analysis of two mark-recapture methods to estimate the fall chinook salmon (*Oncorhynchus tshawytscha*) spawning run in Bogus Creek, California. Calif. Fish & Game 80(1):1-13.

Croci, S. J. and S. Hamelberg. 1997. Evaluation of the Sacramento River winter chinook salmon (*Oncorhynchus tshawytscha*) propagation program in 1996. USFWS Report. U.S. Fish and Wildlife Service, Northern Central Valley Fish and Wildlife Office, Red Bluff, CA

Fisher, F. W. 1993. Historical review of winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River, California. Dept. Fish & Game Inland Fish Div. Office rept.

Hallock, R .J. and F. W. Fisher. 1985. Status of Winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento River. Dept. Fish & Game Anad. Fish Br. Office rept.

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

NMFS (National Marine Fisheries Service). 1996. Recommendations for the recovery of the Sacramento River winter-run chinook salmon. Nat. Marine Fish. Serv. Southwest Region, Long Beach CA. 228 p.

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

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

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

Slater, D. W. 1963. Winter-run chinook salmon in the Sacramento River, California with notes on water temperature requirements for spawning. U.S.Fish & Wildlife Serv. Spec. Sci. Rept. - Fisheries No.461 9 pp.

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

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

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

Snider, B., B. Reavis, S. Hamelberg, S. Croci, S. Hill, and E. Kohler. 1997. 1996 Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Flow & Habitat Evaluation Program, Envir. Serv. Div.

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

USFWS. 1996. Escapement of hatchery-origin winter chinook salmon (*Oncorhynchus tshawytscha*) to the Sacramento River, California in 1995, with on spring chinook salmon in Battle Creek. U.S. Fish and Wildlife Service, Norther Central Valley Fish and Wildlife Office, Red Bluff, CA.

FIGURES

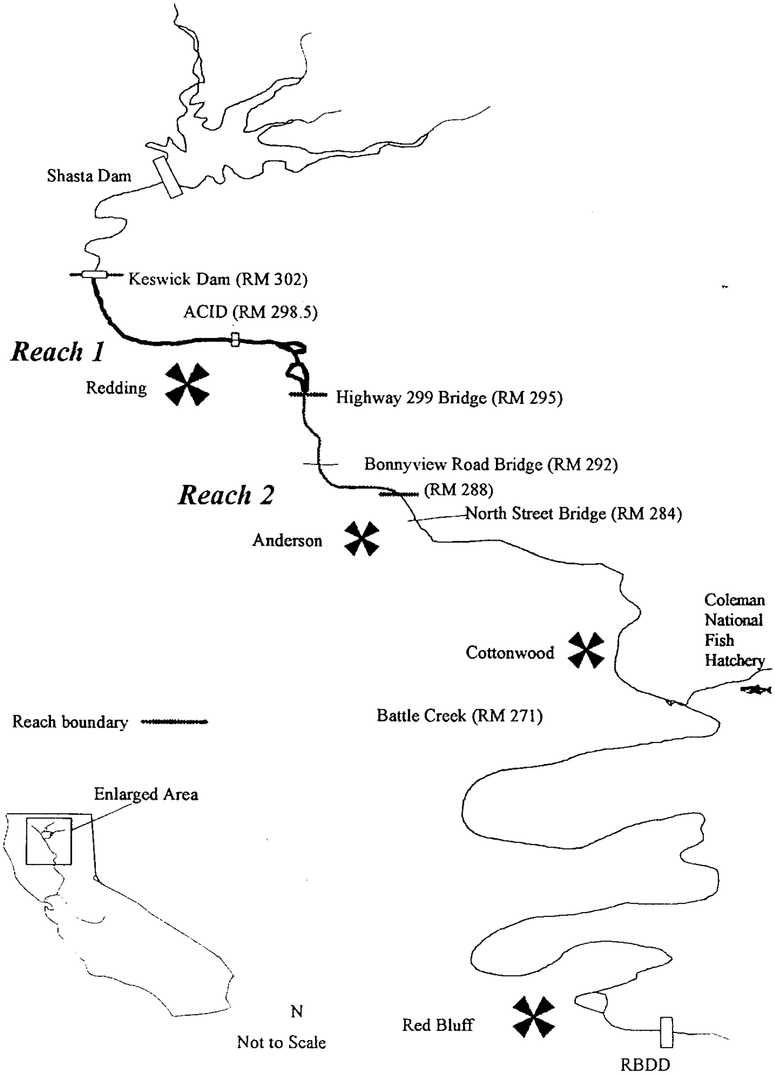

Figure 1. Upper Sacramento River winter-run chinook salmon escapement study location including reach designations, April - August 1997.

