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

Upper Sacramento River
Winter-Run Chinook Salmon Escapement Survey
May–August 2000

by

Bill Snider
Bob Reavis
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Stream Evaluation Program
Technical Report No. 01-1
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2/ Stream Evaluation Program Technical Report No. 01-1

TABLE OF CONTENTS

SUMMARY

The California Department of Fish and Game's Stream Evaluation Program and the U.S. Fish and Wildlife Service's Red Bluff Fish and Wildlife Office jointly conducted a winter-run chinook salmon *Oncorhynchus tshawytscha* escapement survey in the upper Sacramento River during spring-summer 2000 to acquire data on abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning activity. This was the fifth consecutive year that 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 3 May through 29 August 2000. 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 8,400 cubic feet per second (cfs) on 12–13 May to 15,700 cfs on 26–27 July. Secchi disk depths (water transparency) ranged from 8.7 ft on 3–4 May to 20.0 ft on 10–11 August. Water transparency was much greater than during previous surveys providing more favorable survey conditions. Water temperature fluctuated from 51°F to 54°F during the survey. The peak in fresh carcasses observations occurred between 11 and 30 June 2000 indicating that spawning activity peaked during the first two weeks of June (2 weeks prior).

A total 2,482 carcasses (1,091 fresh and 1,391 decayed) was collected. Based on data from measured fresh carcasses (n=1,048), 97.3% of the population were adults and 2.7% were grilse. Overall, 18.2% of measured fresh carcasses were male and 81.8% were female; 16.6% of the adults were male and 83.4% were female. All of the 854 females checked for egg retention had completely spawned. Four adipose-fin-marked carcasses were collected; only one coded-wire tag (CWT) was recovered. The CWT was taken from a 1995 brood year late-fall run released from Coleman National Fish Hatchery.

A carcasses tag-and-recapture survey was used to estimate spawner escapement. A total of 1,053 fresh adult carcasses was tagged and 469 were subsequently recovered (45%). Three mark-and-recapture models were applied to the survey results and compared. The Petersen model was applied using the tag-and-recovery data for adult-sized, fresh carcasses to estimate the adult, winter-run escapement. Total escapement (adult and grilse) was estimated by expanding the adult estimate in proportion to the adult carcass composition in the fresh carcass sample (97.3%). The total population estimate was 6,670 including 6,492 adults and 178 grilse. Similar application of the Schaefer model yielded a total escapement population estimate of 5,707 (5,555 adult and 152 grilse). Application of the Jolly-Seber model and both fresh and decayed carcass data yielded a total escapement estimate of 4,343 (4,227 adult and 116 grilse)

The effective spawner population (e.g., total number of females that spawned) was estimated by applying the total composition of females (81.8%) and the percentage of completely spawned females (100%) to the three escapement estimates. Total effective spawner population estimates

were 5,454 (Petersen estimate), 4,667 (Schaefer estimate), and 3,551 (Jolly-Seber estimate). In comparison, the effective spawner population estimate using winter-run count data collected at Red Bluff Diversion Dam was 517 (43% of the estimated escapement of 1,206 unmarked salmon).

INTRODUCTION

A winter-run chinook salmon, *Oncorhynchus tshawytscha,* escapement survey was conducted in the upper Sacramento River during spring–summer 2000 to acquire data on abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning. This was the fifth consecutive year that 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, Snider *et al.* 1999, and Snider *et al.* 2000). 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. 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 1) relationships between water temperature and temporal distribution of spawning and emergence, 2) spawner abundance and pre-spawning mortality, 3) flow and habitat availability, 4) spawner abundance and habitat use, and 5) 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 site specific spawner escapement surveys should be conducted concurrent with habitat evaluations 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 the Jolly-Seber (Seber 1982) models. The Petersen model 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), Anadromous Fish Restoration Program to determine 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 Central Valley steelhead - 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, Red Bluff Fish and Wildlife Office (RBFWSO) and Livingston Stone National Fish Hatchery (LSNFH) could also use the results to evaluate their winter-run-escapement augmentation program using winter run spawned and reared at LSNFH (USFWS 1996 and Croci and Hamelberg 1997).

Objectives

The objectives of the 2000 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., 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 the time of spawning, and the spawner population (length frequency, age, 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. 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, they now predominantly spawn immediately downstream of Keswick Dam, the upstream barrier to migration in the Sacramento River (Figure 1). A small portion 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 be considered to 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 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% (standard error).

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 upstream of RBDD must 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, the fish ladders provided an opportunity to accurately count fish migrating upstream. 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 of the following year to allow unimpeded upstream passage of most winter run. The diversion and fishways now only operate during the mid-May through mid-September period which typically include only a small portion of the winter-run migration. From 1969 through 1985, counts were usually possible for the entire migration period (Figure 2), except for an occasional, brief period during very high flows.

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 expand 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 $\leq 60°$ 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 RBFWSO and the DFG's Stream Evaluation Program jointly conducted a carcass mark-and-recapture survey during 2000 to estimate the number of winter-run chinook salmon spawning in the upper Sacramento River. The survey was carried out from 3 May through 29 August 2000. Methods were similar to those used during the 1999 winter-run-escapement survey (Snider *et al.* 2000).

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. 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-long 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 2000.

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. Then one day was skipped and the cycle repeated. The 2000 survey comprised 40 survey periods.

Most of the survey was conducted from boats (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 transparency) readings were measured daily by the survey crew. A radio-tagging study was carried out in conjunction with spawner survey to determine the fate of carcasses tagged with hog ring and not later recovered. The details of this study including methods, results, and conclusion will be in a separate report.

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 when the carcass was tagged. Fresh carcasses (those with firm flesh and at least one clear eye) were tagged in the lower jaw and decayed carcasses were tagged in the upper 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 used to calculate the 2000 estimates. This is the first time that the

Schaefer and Jolly-Seber models could be used to calculate winter-run escapement without extensively lumping survey period data. The Petersen model (Ricker 1975) was used to estimate escapement using fresh carcass data only and combined fresh and decayed carcass data.

1. The adjusted Petersen formula (Ricker 1975) used to calculate an escapement estimate (formula no. 3.7) 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.

The variance of the adjusted Petersen estimate was calculated using equation 3.8 presented in Ricker (1975). Standard error was calculated as the square root of the variance.

2. Schaefer model (as described by Taylor 1974): $E = N_{ij} = R_{ij}(T_i C_j / R_i R_j) - T_i$

Where:

- N_{ij} = population size in tagging period *i* recovery period *j*,
- R_{ij} = number of carcasses tagged in the *i*th tagging period and recaptured in the *j*th recovery period,
- T_i = number of carcasses tagged in the *i*th tagging period,
- C_j = number of carcasses recovered and examined in the *j*th recovery period,
- R_i = total recaptures of carcasses tagged in the *i*th tagging period, and
- R_j = total recaptures of tagged carcasses in the *j*th recovery period.

This model differs from the original in that the number of tags applied after the first week is subtracted from the population estimate to account for sampling with replacement. Schaefer's original model was based on sampling without replacement while in salmon survey conditions, sampling occurs with replacement.

3. Jolly-Seber model (as described by Boydstun 1994): $E = N_1 + D_1 + D_2 ... + D_j$

Where:

- N_1 = Number of carcasses in the population in period 1, the first period of spawning and dying, and
- D_i = number of carcasses that joined the population between periods *i* and *i*+1, with j as the last survey 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. Most fresh carcasses were measurable therefore only the fresh carcass data were used to develop length-frequency relationships and sex ratios. The length-frequency distribution of each sex was used to define the length separating adults (>2-years old) and grilse (2-year olds).

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

Spawning activity preceded the observation of fresh carcasses by approximately 2 weeks, based upon observations made in the American River (Snider and Vyverberg 1995). The total number of fresh carcasses observed weekly, in both reaches, 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.

Hatchery-produced winter-run chinook salmon

Carcasses were checked for adipose-fin marks, indicating the fish was of hatchery origin and had been tagged with a coded-wire tag (CWT). Heads were collected from marked carcasses to obtain CWT information on race and hatchery of origin.

RESULTS

General

A total of 1,091 fresh and 1,391 decayed carcasses were observed during 40 survey periods distributed between 3 May and 29 August 2000 (Table 1). Mean flow during the survey ranged from 8,400 to 15,700 cfs (Figure 3). Mean survey-period temperature ranged from 51°F to 54°F (Table 1). Secchi disk depth readings ranged from 8.7 to 20.0 ft and exceeded 12 ft during most of the survey (Table 1).

Population estimates

The adjusted Petersen formula equation 3.7 (Ricker 1975) as well as the Schaefer (1951) and Jolly-Seber (Seber 1982) models were used to estimate spawner population in 2000. Tag recoveries during the 40 survey periods were sufficient to allow use of the Schaefer and Jolly-Seber models for the first time since the winter-run tag-recovery surveys were initiated in 1996.

In total, 1,053 fresh adult carcasses were tagged and 469 (45%) were subsequently recovered (Table 2 and Figure 4). Additionally, a combined total of 1,954 fresh and decayed carcasses were tagged and 829 (42%) were subsequently recovered.

The Petersen formula was applied using the season totals for fresh adult carcasses only and for all (fresh and decayed) adult carcasses. The fresh carcass data yielded an estimate of 6,492 adults +/- 4% (SE) (Table 3). The adult estimate was expanded to 6,670 (includes 178 grilse) based upon data obtained from fresh carcasses that showed that adults comprised 97.3% of the population (based on length-frequency data results described below). A second estimate using fresh and decayed carcass results yielded estimates of 7,667 adults and 210 grilse (7,877 total) (Table 3). Based on Law's (1994) analysis, the estimate based on fresh carcass data is more accurate.

