CALIFORNIA DEPARTMENT OF FISH AND GAME
HABITAT CONSERVATION DIVISION
Native Anadromous Fish and Watershed Branch
Stream Evaluation Program

1999 Upper Sacramento River Winter-Run Chinook Salmon Escapement Survey May–August 1999

by

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Bob Reavis
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Technical Report No. 00-1
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2/ Stream Evaluation Program Technical Report No. 00-1

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SUMMARY

The California Department of Fish and Game's Stream Evaluation Program and the US Fish and Wildlife Service's Northern Central Valley Fish and Wildlife Office jointly conducted a winter-run chinook salmon, *Oncorhynchus tshawytscha,* escapement survey in the upper Sacramento River during spring–summer 1999 to acquire data on spawner abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning activity. This was the fourth 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. The survey was conducted from 5 May through 27 August 1999. 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).

Flows ranged from 9,300 cubic feet per second (cfs) on 17–18 May to 13,700 cfs on 12–13 July. Secchi depths (water clarity) ranged from 5.8 ft (11–12 May 1999) to 10.7 ft (8–9 August 1999). Flow fluctuation was less and water clarity was greater than in past years providing more favorable survey conditions. Water temperature fluctuated between 50 ^{o}F and 54 ^{o}F (mode = 52 ^{o}F) throughout the survey. The peak in fresh carcass observations occurred during mid to late June indicating that peak spawning was from early to mid June (2 weeks prior).

A total of 475 carcasses (212 fresh and 263 decayed) were collected; only measurements from fresh carcasses were used. Length frequency distributions were used to estimate the size distinguishing adults from grilse (<2-year-old salmon) by sex. Males >63 cm FL and females >59 cm FL were classified as adults. Using these criteria, 80.5% of the population were adults and 19.5% were grilse. Overall, 25.2% of all measured carcasses were male and 74.8% were female; 10.7% of the adults were male and 89.3% were female.

We checked 157 females for egg retention: 97% had completely spawned; 1 percent were partially spawned; and 2 percent were unspawned.

Four adipose-fin marked carcasses were collected. Coded-wire tag (CWT) data were obtained from two of these carcasses. The CWT data showed that both were 1995 brood year fish from Coleman National Fish Hatchery: one was a winter run and one a late-fall run.

The carcasses tag-and-recapture survey conducted to estimate spawner escapement resulted in a recovery rate of 22% for fresh adult carcasses (36 out of 161) and a 21% recovery rate for all carcasses. The Petersen formula applied to the fresh carcass data yielded an escapement estimate of 2,262 including 1,821 adults and 441 grilse. The estimated number of adult females was 1,626 (total female estimate = 1,691). The effective spawner population was 1,577.

In comparison, the 1999 winter-run escapement estimate based on counts made at Red Bluff Diversion Dam (RM 243) was 3,208 (1,001 adults, 2,207 grilse). The adult female escapement estimate was 427, and the total female escapement was 982.

INTRODUCTION

A winter-run chinook salmon, *Oncorhynchus tshawytscha*, escapement survey was conducted in the upper Sacramento River during spring–summer 1999 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 forth 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, Snider et al. 1998 and Snider et al. 1999). A fundamental component of the investigation is the identification of salmon-habitat relationships at all life stages, including spawning for all salmon runs in the system. Also, since spawning habitat investigations can be influenced by both spawner abundance and habitat availability, it is important that spawner population surveys and habitat monitoring be conducted concurrently 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 among 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 survey was the first attempt to use carcass mark-and-recapture techniques to estimate winter-run chinook salmon escapement in the Sacramento River. Carcass mark-and-recapture surveys have been 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: the Petersen (Ricker 1975), Schaefer (1951), and Jolly-Seber (Seber 1982) models. The Petersen formula is the simplest but least accurate 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’s (FWS), Central Valley Anadromous Fish Restoration Program to determine habitat requirements for anadromous salmonids. 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 Central Valley steelhead that were listed as threatened under the federal Endangered Species Act in March 1998, 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 Red Bluff Diversion Dam (RBDD). Similarly, the survey could augment weekly winter-run-redd surveys. The FWS, Northern Central Valley Fish and Wildlife Office (NCVFWSO) and Coleman National Fish Hatchery (CNFH) could also use the results to evaluate their winter-run-escapement augmentation program using winter run spawned and reared at CNFH (USFWS 1996 and Croci and Hamelberg 1997).

Objectives

The objectives of the 1999 winter-run chinook salmon spawner escapement survey were:

- To estimate the in-river, winter-run chinook salmon population in 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., Petersen, 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 the time of spawning, and the spawning population (size, age, and sex composition, and spawning success) in order 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. 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 blocks winter run's access to most of its historic spawning habitat, they now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River (Figure 1). A small number of winter run spawn in some of the major upper Sacramento River tributary streams. Due to a drastically declining population, winter run were listed as endangered by the California Fish and Game Commission in 1989, 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 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 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 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 over RBDD. Counts can only be made when: the diversion is in operation, the gates are down, and all fish migrating above RBDD have to 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. Although this dam hampers upstream migration when the gates are down and fish are migrating through the ladders, it provided an opportunity for fish migrating upstream to be accurately counted. Beginning in 1986, the operation of RBDD was modified to improve winter-run migration. With the modified operation, the gates are typically raised from mid-September through mid-May the following year allowing the unimpeded upstream passage of most winter run. The diversion and fishways now only operate during the mid-May through mid-September period which typically included only a small portion of winter-run migration when season long counts were possible (1969–1985) (Figure 1). Annual escapement is now estimated by expanding the abbreviated season-long count, assuming it is proportionate to historic, complete season-long counts. The proportion used to divide the abbreviated count represents the fraction of the total population that passed RBDD (when complete season-long counts were made) based on the date that the diversion is placed in operation.

The method of counting fish through the fishways is essentially the same as when counts covered the entire migration (pre-1986). The procedures employed to count salmon using the RBDD fishways include a combination of actual daytime counts (east and west fishways) and counts made from daytime video recordings of fish using the center fishway. Fish using the east and west ladders are counted directly through viewing facilities from 0600 to 2000 h each day, 7 days per week. Fish using the center ladder are counted by video taping fish passage from 0600 to 2000 h each day 7 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 to identify and count fish that had passed. The single night count is used to determine a correction factor to account for night passage for all other nights of the week. The DFG also operates a fish trap located in the east-bank fish ladder. The trap is usually operated 7 days a week through July, then 5 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).

METHODS

The NCVFWSO and the DFG's Stream Evaluation Program jointly conducted a carcass mark-and-recapture survey during 1999 to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 5 May through 27 August 1999. Methods were similar to those used during the 1998 winter-run-escapement survey (Snider et al. 1998).

In 1996, the survey reach extended 31 miles from Keswick Dam (RM 302) downstream to Battle Creek (RM 271) (Figure 2), which is considered the primary spawning area for winter run in the upper Sacramento River. After observing a low tag recovery rate (15% for all tagged carcasses) and noting over 90% of the winter-run spawning activity occurred in the upper 14 miles of the 31-mile section surveyed in 1996, we shortened the study area to this 14-mile section and increased our survey frequency starting in 1997. The new study area was divided into two 7-mile reaches and each of these reaches was surveyed an average of 2.5 times per week. This change was intended to provide an adequate coverage of most of the area used by winter run to spawn and increase our tag recovery rate which in turn would provide a more accurate escapement estimate. This practice was continued in 1999.

The study section was divided into the following two reaches:

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

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 2-day survey period. This cycle was repeated following a one-day break. 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, then sexed, measured and tagged, 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 identify the survey period that the carcass was tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the upper jaw and decayed carcasses were tagged in the lower jaw. Carcass condition was noted during tagging to accommodate the various population estimators. 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 (based on size). The pertinent data were recorded and the carcass was chopped.

Based on DFG protocol, results from fresh carcass data are normally used to calculate an escapement estimate using the Schaefer model, and results from both fresh and decayed data are used to calculate an estimate using the Jolly-Seber model. The Jolly-Seber (Seber 1982) and Schaefer (1951) models were not used to calculate the 1999 estimates since they require that there be tag recoveries from all tagging periods (about one-third of the periods had no tag recoveries). Instead, the Petersen formula (Ricker 1975) was used to calculate estimates using both sets of data (fresh and combined fresh and decayed) .

The adjusted Petersen formula (Ricker 1975) used to calculate the escapement estimate is as follows:

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

Where:

N	=	population size,
M	=	total number of carcasses tagged,
C	=	total number of examined, and
R	=	total recaptures of tagged carcasses in the *j*th recovery period.

