Upper Sacramento River Winter Chinook Salmon Carcass Survey 2003 Annual Report

A U.S. Fish & Wildlife Service Report

Annual Report to

California Bay-Delta Authority
Ecosystem Restoration Program
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TABLE OF CONTENTS

List of Figures

List of Tables and Appendices

Tables

Appendices

Abstract

The U.S. Fish & Wildlife Service conducts a supplementation program for winter Chinook salmon, an endangered species, at the Livingston Stone National Fish Hatchery. Since 1996, the U.S. Fish & Wildlife Service and the California Department of Fish and Game have cooperated on an annual survey of winter Chinook salmon returning to the upper Sacramento River (Upper Sacramento River winter Chinook salmon carcass survey). Provided in this report is a summary of the 2003 upper Sacramento River winter Chinook salmon carcass survey, including: (1) an evaluation of the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery, and (2) genetic run identification of the spawning population.

Survey results indicate that 475 hatchery winter Chinook salmon returned to the Upper Sacramento River in 2003. Escapement of winter Chinook salmon in 2003 increased by 391 as a result of the winter Chinook salmon supplementation program at Livingston Stone NFH. Recoveries of hatchery carcasses included several coded wire tag codes indicating that hatchery winter Chinook salmon contained several different family groups and likely maintained the genetic diversity of their parent stock. Carcasses of hatchery and natural winter Chinook salmon were observed at similar times, suggesting similar spawn timing. Adult hatchery males and females were smaller than their natural counterparts; however, no fork length differences existed among hatchery and natural grilse males. No fork length comparison was conducted for grilse females because too few were collected. The proportion of hatchery males returning as grilse was greater than natural males but this difference was not observed for females. Compared to natural winter Chinook salmon, hatchery fish returned in similar gender proportions, but considerably more females were recovered overall for both hatchery and natural fish. Hatchery and natural winter Chinook salmon were generally observed in similar proportions per river mile, however hatchery fish had a propensity to be distributed further upstream, closer to the Livingston Stone National Fish Hatchery. Hatchery and natural females appeared to have equal spawning success. Genetic analysis and numbers of carcasses recovered each survey period indicate that the winter Chinook carcass survey adequately surveyed the winter Chinook salmon spawning population in the upper Sacramento River.

Introduction

In 2003, the U.S. Fish and Wildlife Service (Service) and the California Department of Fish and Game (CDFG) conducted a survey for adult winter Chinook salmon *Oncorhynchus tshawytscha* carcasses in the upper Sacramento River. Primary objectives of the upper Sacramento River winter Chinook salmon carcass survey (carcass survey) were to (1) collect information on several important life history attributes of winter Chinook salmon, including: age and gender composition of the spawning population, pre-spawning mortality rate, and temporal and spatial distribution of spawning, (2) collect data useful to evaluate the winter Chinook salmon supplementation program at the Livingston Stone National Fish Hatchery (NFH), and (3) estimate the abundance of winter Chinook salmon returning to the upper Sacramento River. The following report is submitted to satisfy annual requirements of the Service, including objectives one and two. A complimentary report will be generated by the CDFG to address objectives one and three. Together, these reports will satisfy the reporting responsibilities for the third year of this project funded by the California Bay-Delta Authority, formerly CalFed.

Background

The Sacramento River supports four distinct "runs" of Chinook salmon: fall, late-fall, spring, and winter. Winter Chinook salmon begin their freshwater migration from November through June in an immature reproductive state. They migrate into the upper reaches of the Sacramento River, hold in cool waters released from Shasta Dam, and spawn from May through August between the city of Red Bluff and the Keswick Dam (the upper limit of migration). Most winter Chinook salmon spawn at age 3, with the remainder spawning at ages two and four (Hallock and Fisher 1985; Fisher 1994). Virtually all of the grilse (age 2) are precocious males, commonly known as "jacks."

Winter Chinook salmon have been listed as endangered under the Endangered Species Act since 1994 (59 Federal Register 440) due to a small abundance of returning adults and a declining population trend (Figure 1). In 1989, the Service began propagating winter Chinook salmon to supplement natural production and to protect against extinction. The winter Chinook supplementation program was initially located at the Coleman NFH on Battle Creek, a tributary of the Sacramento River. In 1998, the program was moved to a new facility at the base of Shasta Dam, Livingston Stone NFH, to improve imprinting to the mainstem Sacramento River.

A draft recovery plan for Sacramento River winter Chinook salmon was developed in 1997 by the National Marine Fisheries Service (1997). The draft recovery plan specified delisting criteria that requires a mean annual spawning abundance of 10,000 females and a cohort replacement rate greater than one over 13 consecutive years. The recovery plan also stipulated that in order to evaluate progress toward these delisting goals a monitoring system must be in place to estimate abundance of spawning winter Chinook salmon with an estimation error less than 25%. Beginning in 1996 the Service and CDFG began cooperation on the carcass survey to improve the precision of population estimates of winter Chinook salmon.

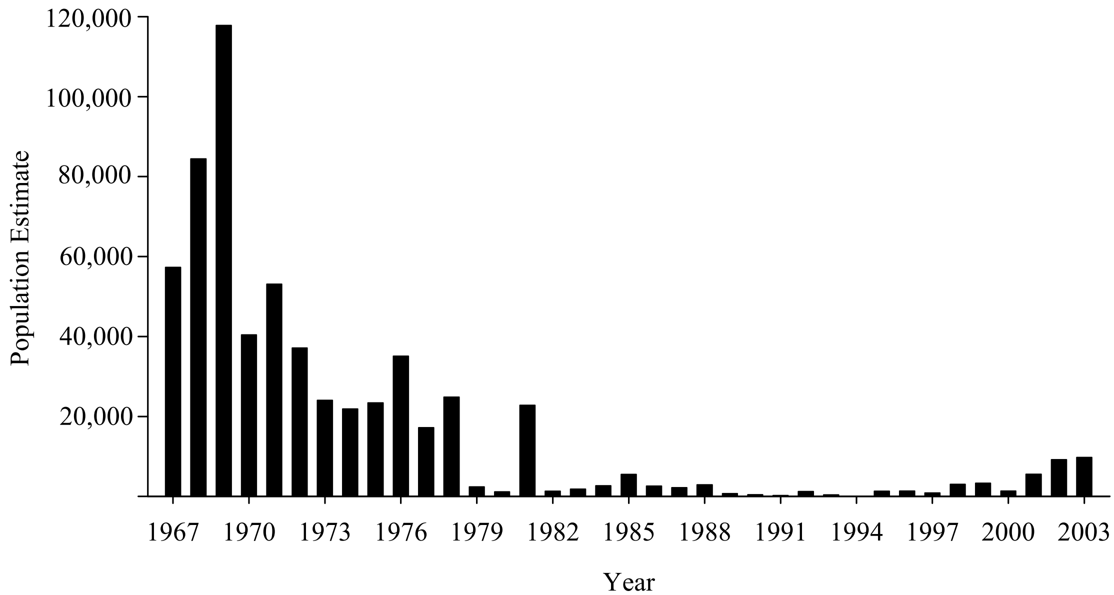

Figure 1. Population abundance estimates for Sacramento River winter Chinook salmon from 1967-2003. Estimates were determined from counts made at the Red Bluff Diversion Dam, California.

Study Area

The 2003 carcass survey was conducted on the upper Sacramento River, California. The carcass survey was designed to encompass the primary spawning areas and entire spawning period of winter Chinook. The survey area covered 16 miles of the Sacramento River and was divided into two reaches (Figure 2); reach 1 extended from Keswick Dam (river mile [RM] 302) to the Cypress Street Bridge in Redding, California (RM 295); reach 2 extended from the Cypress Street Bridge to the bottom of Plywood Riffle (RM 286).

