State of California
The Resources Agency
DEPARTMENT OF FISH AND GAME

Sacramento River
Winter-Run Chinook Salmon Escapement Survey
April–September 2005

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

SRSSAP Technical Report No. 06-2
2006

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Cover Photo by author
The 2005 Winter-run carcass survey demanded the largest labor effort of any winter-run survey done to date. On some days up to five boats with 2 person crews were used to complete the survey on schedule. Crews worked seven days a week to collect the data for this report. The increased labor demands were due to the large number of winter-run in 2005.

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1/ This was a 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's Sacramento River Salmon and Steelhead Assessment Project and the U.S. Fish and Wildlife Service's Red Bluff Fish and Wildlife Office jointly conducted a winter-run Chinook salmon carcass survey on the mainstem Sacramento River in the spring and summer of 2005. The survey was conducted from 28 April through 2 September over a 27.5-mile river section. The survey area was from Keswick Dam near Redding, CA at river mile (RM)-302 downstream to the mouth of Cottonwood Creek (Shasta-Tehama Counties) at RM-273.5. This area contains the majority (100% in 2005) of traditional winter-run spawning habitat and is the uppermost migratory limit for anadromous fish in the Sacramento River.

The 2005 spawner escapement estimate of 15,839 winter-run Chinook was developed through application of a Jolly-Seber model mark-recapture study, Keswick Dam Fish Trap data, and aerial redd counts. Adult females comprised 9,061 or 57.2% of the population.

Survey conditions were fair in 2005. A visibility of at least 15 feet is necessary for maximum carcass recovery. The visibility this year ranged from 2 to over 17 feet with an average of 13.9 feet throughout the survey. River flows ranged from 4,877 to 37,697 cubic feet per second (cfs) during the entire survey, (43 periods). Water temperatures within the survey area ranged from 51 to 59 degrees Fahrenheit, (10.6–15.0^{o} C) with warmer temperatures being recorded as distance from Keswick Dam increased.

Crews encountered a total of 11,772 carcasses, 3,001 of which were recaptured after being tagged and released in prior periods. There were 1,565 carcasses that had questionable or clipped adipose fins indicating that they were probably of hatchery origin. Coded-wire tags were recovered from 1262 of these. Biological measurements (including fork length, sex, location, and spawning condition) were collected from 1,651 carcasses. Biological samples were collected from 2,278 carcasses.

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

INTRODUCTION

A winter-run Chinook salmon (winter-run), *Oncorhynchus tshawytscha,* carcass survey (survey) was conducted on the mainstem Sacramento River during spring and summer of 2005. The objectives of the survey included evaluation of the 2005 winter-run population characteristics and evaluation of the hatchery supplementation program conducted at Livingston Stone National Fish Hatchery (LSNFH). The survey was conducted through a cooperative agreement between the California Department of Fish and Game (Department), the U.S. Fish and Wildlife Service (Service), and the Pacific States Marine Fisheries Commission (PSMFC).

The Department and Service have conducted joint winter-run carcass surveys since 1996. The PSMFC provided Fisheries Technicians to the Department to staff field crews. This is the fifth year that the survey was funded through the California Bay-Delta Authority (CALFED). This report is submitted to satisfy annual reporting requirements for those portions of the survey that fall within the Department's annual reporting responsibilities to describe population characteristics including run size, age and sex composition, spawning success and spatial and temporal distribution.

The survey is used in conjunction with several other data sources to produce a population estimate. The results of the Department's Aerial Redd Survey are used to determine the winter-run population spawning outside the range of the carcass survey. Additionally, data from winter-run collections at the Keswick Dam Fish Trap (Keswick Trap) have again been integrated into the calculation of the winter-run population estimate to determine the gender ratio of the adult population (similarly to estimates from 2003 and 2004).

Objectives

The objectives of the Department's 2005 winter-run salmon carcass survey were:

To estimate the in-river, winter-run spawner population in the mainstem Sacramento River within the established survey reach (RM 273.5–RM 302) 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, 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 ± 25%. These draft recovery criteria for winter-run are currently under review by the NOAA Fisheries Central Valley Technical Recovery Team.

From 1969 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.

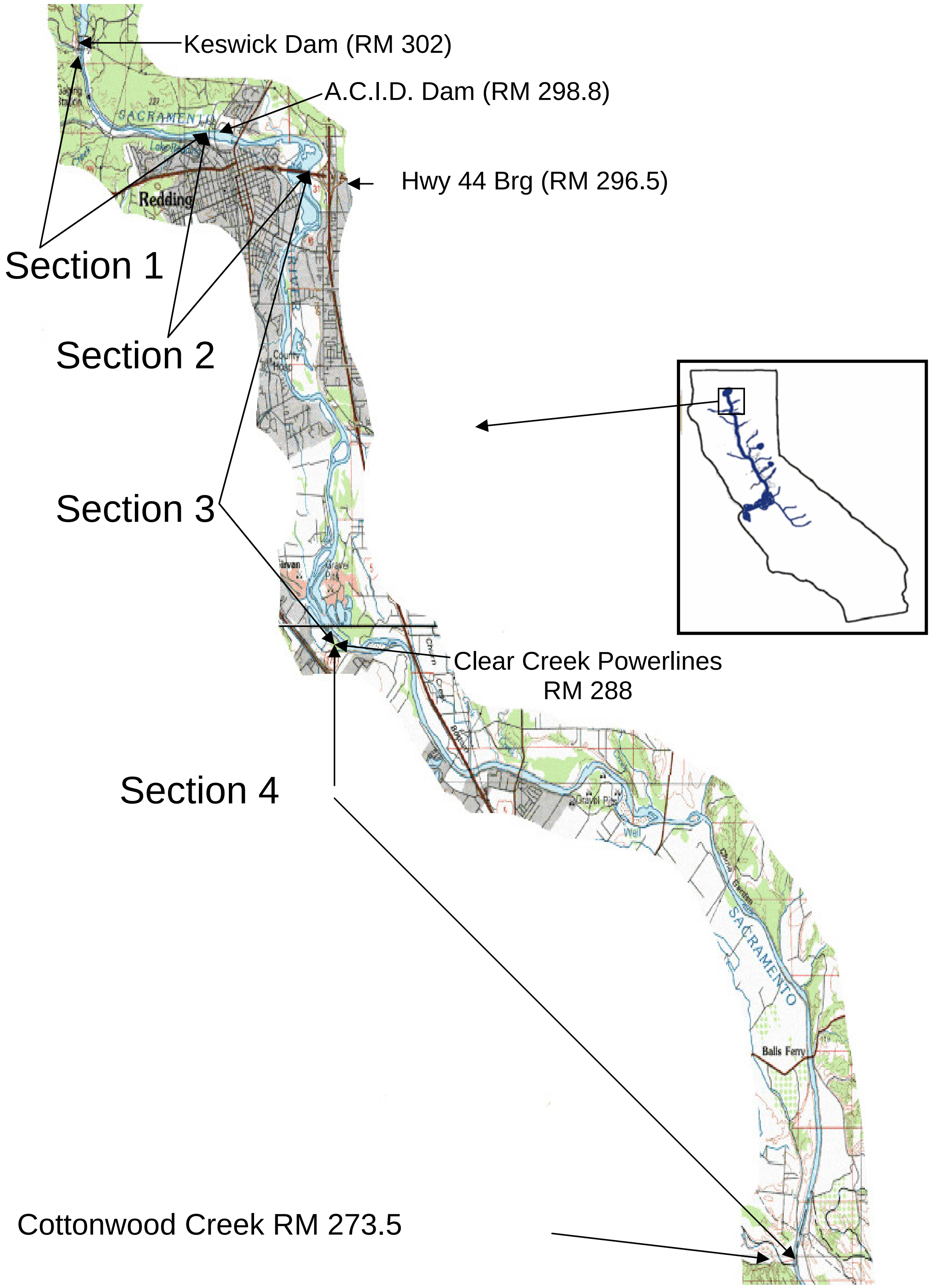

Figure 1 Map of 2005 Winter-run carcass survey area showing prominent landmarks, survey sections and river miles.

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

The 2005 winter-run Chinook salmon spawner escapement survey was conducted from 28 April through 2 September 2005.

Figure 1 shows the survey's location and prominent landmarks. 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 four sections. Sections were chosen as convenient areas for crews to start or stop work for the day. The sections were as follows:

1--Keswick Dam to ACID DAM - RM 302.1 to RM 298.8,
2--ACID Dam to Highway 44 Bridge - RM 298.8 to RM 296.5
3--Highway 44 bridge to Clear Creek Power lines - RM 296.5 to RM 288.4
4-- Clear Creek Power lines to Cottonwood Creek – RM 288.4 to 273.5

These sections differ from previous winter-run surveys and were determined to best represent a full day for crews on each section of river, (sections 1 and 2 normally completed on same day).

The entire survey consisted of 43 survey periods. Each period typically consisted of 3 sampling days. A new period was started every fourth day. 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 Estimate

The winter-run spawner population was estimated using a Jolly-Seber mark-recapture design. Typically, 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. All carcasses, including males and grilse were sampled. The Jolly-Seber estimate was produced from large female carcasses only (> 609 millimeters (mm)). The large male (> 609 mm) component of the population estimate was derived from a proportion using the number of large females and the sex ratios of large salmon from the Keswick Trap data.

The Department's internal Winter-run Technical Team decided in 2005 to utilize length-frequency graphs to decide actual cut-off lengths for distinguishing between adults and grilse in the 2005 Winter-run estimate. Historically 610 mm (24 inches) has been used as the cut-off between grilse and adults in the Upper Sacramento River Basin surveys. For **carcass survey** data collection purposes a cut-off length **must** be chosen before data collection efforts begin in order to avoid the biases associated with unequal recapture rates between small and larger carcasses (large carcasses are recaptured at higher rates than smaller ones). The 610 mm cut-off has been traditionally used both as a population estimation tool (large and small) and as the default biological indicator between 2 year-olds and adult fish. In this report the term large and small refer to salmon data collected before a subsequent fork length cut-off is determined. After determination of a cut-off is made the terms adults and grilse are applied for data analysis.