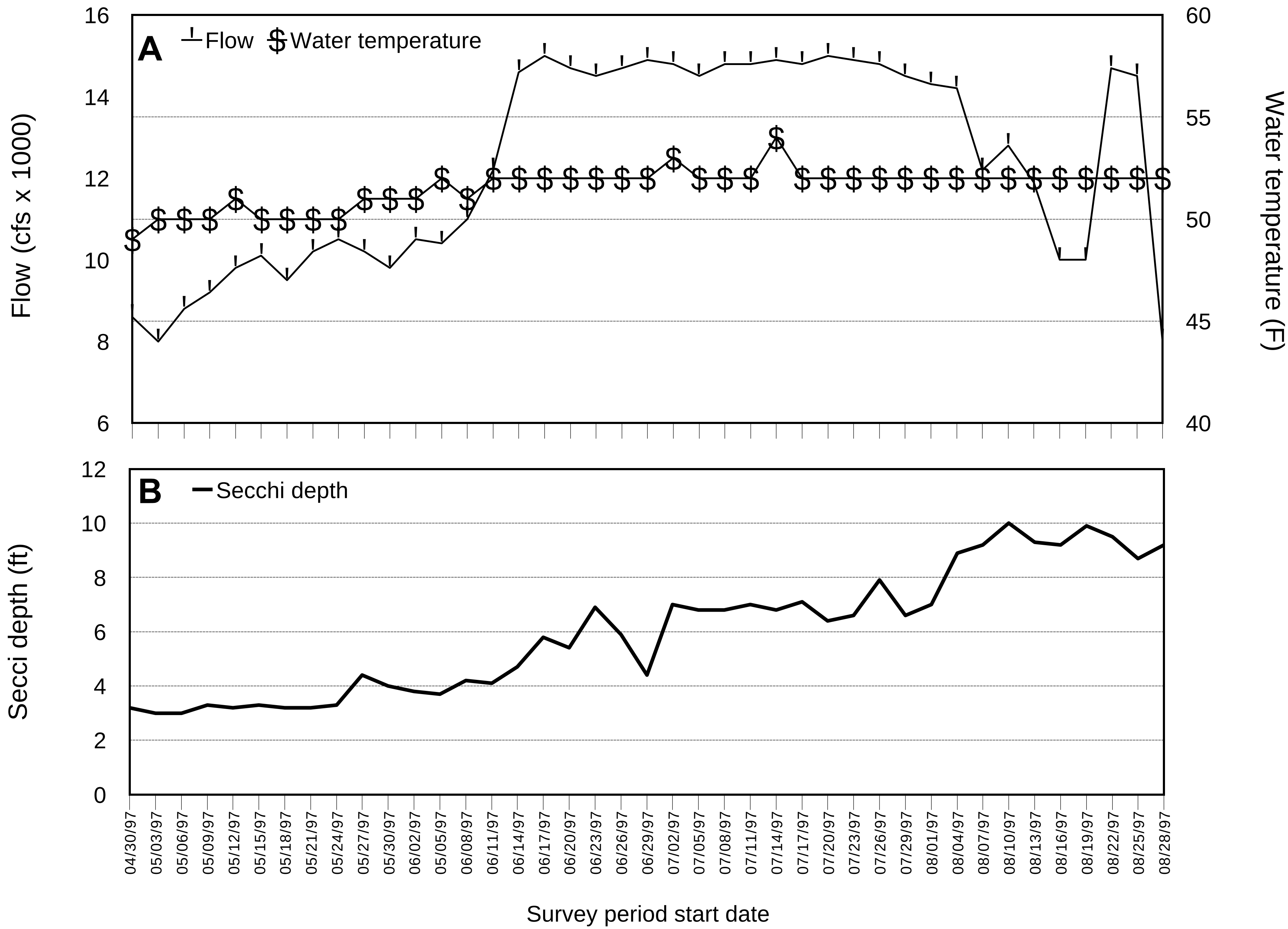

Figure 2. Mean flow and water temperature (A) and Secchi depth (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