The Schaefer and Jolly-Seber models require tag recoveries from all survey periods, therefore several survey periods were combined at both the beginning and end of the study. This was done for survey periods when relatively few carcasses were seen, and had an insignificant effect on the total population estimate. An estimate of 5,555 adults was calculated using the Schaefer formula (Table 3). Fresh carcass data results were used to calculate this estimate (Table 2). The adult estimate was divided by 97.3% for a total escapement estimate of 5,707 winter-run spawners (includes 152 grilse). An estimate of 4,227 adults was calculated using the Jolly-Seber formula (Table 3). Both fresh and decayed carcass data results were used to calculate this estimate (Table 2). The adult estimate was also divided by 97.3% for a total escapement estimate of 4,343 winter-run spawners (includes 116 grilse).

Table 1 Summary of carcass counts and mean flow, water temperature, and Secchi disk depths for each survey period of the upper Sacramento River winter-run chinook salmon escapement survey, May - August 2000.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcasses count[3/]	
					Fresh	Decayed
1		13,300	53	8.7	5	
2		13,000	52	10.0	7	
3		9,600	52	9.6	9	
4		8,400	52	10.6	20	
5		9,000	52	10.1	16	
6		9,700	52	13.5	43	
7		13,200	51	12.8	35	
8		13,200	52	12.5	42	
9		12,700	53	12.1	35	
10		11,900	53	12.6	26	
		11,800	53	13.0	32	
12		10,600	52	13.6	44	
13		10,500	54	12.2	32	
14		11,800	53	12.6	61	
15		14,000	53	11.4	50	
16		13,800	53	12.4	44	
17		14,000	53	12.0	63	
18		13,700	53	11.4	53	
19		14,000	53	12.0	78	
20		14,100	53	12.5	40	
21		14,300	52	14.2	57	
22		14,400	53	14.7	58	
23		14,600	53	21.0	67	
24		14,700[4/]	54	16.5	47	
25		14,600	53	14.5	36	

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 17–18	15,000	53	16.2		
27	July 20–21	15,000	53	14.2		
28	July 23–24	15,000	53	13.1		
29	July 26–27	15,700	53	14.8		
30	July 29–30	15,300	53	13.9		
31	August 1–2	15,100	54	16.2		
32	August 4–5	14,200	53	16.8		
33	August 7–8	13,600	54	15.0		
34	August 10–11	12,100	54	20.0		
35	August 13–14	12,000	53	17.4		
36	August 16–17	10,800	54	17.6		
37	August 19–20	10,000	53	17.0	0	2
38	August 22–23	9,700	54	16.8	0	5
39	August 25–26	9,500	53	17.4	0	1
40	August 28–29	10,000	53	16.6	1	3

1/ Mean flow at Keswick Dam during survey period as measure 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 11 July 2000.

Table 2. Summary of the number observed (fresh and decayed), tagged (fresh), and recaptured (fresh) during 2000 upper Sacramento River winter-run chinook salmon escapement survey for each tagging period, May–August 2000.

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
	May 3–4	10	0	5	0	0
2	May 6–7	10	0	7	0	0
3	May 9–10	24	0	9	0	
4	May 12–13	30	0	20	0	
5	May 15–16	32	0	16	0	
6	May 18–19	77	2	42	1	5(5),5(4),1(3)
7	May 21–22	48	0	35	0	15(6),4(4)
8	May 24–25	73	1	42	0	5(7),2(6)
9	May 27–28	50	0	35	0	15(8),1(6),
10	May 30–31	52	0	26	0	13(9),3(8),1(7),1(6),2(4)
11	Jun 2–3	94	0	32	0	7(10),2(9)
12	Jun 5–6	92	2	43	1	12(11),2(10),1(8)
13	Jun 8–9	63	1	31	1	12(12),1(11),1(10),2(8)
14	Jun 11–12	113	4	58	2	8(13),5(12),1(11),1(10),1(8),1(7)
15	Jun 14–15	91	2	48	2	10(14),1(13),3(12),1(9),2(8)
16	Jun 17–18	76	1	43	1	10(15),1(14),1(13),1(12),1(11)
17	Jun 20–21	150	5	59	4	12(16),3(15),3(14),1(11)
18	Jun 23–24	109	1	52	1	5(17),7(16),3(15),1(14),2(13)
19	Jun 26–27	152	4	76	2	4(18),7(17),1(16),1(15),2(14)
20	Jun 29–30	95	2	38	2	19(19),4(18),4(16),1(13)
21	Jul 2–3	161	3	55	2	5(20),3(19),1(18),3(17),1(16),1(15),2(14)

Table 2. (cont.)

Tagging period	Date	Number observed		Number tagged		Number recovered (Original tagging period)
		Adults	Grilse	Adults	Grilse	
22	Jul 5–6	153	2	57	1	25(21),3(20),3(19),1(18),3(17),1(16), 1(15)
23	Jul 8–9	159	3	65	2	23(22),15(21),2(20),3(19),4(18),2(17), 2(16)
24	Jul 11–12	111	4	43	4	18(23),2(22),3(21),1(20),1(19),1(17)
25	Jul 14–15	85	3	34	2	13(24),6(23)1(22),2(21)
26	Jul 17–18	74	3	20	3	5(25),1(24),3(23),3(21),2(20) [1(24)grilse]
27	Jul 20–21	67	3	28	0	6(26),5(25),1(24)
28	Jul 23–24	41	2	14	1	11(27),2(25),1(22) [1(25),1(24)grilse]
29	Jul 26–27	26	1	4	0	5(28),2(27),1(26),1(22)
30	Jul 29–30	23	2	7	1	1(29),1(28),1(26),1(24)
31	Aug 1–2	23	2	2	0	2(30),3(29),1(28),1(27)
32	Aug 4–5	16	1	1	0	1(31),1(30),1(27)
33	Aug 7–8	11	1	1	0	
34	Aug 10–11	10	0	3	0	
35	Aug 13–14	6	0	1	0	0
36	Aug 16–17	7	1	1	0	0
37	Aug 19–20	2	0	0	0	1(36),1(35),1(34)
38	Aug 23–24	4	1	0	0	0
40	Aug 28–29	4	0	0	0	0
39	Aug 25–26	1	0	0	0	0
Totals		2,425	57	1,053	33	469 adults [3 grilse]

Table 3. Summary of winter-run escapement estimates using the Petersen, Schaefer and Jolly-Seber tag-and-recapture models made during the upper Sacramento River winter-run spawner escapement survey, May–August 2000.

	Petersen(fresh)	Petersen (fresh & decayed)	Schaefer model	Jolly-Seber model
Total estimate	6,670	7,877	5,707	4,343
Adult estimate	6,492	7,667	5,555	4,227
Grilse estimate	178	210	152	116

Size/age distribution and sex composition

A total of 1,048 carcasses was measured (Table 4). Mean FL was 75.8 cm (range: 43–107 cm FL). Male salmon (n = 191) averaged 82.5 cm FL (range: 43–107 cm FL). Female salmon (n = 857) averaged 74.3 cm FL (range: 48–95 cm FL). The largest fish were observed during May (Figure 5). The mean size of males ranged from 87.4 FL in May down to 64.5 cm FL in August. Females ranged from 75.9 cm FL in May down to 71.4 cm FL in August

The male and female length frequency distributions were quite different (Figure 6). Nearly all of the females were grouped in a normal distribution that ranged from 59 to 89 cm FL with a mode of 72 cm FL (Figure 6a). About 99% of the females ranged from 59 to 89 cm FL. The male distribution was positively skewed with about 79% of the males ranging from 75 to 97 cm FL (Figure 6b).

Length-frequency distributions were used to define general size criteria to distinguish grilse (2-year-old salmon) from adults (>2-year-old salmon) for both sexes. Females ≥59 cm FL were considered adults based upon the location of the break between the tail of the length frequency distribution (Figure 6a) and the few fish to the left. Male adults were defined as salmon >60 cm FL based upon an apparent break in the their size distribution between 61 and 63 cm FL (Figure 6b). The age/length relationship for the 2000 spawner population will be verified using scales and otoliths taken from most measured carcasses.

Male grilse averaged 52.1 cm FL (n = 22, SD = 3.9; range: 43–60 cm FL) and female grilse averaged 53.1 cm FL (n = 6, SD = 4.0; range: 48–57 cm FL) (Table 5). Adult males averaged 86.4 cm FL (n = 169, SD = 7.5; range: 64–107 cm FL). Female adults averaged 74.4 cm FL (n = 851, SD = 5.2; range 59–95 cm FL).

The measured fresh carcasses (n = 1,048) comprised 97.3% (n=1,020) adults and 2.7% (n = 28) grilse (Table 6). The grilse portion of the population never exceeded more than five percent of the population during any month, increasing from less than 1 % in May to 5% in July. No grilse were observed during August.

The grilse sample comprised 79% (n = 22) males and 21% (n = 6) females (Table 7). The adult sample comprised 83% (n = 851) females and 17% (n = 169) males. The ratio of male:female adult spawners was 1:5.0 The overall male:female sex ratio, including grilse, was 1:4.5.

Spawning success

All female salmon examined for egg retention (n=854) had completely spawned.

Temporal distribution

Fresh carcasses were observed from survey period 1 (3–4 May) through survey period 40 (28–29 August) (Table 1, Figure 7). Seventy percent of the fresh carcasses were observed between 2 June and 15 July with the maximum occurring 26–27 June. Based upon findings on the lower American River (Snider and Vyverberg 1995) indicating that fresh carcasses become available for observation approximately 2 weeks after spawning, winter-run spawning likely occurred from late April into mid-August and peaked during the first few weeks of June.