Carcass Data

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 genetic samples taken or not taken.
7. Location (river mile and GPS waypoint)
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. The remaining headless carcasses were then chopped in half and returned to the river. Adipose fin clipped carcasses are not part of the mark-recapture portion of the survey since they are chopped upon their first encounter.

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. Fresh carcasses were tagged in the upper jaw and non-fresh carcasses were tagged in the lower jaw if they were deemed suitable for tagging (not too decayed).

Tags were aluminum or copper coated steel hog ring staples with a small (1-2 centimeter) square piece of thin colored plastic sheet 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.

Additionally, 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 samples were collected from many fresh carcasses for genetic analysis. Sub-sampling for tissues occurred when carcass counts were expected to be high. For example, a sub-sample ratio (e.g. 1:3) was chosen at the start of the day and every third fresh carcass would be tissue sampled.

In 2005 crews collected scales from male carcasses measured between 500 and 850 mm (fork length) in the expectation of determining a scale ageing based fork length cut-off for grilse males and adults.

For each carcass that was measured the river mile and GPS location was recorded. This allows analysis of carcass distribution to determine if differences exist between male and female distribution.

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 surveying 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. Water clarity distances above 16 feet (4.88m) were recorded as 16+ for survey purposes. Weather conditions were noted as to the daily conditions (rain, clear, etc) encountered for each section.

RESULTS and DISCUSSION

Population Estimate

The Jolly-Seber model was used to calculate winter-run spawner escapement (Seber 1982), and described by Boydstun (1994). The data from large female carcasses, (both fresh and decayed), was used as a starting point to calculate the winter-run population estimate. The following steps were used to arrive at the final estimate:

1. Jolly-Seber model calculation of large females in carcass survey area.
2. Expansion for adipose fin clipped large females removed for CWT tag analysis.
3. Expansion for large females spawning outside of carcass survey boundaries.
4. Expansion for large males from the Keswick trap data.
5. Expansions for small (separate expansions for males and females).
6. Calculation of adults and grilse based on fork length cut-offs.
7. Addition of winter-run fish that were collected for the LSNFH brood stock.

All of the steps except 4 and 7 above were based solely on survey data. The number of large males (Step 4 above) was determined from the male to female ratios of fish greater than 609 mm fork lengths observed during collections at the Keswick Trap. Step 7 was the number of fish removed from the river for brood stock purposes at LSFNH (these include both spawned and "dead in pond" salmon). The final estimate was calculated by adding the calculated values in steps 6 and 7 above. Table 1 provides the results of the Jolly-Seber model calculation and the subsequent adjustments made to develop the 2005 final winter-run spawner population estimate.

Table 1. Adjustments made to Jolly-Seber model results to determine final winter-run 2005 spawner estimate.

CATEGORY CALCULATION	RESULTS	FACTOR	ADJUSTMENT DESCRIPTION
Jolly-Seber Model Calculation for Large Females	7,205	7,205	This number comes from Jolly-Seber formulas
Large Female Ad-Clipped Fish Adjustment	8,999	1.249	3005 large females were seen / 2406 were not ad-clipped
Number Large Females: Downstream Redds Factor	8,999	1.0000	1968 redds were seen / 1968 were in the survey area
Number Large Males from Keswick Trap Data	5,759	0.6400	144 Large Males / 225 Large Females at Keswick Trap
Total In-River Females (including jills)	9,047	1.0053	Based on Total / Large (3021/3005) Females in carcass data
Total In-River Males (including jacks)	6,683	1.1604	Based on Total / Large (1042/898) Males in carcass data
Fish Removed from In-River by LSNFH	109	109	Number of Salmon taken into LSNFH Hatchery
Final Estimate is	**15,839**		

The 2005 estimate of winter-run salmon spawning in the Upper Sacramento River and collected for brood stock for LSNFH was **15,839**. For fish spawning in the river (not including LSFNH), the Jolly-Seber Model produced an estimate of 7,205 large females based on the mark-recapture methods used in the survey. Appendix Tables 1A through 1D and Appendix 1E provide a summary of the data and calculations used in developing the Jolly-Seber estimate for large females and the expansions for other groups (adult males and grilse). The model's large female number was expanded to account for other large females including adipose fin clipped fish (hatchery), fish downstream of the survey area, and small females. The final in-river total female estimate was 9,047. Large males numbered 5,759, and the total in-river males after expansion for small males numbered 6,683. Personnel from LSNFH retained 109 winter-run for hatchery brood stock purposes.

Carcass Survey Results

Crews handled a total of 11,772 carcasses from 28 April through 2 September 2005. When recaptured fish are not included, a total of 8,771 individual carcasses were handled. Of these, 1,565 were potentially adipose fin clipped (hatchery) fish, 4,758 were tagged and 2,448 were chopped. Another 3,001 carcasses were repeat observations (recaptures-single incident). The overall recapture rate of tagged fish was 63.1%. Table 2 presents a summary of the number of carcasses observed for each data category.

Table 2. Summary of carcasses observed during 2005 winter-run survey.

Category	Non-Fresh Large Female	Non-Fresh Large Male	Fresh Large Female	Fresh Large Male	Non-Fresh Small Female	Non-Fresh Small Male	Fresh Small Female	Fresh Small Male	***TOTAL***
Tagged	1,095	385	2,381	723	4	49	12	109	**4,758**
Chopped	1,728	542	59	45	8	54	0	12	**2,448**
Hatchery	547	146	626	176	2	29	4	35	**1,565**
Recaptured	676	207	1,642	424	2	11	2	37	**3,001**
TOTAL	**4,046**	**1,280**	**4,708**	**1,368**	**16**	**143**	**18**	**193**	**11,772**

Survey Conditions

Water clarity ranged from excellent to poor with 53% of the daily surveys reporting excellent (15 or more feet) visibility. Visibility averaged 13.9 feet, (range: 2 to 17+ feet) with 9.5% of the readings beneath 10 feet. Mean daily river flows from Keswick dam averaged 12,597 cfs (range: 4,877 to 37,697 cfs). Mean water temperature for all the daily survey periods averaged 53.9 ^{o}F (range: 51^{o}F to 59 ^{o}F). Appendix Table 2 presents a summary of environmental data encountered over the survey.

Biological Carcass Data

Biological samples (combinations of tissue, scales and heads) were collected from a total of 2,282 carcasses during the survey (26% of the 8,771 encountered). Most biological data, (origin, sex, length, spawn condition, freshness, and location) was obtained from fresh carcasses (n =

1,560). Non-fresh carcasses (n = 722) were typically sampled during the “slow” workload periods when carcass numbers were low or when a non-fresh carcass with an adipose fin clip was encountered (n = 716). It is important to note that sub-sampling of some biological data, but not adipose fin clip data, occurred during periods with high numbers of carcasses, thus comparisons between clipped (hatchery) carcass numbers and non-clipped (natural) carcass data must be done with care.

Adipose Fin Clipped (Hatchery) Carcasses

On most carcasses encountered without a full and natural looking adipose fin, the head was removed and retained for coded-wire tag (CWT) analysis. Crews encountered 1,565 carcasses that were suspected to be of hatchery-origin during the survey. The heads from 1,552 of these were removed and frozen for analysis. There were 13 carcasses where either the head was lost during removal or the carcass had an adipose fin clip and the head was missing due to predation by birds or otters. The Department’s Ocean Salmon Project dissected the heads from the carcasses for CWT extraction and reading. There were 1,262 CWT’s recovered from the 1,552 heads. Appendix Table 3 provides a summary of the CWT data collected from the survey.

Crews collected heads from 82 carcasses (3 partial and 79 unknown (fin was eaten by otter) that they were unsure of the adipose fin status. Carcasses that were tallied as partial and unknown were re-tallied in the final database (2 partial and 67 unknown) as natural-origin fish if no CWT was detected in the head. After analysis for CWT’s, the survey’s database was adjusted to reflect the results of the CWT findings. Thirteen carcasses were re-labeled as hatchery origin fish based on the finding of a CWT in these uncertain fish (1 partial and 12 unknown), (Appendix Table 3).

The detection of CWT’s was lower (78.9%) for non-fresh adipose fin clipped carcasses (561 of 711) compared to the 84% detection rate of fresh adipose fin clipped carcass heads (699 of 832). This comparison does not include heads which were “lost” either on the boats (n = 13) or during processing (n = 7) or two heads of unknown freshness. The difference between non-fresh and fresh detection rates is consistent with previous winter-run surveys (Killam, 2004, 2006) and is expected given the occasional advanced state of decay of the non-fresh carcasses.

Sex Composition

Data collected on fresh carcasses is more reliable for determining biological characteristics of the population. The decay process can make measuring, sexing and determining spawn condition difficult. For these reasons, the fresh carcass data is used to determine the biological characteristics of the winter-run population, (the data on both fresh and non-fresh carcasses is used to estimate the overall population size). Crews recorded biological data on a total of 4,792 carcasses. Of these, 4,063 were fresh carcasses used to determine the biological characteristics of the population. The sex composition of these was 74.4% female (n = 3,021) vs. 25.6% male (n = 1,042). Table 3 provides a summary of sex composition of the carcass survey’s winter-run population for various categories.

The data from Table 3 shows that males represent only 25.6% of the survey’s sample of fresh carcasses. Previous winter-run surveys (1996-2004) have produced similar results (Appendix

Table 4). Observations by this author, data on other Central Valley salmon races, and the recent increases in the winter-run population suggest male salmon may be leaving the survey area before death, and that consequently the survey may underestimate male numbers. The population calculation methodology for this and previous surveys was designed to eliminate the bias associated with males swimming out of the survey area before death (Killam, 2004, 2006).