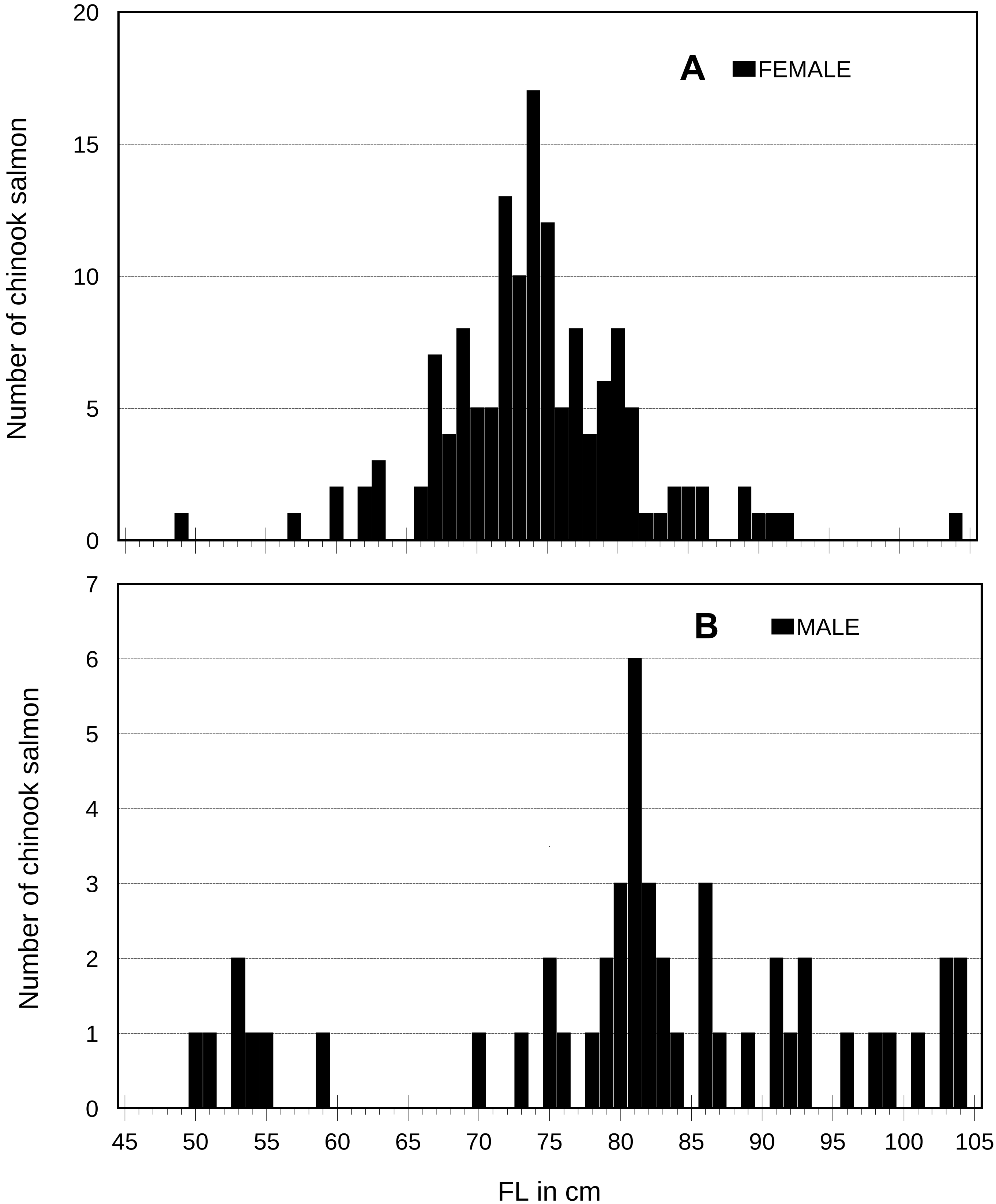

Figure 3. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

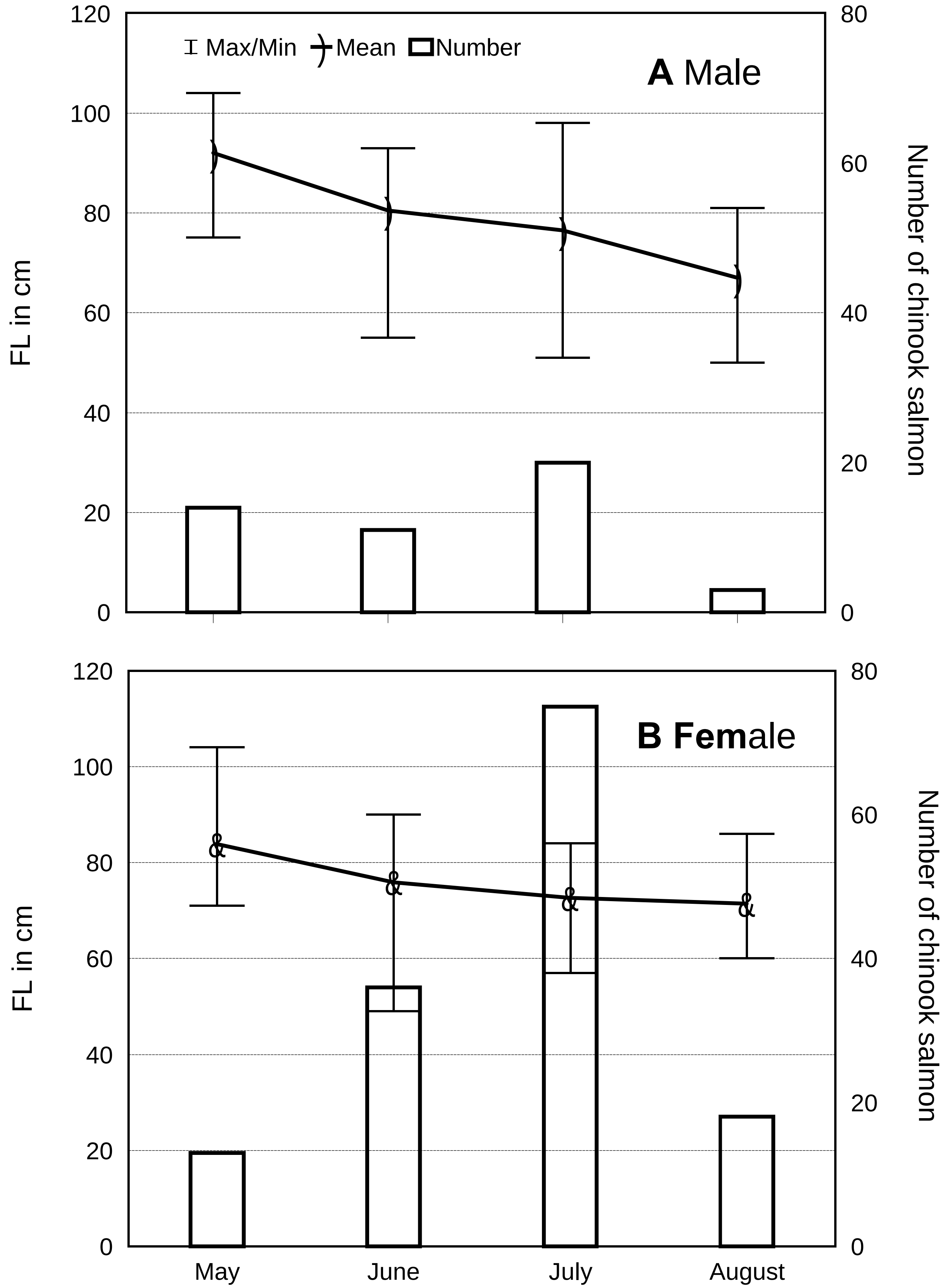

