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 2001

by

Bill Snider
Bob Reavis
Robert G. Titus
and
Scott Hill

Prepared under the direction of
Larry Week, Chief
Native Anadromous Fish and Watershed Branch

Stream Evaluation Program
Technical Report No. 02-1
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2/ Stream Evaluation Program Technical Report No. 02-1

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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*, spawner escapement survey on the upper Sacramento River during spring–summer 2001. This was the sixth consecutive year a winter-run escapement survey was conducted as part of a multi-year investigation to determine Chinook salmon habitat requirements in the Sacramento River system. Data were collected on abundance, age and sex composition of the spawner population, pre-spawning mortality, and temporal and spatial distribution of spawning activity. The survey was conducted from 2 May through 29 August 2001. It covered 14 miles of the Sacramento River comprising the uppermost reach accessible to migrating salmon, from the Redding Water Treatment Plant [river mile 288 (RM 288)] upstream to Keswick Dam (RM 302).

Flow was generally greater than 14,000 cubic feet per second (cfs), (mean = 12,300 cfs, range: 8,500 cfs on 2 May to 15,200 cfs on 15 July). Secchi disk depths (water transparency) averaged 19.5 ft (range: 14.4 ft on 26 June to 21.2 ft on 21 July). Water transparency was much greater than during previous survey years providing very favorable survey conditions. Water temperature fluctuated between 52ºF and 55ºF (mean = 52.8ºF).

A total of 5,145 carcasses (2,235 fresh and 2,910 decayed) was collected. The majority of fresh carcasses were observed between 19 June and 18 July 2001 indicating that spawning activity peaked during June (2 weeks prior to observations). Based on the length-frequency distribution data of unmarked fresh salmon carcasses (n = 1,842) and coded-wire tag (CWT) data (n = 91) for marked, fresh salmon carcasses, 90.3% of the population were adults and 9.7% were grilse. Age compositions and length-frequency distributions of age 2 and age 3 salmon as determined using carcass survey length-frequency distributions to identify age were compared with those determined using scale reading. There were no significant differences between the two methods.

Fresh carcass data were used to determine sex and size composition and spawner success. Overall, 26.6% of the winter-run spawner population were male adults, 8.2% were male grilse, 64.8% were female adults and 0.4% were female grilse; 28.9% of the adults were male and 71.1% were female. We checked 1,198 females for egg retention; 99.4% had completely spawned, 0.2% had not spawned, and 0.4% had partially spawned.

Marked (adipose-fin-clipped) carcass data were used to characterize the hatchery-produced component of the winter-run spawner population. A total of 155 marked carcasses was collected (116 fresh carcasses, 38 decayed carcasses and three carcasses without information on condition). Hatchery-produced winter run accounted for 5.2% of the total escapement based on the portion of marked fresh carcasses (116 out of 2,235 total fresh carcasses). There were 91 CWTs recovered and read from the 116 fresh carcasses and 24 from the 38 decayed carcasses (data on condition (i.e., fresh or decayed) were not obtained from two carcasses with a CWT). All 117 carcasses with a CWT

were identified as winter run. The CWTs obtained from marked, fresh carcasses identified 65 (71%) salmon as winter run from BY 1998 and 26 (29%) from BY 1999. The age/sex composition of fresh, marked carcasses was 22% male adults, 26% male grilse, 50% female adults and 2% female grilse. Overall, the spawner population comprised 3.7% hatchery-produced adults and 1.5% hatchery-produced grilse, 86.6% in-river produced adults and 8.2% in-river produced grilse.

Winter-run spawner escapement estimates were developed by applying the results of a carcass tag-and-recapture survey to three different mark-recapture models: the Petersen, the Schaefer and the Jolly-Seber models. A total of 4,019 (2,017 fresh) adult carcasses was tagged and 2,136 (1,146 fresh) were subsequently recovered (53% and 57%, respectively). The models were applied to estimate the adult portion of the spawner population using 1) the tag-and-recovery data for fresh, adult-sized carcasses (Petersen and Schaefer), and 2) the tag-and-recovery data for both fresh and decayed adult-sized carcasses (Jolly-Seber). Total escapement (adult and grilse) for both hatchery- and in-river-produced salmon, was estimated by expanding the adult estimate in proportion to the adult carcass composition (marked and unmarked) in the fresh carcass sample (90.3%). Expansion of the Petersen model results produced an estimate of 11,502 salmon (10,386 adults and 1,116 grilse). Expansion of the Schaefer model results produced an estimate of 9,631 salmon (8,697 adults and 934 grilse). Expansion of the Jolly-Seber model results produced an estimate of 7,186 salmon (6,489 adults and 697 grilse).

Winter-run spawner escapement to the entire spawning reach, from Keswick Dam downstream to just below Red Bluff Diversion Dam (RM 246), was estimated by combining the results of the carcass survey and of a concurrent winter-run redd distribution survey. The redd survey showed that 88.5% of spawning occurred within the carcass survey area. An expansion factor of 1.13 was applied to the three carcass survey estimates. The expanded Petersen estimate is 12,997 (11,736 adults, 1,261 grilse); the expanded Schaefer estimate is 10,883 (9,828 adults, 1,055 grilse); and the expanded Jolly-Seber estimate is 8,120 (7,333 adults, 787 grilse).

The effective spawner population (i.e., the number of adult females that completely spawned) was estimated by applying a spawning success rate of 99.4% to the estimated number of adult females (64.8% of the total spawner population). Total effective spawner population estimates for the entire spawning reach are 8,372 (Petersen estimate), 7,010 (Schaefer estimate), and 5,230 (Jolly-Seber estimate).

The total number of hatchery-produced winter run was calculated by applying the proportion of hatchery-produced fish determined from the fresh carcass CWT data (3.7% BY 1998 and 1.5% BY 1999) to the expanded escapement estimates. The estimated totals for BY 1998 winter run are 481 (Petersen), 403 (Schaefer), and 300 (Jolly-Seber); the estimated totals for BY 1999 winter run are 195 (Petersen), 163 (Schaefer), and 122 (Jolly-Seber).

INTRODUCTION

A winter-run Chinook salmon, *Oncorhynchus tshawytscha,* escapement survey was conducted on the upper Sacramento River during spring–summer 2001 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 sixth 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, Snider et al. 1999, Snider et al. 2000, Snider et al.2001). 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, CDFG 2001). The investigations on the lower American River strongly suggest that relationships between water temperature and temporal distribution of spawning and emergence, spawner abundance and pre-spawning mortality, flow and habitat availability, spawner abundance and habitat use as well as innate variability in expressed life history attributes can all influence the interpretation of salmon-habitat investigations. Thus, based upon our experiences in evaluating salmon-habitat relationships on the lower American River, we concluded that spawner escapement surveys should be conducted on the upper Sacramento River.

Our initial survey, in 1996, 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). Three different models have been used by the California Department of Fish and Game (DFG) to estimate primarily fall-run Chinook salmon escapement from carcass mark-and-recapture data: the Petersen (Ricker 1975), the 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). The Schaefer model was first used to estimate Chinook salmon escapement within the Central Valley in 1973 on the Yuba River (Taylor 1974). Modifications were made to the Schaefer model to account for sampling with replacement. The modified Schaefer model was first applied on the Yuba River in 1975 (Hoopaugh 1977) and has been the predominant model used since to estimate fall-run Chinook salmon escapement in “larger” Central Valley tributary streams. The Jolly-Seber model was used to estimate escapement in the Feather, Yuba, American, Stanislaus, Tuolumne, and Merced rivers during 1988 (DFG file data).

Objectives

The objectives of the 2001 winter-run Chinook salmon spawner escapement survey were:

- # To estimate the in-river, winter-run Chinook salmon spawner population in the upper Sacramento River within the established habitat study reach (RM 271–RM 302) based on a carcass mark-recapture survey.

- # To examine mark-recapture techniques (i.e., Peterson, Jolly-Seber, and Schaefer population models) when used to estimate winter-run escapement in the upper Sacramento River, and evaluate and develop escapement estimating protocols.

- # 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 Red Bluff Diversion Dam (RBDD) in March and April (Hallock and Fisher 1985). 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 the 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 on the Sacramento River (Fig. 1). Some winter run may spawn in larger, upper Sacramento River tributary streams such as Battle Creek. Due to a drastically declining population, winter run were listed as endangered under the California Endangered Species Act by the California Fish and Game Commission in 1989. Winter run were federally listed as threatened in 1990, then as endangered in 1994 under the Endangered Species Act by the National Marine Fisheries Service (NMFS).

The NMFS (1997) and Botsford and Brittnacher (1998) developed a winter-run extinction model that identifies population conditions corresponding to an acceptable low probability of population extinction. Using the model, NMFS determined that the population will have recovered when the mean annual spawning abundance over any 13 consecutive years is at least 10,000 females. This population level assumes that the male:female ratio is 1:1 and that the age structure is comparable to that observed by Hallock and Fisher (1985) over three brood years. The assumed age structure is 50% 2-year-olds, 44% 3-year-olds, and 6% 4-year-olds for males; and 89% 3-year-olds and 11% 4-year-olds for females. The population criteria also require that annual escapement will be estimated with a precision of $\pm$ 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 and the gates are down, requiring all fish migrating upstream of RBDD 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. Beginning in 1986, the operation of RBDD was modified to improve winter-run migration. Since 1986, the gates are typically raised from mid-September through mid-May the following year to allow unimpeded upstream passage of most winter run. Winter-run counts made when season-long counts were possible (1969–1985) indicate that only a small portion of the winter-run migration typically occurred during the mid-May through mid-September period (Fig. 2). 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.

METHODS

The 2001 winter-run Chinook salmon spawner escapement survey was conducted from 2 May through 29 August 2001. Methods were similar to those used during the 2000 winter-run-escapement survey (Snider et al. 2001).

Originally, in 1996, the survey reach extended 31 miles from Battle Creek (RM 271) upstream to Keswick Dam (RM 302) (Fig. 1). This reach is considered the primary spawning area for winter run in the upper Sacramento River. However, after observing a low tag recovery rate (15% for all tagged carcasses) and that more than 90% of the winter-run spawning activity occurred in the uppermost 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 reach was surveyed an average of 2.5 times per week. This change was to increase our sampling effort and potentially improve the tag recovery rate, and still include most of the winter-run spawning area, to provide a more precise escapement estimate. This sampling design has been applied through 2001.

The 2001 study area comprised 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. One day was skipped and then the cycle was repeated. The 2001 survey comprised 40 survey periods.

Most of the survey was conducted from boats (two boats with two observers per boat). Each boat was generally used to survey along one shoreline out to the middle of the river. Several short stretches of river were surveyed on foot. Survey effort was allocated to assure coverage of 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 were obtained from the Keswick gauge (RM 302) operated by the U.S. Geological Survey. Water temperature and Secchi disk (water transparency) readings were measured at the beginning and end of each survey day by the survey crew.

Distinction of Origin: In-river versus Hatchery-produced Winter-run Chinook Salmon

Sufficient numbers of known, hatchery-produced winter run were collected in 2001 providing the first opportunity during the 6 survey years to distinguish spawner population characteristics of in-river and hatchery-produced winter run (i.e., age, sex, and size composition, spatial and temporal spawning distribution and estimated population composition). Adequate numbers of hatchery-produced winter run that were marked and released from the predominant year classes comprising the 2001 spawner population escaped to the upper Sacramento River to allow collection of a relatively large number of known, hatchery-produced winter run. A total of 147,392 winter-run Chinook salmon produced at the Livingston Stone National Fish Hatchery (LSNFH) were marked and released from BY 98 and 30,840 from BY 99, the two juvenile year classes expected to dominate the 2001 spawner population. All BY 98 and BY 99 winter run produced at LSNFH and released into the Sacramento River were marked (adipose-fin clipped) and tagged with a coded-wire tag (CWT).

All marked carcasses were considered to be of hatchery origin; all unmarked carcasses were considered to have been produced in-river. Each carcass observed during the survey was checked for a mark. The head was collected from each marked carcass to obtain CWT information on race, age, and hatchery of origin. Summaries describing the attributes of the hatchery-produced salmon were determined using only those data collected from marked, fresh carcasses. Information used to describe attributes of unmarked salmon were primarily obtained from data collected from unmarked, fresh carcasses. Exceptions are noted below.

Size/age Distribution and Sex Composition

Fork length (FL) and sex data used to describe attributes of the unmarked, in-river-produced salmon component of the spawner population were only collected from fresh, unmarked carcasses. However, length and sex data used to describe the marked, hatchery-produced salmon component were obtained from both fresh and decayed, marked salmon carcasses. All marked carcasses containing a CWT were used to describe size/age attributes of the hatchery-produced component, although decayed carcasses generally do not allow accurate measurements.

Unmarked, fresh carcass data were used to develop length-frequency relationships and sex ratios for the in-river-produced spawner population. Length-frequency distributions can be used to describe age structure of fish populations using the Petersen method (Bagenal and Tesch 1978), when an age-size relationship exists and when sample size is sufficient to define the distributions. The length-frequency distribution of each sex was used to define the length separating adults (>2-years-olds) and grilse (2-year-olds). A sub-sample of fresh, unmarked carcasses (n = 145) was aged by scale analysis using two independent readings (R. Titus and M. Volkoff, CDFG, unpubl. data). Discrepancies in readings were resolved or dropped from the data set through consultation by the readers. The relative frequencies of male and female grilse and adults as determined with the two ageing methods were compared in a 2-by-2 contingency table to test the null hypothesis that there was no difference in age structure as a function of ageing method(i.e., length frequency versus scale reading). Chi-square analysis was used with Yates' correction to improve accuracy with use of a 2-by-2 table (Box et al. 1978). In addition, the lengths of salmon aged by these two methods were compared to the lengths of known-age coded-wire-tagged salmon recovered in the survey (see below). Analysis of variance (ANOVA) was used to test the null hypothesis that lengths of salmon aged by the three methods did not differ significantly. All analyses assumed significance at $p \leq 0.05$.

Spawning Success

Most measurable (fresh) female carcasses were checked for egg retention among marked and unmarked salmon. Females were classified as: 1) spent if few eggs remained, 2) partially spent if 50% or more of the eggs still remained in the body cavity, and 3) unspent if they appeared to be completely unspawned.

Temporal Distribution

The total number of fresh, female carcasses observed weekly, in both reaches, was used to describe temporal spawning distribution for the entire spawning population. We used female carcasses as indicators of spawning activity relative to using both male and female carcasses, as: 1) females stay on the redd until death, while males leave the spawning site, 2) several males may spawn over a single nest, while there is only one female per redd, and 3) a spent female is a positive indication of spawning activity. Monthly distribution of spawning was distinctly determined for marked and unmarked salmon using the total monthly counts of marked and unmarked fresh, female carcasses. Spawning activity was considered to precede the observation of fresh carcasses by approximately 2 weeks based upon observations made in the American River (Snider and Vyverberg 1995).

Spatial Distribution

We calculated spatial distribution for all salmon spawning activity and distinctly for marked and unmarked salmon based upon the actual counts of fresh female carcasses. For the reasons stated above, using fresh, female carcass data was considered superior to using a combination of male and female data to represent spawning distribution. Fresh carcasses have been susceptible to downstream movement for a shorter time than decayed carcasses. However, 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.

Population Estimates

The winter-run spawner population was estimated using a mark-and-recapture (tag-and-recovery) method. Typically, all but those carcasses in an advanced state of decay were tagged. 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. (Marked, fresh carcasses were tagged by attaching the ribbon to the anterior portion of the spine since heads were removed for recovery of CWTs.) 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 upper jaw and decayed carcasses were tagged in the lower jaw. Carcass condition was noted during tagging to satisfy 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.

Three mark-and-recapture models were used to calculate winter-run spawner escapement: the Petersen model (Ricker 1975), the Schaefer model (Schaefer 1951) as described by Taylor (1974), Hoopaugh (1977) and Boydstun (1994), and the Jolly-Seber model (Seber 1982) as described by Boydstun (1994). All three models were applied as part of the evaluation of the utility of mark and recapture methods to estimate winter-run escapement in the upper Sacramento River. The Petersen model allows development of a population estimate when the population is low and too few carcasses are tagged and recovered to allow use of the other two models; the Schaefer model allows comparisons with results from other Central Valley streams; and the Jolly-Seber model produces the most accurate estimate according to Law (1994).