Table 3. Winter-run carcass survey sex composition results for various categories.

Category	TOTAL	FEMALE %	Count	MALE %	Count
Total carcasses (non fresh & fresh)	*4,792*	***74.5%***	*3,572*	***25.5%***	*1,220*
Fresh carcasses	4,063	**74.4%**	3,021	**25.6%**	1,042
Natural (unmarked) fresh carcasses	3,259	**74.2%**	2,419	**25.8%**	840
Hatchery (marked) fresh carcasses	804	**74.9%**	602	**25.1%**	202
Large fresh carcasses (>609 mm)	**3,903**	**76.9%**	**3,003**	**23.0%**	**898**
Adult fresh carcasses(F>599, M>669 mm)	**3,876**	**77.6%**	**3,007**	**22.4%**	**869**
Adult Natural fresh carcasses	3,114	**77.3%**	2,408	**22.7%**	706
Adult Hatchery fresh carcasses	762	**78.6%**	599	**21.4%**	163
Grilse fresh carcasses	187	**7.5%**	14	**92.5%**	173
Grilse Natural fresh carcasses	145	**7.6%**	11	**92.4%**	134
Grilse Hatchery fresh carcasses	42	**7.1%**	3	**92.9%**	39

The Department's internal Winter-run Technical Team discusses technical issues regarding winter-run salmon. In 2003 the team agreed that the sex differential on the survey warrants additional study and that the survey data likely under represents large male numbers. The team recommended the use of an alternative source of data to estimate large male numbers. These decisions led in 2003 to the use of the data from the Keswick Trap to determine the sex ratio of large salmon in the population. This method was continued in 2005. Table 4 presents data from winter-run salmon sampled at the Keswick Trap in 2005.

Table 4. Summary of characteristics of winter-run salmon trapped at the Keswick Fish Trap.

Category	Total	FEMALE %	Count	MALE %	Count
All winter-run Salmon	395	**57.0%**	225	**43.0%**	170
Natural (unmarked)	166	**54.2%**	90	**45.8%**	76
Hatchery (marked ad-clip)	229	**59.0%**	135	**41.0%**	94
Adults (F>599, M>669 mm)	**348**	**61.8%**	**215**	**38.2%**	**133**
Large (all fish > 609mm)	**369**	**61.0%**	**225**	**39.0%**	**144**
Large Natural	156	**57.7%**	90	**42.3%**	66
Large Hatchery	213	**63.4%**	135	**36.6%**	78
Small (all fish < 610 mm)	26	**0.0%**	0	**100.0%**	26
Small Natural	10	**0.0%**	0	**100.0%**	10
Small Hatchery	16	**0.0%**	0	**100.0%**	16

One hundred-nine of the winter-run trapped at the Keswick Trap (n = 395) were retained by Service personnel for brood stock purposes at LSNFH. Fourteen of these died prior to spawning while 95 were spawned successfully. The other 286 winter-run were floy-tagged and released into the Sacramento River. Thirty-four of these floy-tagged winter-run were recovered by crews during the carcass survey.

The ability to phenotypically determine the correct sex of winter-run salmon is dependent upon the sexual maturation of the fish and the experience of the biologist making the determination. In 2003 and 2004 phenotypic sex identification was used to determine the sex ratio for the winter-run population based on large fish at the Keswick Trap, (Killam, 2004, 2006). In 2005 phenotypic identification of the Keswick Trap salmon was conducted similar to previous years, and was augmented with the addition of a genetic sex "test". Most salmon (475 of 496) caught at the Keswick Trap (non-winter-run fish included) in 2005 were sampled for a male-specific genetic marker that was used to compare phenotypic and genetic sex "calls". The comparison between these calls was also supplemented by data from the carcass survey that was available for the 34 floy-tagged Keswick released carcasses that were recovered in the river. Data resulting from Keswick trap operations and the carcass survey indicated that the genetic sex test accurately identified sex in 95.9% of the salmon tested while phenotypic testing was slightly less accurate (92.4%) (Robert Null, Service personal communication).

Because of the apparent tendency of large males to leave the system before death the Keswick Trap data on the sex ratios of large fish was used as an adjustment to estimate the number of large males in the 2005 winter-run population. Large males (n = 5,759) were calculated to represent 36.3% of the winter-run in the overall in-river population in Table 1. The carcass survey data estimate (if used) would have been only 22.1%, and reinforces the conclusion of the Department's Winter-run Team that the Keswick Trap (in spite of the gender-related difficulties) appears to better reflect the overall sex ratio of the large fish in the winter-run population.

Age Composition

The age composition of the winter-run population was determined by the fresh carcass data from the survey. Snider et al. 2002 determined that utilizing length frequency data from the survey provided an adequate means of characterizing the age structure of the winter run population in comparison to scale ageing and known age analysis from CWT's of hatchery fish.

In 2005 the Department utilized length frequency data to determine age composition of the population based on measurement of 4,063 fresh carcasses. Figures 2 and 3 present the data from the survey used to determine the 600 mm fork length cut-off for females and a 670 mm fork length cut-off for males to distinguish between 2-year-old grilse and 3 + year-old adults. It should be noted that the visual determination of the fork length cut-off does not affect the overall population estimate because the estimate is built around a 610 mm cut-off for large or small fish. The fork length cut-off does adjust the proportions (within the overall estimate) of the male and female grilse and adult numbers and is important for calculation of cohort replacement rates and has importance to regulatory agencies for winter-run management issues.

The overall age composition of the 2005 winter-run population based upon carcass survey data was 57.2% adult female, 35.5% adult male, 0.3% grilse female and 7.0% grilse male. These numbers reflect the 109 fish retained at LSNFH in addition to the 15,730 estimated in-river fish. Calculations for these age groups are presented in Appendix 1-E.

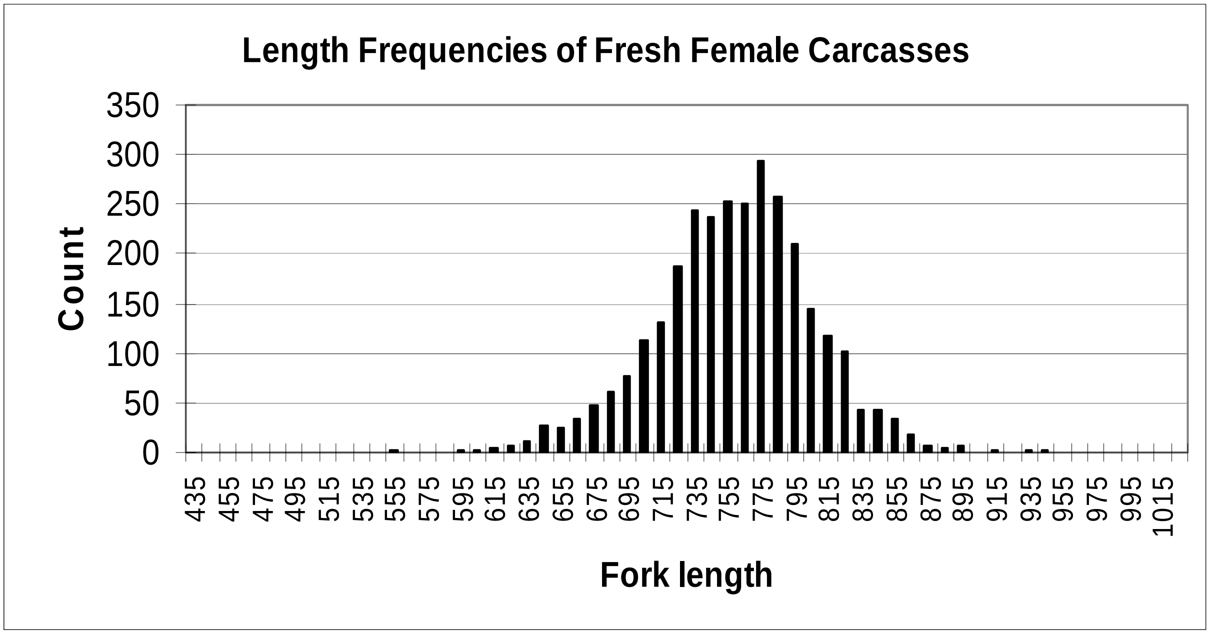

Figure 2. Length frequencies of fresh female carcasses (n = 3,021) measured during the 2005 Winter-run carcass survey. A fork length cut-off of 600 mm was determined.

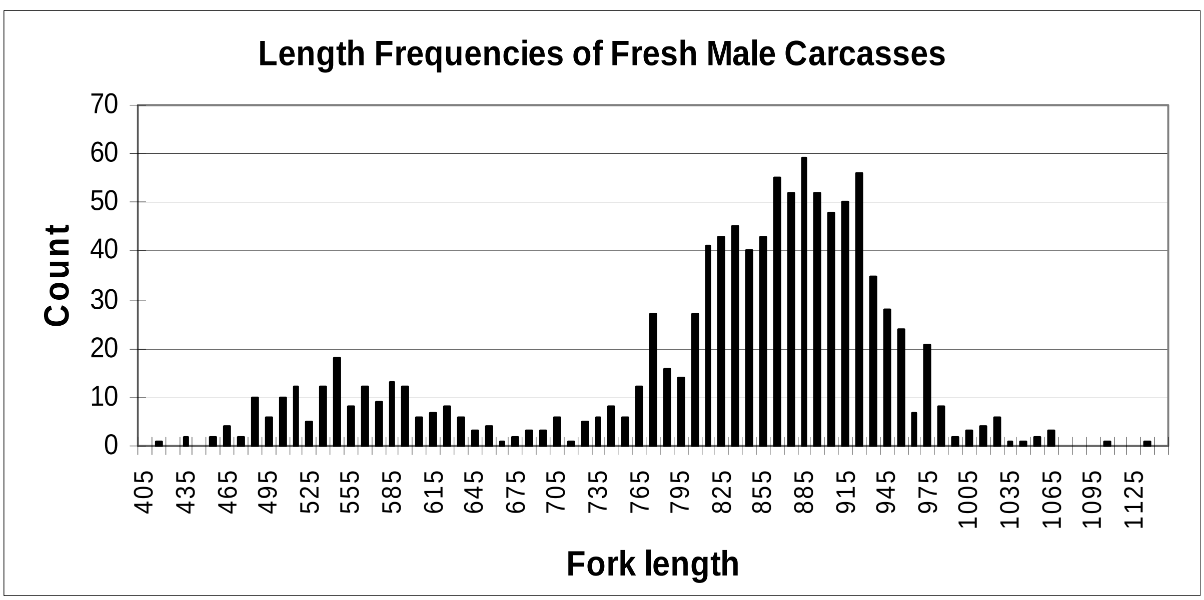

Figure 3. Length frequencies of fresh male carcasses (n = 1,042) measured during the 2005 Winter-run carcass survey. A fork length cut-off of 670 mm was determined.

