State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

# Sacramento River
# Winter-Run Chinook Salmon Carcass Survey
# Summary Report for years 1996-2006

by
Douglas Killam
Northern California-North Coast Region
Sacramento River Salmon and Steelhead Assessment Project

SRSSAP Technical Report No. 06-4
2006

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*Cover Photo by author*

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1/ This report summarizes results of a multi year cooperative investigation with the U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office and was supported by funding administered by the National Fish and Wildlife Foundation and provided by CALFED as part of a cooperative agreement with the California Department of Fish and Game pursuant to the California Bay-Delta Environmental Enhancement and Water Security Act (PL. 104-333).

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## SUMMARY

The California Department of Fish and Game (Department) and the U.S. Fish and Wildlife Service's Red Bluff Fish and Wildlife Office (Service) have jointly conducted annual winter-run Chinook salmon carcass surveys on the mainstem Sacramento River from 1996 through 2006. In 2001 a 3-year CALFED funded Cooperative Agreement was proposed between the Service and the Department. In 2003 this Agreement was signed by both agencies. The Agreement stipulated that the Service would reimburse the Department for the Winter-run surveys expenses and was administered by the National Fish and Wildlife Foundation. As part of the Agreement's obligations the Department was to provide a final summary report of the work performed over the multi-year survey. This report fulfills that obligation and provides an overview of the winter-run Chinook salmon carcass surveys conducted from 1996 through 2006.

This report summarizes the mark-recapture studies and associated data collection efforts necessary to produce the annual winter-run salmon escapement estimates. The U.S. Fish and Wildlife Service will prepare an additional final report using these data to evaluate the winter-run hatchery supplementation program at Livingston Stone National Fish Hatchery and provide characterizations of the genetic composition of the population.

Readers interested in specific details for individual years of the winter-run Chinook salmon carcass surveys should review the annual reports published by the Department and Service for each year. This report provides only an overview of selected data from each year. This report includes data from year 2006 which to date has not yet been incorporated into an annual report.

# INTRODUCTION

A series of annual winter-run Chinook salmon (winter-run), *Oncorhynchus tshawytscha,* carcass surveys (survey) were conducted on the mainstem Sacramento River during late-spring and summer from years 1996 through 2006. The objectives of the surveys included evaluation of the winter-run population characteristics and evaluation of the hatchery supplementation program conducted at Livingston Stone National Fish Hatchery (LSNFH). The surveys were conducted through both informal (1996-2002) and formal (2003-2004) cooperative agreements between the California Department of Fish and Game (Department), the U.S. Fish and Wildlife Service (Service), and in 2005-2006 included the Pacific States Marine Fisheries Commission (PSMFC).

## Contracting

In 2001 the Service received funding from CALFED for three years of winter-run surveys. A formal Cooperative Agreement was planned between the Department and Service for a reimbursable contract by which the Department would invoice the Service for labor and equipment it provided during the annual surveys. The Service's CALFED funding included the anticipated costs for the Departments sub-contracting portion of the survey for the three year period. The Cooperative Agreement was not completed until the final year of the 3-year period, (i.e. 2003). To facilitate the 2004 survey a one-year Agreement Modification was completed utilizing the unspent remaining funds in the Department's portion of the CALFED funding. In 2005 a second Cooperative Agreement was completed transferring unused funds from the first Agreement and augmenting it with additional CALFED funding to allow completion of the 2005 survey. This second Agreement involved the PSMFC which provided Fisheries Technicians previously employed as temporary help by the Department (Scientific Aides). This was necessary due to the Department's budgetary constraints that removed temporary help funding throughout the Department in 2005. The obligation for this report was originally to document the 2001 through 2003 surveys but was extended to include the 2004 and 2005 surveys upon completion of the second Cooperative Agreement. The first Agreement allocated $164,305.35 (later modified to $157,558.29) to the Department. The second Agreement allocated $81,705 to the PSMFC and 42,105.26 to the Department. In addition to these two Agreements there were three modifications (amendments) that allowed for administrative changes to the original Agreements.

## Surveys

The Department and Service began joint winter-run carcass surveys in 1996. This report is intended to satisfy the reporting requirements for the survey period from 2001 through 2005, as stipulated in the Cooperative Agreement funded through the California Bay-Delta Authority (CALFED) and administered by the National Fish and Wildlife Foundation.

Each annual survey was used in conjunction with several other data sources to produce an annual population estimate. The other data sources include the Department's aerial redd survey (used to determine the winter-run population spawning outside the range of the carcass survey), and data

the Keswick Dam Fish Trap (Keswick Trap) to determine the gender ratio of the adult population (2003-2006).

## Objectives

The objectives of the Department's annual winter-run salmon carcass surveys generally were:

# To estimate the in-river, winter-run spawner population in the mainstem Sacramento River within the established survey reach based on a carcass mark-recapture survey.

# To obtain baseline information on the following: spawning distributions (both temporal and spatial), environmental conditions during spawning, and characteristics (origin, length, age, sex composition, and spawning success) of the winter-run spawner population in the upper Sacramento River.

## Background

Winter-run are one of four distinct 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 late-April through mid-August, with peak spawning occurring sometime in June.

The earliest references to winter-run salmon have been summarized by Fisher (1993). In 1874, Livingston Stone noted winter-run in the Sacramento River near Mount Shasta and in the McCloud River, a tributary to the Sacramento River that presently drains into Shasta Lake. The status of winter-run population trends since the construction of Shasta Dam is discussed in 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 which is the upstream barrier to migration on the Sacramento River (Figure 1). Due to a drastically declining population, the California Fish and Game Commission listed winter-run as endangered under the California Endangered Species Act in 1989. Winter-run were federally listed as threatened in 1990, and then re-classified 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, the 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%. These draft recovery criteria for

winter-run are currently under review by the NOAA Fisheries Central Valley Technical Recovery Team.

From 1967 through 2000, winter-run escapement estimates were based upon counts of salmon in the fish ladders that provide passage over the Red Bluff Diversion Dam (RBDD). Starting in 2001, data from the carcass survey was used to provide the Department's "official" winter-run estimate, although the RBDD counts continue to provide an annual estimate. Counts at RBDD 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 three fish ladders available at 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 of the following year to allow unimpeded upstream passage of most winter run adults and the subsequent downstream migration of their juvenile offspring.

Winter-run counts made when season-long counts were possible (1969–1985) indicate that 13-19% of the winter-run migration occurs during the mid-May through mid-September period. Annual RBDD escapement is now estimated by expanding the abbreviated season-long count, and assuming it is proportionate to the average historic migration pattern for winter-run from 1982 through 1986.