Size/age Distribution and Sex Composition

Fork length (FL), sex, and date of collection were recorded for most 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). Fresh carcasses measurements are more accurate and were used to develop length-frequency relationships and sex ratios.

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 2 weeks of spawning completion, based upon observations made in the American River (Snider and Vyverberg 1995). The total numbers of fresh carcasses observed in both reaches were 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.

Hatchery-produced Winter-run Chinook Salmon

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

Radio-tagging Study

During the course of the carcass survey, we conducted a pilot study to determine if we could monitor carcass dispersion using radio tags. Tag recovery rates during the past three winter-run escapement surveys have been low relative to similar surveys on fall-run chinook salmon (Snider et al. 1999a, 199b). The primary differences in sampling conditions between the two survey periods are higher flows and lower visibility. (Another major difference is the size of the spawner populations, thus the number of carcasses available for tag-and-recovery surveys). Tracking carcasses using radio tags could show if the higher flows sweep tagged carcasses out of the survey area before they can be observed during the recovery surveys, and if reduced visibility impedes the ability to find carcasses otherwise visible during the fall surveys.

Thirteen adult carcasses that were tagged with hog rings were also fitted with radio tags during the 12–13 July survey period. These carcasses were released back into running water in the same manner that tagged carcasses are normally released during escapement surveys. Carcasses were tagged in about the proportion to their relative abundance in the two reaches. All tags had distinct signals to allow tracking individual carcasses.

Two radio-tagged carcasses were released at each of the following river miles (RM): 301, 298, 296.5, 296, 295 and 294. One radio-tagged carcass was released at RM 300 upstream of ACID dam. Carcasses were tagged then released in the same general area they were first observed.

A monitoring station was set up at the lower end (RM 288) of the study section to detect any radio-tagged carcass drifting out of the survey reach. This receiver unit was operated around the clock from 12:00 a.m. on 12 July to 11:00 a.m. on 16 July.

On 15 July, the section of stream from ACID dam (RM 298.5) to the monitoring station (RM 288) was surveyed from a boat using a another receiver unit and antenna in an attempt to precisely locate radio-tagged carcasses remaining in the survey reach. The section of river from Keswick Dam (RM 302) downstream to ACID dam was surveyed from a boat on July 20, and the section downstream of ACID dam was surveyed a second time on July 21. After detecting a radio tag, the crew then determined if the tag was “recoverable” (i.e., could be observed by the carcass survey crew).

RESULTS

General

A total of 212 fresh and 263 decayed carcasses were observed during the 38 survey periods (Table 1). Mean flow ranged from 9,300 to 13,700 cfs (Figure 3). Mean temperature ranged from 50 ^{o}F to 54 ^{o}F (mode = 52 ^{o}F). Secchi depth readings ranged from 5.8 to 10.7 ft and generally increased as the survey season progressed.

Population Estimates

The Petersen (Ricker 1975) formula was used to estimate escapement. The Schaefer and Jolly-Seber models were not used since there were no recoveries made from about one-third of the released tag groups. A total of 161 fresh adult carcasses were tagged and 36 (22%) were subsequently recovered (Table 2). The adult tag recovery rate for decayed and fresh carcasses combined was 21%.

The Petersen formula was applied using the season totals for both fresh adult carcasses and for all (fresh and decayed) adult carcasses. The fresh carcass data yielded an estimate of 1,821 adults. Assuming adults comprised 80.5% of the population, (based on length-frequency data results described below), the total population estimate was 2,262 salmon, including 441 grilse. The second estimate of adults using data from all tagged carcasses yielded a total population estimate of 2,493 (2,007 adults and 586 grilse). Based on Law's (1994) analysis, the estimate based on fresh carcass data is more accurate.

Size/age Distribution and Sex Composition

A total of 210 fresh carcasses was measured (Table 3). Mean FL was 67.3 cm (range: 45–105 cm FL). Male salmon (n = 53) averaged 64.5 cm FL (range: 46–105 cm FL) (Figure 4). Female salmon (n = 157) averaged 68.1 cm FL (range: 45–91 cm FL). The largest fish were observed during May (Figure 4). The monthly mean size ranged from 58.5 cm FL in July to 80.9 FL in May for males, and from 63.7 cm FL in August to 72.0 cm FL in May for females.

Length-frequency distributions were used to define a general size criteria to distinguish grilse (2-year-old salmon) from adults (>2-year-old salmon) for both sexes (Table 4 and Figure 5). The male and female length frequency distributions were quite different (Table 4 and Figure 5). About 96% of the females were grouped in a normal distribution (Figure 5a) that ranged from 66 to 91 cm FL with a mode of 66 cm FL. These fish were considered 3-year old fish. Females >59 cm FL were considered adults based upon the location of the break between the tail of this distribution and the few fish that were to the left. The male distribution was skewed with about 85% of the males ranging from 45 to 58 cm FL (Figure 5b). Based upon an apparent break in the distribution between 63 and 66 cm FL, male adults were defined as salmon >63 cm FL. We

Table 1. Summary of mean flow, mean water temperature, Secchi depths, and carcass count totals during each survey period of the upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (°F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
1	May 5–6	10,500	52	9.0	4	11
2	May 8–9	11,000	53	8.4	0	3
3	May 11–12	11,000	52	5.8	4	6
4	May 14–15	10,700	52	7.1	2	2
5	May 17–18	9,300	52	7.7	5	2
6	May 20–21	9,600	53	7.8	0	2
7	May 23–24	10,100	53	6.9	3	5
8	May 26–27	10,800	50	8.2	8	2
9	May 29–30	11,400	50	7.8	3	4
10	June 1–2	11,000	50	8.1	5	7
11	June 4–5	10,800	52	6.8	10	12
12	June 7–8	10,500	52	8.2	15	6
13	June 10–11	10,500	52	10.2	8	6
14	June 13–14	10,500	52	9.4	5	8
15	June 16–17,	11,000	52	9.6	17	5
16	June 19–20	11,800	50	9.0	8	6
17	June 22–23	12,400	52	10.4	16	12
18	June 25–26	13,000	52	8.9	14	10
19	June 28–29	13,500	52	8.8	10	9
20	July 2–3	13,000	53	9.9	5	11
21	July 6–7	13,000	52	10.4	8	16
22	July 9–10	13,000[4/]	53	9.7	5	15
23	July 12–13	13,700	52	8.6	13	12
24	July 15–16	13,500	54	9.6	6	11
25	July 18–19	13,500	52	9.6	7	13

Table 1 (cont.)

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (°F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
26	July 21–22	13,000	52	9.8	8	7
27	July 24–25	13,000	53	10.1	5	9
28	July 27–28	13,000	53	10.0	3	4
29	July 30–31	12,900	53	8.5	3	6
30	August 2–3	13,000	54	10.4	3	4
31	August 5–6	12,000[4/]	54	10.0	2	5
32	August 8–9	11,000	54	10.7	2	4
33	August 11–12	10,600	53	9.9	1	10
34	August 14–15	9,800	52	10.0	1	3
35	August 17–18	9,500	52	8.2	0	6
36	August 20–21	9,500	52	8.8	1	2
37	August 23–24	9,500	52	9.2	1	4
38	August 26–27	9,500	51	9.2	1	3
				Totals	212	263

1/ Mean flow at Keswick Dam during survey period as measured by U.S. Geological Survey.
2/ Mean water temperature measured each day by survey crew.
3/ Includes grilse and adults; does not include tag recoveries.
4/ No flow measurement recorded for 9 July and 6 August 1999.

Table 2. Summary for each tagging period of number of carcasses observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during the 1999 upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
1	May 5–6	14	1	3	1	0
2	May 8–9	3	0	0	0	0
3	May 11–12	9	1	3	1	0
4	May 14–15	4	0	2	0	0[1,(3)-grilse]
5	May 17–18	6	1	5	0	1(4)
6	May 20–21	2	0	0	0	3(5)
7	May 23–24	8	0	3	0	0
8	May 26–27	9	1	7	1	0
9	May 29–30	7	0	3	0	1(8),1(7)
10	June 1–2	11	1	4	1	1(9)
11	June 4–5	21	1	10	0	1(10)
12	June 7–8	17	4	12	3	2(11),1(8)
13	June 10–11	13	1	7	1	2(12),1(11)
14	June 13–14	11	2	3	2	1(12)
15	June 16–17	20	2	16	1	2(14)
16	June 19–20	11	3	7	1	[1(15)-grilse]
17	June 22–23	26	2	15	1	2(16),1(14),1(12),1(10)
18	June 25–26	20	4	12	2	1(15),1(13),1(12)
19	June 28–29	14	5	7	3	1(17)
20	July 2–3	12	4	4	1	0
21	July 6–7	18	6	3	5	1(18)
22	July 9–10	9	11	1	4	0
23	July 12–13	19	6	10	3	0
24	July 15–16	16	1	5	1	1(23)
25	July 18–19	13	7	3	4	0

Table 2 (cont).