Crews collected scale samples from 178 male carcasses between 500 and 850 mm fork length. Once the scale reading is complete the data will be used to compare the length frequency cut-off determined in Figure 3 to the cut-off obtained from the scales. These scales have not yet been analyzed as of this report writing.

Spawning Success

Examination of 3,021 fresh female carcasses (Table 3) caught by crews revealed that only 2.2% (n = 66) were classified as unspawned based on egg retention and deteriorated caudal fins from digging redds. The category of “partial” spawned fish in previous winter-run surveys was eliminated due to the subjective nature of the category. If the caudal fin was worn from digging and few or no eggs were present when examined then the carcass was tallied as spawned. If eggs were present in the carcass (a handful or greater) then the carcass was tallied as unspawned.

Temporal Distribution

The survey began in late-April, immediately following the Department’s 2005 Late-fall-run Chinook Salmon (late-fall-run) survey. There is some temporal overlap with the late-fall run but typically by mid-April there are very few fresh late-fall-run carcasses encountered. In 2005 we encountered only seventeen fresh carcasses in two complete late-fall-run survey periods in mid-to-late April. The scarcity of fresh carcasses from mid-April to mid-May indicates that there is a good (but not complete) temporal separation between the winter and late-fall runs. Most fresh carcasses were tissue sampled in April and the results of genetic testing for these suspected late-fall-run fish will be available in the Service’s Upper Sacramento River Winter Chinook Salmon Carcass Survey 2005 Annual Report, (available in early 2007).

Table 5 presents the percentages for large female and male carcasses, small, and adipose fin clipped carcasses encountered by period during the survey. Collection of carcasses peaked during survey period 27 or 15-17 July. The temporal distribution by month for all carcasses was approximately as follows: April-May-2%, June-28%, July-58%, August-September-12%. Spawning salmon die and become available as carcasses approximately 2 weeks after the onset of spawning (Snider and Vyverberg 1995). Table 5 reveals that peak spawning (two weeks prior to the peak number of carcasses) occurred from approximately mid-June to early-July.

Spatial Distribution

The spatial distribution of sampled carcasses (n = 4,792) is presented by river mile and by river section in Table 6. River mile 296 contained 33.4% of the carcasses sampled during the survey. Turtle Bay is located near RM 296.5 and is a wide shallow borrow pit that was used to provide aggregate for the construction of Shasta Dam. The hydrological pattern of the Sacramento River in Redding makes Turtle Bay a stopping point for many of the carcasses washing out of the river from upstream. Table 6 also reveals that the majority of fresh sampled carcasses (n = 2,174) were collected in Section 2 of the survey.

Table 5. The temporal distribution of various winter-run carcass categories from the 2005 carcass survey by tagging period.

Period	Large females	Large males	Small combined	Ad-Clips	ALL % By Period	ALL % Cumulative	Dates
1	5	1	0	3	0.1%	0.1%	Apr 28 - 30
2	0	3	0	6	0.1%	0.2%	May 1 - 3
3	1	2	0	4	0.1%	0.3%	May 4 - 6
4	2	2	0	4	0.1%	0.4%	May 7 - 9
5	4	1	0	1	0.1%	0.4%	May 10 - 12
6	4	2	0	4	0.1%	0.6%	May 13 - 15
7	0	1	0	1	0.0%	0.6%	May 16 - 18
8	5	3	0	3	0.1%	0.7%	May 19 - 21
9	19	8	0	2	0.3%	1.0%	May 22 - 24
10	14	13	0	2	0.3%	1.4%	May 25 - 27
11	16	15	1	5	0.4%	1.8%	May 28 - 30
12	23	16	1	7	0.5%	2.3%	May 31 - 2
13	24	33	3	15	0.9%	3.2%	Jun 3 - 5
14	38	34	0	12	1.0%	4.1%	Jun 6 - 8
15	72	34	0	37	1.6%	5.8%	Jun 9 - 11
16	89	59	3	49	2.3%	8.0%	Jun 12 - 14
17	104	71	5	42	2.5%	10.6%	Jun 15 - 17
18	203	92	5	63	4.1%	14.7%	Jun 18 - 20
19	207	99	8	53	4.2%	18.9%	Jun 21 - 23
20	269	107	9	73	5.2%	24.1%	Jun 24 - 26
21	297	113	13	93	5.9%	30.0%	Jun 27 - 29
22	327	**136**	17	80	6.4%	36.4%	Jun 30 - 2
23	326	116	12	79	6.1%	42.5%	July 3 - 5
24	295	94	16	91	5.7%	48.1%	July 6 - 8
25	333	126	23	84	6.5%	54.6%	July 9 - 11
26	304	83	15	64	5.3%	59.9%	July 12 - 14
27	**357**	96	**23**	114	**6.7%**	66.6%	July 15 - 17
28	289	74	11	106	5.5%	72.1%	July 18 - 20
29	356	74	20	**119**	6.5%	78.6%	July 21 - 23
30	278	73	19	116	5.5%	84.1%	July 24 - 26
31	249	25	11	66	4.0%	88.1%	July 27 - 29
32	209	35	9	70	3.7%	91.8%	July 30 - 1
33	152	22	6	34	2.4%	94.2%	Aug 2 - 4
34	114	12	7	20	1.7%	96.0%	Aug 5 - 7
35	91	11	5	17	1.4%	97.4%	Aug 8 - 10
36	59	5	4	6	0.8%	98.2%	Aug 11 - 13
37	52	1	1	12	0.8%	99.0%	Aug 14 - 16
38	21	1	1	3	0.3%	99.3%	Aug 17 - 19
39	28	1	0	2	0.4%	99.6%	Aug 20 - 22
40	13	0	0	3	0.2%	99.8%	Aug 23 - 25
41	10	1	0	0	0.1%	100.0%	Aug 26 - 28
42	2	0	0	0	0.0%	100.0%	Aug 29 - 31
43	2	0	0	0	0.0%	100.0%	Sep 1 - 3
TOTALS	**5,263**	**1,695**	**248**	**1,565**	**8,771**		

Table 6. The spatial distribution of sampled winter-run carcasses from the 2005 carcass survey by river mile and survey section.

River Mile	Adult Female	Adult male	Grilse	Ad-Clips	All Carcasses	Section
274	0.0%	0.0%	0.0%	0.2%	0.1%	4
275	0.0%	0.1%	0.0%	0.1%	0.0%	4
276	0.0%	0.3%	0.0%	0.1%	0.1%	4
277	0.0%	0.4%	0.0%	0.4%	0.2%	4
278	0.0%	0.3%	0.0%	0.2%	0.1%	4
279	0.1%	0.0%	2.1%	0.4%	0.3%	4
280	0.0%	0.4%	0.7%	0.4%	0.2%	4
281	0.0%	1.1%	1.4%	0.4%	0.4%	4
282	0.1%	0.4%	1.4%	0.4%	0.3%	4
283	0.0%	0.3%	2.1%	0.3%	0.2%	4
284	0.1%	0.7%	1.4%	0.1%	0.3%	4
285	0.0%	0.3%	0.0%	0.4%	0.2%	4
286	0.1%	0.3%	1.4%	0.4%	0.3%	4
287	0.3%	2.1%	1.4%	0.7%	0.8%	4
288	1.9%	5.6%	11.0%	3.6%	3.3%	4 - 3
289	0.7%	2.1%	2.1%	1.5%	1.2%	3
290	0.1%	1.0%	0.7%	0.4%	0.4%	3
291	1.2%	2.6%	2.1%	1.0%	1.4%	3
292	0.7%	1.4%	4.1%	1.6%	1.2%	3
293	0.4%	1.9%	0.7%	0.9%	0.8%	3
294	4.8%	8.0%	13.0%	4.2%	5.3%	3
295	8.1%	10.6%	15.8%	8.6%	8.9%	3
296	36.3%	32.3%	19.2%	30.8%	33.4%	3 -- 2
297	13.2%	9.4%	8.2%	9.0%	11.1%	2
298	9.3%	8.0%	4.8%	9.2%	8.9%	2 -- 1
299	11.6%	6.4%	4.8%	14.6%	11.6%	1
300	5.5%	3.3%	1.4%	6.1%	5.2%	1
301	5.2%	0.4%	0.7%	4.0%	4.0%	1
TOTALS	**2,382**	**699**	**146**	**1,563**	**4,790**	
Section	**Adult Female**	**Adult male**	**Grilse**	**Ad-Clips**	**All Carcasses**	**Section**
1	679---28.5%	105---15.0%	14---9.6%	490---31.3	1288--26.9%	**1**
2	1208---50.7%	292---41.8%	41---28.1%	633---40.4%	2174--45.4%	**2**
3	470---19.7%	252---36.1%	73---50.0%	369---23.6%	1164--24.3%	**3**
4	25---1.0%	50---7.2%	18---12.3%	73---4.7%	166--3.5%	**4**

*Adult and grilse categories do not include any ad-clip carcasses.