Data from fresh carcasses were used to calculate an escapement estimate using the Schaefer and Petersen models. The combined data from all carcasses (i.e., both fresh and decayed, adult carcasses) were used to calculate an estimate using the Jolly-Seber model. Applying both fresh and decayed carcass data to these models produces higher estimates than using only fresh carcass data (Law 1994). Since both the Petersen and Schaefer models tend to overestimate the population (Boydstun 1994, Law 1994), even when only using fresh carcass data, the reported estimates produced from these two models are based on fresh-carcass-only derivations. Similarly, since the Jolly-Seber model tends to slightly underestimate the population (Boydstun 1994, Law 1994), we applied both fresh and decayed carcass data to this model.

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

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

where:

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

2. The Schaefer model (Schaefer 1951 as described by Taylor 1974, Hoopaugh 1997, Boydstun 1994) is:

$$\mathbf{N = \sum N_{ij} = \sum [R_{ij}(T_i C_j / R_i R_j) - T_i]}$$

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 version 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. The Jolly-Seber model (Seber 1982 as described by Boydstun 1994) is:

$$\mathbf{N = N_1 + D_1 + D_2 ... + D_j}$$

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.

The models were used to estimate the total *adult* portion of the spawner population (i.e., marked and unmarked salmon). Total populations (adult and grilse) were estimated by expanding the adult estimates based upon the proportion of adults obtained from the fresh carcass data.

The total spawner population was estimated as the adult estimate divided by the proportion of adults (P_{adult}), as

$$\mathbf{P_{adult} = (n_{marked\ adult} + n_{unmarked\ adult})/\ n_{total}}$$

where:

$n_{marked\ adult}$ = number of measured, marked fresh carcasses identified by CWT as BY 98 salmon expanded proportionately to account for all marked, fresh carcasses;
$n_{unmarked\ adult}$ = number of measured, unmarked fresh carcasses identified as adults using length frequency distribution expanded proportionately to account for all unmarked, fresh carcasses; and,
n_{total} = all observed, fresh carcasses (marked + unmarked).

The estimated number of grilse was calculated by subtracting the adult estimate from the total estimate.

The number of hatchery-produced salmon (N_m) was estimated as:

$$\mathbf{N_m = N_{total\ marked\ adult} + N_{total\ marked\ grilse}}$$

where:

$N_{total\ marked\ adult} = (n_{marked\ adult}/n_{total}) \times N$;
$N_{total\ marked\ grilse} = (n_{marked\ grilse}/n_{total}) \times N$; and
N = estimated total number of spawners.

We also estimated the number of female adults that completed spawning, herein defined as the effective spawner population. The total (i.e., both marked and unmarked) effective spawner population was calculated as the product of the proportion of the adult female spawners that completely spawned and the estimated number of adult female spawners. The estimate of adult female spawners was calculated as the product of the proportion of female adults, per the fresh-carcass data, and the adult estimate. An effective spawner population was also calculated individually for marked and unmarked fish by applying the proportions of completely spawned females for marked and unmarked carcasses (fresh-carcass data) to the corresponding estimates of marked and unmarked, adult female spawners.

RESULTS

General

We observed 2,235 fresh and 2,910 decayed (5,145 total) carcasses from 2 May through 29 August 2001 (Table 1). Included in the total were 155 carcasses marked with an adipose-fin clip (hatchery produced) and 4,900 unmarked carcasses (in-river produced).

Mean survey-period flow averaged more than 12,300 cfs (range: 8,500 to 15,200 cfs) (Fig. 3). Mean survey-period temperature averaged 52.8°F (range: 50°F to 55°F) (Table 1). Secchi disk depth readings averaged 19.5 ft (range: 4.4 to 21.2 ft) (Table 1).

Hatchery-produced Winter-run Chinook Salmon

Personnel from the Red Bluff Fish and Wildlife Office (RBFWO) checked all 155 marked carcasses (116 fresh, 36 decayed, three unknown) for CWTs (Appendix Table 1). CWTs were recovered from 117 carcasses; seven tags were lost during processing, and 31 carcasses did not have a CWT. Most of the marked carcasses that contained a CWT were fresh carcasses; 91 had a CWT, and 25 had no tag. Twenty-four decayed carcasses contained a CWT, and 12 did not have a tag. Three carcasses had no information regarding sex, size or state of decay. Two of these carcasses had tags. All tagged carcasses were winter run from BY 1998 and BY 1999 that were reared at LSNFH and released into the Sacramento River at Lake Redding Park.

Size/age Distribution and Sex Composition

Unmarked Salmon

We measured 1,842 of the 2,119 observed unmarked, fresh carcasses (Table 2). Mean FL was 77.0 (range: 40–110 cm FL). Male salmon (*n* = 640) averaged 79.6 cm FL (range: 40–110 cm FL). Female salmon (*n* = 1,202) averaged 75.7 cm FL (range: 45–102 cm FL). The largest fish were observed during May (Fig. 4). The mean size of males ranged from a high of 90.9 cm FL in May to a low of 78.0 cm FL in July. The mean size of females ranged from 79.5 cm FL in May to 73.7 cm FL in August.

The male and female length-frequency distributions were noticeably different (Fig. 5). Nearly all of the females were grouped in a normal distribution that ranged from 61 to 89 cm FL with a mode at 76 cm FL (Fig. 5a). About 99% of the females ranged from 61 to 89 cm FL. In contrast, the male distribution was strongly bimodal with modes around 53 cm and 87 cm FL (Fig. 5b). About 68% of the males were between 72 and 95 cm FL.

Table 1. Summary of carcass counts and mean flow, water temperature, and Secchi disk depths for each survey period of the 2001 upper Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcass count[3/]		
					Fresh	Decayed	Marked
1	May 2–3	8,500	50	17.5	3	9	0
2	May 5–6	8,600	50	17.5	6	6	0
3	May 8–9	8,900	51	19.5	4	5	1
4	May 11–12	9,400	51	19.8	6	1	2
5	May 14–15	10,700	50	17.8	9	5	1
6	May 17–18	10,500	52	19.2	6	2	0
7	May 20–21	10,600	54	19.2	10	7	0
8	May 23–24	10,600	50	20.2	17	8	1
9	May 26–27	10,000	52	20.0	13	5	0
10	May 29–30	11,100	53	19.5	24	11	1
11	June 1–2	11,000	53	21.0	23	12	0
12	June 4–5	11,500	52	19.9	44	19	1
13	June 7–8	12,900	53	17.2	37	21	2
14	June 10–11	13,800	52	16.2	55	32	2
15	June 13–14	13,900	54	19.4	64	31	4
16	June 16–17	14,400	53	20.0	83	43	6
17	June 19–20	14,400	55	19.8	106	53	6
18	June 22–23	14,400	52	19.8	124	74	9
19	June 25–26	14,200	52	14.4	116	72	8
20	June 28–29	14,200	54	19.8	153	86	12
21	July 1–2	14,200	54	20.0	138	109	6
22	July 5–6	14,600	53	20.0	169	222	15
23	July 8–9	14,600	54	18.5	181	206	17

Table 1. (cont.).

Survey period	Dates	Mean flow (cfs)[1/]	Mean water temperature (° F)[2/]	Mean Secchi depth (ft)	Carcass count3/		
					Fresh	Decayed	Marked
24	July 11–12	14,900	54	19.5	158	204	9
25	July 14–15	15,200	54	20.0	137	148	7
26	July 17–18	14,500	54	20.5	135	177	9
27	July 20–21	15,000	54	21.2	93	194	4
28	July 23–24	15,000	54	20.2	91	193	8
29	July 26–27	15,000	54	20.0	65	144	3
30	July 29–30	14,100	53	21.0	50	141	8
31	August 1–2	12,900	52	20.0	35	149	3
32	August 4–5	12,500	52	19.5	25	103	2
33	August 7–8	12,300	53	20.0	19	124	5
34	August 10–11	12,200	53	20.0	8	54	0
35	August 13–14	11,800	53	20.0	8	92	2
36	August 16–17	11,000	53	21.0	11	77	0
37	August 19–20	10,300	53	20.0	3	15	1
38	August 22–23	9,300	53	20.0	4	34	0
39	August 25–26	10,000	53	20.0	2	10	0
40	August 28–29	9,400	54	20.0	0	12	0
				Totals	2,235	2,910	155

1/ Mean flow at Keswick Dam during survey period from U.S. Geological Survey.

2/ Mean water temperature measured each day by survey crew.

3/ Includes grilse and adults; does not include tag recoveries.

Table 2. Size and sex statistics for unmarked winter-run Chinook salmon carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

Month	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
May	93	84.1	55–110	37	90.9	55–110	56	79.5	67–101
June	760	77.2	43–105	299	79.5	43–105	461	75.7	45–98
July	892	73.3	40–102	288	78.0	40–102	604	75.6	53–102
August	97	75.4	62–98	16	83.6	63–98	81	73.7	62–87
Totals	1,842	77	40–110	640	80	40–110	1,202	76	45–102

Length-frequency distributions were used to identify some general size criteria to distinguish grilse (2-year-old salmon) from adults (>2-year-old salmon) by sex. Females $\geq$61 cm FL were considered adults based upon the location of the break between the tail of the length frequency distribution and the few fish to the left (Fig. 5a). Male adults were defined as salmon $\geq$67 cm FL based upon an apparent break in their size distribution between 65 and 71 cm FL
(Fig. 5b).

Based upon the age criteria defined using length-frequency distributions, the measured fresh carcasses (*n* = 1,842) comprised 91.4% (*n* = 1,683) adults and 8.6% (*n* = 159) grilse (Table 3). The grilse portion of the population never exceeded 10.1% of the sample during any month, increasing from about 1% in May to 10.1% in July.

The grilse sample comprised 95% (*n* = 151) males and 5% (*n* = 8) females (Table 4). The adult sample comprised 71% (*n* = 1,194) females and 29% (*n* = 489) males. The ratio of male:female adult spawners was 1:2.4. The male:female sex ratio, including grilse, was 1:1.9. The age/sex composition of unmarked salmon, based upon the fresh carcass data, was 26.6% male adults, 8.2% male grilse, 64.8% female adults and 0.4% female grilse. Overall age composition of in-river produced salmon was 86.6% adult and 8.2% grilse.

Adult males averaged 87.0 cm FL (*n* = 489, SD = 6.6; range: 67–110 cm FL) (Table 5). Female adults averaged 75.8 cm FL (*n* = 1,194, SD = 5.7; range 61–102 cm FL). Male grilse averaged 55.7 cm FL (*n* = 151, SD = 5.5; range: 40–66 cm FL) and female grilse averaged 55.6 cm FL (*n* = 8, SD = 5.0; range: 45–60 cm FL).

Marked Salmon

We measured 152 of the 155 marked salmon that were observed during the survey (Table 6). The sex composition of all salmon carcasses was 43% male (*n* = 65) and 57% female (*n* = 87). The sex composition of fresh marked salmon carcasses was 44% male (*n* = 51) and 56% female (*n* = 65) (Table 7).

The mean length of all marked salmon was 70.1 cm FL (range: 39–92 cm FL) (Table 6); males averaged 68.1 cm FL (range: 39–92 cm FL) and females averaged 71.6 cm FL (range: 54–91 cm FL). The mean length for fresh marked salmon carcasses was essentially the same at 70.2 cm FL (range: 39–92 cm FL); males averaged 67.1 cm FL (range: 39–92 cm FL) and females averaged 72.6 cm FL (range: 63–82 cm FL). The largest males were observed during June (Fig. 6) and the largest females were observed during July. The mean size of males ranged from a high of 81.3 cm FL in August to a low of 65.0 cm FL in May (Table 6). The mean size of females ranged from 72.9 cm FL in June to 71.2 cm FL in July.

The age composition of all carcasses with CWTs (Table 8) collected during the survey (*n* = 117, including two carcasses with CWTs but without data on sex, size or condition) was 74% (86) adults and 27% (31) grilse (22% male adults, 24% male grilse, 51% female adults, and 3% female grilse). The age composition of fresh, marked carcasses with CWTs (*n* = 91) was similar at 71% (65) adults and 29% (26) grilse (22% male adults, 26% male grilse, 50% female adults, and 2% female grilse). Overall, the winter-run spawner population comprised 3.7% hatchery-produced adults (BY 98) and 1.5% hatchery-produced grilse (BY 99)

All 31 male grilse recovered during the survey were ≤65 cm FL, while all male adults were ≥ 69 cm FL (Appendix Table 1, Fig. 7). Three female grilse were recovered; one was 54 cm FL and two were >70 cm FL. The latter two females were large for Chinook grilse.

Table 3. Composition and temporal distribution of grilse and adult, unmarked fresh winter-run Chinook salmon carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

	Adults[4/]		Grilse[4/]	
Survey period	Number	%	Number	%
May	92	98.9	1	1.1
June	694	92.3	66	8.7
July	802	89.9	90	10.1
August	95	97.9	2	2.1
Totals	1,683	91.4	159	8.6

4/ Age determined from length frequency distributions; adults were defined as females ≥ 61 cm FL and as males ≥ 67 cm FL.

Comparison of Ageing Methods

The age composition of winter-run, as determined by 1) length frequencies observed in the carcass survey, 2) ageing from scales obtained from carcasses, and 3) known-age salmon obtained from carcasses containing CWTs, were contrasted (Table 9). Notably, carcass survey length frequencies and scale ageing resulted in similar grilse and adult proportions in the spawner population. In contrast, age composition from CWT returns showed a high proportion of male grilse and a corresponding low proportion of male adults relative to the overall observed proportions. Age composition as determined from carcass survey length frequencies and scale ageing were compared for each sex to test the efficacy of using the Petersen length-frequency method to determine age structure (Table 10). In the

Table 4. Sex composition of unmarked, fresh winter-run Chinook adult and grilse carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

	Adults[5/]				Grilse[5/]			
	Male		Female		Male		Female	
Month	Number	%	Number	%	Number	%	Number	%
May	36	38.7	56	60.2	1	1.1	0	0
June	235	30.9	459	60.4	64	8.4	2	0.3
July	204	22.9	598	67.0	84	9.4	6	0.7
August	14	14.4	81	83.5	2	2.1	0	0
Totals	489	26.6	1,194	64.8	151	8.2	8	0.4

5/ Age determined from length frequency distributions; adults were defined as females ≥ 61 cm FL and as males ≥ 67 cm FL.

Table 5. Summary of adult and grilse size and number by sex for unmarked, fresh winter-run Chinook salmon carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

	Female		Male	
	Grilse[6/]	Adults	Grilse[6/]	Adults
Total measured	8	1,194	151	489
Mean	55.6	75.8	55.7	87.0
Range FL (cm)	45–60	61–102	40–66	67–110
SD	5.0	5.7	5.5	6.6

6/ Age determined from length-frequency distributions; adults were defined as females ≥ 61 cm FL and as males ≥ 67 cm FL.

Table 6. Size and sex statistics for marked (fresh and decayed) winter-run Chinook salmon carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

Month	All salmon			Male salmon			Female salmon		
	Number measured	Length (FL in cm)		Number measured	Length (FL in cm)		Number measured	Length (FL in cm)	
		Mean	Range		Mean	Range		Mean	Range
May	6	68.8	55–82	3	65.0	55–82	3	72.7	67–79
June	48	71.6	48–92	26	70.5	48–92	22	72.9	63–81
July	85	69.1	39–91	33	65.7	39–87	52	71.2	54–91
August	13	73.7	61–83	3	81.3	78–83	10	71.4	61–77
Totals	152	70.1	39–92	65	68.1	39–92	87	71.6	54–91

Table 7. Size and sex statistics for marked, fresh winter-run Chinook salmon carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

	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	3	69.0	58–82	2	70.0	58–82	1	82.0	82
June	41	70.1	48–92	21	67.0	48–92	20	73.4	66–81
July	64	69.6	39–85	25	65.2	39–85	39	72.5	63–81
August	8	75.6	71–83	3	81.3	78–83	5	72.2	71–74
Totals	116	70.2	39–92	51	67	39–92	65	73	63–82

Table 8. Age and sex composition of carcasses containing a coded-wire-tag[7/] (both fresh and decayed carcasses and only fresh carcasses) collected during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

Brood Year	All/Fresh	Sex	Number	Length (FL in cm)	
				Mean	Range
98	All	M	25	81.0	69–82
98	All	F	59	72.5	55–91
99	All	M	28	53.5	39–65
99	All	F	3	66.0	54–73
98	Fresh	M	20	81.7	76–92
98	Fresh	F	45	72.4	63–81
99	Fresh	M	24	53.9	39–65
99	Fresh	F	2	72.0	71–73

7/ No size, sex or condition data were collected from two carcasses containing a CWT that identified them as adults.