## METHODS

This report provides an overview of the eleven year period of annual surveys from 1996 though 2006. Specific details regarding methods and changes for each year can be found in the annual report specific to that year. Each year included specific methodology changes that were made to provide improvement to the previous year survey in coping with the general increase in population observed over the 11-year period.

Figure 1 shows the survey's location and prominent landmarks (year 2005 shown). The survey's boundaries and sections within the boundaries have changed over the years to provide for staffing levels, sampling protocols and predicted populations. The survey was conducted from boats, each having two or more observers. Typically, two boats (one from the Service and one from the Department) were used. During the peak carcass collections up to five boats were used to ensure that complete coverage of each section was maintained. Each boat typically surveyed the areas from one shore out to the center of the river. In some areas of high carcass concentrations (e.g. Turtle Bay at RM 296.5) the boats would work side by side to process the carcasses. Carcasses were not accessible in some sections of the river due to hazards or deep water. In addition, crews were instructed to search all areas of the visible river bottom to avoid pre-determining search patterns based upon their prior experiences in locating carcasses.

The survey was divided into sections. Sections were chosen as convenient areas for crews to start or stop work for the day.

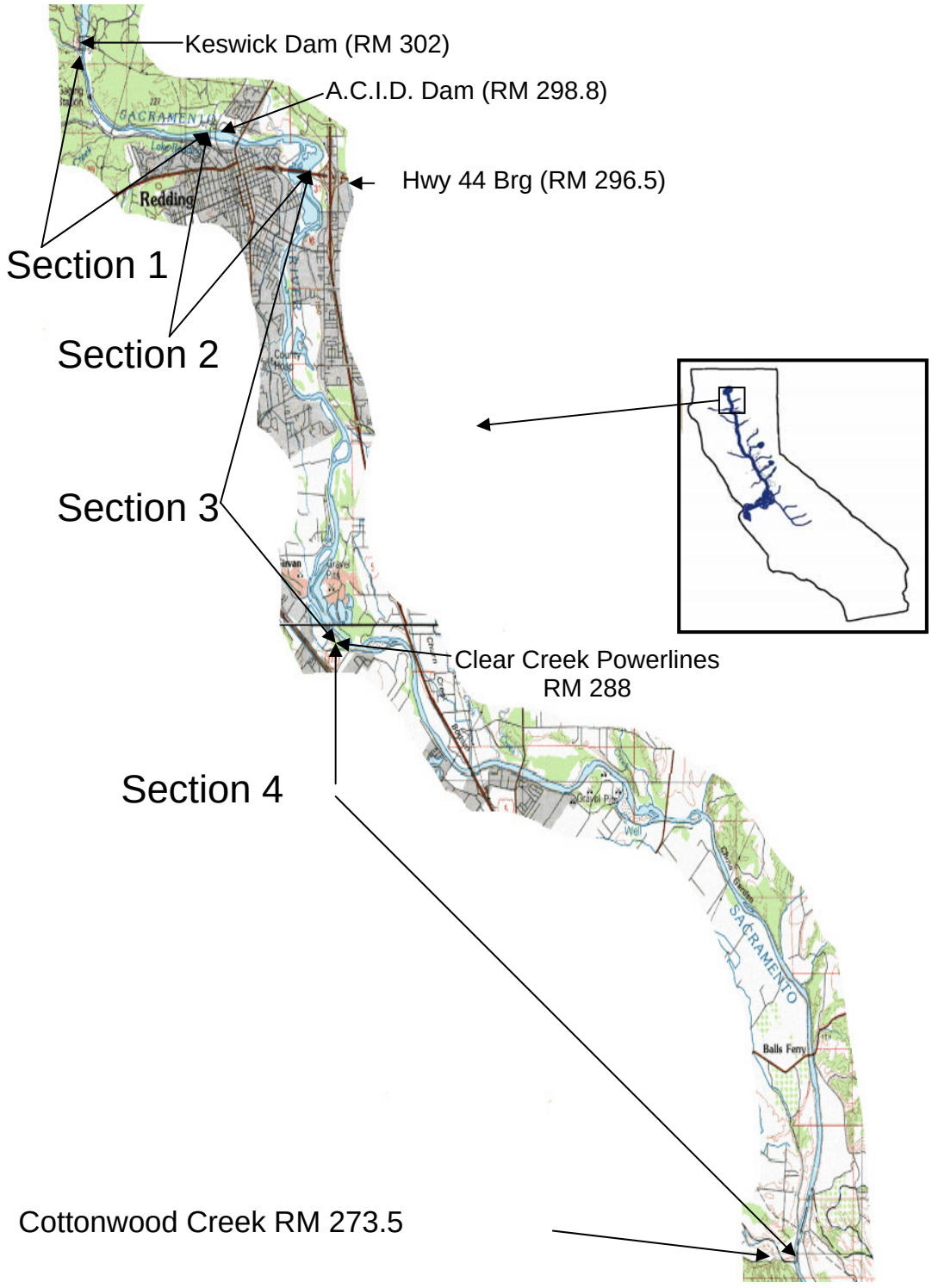


Figure 1 Map of 2005 Winter-run carcass survey area showing prominent landmarks, survey sections and river miles. Sections were subject to change from year-to-year based on staffing and survey protocols and projected population sizes.

Each survey consisted of multiple survey periods. During periods and days with low numbers of carcasses, crews would attempt to collect data from all carcasses encountered. During busy periods, crews would sub-sample the amount of data collected from carcasses to allow for completion of the survey section by the end of the day.

## Population Estimates

The winter-run spawner population was estimated using a Jolly-Seber mark-recapture design from 2001 through 2006. Previous years utilized a combination of Peterson, Schaefer and Jolly-Seber methods. Generally, all carcasses not in an advanced state of decay were marked (tagged). Carcasses not receiving tags were counted then cut in two (chopped). All chopped carcasses were disregarded in subsequent surveys. All carcasses upon tagging were returned to flowing water near where they were collected in an attempt to simulate "natural" carcass dispersion.

In addition to the carcass surveys the Service and Department have worked cooperatively at the RBDD to generate an annual winter-run population estimate from 1967 to present-day. The RBDD estimates are based on the phenotypic identification and counting of winter-run salmon passing the RBDD fish ladders and subsequent expansion of these counts for periods when RBDD was not in operation, and also for the number of spawners downstream of RBDD.

The spawning distribution of winter-run salmon is determined each year through the use of weekly helicopter of airplane flights. These aerial redd surveys map and count the location of new redds and are used by the Department to expand both the carcass survey and RBDD estimates. The proportion of redds downstream of either the carcass survey or RBDD is used to increase the overall estimate.

Since 2003 the ratio of live adult/large males to adult/large females captured at the Keswick Dam Fish Trap (Keswick) has been used in the carcass survey estimate methodology. The carcass survey consistently underestimates male winter-run since these fish are known to exit downstream of the carcass survey reaches while still alive and are subsequently under represented in the mark-recapture portion of the estimate.