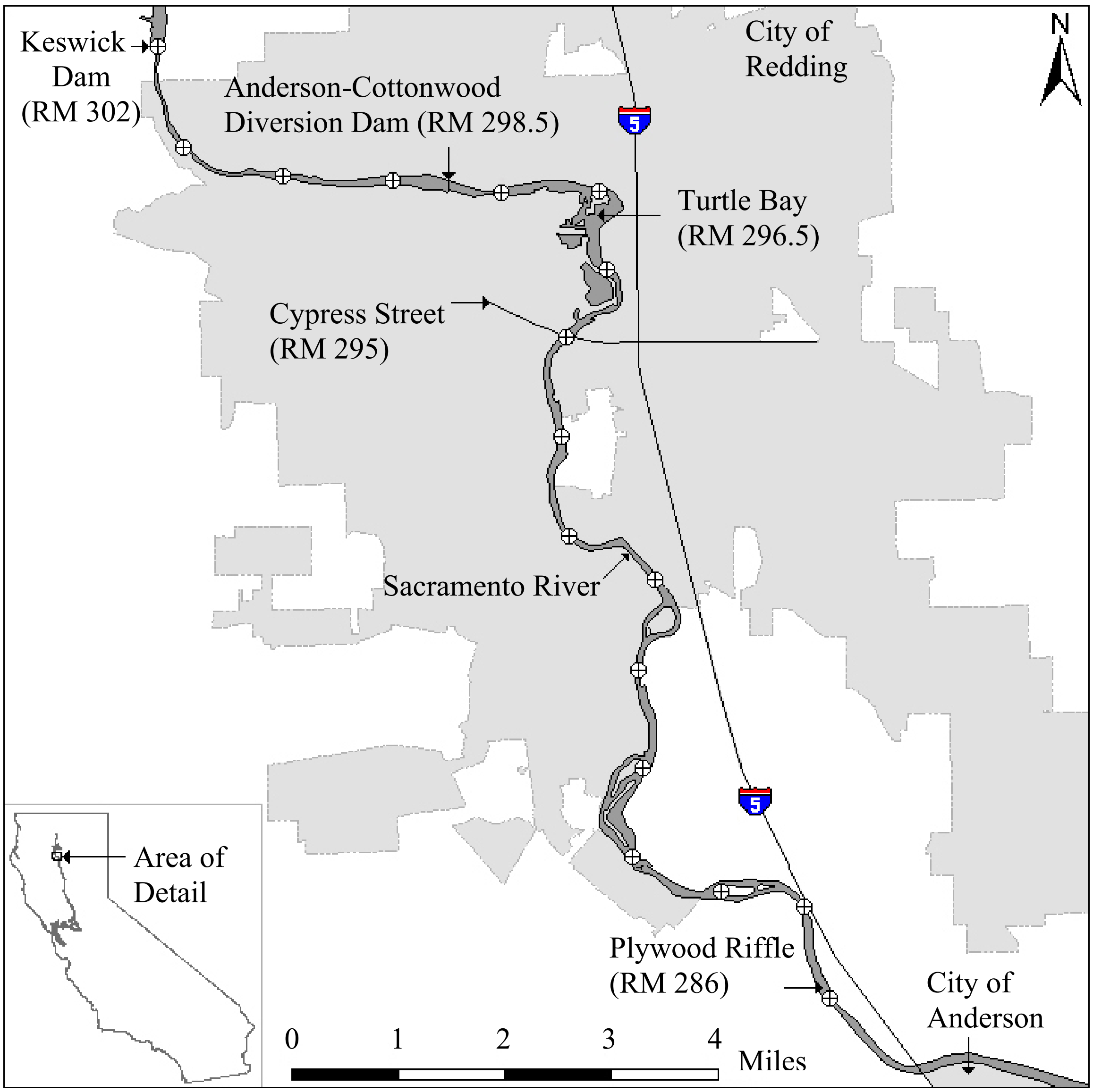

Figure 2. Upper Sacramento River and the 2003 winter Chinook salmon carcass survey sampling area. Reach 1 extends from Keswick Dam (river mile [RM] 302) down to Cypress Street Bridge (RM 295). Reach 2 extends from RM 295 down to the bottom of Plywood Riffle (RM 286).

Methods

Carcass Recoveries

The carcass survey was conducted from 6 May through 4 September 2003 and began later than previous years due to high flows in early May. The carcass survey was conducted in 3-day cycles with Reach 1 surveyed on the first day, Reach 2 surveyed on the second day, and no survey conducted on the third day. The survey was conducted with two boats, each having two observers. The boats surveyed from opposite shorelines to the middle of the river. Carcasses were collected using a 3 meter pole with an attached five-pronged gig.

Data gathered included the following: date, location (reach and RM), carcass condition (fresh or non-fresh), gender, spawn status (spawned, unspawned, and unknown), fork length, and adipose fin status (absent, present, or unknown). Carcasses were considered to be fresh if they had two clear eyes or one clear eye and a firm body texture. Spawn status of females was based on an estimation of eggs remaining. Females were categorized as *spawned* (abdomen extremely flaccid or very few eggs remaining), *unspawned* (abdomen firm and swollen or many eggs remained), or as *unknown* (indeterminable spawn status, usually due to predation on the carcass). Males were always categorized as unknown because their spawn status could not be determined. Adipose fin status was used to determine origin. An intact adipose fin was assumed to indicate "natural" origin. Carcasses missing an adipose fin were assumed to be of "hatchery" origin and likely contained a coded wire tag. The head was collected from all hatchery carcasses for coded wire tag extraction in the laboratory. In addition, the head was collected from carcasses with an adipose fin status of unknown. These carcasses were included as hatchery carcass if they contained a coded wire tag and as natural carcasses if they did not. The tag code provided the brood year and early life history information for hatchery fish.

We evaluated the winter Chinook supplementation program at Livingston Stone NFH by comparing spatial distribution, spawn timing, gender composition, spawn status, age composition, and body size of hatchery and natural winter Chinook. For hatchery carcasses, data from those containing a coded wire tag or with a clipped adipose fin were used in the spatial distribution, spawn timing, gender composition, and spawn status analyzes. Only data from hatchery carcasses containing a coded wire tag were used in the age composition and body size analyzes.

- Spatial Distribution of only female hatchery and natural winter Chinook were evaluated by comparing relative location of carcass recoveries. The frequency of carcass recoveries was plotted against river mile. Frequency distributions were visually compared and examined for substantive differences.

- Spawn Timing was evaluated by comparing temporal distributions of hatchery and natural carcasses recovered. The frequency of carcass recoveries was plotted against date for hatchery and natural winter Chinook. Frequency distributions were visually compared and examined for substantive differences.

- Gender Composition of hatchery and natural winter Chinook salmon was compared using Chi-square analysis.

- Spawn status of hatchery and natural female winter Chinook was compared using Chi-square analysis.

- Age Composition of hatchery winter Chinook salmon was evaluated using brood year information obtained from coded wire tag data. Age composition of natural winter Chinook salmon was determined using length frequency histograms. By looking for logical breaks in the frequency distributions, a cutoff value was determined to distinguish between grilse (age-2) and adults (≥ age-3) for both males and females. Age of hatchery and natural winter Chinook salmon was compared using Chi-square analysis.

- Body Size of hatchery carcasses containing a coded wire tag and natural carcasses was compared using a separate t-test on fork length (mm) of carcass recoveries grouped by gender and age.

A tissue sample was collected from the fin or operculum of carcasses that were not extremely decayed. On days in which the number of carcasses was expected to be less than 100, all suitable carcasses were tissue sampled. On days in which the number of carcasses was expected to exceed 100, tissue samples were collected from a sub-sample of carcasses. For example, on days when the survey crew anticipated collecting >100 carcasses a sub-sample ratio (e.g., 1:3) was chosen for the day, with one tissue sample collected for every three suitable carcasses.

A sub-sample of collected tissues was sent to the University of California-Davis genetics laboratory at Bodega Marine Laboratory. Tissue samples were analyzed at a suite of seven microsatellite genetic markers that were selected for their diagnostic power in distinguishing winter Chinook from other Chinook salmon populations (University of California – Davis Bodega Marine Laboratory 2001). A run assignment (winter and non-winter) was made based on a LOD score generated using the computer software WHICHRUN. Samples receiving a LOD score greater than zero were classified as a winter Chinook salmon. We hypothesized that nearly all Chinook salmon carcasses recovered during the peak winter Chinook spawning period (i.e., June and July) would be identified as winter Chinook and non-winter Chinook carcasses were more likely to be recovered during the early (May) and late (August and September) segments of the run. Therefore, we randomly selected a set of tissues stratified by sample date. The required sample size for determining the proportion of winter Chinook salmon was estimated to be 380 tissues. These were apportioned so that all fresh tissues were analyzed from the early and late segments of the run as well as a random sub-sample of tissues from the peak spawning period.

Demographic Benefit of Hatchery Supplementation

The primary objective of the winter Chinook salmon supplementation program at Livingston Stone NFH is to increase abundance of the naturally spawning population. To evaluate this objective, we estimated replacement rates for naturally spawning salmon and applied these rates to the adults used as broodstock in the supplementation program. We then estimated the abundance of hatchery adult winter Chinook returning to the upper Sacramento River. Lastly, we compared these estimates of abundance with and without the supplementation program.

To conduct our comparison, we first estimated the number of adult winter Chinook salmon that would have been produced by the hatchery broodstock if they had not been removed from the naturally spawning population. We then calculated age-specific cohort replacement rates for the hatchery broodstock based on the typical age composition of winter Chinook salmon (Hallock and Fisher 1985) and recent winter Chinook salmon population estimates based on the Peterson mark-recapture method (Snider et al., 2000, 2001, and 2002, Killam 2004; Appendix A-1). We then estimated the number of hatchery winter Chinook salmon that returned in 2003 by expanding coded wire tag, unreadable tag, and no tag detected recoveries. This estimate was then expanded to include carcasses believed to have been present, but not observed, during the carcass survey based on the Jolly-Seber mark-recapture method (Killam 2004). We then accounted for hatchery fish retained at Livingston Stone NFH for use as broodstock. We then expanded our clipped hatchery fish estimate to include non-clipped hatchery fish (Appendix A-2). Estimates of abundance with and without the supplementation program were then compared (Appendix A-3).