Table 9. Age composition of winter-run Chinook salmon as determined from length frequencies in the 2001 carcass survey, reading scales taken from carcasses collected during the survey, and coded-wire-tagged carcasses collected during the survey.

	% (size range in cm FL)		
	Carcass survey[8/]	Scale	Coded-wire tagged carcasses[9/]
Male adults	26.6 (67-110)	34.5 (72-110)	21.6 (69-92)
Female adults	64.8 (61-102)	55.2 (65-101)	50.5 (59-81)
Male grilse	8.2 (40-66)	9.0 (45-65)	25.2 (39-65)
Female grilse	0.4 (45-60)	1.4 (65-78)	2.7 (54-73)[10/]

8/ Percent estimate excludes coded-wired-tagged carcasses from the sample (n = 1,842).
9/ Coded-wire-tag results provided by Randy Rickert, U.S. Fish & Wildlife Service.
10/ Sample composed of three carcasses, one measuring 54 cm FL and two measuring >70 cm FL.

Table 10. Frequencies of winter-run Chinook salmon by age group as determined by the Petersen length-frequency method and scale ageing (naturally-produced salmon only). Grilse are 2-year-olds, adults are 3- and 4-year-olds.

Aging method	No. grilse (%)	No. adults (%)	Chi-square statistics
		Males	
Length frequency	154 (23.9)	490 (76.1)	$\chi^2 = 0.18$, df = 1,
Scale ageing	13 (20.6)	50 (79.4)	$p = 0.6677$
		Females	
Length frequency	8 (0.7)	1190 (99.3)	$\chi^2 = 1.24$, df = 1,
Scale ageing	2 (2.4)	80 (97.6)	$p = 0.2652$

We also compared lengths among winter run of equal age as determined by length-frequencies in the carcass survey, scale ageing, and ages from known-age CWT fish. (The analysis was restricted to age-2 grilse and age-3 adults because there were no 4-year-old CWT returns). Salmon ≥00 cm FL were case of both males and females, we cannot reject the null hypothesis that there is no difference in the frequencies of male and female grilse and adults as determined by carcass survey length-frequency distributions and scale ageing. omitted from the analysis based on results of scale ageing that showed four of six age-4 salmon were ≥100 cm FL.

Male salmon aged as 2-year-olds with the three methods were very homogeneous in length (Table 9; ANOVA, F = 1.91, df = 194, p>0.15). In contrast, there was significant heterogeneity in lengths of 3-year-old males (Table 9; ANOVA, F = 1.91, df = 547, p<0.0001), although multiple-range testing indicated no significant difference in mean lengths of 3-year-old males aged from length frequencies and scales (Fisher's least significant difference [LSD] procedure, p>0.05; Fig. 8). However, these two groups differed significantly with the mean length of 3-year-old CWT males (Fisher's LSD, p<0.05). Overall, the mean length (81 cm FL) of 3-year-old CWT males was significantly less than that of length-frequency and scale-aged males (86 and 87 cm FL, respectively).

The lengths of female winter run aged as 2-year-olds with the three methods could not be compared statistically because of their low frequencies (total n = 13). Overall, these salmon averaged 60 cm FL and the distribution of lengths from length-frequency and scaled-aged fish was bridged by that of 2-year-old CWT females (Table 4). Lengths of 3-year-old female adults aged with the three methods differed significantly (ANOVA, F = 15.65, df = 1,329, p<0.0001), although, as with 3-year-old males, multiple-range testing indicated no significant difference in mean lengths of 3-year-old females aged from length frequencies and scales (Fisher's LSD procedure, p>0.05; Fig. 9). However, each of these groups differed significantly with the mean length of 3-year-old CWT females (Fisher's LSD, p<0.05). Overall, the mean length (72 cm FL) of 3-year-old CWT females was significantly less than that of length-frequency and scale-aged females (both 76 cm FL).

In summary, the above comparisons provided evidence that the use of carcass survey length-frequency distributions appears to be an appropriate method for determining the age structure of observed winter-run spawners, at the population level, in terms of grilse and adults. In addition, known-age salmon sizes may not be applicable to the in-river produced population.

Spawning Success

A total of 1,198 unmarked, female salmon was examined for egg retention; 1,190 (99.4%) had completely spawned, three (0.2%) had partially spawned, and five (0.4%) were unspawned. We also examined 65 marked, female salmon for egg retention. All of the marked females had completely spawned.

Temporal Distribution

Unmarked Salmon

Unmarked female carcasses were observed from survey period 1 (2–3 May) through survey period 39 (25–26 August) (Appendix Table 1, Table 11, Figs. 10a and 11a). The monthly distribution of unmarked females was 4.7% in May, 38.4% in June, 50.2% in July and 6.7% in August. Sixty-seven percent of the fresh carcasses were observed during periods 16 through 26 (16 June–18 July) with the maximum (9%) occurring during period 23 (8–9 July). Based upon findings on the lower American River (Snider and Vyverberg 1995), which indicate 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 mid June.

Marked Salmon

Marked female carcasses were first observed during period 3 (8–9 May) and last observed during period 37 (19–20 August) (Appendix Table 1, Table 11, Figs. 10b and 11b). The monthly distribution of marked females was 2% in May, 31% in June, 59% in July and 8% in August. Sixty-eight percent of marked, female carcasses were observed during periods 16 through 26 (16 June–18 July) with the maximum (11%) occurring during period 23 (8–9 July). As with the unmarked winter run, the peak of marked salmon spawning also likely occurred during the last week of June.

Table 11. Temporal and spatial distribution of marked and unmarked, fresh female carcasses observed during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

	Reach 1		Reach 2	
Month	Unmarked	Marked	Unmarked	Marked
May	37	0	19	1
June	288	12	173	8
July	480	26	124	12
August	66	3	15	2
Total	871	41	331	23

Spatial Distribution

Unmarked Salmon

The spatial distribution of fresh, unmarked female carcasses was 72% (*n* = 871) in Reach 1 and 28% (*n* = 331) in Reach 2 (Table 11, Fig. 12a). Distribution of decayed carcasses was 74% (*n* = 2,157 in Reach 1, and 26% (*n* = 753) in Reach 2. The ratios of fresh:decayed carcasses were 1:1.4 in Reach 1 and 1:1.1 in Reach 2.

Marked Salmon

The spatial distribution of fresh, marked female carcasses was comparable to that observed for unmarked females. The majority of marked salmon spawned in the upper reach: 64% in Reach 1 and 36% in Reach 2 (Table 11, Fig. 12). Although a substantially higher proportion of the marked fish, versus unmarked fish, spawned in the lower reach, the observed difference in carcass distribution did not vary significantly between unmarked and marked salmon ($\chi^2 = 1.73$, df = 1, p = 0.19).

Population Estimates

Tag recoveries during the 40 survey periods were sufficient to allow use of the Schaefer and Jolly-Seber models for only the second time since the winter-run tag-recovery surveys were initiated in 1996. We tagged 2,017 fresh adult carcasses (adipose-clipped and unmarked) and subsequently recovered 1,146 (57%), (Appendix Table 2 and Fig. 13). Additionally, a combined total of 4,019 fresh and decayed carcasses was tagged of which 2,136 (53%) were subsequently recovered (Appendix Table 3).[11]

The Petersen model and the season totals for fresh, adult carcasses were used to calculate a spawner population estimate of 10,386 adults (Appendix Table 2). The adult estimate was expanded to 11,502 spawners (including 1,116 grilse) (Table 12) based on the proportion of adults observed in the fresh carcass data (90.3%) determined from length-frequency age distribution as described earlier.

An estimate of 8,697 adult spawners was calculated using the Schaefer formula (Appendix Table 2, Table 12). Only fresh carcass data results were used to calculate this estimate (Appendix Table 2). As

11/ We also tagged 186 fresh grilse carcasses of which 44 (24%) were recovered (Appendix Table 3). Additionally, 345 fresh and decayed grilse were tagged of which 66 (19%) were recovered (Appendix Table 4). These data were not used to estimate grilse population.

described above, the adult estimate was divided by 90.3% to calculate a total escapement estimate of 9,631 winter-run spawners (including 934 grilse). An estimate of 6,489 adults[12] was calculated with the Jolly-Seber formula (Appendix Table 3) using fresh and decayed carcass data combined. The adult estimate was also divided by 90.3% for a total escapement estimate of 7,186 winter-run spawners (includes 697 grilse) (Table 12).

Estimated numbers of adult females, calculated as 64.8% of the total escapement estimate, were 7,453 (Petersen), 6,241 (Schaefer), and 4,657 (Jolly-Seber). Estimated numbers of female grilse (0.4% of the total population) were 46 (Petersen), 39 (Schaefer), and 29 (Jolly-Seber).

Unmarked Salmon

Of the 2,235 fresh carcasses examined, 2,119 (94.8%) were unmarked and 116 (5.2%) were marked. The estimated numbers of unmarked, in-river-produced winter run that spawned in the survey reach were calculated as 94.8% of the three escapement estimates. Based upon the results of the Petersen model, the in-river-produced component of the spawner population was 10,904 total spawners including 9,961 adult and 943 grilse spawners, 7,066 female adults and 44 female grilse. Based upon the Schaefer derived estimate, the in-river-produced spawner population was 9,130 total spawners, including 8,340 adults and 790 grilse spawners, 5,916 female adults and 37 female grilse. Based on the Jolly-Seber estimate, the in-river-produced spawner population comprised 6,812 total spawners, including 6,223 adult and 589 grilse spawners, 4,414 female adults and 27 female grilse

Marked Salmon

The estimated numbers of marked, hatchery-produced winter run that spawned in the survey reach were calculated as 5.2% of the three escapement estimates. An estimated 598 hatchery-produced winter run spawned within the reach based on the Petersen estimate, 501 based on the Schaefer estimate, and 374 based on the Jolly-Seber estimate. The estimated numbers of hatchery-produced, adult female spawners were 388, 325, and 242, respectively.

12/ Estimate calculated by Philip Law, Marine Region, California Department of Fish & Game.

Table 12. Summary of winter-run escapement estimates within the escapement survey reach, using the Petersen, Schaefer and Jolly-Seber tag-and-recapture models made during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May–August 2001.

Estimate	Petersen model	Schaefer model	Jolly-Seber model
Marked adults	425	357	266
Marked grilse	173	144	108
Marked total	598	501	374
Unmarked adults	9,961	8,340	6,223
Unmarked grilse	943	790	589
Unmarked total	10,904	9,130	6,812
Total adults	10,386	8,697	6,489
Total grilse	1,116	934	697
Total salmon	11,502	9,631	7,186

Expansion of carcass estimate to entire spawning reach

To obtain an escapement estimate for the entire, winter-run spawning reach, the number of spawners estimated in the survey reach was expanded to account for spawning that occurred downstream of the survey area. Since the 1997 survey, the assumption has been that the current survey area contains about 90% of the total spawner population, based upon the results of the 1996 survey (Snider et al. 1997). Results of the 2001 winter-run redd survey indicated that the carcass survey reach still supports the majority of spawning (88.5% in 2001). We applied the redd survey results to expand the carcass survey estimates to calculate the total winter-run spawner population for 2001 (e.g., Jolly-Seber estimate/0.885 or 1.13 x estimate). The sex and age composition of fish spawning downstream of the carcass survey area was assumed to be the same as that observed in the carcass survey area. The expansion was applied to the results of all three models (Table 13).

Table 13. Estimated winter-run spawner escapement for the entire spawning reach based upon expansion of estimated spawner population within the carcass survey reach using redd survey results indicating that 88.5% of spawning occurred within the carcass survey reach.

	Petersen	Schaefer model	Jolly-Seber model
Unmarked adults	11,256	9,425	7,032
Unmarked grilse	1,066	892	666
Unmarked total	12,321	10,317	7,698
Marked adults	481	403	300
Marked grilse	195	163	122
Marked total	676	566	422
Total adult estimate	11,736	9,828	7,333
Total grilse estimate	1,261	1,055	788
Total estimate	12,997	10,883	8,120

Effective Spawner Population

The effective spawner population is defined as the estimated number of females that successfully spawned, assuming there were enough males to service all the redds. Only adult females are used to calculate the effective spawner population since there is some question as to the contribution of female grilse to the spawning population. Adult, female winter run comprised 64.8% of the total spawner population. Spawning success was measured as 99.4%. The effective spawner population equals the proportion of adult, female spawners that successfully spawned, or 64.8% of the total spawner population times a 99.4% spawning success rate. As such, the effective spawner population estimates were 8,372 (Petersen), 7,010 (Schaefer) and 5,230 (Jolly-Seber)

DISCUSSION

Additional carcass surveys are planned to continue to address the issues of winter-run spawning habitat availability relative to flow and other physical habitat attributes. Overall, spawning habitat requirements will be evaluated by combining spawner population data with results of other studies including 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 population levels observed during the first five survey years may have been too low, relative to habitat availability, to adequately identify habitat needs by themselves, especially relative to the habitat conditions necessary to support the targeted, recovery population of at least 20,000 fish (NMFS 1997). However, if habitat has been limiting at these low populations, habitat requirements should be identifiable.

Population Estimates

Estimate precision and accuracy

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, survival (carry over of tagged carcasses from one survey period to the next), and tag recovery rates. He concluded that the Jolly-Seber model provided precise and accurate estimates for the various combinations of rate parameters studied, especially when catch and survival rates of tagged carcasses were high (Law 1994; P. Law, CDFG, pers. comm. with R. Titus, CDFG, 9 April 2002). Law's simulation analysis showed that the Jolly-Seber estimate was equal to 0.91 of the actual population when the catch rate was 40% (using fresh and decayed carcass recoveries) and the survival rates for consecutive survey periods were 80%, 40%, 20% and 0%. The tag-recovery rate (the term used in this report) includes both survival and catch rates (the terms used by Law). The tag-recovery rate calculated for the example used in Law's simulation analysis was 41% for fresh carcasses (see Table 4 in Law 1994). The tag-recovery rates during the 2001 winter-run survey (53% for all carcasses and 57% for fresh carcasses), were greater than the rate found in Law's analysis. The apparent high survival rate observed during the winter-run surveys may be due to the short duration (2 days), and thus high survival between surveys.

Recaptures during essentially all tagging episodes during 2001 allowed the Schaefer and Jolly-Seber models to be used to calculate population estimates for only the second time during the six survey years. These models are more accurate than estimates calculated with the Petersen model (Law 1994), however, the apparent influence of water clarity on the "recoverability" of tagged carcasses (as discussed below) makes use of these two models unpredictable. Data have been adequate during all survey years to enable calculation of an escapement estimate using the Petersen model. As a result, only the Petersen estimates allow interrogation of population trends over the period of record since the carcass surveys were begun. Even though the Petersen model tends to overestimate true population size in salmon carcass surveys, its precision has been high in doing so for adult winter run. The 80% confidence interval (CI) in 2001 was ± 413, or only 4.0% of the adult estimate based on fresh carcasses. The 80% CI during the six survey years has ranged from 4.0% to 36.6% of the adult Petersen estimate ($\bar{x}$ = 19.7%), and the standard error of the estimate has consistently been less than 25% (2.6–24.4%, $\bar{x}$ = 13.1%), thus meeting the criterion required for estimation of winter-run spawner populations that is identified in the draft winter-run recovery plan (NMFS 1997).