## Carcass Data

**Note: This section contains generalized methodology. Later years incorporated significant modifications to protocols developed in early years. For specific methods refer to annual reports for each year.**

Carcasses were collected using 4.6 meter (15-feet) long wooden poles with a five-pronged gig attached to one end. Data was collected from carcasses after they were speared and lifted onto the deck of the boat. Each carcass was then categorized using the following criteria:

1. Adipose fin absent (hatchery), present (natural), or unknown.
2. Male or female.
3. Recaptured (previously tagged) or new encounter.
4. Fresh (recently died-with clear eyes) or non-fresh (decayed).

5. Spawned or not spawned (eggs present in females).
6. Fork length and samples taken or not taken.
7. Location (river mile and GPS waypoint (2004-2006))
8. Carcass to be tagged or chopped.

In accordance with the Service's task to evaluate the hatchery supplementation at LSNFH, the heads of all carcasses with adipose fins missing, partially present, or unknown, were collected for coded-wire tag recovery.

A carcass with the adipose fin present (natural fish) was processed (steps 2-8) and returned to the river either chopped in half or with a tag (i.e. mark) placed in the upper or lower jaw. Carcasses to be tagged were typically classified as fresh or non-fresh. A fresh carcass was one with at least one clear eye or red/pink gills. (Note: In years 1996 through 2002 fresh carcasses were tagged in lower jaw to allow tagging of carcasses with upper jaw and head removed for tag analysis, this is a correction to reported methods during these years. In recent years fresh carcasses were tagged in upper jaw.)

Tags were aluminum or copper coated steel hog ring staples with a small (1-2 centimeter) square piece of thin colored plastic sheet or ribbons attached to them. Tags were applied with hog-ring pliers to the carcass by squeezing the ends of the staple around the jaw. The tags of each sample period had a unique color to enable the subsequent analysis of recaptured carcasses by period.

In 2004-2006, many of the fresh carcasses encountered were also tagged with a 3 centimeter round aluminum "**disc tag**" bearing a unique number. These tags allowed data to be collected on individual carcasses movements (via GPS) and also on the length of time and number of times individual carcasses could be recovered.

Spawn condition was typically determined for female carcasses only. Female carcasses were classified as spawned if few eggs remained in the carcass and the caudal (tail) fin was worn from redd construction. Unspawned females typically were those with unworn caudal fins indicating they had not constructed redds or those where numerous eggs remained in the carcass after it had died.

A recaptured carcass was one that had been previously tagged with a hog staple and was recaptured on a subsequent survey. Sex, tag color, and location of the tag (upper or lower jaw) were recorded for all recaptured carcasses. Recaptured disc tagged carcasses were immediately returned to the river after the disc number and GPS location were noted. Recaptured carcasses **without** disc tags were chopped and returned to the river. In subsequent analysis of disc tagged recaptured fish only the first incidence of an individual carcass's recapture was used in the calculation of a population estimate. Further incidences of recaptures of disc tagged carcasses were used to analyze carcass "survival" and the distance traveled in the survey.

Most fresh (and some non-fresh) carcasses were measured for fork length to determine age structure of the population. Additionally, tissue, otolith and scale samples were collected from many carcasses for analysis.

## Carcass Survey Environmental Data

Other data collected by survey period included the following:

1. Flow from Keswick Dam.
2. Water temperature.
3. Water clarity.
4. Weather conditions.

River flow based on the outflow from Keswick Dam was obtained from the California Data Exchange Center at http://cdec.water.ca.gov. Water temperature was collected for each survey section via a handheld thermometer and recorded in degrees Fahrenheit. Water clarity was measured by lowering a Secchi disc attached to a measuring tape or survey rod graduated in tenths of a foot into the water column. When the Secchi disc disappeared/reappeared the measurement at the water surface was recorded. Weather conditions were noted as to the daily conditions (rain, clear, etc) encountered for each section.

## RBDD and Aerial Redd Data

Annual reports describing the salmon and steelhead estimates in the Upper Sacramento River Basin, (upstream of the town of Princeton) are produced by the Red Bluff Sacramento River Salmon and Steelhead Assessment Project (SRSSAP). These reports detail the RBDD and aerial redd surveys methodology and data collected each year. The reports summarize main-stem and tributary data collection and estimates for all runs including winter-run and are available electronically upon request, (dkillam@dfg.ca.gov) (Killam and Harvey-Arrison, 2006).

## Data Storage and Management

Currently the responsibilities for the database management for the annual surveys are split between the Department and the Service. The Department is responsible for creation and quality control of the mark-recapture data and population estimate. The Service is responsible for the creation and quality control of the hatchery and natural fish genetic and biological sampling database. Both the Department and Service conduct multiple and independent quality control checks on the mark-recapture data to ensure that the population estimate is correct.

Data for the annual winter-run carcass surveys is made available in annual reports for each year from 1996 to 2005. The original survey datasheets for years 1996 through 2002 are archived at the Department's Fisheries Branch, Anadromous Resource Assessment Unit (formerly Stream Evaluation Program) in Sacramento California. Copies of these datasheets are also stored at the Service's Red Bluff FWO.

Survey data for years 2003 to present are archived at the Department's Red Bluff SRSSAP office and at the Service's Red Bluff FWO. Beginning in 2003 all survey data was compiled in Microsoft Access and Excel databases. From 2003 to present the mark-recapture data is available upon request (dkillam@dfg.ca.gov). Original "boat" datasheets are electronically scanned and available in Adobe's PDF format. Annual reports in either Microsoft Word or PDF

format are also available. At this time, efforts are underway to put these files on an internet website to allow easy access to the winter-run survey data.

Data from the RBDD and aerial redd surveys is also kept at the Department's SRSSAP office (Red Bluff) and is available electronically upon request.

# RESULTS and DISCUSSION

## Carcass Survey Population Estimates

Carcass surveys (surveys) for Winter-run Chinook salmon, (winter-run), on the mainstem Sacramento River began in 1996 and continue to present-day. Generally the surveys begin in late-April or early-May and continue through late-August or early-September. The Department's Stream Evaluation Program conducted the surveys from 1996 until 2002. From 2003 through 2006 the surveys were conducted by the Department's Sacramento River Salmon and Steelhead Assessment Project. Both Department efforts were conducted in cooperation with the Red Bluff Fish and Wildlife Office (formerly Fisheries Resource Office) of the US Fish and Wildlife Service (Service).

Throughout the eleven years of surveys the mark-recapture protocols and basic data collection efforts have become more refined. Each successive year has allowed the ability to utilize adaptive management techniques to improve the survey and ultimately improve the management abilities of the agencies responsible for managing winter-run.