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
26	July 21–22	11	4	5	3	1(22)
27	July 24–25	11	3	3	2	1(23),1(22)
28	July 27–28	6	1	2	1	0
29	July 30–31	4	5	1	2	0
30	August 2–3	5	2	2	1	1(27)
31	August 5–6	4	3	1	1	1(29),1(27)
32	August 8–9	4	2	1	1	0
33	August 11–12	5	6	0	1	1(32),1(30)
34	August 14–15	3	1	1	0	0
35	August 17–18	4	2	0	0	0
36	August 20–21	2	1	0	0	0
37	August 23–24	4	1	0	0	0
38	August 26–27	3	1	0	0	0
Totals		377	98	161	48	36 adults and 2 grilse

Table 3. Size and sex statistics for winter-run chinook salmon carcasses measured during the upper Sacramento River escapement survey, May – August 1999.

	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	29	74.8	52–105	9	80.9	52–105	20	72.0	60–90
June	108	67.5	45–91	20	63.0	48–82	88	68.6	45–91
July	63	63.4	46–84	21	58.5	46–84	42	65.9	53–84
August	10	64.5	56–79	3	63.3	58–79	7	63.7	56–78
Totals (mean)	210	(67.3)	45–105	53	(64.5)	46–105	157	(68.1)	45–91

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, May – August 1999.

	Female		Male	
	Grilse*	Adults	Grilse*	Adults
Total measured	6	151	35	18
Mean	54.3	68.8	55.4	82.1
Range FL (cm)	45–58	60–91	46–63	66–105
Standard deviation	4.9	6.1	4.5	12.0

* Grilse were defined as females $\leq$ 59 cm FL and males as $\leq$ 63 cm FL..

plan to verify the age/length relationship for the 1999 spawner population using scales and otoliths taken from most measured carcasses.

Male grilse averaged 55.4 cm FL (SD = 4.5; range: 46–63 cm FL) while female grilse averaged 54.3 cm FL (SD = 4.9; range: 45–58 cm FL) (Table 4). Adult males averaged 82.1 cm FL (SD = 12.0; range: 66–105 cm FL). Female adults averaged 68.8 cm FL (SD = 6.1; range 60–91 cm FL).

Adults comprised 80.5% (n = 169) of the population (measured carcasses) and grilse comprised 19.5% (n = 41) (Table 5). The proportion of grilse in the population increased from 10% in May to 40% in August.

The grilse population was comprised of 85% males (n = 35) and 15% females (n = 6) (Table 6). The adult population comprised 89% (n = 151) females and 11% (n = 18) males. The ratio of male to female for adult spawners was 1 to 8.4. The overall sex ratio, including grilse, was 1 to 3.0.

Table 5. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, May – August 1999.

Survey period	Adults		Grilse	
	Number	%	Number	%
May	26	90	3	10
June	94	87	14	13
July	43	68	20	32
August	6	60	4	40
Totals (Mean)	169	(80.5)	41	(19.5)

Table 6. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, May – August 1999.

	Adults				Grilse			
	Male		Female		Male		Female	
Month	Number	%	Number	%	Number	%	Number	%
May	6	23	20	77	3	100	0	0
June	7	7	87	93	13	93	1	7
July	4	9	39	91	17	85	3	15
August	1	14	5	86	2	50	2	50
Totals (mean)	18	(11)	151	(89)	35	(85)	6	(15)

Spawning Success

Ninety-seven percent (n = 147) of the 151 fresh, adult female carcasses examined for egg retention had completely spawned. One percent (n = 1) had partially spawned, and 2.6% (n = 4) had not spawned. One of six grilse-sized females checked for spawning success was unspawned (83.3% success). The unspawned female grilse was 45 cm FL, the smallest salmon measured.

There was one unspawned female observed in May, two in June (1 adult and 1 grilse), and one in August. One partially spawned female was observed in June.

Temporal Distribution

Fresh carcasses were observed from survey period 1 (5–6 May) through survey period 38 (26–27 August) (Table 1, Figures 6 and 7). Seventy percent of the fresh carcasses were observed between 4 June and 13 July with the maximum occurring 17–18 June. Assuming that fresh carcasses become available for observation approximately 2 weeks after spawning, spawning occurred from late April into mid-August and peak spawning occurred during early June.

Spatial Distribution

Seventy-three percent (n = 154) of the fresh carcasses were observed in Reach 1 and 27% (n = 58) in Reach 2 (Table 7). For decayed carcasses, 58% (n = 152) were observed in Reach 1 and 42% (n = 111) in Reach 2. The ratio of fresh to decayed carcasses was 1 to 1 in Reach 1 and 1 to 1.9 in Reach 2.

Hatchery-produced Winter-run Chinook Salmon

Four adipose-fin marked carcasses were observed during the survey (Table 8). CWTs were recovered from two of the these carcasses. Both carcasses with tags were fresh. The other two were decayed making mark identification less certain. Both of the CWTs were from CNFH. One of the CWTs was from a 105 cm FL late-fall-run male (Tag # 054119) from the 1995 brood year; it was recovered on 24 June 1999. The other CWT was from a 66 cm FL winter-run female (Tag # 0501011407) from the 1995 brood year; it was recovered on 12 July 1999.

Radio-tagging Study

The carcass survey crew recovered 2 (15%) of the 13 radio-tagged carcasses. The remaining 11 carcasses were located by the boat crew using a receiver unit. None of these 11 carcasses was considered recoverable, i.e., they were located in deep water or under brush.

No radio-tag signals were detected at the stationary monitoring site. All 13 radio tags released were either located during the roving boat survey or recovered during the carcass survey. All three of the radio-tagged carcasses released above ACID dam were also detected upstream of the dam. All 10 radio carcasses released downstream of the dam were located or recovered between RM 292 and 296.

Two radio-tagged carcasses were recovered by the carcass survey crew, one on July 15 and the second on July 24. The second carcass had also been located by the roving, radio-tag monitoring crew on July 21, and classified as recoverable. None of the other remaining 11 radio-tagged carcasses were considered recoverable; nine were located in deep areas and two were located under overhanging brush.

DISCUSSION

Several more years of survey are planned. These survey's 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

Law (1994) found that the Petersen formula consistently showed substantially greater overestimation than either the Schaefer or Jolly-Seber models. When both fresh and decayed carcasses are used, Law found that the Petersen formula overestimated the known population by as much as 151%, and by as much as 84% when only fresh carcasses were used. The population based on the Petersen formula, using fresh carcass data, is 2,262. The estimate calculated from fresh and decayed carcass data is 2,493. There were no recoveries from almost a third of the survey periods when tags were released precluding the use of the Jolly-Seber and Schaefer models.

The most appropriate winter-run escapement estimate to determine population trends is the one derived from the Petersen formula using fresh carcass data.   Although this formula will likely overestimate the true population, data will likely be available every year to permit calculation of a population estimate, unlike the Schaefer and Jolly-Seber models. Unless winter-run population increases, there will not be enough tag recoveries to allow use of the Jolly-Seber or Schaefer models in most years even though these models will provide a more accurate estimate.

Table 7. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999. Includes adults and grilse, fresh and decayed carcasses, but not tag recoveries.

Survey period	Reach 1		Reach 2	
	Fresh	Decayed	Fresh	Decayed
1	3	9	1	2
2	0	0	0	3
3	3	2	1	4
4	1	2	1	0
5	4	1	1	1
6	0	0	0	2
7	1	2	2	3
8	5	1	3	1
9	0	0	3	4
10	4	2	1	5
11	7	9	3	3
12	11	3	4	3
13	8	5	0	1
14	3	5	2	3
15	12	3	5	2
16	8	6	0	0
17	11	8	5	4
18	11	4	3	6
19	8	3	2	6
20	5	4	0	7
21	5	11	3	5
22	4	7	1	8
23	10	7	3	5
24	5	6	1	5
25	4	6	3	7
26	7	3	1	4
27	3	6	2	3
28	1	3	2	1
29	2	6	1	0
30	2	0	1	4
31	1	5	1	0
32	2	1	0	3
33	1	8	0	2
34	0	3	1	0
35	0	3	0	3
36	0	2	1	0
37	1	4	0	0
38	1	2	0	1
Totals	154	152	58	111

Table 8. Summary of adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, May – August 1999.