Spatial distribution

The spatial distribution of fresh carcasses was 80% (n = 869) in Reach 1 and 20% (n = 222) in Reach 2 (Table 8). For decayed carcasses, 77% (n = 1,073) were observed in Reach 1 and 23% (n = 318) in Reach 2. The ratios of fresh:decayed carcasses were 1:1.2 in Reach 1 and 1:1.4 in Reach 2. Fresh carcass data best defines spatial distribution of spawning since these carcasses would have spent less time floating downstream than the decayed carcasses.

Hatchery-produced winter-run chinook salmon

Four carcasses with an adipose-fin mark were observed during the survey (Table 9). A CWT was recovered from one of the these carcasses. It was from a 104-cm FL late-fall-run male (Tag # 054107) from the 1995 brood year. It was recovered from a decayed carcass on 16 May 2000.

Table 4. Size and sex statistics for winter-run chinook salmon carcasses measured during upper Sacramento River escapement survey, May - August 2000.

	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	235	80.6	50–105	95	87.4	50–105	140	75.9	62–95
June	491	76.0	49–107	65	81.2	49–107	426	74.1	50–88
July	311	73.6	43–97	29	82.2	43–97	282	74.0	48–93
August	11	75.2	64–77	2	64.5	64–65	9	71.4	64–77
Totals (mean)	1,048	(75.8)	43–107	191	(82.5)	43–107	857	(74.3)	48–95

Table 5. 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 2000.

	Female		Male	
	Grilse*	Adults	Grilse*	Adults
Total measured	6	851	22	169
Mean	53.1	74.4	52.1	86.4
Range FL (cm)	48–57	59–95	43–60	64–107
Standard deviation	4.0	5.2	3.9	7.5

* Grilse were defined as females < 59 cm FL and as males ≤ 60 cm FL..

Table 6. Age composition (grilse and adult) of winter-run chinook salmon carcasses measured during the upper Sacramento River spawner escapement survey, May–August 2000.

	Adults		Grilse	
Survey period	Number	%	Number	%
May	234	100	1	<1
June	479	98	12	2
July	296	95	15	5
August	11	100	0	0
Totals (Mean)	1,020	(97)	28	(3)

Table 7. Sex composition of winter-run chinook adult and grilse carcasses measured during the upper Sacramento River escapement survey, May–August 2000.

	Adults				Grilse			
	Male		Female		Male		Female	
Month	Number	%	Number	%	Number	%	Number	%
May	94	40	140	60	1	100	0	0
June	55	11	424	89	10	83	2	17
July	18	6	278	94	11	73	4	27
August	2	18	9	82	0	-	0	-
Totals (mean)	169	(17)	851	(83)	22	(79)	6	(21)

Table 8. Summary of salmon carcass distribution observed during the upper Sacramento River winter-run chinook salmon escapement survey, May–August 2000. Includes adults, grilse, fresh and decayed carcasses but not tag recoveries.

	Reach 1		Reach 2	
Survey period	Fresh	Decayed	Fresh	Decayed
1	5	2	0	
2	2	1	5	
3	5	13	4	
4	17	8	3	
5	8	6	8	
6	32	28	11	
7	25	8	10	
8	31	18	11	
9	26	6	9	
10	17	22	9	
11	29	48	3	
12	32	34	12	
13	27	26	5	
14	47	39	14	
15	42	37	8	
16	39	26	5	
17	48	68	15	
18	42	49	11	
19	70	61	8	
20	29	44	11	
21	51	88	6	
22	42	89	16	
23	51	74	16	
24	37	42	10	
25	32	47	4	
26	21	42	3	

Table 8 (cont.)

Survey period	Reach 1		Reach 2	
	Fresh	Decayed	Fresh	Decayed
27	27	30	2	11
28	12	25	3	3
29	4	21	0	2
30	8	12	0	5
31	2	18	0	5
32	1	10	0	6
33	2	8	0	2
34	3	6	0	1
35	1	4	0	1
36	1	3	0	4
37	0	2	0	0
38	0	4	0	1
39	0	1	0	0
40	1	3	0	0
Totals	869	1073	222	318

Table 9. Summary of adipose-clipped (hatchery-produced) carcasses collected during the upper Sacramento River winter-run chinook salmon escapement survey, May–August 2000.

Date collected	Tag code	Sex	FL (cm)	Race (brood year)
May 16	054107	Male	104	Late fall (1995)
May 18	-1/	Female	68	
June 12	-1/	Male	54	
July 17	-1/	Male	52	

1/ No CWT was found.

DISCUSSION

Several more years of carcass surveys are planned to better address the issues of winter-run spawning habitat availability relative to flow and other physical habitat attributes. Spawning habitat requirements will ultimately be evaluated by combining spawner population data with results of other studies. These other studies will include aerial photographic surveys of redds, physical habitat modeling, and focused evaluation of the hydraulic and substrate attributes of spawning habitat to augment identification of salmon spawning habitat requirements. The low population levels observed during the five survey years may have been too low, relative to habitat availability, to adequately identify habitat needs by themselves. This is especially true relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1996). However, if habitat has been limiting at these low populations, habitat requirements should be identifiable.

Population Estimates

Law (1994) evaluated the relative accuracy of the Petersen, Schaefer and Jolly-Seber models in estimating a known population by simulating model runs using varying levels of tagging and recovery rates. He concluded that the Jolly-Seber formula showed a "remarkable concise and accurate estimate" for the various combinations of rate parameters studied, especially when recovery rates were high. Law's simulation analysis showed that the Jolly-Seber estimate was equal to 0.91 of the actual population when the tag-recovery rate was 31% (using fresh and decayed carcass recoveries). This recovery rate is comparable to that observed during the 2000 winter-run survey (42% for both fresh and decayed carcass). We compared the relative accuracy (% of actual population size) of our 2000 escapement estimates with those identified by Law. We assumed that our Jolly-Seber estimate was 91% of the actual escapement number yielding an actual escapement population of 4,772 salmon. We then compared the percent accuracy of the Petersen and Schaefer estimates with those identified by Law (for recovery rate = 31%) and found that the variation among the population estimates calculated from the Petersen, Schaefer, and Jolly-Seber models using the 2000 upper Sacramento River winter-run salmon survey results was similar to the variation among the results that Law (1994) calculated in his hypothetical simulations (Table 10).

The higher tag-recovery rates observed during 2000 allowed the Schaefer and Jolly-Seber models to be used to calculate population estimates. These models are considerably more accurate than estimates calculated with the Petersen formula. Unfortunately, clear water conditions that appear to provide for higher recovery rates are not generally present during the winter-run spawning period.

During the five survey years sufficient data have been collected to allow calculation of a population estimate using the Petersen model, but not necessarily using the Schaefer or Jolly-Seber models. As such, interrogation of population trends should only include the escapement estimate calculated by the Petersen formula using fresh carcass, although this model tends to overestimate the true population (Appendix Table 1).

Table 10 Comparison of relative percentages of actual population obtained by Petersen, Schaefer, and Jolly-Seber models from Law's simulation <u>with</u> results from the same models using 2000 upper Sacramento River winter-run carcass survey data. Comparisons assume 4,772*(calculated by dividing the Jolly-Seber estimate by 0.91) is the actual population.

	Estimated percentage of actual population predicted by Law (1994)		
	Petersen	Schaefer	Jolly-Seber
Fresh and decayed	251	178	91
Fresh	184	152	83
	Percent of 4,772* of estimates calculated from carcass survey results (Numerical estimate)		
	Petersen	Schaefer	Jolly-Seber
Fresh and decayed	165(7,877)	-	91*(4,343)
Fresh	140(6,670)	120(5,707)	-

* The use of this number (4,772) as a basis for comparison is predicated on Law's conclusion that "the Jolly-Seber formula shows a remarkable concise and accurate estimate for the various combinations of rate parameters studied." The number was based on Law's simulation analysis that Jolly-Seber estimate using fresh and decayed carcass recoveries is equal to 0.91 of the actual population when the tag-recovery rate is 40%.

Tag-recovery rate appears to be due to greater-than-average water transparency rather than flow conditions present during the survey (Appendix Figure 1). The tag-recovery rate during the 2000 survey was 45% which is considerably greater than the rates observed during any previous survey year (22% in 1999, 15% in 1998, 12% in 1997, and 15% in 1996) (Appendix Table 1). In 2000, water transparency equaled or exceeded 12 ft during 85% of the survey period and flows ranged from 8,400 to 15,700 cfs. During 1999, when the second highest tag-recovery rate occurred (22%), water transparency exceeded 8 ft during 92% of the survey periods and mean flows fluctuated from only 9,300 to 13,700 cfs. In contrast, water transparency never exceeded 8.4 ft and was less than 8 ft over 64 % of the time in 1998 (recovery rate = 15%, flow range: 10,000–23,500 cfs) and water transparency never exceeded 7.1 ft (flow range: 8,000–15,000) in 1997 when the recovery rate was the lowest observed during the five surveys (12%).

The standard error of the estimate of spawner abundance during the five study years ranged from 4% to 24% of the estimate (Appendix Table 1).

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. The proportion of females in the population was calculated as the percentage of measured fresh carcasses that were female (81.8%). All measured females (adults and grilse) was used here to calculate the effective spawner population, although there is some disagreement among agencies responsible for winter-run management as to the contribution of female grilse to the spawning population. Since 81.8% of the total escapement was female, the estimated adult female population was 5,454 (based on the Petersen formula using fresh carcass data). There was no prespawning mortality observed in the 854 fresh females examined during the carcass survey resulting in an estimated effective spawner population of 5,454. Similar calculations using the Schaefer and Jolly-Seber escapement estimates yielded effective spawner population estimates of 4,667 (Schaefer) and 3,551 (Jolly- Seber).