Continued evaluation of the various mark-and-recapture models may identify a relationship among their results that could enable improved accuracy of winter-run escapement estimation even when data are only adequate for use of the Petersen model. For example, although there have been only two instances allowing comparisons between the results of the Petersen and Jolly-Seber models, the observed relationships have been fairly close. The escapement estimate derived from the Petersen model was 60% greater than the Jolly-Seber model estimate in 2001 (present report) and 54% greater than the Jolly-Seber estimate in 2000 (Snider et al. 2001). We are also considering modifying application of the Petersen model to account for sampling with replacement. The present use of the Petersen model, as described earlier and by Boydstun (1994) does not account for sampling with replacement, although replacement does occur with our present mark-and-recapture method. Adjustment in the model are being developed and will likely be used in future surveys.

Influence of visibility on tag-recapture

Tag-recovery rate appears to be directly related to water transparency rather than flow conditions present during the survey. Tag-recovery rate in the winter-run carcass surveys has varied from 12% to 57% since 1996 while mean visibility, measured as Secchi depth, also varied from a low of 6 ft to a high of nearly 20 ft (Appendix Table 6). The tag-recovery rate of fresh carcasses during the 2001 survey was 57%, and mean visibility during all 2-day surveys averaged near 20 ft (range, 14–21 ft; Table 1), the highest levels measured to date (Appendix Table 6). In 2000, the recovery rate was 45% and water clarity averaged 13 ft (range: 9–21 ft); in 1999, the tag-recovery rate was 22% and water transparency averaged 9 ft (range: 6–11 ft); in 1998, the recovery rate was 15% and water clarity averaged 7 ft (range: 4–11 ft), and in 1997, tag-recovery rate was 12% (the lowest of all years) and water clarity averaged only 6 ft (range 3–10 ft). Analysis show tag-recovery rate to be strongly correlated to mean visibility during the survey period ($r = 0.98$, $p<0.005$; Figure 14). In contrast, we found that tag-recovery rate did not vary significantly as a function of mean river flow during the carcass survey period from 1997 to 2001 ($r = -0.3$, $p>0.64$). recovery rate was 15% and water clarity averaged 7 ft (range: 4–11 ft). The tag-recovery rate was 12% in 1997 (the lowest of all years) and water clarity averaged only 6 ft (range 3–10 ft).

Spatial distribution

About 69% of fresh, female salmon carcasses were observed in the upper 7-mile-long reach and 31% in the lower 7-mile-long reach of the survey area. This distribution provided an indication of the relative proportion of spawning occurring in the two study reaches. Chinook salmon spawning activity is typically much more concentrated in the upper sections of streams where upstream migration has been blocked by a dam. An estimated 4,656 females spawned in the 14-mile study section (3,213 in upper reach and 1,443 in the lower reach) based on the female population estimate derived from the Jolly-Seber model, which typically provides a conservative estimate. About 1,252 redds (818 or 65% in the upper reach, and 434 or 35% in the lower reach) were counted by DFG Northern California-North Coast Region (NCNCR) personnel (D. Killam, CDFG, pers. comm.). The redd survey results are comparable to the carcass survey results, indicating that more fish spawn in the uppermost reach. The carcass survey results indicated that a greater proportion of spawning occurred in the upper reach. The difference in frequencies between the two surveys were significant ($\chi^2 = 4.78$, df = 1, $p < 0.03$). The ratio of female spawners:redds was 3.9 in the upper reach and 3.3 in the lower reach, which may suggest that accuracy of redd counts decreases as the density of spawning (redds) increases. This observation is consistent with the results of redd surveys conducted on the lower American River where we observed a significant, negative relationship between the precision of aerial redd counts and spawning density (CDFG Stream Evaluation Program, unpubl. data).

The only carcass survey that was conducted on most of the potential winter-run spawning reach (1996) showed that about 90% of spawning occurred within the present, 14-mile-long survey area. Results of the 2001 redd survey showed that 88.5% of redds (spawning) occurred in the present study area. The likelihood that carcasses tend to drift out of the area where the fish spawned and that redd surveys may undercount the number of redds as redd density increases, suggest that the assumption underlying the shortening of the carcass survey reach beginning in 1997 (i.e., 90% of spawning occurs in the present study reach) may be conservative.

RECOMMENDATIONS

1. The mark and recapture carcass surveys should be continued to provide important information on the status and dynamics of the winter-run population and to allow continued evaluation of methods used to develop winter-run escapement estimates.

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

3. 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 and refine spawner escapement estimation methods to develop 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 spawner escapement.

4. 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 (0.5% of the population), the spawning success data collected during the carcass survey indicated that all of the female grilse checked for spawning success had completely spawned.

5. Develop, evaluate and apply, as appropriate, a modification to the current application of the Petersen model to account for sampling with replacement.

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APPENDIX

Appendix Table 1. Summary of data obtained on marked salmon carcasses collected during the 2001 upper Sacramento River winter-run Chinook salmon spawner escapement survey, May–August 2001.

Tag Number	Brood Year	Sample ID	Sample Date	Condition	Sample period	SEX	FL	River mile	Section
501020905	98	01-3506	05/08/2001	d	3	2	790	296	1
501020902	98	01-2520	05/11/2001	d	4	2	720	294	2
501020908	98	01-2521	05/11/2001	f	4	2	670	295	2
501020904	98	01-2530	05/14/2001	f	5	1	820	296	1
501021214	99	01-2560	05/24/2001	d	8	1	550	294	2
501021214	99	01-2604	05/30/2001	f	10	1	580	294	2
		01-2664	06/05/2001	f	12	2	790	288	2
501020906	98	01-3557	06/07/2001	f	13	2	730	296	1
501020911	98	01-2715	06/08/2001	f	13	2	780	293	2
501020913	98	01-3590	06/13/2001	f	15	2	780	299	1
501020913	98	01-2812	06/13/2001	f	15	2	680	296	1
501020814	98	01-2847	06/14/2001	f	15	2	710	289	2
501020905	98	01-2861	06/14/2001	f	15	1	800	294	2
501020811	98	01-2896	06/16/2001	f	16	1	920	296	1
501020901	98	01-2797	06/16/2001	f	16	2	770	296	1
501020908	98	01-2884	06/16/2001	f	16	1	780	296	1
501021213	99	01-2890	06/16/2001	f	16	1	480	298	1
501020905	98	01-2922	06/17/2001	f	16	1	830	294	2
501021306	99	01-2907	06/17/2001	f	16	1	520	289	2
501020815	98	01-2985	06/19/2001	f	17	2	720	299	1
501020909	98	01-2945	06/19/2001	f	17	2	760	296	1
501020911	98	01-2977	06/19/2001	f	17	1	910	296	1
501021210	99	01-2969	06/19/2001	f	17	1	550	296	1
		01-3676	06/19/2001	f	17	2	770	300	1
501021302	99	01-3022	06/20/2001	f	17	1	590	294	2
501020811	98	01-3053	06/22/2001	f	18	2	810	296	1
501020811	98	01-3048	06/22/2001	d	18	1	760	296	1
501020906	98	01-3034	06/22/2001	f	18	1	760	296	1
501021301	99	01-3051	06/22/2001	f	18	1	480	296	1
		01-3058	06/22/2001	f	18	2	670	296	1

Appendix Table 1 (cont.)

Tag Number	Brood Year	Sample ID	Sample Date	Condition	Sample period	SEX	FL	River mile	Section
501020811	98	01-3116	06/23/2001	f	18	2	660	294	2
501021302	99	01-3103	06/23/2001	f	18	1	650	289	2
501021306	99	01-3119	06/23/2001	f	18	1	590	294	2
		01-3093	06/23/2001	d	18	1	880	292	2
501020904	98	01-3136	06/25/2001	f	19	1	820	295	2
		01-3279	06/25/2001	f	19	2	710	300	1
501020814	98	01-3168	06/26/2001	d	19	2	720	291	2
501021212	99	01-3198	06/26/2001	f	19	1	620	290	2
501021302	99	01-3282	06/26/2001	f	19	1	600	292	2
		01-3283	06/26/2001	f	19	2	720	293	2
		01-3170	06/26/2001	d	19	2	630	291	2
		01-3313	06/26/2001	d	19	1	900	289	2
501020905	98	01-3405	06/28/2001	f	20	2	710	296	1
501020909	98	01-3429	06/28/2001	f	20	1	760	296	1
501020912	98	01-3420	06/28/2001	f	20	2	680	295	2
501021215	99	01-3433	06/28/2001	f	20	1	530	296	1
501021215	99	01-3431	06/28/2001	f	20	1	530	296	1
		01-3442	06/28/2001	f	20	2	760	297	1
		01-3444	06/28/2001	d	20	1	860	296	1
		01-3434	06/28/2001	f	20	1	870	296	1
		01-3417	06/28/2001	d	20	1	840	296	1
501020905	98	01-3944	06/29/2001	f	20	2	730	289	2
501021215	99	01-3955	06/29/2001	f	20	1	490	294	2
LOST HEAD		01-3728	06/29/2001	f	20	2	740	294	2
501020906	98	01-4003	07/01/2001	f	21	2	780	298	1
501020912	98	01-4004	07/01/2001	f	21	2	740	298	1
501021306	99	01-4002	07/01/2001	f	21	1	560	298	1
		01-4015	07/01/2001	f	21	2	720	301	1
501020813	98	01-4076	07/02/2001	f	21	2	740	292	2
501021304	99	01-4016	07/02/2001	d	21	1	480	288	2
501020811	98	01-4151	07/05/2001	f	22	1	830	296	1
501020815	98	01-4163	07/05/2001	f	22	2	770	296	1

Appendix Table 1 (cont.)

Tag Number	Brood Year	Sample ID	Sample Date	Condition	Sample period	SEX	FL	River mile	Section
501020904	98	01-4193	07/05/2001	d	22	2	610	298	1
501020906	98	01-4150	07/05/2001	f	22	1	840	296	1
501020908	98	01-4164	07/05/2001	d	22	2	620	296	1
501020914	98	01-4166	07/05/2001	d	22	1	690	296	1
501021210	99	01-4165	07/05/2001	d	22	2	540	296	1
501021302	99	01-4192	07/05/2001	f	22	2	730	298	1
501021305	99	01-4149	07/05/2001	f	22	1	510	296	1
		01-4167	07/05/2001	d	22	2	910	296	1
		01-4169	07/05/2001	d	22	2	550	296	1
		01-4168	07/05/2001	d	22	1	760	296	1
501020908	98	01-4347	07/06/2001	f	22	1	850	288	2
501021213	99	01-4317	07/06/2001	d	22	1	470	290	2
501021214	99	01-4314	07/06/2001	f	22	1	570	290	2
501020811	98	01-4930	07/08/2001	f	23	2	680	298	1
501020904	98	01-4945	07/08/2001	f	23	1	780	296	1
501020905	98	01-4902	07/08/2001	f	23	2	790	296	1
501020909	98	01-4937	07/08/2001	f	23	1	780	295	2
501020911	98	01-4988	07/08/2001	f	23	2	750		0
501020914	98	01-4987	07/08/2001	f	23	2	720	300	1
501021303	99	01-4952	07/08/2001	f	23	1	590	296	1
501021305	99	01-4951	07/08/2001	f	23	1	390	296	1
501021307	99	01-4936	07/08/2001	f	23	1	440	295	2
		01-4954	07/08/2001	f	23	1	590	297	1
		01-4918	07/08/2001	f	23	2	800	297	1
		01-4950	07/08/2001	f	23	2	680	296	1
501020814	98	01-4988	07/09/2001	d	23	1	810		0
501020908	98	01-4881	07/09/2001	d	23	1	870	289	2
501020913	98	01-4882	07/09/2001	f	23	2	700	289	2
501020913	98	01-4883	07/09/2001	f	23	2	720	294	2
		01-4880	07/09/2001	f	23	2	750	289	2
501020811	98	01-5006	07/11/2001	f	24	2	730	296	1
501020902	98	01-5016	07/11/2001	f	24	2	760	296	1

Appendix Table 1 (cont.)

Tag Number	Brood Year	Sample ID	Sample Date	Condition	Sample period	SEX	FL	River mile	Section
501021215	99	01-5015	07/11/2001	f	24	1	560	296	1
501020812	98	01-5046	07/12/2001	f	24	2	690	294	2
501020814	98	01-5143	07/12/2001	f	24	1	780	294	2
501020908	98	01-5032	07/12/2001	f	24	2	730	291	2
501021213	99	01-5038	07/12/2001	f	24	1	530	293	2
		01-5043	07/12/2001	f	24	1	620	296	1
		01-5045	07/12/2001	f	24	2	680	294	2
501020811	98	01-5333	07/14/2001	f	25	2	770	298	1
501020815	98	01-5309	07/14/2001	f	25	2	630	297	1
501020914	98	01-5344	07/14/2001	d	25	2	720	301	1
501021305	99	01-5342	07/14/2001	f	25	1	490	301	1
		01-5343	07/14/2001	f	25	1	780	301	1
501020812	98	01-5369	07/15/2001	f	25	1	840	294	2
501020912	98	01-5358	07/15/2001	f	25	2	760	289	2
501020814	98	01-5065	07/17/2001	f	26	2	720	296	1
501020815	98	01-5087	07/17/2001	f	26	2	710	299	1
501020903	98	01-5089	07/17/2001	d	26	1	770	299	1
501021301	99	01-5086	07/17/2001	f	26	2	710	299	1
		01-5088	07/17/2001	f	26	1	490	299	1
		01-5075	07/17/2001	f	26	2	660	298	1
		01-5073	07/17/2001	f	26	2	750	297	1
		01-5071	07/17/2001	f	26	2	730	297	1
		01-5096	07/18/2001	f	26	1	760	288	2
501020811	98	01-5378	07/20/2001	f	27	2	740	299	1
501020813	98	01-5178	07/20/2001	d	27	2	590	296	1
501020911	98	01-5192	07/20/2001	f	27	2	720	297	1
501021208	98	01-5196	07/20/2001	d	27	2	730	296	1
501020910	98	01-3474	07/23/2001	d	28	2	720	296	1
501020911	98	01-3463	07/23/2001	f	28	2	640	296	1
501021213	99	01-3462	07/23/2001	f	28	1	600	296	1
		01-3460	07/23/2001	f	28	2	810	296	1
		01-3473	07/23/2001	f	28	1	830	298	1

Appendix Table 1 (cont.)

Tag Number	Brood Year	Sample ID	Sample Date	Condition	Sample period	SEX	FL	River mile	Section
501020815	98	01-3499	07/24/2001	f	28	1	800	295	2
501020901	98	01-3489	07/24/2001	f	28	2	690	291	2
501021215	99	01-3500	07/24/2001	d	28	1	550	295	2
501020907	98	01-5387	07/26/2001	f	29	2	740	297	1
501021307	99	01-5398	07/26/2001	f	29	1	480	297	1
501020812	98	01-5614	07/27/2001	f	29	2	680	292	2
501020903	98	01-5645	07/29/2001	d	30	2	690	298	1
501020905	98	01-5634	07/29/2001	d	30	2	720	296	1
501020909	98	01-5635	07/29/2001	d	30	2	670	296	1
501020911	98	01-5647	07/29/2001	f	30	2	690	299	1
		01-5627	07/29/2001	d	30	2	690	296	1
501020812	98	01-5650	07/30/2001	f	30	2	760	289	2
501020907	98	01-5650	07/30/2001	f	30	2	690	289	2
			07/30/2001	X	30				0
501020905	98	01-5675	08/01/2001	f	31	2	710	296	1
		01-5679	08/01/2001	d	31	2	770	297	1
501020905	98	01-5688	08/02/2001	f	31	1	830	294	2
501020911	98	01-5708	08/04/2001	f	32	1	830	296	1
		01-5720	08/05/2001	d	32	2	760	289	2
501020812	98	01-5749	08/07/2001	f	33	2	710	299	1
501020901	98	01-5733	08/07/2001	d	33	2	720	296	1
		01-5741	08/07/2001	f	33	2	740	295	2
		01-5736	08/07/2001	d	33	2	610	297	1
501020905	98	01-5762	08/08/2001	f	33	2	730	289	2
501020813	98	01-5819	08/13/2001	f	35	1	780	296	1
		01-5846	08/16/2001	f	35	2	720	301	1
501020907	98	01-5850	08/19/2001	d	37	2	670	299	1
501020905	98	(01-5462)	NA	x		NA			0
501020905	98	(01-5657)	NA	x		NA			0

Appendix Table 2. Summary of winter-run chinook salmon tag-recapture results for fresh adult carcasses used for Schaefer and Petersen population estimates

Week of Recovery	Week of Tagging 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Total Tag Rec	Total Carc
1																																						0	12
2																																						0	12
3		3																																				3	12
4		1	3																																			4	11
5			1	3																																		4	18
6				2	5																																	7	15
7						1																																1	18
8					1	2	6																															9	32
9								8																														8	26
10								2	5																													7	40
11									1	11																												12	47
12										1	6																											7	69
13											5	8																										13	71
14							1		1	1	2	7	7																									19	96
15										1			2	19																								22	114
16												1	3	4	19																							27	149
17											1			3	4	39																						47	193
18											1				2	8	40																					51	220
19																2	10	44																				56	226
20													1	1	3	1	2	9	45																			62	274
21																		5	11	52																		58	295
22																		4	3	14	44																	65	418
23																	1		1	4	13	69																88	431
24																	1	3	1	4	12	12	48															81	411
25																			2	3	2	6	15	47														75	333
26																					1	1	4	15	34													55	340
27																					2	4	4	7	11	46												74	339
28																					1	4			14	10	39											69	327
29																						1			2	2	2	34										41	243
30																									2	4	2	10	19									37	219
31																									4	5		4	7	20								40	212
32																													3	2	15							20	142
33																								1		1			1	2	6	14						25	164
34																									1					1	1	1	4					8	69
35																														1	1	5	7	5				19	117
36																															3	1	3	2	2			11	96
37																																	1		1	1		3	21
38																															1	1	1			2		5	43
39																																1						1	13
40																																				2		2	14
Tag Recover'd	0	4	4	5	6	3	7	10	7	14	15	16	13	27	28	50	54	65	63	77	75	97	71	71	68	68	43	48	30	26	27	23	16	7	3	5	0	1136	5902
No. tagged	3	6	4	6	9	6	10	17	13	21	23	43	37	49	63	80	99	100	101	134	122	152	142	141	124	123	88	83	60	49	35	25	19	8	8	11	3		

Appendix Table 3. Summary of winter-run chinook salmon tag-recapture results for fresh and decayed adult carcasses used with Jolly-Seber model.