Date collected	Tag code	Sex	FL (cm)	Race (brood year)
May 14	054119	Male	103	Late fall (1995)
June 13	-	Female	66	-
June 19	-	Female	64	-
July 12	0501011407	Female	66	Winter (1995)

The carcass recovery rate for the 1999 survey was considerable greater than the rates observed during the earlier surveys (15% in 1998, 12% in 1997, and 15% in 1996) (Appendix Table 1). Possible reasons for increased tag recoveries include greater water clarity and more stable flows. During 1999, water clarity exceeded 8 ft during 92% of the survey periods and mean flows fluctuated from only 9,300 to 13,700 cfs. During 1998, water clarity was less than 8 ft during 64% of the surveys while flows fluctuated from 10,000 to 23,500 cfs.

In contrast to winter run, recovery rates observed during the 1995 through 1998 upper Sacramento River fall-run chinook salmon escapement surveys ranged from 26% to 33% (Snider et al. 1999b). Flows during the fall-run survey periods are typically are around 5,000 cfs, which are much less than during the winter-run surveys. Flows during the late-fall-run surveys have fluctuated the most ranging from 5,500 to 29,800 in 1999 and 4,200 to 52,800 in 1998. Recovery rates observed during the 1999 and 1998 late-fall-run surveys were 29% and 6%, respectively.

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. Only adult females are used here to calculate the effective spawner population since there is some disagreement among agencies responsible for winter-run management as to the contribution of female grilse to the spawning population. Since 89.3% of the adult escapement was female, the estimated adult female population was 1,626 (based on the Petersen formula using fresh carcass data). Prespawning mortality was 3% yielding an estimated effective spawner population of 1,577.

The issue of female grilse contributing to the spawning population needs to be further evaluated. Although the estimated proportion of females that were grilse (per the carcass survey) was very low (3.8%), the estimated proportion of female grilse (based upon the RBDD counts, see below) was high (56.5%). The spawning success data collected during the carcass survey showed that one of the four unspawned salmon was grilse-sized; 16.7% of grilse-sized females was unspawned, compared to 2% of adult-sized females. The unspawned grilse was 45 cm FL, the smallest salmon measured.

Sex Composition

The ratio of males:females for adults only in 1999 was 1:8.4 compared to 1:8.9 in 1998, 1:3.2 in 1997 and 1:6.4 in 1996. Including adults and grilse, the observed ratio during the 1999 carcass surveys was 1:3.0 compared to 1:7.5 during 1998, 1:3.2 during 1997, and 1:2.4 during 1996 (Appendix Table 1). The sex ratio varied throughout the survey ranging from 1:2.2 in May (n = 29), 1:4.4 in June (n = 108), 1:2.0 in July (n = 63) and 1:2.3 in August (n = 11).

The following are possible explanations for the observed 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 only 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.*). Furthermore, if the proportion of males that remain in the ocean for more than three years is different from females, than the number of males returning as 3-year olds would be further decreased.

3. Behavioral differences between males and females after spawning may reduce the relative availability of males to a traditional carcass survey. If, for example, males leave the redd and move to deep pools or downstream out of the survey area, and females remain on the redd, the proportion of females available to the survey would be greater.

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

It should be noted that the disparity between males and females has not been observed during surveys of late-fall-run and fall-run salmon in the upper Sacramento River. During 1999 and 1998 late-fall-run surveys, the male:female ratios were 1:1.9 and 1:1.1. Late-fall-run surveys have been conducted during high flow conditions similar to those occurring during winter-run surveys. For fall run, male:female ratios have been 1:1.6 during 1998, 1:1.2 during 1997, 1:1.2 during 1996, and 1:1.6 during 1995. *Therefore, the high ratios of females observed during the winter-run carcass surveys should not be entirely attributed to differences in availability between male and female salmon.*

Age Composition

Length frequency distributions help identify possible trends in age distribution when age-size relationships occur and when sufficient sample sizes are available. Preliminary data obtained from scale analyses conducted by DFG and NCVFWSO indicate that there is significant overlap in size at age.

Comparison with Red Bluff Diversion Dam Winter-run Escapement Estimates

Based on the salmon counts at RBDD, an estimated 3,208 winter-run salmon migrated upstream. Applying the 61 cm FL criterion[1] to separate adult from grilse, 459 (14.3%) were male adults, 427 (13.3%) were female adults, 1,767 (55.1%) were male grilse, and 555 (17.3%) were female grilse. In comparison, the carcass survey escapement estimate was 2,262 comprising 194 (8.6%) adult males[2], 1,626 (71.9%) adult females, 377 (16.7%) male grilse, and 65 (2.8%) female grilse (Tables 9 and 10, Figure 8).

The population structure defined by the results of the two surveys were quite different. The RBDD data shows a higher proportion of males (2.8 times greater), a higher proportion of grilse-sized fish (6.0 times greater for females and 3.3 times greater for males), and much smaller fish than the carcass survey data. At RBDD, females comprised 30.6% of the sample and had a mean size of 60.7 cm FL (range: 77–82 cm FL). Females comprised 74.8% of the carcass survey and had a mean size of 64.6 cm FL (range: 45–91 cm FL). Males collected at RBDD had a mean size of 55.9 (range: 38–79 cm FL); males collected during the carcass survey had a mean size of 64.6 (range: 46–105 cm FL). The size structure observed at RBDD was comparable to the size distributions observed late in the carcass survey (August) when the size range was compressed and the occurrence of grilse was highest.

Applying the carcass age-size criteria to the RBDD and the RBDD criterion to the carcass survey results yielded little change in the estimated age compositions. Applying the 61-cm criterion to the carcass data yielded a change in the estimated age composition from 8.6 to 9.5% for male adults, 71.9 to 65.7% for female adults, 16.6 to 15.7% for male grilse and 2.9 to 7.1% for female grilse. The overall change in grilse composition for the carcass survey data was 3% (20% using length frequency data criteria, 23% using the 61 cm FL criterion).

Similarly, applying the carcass based criteria to the RBDD data yielded no change in the percent composition of female adults and grilse and an 8% decrease in male adult composition. The percentage of grilse was 19.4% using the carcass survey criteria versus 27.6% using the RBDD criterion. *The disparity in adult:jack ratios between the RBDD and carcass survey results relates more to the differences in size composition than to the different size criteria.*

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[1] All chinook salmon measured at RBDD that are ≥61 cm Fl are considered adults.

[2] The age-size criteria applied to the carcass survey data was adults are >59 cm FL for females and >63 cm Fl for males.

RECOMMENDATIONS

1. Continue the mark and recapture carcass surveys for at least two more years.

2. Investigate the differences between the sex ratios and age composition of fish observed during the carcass survey and fish trapped at RBDD.

3. Expand the radio-tagging survey to evaluate the effects of flow, visibility, and other factors on recovery rates

4. Expand the survey to include investigation of deep pools. The results of the radio-tagging survey show that a large portion of carcasses drift into pools. Separate surveys of the pools could be conducted biweekly to determine the sex, size, and age composition, number of marked and unmarked carcasses that end up in pools, unavailable to the typical carcass survey methods. These data could be compared with the carcass survey results and the radio-tagging survey results to see if there are biases associated with carcasses moving into pools.

5. Age composition and 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. Information from known-age CWT winter run should be included in such an evaluation.

6. Evaluate the relationship between age and size of females and contribution to the spawning population.

Table 9. Comparison of results of the RBDD carcass data collected during the winter-run carcass survey, May–August 1999.

	RBDD	Carcass
Total estimate	3,208	2,262
%adult	27.6	80.5
% male adult	13.1	8.6
% female adult	13.1	71.9
Size criteria (grilse/adult)	61	59 female/ 63 male
% male grilse	56.6	16.7
% female grilse	17.1	2.8
No. adult female	427	1,626
No. grilse female	555	65
Total female	982	1,691

Table 10. Comparison of size statistics for male and female winter-run chinook salmon collected at RBDD and during the winter-run carcass survey, May–August 1999.

	RBDD Counts	Carcass Survey
	Male	
Number	68	53
Mean FL	55.9	64.5
Range FL	38-79	46-105
SD	7.62	15.0
	Female	
Number	30	157
Mean FL	60.7	68.1
Range FL	44-82	45-91
SD	9.06	6.6

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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. CA 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. CA 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.