Results

Carcass Recoveries

A total of 4,536 carcasses was observed, including 4,326 natural, 182 hatchery, and 28 of unknown origin. All of the hatchery and 1,313 of the natural carcasses were tissue sampled.

Coded Wire Tag Recoveries
A total of 210 heads was collected with 134 containing a coded wire tag and 76 with no tag detected. The coded wire tag was decoded for 125 tags (Table 1, Appendix C) and was determined to be unreadable for nine tags. All carcasses with a decoded tag were from brood year 1999, 2000, and 2001 winter Chinook salmon reared at Livingston Stone NFH (Figure 3, Table 2, Appendix D). Six decoded tags (code 0501030705) were recovered from progeny of brood year 2001 winter Chinook salmon captive broodstock.

Spatial Distribution
The river mile was not recorded for two of the recovered fresh natural carcasses. Both hatchery and natural carcasses were collected throughout the survey area. The largest concentration of hatchery carcasses (25.8%) was found at Turtle Bay (RM 296.5) followed closely by 24.2% found at RM 299 immediately upstream of the ACID dam (Figure 4). The largest concentration of natural carcasses (24.0%) was also found at Turtle Bay (RM 296.5) and followed by RM 299 (19.8%). While the proportion of hatchery and natural carcasses at each river mile was generally the same, overall 39.1% of the hatchery carcasses occurred above ACID dam (RM 298.5) compared to 31.3% of the natural carcasses.

Spawn Timing
We recovered hatchery and natural winter Chinook salmon carcasses throughout the survey period. Hatchery and natural carcass recoveries followed a fairly normal (bell-shaped) temporal distribution with a peak in early July (Figure 5). A total of 182 hatchery carcasses were recovered: 8 in May, 42 in June, 112 in July, 19 in August, and 1 in September. Natural carcass recoveries (n = 4326) consisted of 194 in May, 1143 in June, 2456 in July, 529 in August, and 4 in September.

Gender Composition
Hatchery carcasses consisted of 16.5% (n = 30) male and 83.5% (n = 152) female, whereas, natural carcasses consisted of 16.5% (n = 382) male and 83.5% (n = 1929) female. The proportion of males to females for returning hatchery fish was similar to natural fish (Chi square; df = 1, P = 0.987).

Spawn status
All (n = 151) recovered female hatchery carcasses were classified as spawned. Of the female natural carcasses, 99.4% (n = 1,917) were classified as spawned and 0.6% (n = 12) as unspawned. The proportion of spawned and unspawned hatchery and natural

females was not statistically different (Chi square; df = 1, P = 0.331). Spawn status was not determined for males.

Table 1. Number of coded wire tag (CWT) recoveries, tags not detected (NTD), and tags with an unreadable code (Unreadable) found during processing of heads from winter Chinook salmon collected during the 2003 upper Sacramento River carcass survey. See text for description of 'Carcass condition' and 'Adipose fin' status.

Gender	Carcass condition	Adipose Fin	CWT	NTD	Unreadable	Total
Female	Fresh	Hatchery	65	26	6	97
Female	Fresh	Unknown	1	16	0	17
Female	Non-fresh	Hatchery	32	17	2	51
Female	Non-fresh	Unknown	3	10	0	13
Male	Fresh	Hatchery	18	4	1	23
Male	Fresh	Unknown	0	1	0	1
Male	Non-fresh	Hatchery	5	1	0	6
Male	Non-fresh	Unknown	1	1	0	2
			125	76	9	210

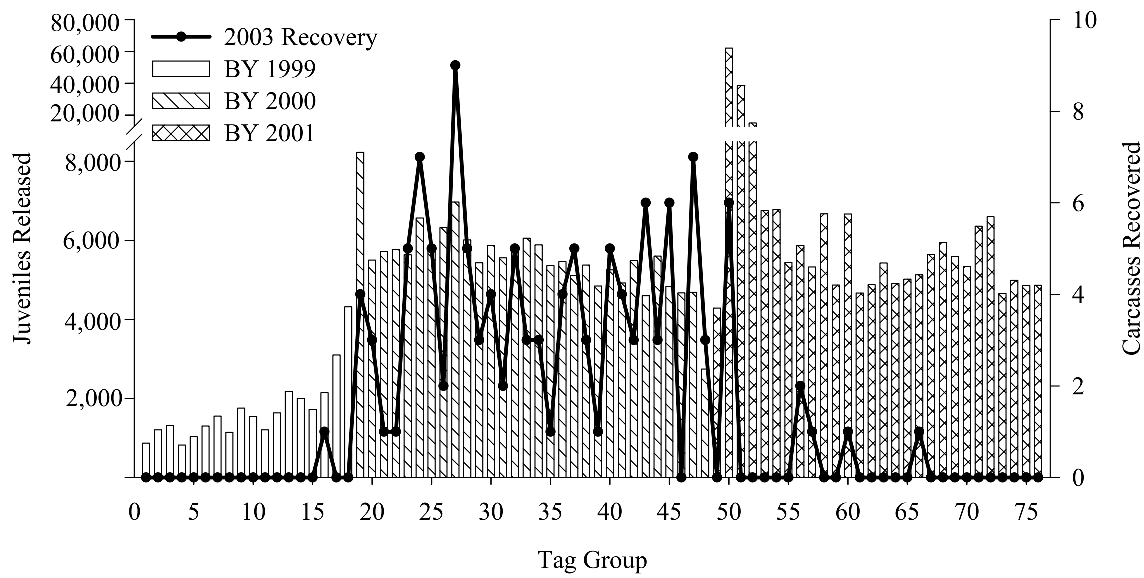

Figure 3. Number of juvenile winter Chinook salmon released and number of carcass recoveries by tag code and brood year (BY) in 2003 (each tag number corresponds to an individual tag code listed in Table 2).

Table 2. Coded wire tag (CWT) codes released from Livingston Stone National Fish Hatchery during brood years 1999, 2000, and 2001 (tag groups correspond to those reported in Figure 3). *CWT codes 0501021307 and 0501030705 were used for the progeny of captive broodstock held at the University of California-Davis Bodega Marine Laboratory.

Broodyear 1999		Broodyear 2000		Broodyear 2001	
Tag Group	CWT Code	Tag Group	CWT Code	Tag Group	CWT Code
1	0501021205	19	0501030107	49	0501020507
2	0501021206	20	0501030108	50	0501030705*
3	0501021207	21	0501030109	51	0501030706
4	0501021208	22	0501030201	52	0501030707
5	0501021209	23	0501030202	53	0501030708
6	0501021210	24	0501030203	54	0501030709
7	0501021211	25	0501030204	55	0501030801
8	0501021212	26	0501030205	56	0501030802
9	0501021213	27	0501030206	57	0501030803
10	0501021214	28	0501030207	58	0501030804
11	0501021215	29	0501030208	59	0501030805
12	0501021301	30	0501030209	60	0501030806
13	0501021302	31	0501030301	61	0501030807
14	0501021303	32	0501030302	62	0501030808
15	0501021304	33	0501030303	63	0501030809
16	0501021305	34	0501030304	64	0501030901
17	0501021306	35	0501030305	65	0501030902
18	0501021307*	36	0501030306	66	0501030903
		37	0501030307	67	0501030904
		38	0501030308	68	0501030905
		39	0501030309	69	0501030906
		40	0501030401	70	0501030907
		41	0501030402	71	0501030908
		42	0501030403	72	0501030909
		43	0501030404	73	0501040101
		44	0501030405	74	0501040102
		45	0501030406	75	0501040103
		46	0501030407	76	0501040104
		47	0501030408		
		48	0501030409		