Week of	Week of Tagging																																					Total	Total
Recovery	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	tag rec	carc
1																																						0	12
2	3																																					3	15
3	2	4																																				6	15
4		3	3																																			6	13
5	1		1	3																																		5	19
6	1		1	2	5																																	9	17
7						1																																1	19
8					1	2	9																															12	35
9								8																														8	26
10								3	6																													9	42
11									1	13																												14	49
12										2	11																											13	75
13								1			5	16																										22	80
14							1		2	1	3	9	13																									29	106
15										1		1	4	27																								33	125
16												1	4	5	28																							38	160
17									1		2		1	3	10	55																						72	218
18											1			2	2	10	54																					69	238
19													1			3	15	65																				84	254
20													1	2	3	2	4	16	64																			92	304
21																		5	19	74																		98	325
22																1		6	3	21	76																	107	460
23																	2	2	2	8	22	147																183	526
24																	2	4	1	4	15	25	95															146	476
25																		1	2	3	2	13	28	94														143	401
26																		1		1	1	5	10	29	63													110	395
27																				1	2	6	10	19	31	72												141	406
28																					1	6	2	9	26	20	86											150	408
29																						1	3	2	6	5	12	65										94	296
30																								2	4	7	9	27	40									89	271
31																									6	6	5	10	14	43								84	256
32																							1		1	1			6	5	32							46	168
33																								1		3			2	8	23	35						72	211
34																									1					3	2	4	21					31	92
35																														3	3	10	15	12				43	141
36																															6	3	14	5	9			37	122
37																																1	3		1	6		11	29
38																															1	1	2		1	4		9	47
39																															1		1	1	4	3		10	22
40																																2		1		3		6	18
Tag Recove'd	7	7	5	5	6	3	10	12	10	17	22	27	24	39	43	71	77	100	91	112	119	203	149	156	138	114	112	102	62	62	68	56	56	19	15	16		2135	6892
No. tagged	10	8	6	7	11	7	14	21	18	31	35	59	58	72	87	121	140	157	160	208	209	332	301	313	240	236	229	231	150	147	107	93	90	25	34	45			

Appendix Table 4. Summary of upper Sacramento River winter-run chinook salmon tag-recapture results for fresh grilse carcasses.

Week of Recovery	Week of Tagging 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Total Tag Rec	Total Carc
1																																						0	0
2																																						0	0
3																																						0	0
4																																						0	0
5																																						0	0
6																																						0	0
7																																						0	0
8																																						0	2
9																																						0	0
10																																						0	2
11																																						0	0
12																																						0	1
13																																						0	0
14																																						0	10
15																																						0	3
16																																						0	4
17																2																						2	15
18																	2																					2	31
19																	1	2																				3	21
20																			1																			1	28
21																				2																		2	22
22																				1	2																	3	41
23																					1	5																6	50
24																			1		1	1	3															6	38
25																				1																		1	28
26																								1	2													3	30
27																									1	3												4	26
28																							1		1		2											4	30
29																											1	3										4	11
30																													1									1	10
31																														1								1	13
32																																						0	6
33																																						0	4
34																																						0	1
35																																						0	2
36																																						0	3
37																																						0	0
38																																						0	0
39																																						0	0
40																												1										1	1
Tag Recover'd	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3	2	2	4	4	6	4	1	4	3	3	4	1	1	0	0	0	0	0	0	0	44	433
No. tagged0	0	0	0	0	0	0	0	2	0	2	0	0	0	5	1	3	7	22	12	19	15	17	22	17	13	12	5	8	3	1	0	0	0	0	0	0	0		

Appendix Table 5. Summary of upper Sacramento River winter-run chinook salmon tag-recapture results for fresh and decayed grilse carcasses.

Week of	Week of Tagging																																				Total	
Recovery	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	Tag Rec	Total Carc
1																																						0	0
2																																						0	0
3																																						0	0
4																																						0	0
5																																						0	0
6																																						0	0
7																																						0	0
8																																						0	2
9																																						0	0
10																																						0	2
11																																						0	0
12																																						0	1
13																																						0	0
14																																						0	10
15														1																								1	4
16															1																							1	5
17																2																						2	15
18														1			3																					4	33
19																	1	3																				4	22
20																			2																			2	29
21																	1			3																		4	24
22																				1	2																	3	41
23																					1	7																8	52
24																	1		1		1	1	3															7	39
25																				1			1	1														3	30
26																								1	2													3	30
27																									1	3												4	26
28																							2		1		4											7	33
29																											1	3										4	11
30																												1	1									2	11
31																													1	1								2	14
32																																						0	6
33																																1						1	5
34																																						0	1
35																																						0	2
36																																						0	3
37																																						0	0
38																																						0	0
39																																		1				1	1
40																																1						1	1
Tag Recover'd	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	6	3	3	5	4	8	6	2	4	3	5	4	2	1	0	2	0	1	0	0	0	64	453
No. tagged0	0	0	0	0	0	0	0	2	0	2	0	1	0	5	3	4	13	26	17	27	20	36	44	31	24	21	16	24	7	7	4	5	1	1	1	3	0		

Appendix Table 6. Summary of results from the 1996 through 2001 upper Sacramento River winter-run spawner surveys.

Parameter	1996	1997	1998	1999	2000	2001
Survey dates	29 April– 5 September	30 April– 29 August	5 May– 28 August	5 May– 27 August	3 May- 29 August	2 May- 29 August
No. of total carcasses	118	239	785	475	2,482	5,145
No. of fresh carcasses	52	105	382	212	1,091	2,235
No. of decayed carcasses	66	134	403	263	1,391	2,910
Tag recovery rate	15%	12%	15%	22%	45%	57%
Estimated population (Petersen)	820	2,053	5,501	2,262	6,647	11,502
Adult estimate	664	1,888	5,391	1,821	6,469	10,386
Grilse estimate	156	165	110	441	178	1,116
Adult female estimate	571	1,437	4,847	1,626	5,397	7,453
Adult male estimate	93	451	544	194	1,072	3,060
Grilse female estimate	10	92	0	65	38	46
Grilse male estimate	146	73	110	377	140	943
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	5.0:1/4.5:1	2.4:1/1.9:1
Size criterion (male)	Adult>65 cm	Adult>63 cm	Adult>60 cm	Adult>63 cm	Adult>60 cm	Adult>66 cm
Size criterion (female)	Adult>64 cm	Adult>63 cm	Adult>54 cm	Adult>59 cm	Adult>57 cm	Adult>60 cm
Spawning success (%)	94%	96%	95%	97%	100%	99%

Appendix Table 6 (cont.).

Parameter	1996	1997	1998	1999	2000	2001
Spatial distribution (Reach 1,2, 3, and 4)	50%, 39%, 9%, 2%	48%, 52%	58%, 42%	73% 27%	80%, 20%	72%,28%
Peak spawning period	Early - mid July	Late June - early July	Early July	Early -mid June	Early - mid June	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	8,500-15,200
Temperature range	52–59^{0}F	49–52^{0}F	50–54^{0}F	50–54^{0}F	51–54^{0}F	50–55^{0}F
Transparency (Secchi depth)	na	3–10 ft	4.5–11 ft	6–11 ft	9–20 ft	14-20 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.

FIGURES

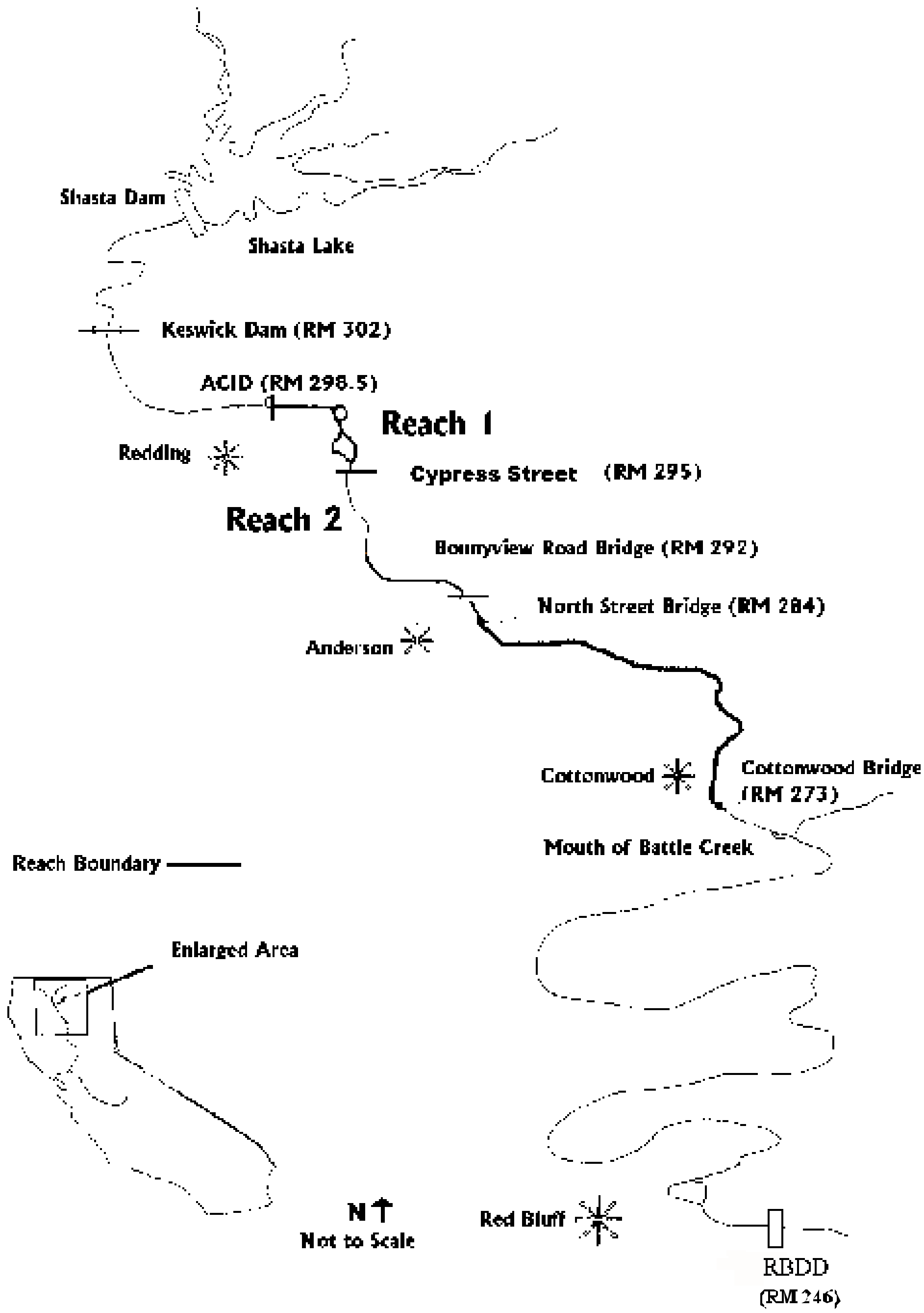

Figure 1. Location of reaches surveyed during the 2001 winter-run chinook salmon escapement survey, May–August 2001.

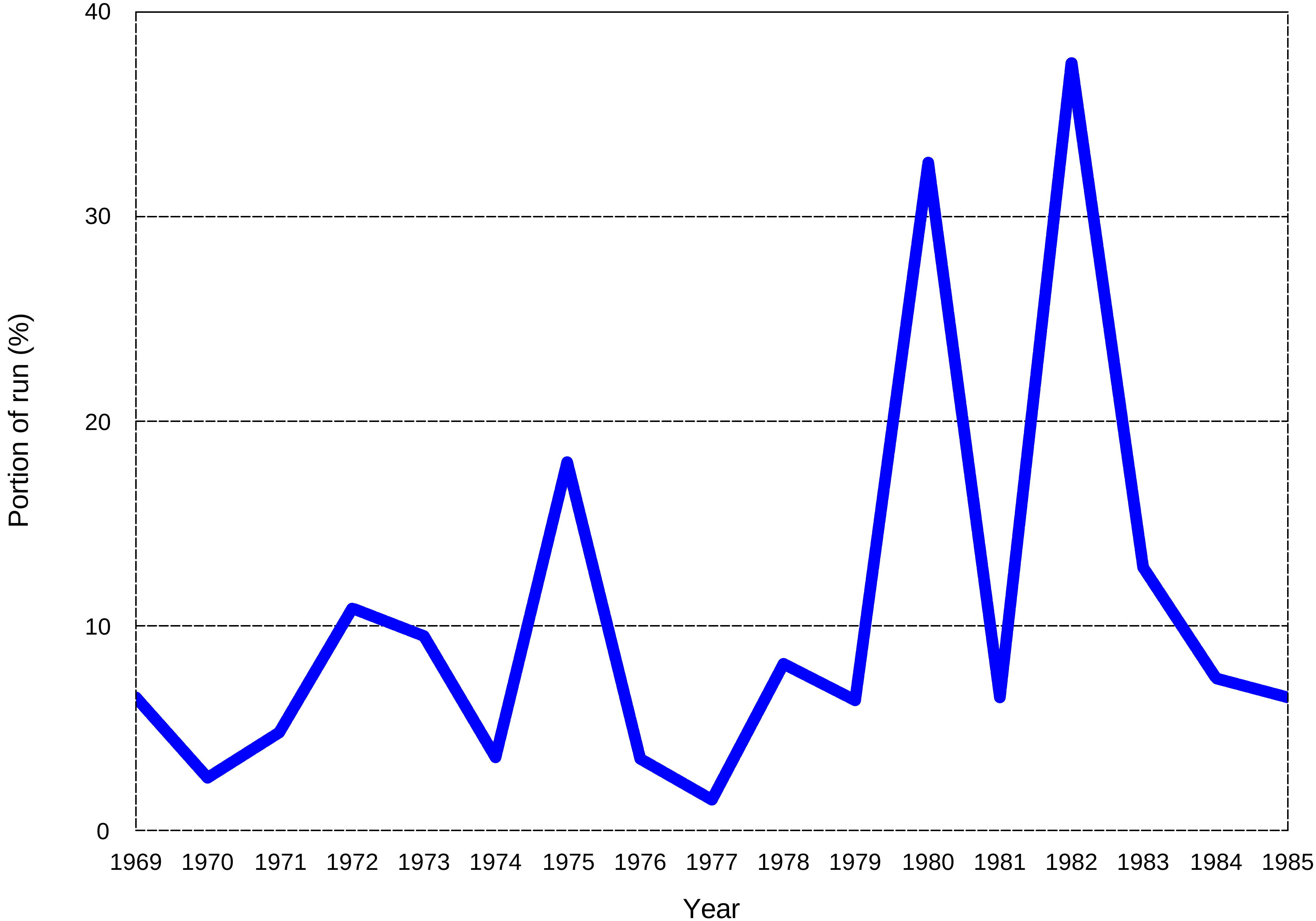

Figure 2. Percentage of the total migration of winter-run Chinook salmon passing Red Bluff Diversion Dam after mid May (Week 20) from1969 through 1985.