The results from Table 6 support the findings that male salmon may be leaving the system before death. The percentage of adult male and grilse (mostly males) increases in section 3 (further downstream than sections 1 and 2) in comparison to adult females. This situation is reversed in section 1, and along with the spawning distribution data from aerial redd counts in Table 7, supports the hypothesis that female salmon guard their redd's from other spawners until weakness or death overcome them, while male salmon move downstream with the current until they die. It should also be noted that carcass distribution does not accurately reflect spawning distribution since carcasses tend to collect in slow moving water. Spawning distribution is determined independently from the carcass survey through the aerial redd survey data found in Table 7.

Winter-run spawning distribution is determined by aerial redd surveys conducted weekly by helicopter or plane from late April until August. Aerial redd flights are used to provide an index of spawning distribution rather than a complete count. Riparian vegetation, and cloudy or deep water prevent viewing of all areas, so the total redd numbers are less than the total female spawner estimate. Table 7 provides a summary of the eleven winter-run aerial redd flights made in 2005. All of the new redds observed were located within the carcass survey boundaries. The majority (52.3%) of the winter-run redds counted (n = 1,968) were located upstream of the A.C.I.D. Dam in Redding (RM 298) which also represents Section 1 of the carcass survey. This indicates that the majority of winter-run spawned as far upstream as possible (Keswick Dam at RM 301 is impassable). The spawning distribution of winter-run can vary widely from year-to-year. In 2004 only 16% of redds were above A.C.I.D. Dam, while in 2003 the same section held over 65% of the winter-run redds (Killam, 2004, 2006). The reasons for the redd distribution shifts from year-to-year are unknown. Appendix Table 5 provides a summary of historical winter-run aerial redd distributions from 1982 through the present for all years surveyed.

Table 7. Summary of eleven aerial redd flights for the 2005 winter-run spawners.

New Redds	% Distribution	LOCATION	RIVER MILE
1,029	52.3%	Keswick Dam to A.C.I.D. Dam	RM 302-298
701	35.6%	A.C.I.D. Dam to Highway 44 Bridge	RM 298-296
234	11.9%	Highway 44 Bridge to Airport Rd. Bridge	RM 296-284
4	0.2%	Airport Rd. Bridge to Balls Ferry Bridge	RM 284-276
0	0.0%	Balls Ferry Bridge to Battle Creek	RM 276-271
0	0.0%	Battle Creek to Jellys Ferry Bridge	RM 276-266
0	0.0%	Jellys Ferry Bridge. to Bend Bridge	RM 266-257
0	0.0%	Bend Bridge to Red Bluff Diversion Dam	RM 257-242
0	0.0%	Red Bluff Diversion Dam to Tehama Bridge	RM 242-229
0	0.0%	Tehama Bridge To Woodson Bridge	RM 229-218
1,968	**100%**	**TOTALS**	

Disc Tagging Data

During the survey crews placed individually numbered disc tags on 1,476 fresh carcasses. Crews subsequently recovered 897 (60.8%) of these at least once. Since these disc-tagged carcasses were not chopped upon recapture many of these, (n = 564), were recaptured multiple times during subsequent survey periods. A summary of the disc tag results is presented in Table 8. In order to avoid conflicts with the mark-recapture methodology used by the Jolly-Seber formulas the recaptured disc-tagged carcasses were only counted once (on the first incidence of recapture) as part of the mark-recapture study. Subsequent multiple recaptures (in later periods) of disc-tagged carcasses were tallied separately. This allowed analysis for both the Jolly-Seber population estimate and the survival characteristics of winter-run carcasses.

Survival of carcasses (from period to period) in a mark-recapture study is the length of time a carcass is available for crews to encounter them. Factors affecting carcass survival include river flow, depth, and visibility, (e.g. a carcass that is too deep to observe has not "survived"). The decay of carcasses also directly influences the survival from one period to the next. The survival range of disc-tagged recaptured carcasses in 2005 was from 2 to 41 days. Of the total (n = 897) carcasses that were recaptured most were recaptured only once (n = 333, 37.1%) but some were recaptured up to a total of 9 times (Table 8). The average time between the initial tagging date and the first recapture date was 6.1 days or 2 survey periods, (range of 2 to 32 days). The average time between the initial tagging date and the last recapture date was 12.7 days or 4 survey periods, (range of 2 to 41 days).

The use of GPS data on the winter-run carcass survey allows the calculation of distances traveled and spatial distribution in a great degree of detail. Table 8 provides some information on distance traveled for the disc-tagged carcasses. The GPS methodology that was used for calculating distances is explained in Appendix Table 6. Table 8 provides some interesting information with regards to distance traveled comparisons between adult males and females. The average first encounter distance traveled for adult females was 1,308 meters while the same distance for recaptured adult male carcasses was 2,165 meters. This is similar to the data from the 2004 survey (Killam, 2006). The reasons for these differences remains unclear but is thought to be related to the fact that females are found predominantly in the upper river sections and males in the lower sections, and not to any physiological differences in male and female carcasses.

Table 8. Summary of disc tagged winter-run carcasses showing recapture information including counts, days and distances traveled for a variety of categories.

Count of Times Recapured in later survey periods	Count of All Tagged fish	Count of adult female	Percent of adult female	Count of adult male	Percent of adult male	Count of grilse	Percent of grilse
0	579	347	33.9%	186	49.2%	46	63.0%
1	333	241	23.5%	78	20.6%	14	19.2%
2	229	174	17.0%	48	12.7%	7	9.6%
3	147	113	11.0%	31	8.2%	3	4.1%
4	80	62	6.0%	18	4.8%	3	4.1%
5	54	44	4.3%	7	1.9%	0	0.0%
6	37	29	2.8%	8	2.1%	0	0.0%
7	11	10	1.0%	1	0.3%	0	0.0%
8	5	4	0.4%	1	0.3%	0	0.0%
9	1	1	0.1%	0	0.0%	0	0.0%
TOTALS	**1,476**	**1,025**		**378**		**73**	
Data From The Recovered Disc Tagged Carcasses (rows 1-9 above)							
Recaptured Tag Totals	**897**	**678**		**192**		**27**	
Avg. First Distance *	1,464	1,308		2,165		323	
Avg. Maximum Distance	1,888	1,696		2,766		430	
Avg. Days to First Recap	6.1	6.3		5.7		5.0	
Avg. Days to Last Recap	12.7	13.0		12.2		9.3	
* all distances in meters and are from original tagging GPS points to recapture GPS points.							

The geomorphology of the river in the lower sections may facilitate movement better than the upper sections. This is the second year of GPS data collection on winter-run carcasses and as future data is collected it may provide less speculative results.

Other Winter-Run Population Estimates

The Jolly-Seber model was used to calculate the Department's "official" estimate of 15,839 for the 2005 winter-run escapement. Based upon discussions in the Department's internal Winter-run Project Work Team the winter-run estimate based on the Jolly-Seber model was deemed most accurate. Other estimates include those based on RBDD counts, and the calculation of the Peterson Model using the carcass survey data. The RBDD and Peterson estimates are used to provide trend information on winter-run since the Jolly-Seber estimate was not available prior to 2000 (Snider et al. 2001). The Schaefer estimate was not developed in this report to simplify reporting results. The Peterson estimate was 13,549 based on all female adults with adjustments similar to the Jolly Seber estimate methods. The Peterson method in some past years was based only on fresh female carcasses (Peterson fresh only = 14,425), but it is recommended to use the estimate based on fresh and non-fresh female carcasses for comparative purposes to the Jolly-Seber estimate, (Killam, 2004).

Prior to 2001, the Department used the results of the ladder counts and fish trapping data from the RBDD to produce the winter-run escapement estimate. The RBDD estimate for 2005 was **5,299**. In 2005 unusually heavy rain events in May necessitated the raising of the dam gates at RBDD to facilitate flood water passage. This likely resulted in a much lower RBDD estimate than would have been determined during a normal seasonal precipitation pattern for the Upper Sacramento River Basin. The RBDD historical winter-run data is provided in Appendix Table 7.

Of special interest are 4 individual winter-run hatchery adipose fin clipped salmon that were collected outside of the carcass survey, and identified through coded-wire tag identification. One hatchery winter-run salmon carcass was collected on Butte Creek a downstream tributary to the Sacramento River having fall and spring-run Chinook populations, but not known to normally attract winter-run. The carcass was an adult male collected on 5 July, 2005 upstream of the Centerville powerhouse, (Tracy McReynolds, Department, personal communication). The remaining three carcasses were collected during the Department's Fall-Run Chinook Salmon Mainstem Sacramento River carcass survey between 30 November and 21 December, 2005, and were fresh adults, two of which had apparently spawned (male and female brood year 2002, i.e. 3-year-olds), while a third female was unspawned and of adult length (748 mm) but from the 2003 brood year. These three carcasses are being genetically tested (scales) for unusual characteristics by the Service; however, the results of these tests were not yet available at the time of this report writing.

Hatchery Contributions

More details of the hatchery contributions will be available in the Upper Sacramento River Winter Chinook Salmon Carcass Survey 2005 Annual Report (Service). Table 9 provides the estimated hatchery and natural components of the winter-run population as determined by analysis of the mark-recapture survey data. Estimates of winter-run hatchery contributions developed in Table 9 may be different from those in the Service's annual report due to calculation differences.