Figure 4. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

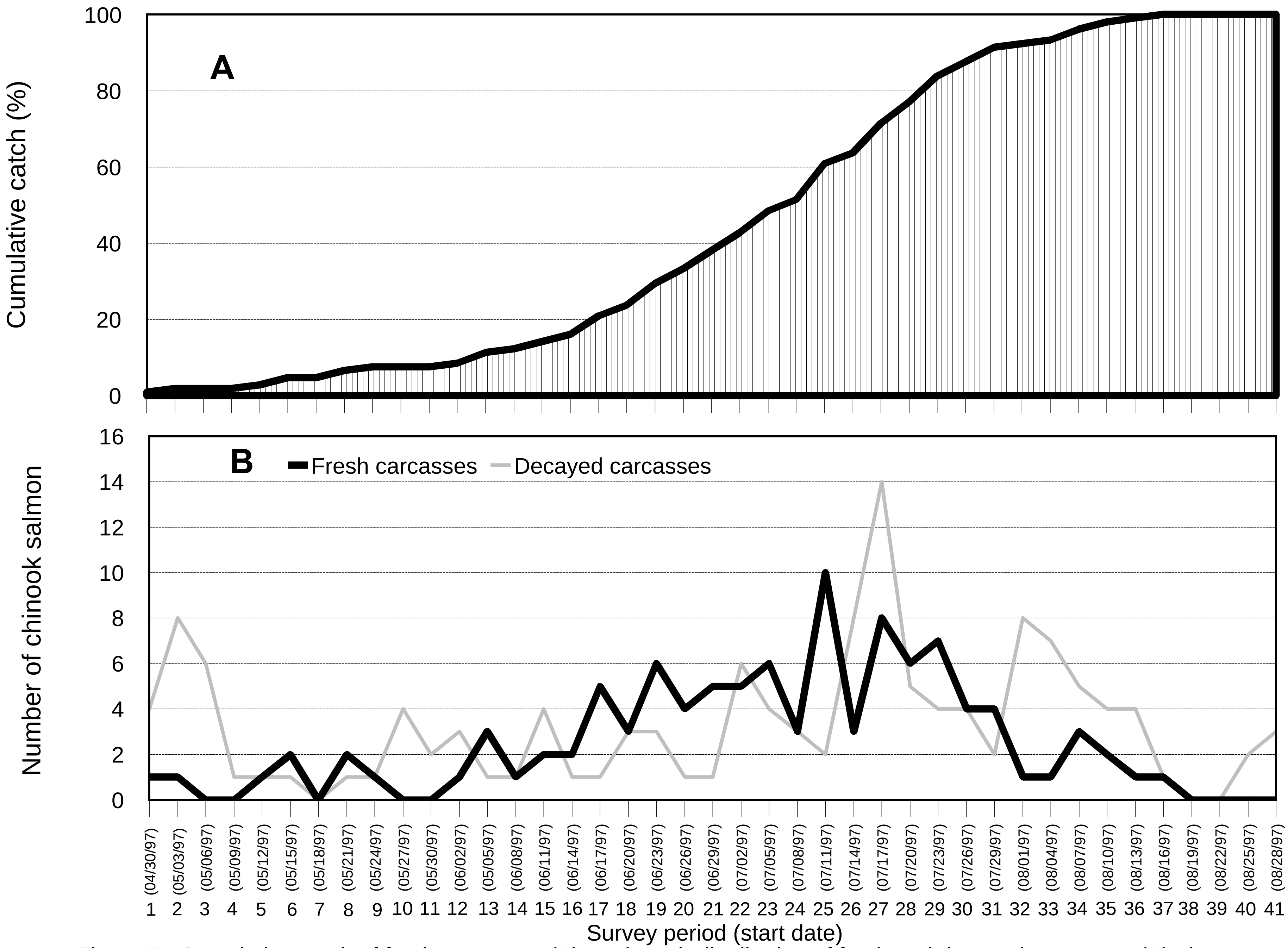

Figure 5. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B) , by survey period, during the upper Sacramento River winter-run chinook salmon escapement survey, April-August 1997.