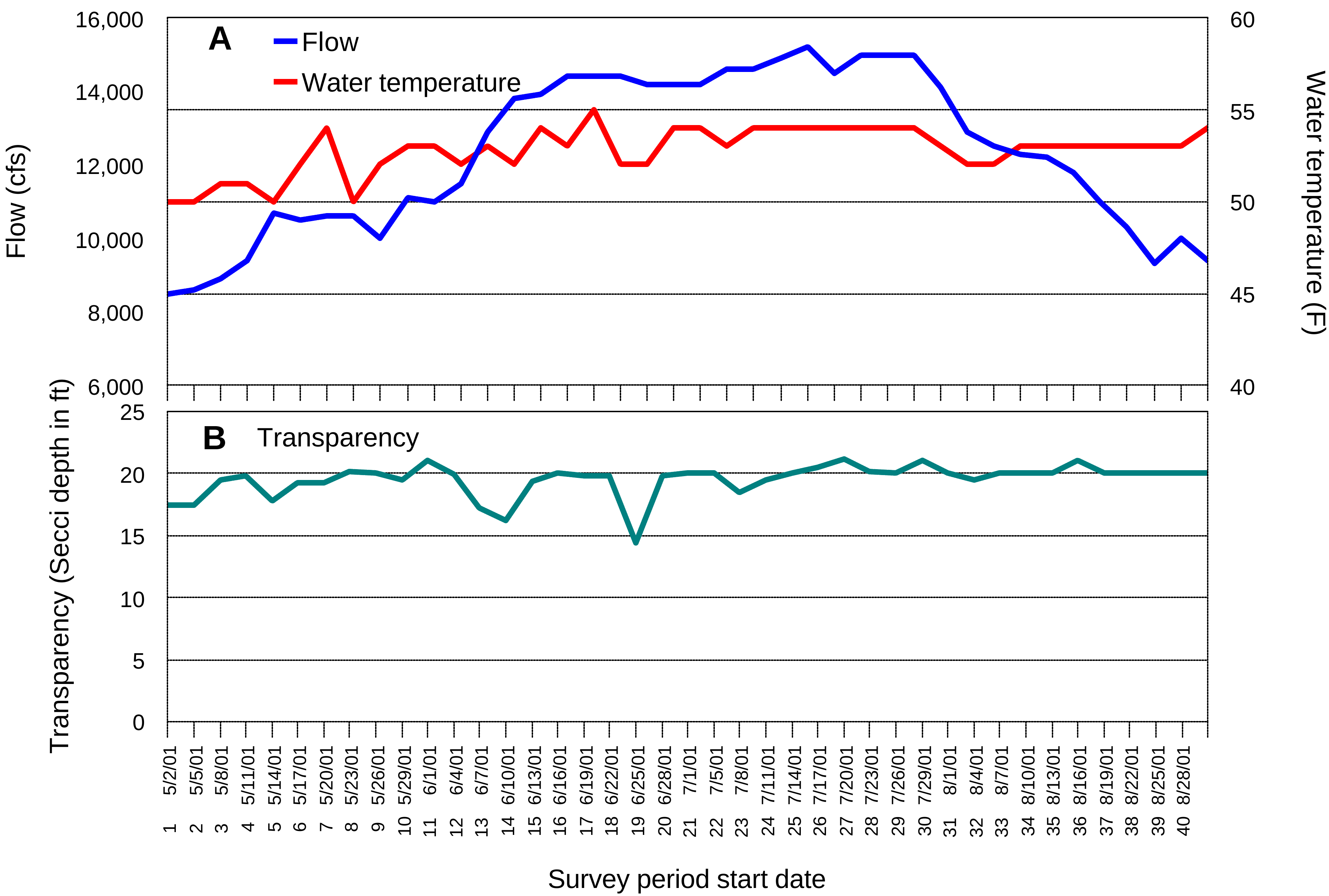

Figure 3. Mean (A) flow and water temperature and (B) water transparency (Secchi disk depth) measured for each survey period during the 2001 upper Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

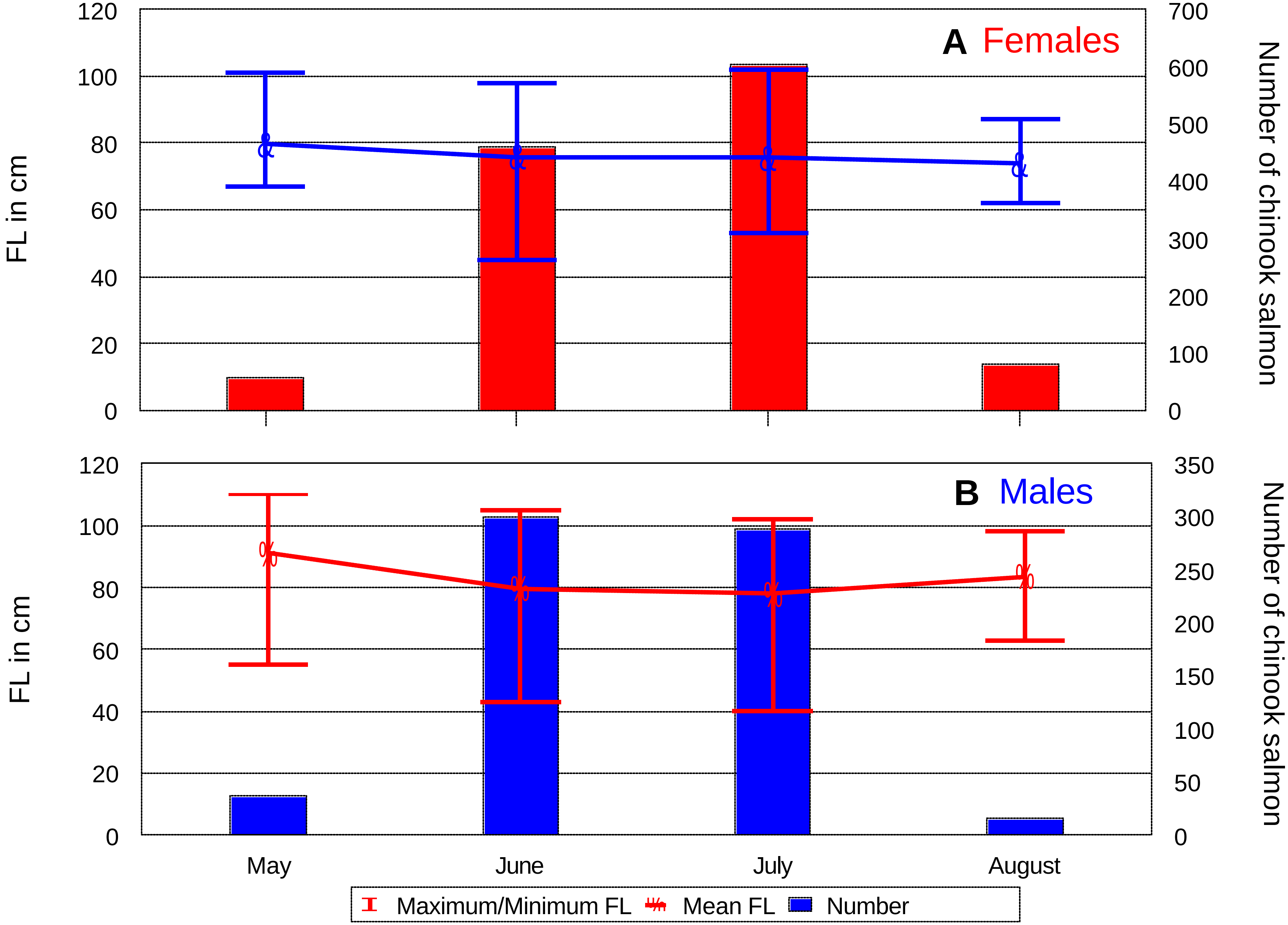

Figure 4. Catch and size distribution of fresh, unmarked (A) female and (B) male Chinook salmon carcasses measured during the 2001 upper Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

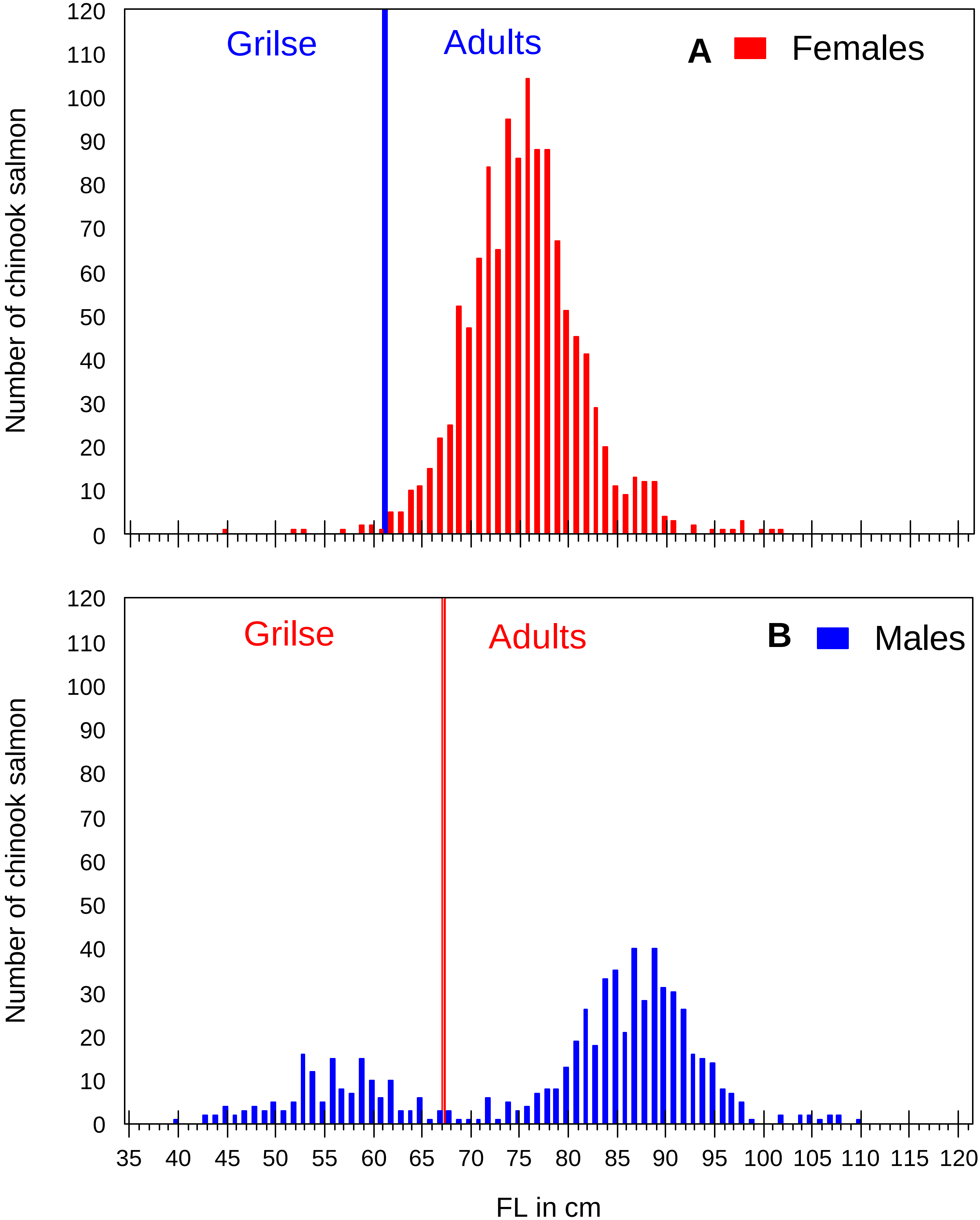

Figure 5. Length-frequency distributions for fresh, unmarked (A) female and (B) male salmon carcasses measured during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

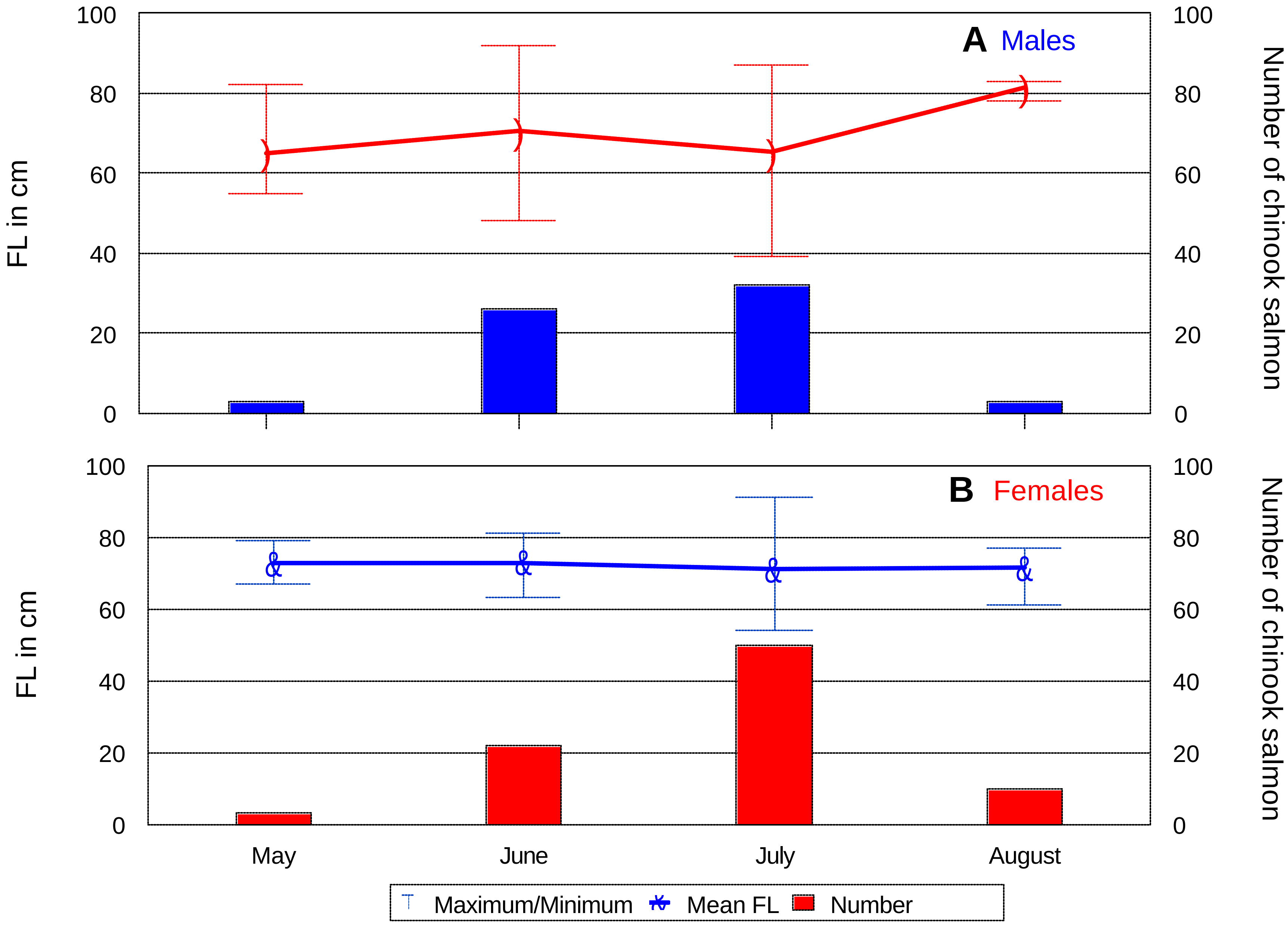

Figure 6. Catch and size distribution of marked (A) male and (B) female Chinook salmon carcasses collected during the 2001 upper Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