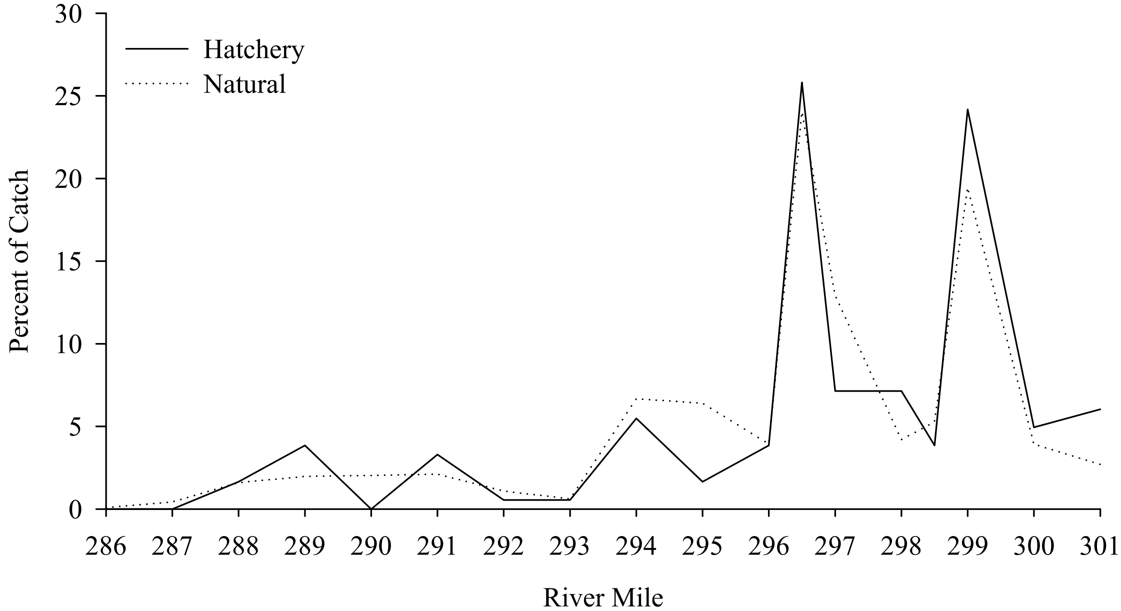

Figure 4. Percentage of carcasses with (Hatchery) and without (Natural) an adipose fin clip collected by river mile during the 2003 upper Sacramento River winter Chinook salmon carcass survey.

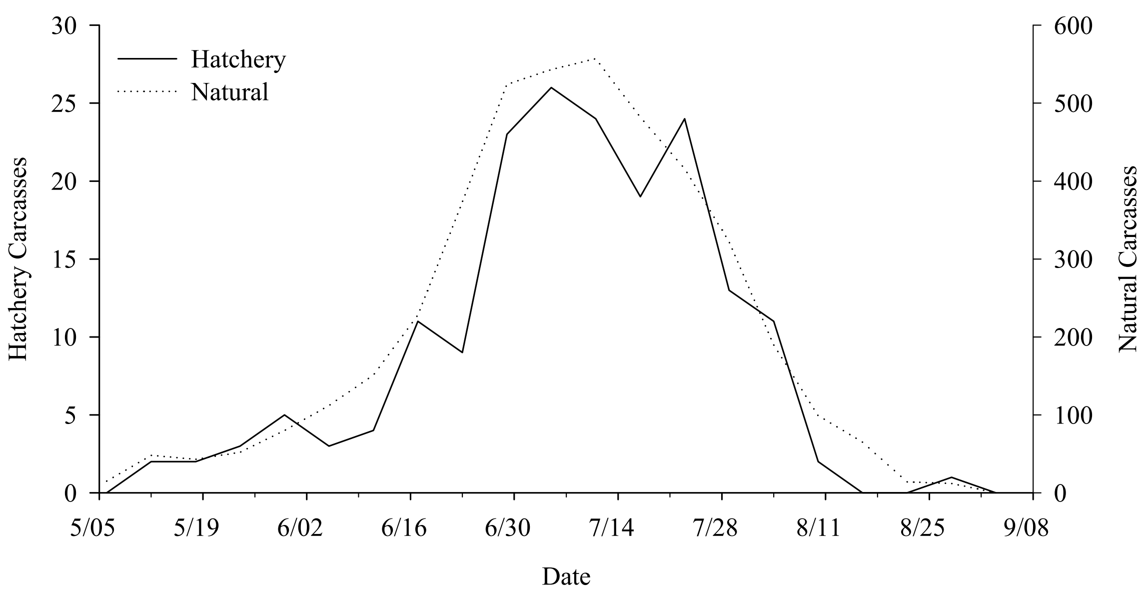

Figure 5. Date of collection for fresh carcasses with (Hatchery) and without (Natural) an adipose fin clip recovered during the 2003 upper Sacramento River winter Chinook salmon carcass survey

Age Composition
Hatchery carcasses consisted of 8.8% (n = 11) age two, 90.4% (n = 113) age three, and 0.8% (n = 1) age four, based on recovered coded wire tags. Hatchery females consisted of 99.0% (n = 100) age three and 1.0% (n = 1) age four, whereas, hatchery male carcasses were 45.8% (n = 11) age two and 54.2% (n = 13) age three.

Natural carcasses consisted of 2.6% (n = 59) grilse and 97.4% (n = 2252) adult, based on length-frequency histograms (Figure 6). Natural female carcasses were 0.2% (n = 4) grilse and 99.8% (n = 1925) adult, whereas, natural males consisted of 14.4% (n = 55) grilse and 85.6% (n = 327) adult.

The proportion of hatchery males returning at age 2 was significantly greater than natural males (Chi square; df = 1, P < 0.001). The proportion of hatchery females returning as grilse was not significantly different than natural females (Chi square; df = 1, P = 0.647).

Body Size
Body size of hatchery fish was determined from carcasses containing a coded wire tag. No hatchery grilse female was collected. Adult hatchery females average 727 mm (range = 630-870 mm, SD = 42.9, Figure 6). Hatchery males averaged 509 mm (range = 420-580 mm, SD = 58.2) for grilse and 815 mm (range = 750-910 mm, SD = 57.4) for adults.

Using length-frequency analyses, we determined that natural females <560 mm were grilse and >=560 mm were adults. Males <640 mm were categorized as grilse and >=640 mm as adults. Natural females averaged 530 mm (range = 510-550, SD = 16.3) for grilse and 740 mm (range = 570-1010 mm; SD = 52.1) for adults. The average length of natural males averaged 519 mm (range = 410-630 mm; SD = 48.6) for grilse and 864 mm (range = 650-1170 mm; SD = 76.5) for adults.

Fork lengths of adult hatchery males and females were significantly smaller than adult natural males (separate variance t-test; df = 13.8, P = 0.011) and females (separate variance t-test; df = 116.0, P = 0.004). No difference in fork lengths was found for hatchery and natural grilse males (separate variance t-test; df = 12.9, P = 0.616) No hatchery grilse female was collected for comparison with natural grilse females.