Table 1 provides a summary of the eleven surveys and lists parameters useful for comparing and contrasting the differences in the surveys. Footnotes in Table 1 are explained in detail in the text following the Table. The results of Table 1 are described much more fully in the reports specific to each year, (Snider et al. 1997, 1998, 1999, 2000, 2001, 2002, Reavis et al 2005, and Killam 2004, 2005, 2006). Note that the data for the 2006 survey is not yet available in an annual report format at the time of this report's writing.

The data in Table 1 should be used with caution by independent researchers. Table 1 provides a summary of data in general categories. These categories are meant to provide a year-to year comparison and may not provide the specific data that researchers interested in winter-run adult escapement require. For example, the estimated adult females in-river in Table 1 do not include the winter-run females used for brood stock at Livingston Stone National Fish Hatchery while some analysis may require all females. For this reason it is suggested that researchers interested in data from winter-run adult escapements review the yearly reports or contact the Department's SRSSAP staff directly for their data requirements.

Table 1. A summary of winter-run Chinook salmon data from carcass surveys and Red Bluff Diversion Dam for years 1996-2006. Detailed footnote descriptions are located in the text following the table.

| Parameter | Yearly Winter-run Chinook Salmon Data from Carcass Surveys and RBDD | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
| Official total System estimate [1] | 1,337 | 880 | 3,002 | 3,288 | 1,352 | 8,224 | 7,464 | 8,218 | 7,869 | 15,839 | 17,334 |
| In-river spawner estimate [2] | 1,012 | 836 | 2,903 | 3,264 | 1,263 | 8,120 | 7,360 | 8,133 | 7,784 | 15,730 | 17,205 |
| Removed for hatchery use [3] | 325 | 44 | 99 | 24 | 89 | 104 | 104 | 85 | 85 | 109 | 93 |
| Peterson Standardized estimate [4] | 273 | 564 | 2,165 | 1,135 | 4,290 | 6,760 | 6,106 | 6,602 | 6,205 | 13,549 | 13,924 |
| Reported Peterson estimate [5] | 820 | 2,053 | 5,501 | 2,262 | 6,647 | 11,502 | 10,541 | n/a | n/a | n/a | n/a |
| Jolly-Seber in-river + expansions [6] | n/a | n/a | n/a | n/a | 5,939 | 8,120 | 7,360 | 8,133 | 7,784 | 15,730 | 17,205 |
| RBDD estimate [7] | 1,337 | 880 | 3,002 | 3,288 | 1,352 | 5,523 | 9,169 | 9,757 | 7,192 | 5,299 | 7,436 |
| Estimated Adult Females in-river [8] | 190 | 395 | 1908 | 816 | 3,483 | 5,262 | 5,682 | 5,179 | 3,252 | 9,005 | 8,811 |
| Carcasses Tagged (all) [9] | 82 | 191 | 575 | 313 | 2,000 | 4,364 | 3,770 | 3,457 | 2,072 | 4,758 | 4,121 |
| Carcasses Chopped (all) [10] | 32 | 48 | 208 | 162 | 482 | 781 | 1,189 | 882 | 958 | 2,448 | 2,656 |
| Carcasses with CWT (Hatchery) [11] | 0 | 5 | 2 | 4 | 4 | 155 | 208 | 179 | 250 | 1,565 | 885 |
| Carcasses Recaptured (all) [12] | 13 | 22 | 75 | 57 | 832 | 2,200 | 2,159 | 2,175 | 1,128 | 3,001 | 2,206 |
| Percent recapture of tagged (all) [13] | 16% | 12% | 13% | 18% | 42% | 50% | 57% | 63% | 54% | 63% | 54% |
| Percent grilse [14] | 19.0% | 8.0% | 0.2% | 19.5% | 2.7% | 9.7% | 5.5% | 3.3% | 26.1% | 7.3% | 1.5% |
| Percent males in carcass survey [15] | 40% | 34% | 13% | 34% | 23% | 53% | 29% | 16% | 30% | 26% | 27% |
| Percent adult males in survey [16] | 16% | 31% | 11% | 12% | 20% | 42% | 22% | 14% | 20% | 22% | 27% |
| Percent female spawn success [17] | 94% | 96% | 95% | 97% | 100% | 99% | 99% | 100% | 99% | 98% | 98% |
| Percent of redds within survey [18] | 100% | 100% | 94.2% | 92.6% | 73.1% | 88.5% | 95.9% | 99.3% | 100% | 100% | 99.9% |
| Survey date start | 4-Apr | 30-Apr | 5-May | 5-May | 3-May | 2-May | 1-May | 30-Apr | 30-Apr | 28-Apr | 1-May |
| Survey date end | 5-Sep | 29-Aug | 28-Aug | 27-Aug | 29-Aug | 29-Aug | 27-Aug | 4-Sep | 3-Sep | 2-Sep | 25-Aug |
| Survey periods | 19 | 41 | 39 | 38 | 39 | 40 | 40 | 41 | 43 | 43 | 39 |
| Flow range (cfs x 1000) | 7 - 16 | 8 - 15 | 10 - 23 | 9 - 13 | 8 - 15 | 8 - 15 | 7 - 15 | 8 - 29 | 8 - 16 | 4 - 37 | 6 - 15 |
| Water temp ($^{o}$F) range | 52 - 59 | 49 - 52 | 50 - 54 | 50 - 54 | 51 - 54 | 50 - 55 | 50 - 56 | 50 - 54 | 50 - 57 | 51 - 59 | 50 - 56 |
| Visibility range (ft) [19] | n/a | 3 - 10 | 4.5 - 11 | 6 - 11 | 9 - 21 | 14 - 21 | 17 - 22 | 8 - 15+ | 8.5 - 16 | 2 - 16+ | 5 - 13 |

**Discussion of Table 1 footnotes and specific application to yearly surveys**

1 - Official total System estimate: This is the official number used by the Department and other agencies when reporting winter-run spawning populations (both hatchery and in-river). This data is also available in the Department's "GrandTab", an electronic summary of Central Valley salmon escapements. The RBDD number was used from 1996 to 2000. From 2001 to 2006 the Jolly-Seber estimate from the carcass survey was used. It is important to note that this number includes some winter-run that were estimated to have entered Battle Creek (1996 = 325, 1997 = 44, 2006 = 36).

2 – In river spawner estimate: This number is the number of winter-run salmon thought to have spawned naturally in the Sacramento River. It includes both natural origin and hatchery fish which spawned in the river.