Snider, B., B. Reavis, and S. Hill. 1998. 1997. Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Evaluation Program, Envir. Serv. Div.

Snider, B., B. Reavis, and S. Hill. 1999a. 1998. Upper Sacramento River winter-run chinook salmon escapement survey, May–August 1998. Calif. Dept. Fish & Game, Stream Evaluation Program, Habitat Conservation Division.

Snider, B., B. Reavis, and S. Hill. 1999b. 1998. Upper Sacramento River fall-run chinook salmon escapement survey, September–December 1998. Calif. Dept. Fish & Game, Stream Evaluation Program, Habitat Conservation Division.

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.

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

APPENDIX

Appendix Table 1. Summary of results from the 1996, 1997, 1998 and 1999 upper Sacramento River winter run spawner surveys.

Parameter	1996	1997	1998	1999
Survey dates	29 April– 5 September	30 April– 29 August	5 May– 28 August	5 May– 27 August
No. of total carcasses	118	239	785	475
No. of fresh carcasses	52	105	382	212
No. of decayed carcasses	66	134	403	263
Tag recovery rate	15%	12%	15%	22%
Estimated population (Petersen)	820	2,053	5,501	2,262
Adult estimate	664	1,888	5,391	1,821
Grilse estimate	156	165	110	441
Adult female estimate	571	1,437	4,847	1,626
Adult male estimate	93	451	544	194
Grilse female estimate	10	92	0	65
Grilse male estimate	146	73	110	377
Female:male ratio: adults/all	6.1:1/2.5:1	3.2:1/3.2:1	8.9:1/7.5:1	8.4:1/3:1
Size criterion (male)	Adult >65 cm	Adult >63 cm	Adult >60 cm	Adult >63 cm
Size criterion (female)	Adult >64 cm	Adult >63 cm	Adult >54 cm	Adult >59 cm
Spawning success (%)	94%	96%	95%	97%
Spatial distribution (Reach 1,2,3, and 4)[1]	50%, 39%, 9%, 2%	48%, 52%	58%, 42%,	73%, 27%,
Peak spawning period	early– mid July	late June - early July	early July	early– mid June
Flow range	7,200–16,200	8,000–15,000	10,000– 23,5000 cfs	9,300– 13,700 cfs
Temperature range	52–59 °F	49–52 °F	50–54 °F	50–54 °F
Visibility range	na	3–10 ft	4.5–11 ft	6–11 ft

FIGURES

Figure 1. Percentage of the total migration of winter-run chinook salmon passing Red Bluff Diversion Dam after Week 20 (1969 through 1985).

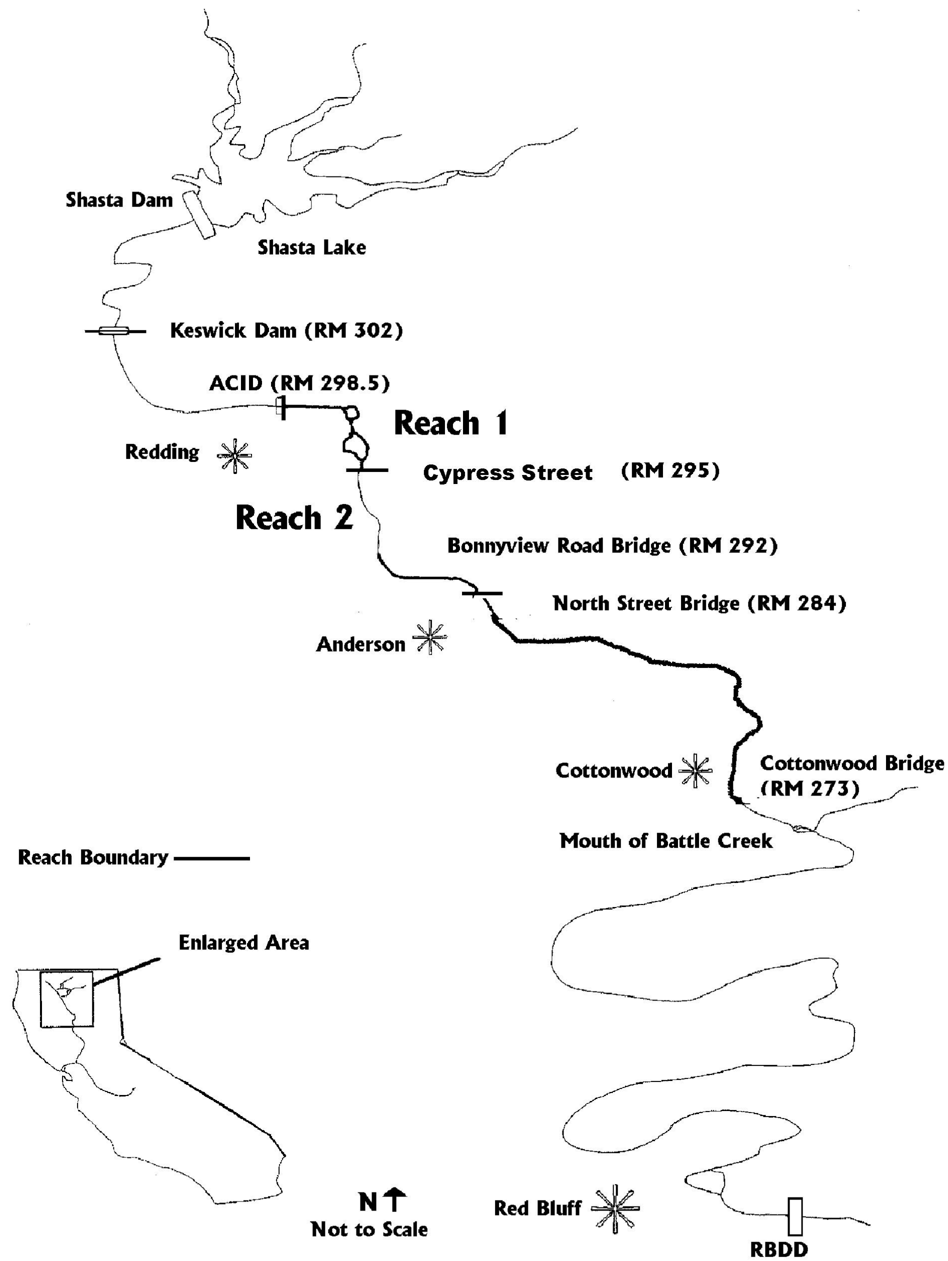

Figure 2. Location of reaches surveyed during the 1999 winter-run chinook salmon escapement survey, May-August 1999.