The escapement estimate for hatchery (LSNFH) winter-run was determined by multiplying the results of the in-river escapements for the four categories (female adult, male adult, female grilse, and male grilse) to the ratio of adipose fin-clipped to not-clipped carcasses present in the fresh carcass sample from the survey. Additionally an average adjustment of 0.46% and 0.032% was applied to ad-clipped adult totals and grilse respectively to account for the number of hatchery fish released that did not receive an ad-clip (Robert Null, Service, personal. comm.) This adjustment factor is an average of brood years and release groups.

Table 9. Summary of the 2005 hatchery and natural origin winter-run salmon numbers for selected categories. Hatchery data is based on average mark loss rates.

	Hatchery Component		Natural Component		OVERALL
CATEGORY	In-River	Into LSNFH	In-River	Into LSNFH	
Number of adult females	1,835	4	7,170	52	9,061
Number of adult males	1,066	0	4,507	49	5,622
Number of grilse females	9	0	33	0	42
Number of grilse males	250	0	859	4	1,114
Totals	**3,161**	**4**	**12,569**	**105**	**15,839**

RECOMMENDATIONS

1. The mark-recapture carcass study should be continued to provide important information on the status of winter-run populations.

2. The sampling/handling winter-run salmon at the ACID Dam in Redding should be implemented to provide an alternative to the logistical problems of trapping salmon at Keswick Dam.

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APPENDIX

Appendix Table 1-A. The Jolly-Seber Model variables and formulas defined. Data and variables shown in Appendix Tables 1B-1E.

VARIABLE EXPLANATIONS	
T(i)	The number of carcasses **T**agged in period i
E(i)	The total number of carcasses **E**xamined in period i including tagged, chops and recaptures.
R(i)	The sum of all recaptures in a single period i regardless of which survey period it was tagged in. (**R**ow sums)
C(i)	The sum of all recaptures over all periods for a survey period i. (**C**olumn sums)
K(i)	Sum of all recaptures made later than period i of carcasses tagged before period i
b(i)	The estimate of the number of tags available for recapture in each survey period
S(i)	The survival rate of tagged carcasses from period i to period i + 1
N(i)	The estimate of the total number of carcasses in the population immediately prior to each survey
B(i)	The number of carcasses that joined the population between periods i and i+1: Does not account for carcasses leaving population between surveys like Di
N(1)	The number of carcasses in the population at the start of the survey period number 1
D(i)	The number of carcasses that joined the population between periods i and i + 1 : Accounts for carcasses leaving population between survey periods.
ESTIMATE =	The sum of N1 and all the Di's
bi = (Ti + 1)* Ki / (Ci + 1) + Ri	
Si = b_{i+1} / (bi - Ri + Ti)	
Ni = bi (Ei + 1) / (Ri + 1)	**Note that N1 = E1 + (N2- T1 * S1) / SQRT (S1)**
Bi = N_{i+1} - Si (Ni - Ei + Ti)	
Di = Bi / (SQRT Si)	

Appendix Table 1-B. Summary of carcass mark-recapture results for 2005 Winter-run large female carcasses.

SURVEY PERIOD	T(i) NUMBER TAGGED	NUMBER CHOPPED	E(i) TOTAL EXAMINED	R(i) NUMBER RECAPTURED
1	5	0	5	0
2	0	0	1	1
3	1	0	1	0
4	1	1	2	0
5	3	1	5	1
6	1	3	4	0
7	0	0	0	0
8	4	1	5	0
9	12	7	20	1
10	11	3	21	7
11	12	4	20	4
12	20	3	28	5
13	24	0	39	15
14	27	11	46	8
15	60	12	92	20
16	83	6	119	30
17	89	15	132	28
18	179	24	258	55
19	172	35	288	81
20	235	34	384	115
21	214	83	463	166
22	251	76	493	166
23	258	68	491	165
24	223	72	447	152
25	260	73	481	148
26	219	85	423	119
27	227	130	484	127
28	195	94	417	128
29	185	171	512	156
30	143	135	401	123
31	125	124	365	116
32	86	123	346	137
33	62	90	215	63
34	34	80	162	48
35	25	66	135	44
36	10	49	90	31
37	10	42	75	23
38	3	18	36	15
39	3	25	36	8
40	1	12	21	8
41	2	8	13	3
42	1	1	2	0
43	0	2	3	1
TOTALS	**3,476**	**1,787**	**7,581**	**2,318**

Appendix Table 1-C. The recapture matrix for the 2005 winter-run large female carcasses.

	RECAPTURE MATRIX OF TAGGED FISH MARKED IN SURVEY PERIOD (columns) and RECOVERED DURING RECOVERY PERIODS (rows)																																									
Recovery Period	**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**	**38**	**39**	**40**	**41**	**42**	**43**
1	1																																										
2		0																																									
3			0																																								
4				1																																							
5					0																																						
6						0																																					
7							0																																				
8								1																																			
9								2	5																																		
10									1	3																																	
11	1										4																																
12											4	11																															
13											1	1	6																														
14									0		1	2	4	13																													
15									1						29																												
16											1			1	1	25																											
17											0		3	1	2	11	38																										
18													1	1	2	4	7	66																									
19										1		1	0	2	2	4	7	20	78																								
20												1		0	3	6	5	19	17	115																							
21													1		2	0	1	12	13	28	109																						
22															0	5		3	5	11	21	120																					
23															1	1	2	5	8	6	7	13	109																				
24																1	1	2	0	3	6	10	19	106																			
25																		0		1	1	6	6	10	95																		
26																		1	1	0	0	2	13	15	27	68																	
27																			1	1		2	3	5	14	20	82																
28																			1	1	0	4	11	3	9	8	26	93															
29																			1	3		1	1	3	10	11	9	9	75														
30																						1	1	5	5	4	7	10	21	62													
31																							2	4	6	8	9	9	14	21	64												
32																								2	1	1	4	3	4	6	10	32											
33																								1	2	2			8	1	3	10	21										
34																								1	2		3	5	3	5	5	4	7	9									
35																													3	1	2	2	6	3	14								
36																								1	1	1		1	1		2	3	1	1	5	6							
37																												2	1	3	1	1	1	2			4						
38																													1			2	2	1		2		0					
39																																1	0	3	1	1	1		1				
40																																					1	2		0			
41																																									0		
42																																					1					0	
C(i) Sums	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**7**	**4**	**11**	**16**	**15**	**18**	**42**	**57**	**61**	**128**	**125**	**169**	**144**	**159**	**165**	**156**	**172**	**123**	**140**	**132**	**131**	**99**	**87**	**55**	**38**	**19**	**20**	**9**	**7**	**2**	**1**	**0**	**0**	**0**	**0**

Appendix Table 1-D. The Jolly-Seber Model calculations for the 2005 Winter-run large female carcasses.

JOLLY-SEBER CALCULATIONS							
i	K(i)	b(i)	S(i)	N(i)	B(i)	N(1)	D(i)
1			0.4000	10	-2	5	-3
2	1	2.0	2.0000	2	2		1
3	1	2.0	0.3333	4	2		3
4	1	1.0	2.5000	3	10		6
5	1	5.0	0.2857	15	6		12
6	1	2.0	0.3333	10	-1		-2
7	1	1.0	1.2500	1	6		6
8	1	1.3	1.1190	8	54		51
9	3	5.9	0.8415	62	-6		-7
10	3	14.2	0.3984	39	19		30
11	3	7.3	1.0569	30	54		53
12	9	16.1	0.9842	78	8		8
13	10	30.6	0.8341	77	121		133
14	17	33.1	0.7930	173	61		68
15	15	41.3	0.8502	183	139		151
16	27	69.1	0.8951	267	294		311
17	56	109.3	0.8310	501	274		300
18	62	141.5	0.8687	654	313		336
19	109	230.7	0.8711	813	323		346
20	119	280.2	0.8668	930	287		308
21	122	346.9	0.8192	964	371		410
22	100	323.5	0.7629	957	378		433
23	94	311.7	0.7529	924	372		429
24	107	304.7	0.8558	892	468		506
25	115	321.5	0.9621	1040	686		699
26	168	417.1	0.7585	1474	523		601
27	164	392.2	0.7870	1486	288		325
28	176	387.4	0.8147	1255	368		407
29	152	370.2	0.8853	1210	364		387
30	160	353.4	0.8590	1146	241		260
31	143	320.8	0.8536	1003	56		61
32	93	281.5	0.8691	708	287		308
33	85	200.3	0.8994	676	126		133
34	75	179.3	0.6409	596	20		25
35	50	105.9	0.8504	320	32		34
36	39	73.9	1.0846	210	41		39
37	25	57.4	0.8488	182	-12		-13
38	17	37.7	1.1688	87	60		56
39	11	30.0	0.6400	123	-19		-23
40	4	16.0	0.5714	39	7		9
41	1	5.1	0.5793	18	2		2
42	1	2.4	2.0000	6	3		2
43		6.0		12			
				Large Female Estimate =			**7205**

Appendix 1-E. Calculations and adjustments used for determining the entire winter-run spawner population based on the Jolly-Seber estimate of large females from the carcass survey.

The Jolly-Seber model was applied to only large female carcasses (> 609mm) encountered. The model estimated 7,205 large females in the tag and recapture survey. Adjustments to this number result in the overall escapement estimate (15,839) for 2005 and are shown in Table 1.