The issue of female grilse contributing to the spawning population needs to be evaluated. Although the proportion of females grilse observed during the carcass survey was very low (0.6%), the spawning success data collected during the carcass survey indicated that all female grilse spawned

Sex composition

The adult, male:female ratio was 1:5.0 in 2000, compared to 1:8.4 in 1999, 1:8.9 in 1998, 1:3.2 in 1997 and 1:6.4 in 1996. The total population sex ratio (includes grilse) during was 1:4.5 in 2000, compared to 1:3.0 during 1999, 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 2000 survey: 1:1.5 in May (n = 235), 1:7.5 in June (n = 491), 1:9.7 in July (n = 311), and 1:4.5 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 than the rate for females (Boydstun 1994). Obviously a similar rate differential would not account for the large differences in the ratio of male:female carcass recoveries observed during the five survey years.

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 than any one factor.

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 2000, 1999, and 1998 late-fall-run surveys, the male:female ratios were 1:1.8, 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 1:1.8 during 1999, 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 sampling 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 RBFWSO indicate that there is substantial overlap in size at age.

Comparison with Red Bluff Diversion Dam Winter-run Escapement Estimates

Salmon counts made at RBDD yielded an estimate of 1,352 winter-run salmon migrating upstream of RBDD during the 2000 spawner migration. Of this total, 1,205 were classified as produced in-river based on the absence adipose fin clip information. Applying the 61 cm FL criterion[1] to separate adult from grilse, 172 (14.3%) were male adults, 344 (28.6%) were female adults, 517 (42.8%) were male grilse, and 172 (14.3%) were female grilse. In comparison, the carcass survey escapement estimate, based upon Petersen's formula using fresh carcasses, was 6,670 comprising 1,076 (16.1%) adult males[2], 5,416 (81.2%) adult females, 140 (2.1%) male grilse, and 38 (0.6%) female grilse (Tables 10 and 11, Figure 8). Assuming that the three, unidentified, adipose-clipped carcasses were winter run, only 0.1% (3 out of 2,482 carcasses) of the estimated spawner population were hatchery produced (8 salmon). Furthermore, two of the marked carcasses were male grilse and one was an adult female indicating that the hatchery-reared component of the spawner escapement consisted of 6 male grilse and 2 female adults.

The population structure defined by the results of the RBDD and carcass surveys were quite different (Figure 9). The RBDD data shows a higher proportion of grilse: 57.3% versus 2.7% for the carcass survey or 21 times greater. Adult females comprised 81.2% of carcass survey and 28.6% of the RBDD trap survey. The proportion of adult males were similar: 14.3% observed in the RBDD sample and 16.1% in the carcass survey. At RBDD, females had a mean size of 67.8 cm FL (range: 50–86 cm FL). Females from carcass survey had a mean size of 74.3 cm FL (range: 48–95 cm FL). Males collected at RBDD had a mean size of 58.3 (range: 42–92 cm FL); males collected during the carcass survey had a mean size of 82.5 (range: 43–107 cm FL).

Applying the carcass age-size criteria to the RBDD results does not change the estimated age composition, and applying the RBDD criterion to the carcass survey results yielded little change in the estimated age compositions. The 61-cm age-size criterion used at RBDD yielded no change for the age composition of males observed during the carcass survey, and only a slight change in the estimated age composition for females - from 81.2 to 80.8% for adults and 0.6 to 1.0% for grilse. Since the number and composition of grilse increased later in the carcass survey, it is reasonable to conclude that the late portion of the migration monitored at RBDD would

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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 >57 cm FL for females and >60 cm Fl for males.

contain a higher proportion of grilse than the earlier portion that passes RBDD before counts can be made. *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.*

Comparisons of population estimates based on carcass surveys and ladder counts:

1. The carcass survey appears to provide a more precise and possibly a more accurate (particularly when tag-recovery rates are high) description of the winter-run spawner population than the existing method that relies on expanding counts of an unknown portion of the population passing RBDD after mid May. Historic records indicate that ladder counts reflect an unknown portion of the population ranging from 3 to 48 %. There is presently no method to determine the percentage of the run represented by the RBDD counts. Even with low, carcass survey tag-recovery rates, the attributes of the population, including relative magnitude, appears to be more accurately determined using the carcass counts.

2. Based on the analysis by Law (1994), the Jolly-Seber formula with tag-recovery rate of 42%, as occurred in 2000, provides an accurate estimate of winter-run escapement. The estimated escapement of 4,337 winter run based on the Jolly-Seber model suggests that the estimate of 1,350 based on ladder counts is too low by nearly four fold.

3. Results from the carcass survey represent the total winter-run escapement while ladder counts represent an unknown portion of the latter portion of the total escapement. As such, the carcass survey provides more baseline information on spawning distribution (spatial and temporal), environmental conditions at time of spawning, and spawning success. Both methods may provide biased information on sex and age composition. The ladder counts in 2000 appeared to represent a small portion of the tail end of the winter-run escapement when the greatest concentration of grilse occur (as indicated by carcass survey). The fresh carcass sample used to determine sex and age composition may under represent adult males and likely under represents grilse, based on the Bogus Creek studies (Boydstun 1994, Law 1994).

4. The effective spawner population can be more accurately determined by carcass survey than by RBDD counts. The carcass survey results adequately represents the adult female portion of total population, including prespawning mortality of both adults and grilse.

5. Estimation of spawner abundance using the Petersen model during the initial five survey years (1996–2000) has met the population estimation criteria established NMFS (1997). The standard error was less than 25% of the estimate for all five years, ranging from 4% in 2000 to 24% in 1996 (Appendix Table 1).

RECOMMENDATIONS

1.The mark and recapture carcass surveys should be continued.

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

3. 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.

3. Further evaluate the age composition of winter-run adults.

4. 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.

5. The agencies responsible for managing the winter-run population, including estimating spawner escapement and defining allowable levels of take, and agencies affected by such determinations, should work together to evaluate the feasibility of the existing methodologies (RBDD counts and subsequent estimates of juvenile production) to provide a more precise and accurate estimate of winter run spawner population. Such an evaluation should identify responsibilities for long term monitoring including funding, and should consider actions necessary to support recommendations in the winter-run recovery plan that rely heavily upon the ability to accurately monitor winter-run chinook salmon escapement.

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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. 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.

Snider, B., B. Reavis, and S. Hill. 1998. 1997. 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. 1999. 1998. 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. 2000. 1999. Upper Sacramento River winter-run chinook salmon escapement survey. Calif. Dept. Fish & Game, Stream Evaluation Program, Habitat Conservation Div. Stream Evaluation Technical Report 00-1.

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

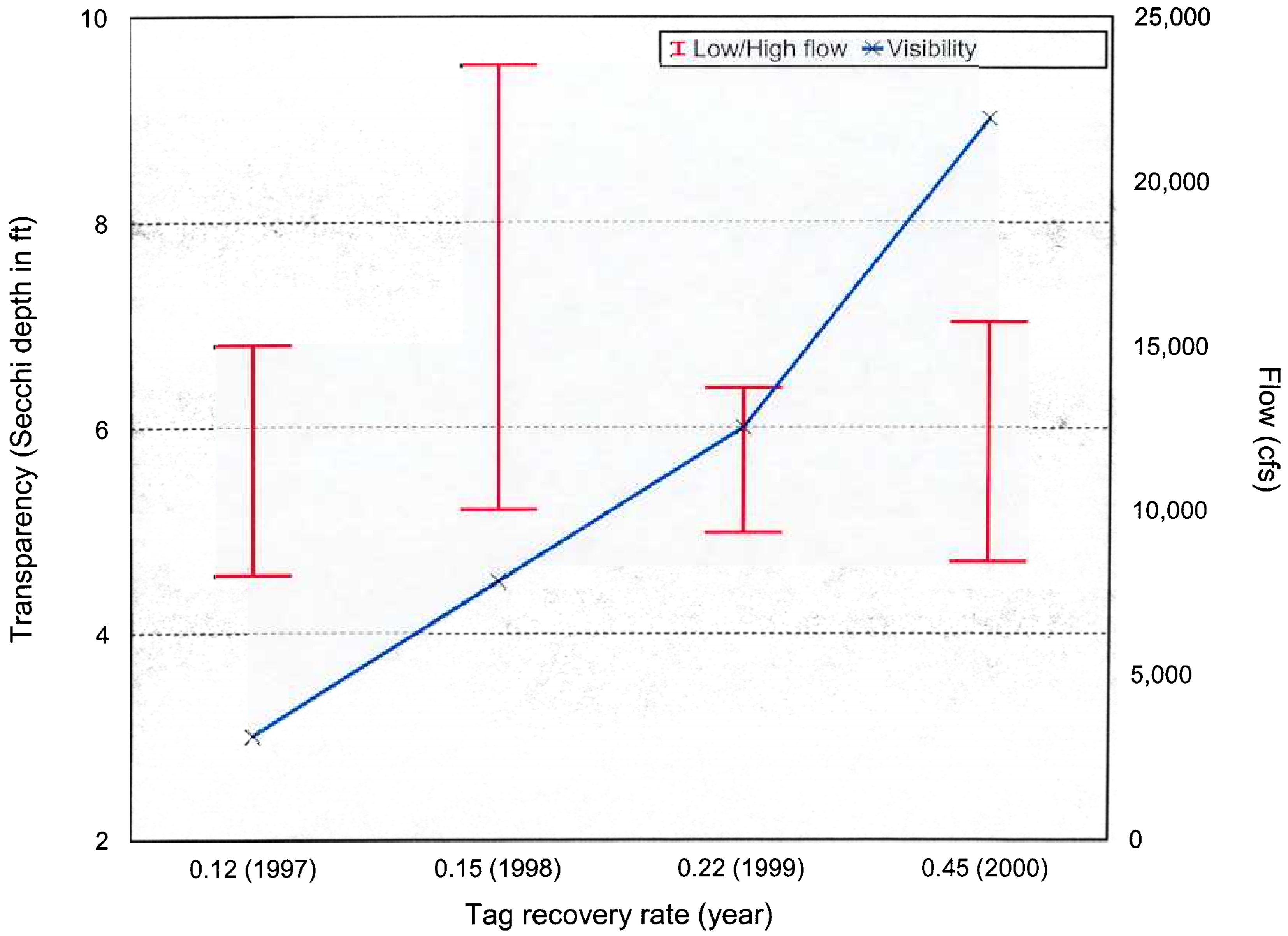
Appendix Table Summary of results from the 1996 through 2000 upper Sacramento River winter-run spawner surveys.