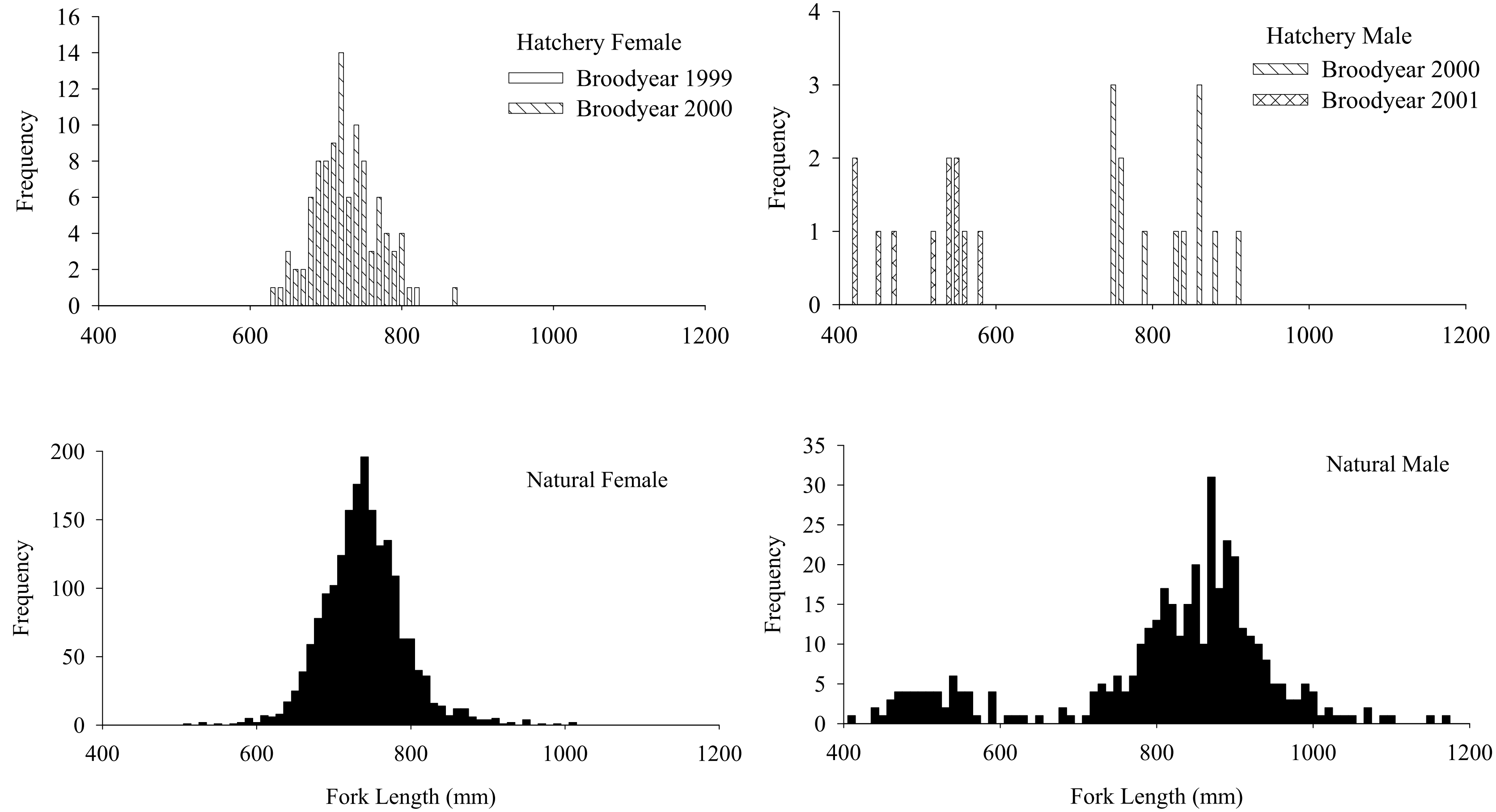

Figure 6. Length-frequency distribution of winter Chinook salmon collected during the 2003 upper Sacramento River winter Chinook salmon carcass survey. Data is presented for males and females with (Hatchery Male, Hatchery Female) and without (Natural Male, Natural Female) a clipped adipose fin.

Genetic Analyses
Tissue samples were collected from 1,369 natural carcasses. Of these tissue samples, 380 were sent to Bodega Marine Laboratory and 358 (94.2%) amplified at sufficient loci to make a run determination (Appendix B). Three hundred forty five of the 358 tissue samples successfully analyzed were identified as winter Chinook salmon, including: 92.2% (n = 106 of 115) in May, 100.0% (n = 71 of 71) in June, 98.6% (n = 69 of 70) in July, 98.0% (n = 99 of 101) in August, and 0.0% (n = 0 of 1) in September (Figure 7). The first genetically identified winter Chinook salmon was collected on 7 May 2003. The last genetically identified winter Chinook salmon was collected on 23 August 2003, after which only two carcasses suitable for tissue sampling were collected.

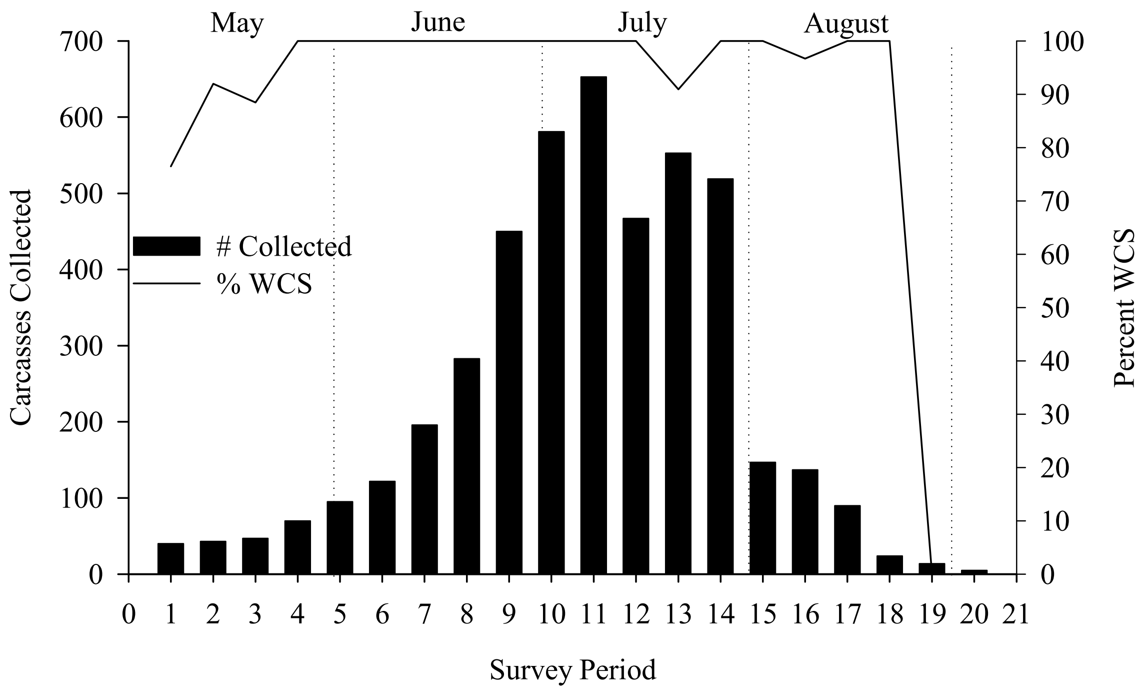

Figure 7. Total number of carcasses collected and percentage of tissue samples genetically identified (LOD > 0) as winter Chinook salmon (WCS) during the 2003 upper Sacramento River winter Chinook salmon carcass survey. One 'survey period' is equal to two surveys of each Reach 1 and Reach 2 (two survey cycles).

Demographic Benefit of Hatchery Supplementation

We estimate that 475 hatchery winter Chinook salmon returned in 2003 (Appendices A1-A3). Additionally, we estimate that the Chinook salmon adults used as hatchery broodstock at the Livingston Stone NFH in 1999, 2000, and 2001 would have resulted in 84 adult returns in 2003 had they been allowed to reproduce naturally. The results of our analyses indicate that the Service's winter Chinook salmon supplementation program increased escapement to the upper Sacramento River by 391 fish, equating to an increased demographic contribution of 464% by those fish used as hatchery broodstock.

Discussion

Carcass Recoveries

The Service's winter Chinook salmon supplementation program was moved from the Coleman NFH to the Livingston Stone NFH in 1998. The primary reason for moving the supplementation program to the mainstem of the Sacramento River was to improve homing of hatchery fish to spawning areas used by natural winter Chinook salmon. When the program was located at the Coleman NFH many hatchery winter Chinook salmon returned to Battle Creek. By incubating eggs and rearing juveniles at Livingston Stone NFH, it was believed that hatchery winter Chinook salmon would be much more likely to return to spawning areas in the mainstem Sacramento River. Recoveries of hatchery carcasses during the 2003 carcass survey shows that hatchery winter Chinook salmon from Livingston Stone NFH are imprinting and returning to spawning areas in the mainstem Sacramento River.

Coded Wire Tag Recoveries

All hatchery winter Chinook salmon recovered during the 2003 carcass survey were from Livingston Stone NFH brood years 1999, 2000, and 2001. Nearly all of the tag codes released from Livingston Stone NFH for brood year 2000 (age-3) were represented in the carcass recoveries. Each tag code represents an individual family group or a cluster of family groups, where a family group is defined as the progeny of an individual female and male mating. The recovery of many tag codes during the 2003 carcass survey provides evidence that hatchery winter Chinook maintained the genetic diversity of their parent stock.

Spatial Distribution

The distribution of salmon carcasses was variable throughout the survey area, with areas of decreased velocity (pools) located below spawning areas typically showing a larger concentration of carcasses compared to areas of increased velocity (runs and riffles). We assume the spatial distributions of carcasses provide evidence of relative spawning locations for hatchery and natural winter Chinook. This assumption should be valid unless post-spawning behavioral difference exists between hatchery and natural winter Chinook.

Spatial distributions of hatchery and natural carcasses were remarkably similar throughout the survey area. The notable exception was the three miles immediately below Keswick Dam where a larger proportion of hatchery carcasses were observed. Hatchery winter Chinook salmon are incubated and reared at Livingston Stone NFH, located at the base of Shasta Dam (RM 314), and therefore they would be expected to imprint to waters coming out of Shasta Dam. Natural winter Chinook salmon imprint to waters within their natal spawning areas below Keswick Dam (below RM 302). The increased incidence of hatchery carcasses within the uppermost region of the survey area suggests that a larger proportion of winter Chinook reared at the Livingston Stone NFH imprint and return to the uppermost reaches of available spawning habitats. In 2002, an increased collection, from previous years, of both Hatchery and Natural carcasses above the ACID Dam also occurred. The increased collection above the ACID Dam continued in 2003 and is most likely due to past improvements of the fish ladders allowing easier passage.

Spawn Timing
Hatchery carcasses were recovered in a similar temporal pattern as natural carcasses. We assume the temporal occurrence of carcass recoveries provides evidence of similar spawn timing for hatchery and natural winter Chinook salmon. This assumption should be valid unless differences exist in post-spawning longevity between hatchery and natural winter Chinook salmon.