Adult Females

Adipose fin-clipped large female carcasses were not included in the mark-recapture study since their heads were removed for CWT analysis. Adipose fin-clipped females are accounted for by expanding the estimated number of fresh large females based on the number of fresh large natural (3,005) and hatchery (599) females. An adjustment factor of 1.249 (3,005 / 2,406) is multiplied by Jolly-Seber estimate of natural large females (7,205) to arrive at the total number of large females within the carcass survey area (8,999). Next, the fish that spawned outside of the survey area are accounted for. The number of redds outside of the survey area in 2005 was zero out of a total 1,968 redds (Table 7), so no adjustment is necessary in 2005. The fresh carcass database was used to generate a total female number of 9,047 based on the proportions of large to small females in the database. The length frequency chart (Figure 2) was utilized to establish a female fork length cut-off of 600 mm to distinguish adults (3 + years) from 2-year-old grilse. The total female number (9,047) was subsequently multiplied by the database's proportion of total (3,021) to adult (3,007> 599 mm) female carcasses to estimate the in-river adult females, (9,005). In addition, LSNFH retained 56 adult females, (Table 9), so the 2005 estimate of escapement for adult females is **9,061.**

Adult Males

The number of large males was derived from data from the Keswick Trap. Large salmon data from Keswick Trap (Table 4) reported 369 large fish, (225 females and 144 males). No adjustment for males outside of the carcass survey area was necessary since these were already accounted for in calculating the female total. The adjustment factor generated to produce the final estimate was 0.6400 (144 / 225) and was multiplied by 8,999 to generate an estimate of **5,759** large in-river males. The length frequency chart (Figure 3) was utilized to establish a male fork length cut-off of 670 mm to distinguish adults (3 + years) from 2-year-old grilse. The fresh carcass database was used to generate a total male number of 6,683 based on the proportions of large to small males in the database. The total male number (6,683) was subsequently multiplied by the database's proportion of total (1,042) to adult (869> 669 mm) male carcasses to estimate the adult males (5,573) in-river. The LSNFH retained 49 adult males so the 2005 total estimate for adult males is **5,622**.

Grilse Females (Jills)

To estimate the total number of female grilse the adult female in-river estimate (9,005) was subtracted from the total female estimate (9,047) (Table1) resulting in 42 in-river female grilse (jill). No jills were retained at LSNFH so the 2005 total estimate is **42** female grilse.

Grilse Males (Jacks)

To estimate the total number of male grilse the adult male in-river estimate of 5,573 was subtracted from the total male estimate of 6,683 to get a male grilse (jack) estimate of 1,110. Four jacks were retained at LSNFH so the 2005 total estimate is **1,114** male grilse.

Appendix Table 2. Summary of the measured environmental conditions encountered during each day of the 2005 winter-run Chinook carcass survey.

Date	Water Temp.	Visibility (ft)	Weather	Flow (cfs)	max Air temp.
4/28/2005	57	9.5	Partly Cloudy	5,082	75
4/29/2005	54	12.5	Partly Cloudy	4,877	72
4/30/2005	52	12.5	Partly Cloudy	5,090	73
5/1/2005	56	12	Clear	5,091	75
5/2/2005	54	12	Clear	5,418	80
5/3/2005	53	14	Partly Cloudy	5,811	79
5/4/2005	55	10	Rain	5,588	71
5/5/2005	53	8.5	Rain	6,010	67
5/6/2005	51	11.5	Rain	6,037	67
5/7/2005	52	10	Cloudy	6,045	70
5/8/2005	51	7	Rain	6,045	58
5/9/2005	51	4.5	Rain	7,067	59
5/10/2005	54	5.5	Clear	11,618	68
5/11/2005	52	8	Clear	16,017	83
5/12/2005	52	8	Partly Cloudy	19,735	84
5/13/2005	55	8.5	Partly Cloudy	19,592	84
5/14/2005	53	9	Clear	19,801	87
5/15/2005	53	9.5	Rain	19,789	71
5/16/2005	54	11.5	Clear	10,220	73
5/17/2005	52	**2**	Rain	37,697	57
5/18/2005	51	5.5	Rain	29,149	60
5/19/2005	53	6	Partly Cloudy	25,105	71
5/20/2005	53	10.5	Clear	20,390	77
5/21/2005	53	12.5	Clear	20,149	84
5/22/2005	56	8	Clear	20,176	86
5/23/2005	54	13.5	Clear	20,086	89
5/24/2005	53	16	Clear	9,200	93
5/25/2005	55	13	Clear	14,449	99
5/26/2005	53	16	Clear	14,602	95
5/27/2005	51	16	Clear	14,365	94
5/28/2005	53	13.5	Partly Cloudy	14,380	77
5/29/2005	51	16	Cloudy	14,273	77
5/30/2005	51	16.5	Clear	12,901	91
5/31/2005	54	15	Clear	12,971	93
6/1/2005	52	14.5	Clear	12,872	84
6/2/2005	51	14.5	Clear	12,602	84
6/3/2005	54	14	Clear	11,881	92
6/4/2005	53	>16	Clear	11,915	88
6/5/2005	51	14	Clear	11,956	78
6/6/2005	53	11	Cloudy	11,530	68
6/7/2005	52	13	Partly Cloudy	11,860	74
6/8/2005	51	11	Rain	11,869	61
6/9/2005	54	12.5	Partly Cloudy	11,818	80

Appendix Table 2. continued

Date	Water Temp.	Visibility (ft)	Weather	Flow (cfs)	max Air temp.
6/10/2005	54	>16	Clear	11,886	90
6/11/2005	51	15.5	Clear	11,904	89
6/12/2005	54	13	Clear	11,859	90
6/13/2005	54	16	Clear	11,887	97
6/14/2005	52	15.5	Clear	11,896	96
6/15/2005	56	11.5	Clear	11,913	91
6/16/2005	53	11.5	Rain	11,110	72
6/17/2005	51	13	Rain	10,535	68
6/18/2005	54	10.5	Cloudy	10,532	71
6/19/2005	54	11.5	Partly Cloudy	10,524	78
6/20/2005	52	16	Clear	10,523	87
6/21/2005	56	13.5	Clear	11,050	85
6/22/2005	53	16	Clear	12,002	91
6/23/2005	52.5	16	Clear	12,893	92
6/24/2005	57	12	Clear	12,967	91
6/25/2005	54	12	Partly Cloudy	12,968	86
6/26/2005	52	>16	Clear	12,984	88
6/27/2005	56	13.5	Clear	12,978	85
6/28/2005	54	16	Clear	13,014	93
6/29/2005	52	>16	Clear	12,962	103
6/30/2005	56	14.5	Clear	12,973	106
7/1/2005	54	16	Clear	12,961	103
7/2/2005	52	16	Clear	13,811	102
7/3/2005	53	14.5	Clear	13,816	102
7/4/2005	54	>16	Clear	13,815	103
7/5/2005	52	16	Clear	14,114	105
7/6/2005	56	13	Clear	13,967	103
7/7/2005	58	16	Clear	13,547	96
7/8/2005	53.5	14	Clear	13,709	93
7/9/2005	56	10	Cloudy	14,079	88
7/10/2005	53	16	Clear	14,225	91
7/11/2005	52	14	Clear	14,281	102
7/12/2005	55	14.5	Clear	15,186	106
7/13/2005	54	15.5	Clear	15,109	108
7/14/2005	52	14.5	Clear	14,904	109
7/15/2005	56	12	Clear	15,320	109
7/16/2005	55	14	Clear	15,274	108
7/17/2005	54	15	Clear	15,229	**114**
7/18/2005	58	13	Clear	15,319	113
7/19/2005	55	15	Clear	15,116	108
7/20/2005	53	15	Clear	15,247	109
7/21/2005	55	11.5	Cloudy	15,228	98
7/22/2005	54	16	Clear	14,972	98
7/23/2005	52	15	Clear	14,196	110
7/24/2005	55	12.5	Clear	14,213	104
7/25/2005	54	15	Clear	14,377	106

Appendix Table 2. continued

Date	Water Temp.	Visibility (ft)	Weather	Flow (cfs)	max Air temp.
7/26/2005	53	15	Clear	14,367	109
7/27/2005	55	15	Clear	13,686	104
7/28/2005	55	15	Clear	13,153	105
7/29/2005	54	15.5	Clear	12,571	103
7/30/2005	58	13	Clear	12,712	104
7/31/2005	56	16	Clear	12,747	103
8/1/2005	55	16	Clear	12,742	101
8/2/2005	58	13	Clear	13,039	101
8/3/2005	55	15.5	Clear	13,078	104
8/4/2005	54	16	Clear	12,981	106
8/5/2005	58	14	Clear	12,547	106
8/6/2005	57	16	Clear	12,664	107
8/7/2005	55	15	Clear	12,094	106
8/8/2005	58	14	Clear	12,328	104
8/9/2005	56	>16	Clear	11,482	107
8/10/2005	55	>16	Clear	10,277	104
8/11/2005	58	13.5	Clear	10,058	105
8/12/2005	57	>16	Clear	10,052	106
8/13/2005	56.5	16	Clear	9,786	104
8/14/2005	57	15	Clear	9,520	100
8/15/2005	57	16	Clear	9,970	93
8/16/2005	56	>16	Clear	9,866	97
8/17/2005	58	14	Clear	9,812	98
8/18/2005	57	>16	Clear	10,059	92
8/19/2005	55	16	Clear	10,069	96
8/20/2005	58	14	Clear	9,603	98
8/21/2005	57	>16	Clear	9,568	100
8/22/2005	55	16.5	Clear	9,690	106
8/23/2005	58	14	Clear	9,882	101
8/24/2005	57	16	Clear	9,569	96
8/25/2005	54	16.5	Clear	9,554	97
8/26/2005	58	14	Clear	9,530	99
8/27/2005	56	16	Clear	9,565	102
8/28/2005	55	15.5	Clear	9,575	99
8/29/2005	59	13.5	Clear	9,580	93
8/30/2005	57	15	Clear	9,546	97
8/31/2005	55	16	Clear	9,557	102
9/1/2005	57	>16	Clear	9,517	100
9/2/2005	56	16	Clear	9,558	95
AVERAGE	**54**	**13.3**		**12,597**	**92**

Appendix Table 3. Summary of results for 2005 winter run carcasses suspected of having coded-wire tags.