3 – Removed for hatchery use: This number is the number of fish removed for hatchery brood stock including fish which died before being spawned. It includes mostly natural origin fish as well as some hatchery origin fish used for brood stock or sacrificed to determine hatchery origin. In 1996 and 1997 this number represents the number of fish that were observed in Battle Creek at Coleman National Fish Hatchery. In 2006, five coded-wire-tagged winter-run were sacrificed at the Coleman Barrier Weir to determine hatchery origin. These five fish (along with an additional 31 estimated natural winter-run) are not listed here, but are included in the total System estimate row above.

4 – Peterson Standardized estimate: This number represents an expanded and corrected Peterson estimate from earlier carcass surveys that allows for comparison of numbers for all years using identical data parameters to generate an estimate. In this estimate both fresh and non-fresh adult carcasses are used in calculations. In addition grilse numbers and salmon spawning outside of carcass survey area (determined by aerial redd counts) are included. A correction to the Peterson estimate was applied to the 1996-2002 survey results. The correction eliminated the inclusion of tagged fish in the "examined fish" variable of the Peterson formula. A discussion of the details surrounding this correction is available in Killam, 2004: Appendix 6.

5 - Reported Peterson estimate: This number represents the Peterson estimate reported in the Department reports from 1996-2002. In years 1998-2000 it does not include spawners outside of the carcass area (in 1996-1997 this number was zero, and in 2001-2002 aerial redd data was included). It also includes (except 1996-1997) the data from only fresh adult carcasses. Estimates produced using only fresh carcasses must account for the non-fresh tagged carcasses as fish examined or the Peterson estimate will be incorrect (Killam, 2004: Appendix 6). This problem is corrected for by using both fresh and non-fresh data in the Peterson Standardized estimate in Table 1.

6 – Jolly-Seber in-river + expansions: This number represents the number of in-river spawners estimated through the use of the Jolly-Seber model and other expansions (including hatchery in-river spawners, downstream spawners, adult males, and grilse). The Jolly-Seber number has been the official Department estimate since 2001. Due to insufficient recaptures in earlier years

the Jolly-Seber model was unable to be used. During the calculations in the Jolly-Seber model if recaptures are zero for any recovery period an error is generated as a result of dividing by zero.

7 – RBDD estimate: This number results from calculations at the Red Bluff Diversion Dam fish trap and fish ladders. The RBDD numbers go back to 1967 and represent a long term database for winter-run populations. Since 1986 the RBDD number has been calculated using an average number which recently has resulted in significantly different numbers from the carcass survey. Beginning in 2001 the Department recognized that the carcass survey provided an improved method of counting winter-run salmon. The RBDD number is still developed to provide a continuation of data trends since 1967 but is no longer recognized as an official number.

8 – Estimated Adult Females in-river: This number (carcass survey) provides an estimate of the number of adult females that can be useful in comparing the number of juveniles produced by the winter-run spawners. The calculation of this number has been "standardized" for the survey years. The numbers in Table 1 years 1996-2000 are based on the standardized Peterson estimates for those years, but these numbers are not the official ones (see below). From 2001 to 2006 the number is based on the Jolly-Seber estimates (official). The adult female numbers for years 1996 to 2000 from the RBDD "official" reporting are as follows: 1996 = 421, 1997 = 308, 1998 = 1,183, 1999 = 427, and 2000 = 394.

9 – Carcasses Tagged (all): This number is the total of all carcasses tagged during the surveys. It includes both males and females, and the smaller grilse or 2 year old fish. In all surveys the grilse and adults were recorded as separate categories. Population estimates were based on adult or large fish and expanded for grilse after an adult estimate was made.

10 – Carcasses Chopped (all): In Table 1 this number includes the carcasses (including grilse) that were not tagged and did not have a tag in them (recaptures). A chopped carcass is typically non-fresh; meaning it is not suitable for tagging or collecting biological data from. In some cases fresh carcasses were chopped if they had been eaten by scavengers. It is also important to note that a recaptured tagged carcass is also chopped after the tag color and location is recorded, but these are not labeled as Chopped in the database. For purposes of the Peterson estimate examined fish include both recaptured and chopped carcasses, but not tagged fish.

11 – Carcasses with CWT (Hatchery): This number represents the number of adipose fin clipped or coded-wire-tagged (CWT) hatchery fish that were collected during the surveys. A carcass is identified as a hatchery fish by the absence of the adipose fin that is clipped off during hatchery tagging. In some cases the carcass is too decayed (or eaten) to tell if the fin has rotted off or was clipped off. In these "unknown clipped" cases the carcass was classified as a hatchery fish if a tag was found or as a natural fish if no tag was found. If crews were positive that it was an adipose fin clip the fish was labeled as a hatchery fish even if no CWT was found. Not all hatchery fish found on the surveys were winter-run as some late-fall-run and spring-run fish were encountered. In recent years (2001-2006) the vast majority of hatchery fish were winter-run salmon produced at Livingston Stone National Fish Hatchery. More specific details of hatchery evaluation are located in the Service's Annual reports. (USFWS, 2003, 2004, 2006)

12 – Carcasses Recaptured (all): This number represents the number of previously tagged carcasses (including grilse) that are recaptured in the subsequent survey periods. It does not include hatchery tags or other types of tags applied when the fish was alive. The survey protocols dictate that all recaptures be chopped upon recapture. This was done to ensure that the surveys were conducted as "sampling without replacement" surveys. Starting in 2004 individually numbered "disc" tags were applied to fresh carcasses to determine carcass decay times and movements over time. These carcasses were not chopped upon recapture but their first recapture date was used as if they were chopped for purposes of the population estimate protocols, (all subsequent recaptures were ignored for mark-recapture purposes). This type of sampling was still "sampling without replacement" but the data on these disc tagged fish can be used in the future as "sampling with replacement" if desired.

13 – Percent recapture of tagged (all): This number is the total recaptured divided by the total tagged from Table 1. It is a useful way to see if there was consistency over the yearly surveys. A high percent recapture indicates that many of the tagged fish released are recovered in future survey periods. A high recapture rate generally means that the survey periods were spaced close in time and that a lot of effort by crews was applied to the survey. Water visibility and number of fish both can lead to varying recapture rates. Turbid water makes the decaying tagged fish harder to see and lowers recapture percentages. Fewer fish makes finding any fish difficult and increases the likelihood of scavengers eating the released tagged fish (often observed at the start and end of the surveys).