Gender Composition
We observed a 1:4 hatchery and 1:5 natural male to female ratio during the carcass survey. These data suggest females are substantially more abundant or that the carcass survey may be biased against males. This greater abundance of females has been observed during both previous carcass surveys. However, this skewed gender ratio is not supported by observations at the Keswick Dam and Red Bluff Diversion Dam fish traps. For hatchery and natural fish, males exhibit a different post-spawn behavior that may preclude them from observation on the carcass survey. This assumption is supported by observations of females guarding redds, whereas male Chinook salmon are not typically observed near the vicinity of the redd after spawning.

Spawn status
Small numbers of unspawned hatchery and natural female carcasses were observed suggesting similar spawning success. However, spawning success does not necessarily indicate that hatchery and natural fish are contributing equally to future generations. Many studies have shown that offspring from naturally reproducing hatchery fish, and matings between hatchery and natural fish, may have lower survival than offspring of natural fish (Waples 1991; Utter et al. 1993; Campton 1995). However, Ardren et al. (1999) found equal reproductive potential of hatchery and natural steelhead in the Hood River, Oregon. A literature review of Pacific Northwest salmonid hatcheries by Brannon et al. (2004) concluded that hatchery fish, when properly propagated, have an equivalent reproductive performance as wild fish. Rates of survival for progeny of naturally spawning hatchery winter Chinook salmon in the upper Sacramento River are not known.

Age Composition
Two year old hatchery and natural carcasses were almost exclusively male, "jacks." Two year old males occurred more than three times as often in the hatchery male population (45.8%) compared to the natural male population (14.4%). Larson et al. (2004) found that increased precocial maturation of hatchery Chinook salmon is likely a result of accelerated growth in the hatchery environment.

Body Size
We determined that hatchery adult males and females returned at a smaller size than natural adult males and females. Possible explanations for this observed size difference include the following:

1) Hatchery fish may have difficulty transitioning to natural feeding strategies (Einum and Fleming 2001).

2) Hatchery adults have been found to place more energy into development of gonadal tissue, as opposed to somatic tissue (Fleming and Gross 1992).

3) Hatchery fish are more likely to return to fresh water earlier in the spawning season (Chandler and Bjornn 1988; Einum and Fleming 2000; Mackey et al. 2001). Fish returning early would not benefit from the additional feeding time under ocean conditions.

4) Fish exhibiting faster growth are more likely to return at age 2 (Mullan et al. 1992; Silverstein et al. 1998; Larson et al. 2004). This occurs more often for males than females and in larger proportions for hatchery rather than natural fish (Larson et al. 2004). If this were to occur, a smaller proportion of fish predisposed for faster growth would be left in the hatchery population relative to the natural population.

Whether or not the observed size differences are merely statistical error or are a reflection of actual biological differences will hopefully be established with the accumulation of more data from subsequent survey years.

Genetic Analyses

The greater frequency of salmon identified as winter Chinook during the carcass survey, along with the smaller abundance of salmon at the beginning and end of the survey, suggests the winter Chinook salmon spawning period is being adequately surveyed in the carcass survey.

Demographic benefit of hatchery supplementation

Hatchery fish represented 5.8% of the total winter Chinook salmon spawning population in 2003. Based on our calculations, it appears the winter Chinook salmon supplementation program succeeded in demographically enhancing the winter Chinook salmon population in 2003.

Conclusions

Adult escapement of winter Chinook salmon increased in 2003 as a result of the winter Chinook salmon supplementation program at Livingston Stone NFH. Recoveries of hatchery carcasses included several coded wire tag codes indicating that hatchery winter Chinook salmon contained several different family groups and likely maintained the genetic diversity of their parent stock. Both hatchery and natural winter Chinook were found throughout the survey area. However, hatchery fish were more likely to be recovered further upstream suggesting possible differences in spawning distribution. Hatchery winter Chinook salmon were recovered at the same times as natural fish which likely indicates similar spawn timing. Adult hatchery males and females were smaller than their natural counterparts; however, no fork length differences existed among hatchery and natural grilse males and no hatchery grilse female was collected for comparison. The proportion of hatchery males returning as grilse was greater than natural males but this difference was not observed for females. Compared to natural winter Chinook salmon, hatchery fish returned in similar proportions as males, but considerably more females were recovered overall for both hatchery and natural fish. Hatchery and natural females appeared to have equal spawning success. Genetic analysis and other survey data indicate that we are adequately surveying the winter Chinook salmon spawning population in the upper Sacramento River.

Notes on apparent inconsistencies between the Sacramento River winter Chinook salmon carcass survey and fish trapping at the Keswick Dam

Winter Chinook salmon broodstock collection at Keswick Dam Fish Trap

Keswick Dam (RM 302) is a barrier to fish passage and represents the uppermost point of salmonid migration in the Sacramento River. A fish trap at Keswick Dam is used to capture broodstock for the winter Chinook salmon supplementation program. Broodstock collection activities for winter Chinook salmon are conducted according to an annual Adult Collection Plan that identifies monthly broodstock collection targets for January through July. Winter Chinook salmon in excess of broodstock needs (or in excess of monthly targets) and non-winter Chinook salmon are returned to the Sacramento River either at Bonnyview Road boat ramp (RM 292) or Caldwell Park boat ramp (RM 298), depending on flow. Fish are floy tagged for identification before they are released back into the river.

Comparison of adipose fin clip rates

During 2003, hatchery Chinook salmon (n = 161) comprised 41.6% of the total Chinook salmon (n = 387) trapped at the Keswick Dam Fish Trap (KDFT), whereas hatchery carcasses (n = 121) represented only 5.4% of the total fresh carcasses (n = 2,250) recovered on the carcass survey. This discrepancy may result if hatchery winter Chinook salmon have a tendency to return to the uppermost reaches of the Sacramento River. This hypothesis is supported by the large proportion of hatchery winter Chinook salmon captured at the KDFT. This hypothesis is also supported by our 2003 carcass survey where hatchery Chinook salmon were found at a greater rate than natural Chinook salmon within the three miles immediately below Keswick Dam.

Recoveries of floy tagged fish released from the Keswick Dam Fish Trap

During 2003, a total of 153 genetically identified winter Chinook salmon were captured at the KDFT, floy tagged, and then released back into the Sacramento River. Seventeen of these tagged fish were subsequently recovered on the carcass survey (Table 3), for a recovery rate of 11.1%. This recovery rate for fish released from the KDFT compares to a recovery rate of approximately 63% for Chinook salmon that were tagged as part of the carcass survey mark-recapture estimate (Killam 2004). During the carcass survey, 3,457 adult natural carcasses were tagged, of which 2,175 were subsequently recovered giving a recovery rate of 62.9%. Considering only fresh natural carcasses, the recovery rate was similar with 1,445 recoveries out of a total of 2,250 fresh carcasses tagged, for a recovery rate of 64.2%.

Several hypotheses have been proposed to explain the discrepancy between recovery rates for floy tagged fish released from the KDFT and carcasses tagged as part of the mark-recapture survey. These include: 1) live fish released from the KDFT may shed their floy tags during spawning activities, or post-spawning as their body condition deteriorates, 2) the fish released from the KDFT may spawn in the deep water areas immediately below Keswick Dam where their carcasses may be unlikely to be recovered due to the river's morphology, or 3) the fish released from the KDFT may fall back below the survey areas due to the stress of being captured, transported, tissue sampled, tagged, and released.

Table 3. Floy tag and date of Chinook salmon captured at the Keswick Dam Fish Trap, location (name of boat ramp and river mile [RM]) and date they were released back into the Sacramento River, and location (RM) and date floy tagged carcass were recovered during the 2003 upper Sacramento River winter Chinook salmon carcass survey. Exact RM was not recorded for recovery of floy tag R-04227; however, it was recovered on Reach 2 (RM 286 – 295).