Parameter	1996	1997	1998	1999	2000
Survey dates	29 April– 5 September	30 April– 29 August	5 May– 28 August	5 May– 27 August	3 May- 29 August
No. of total carcasses	118	239	785	475	2,482
No. of fresh carcasses	52	105	382	212	,091
No. of decayed carcasses	66	134	403	263	,391
Tag recovery rate	15%	12%	15%	22%	45%
Estimated population (Petersen)	820	2,053	5,501	2,262	6,670
Adult estimate	664	1,888	5,391	1,821	6,492
(standard error, % of adult estimate)	24.4	19.4	12.7	15.5	4.2
Grilse estimate	156	165	110	441	178
Adult female estimate	571	,437	4,847	1,626	5,416
Adult male estimate	93	451	544	194	,076
Grilse female estimate	10	92	0	65	38
Grilse male estimate	146	73	110	377	140
Female:male ratio: adults/all	6.1:1/2.5:1	3.2:1/3.2:	8.9:1/7.5:1	8.4:1/3:1	5.0:1/4.5:1
Size criterion (male)	Adult >65 cm	Adult >63 cm	Adult >60 cm	Adult >63 cm	Adult>60 cm
Size criterion (female)	Adult >64 cm	Adult >63 cm	Adult >54 cm	Adult >59 cm	Adult>57 cm
Spawning success (%)	94%	96%	95%	97%	100%

Appendix Table (cont.).

Parameter	1996	1997	1998	1999	2000
Spatial distribution (Reach 1,2, 3, and 4)[1]	50%, 39%, 9%, 2%	48%, 52%	58%, 42%	73%, 27%	80%, 20%
Peak spawning period	early - mid July	late June - early July	early July	early -mid June	early - mid June
Flow range (cfs)	7,200–16,200	8,000–15,000	10,000–23,500	9,300–13,700	8,400–15,700
Temperature range	52–59°F	49–52°F	50–54°F	50–54°F	51–54°F
Transparency (Secchi depth)	na	3–10 ft	4.5–11 ft	6–11 ft	9–20 ft

1/ In 1996 the study section was a 31-mile section of stream divided into four reaches. Since 1996, the study section has comprised the uppermost 14 miles of the previous (31-mile-long) section and now consists of only two reaches.



Appendix Figure 1. Comparison of carcass recovery rate relative to flow and water transparency during winter-run chinook salmon escapement surveys conducted on the upper Sacramento River from1996 through 2000.

FIGURES

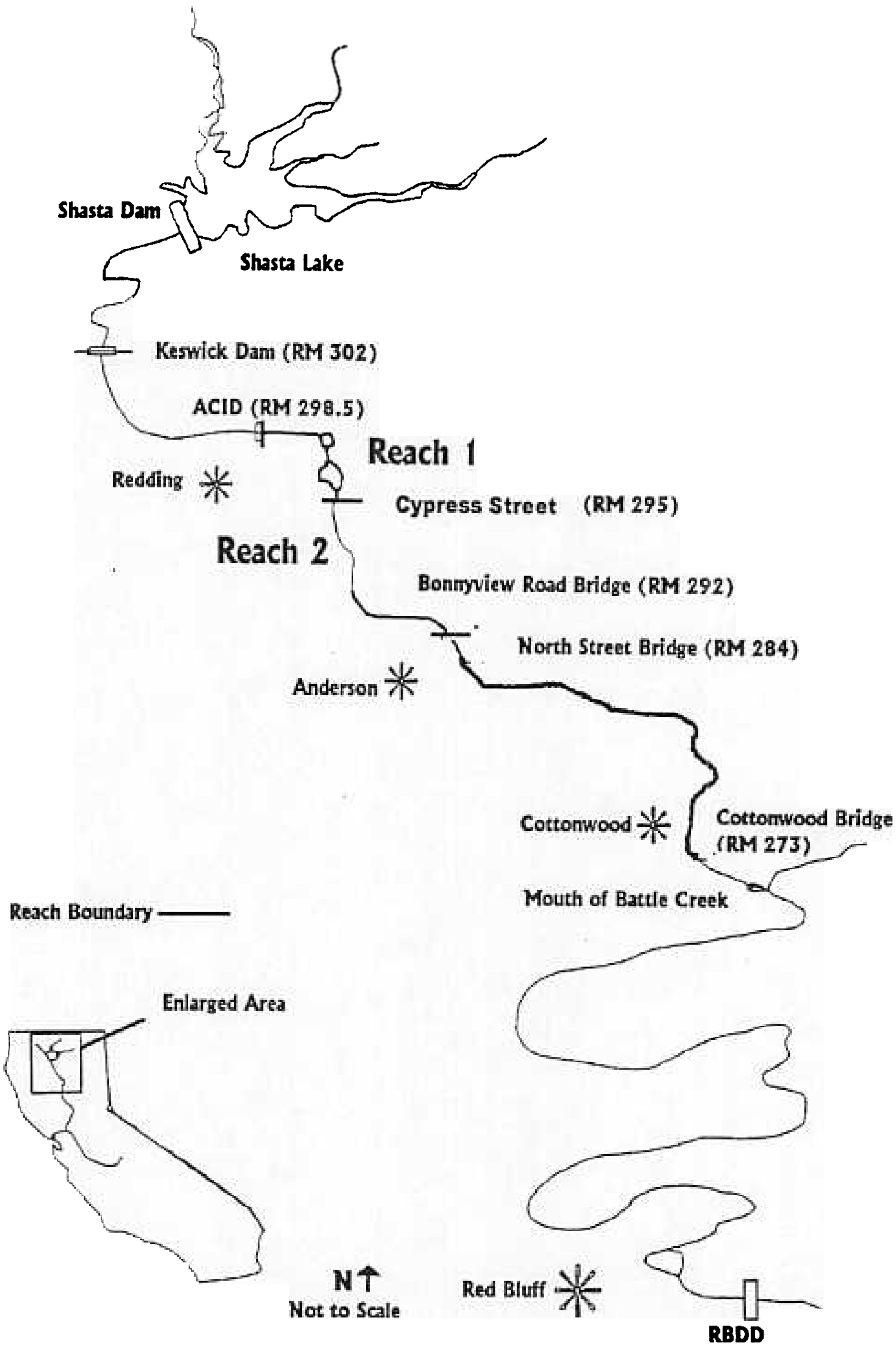


Figure 1. Location of reaches surveyed during the 2000 winter-run chinook salmon escapement survey, May–August 2000.

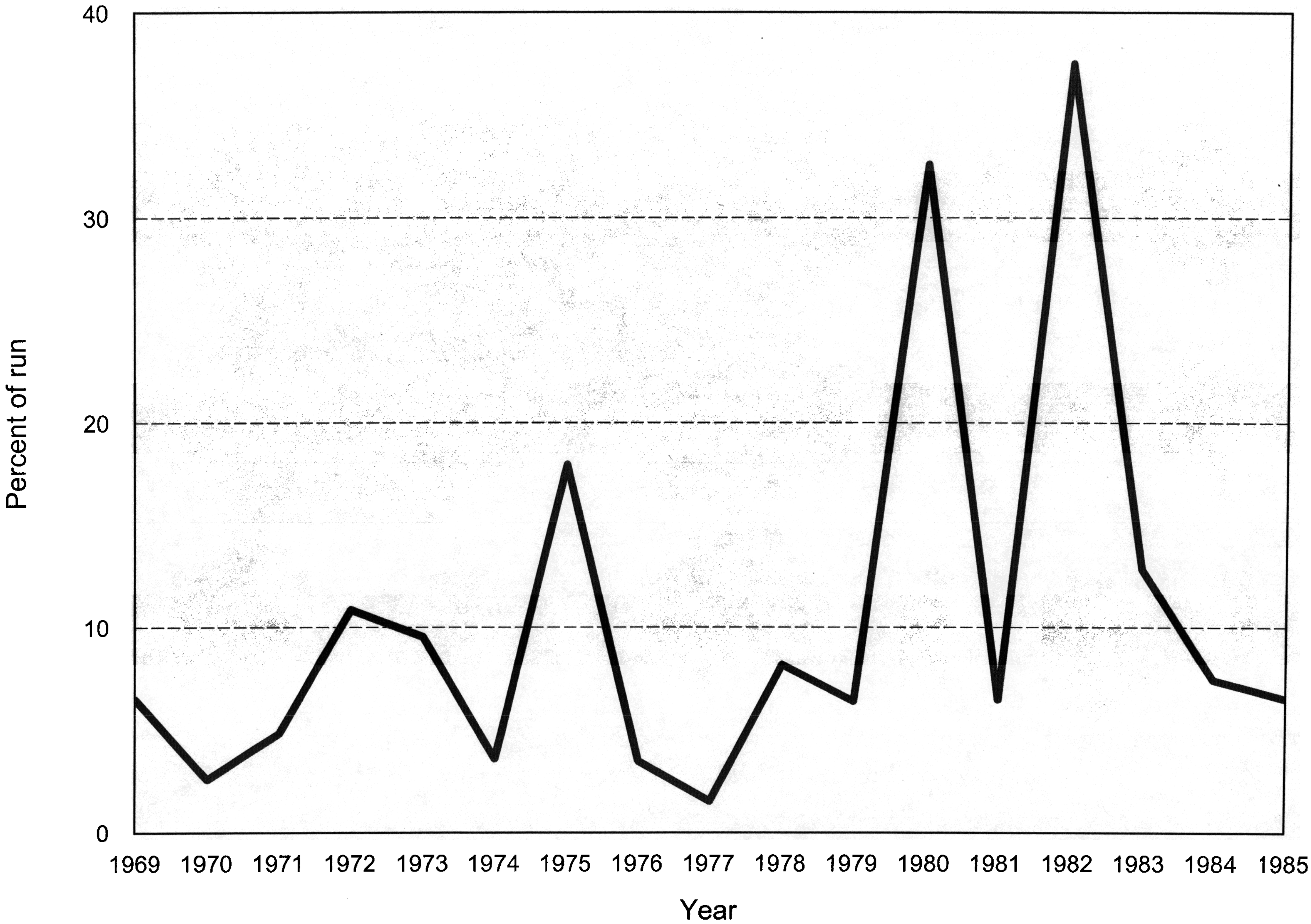


Figure 2. Percentage of the total migration of winter-run chinook salmon passing Red Bluff Diversion Dam after mid May (Week 20) from1969 through 1985.