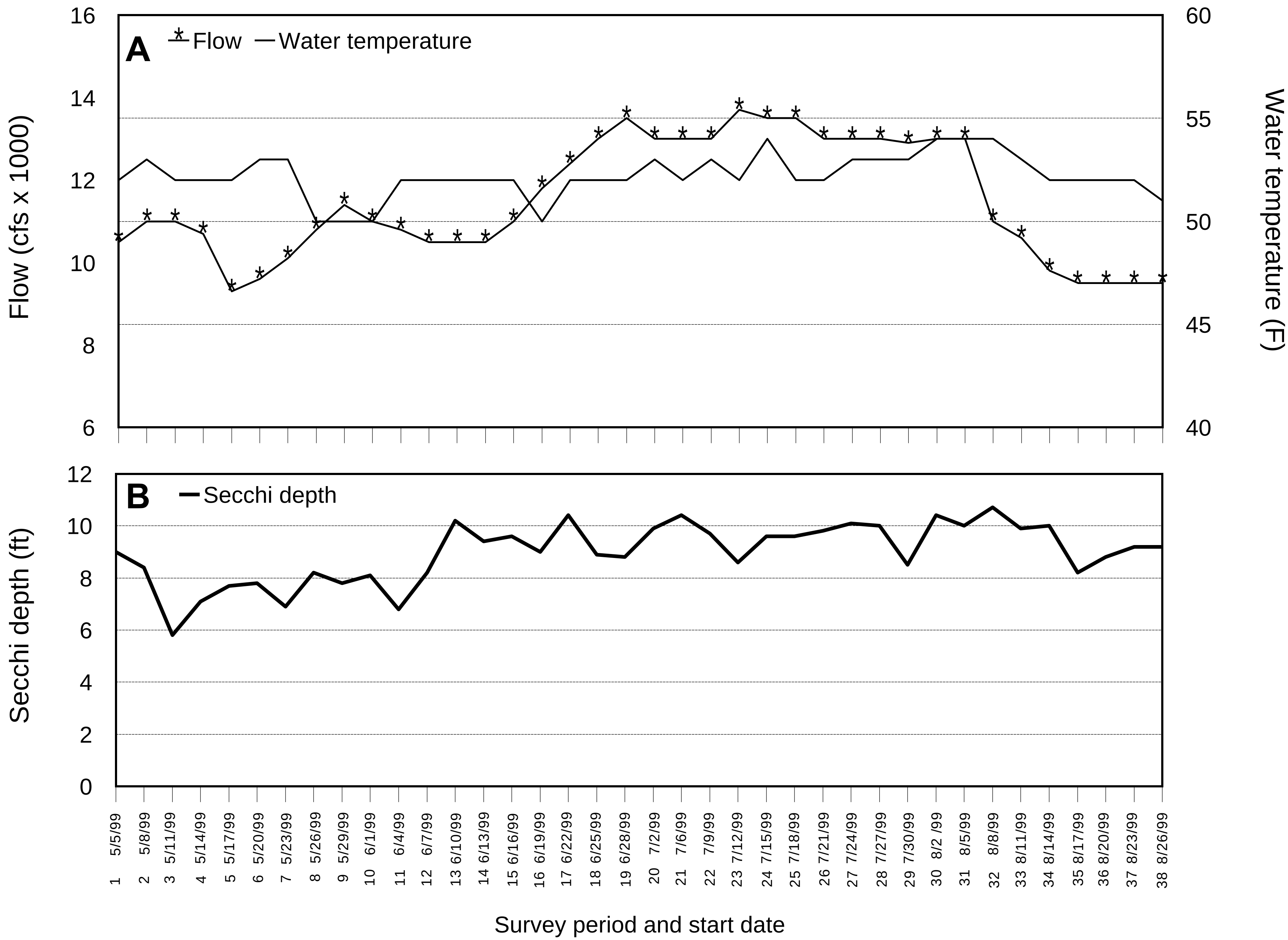

Figure 3. Mean flow and water temperature (A) and Secchi depth (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