Floy Tagged		Released			Recovered	
Number	Tag Date	Boat Ramp	RM	Date	RM	Date
R-04210	3/11/2003	Bonneyview	292	3/11/2003	295	6/26/2003
R-04213	3/11/2003	Bonneyview	292	3/11/2003	299	7/5/2003
R-04211	3/11/2003	Bonneyview	292	3/11/2003	296.5	7/26/2003
R-04224	3/19/2003	Bonneyview	292	3/19/2003	296.5	8/7/2003
R-04434	4/9/2003	Bonneyview	292	4/9/2003	294	5/19/2003
R-04247	4/23/2003	Bonneyview	292	4/23/2003	299	5/18/2003
R-04464	4/23/2003	Bonneyview	292	4/23/2003	296.5	5/24/2003
R-04227	4/23/2003	Bonneyview	292	4/23/2003	Reach 2	5/28/2003
R-04238	4/23/2003	Bonneyview	292	4/23/2003	299	7/8/2003
R-04457	4/23/2003	Bonneyview	292	4/23/2003	299	7/8/2003
R-04450	4/23/2003	Bonneyview	292	4/23/2003	288	7/9/2003
R-04469	4/23/2003	Bonneyview	292	4/23/2003	296.5	7/11/2003
R-04237	4/23/2003	Bonneyview	292	4/23/2003	296.5	7/23/2003
R-04329	4/23/2003	Bonneyview	292	4/23/2003	299	7/26/2003
OR-029	4/23/2003	Caldwell	298	4/30/2003	299	6/2/2003
R-04278	5/28/2003	Caldwell	298	5/28/2003	294	6/18/2003
R-04295	6/25/2003	Caldwell	298	6/25/2003	301	7/2/2003

Recommendations

In order to address these apparent inconsistencies between the KDFT and the carcass survey, we recommend that additional research be conducted to assess the abundance and composition of that segment of the winter Chinook salmon population that returns in the uppermost section of the Sacramento River, between the Anderson-Cottonwood Irrigation District Diversion Dam and the Keswick Dam. We believe that the fish ladders at the Anderson-Cottonwood Irrigation District Diversion Dam may provide a valuable monitoring location for winter Chinook salmon beginning in April when the flashboards are installed. Additional research using radio telemetry would allow us to document the movements of winter Chinook salmon in the upper Sacramento River. These studies have the potential to provide valuable insights into possible biases associated with winter

Chinook salmon population estimates in the upper Sacramento River based on the mark-recapture methods.

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Appendix A. Analysis of demographic benefit resulting from the winter Chinook salmon supplementation program at Livingston Stone NFH based on the 2003 upper Sacramento River winter Chinook salmon carcass survey. Analysis includes estimation of winter Chinook salmon escapement in absence of a supplementation program (Appendix A-1), estimation of hatchery winter Chinook salmon escapement with the existing supplementation program (Appendix A-2), and a comparison of these two estimates (Appendix A-3).

Appendix A-1. Estimation of the 2003 winter Chinook salmon escapement in absence of a supplementation program.

Methods and Equations

We estimated the number of natural fish that would have returned without supplementation from Livingston Stone NFH. More specifically, we estimated the number of natural offspring that would have been produced by fish retained for hatchery broodstock had these fish been allowed to spawn naturally. We first calculated the abundance of each age class (n_A):

$$n_A = P_{Total} \times A_P \quad (1)$$

where,

P_{Total} = total adult winter Chinook salmon population (as estimated by the Peterson method) and

Note: The Jolly-Seber method is generally considered the more accurate estimator of winter Chinook escapement; however, estimates using the Jolly-Seber method have only been available since 2000. Therefore, we used the escapement estimate based on the Peterson method because it is available for all survey years and provides consistent methodology for estimating population abundance trends.

A_P = proportion of each age class present in the overall population (assumed: 0.25 age 2, 0.67 age 3, and 0.08 age 4 [Hallock and Fisher 1985]).

Replacement rates for each age class (r_A) were then estimated:

$$r_A = n_A / P_{BY} \quad (2)$$

where,

P_{BY} = total winter Chinook salmon escapement estimate for the corresponding brood year. For example, for fish returning in 2003 the corresponding brood year is: 2001 for age 2, 2000 for age 3, and 1999 for age 4.

For each age, we estimated the expected number of adult returns ($n_{Natural}$) that would have resulted had the adults retained for broodstock in previous years been allowed to spawn naturally:

$$n_{Natural} = r_A \times n_B \quad (3)$$

where,

n_B = number of adults retained as hatchery broodstock for the corresponding brood year. For example, for fish returning in 2003 the corresponding brood year is: 2001 for age 2, 2000 for age 3, and 1999 for age 4.

Summing across years, we estimated the total expected number of natural adult returns ($N_{Natural}$) that would have resulted had the adults retained for broodstock in previous years been allowed to spawn naturally:

$$N_{Natural} = \Sigma\,(n_{Natural}). \tag{4}$$

Data and Calculations

	P_{Total}	=	**7,397**	**=**	2003 Total escapement
2 year old	P_{BY}	=	**12,120**	**=**	2001 Total escapement
3 year old	P_{BY}	=	**6,670**	**=**	2000 Total escapement
4 year old	P_{BY}	=	**2,262**	**=**	1999 Total escapement
2 year old	n_B	=	**97**	**=**	2001 Adult broodstock
3 year old	n_B	=	**85**	**=**	2000 Adult broodstock
4 year old	n_B	=	**24**	**=**	1999 Adult broodstock

Age Composition

P_{Total}	×	A_P	=	n_A		
7,397	×	0.25	=	**1,849.2500**	=	2003 , 2 year old escapement
7,397	×	0.67	=	**4,955.9900**	=	2003 , 3 year old escapement
7,397	×	0.08	=	**591.7600**	=	2003 , 4 year old escapement

Contribution Rate

n_A	/	P_{BY}	=	r_A		
1,849.2500	/	12,120	=	**0.1526**	=	2001 Contribution rate
4,955.9900	/	6,670	=	**0.7430**	=	2000 Contribution rate
591.7600	/	2,262	=	**0.2616**	=	1999 Contribution rate

Recruitment of Adults

r_A	×	n_B	=	$n_{Natural}$		
0.1526	×	97	=	**14.8001**	=	2001 Adult Returns
0.7430	×	85	=	**63.1573**	=	2000 Adult Returns
0.2616	×	24	=	**6.2786**	=	1999 Adult Returns
				84.2360	**=**	**$N_{Natural}$**

Appendix A-2. Estimated escapement of hatchery winter Chinook salmon in the upper Sacramento River for 2003.

<u>Methods and Equations</u>

We estimated total abundance of hatchery winter Chinook salmon returning to the upper Sacramento River in 2003 by using a series of expansions to correct for biases and incomplete counts associated with the carcass survey. Beginning with the number of hatchery Chinook observed during the survey, we first expanded to include unrecognized fin clips and undetected coded wire tags in non-fresh carcasses. Secondly, we expanded our estimate to include carcasses not observed during the survey. Thirdly, hatchery fish that were captured for use as broodstock at the Livingston Stone NFH were added in to the estimate. Lastly, we expanded to include hatchery fish that did not have a clipped adipose fin. Rationale and descriptions of these expansions are contained in the following sections:

1. Based on observations from previous years, we believe there is a decreased likelihood for recovering a coded wire tag among non-fresh carcasses compared to fresh carcasses. We also believe an adipose fin clip is less likely to be identified among non-fresh carcasses compared to fresh carcasses. To account for these biases, we expanded non-fresh hatchery carcasses recovered during the carcass survey based on the recovery rates observed for fresh hatchery carcasses recovered ($H_{NF\text{-}Exp}$):

$$H_{NF\text{-}Exp} = (H_{F\text{-}Obs} \times T_{NF\text{-}Obs}) / T_{F\text{-}Obs} \qquad (5)$$

where,

$H_{F\text{-}Obs}$ = total number of fresh hatchery carcasses,

$T_{NF\text{-}Obs}$ = total number of non-fresh hatchery and natural carcasses, and

$T_{F\text{-}Obs}$ = total number of fresh hatchery and natural carcasses recovered during the carcass survey.

2. We then expanded to include hatchery carcasses believed to be present in the upper Sacramento River population but not observed during the survey (H_{Sac}). This expansion is based on the proportion of hatchery carcasses observed during the carcass survey to the total estimated escapement of naturally reproducing winter Chinook salmon in the upper Sacramento River, based on the Jolly-Seber population estimate ($N_{J\text{-}S}$):

$$H_{Sac} = (H_{NF\text{-}Exp} + H_{F\text{-}Obs}) / T_{Obs} \times N_{J\text{-}S} \qquad (6)$$

where,

T_{Obs} = the total number of carcasses observed during the carcass survey (including fresh and non-fresh and hatchery and natural carcasses).

3. Hatchery fish that were captured for use as broodstock at the Livingston Stone NFH ($LSNFH_H$) were accounted for by adding them to H_{Sac}. This yielded the total number of adipose fin clipped hatchery fish present in the upper Sacramento River and at the Livingston Stone NFH (H_{Clip}).

$$H_{Clip} = H_{Sac} + LSNFH_H \quad (7)$$

4. To account for non-adipose fin clipped hatchery fish, we expanded H_{Clip} based on mark retention rates measured prior to release of juvenile winter Chinook. To accomplish this, we must first apportioned H_{Clip} among each tag code recovered (CWT_{App}).

$$CWT_{App} = H_{Clip} \times (CWT_{Rec} / CWT_T) \quad (8)$$

where,

CWT_{Rec} = the number of coded wire tags recovered for an individual tag code and

CWT_T = the total number of all coded wire tags recovered.

5. We can now expand CWT_{App} to include all hatchery fish without an adipose fin clip (CWT_{Final}) based on mark retention rates measured prior to release of juvenile winter Chinook.

$$CWT_{Final} = CWT_{App} / (J_{Clip} / J_{Obs}) \quad (9)$$

where,

J_{Clip} = the number of juveniles observed with an adipose fin clip during tag retention studies prior to release, by individual tag code and

J_{Obs} = the total number of juveniles observed during tag retention studies prior to release, by individual tag code.