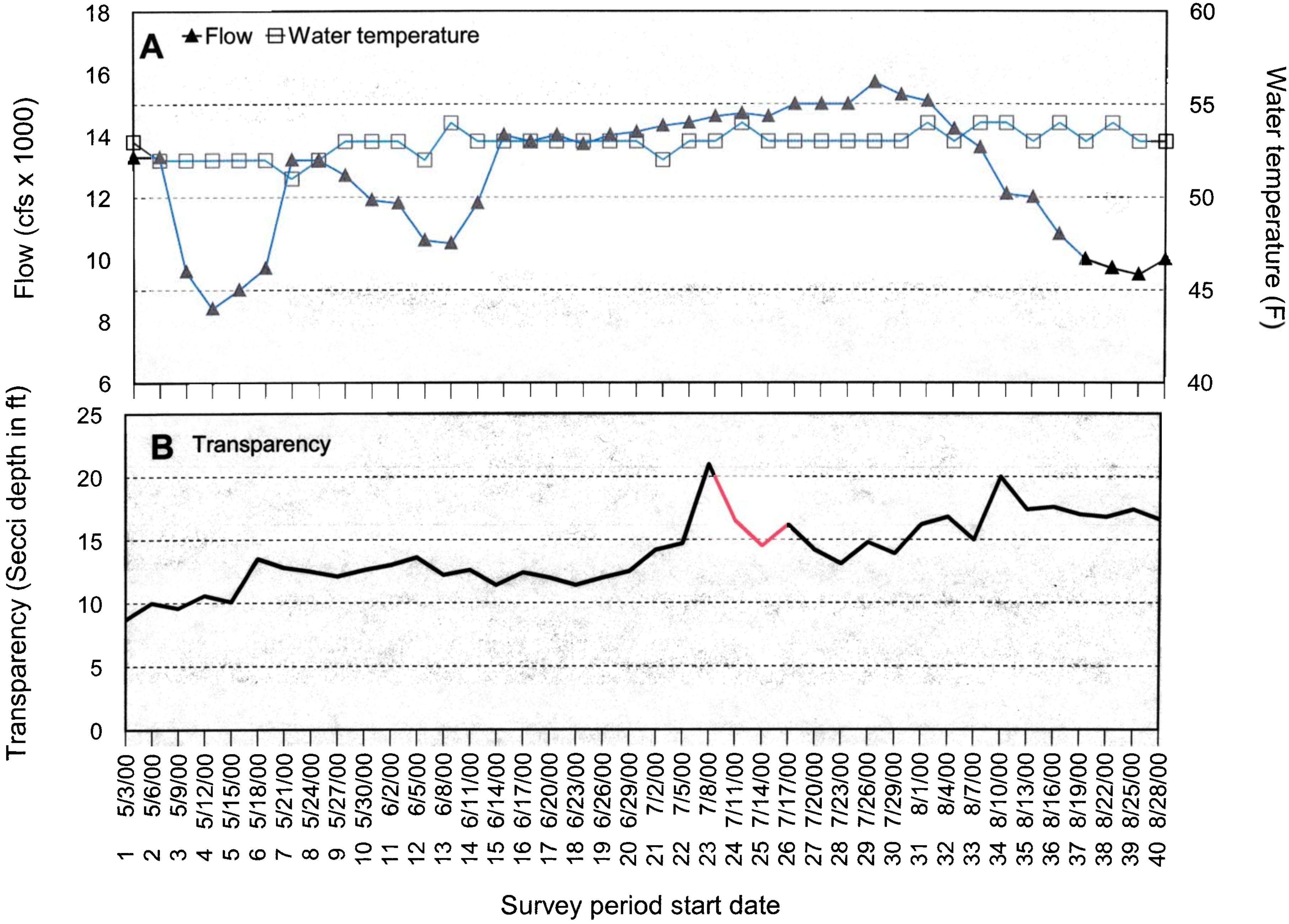


Figure 3. Mean flow and water temperature (A) and water transparency (Secchi disk depth) (B) measured for each survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 2000.

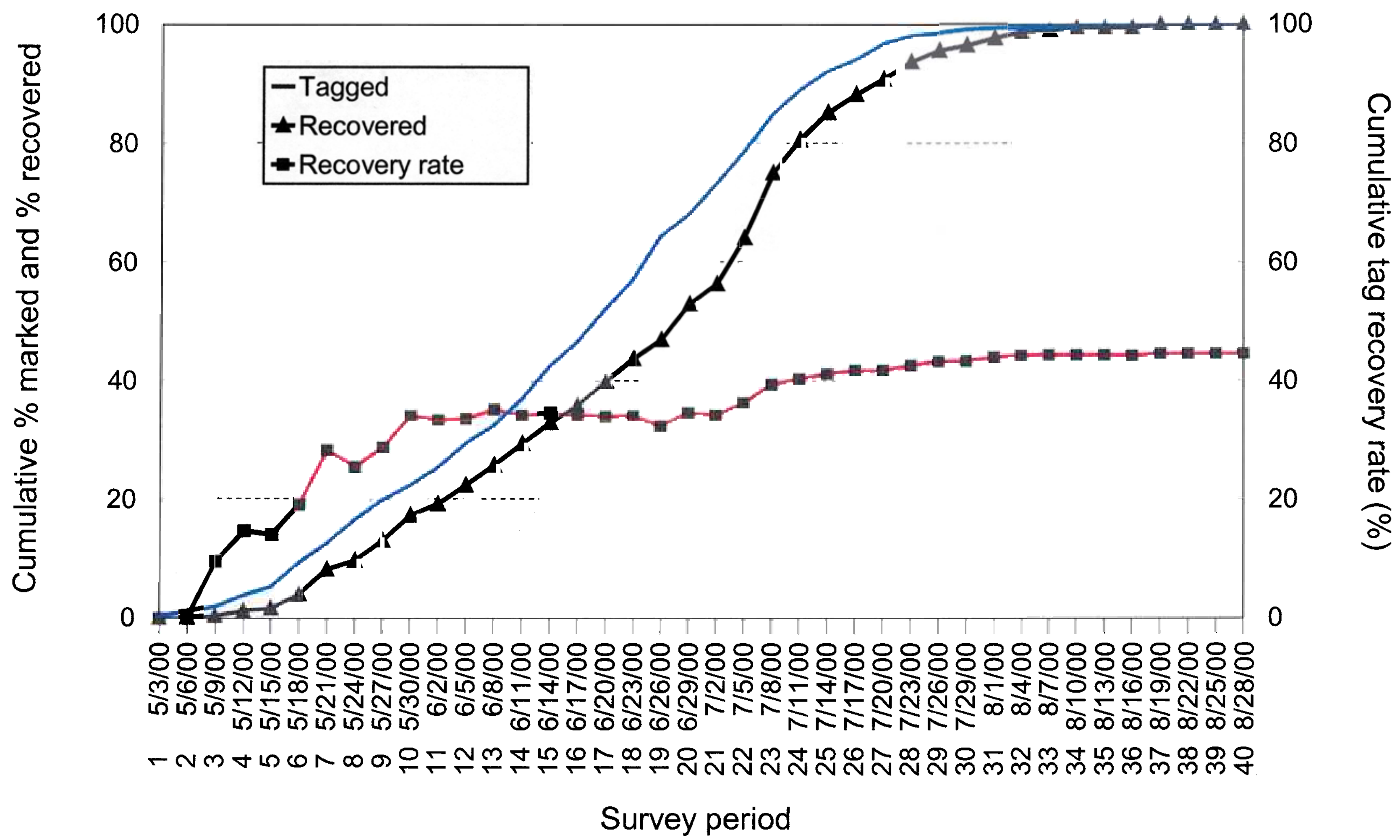


Figure 4. Comparison of temporal distribution of tagging versus recovering of tagged fresh carcasses and tag recovery rate (n tagged/n recovered) during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 2000.