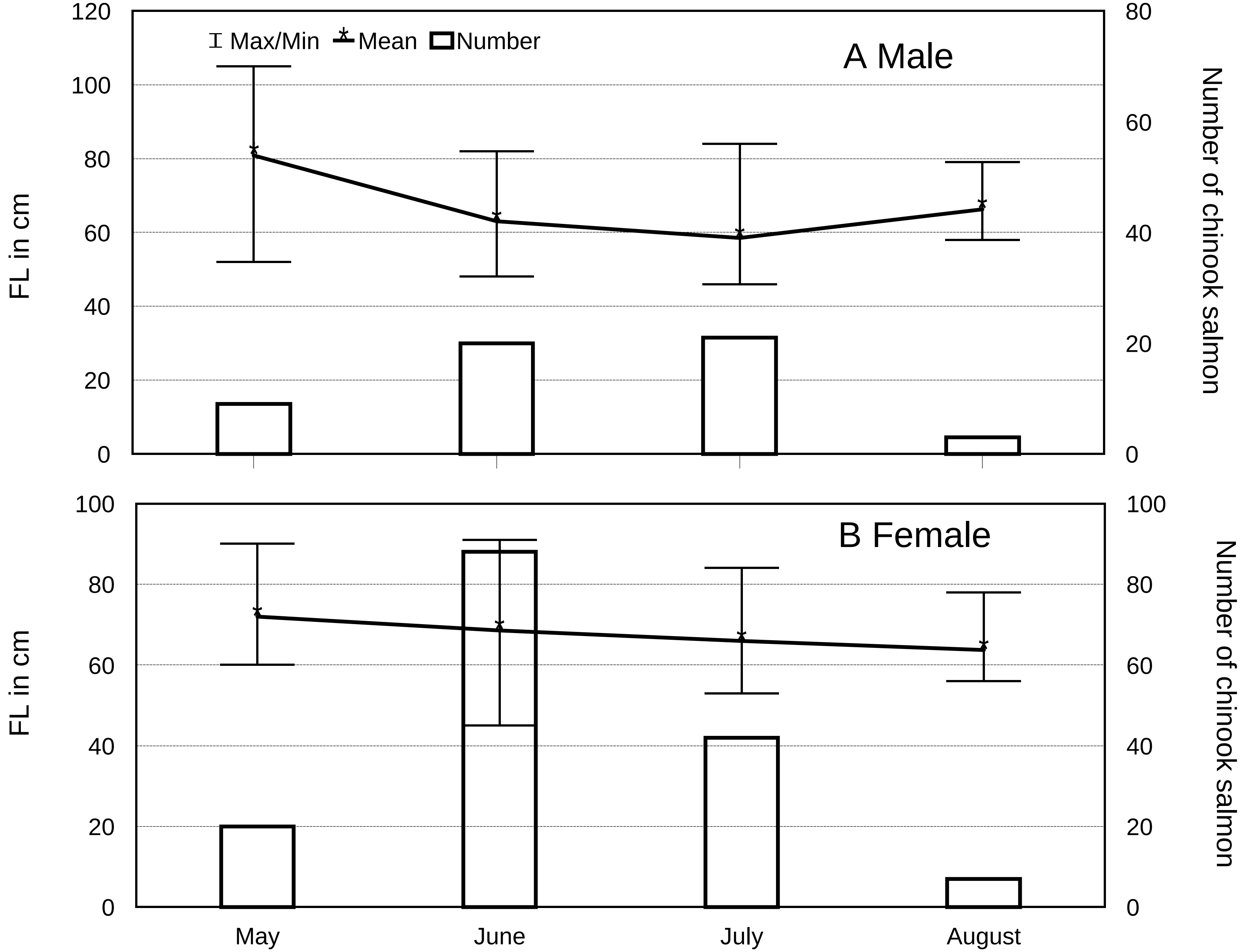

Figure 4. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

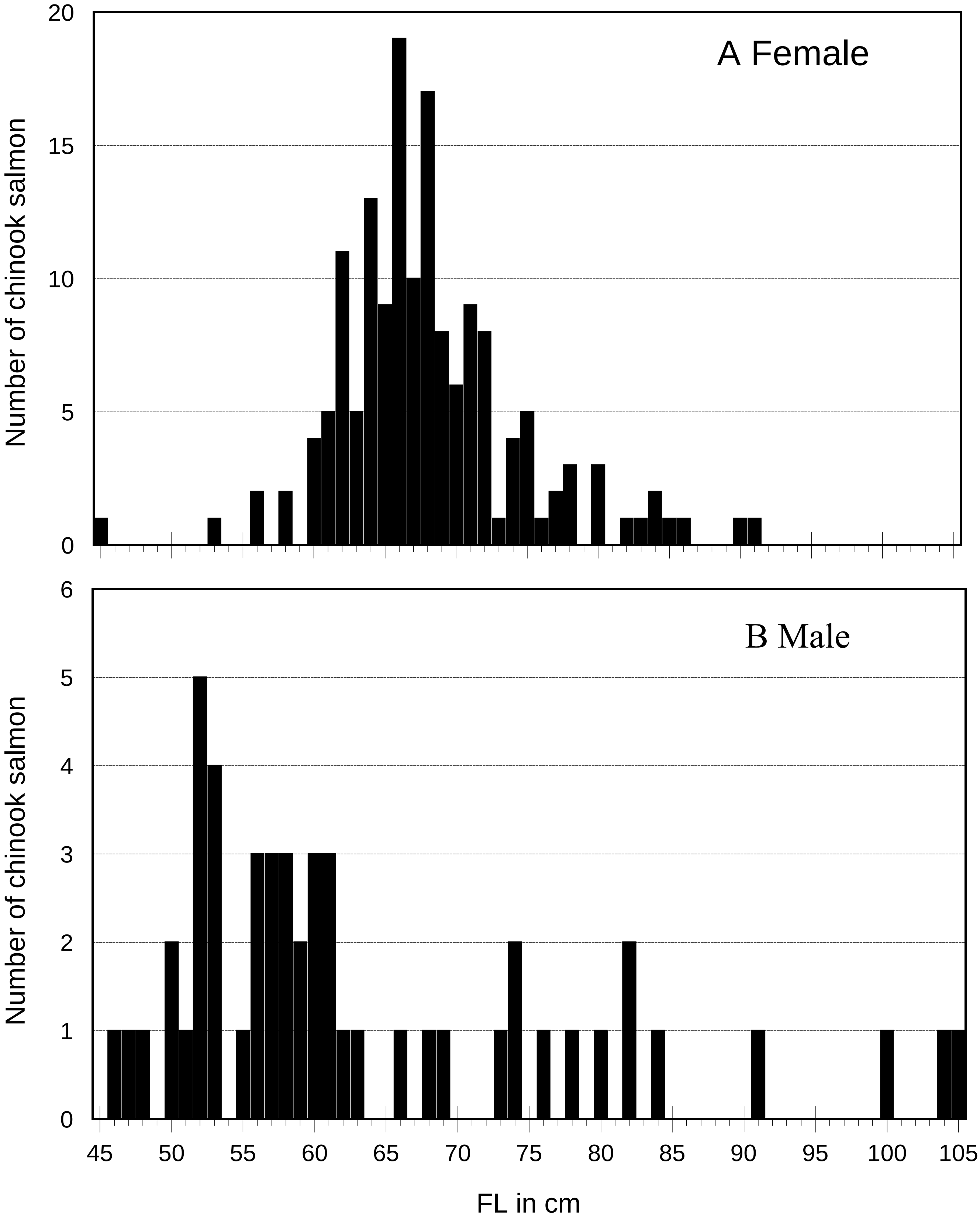

Figure 5. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

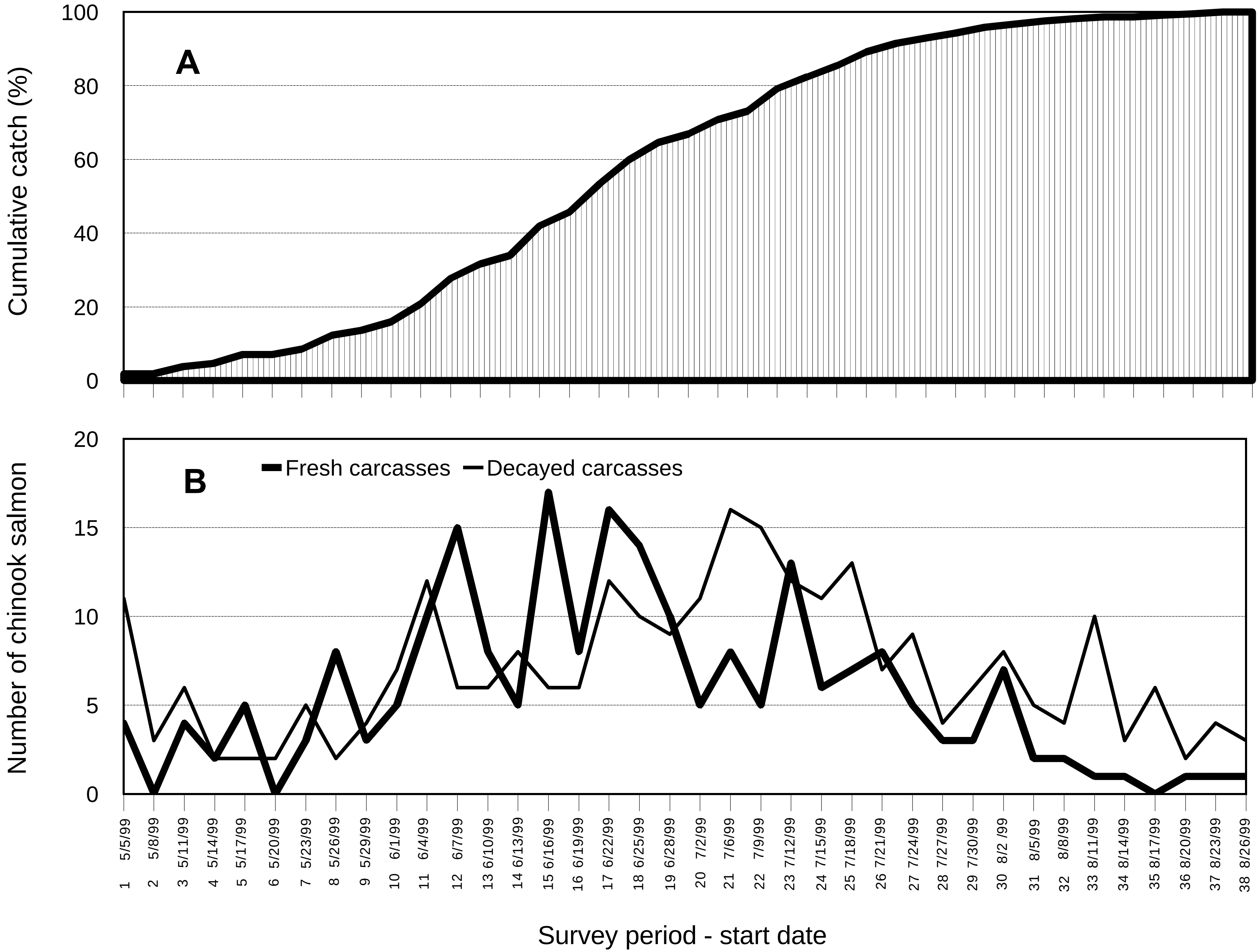

Figure 6. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B), by survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May-August 1999.

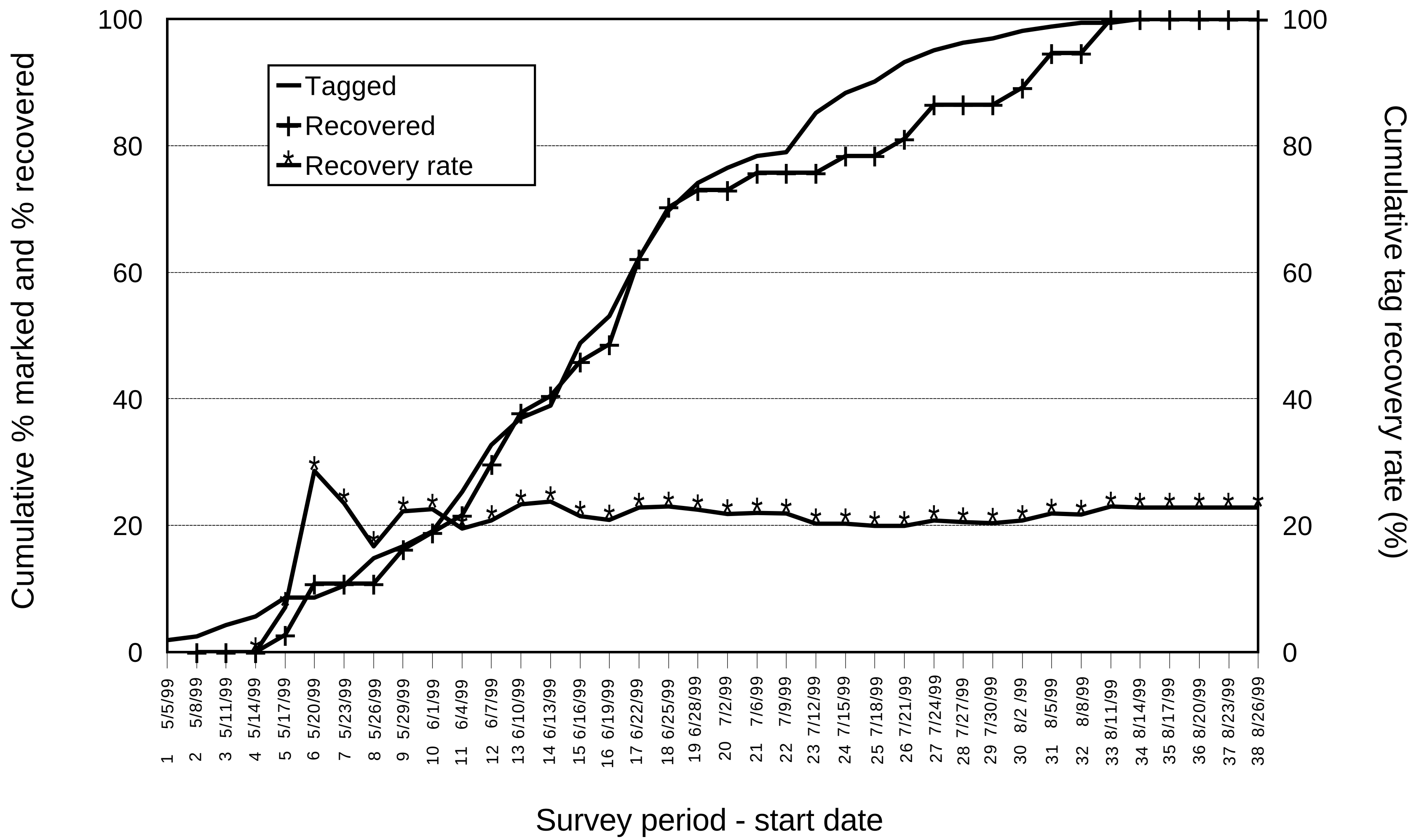

Figure 7. Comparison of temporal distribution of tagging versus recovering of tagged fresh carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 1999.