14 – Percent Grilse: This number is the percentage of smaller (2-year old fish) observed in the surveys. This number includes both males (jacks) and females (jills) observed, although for winter-run and other runs in the Sacramento River most of the grilse are typically males (Killam, 2004). The specific size for determining what a grilse is varies depending upon the project. The traditional grilse size cut-off used by the Department's SRSSAP Red Bluff project was 610 mm or 24 inches. The Department's Stream Evaluation Program used length frequency data to determine the grilse cut-off from 1996-2002, but this method affects the mark-recapture calculations because crews collected mark-recapture data on adults and grilse separately before the length frequency analysis was conducted leading to problems with numbers of carcasses tagged, chopped and recaptured with lengths near the cut-off length. This difficulty was eliminated in 2004 and later years by instructing crews to use a 610mm cut-off to separate "larger and smaller" fish. The Jolly-Seber estimate was applied to the larger carcasses to get a population estimate and the number of adults and grilse was determined by multiplying the entire population estimate by the percent of grilse found in a sub-sample of the carcasses (fresh fish) measured (Killam, 2005). The percent of grilse was the number of fish below a specific length (determined by looking at length frequency graph) versus all the numbers of fish in the sample.

The overall reason of separating grilse from adults originated because the recapture rate of small fish is less than large fish (smaller fish are difficult to find). An assumption of the population models is that each fish has an equal chance of being recaptured. Since this is not the case the data from the large fish is used in the models each year, (we assume that fish larger than 610mm have equal recapture rates). For ocean management of the winter-run stocks it is important to know the contributions that grilse are making to each new brood year.

15 – Percent males in carcass survey: This number is the proportion of all males (jacks included) to the total number of fresh carcasses observed. It is useful in comparing and contrasting the carcass survey results with other data and also for simple observations on the number of jacks compared to adult males in number 16 below.

16 - Percent adult males in survey: This number is the percentage of adult males among all adult fresh carcasses in the survey. This number for winter-run carcass surveys has generally been much lower than would normally be "expected" for an increasing salmon population. Starting in 2003 the Department recommended the use of sex composition data from the Keswick Fish Trap be used to calculate the number of adult males. Since 2003 the Jolly-Seber model is used to calculate the number of large females. The sex ratio of winter-run at the Keswick Fish Trap is used to calculate the corresponding large males. The male winter-run salmon have been observed to leave the survey area while still alive and carcass GPS data indicates that they are more likely to be found lower in the survey sections than females (Killam 2003). This indicates that male salmon are likely underrepresented in the carcass survey data and that including male carcass survey numbers, (from the mark-recapture data) would result in a low population estimate. The ability to isolate the large females in the database to produce a population estimate was not available prior to 2003. In years 1996-2002 the sex of the recaptured fish was not recorded, so for those years (1996-2002) the population estimates are based on all adult fish.

17 – Percent female spawn success: This number is the percentage of fresh female carcasses that had spawned (expelled eggs) before death. The percentages for winter-run are typically very high indicating that the population is not incurring any density dependent spawning mortality at the present time. This number is determined by examining each winter run fresh female carcass for signs of spawning, (worn tail, and gaunt body cavity). Unsuccessful spawners are those with without tail damage or those with more than a small (handful) of eggs remaining in their body cavity.

18 - Percent of redds within the survey area: This number represents the percentage of new redds observed within the boundaries of the carcass survey by the Department's aerial redd flights. These flights are to count new redds and determine the spawning distributions of all salmon runs on the mainstem Sacramento River. The winter-run flights are done in helicopters and begin downstream of RBDD in Corning California. If winter-run redds are observed outside of the survey area the population estimate is expanded by the percent of redds noted outside the boundaries (Killam 2004).

19 – Visibility range (ft): This number is a measure of the range of water visibility that was observed during the yearly surveys. It is a rough gauge of the overall water clarity conditions that crews encountered during the winter-run spawning season. This parameter is influenced by a number of factors including: location in the river, time, personnel, cloud cover, wind and currents. It is taken once each survey day but not under strict controlled conditions. Crews take visibility measurements once per day in deep areas by lowering a Secchi disc attached to a survey rod (2003-2006) or flexible measuring tape (1996-2002) and recording the depth that it can no longer be seen. Official standards are not adhered to and this measurement should be used for comparative purposes only.

## Other Winter-run Data Sources

The Department has two other sources of data for winter-run adult escapements. The first is the Red Bluff Diversion Dam; (RBDD). The RBDD is the historical means of determining the winter-run population estimates. Table 2 provides the data from the RBDD for years 1967 through 2006. Beginning in 2001 the Department has used the carcass survey estimate as the official estimate for winter-run adult escapements. The RBDD estimate is still utilized by some groups for specific purposes because it provides a long term trend of what the population is each year. Beginning in 1986 the RBDD was operated to minimize passage delays for adult winter-run. Because of this, the ability to count winter-run at RBDD has been compromised. Since 1986 the RBDD estimate has been based, in part, on a "historical average population" rather than the actual population which passes RBDD each year. As the population has grown in recent years the disparity between the RBDD and the carcass survey estimates has become more pronounced (Table 1). A detailed description of the RBDD methodology is available within the annual reports of the SRSSAP, (Killam and Harvey Arrison 2006).

A second source of winter-run data is aerial redd surveys that are used to count the number of new winter-run redds and determine the spawning distribution of the winter-run population during the spawning season. Winter-run spawning distribution is determined by aerial redd surveys conducted weekly by helicopter or plane from late-April until August. Table 3 provides a summary of aerial redd flight data for winter-run on the Sacramento River during the years for which data is available. Aerial redd flights are used to provide an index of spawning distribution rather than a complete count. Riparian vegetation, air traffic, and cloudy or deep water prevent viewing of all areas, so the total redd numbers are less than the total female spawner estimate. In addition these flights often are cancelled when forest fires preempt the use of the contracted helicopter. The qualitative aerial redd data should be used with caution. The Department does not recommend the use of the redd data for any specific use other than for determining the general distribution and subsequent population expansion for winter-run spawners in the Sacramento River.

Once the winter-run have finished spawning, the redd distribution data is used to expand the carcass survey or the RBDD annual estimates for winter-run that may have spawned outside (downstream) of either method. A simple proportion is used to expand the estimates. The proportion is constructed as follows: Number of salmon downstream = (salmon upstream after harvest in main-stem / redds upstream) * redds downstream. This expansion for the number of salmon downstream of the respective estimate is then added to the "upstream" estimate and a final mainstem Sacramento River population estimate is made. In years 1996 to 2000 no expansion was made in the carcass survey reports. In Table 1 a standardized estimate has been added that includes aerial redd results for all the carcass surveys.

## Recommendations

The winter-run carcass survey has proven to be a valuable tool in the recovery and management of the species. It has the support of all agencies involved in winter-run management. Funding for the Survey is currently in place for one additional year and a more permanent source of funding should be secured to allow for future monitoring efforts.