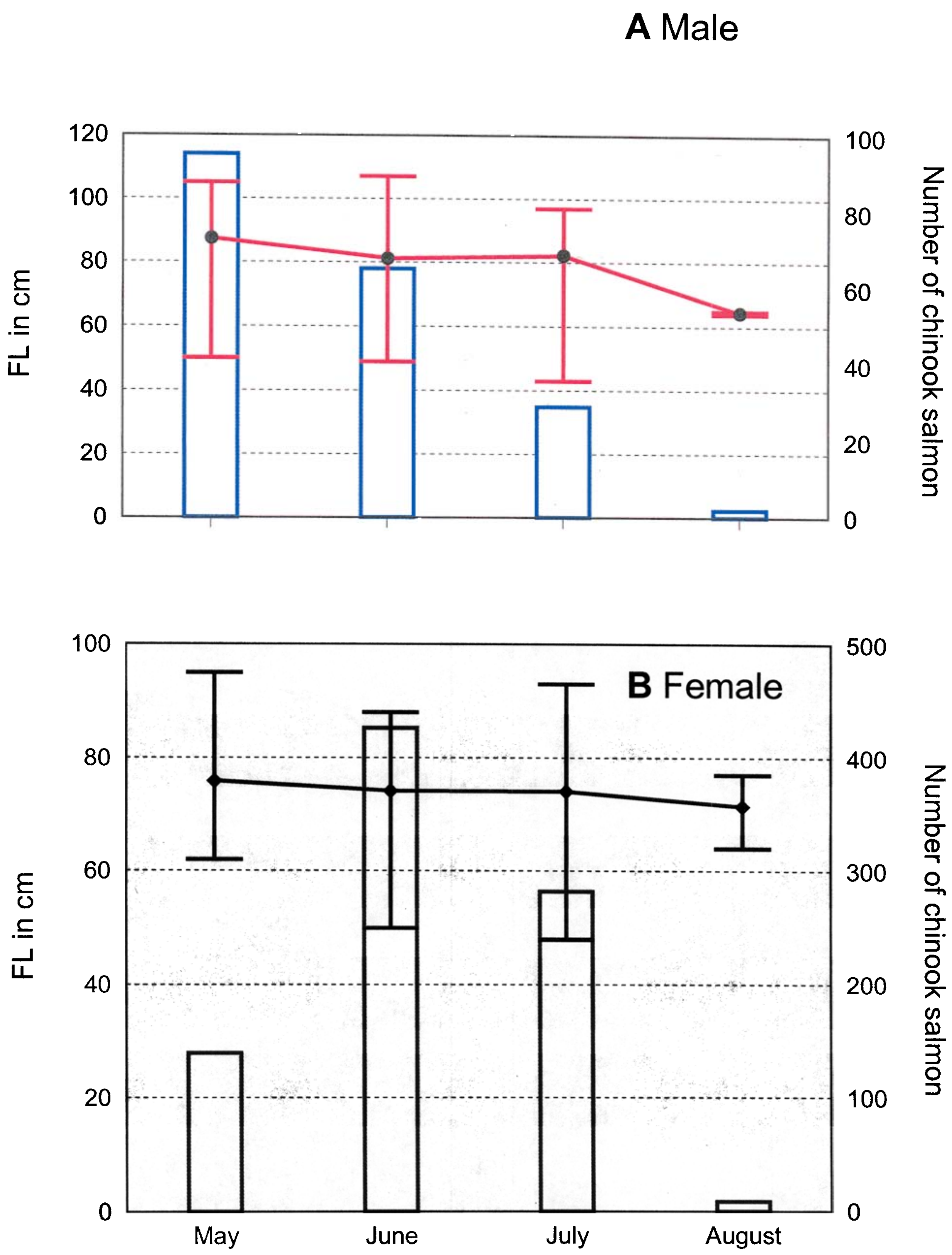


Figure 5. Catch and size distribution of (A) male and (B) female chinook salmon collected during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 2000.

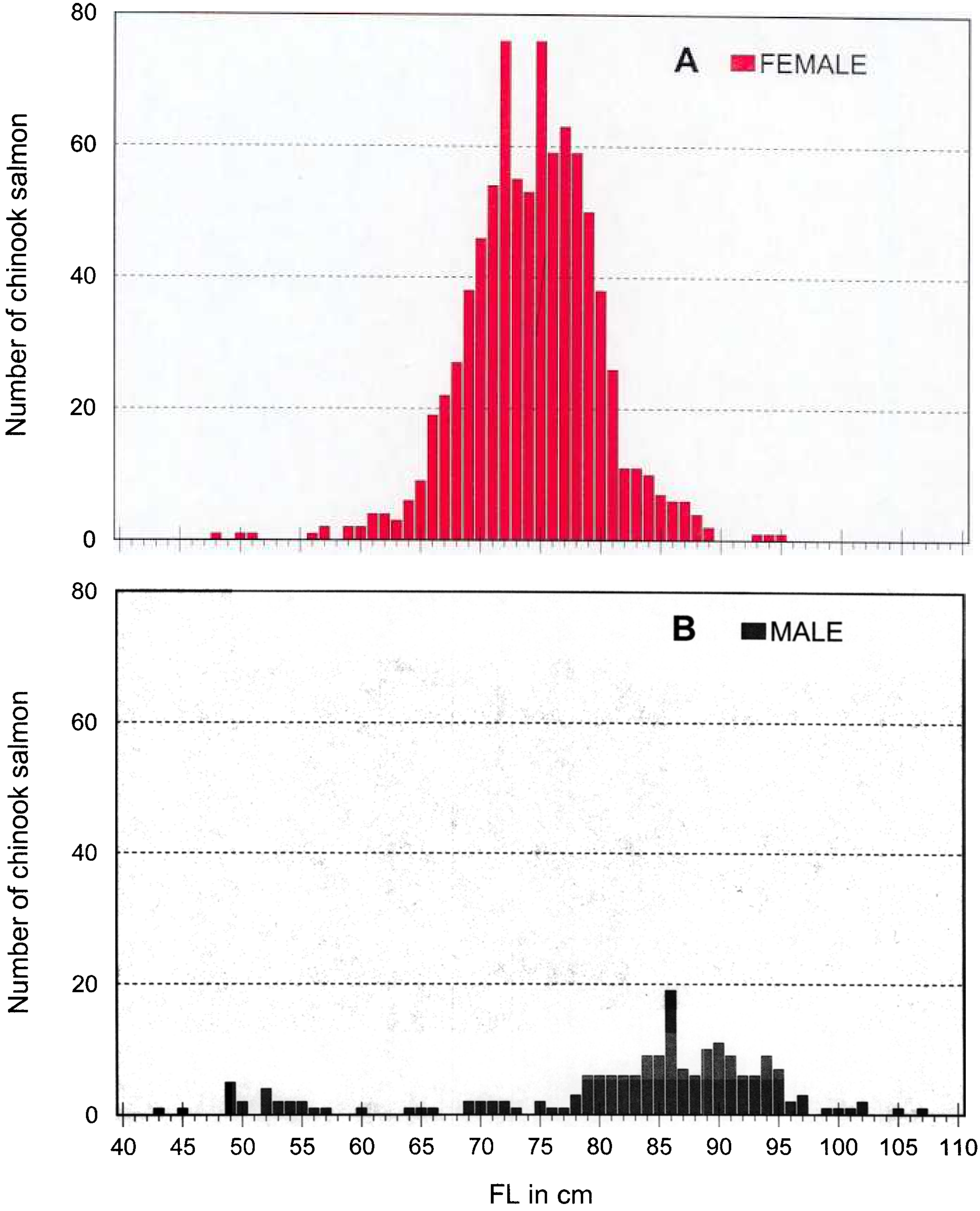


Figure 6. Length-frequency distributions for (A) female and (B) male salmon measured during the upper Sacramento River winter-run chinook salmon escapement survey, May - August 2000.