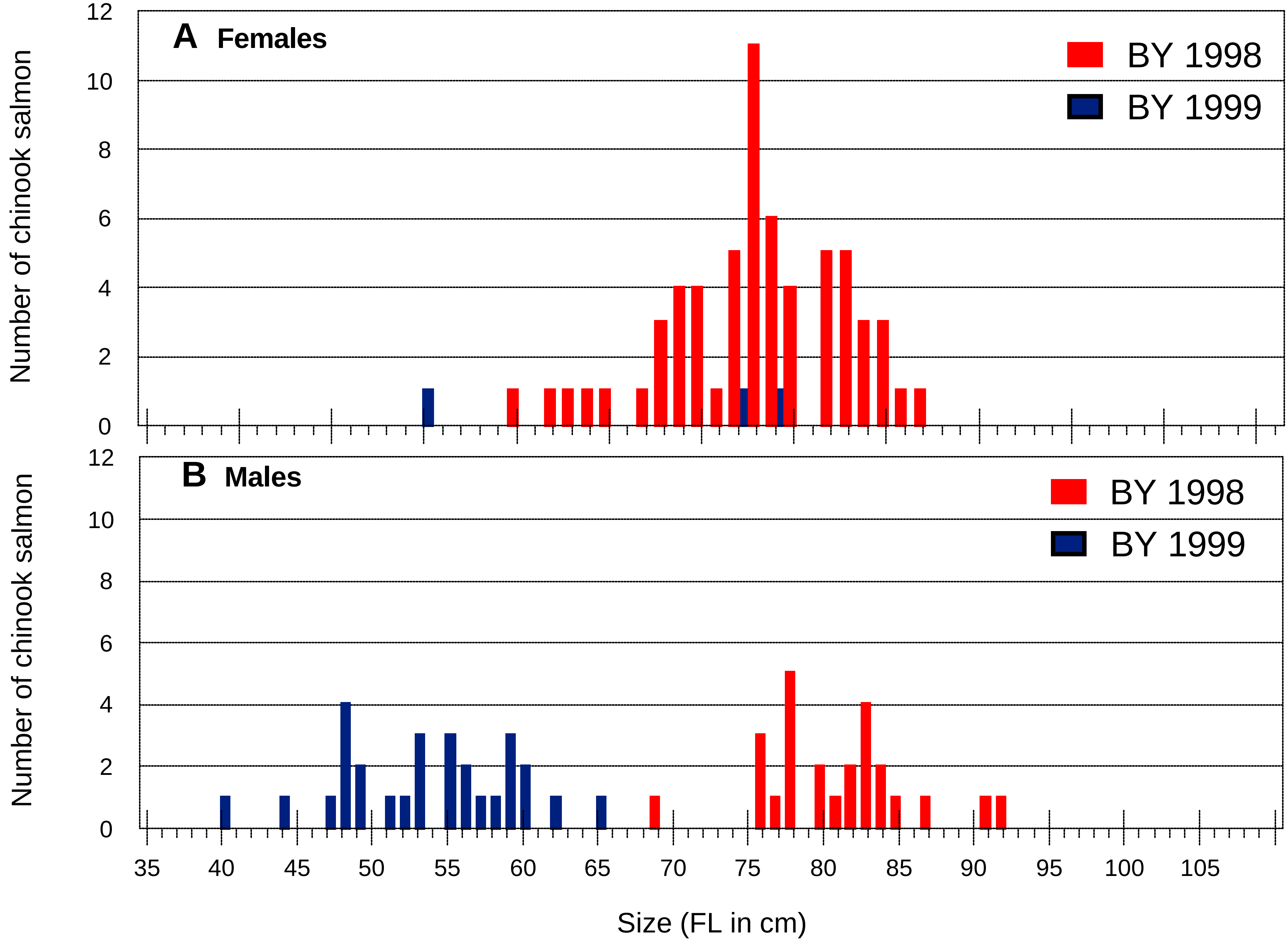

Figure 7. Length-frequency distributions for marked brood year 1998 and 1999 (A) female and (B) male Chinook salmon carcasses aged using coded-wire-tag information collected during the 2001 Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

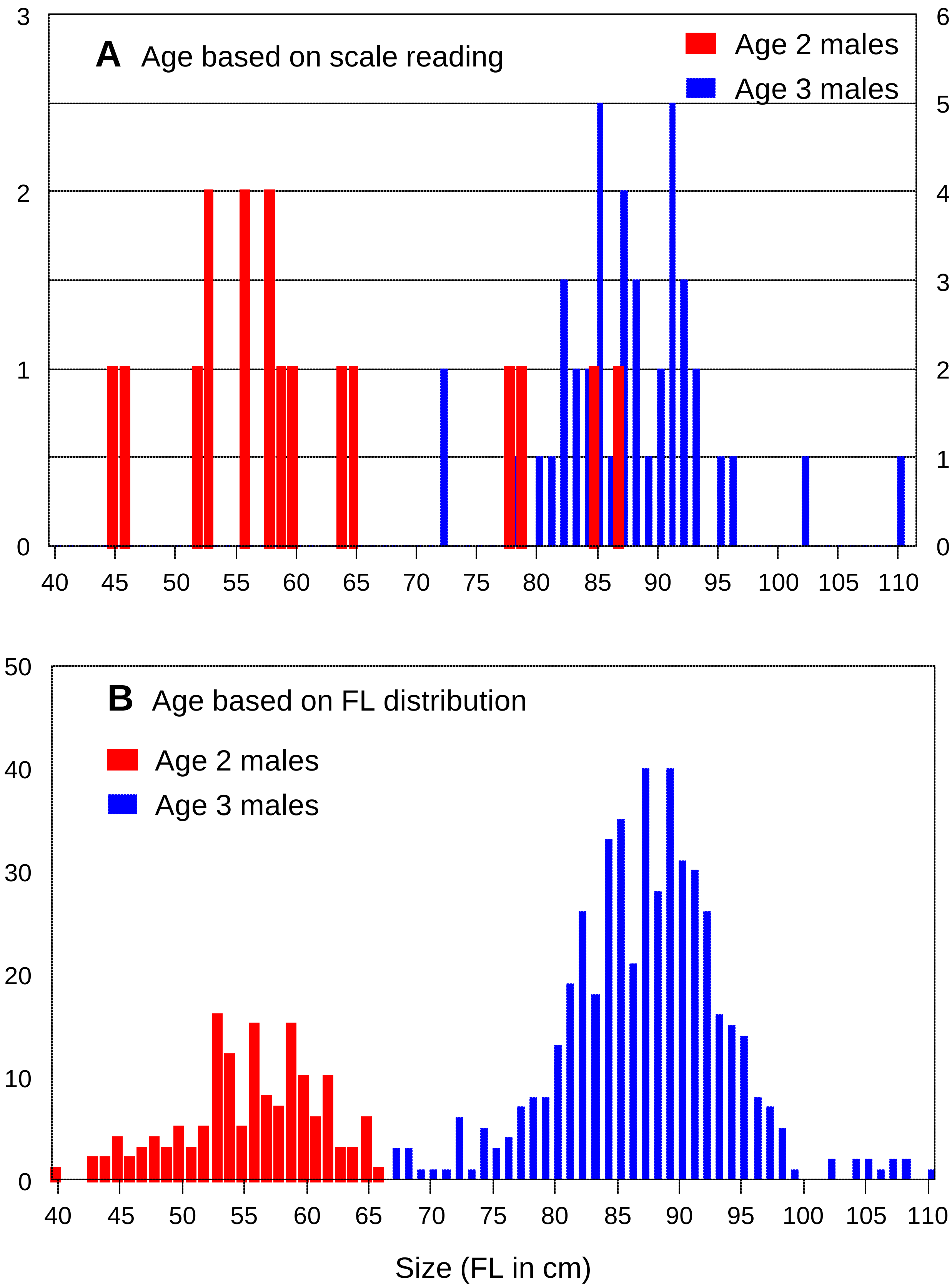

Figure 8. Length-frequency distribution for male winter run aged using (A) scale readings versus (B) carcass length-frequency distribution during the 2001 winter-run Chinook salmon spawner escapement survey, May - August 2001.

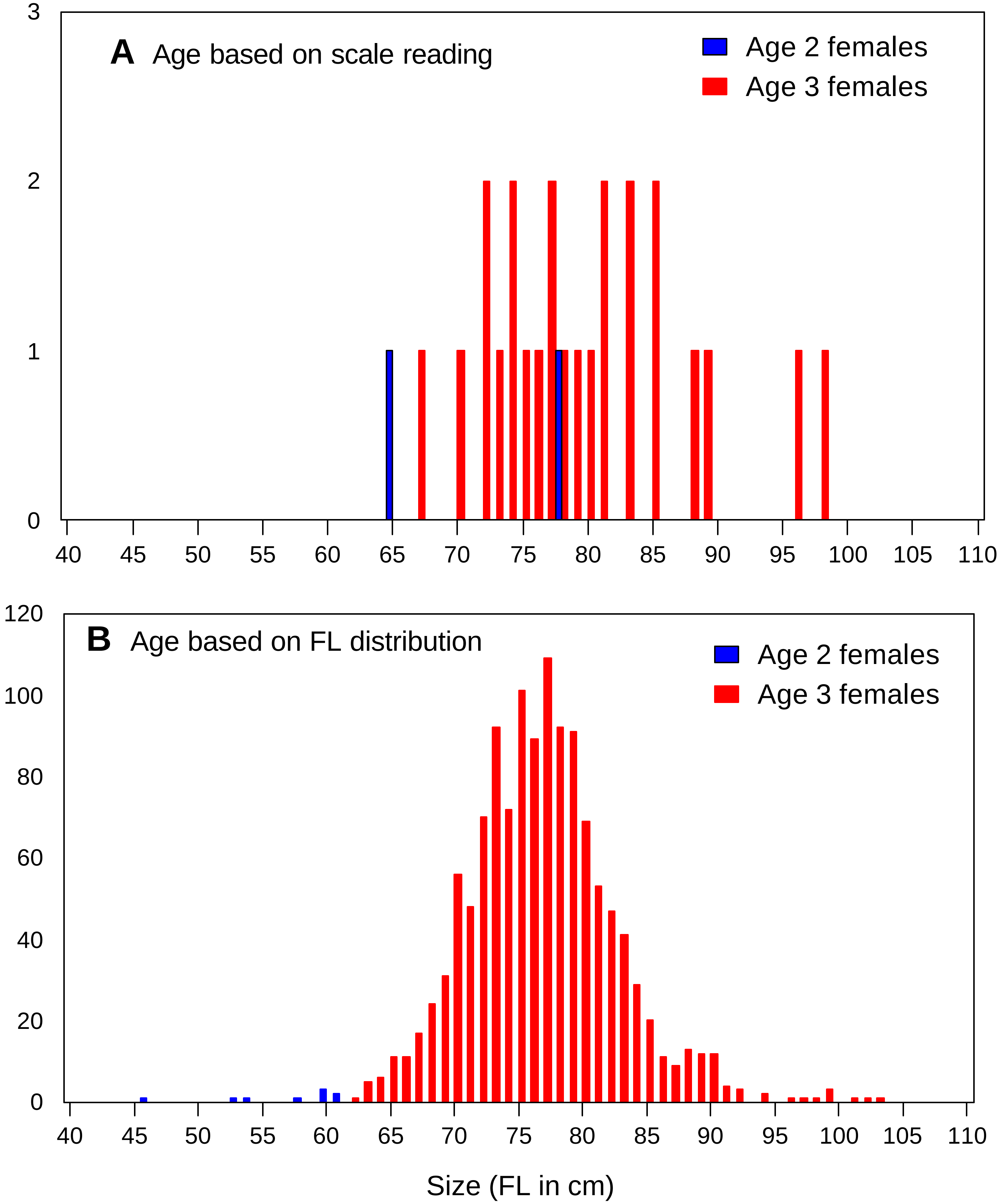

Figure 9. Length-frequency distributions for female winter run aged using (A) scale readings versus (B) carcass length-frequency distribution during the 2001 winter-run Chinook salmon spawner escapement survey, May - August 2001.

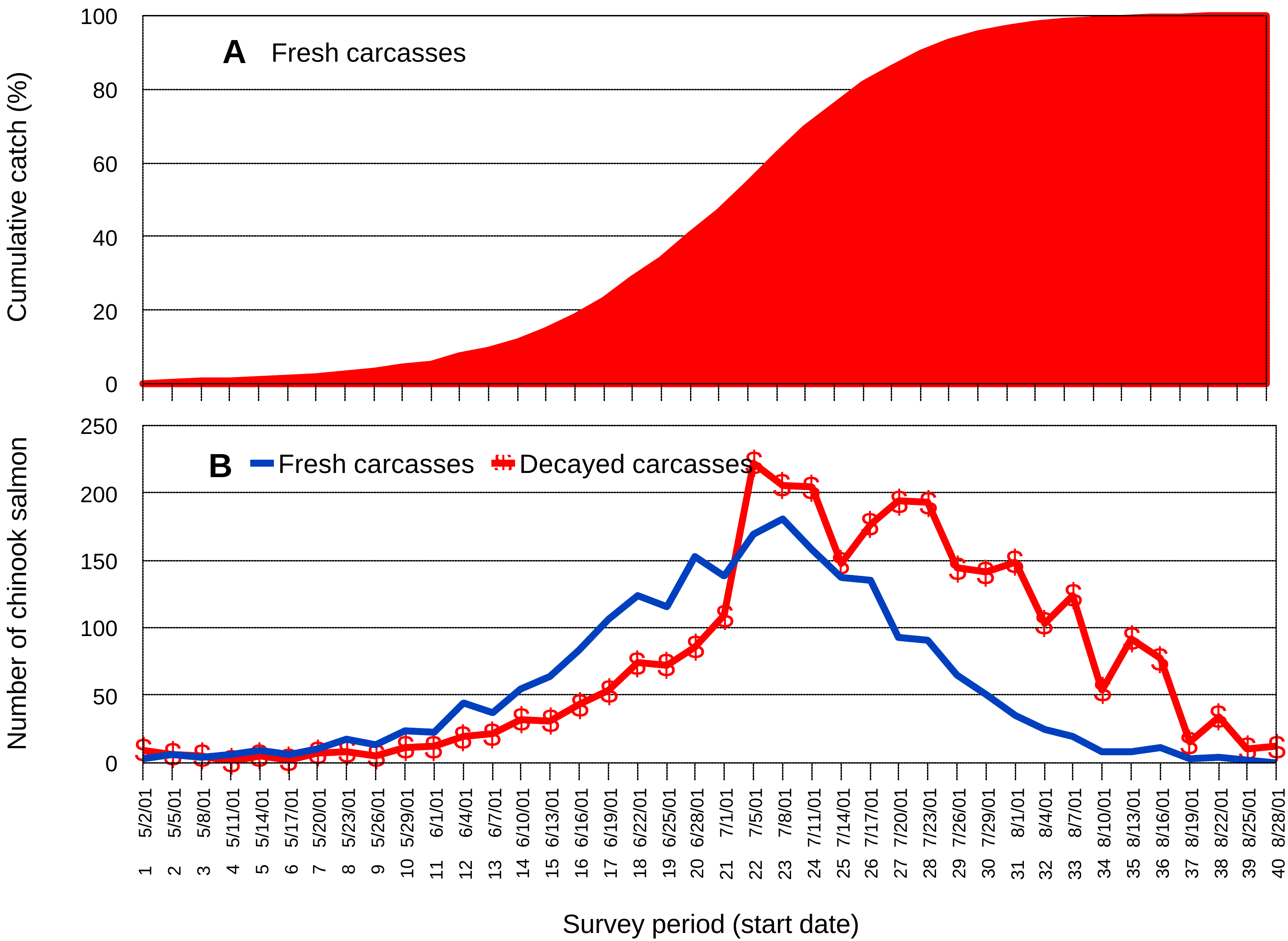

Figure 10. Cumulative catch of (A) fresh carcasses, and (B) catch distribution of fresh and decayed carcasses by survey period during the upper Sacramento River winter-run Chinook salmon escapement survey, May-August 2001.