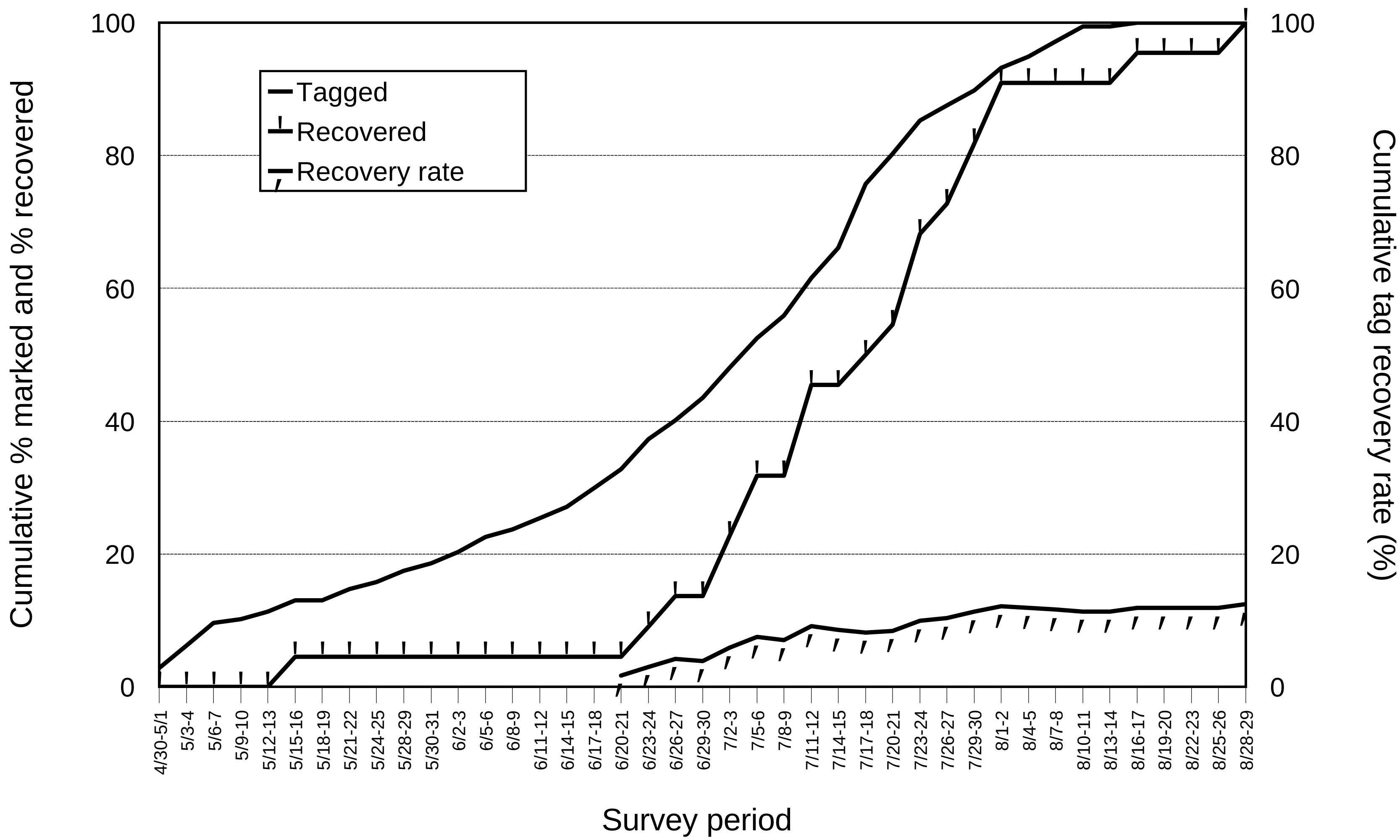

Figure 6. Comparison of temporal distribution of tagging versus recovering of tagged carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, April - August 1997.

Figure 7. Percentage of the total migration of winter-run chinook salmon passing Red Bluff Diversion Dam after Week 19 (1969 through 1985).