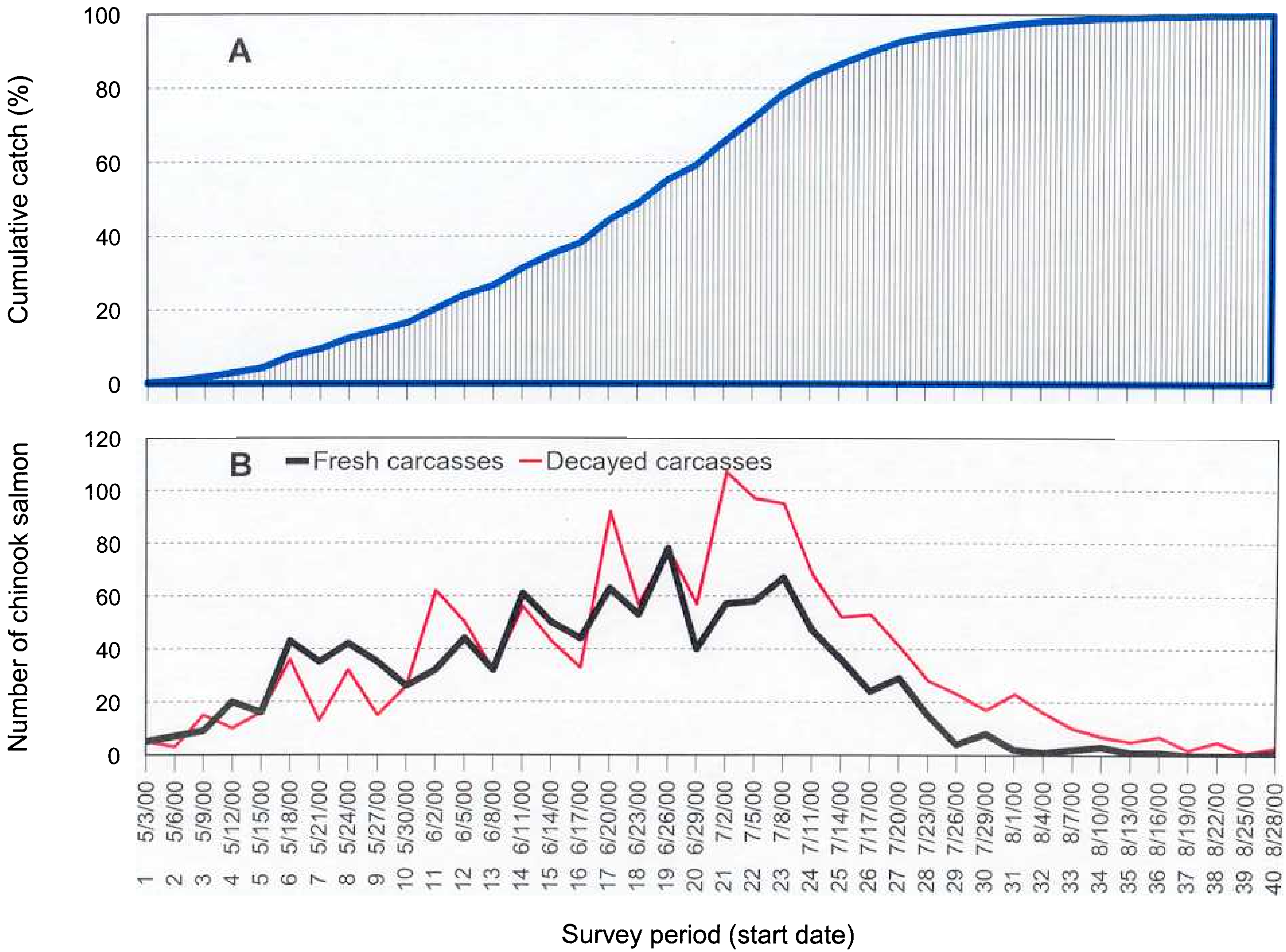


Figure 7. Cumulative catch of fresh carcasses (A), and catch distribution of fresh and decayed carcasses (B) , by survey period during the upper Sacramento River winter-run chinook salmon escapement survey, May-August 2000.

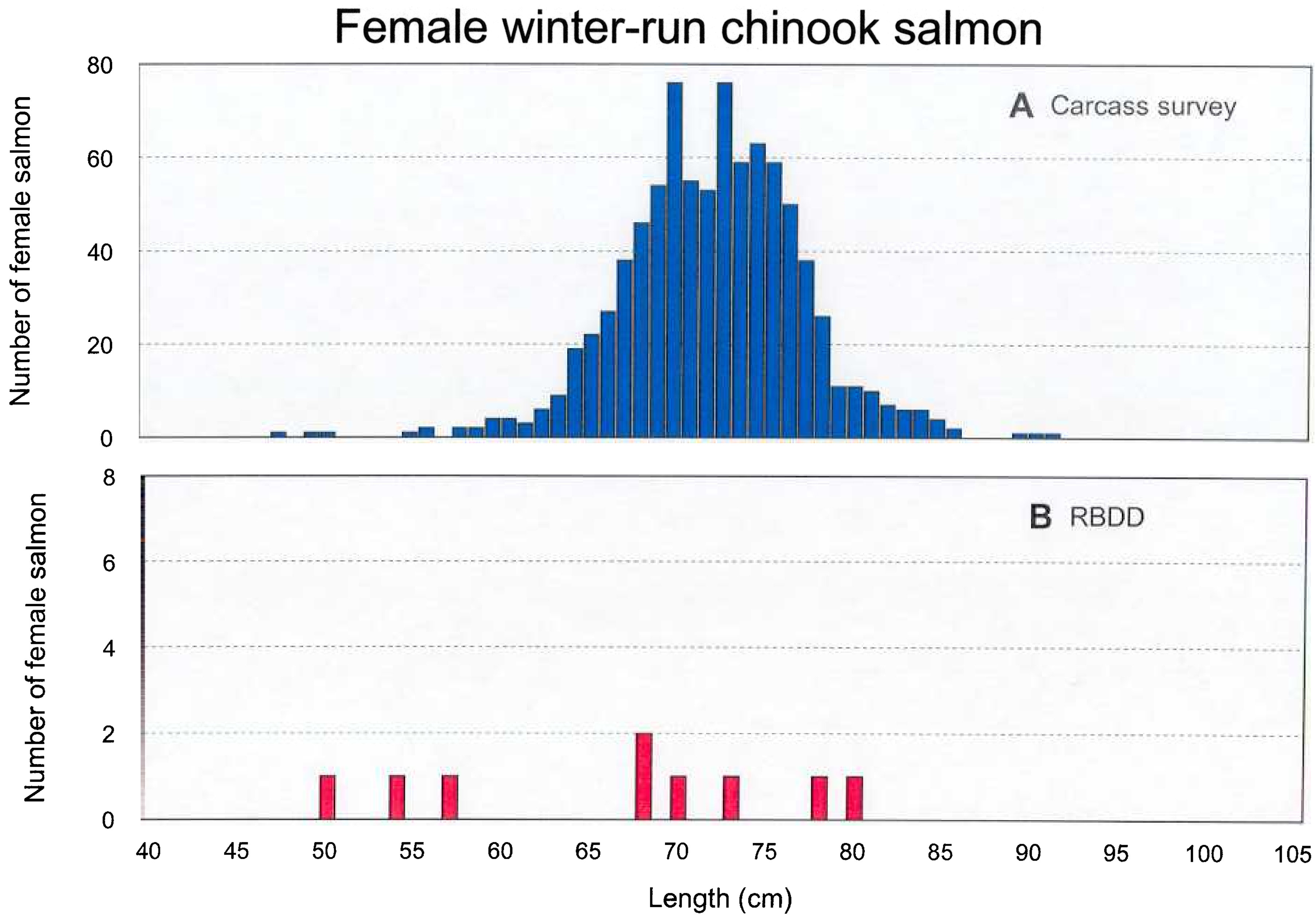


Figure 8. Comparison of length frequency distributions for female winter-run chinook salmon collected during (A) the winter-run chinook salmon escapement survey and (B) at RBDD, May - August 2000.

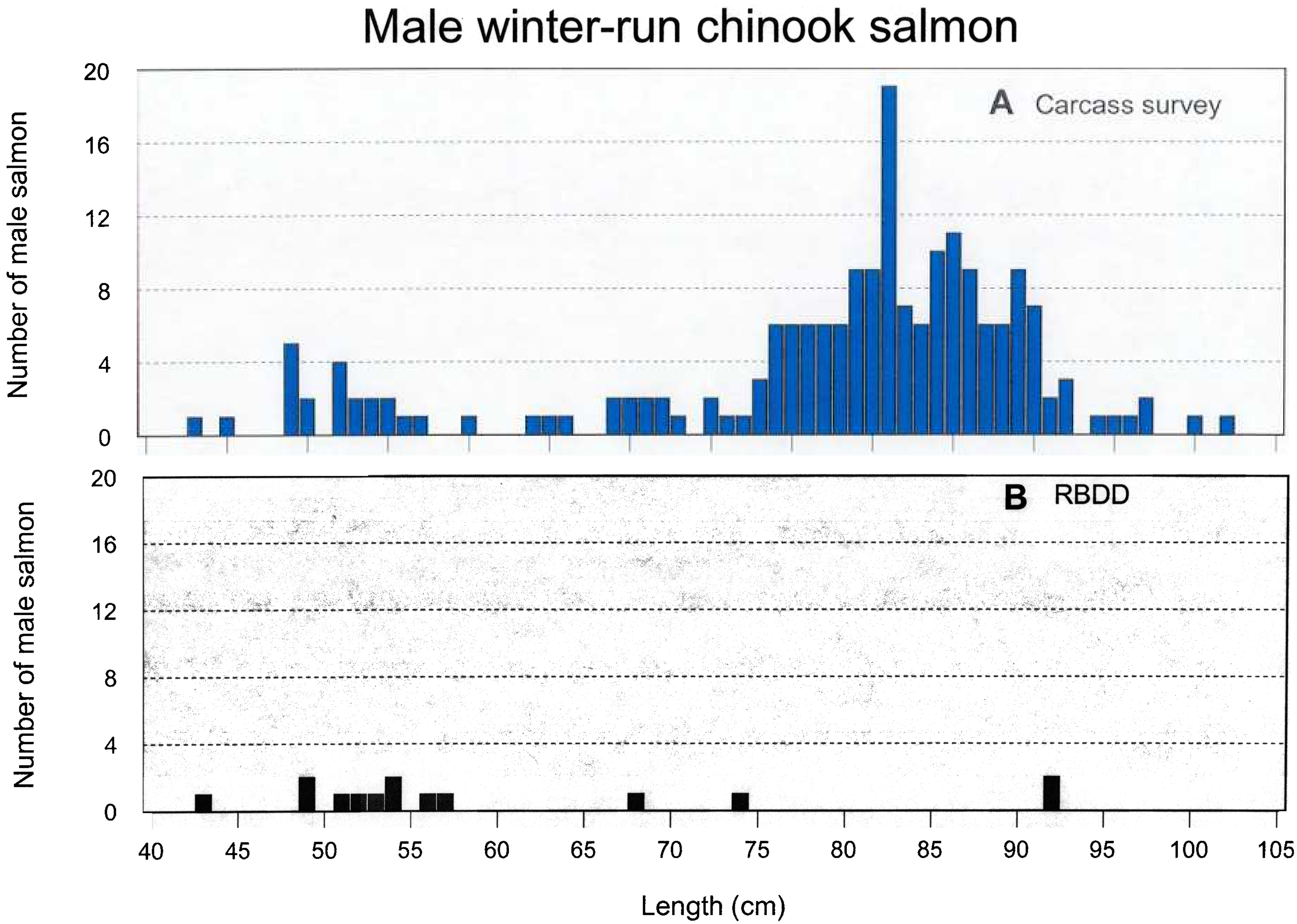


Figure 9. Comparison of length frequency distributions for male winter-run chinook salmon collected (A) during the winter-run chinook salmon escapement survey and (B) at RBDD, May - August 2000.