## ACKNOWLEDGEMENTS

Many people and many agencies have contributed to the data collection and data analysis on the winter-run carcass surveys. I wish to thank everyone who contributed to the surveys and leave the specific acknowledgements to the individual annual reports. The field work for the winter-run survey is both tedious and grueling exposing field crews to the hottest days each year in the Upper Sacramento River Basin. The ability to collect data and maintain a positive outlook despite temperatures in excess of 115 degrees and the ever present hazard of either (a) chopping your leg off or (b) getting a piece of decaying salmon innards flung in your face make the acknowledgement of field staff very important. While many persons contributed to the effort, special thanks go to James Lyons from the Department for his efforts from the earliest years to the present. I also would like to specifically acknowledge the Service and the many days they put into management and administrative duties to make sure the annual surveys functioned smoothly. Specific thanks are due Kevin Niemala and Robert Null for their hard work in making this effort a success. Other agencies including the NMFS and the U.S. Bureau of Reclamation have also funded (helicopter surveys) the Department to allow winter-run monitoring and deserve thanks.

Table 2. A summary of the Red Bluff Diversion Dam historical winter-run population data for years 1967 to 2006.

| YEAR | TOTAL | Natural | Ad-Clip | % Nat | % Ad | Adults | Grilse | % A | % G | Male | Female | % M | % F | Removal* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1967** | **57,306** | 57,306 | 0 | 100% | 0% | 32,321 | 24,985 | 56% | 44% | n/a | n/a | n/a | n/a | n/a |
| **1968** | **84,414** | 84,414 | 0 | 100% | 0% | 74,115 | 10,299 | 88% | 12% | n/a | n/a | n/a | n/a | n/a |
| **1969** | **117,808** | 117,808 | 0 | 100% | 0% | 108,855 | 8,953 | 92% | 8% | n/a | n/a | n/a | n/a | n/a |
| **1970** | **40,409** | 40,409 | 0 | 100% | 0% | 32,085 | 8,324 | 79% | 21% | n/a | n/a | n/a | n/a | n/a |
| **1971** | **53,089** | 53,089 | 0 | 100% | 0% | 32,225 | 20,864 | 61% | 39% | n/a | n/a | n/a | n/a | n/a |
| **1972** | **37,133** | 37,133 | 0 | 100% | 0% | 28,592 | 8,541 | 77% | 23% | n/a | n/a | n/a | n/a | 1204 |
| **1973** | **24,079** | 24,079 | 0 | 100% | 0% | 19,456 | 4,623 | 81% | 19% | n/a | n/a | n/a | n/a | 1428 |
| **1974** | **21,897** | 21,897 | 0 | 100% | 0% | 18,109 | 3,788 | 83% | 17% | n/a | n/a | n/a | n/a | 508 |
| **1975** | **23,430** | 23,430 | 0 | 100% | 0% | 15,932 | 7,498 | 68% | 32% | n/a | n/a | n/a | n/a | 851 |
| **1976** | **35,096** | 35,096 | 0 | 100% | 0% | 26,462 | 8,634 | 75% | 25% | n/a | n/a | n/a | n/a | 2067 |
| **1977** | **17,214** | 17,214 | 0 | 100% | 0% | 15,028 | 2,186 | 87% | 13% | n/a | n/a | n/a | n/a | 744 |
| **1978** | **24,862** | 24,862 | 0 | 100% | 0% | 23,669 | 1,193 | 95% | 5% | n/a | n/a | n/a | n/a | 127 |
| **1979** | **2,364** | 2,364 | 0 | 100% | 0% | 2,251 | 113 | 95% | 5% | n/a | n/a | n/a | n/a | 25 |
| **1980** | **1,156** | 1,156 | n/a | 95% | >5% | 84 | 1,072 | 7% | 93% | n/a | n/a | n/a | n/a | 14 |
| **1981** | **22,832** | 22,832 | n/a | 95% | >5% | 18,297 | 1,744 | 91% | 9% | n/a | n/a | n/a | n/a | 246 |
| **1982** | **1,281** | 1,281 | n/a | 95% | >5% | 972 | 270 | 78% | 22% | n/a | n/a | n/a | n/a | 9 |
| **1983** | **1,831** | 1,831 | 0 | 100% | 0% | 1,439 | 392 | 79% | 21% | n/a | n/a | n/a | n/a | 4 |
| **1984** | **2,663** | 2,663 | 0 | 100% | 0% | 794 | 1,869 | 30% | 70% | n/a | n/a | n/a | n/a | 1 |
| **1985** | **5,515** | 5,515 | n/a | 95% | >5% | 3,633 | 329 | 92% | 8% | n/a | n/a | n/a | n/a | 276 |
| **1986^** | **2,596** | 2,596 | 0 | 100% | 0% | 2,101 | 496 | 81% | 19% | 1,623 | 974 | 63% | 38% | 30 |
| **1987** | **2,186** | 2,186 | 0 | 100% | 0% | 1,909 | 277 | 87% | 13% | n/a | n/a | n/a | n/a | 20 |
| **1988** | **2,886** | 2,886 | 0 | 100% | 0% | 1,878 | 1,008 | 65% | 35% | 962 | 1,924 | 33% | 67% | 21 |
| **1989** | **696** | 696 | 0 | 100% | 0% | 571 | 125 | 82% | 18% | 232 | 464 | 33% | 67% | 47 |
| **1990** | **430** | 430 | 0 | 100% | 0% | 387 | 43 | 90% | 10% | 168 | 262 | 39% | 61% | 18 |
| **1991** | **211** | 211 | 0 | 100% | 0% | 192 | 19 | 91% | 9% | 35 | 176 | 17% | 83% | 34 |
| **1992** | **1,240** | 1,240 | 0 | 100% | 0% | 1,160 | 80 | 94% | 6% | 531 | 709 | 43% | 57% | 37 |
| **1993** | **387** | 387 | 0 | 100% | 0% | 250 | 137 | 65% | 35% | 193 | 193 | 50% | 50% | 9 |
| **1994** | **186** | 148 | 38 | 80% | 20% | 62 | 124 | 33% | 67% | 152 | 34 | 82% | 18% | 42 |
| **1995** | **1,297** | 1,261 | 35 | 97% | 3% | 1,267 | 29 | 98% | 2% | 501 | 796 | 39% | 61% | 131 |
| **1996** | **1,337** | 1,022 | 315 | 76% | 24% | 708 | 629 | 53% | 47% | 810 | 527 | 61% | 39% | 325 |
| **1997** | **880** | 835 | 44 | 95% | 5% | 528 | 352 | 60% | 40% | 541 | 338 | 62% | 38% | 44 |
| **1998** | **3,002** | 2,948 | 54 | 98% | 2% | 2,079 | 924 | 69% | 31% | 1,419 | 1,583 | 47% | 53% | 99 |
| **1999** | **3,288** | 3,262 | 26 | 99% | 1% | 822 | 2,466 | 25% | 75% | 2,301 | 986 | 70% | 30% | 24 |
| **2000** | **1,352** | 1,206 | 146 | 89% | 11% | 563 | 789 | 42% | 58% | 789 | 563 | 58% | 42% | 89 |
| **2001** | **5,523** | 5,254 | 268 | 95% | 5% | 1,696 | 3,827 | 31% | 69% | 4,262 | 1,261 | 77% | 23% | 104 |
| **2002** | **9,169** | 7,908 | 1,261 | 86% | 14% | 7,614 | 1,555 | 83% | 17% | 4,424 | 4,745 | 48% | 52% | 104 |
| **2003** | **9,757** | 8,297 | 1,460 | 85% | 15% | 6,172 | 3,585 | 63% | 37% | 6,247 | 3,510 | 64% | 36% | 85 |
| **2004** | **7,192** | 5,675 | 1,516 | 79% | 21% | 2,588 | 4,604 | 36% | 64% | 5,881 | 1,311 | 82% | 18% | 85 |
| **2005** | **5,299** | 4,263 | 1,036 | 80% | 20% | 3,521 | 1,778 | 66% | 34% | 3,068 | 2,231 | 58% | 42% | 109 |
| **2006** | **7,436** | 6,952 | 484 | 93% | 7% | 4,806 | 2,630 | 65% | 35% | 5,109 | 2,327 | 69% | 31% | 98 |
| **AVG** | **16,018** | **15,851** | **186** | **96%** | **4%** | **12,380** | **3,529** | **70%** | **30%** | **1,962** | **1,246** | **55%** | **45%** | **259** |