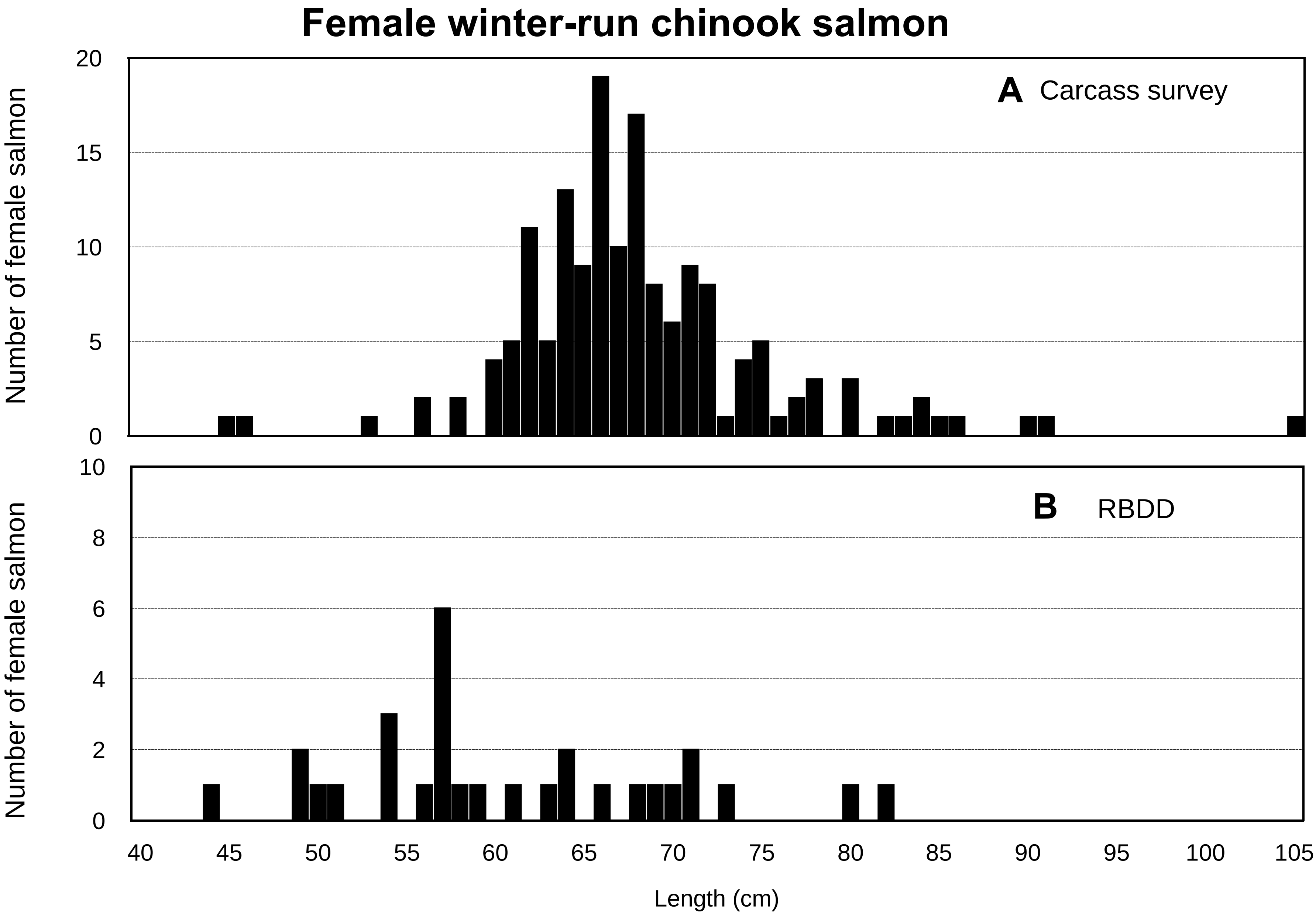

Figure 8. Comparison of length frequency distributions for female winter-run chinook salmon collected during (A) the winter-run chinook salmon escapement survey and (B) at RBDD, May - August 1999.

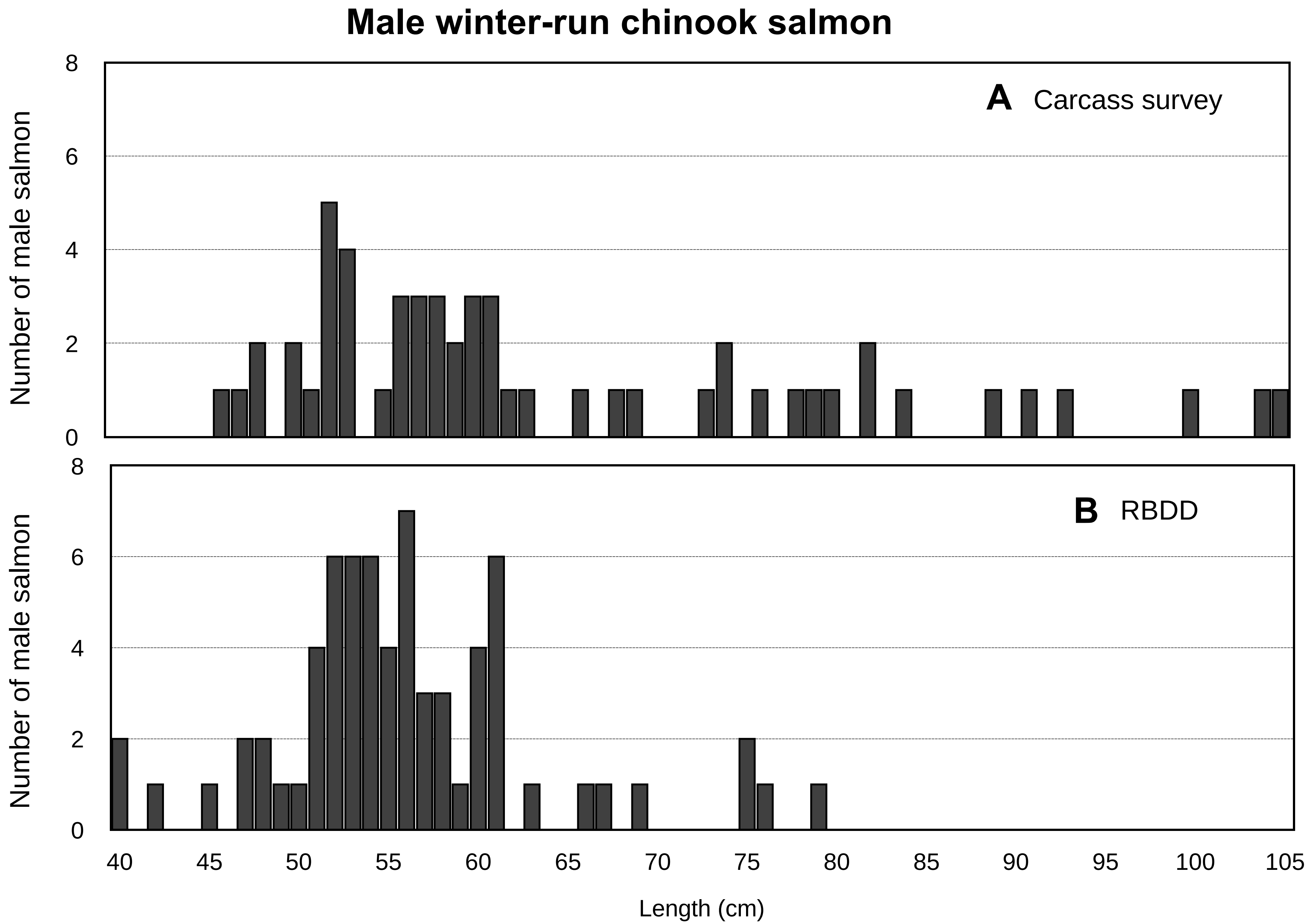

Figure 9. Comparison of length frequency distributions for male winter-run chinook salmon collected (A) during the winter-run chinook salmon escapement survey and (B) at RBDD, May - August 1999.