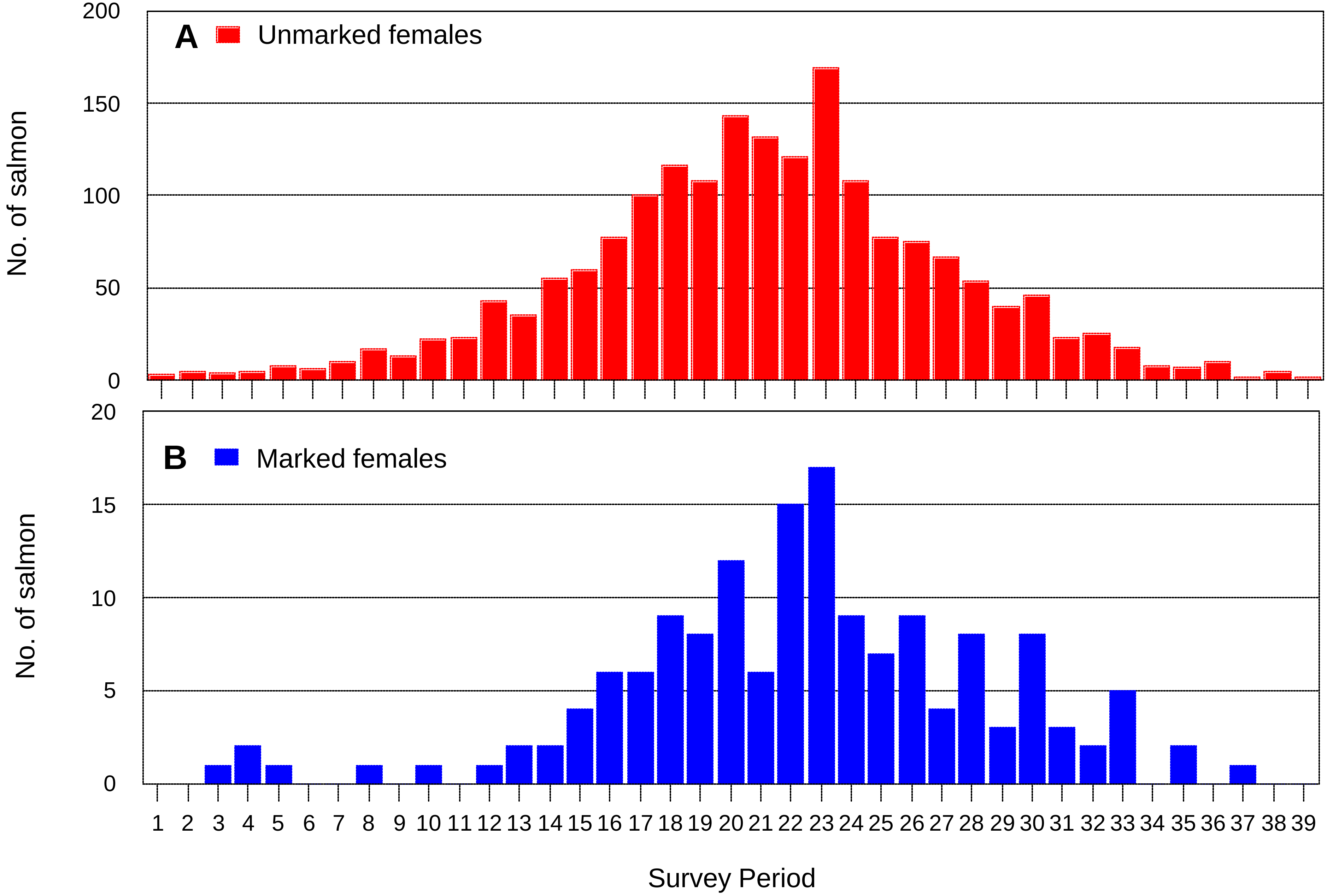

Figure 11. Temporal distribution of (A) marked and (B) unmarked female salmon carcasses observed during the 2001 Sacramento River winter-run Chinook salmon survey, May - August 2001.

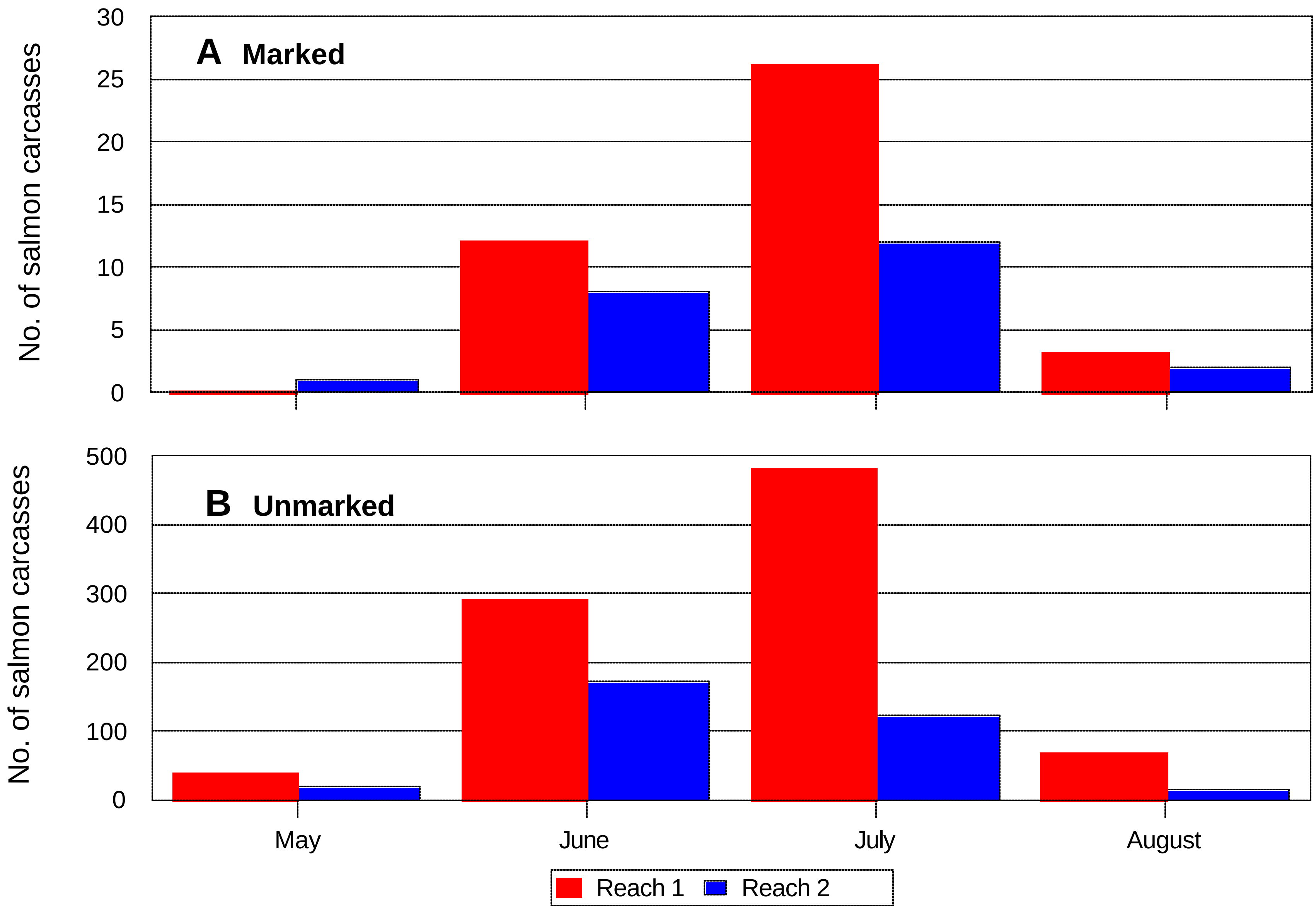

Figure 12. Spatial distribution of both (A) marked and (B) unmarked salmon carcasses observed during the 2001 upper Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

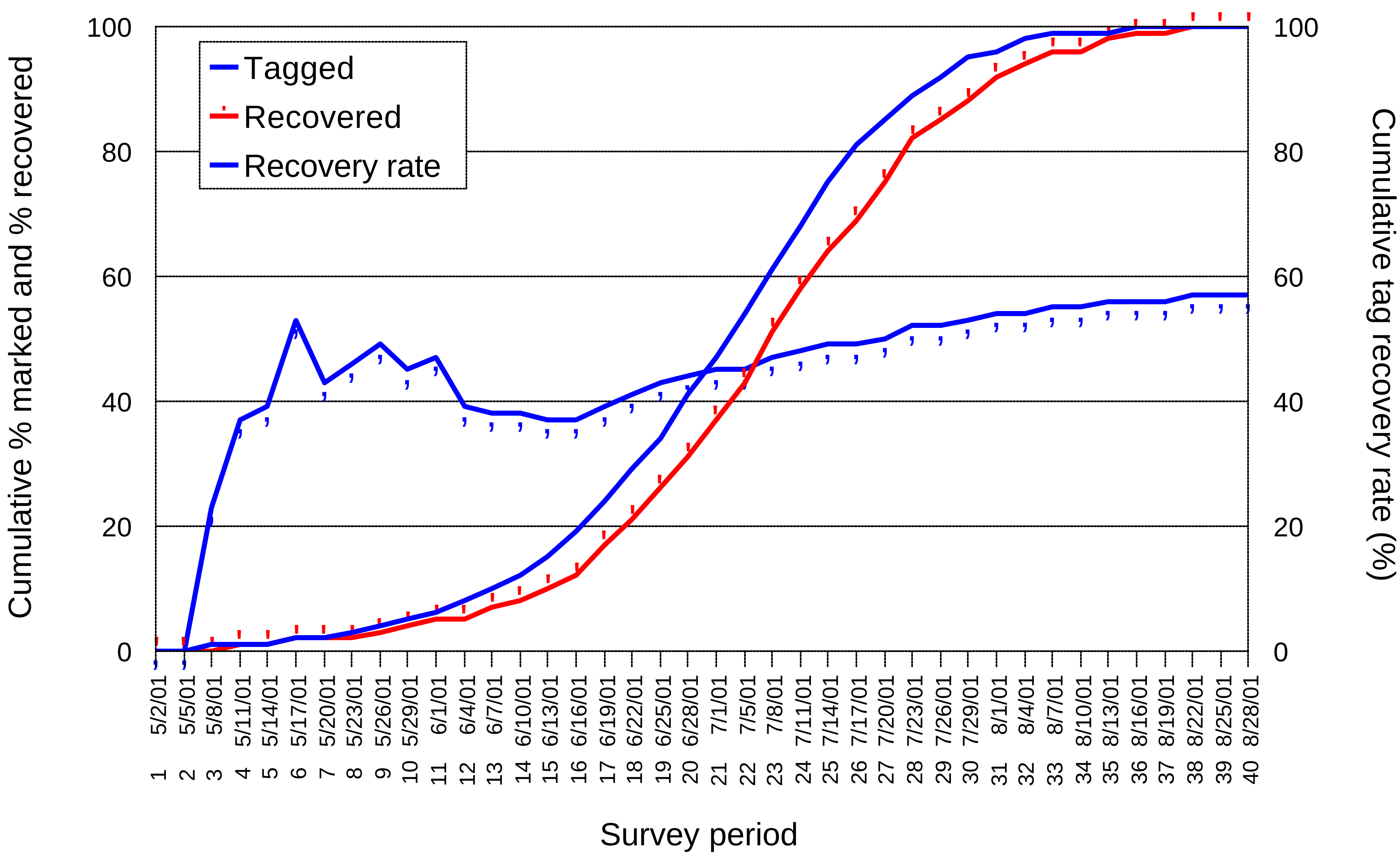

Figure 13. Comparison of temporal distribution of tagging versus recovering of tagged fresh carcasses and tag recovery rate (n tagged/n recovered) during the 2001 upper Sacramento River winter-run Chinook salmon escapement survey, May - August 2001.

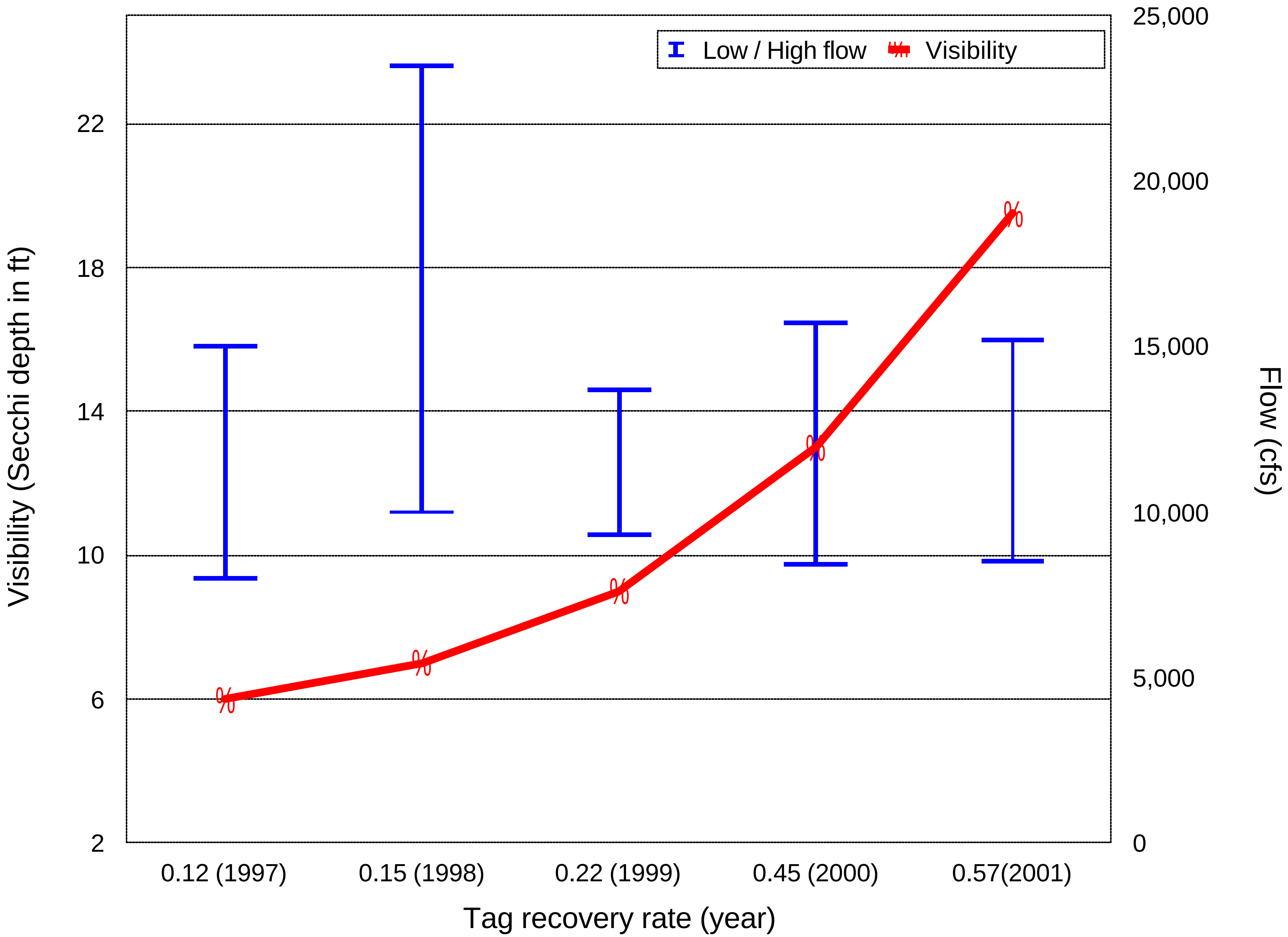

Figure 14. Comparison of carcass recovery rate relative to flow and water transparency during upper Sacramento River winter-run Chinook salmon escapement surveys conducted from1996 through 2001.