CWT- Code	Count	Brood Year		CWT- Code	Count	Brood Year
0501030707	1	**2001**		051369	47	2002
051276	23	2002		051370	29	2002
051277	34	2002		051371	35	2002
051278	35	2002		051372	35	2002
051279	24	2002		051373	25	2002
051280	17	2002		053737	63	2002
051281	28	2002		051679	1	**2003**
051282	51	2002		051964	3	2003
051283	22	2002		051970	3	2003
051284	34	2002		051971	1	2003
051285	25	2002		051972	1	2003
051286	37	2002		051973	7	2003
051287	22	2002		051974	8	2003
051288	27	2002		051977	1	2003
051289	25	2002		051978	3	2003
051290	38	2002		051980	1	2003
051291	28	2002		051982	1	2003
051292	17	2002		051983	1	2003
051293	34	2002		051984	3	2003
051294	35	2002		051985	1	2003
051295	8	2002		051986	3	2003
051296	61	2002		051988	2	2003
051297	72	2002		051991	2	2003
051298	108	2002		051993	3	2003
051299	27	2002		051995	5	2003
051364	19	2002		051996	10	2003
051365	23	2002		051997	7	2003
051366	31	2002		**062756**	**1**	**Spring-FRH 2002**
051367	25	2002		**200000 ^**	**7**	**Tag or Head Lost**
051368	29	2002		**100000 ***	**283**	**No tag Detected**

^ These fish were recorded as potential hatchery fish but their heads or tags were lost during the process of head removal, transportation or reading of the coded-wire tags. An additional 13 heads of carcasses with ad-clips were not recovered (code **300000**) due to predation, or crews dropping head in river during removal.

* These fish had potential ad-clips but no coded-wire-tag was ever detected. Many of these were fish with unknown adipose fin status due to otters or bird scavenging. Survey protocols were to remove the head if adipose fin status was unknown to ensure that all carcasses were examined for CWT's.

Appendix Table 4. Summary of past results for the Winter-run carcass survey for the years 1996 to 2005.

Parameter	WINTER-RUN CARCASS SURVEY RESULTS									
Year	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Survey Dates	4/29 - 9/5	4/30 - 8/29	5/5 - 8/28	5/5 - 8/27	5/3 - 8/29	5/2 - 8/29	5/1 - 8/27	4/30 - 9/4	4/30 - 9/3	**4/28 - 9/2**
Carcasses counted	118	239	785	475	2,482	5,145	4,959	4,549	3,280	**8,771**
Percent recaptured	15%	12%	15%	22%	45%	57%	59%	50%	54%	**63%**
Reported Population*	820*	2,053*	5,501*	2,262*	6,647*	8,224	7,464	8,218	7,869	**15,839**
Percent grilse	19.00%	8.00%	0.20%	19.50%	2.70%	9.70%	5.50%	3.30%	26.12%	**7.30%**
Percent male[!]	16%	31%	11%	12%	20%	42%	22%	16%	30%	**26%**
Spawning success (%)	94%	96%	95%	97%	100%	99%	99%	100%	99%	**98%**
Percent carcasses in Upper Area[&]	50%	48%	58%	73%	80%	72%	87%	88%	75%	**72%**
Flow range (cfs x 1000)	7.2 - 16.2	8 - 15	10 - 23.5	9.3 - 13.7	8.4 - 15.7	8.5 - 15.2	7.8 - 15	8.1 - 29.8	8.1 - 16.3	**4.8 - 37.7**
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**
Visibility range (ft)	n/a	3 - 10	4.5 - 11	6 - 11	9 - 20	14 - 20	17 - 22	8 - >15	8.5 - 16	**2 - 16 +**

* Peterson Model from 1996-2000. From 2001-2005 estimates derived from Jolly-Seber Model.

! Percent Male category is based on carcass survey data (not Keswick Trap Data).

& Upper Area is from Keswick Dam to the Cypress Street Bridge in Redding.

Appendix Table 5. Aerial redd summary for new winter-run redds counted for years surveyed from 1982 through 2005.

	YEAR																				
River Section	**82**	**85**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**
Keswick to A.C.I.D. Dam.	0%	6%	0%	1%	6%	0%	0%	2%	5%	0%	7%	3%	0%	3%	0%	6%	35%	49%	66%	16%	**52%**
A.C.I.D. Dam to Highway 44 Bridge	58%	13%	15%	23%	30%	35%	70%	20%	61%	29%	83%	71%	83%	77%	31%	27%	15%	22%	17%	35%	**36%**
Highway 44 Br. to Airport Rd. Br.	36%	29%	17%	30%	47%	51%	20%	49%	25%	24%	9%	26%	17%	16%	65%	47%	45%	28%	16%	49%	**12%**
Airport Rd. Br. to Balls Ferry Br.	3%	14%	18%	7%	2%	6%	10%	15%	2%	41%	0%	0%	0%	1%	1%	5%	4%	1%	0%	0%	**0%**
Balls Ferry Br. to Battle Creek.	0%	0%	9%	2%	0%	1%	0%	5%	0%	6%	0%	0%	0%	1%	2%	6%	0%	0%	0%	0%	**0%**
Battle Creek to Jellys Ferry Br.	0%	1%	21%	2%	0%	1%	0%	0%	2%	0%	1%	0%	0%	0%	0%	2%	0%	0%	0%	0%	**0%**
Jellys Ferry Br. to Bend Bridge	0%	4%	14%	9%	13%	0%	0%	5%	2%	0%	0%	0%	0%	0%	0%	8%	1%	0%	0%	0%	**0%**
Bend Bridge to RBDD	0%	6%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	**0%**
RBDD to Tehama Br.	3%	28%	4%	16%	0%	5%	0%	4%	2%	0%	1%	0%	0%	2%	0%	0%	0%	0%	0%	0%	**0%**
Tehama Br. To Woodson Bridge	n/s	0%	0%	9%	2%	2%	0%	0%	0%	0%	0%	n/s	n/s	0%	0%	0%	0%	0%	0%	0%	**0%**
Woodson Bridge to Hamilton City Br.	n/s	0%	n/s	0%	0%	n/s	0%	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
Hamilton City Bridge to Ord Ferry Br.	n/s	n/s	n/s	n/s	0%	n/s	0%	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s	n/s
Ord Ferry Br. To Princeton Ferry.	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	n/s	n/s	n/s	n/s	n/s	n/s	n/s
Total New Redds Counted	**33**	**103**	**313**	**1,295**	**47**	**104**	**10**	**55**	**44**	**17**	**175**	**70**	**30**	**121**	**1,144**	**588**	**1,396**	**610**	**878**	**621**	**1,968**

Note: Some years (1983, 1984, and 1986) and some areas not sampled (n/s).

Appendix Table 6. The methodology used to determine GPS calculated distances.

Data for the GPS analysis was collected using Garmin Model Map-76 handheld units. Established winter-run "carcassing" waypoints from the 2004 survey were used to begin the 2005 survey. They were uploaded to the GPS units using Arc View 3.1 software. It was known that additional "field collected" waypoints were going to be required so each unit was assigned a unique series of numbers to avoid waypoint overlap. GPS unit "DFG-1" began compiling new waypoints at 700, "DFG-2" began compiling new waypoints at 800, and "DFG-3" began compiling new waypoints at 900. Acquisition of field data was done at standard range of 80 ft. New waypoints were necessary in the field when no waypoint was available on the screen at the 80 foot range. If there were multiple waypoints on the screen within the 80 foot range then the point closest to the boat was recorded.

A waypoint was typically recorded for all carcasses that were disc-tagged, recaptured disc-tagged, rainbow trout and suspected adipose fin-clips. Data analysis was conducted using MapSource, ArcView 3.1, Microsoft Excel, and Access. The first step was downloading the GPS units using MapSource software into UTM NAD-83 coordinates. Once the units were downloaded they were exported from MapSource as a text file and imported into Excel. The data from the three GPS units were combined and a master list was created. This file was then saved as a text file and imported into ArcView 3.1. These points were imported as a table and plotted as an event theme. They were then converted to a shape file.

Even though carcasses and the corresponding waypoints were encountered all over the river it was reasoned that a river centerline overlaid on aerial photographs of the river would allow analysis of distances. Typically the river flow transports carcasses directly downstream (linearly) from one point to another rather than drifting from river side to side. We assumed that this was the case so that an imaginary centerline would accurately reflect the distance moved in most river sections even though the carcass may have been encountered on one shoreline or the other. By drawing the centerline in the middle of the river on linear sections and on the fast moving flow areas of non-linear sections we feel that we accurately portrayed "general distance" for each waypoint in the study. Three different lines were drawn from Keswick reservoir to the mouth of Cottonwood Creek down the center of the river deviating from each other only in the Turtle Bay area (RM 296.5). Line One later noted as "route 1" was drawn down the side channel of Turtle Bay, Line Two later noted as "route 2" was drawn into Turtle Bay between the island and the side channel, and Line Three later noted as "route 3" was drawn around the point bar and past Turtle Bay. These lines were then converted to polyline M lines that prepare the line for distances to be calculated. Three separate centerlines were used so accurate distances could be calculated in the Turtle Bay area. Points were assigned (snapped) to a certain centerline based on their proximity (and to field experience of river flow patterns) to the three centerlines. As each waypoint then had a corresponding location on the centerlines it was possible to run a "script" program which calculated the distance of the now "snapped" waypoints. Three separate distance estimates from Keswick Dam in meters for each waypoint were then created based on each of the 3 routes. Since most carcasses are encountered in Turtle Bay this route (2) was used as the default route for all carcasses except those encountered in either route 1 or route 3. If any carcass was encountered at any waypoint in those routes, (1 or 3), it was assigned to that routes instead of route 2. This data was used to calculate the distance a carcass moved by taking the difference of the distance estimates for each waypoint the carcass was encountered at.

Appendix Table 7. A summary of the Red Bluff Diversion Dam historical winter-run population data.

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
AVG	16,238	16,079	177	96%	4%	12,574	3,552	70%	30%	1,797	1,189	54%	46%	264

^ 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.