^ Data from 1986 to 2001 was revised from earlier reports based on a quality control review of historical data. Dam gates were raised during winter-run migration from 1986 to Present requiring estimation of actual numbers.

* Removal indicates the number of salmon estimated to have been removed from the river for hatchery brood stock (Livingston Stone or Coleman National Fish Hatcheries), and in some earlier years the combination of hatchery and angler removals. (Note in 2006 removal includes 93 for Livingston Stone and 5 for Late-fall/Spring-run management at Coleman Hatchery(s)).

Table 3. Summary of available winter-run aerial redd distributions for years shown. (Note: Not all years reflect identical data collection efforts. Aerial redd data should be used with caution.)

| WINTER-RUN | YEAR | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **River Section** | **06** | **05** | **04** | **03** | **02** | **01** | **00** | **99** | **98** | **97** | **96** | **95** | **94** | **93** | **92** | **91** | **90** | **89** | **88** | **87** | **86** | **85** | **84** | **83** | **82** | **81** |
| Keswick to A.C.I.D. Dam. | 34.9% | 52.3% | 16.4% | 65.8% | 48.7% | 34.7% | 5.8% | 0.1% | 3.3% | 0% | 2.9% | 6.9% | 0% | 4.5% | 1.8% | 0% | 0% | 6.4% | 0.9% | 0.3% | | 5.8% | | | 0% | 2.2% |
| A.C.I.D. Dam to Highway 44 Bridge | 48.8% | 35.6% | 34.6% | 17.2% | 22.0% | 15.4% | 26.7% | 31.5% | 76.9% | 83.3% | 71.4% | 82.9% | 29.4% | 61.4% | 20.0% | 70.0% | 34.6% | 29.8% | 22.9% | 14.7% | | 12.6% | | | 57.6% | 0% |
| Highway 44 Br. to Airport Rd. Br. | 16.0% | 11.9% | 48.6% | 16.3% | 27.5% | 44.7% | 46.6% | 65.0% | 15.7% | 16.7% | 25.7% | 9.1% | 23.5% | 25.0% | 49.1% | 20.0% | 51.0% | 46.8% | 29.9% | 16.9% | | 29.1% | | | 36.4% | 85.6% |
| Airport Rd. Br. to Balls Ferry Br. | 0% | 0.2% | 0.3% | 0.3% | 1.1% | 3.9% | 5.4% | 1.3% | 0.8% | 0% | 0% | 0% | 41.2% | 2.3% | 14.5% | 10.0% | 5.8% | 2.1% | 6.7% | 17.9% | | 13.6% | | | 3.0% | 0% |
| Balls Ferry Br. to Battle Creek. | 0% | 0% | 0% | 0% | 0.5% | 0.1% | 6.0% | 2.0% | 0.8% | 0% | 0% | 0% | 5.9% | 0% | 5.5% | 0% | 1.0% | 0% | 2.3% | 8.9% | | 0% | | | 0% | 0% |
| Battle Creek to Jellys Ferry Br. | 0% | 0% | 0% | 0% | 0% | 0.1% | 1.7% | 0.1% | 0% | 0% | 0% | 0.6% | 0% | 2.3% | 0% | 0% | 1.0% | 0% | 1.7% | 20.8% | | 1.0% | | | 0% | 0% |
| Jellys Ferry Br. to Bend Bridge | 0% | 0% | 0% | 0% | 0% | 0.6% | 7.8% | 0% | 0% | 0% | 0% | 0% | 0% | 2.3% | 5.5% | 0% | 0.0% | 12.8% | 8.6% | 14.4% | | 3.9% | | | 0% | 0% |
| Bend Bridge to RBDD | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 1.4% | 1.6% | | 5.8% | | | 0% | 0% |
| RBDD to Tehama Br. | 0.3% | 0% | 0% | 0.3% | 0.2% | 0.4% | 0% | 0% | 2.5% | 0% | 0% | 0.6% | 0% | 2.3% | 3.6% | 0% | 4.8% | 0% | 15.8% | 4.5% | | 28.2% | | | 3.0% | 12.2% |
| Tehama Br. To Woodson Bridge | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | n/s | n/s | 0% | 0% | 0% | 0% | 0% | 1.9% | 2.1% | 9.3% | 0% | | 0% | | | n/s | 0% |
| Woodson Bridge to Hamilton City Br | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | n/s | n/s | n/s | n/s | n/s | n/s | 0% | n/s | 0% | 0.3% | n/s | | 0% | | | n/s | n/s |
| Hamilton City Bridge to Ord Ferry Br | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | n/s | n/s | n/s | n/s | n/s | n/s | 0% | n/s | 0% | n/s | n/s | | n/s | | | n/s | n/s |
| Ord Ferry Br. To Princeton Ferry. | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | n/s | n/s | n/s | n/s | n/s | n/s | 0% | n/s | n/s | n/s | n/s | | n/s | | | n/s | n/s |
| **Total New Redds Counted** | **717** | **1,968** | **621** | **878** | **610** | **1,396** | **588** | **1,144** | **121** | **30** | **70** | **175** | **17** | **44** | **55** | **10** | **104** | **47** | **1,295** | **313** | | **103** | | | **33** | **90** |

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