6. Lastly, we sum CWT_{Final} to obtain our final 2003 hatchery winter Chinook salmon population estimate (H_{Final}).

$$H_{Final} = \Sigma\ CWT_{Final} \quad (10)$$

Data and Calculations

138 =	$H_{F\text{-}Obs}$	=	Number of fresh hatchery carcass recoveries
2,126 =	$T_{NF\text{-}Obs}$	=	Number of non-fresh hatchery and natural carcass recoverie
2,423 =	$T_{F\text{-}Obs}$	=	Number of fresh hatchery and natural carcass recoveries
4,549 =	T_{Obs}	=	Total carcasses observed during the carcass survey
8,133 =	$N_{J\text{-}S}$	=	Total naturally reproducing winter Chinook salmon escaper
11 =	$LSNFH_H$	=	Hatchery fish retained for LSNFH broodstock

For 'Juvenile tag retention data':

C = fish with an adipose fin clip
NC = fish with no adipose fin clip
T = fish with a coded wire tag
NT = fish with no coded wire tag

CWT Code	CWT_{Rec} Survey	LSNFH	Juvenile tag retention data T/C	NT/C	T/NC	NT/NC
0501021305	1	0	198	2	0	0
0501030107	4	0	194	3	2	1
0501030108	3	0	192	8	0	0
0501030109	1	0	194	6	0	0
0501030201	1	0	188	12	0	0
0501030202	5	1	186	14	0	0
0501030203	7	0	195	5	0	0
0501030204	5	0	193	7	0	0
0501030205	2	0	195	5	0	0
0501030206	9	1	198	2	0	0
0501030207	5	0	200	0	0	0
0501030208	3	0	198	2	0	0
0501030209	4	0	192	5	3	0
0501030301	2	1	198	2	0	0
0501030302	5	1	196	2	2	0
0501030303	3	0	197	3	0	0
0501030304	3	1	198	1	1	0
0501030305	1	1	199	1	0	0
0501030306	4	0	195	5	0	0
0501030307	5	0	196	4	0	0
0501030308	3	0	196	4	0	0
0501030309	1	0	198	2	0	0
0501030401	5	0	195	5	0	0
0501030402	4	0	196	4	0	0
0501030403	3	0	194	6	0	0
0501030404	6	0	193	7	0	0
0501030405	3	0	194	6	0	0
0501030406	6	0	197	3	0	0
0501030408	7	0	199	1	0	0
0501030409	3	0	192	8	0	0
0501030705	6	0	592	6	1	1
0501030802	2	0	188	12	0	0
0501030803	1	1	184	16	0	0
0501030806	1	0	188	12	0	0
0501030903	1	0	193	7	0	0
	125	7				

1. Non-fresh carcass expansion based on fresh carcass recovery rate

$$\left(\overset{H_{F\text{-}Obs}}{138} \times \overset{T_{NF\text{-}Obs}}{2{,}126} \right) / \overset{T_{F\text{-}Obs}}{2{,}423} = \overset{H_{NF\text{-}Exp}}{\mathbf{121.0846}}$$

2. Expansion to include carcasses not observed

$$\left(\overset{H_{NF\text{-}Exp}}{121.0846} + \overset{H_{F\text{-}Obs}}{138} \right) / \overset{T_{Obs}}{4{,}549} \times \overset{N_{J\text{-}S}}{8{,}133} = \overset{H_{Sac}}{\mathbf{463.2084}}$$

3. Addition of hatchery fish retained for Livingston Stone NFH broodstock

$$\overset{H_{Sac}}{463.2084} + \overset{LSNFH_{H}}{11} = \overset{H_{Clip}}{\mathbf{474.2084}}$$

4. Apportioning by tag code

CWT Code		H_{Clip}			CWT_{Rec}		CWT_T		CWT_{App}
0501021305	:	474.2084	×	(	1	/	132	) =	**3.5925**
0501030107	:	474.2084	×	(	4	/	132	) =	**14.3700**
0501030108	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030109	:	474.2084	×	(	1	/	132	) =	**3.5925**
0501030201	:	474.2084	×	(	1	/	132	) =	**3.5925**
0501030202	:	474.2084	×	(	6	/	132	) =	**21.5549**
0501030203	:	474.2084	×	(	7	/	132	) =	**25.1474**
0501030204	:	474.2084	×	(	5	/	132	) =	**17.9624**
0501030205	:	474.2084	×	(	2	/	132	) =	**7.1850**
0501030206	:	474.2084	×	(	10	/	132	) =	**35.9249**
0501030207	:	474.2084	×	(	5	/	132	) =	**17.9624**
0501030208	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030209	:	474.2084	×	(	4	/	132	) =	**14.3700**
0501030210	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030211	:	474.2084	×	(	6	/	132	) =	**21.5549**
0501030212	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030213	:	474.2084	×	(	4	/	132	) =	**14.3700**
0501030214	:	474.2084	×	(	2	/	132	) =	**7.1850**
0501030215	:	474.2084	×	(	4	/	132	) =	**14.3700**
0501030216	:	474.2084	×	(	5	/	132	) =	**17.9624**
0501030217	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030218	:	474.2084	×	(	1	/	132	) =	**3.5925**
0501030219	:	474.2084	×	(	5	/	132	) =	**17.9624**
0501030220	:	474.2084	×	(	4	/	132	) =	**14.3700**
0501030221	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030222	:	474.2084	×	(	6	/	132	) =	**21.5549**
0501030223	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030224	:	474.2084	×	(	6	/	132	) =	**21.5549**
0501030225	:	474.2084	×	(	7	/	132	) =	**25.1474**
0501030226	:	474.2084	×	(	3	/	132	) =	**10.7775**
0501030227	:	474.2084	×	(	6	/	132	) =	**21.5549**
0501030228	:	474.2084	×	(	2	/	132	) =	**7.1850**
0501030229	:	474.2084	×	(	2	/	132	) =	**7.1850**
0501030230	:	474.2084	×	(	1	/	132	) =	**3.5925**
0501030231	:	474.2084	×	(	1	/	132	) =	**3.5925**
									474.2084

5. Expansion to include hatchery fish without an adipose fin clip

CWT Code	CWT_{App}		J_{Clip}		J_{Obs}		CWT_{Final}
0501021305	3.5925	/ (	200	/	200	) =	**3.5925**
0501030107	14.3700	/ (	197	/	200	) =	**14.5888**
0501030108	10.7775	/ (	200	/	200	) =	**10.7775**
0501030109	3.5925	/ (	200	/	200	) =	**3.5925**
0501030201	3.5925	/ (	200	/	200	) =	**3.5925**
0501030202	21.5549	/ (	200	/	200	) =	**21.5549**
0501030203	25.1474	/ (	200	/	200	) =	**25.1474**
0501030204	17.9624	/ (	200	/	200	) =	**17.9624**
0501030205	7.1850	/ (	200	/	200	) =	**7.1850**
0501030206	35.9249	/ (	200	/	200	) =	**35.9249**
0501030207	17.9624	/ (	200	/	200	) =	**17.9624**
0501030208	10.7775	/ (	200	/	200	) =	**10.7775**
0501030209	14.3700	/ (	197	/	200	) =	**14.5888**
0501030210	10.7775	/ (	200	/	200	) =	**10.7775**
0501030211	21.5549	/ (	198	/	200	) =	**21.7727**
0501030212	10.7775	/ (	200	/	200	) =	**10.7775**
0501030213	14.3700	/ (	199	/	200	) =	**14.4422**
0501030214	7.1850	/ (	200	/	200	) =	**7.1850**
0501030215	14.3700	/ (	200	/	200	) =	**14.3700**
0501030216	17.9624	/ (	200	/	200	) =	**17.9624**
0501030217	10.7775	/ (	200	/	200	) =	**10.7775**
0501030218	3.5925	/ (	200	/	200	) =	**3.5925**
0501030219	17.9624	/ (	200	/	200	) =	**17.9624**
0501030220	14.3700	/ (	200	/	200	) =	**14.3700**
0501030221	10.7775	/ (	200	/	200	) =	**10.7775**
0501030222	21.5549	/ (	200	/	200	) =	**21.5549**
0501030223	10.7775	/ (	200	/	200	) =	**10.7775**
0501030224	21.5549	/ (	200	/	200	) =	**21.5549**
0501030225	25.1474	/ (	200	/	200	) =	**25.1474**
0501030226	10.7775	/ (	200	/	200	) =	**10.7775**
0501030227	21.5549	/ (	598	/	600	) =	**21.6270**
0501030228	7.1850	/ (	200	/	200	) =	**7.1850**
0501030229	7.1850	/ (	200	/	200	) =	**7.1850**
0501030230	3.5925	/ (	200	/	200	) =	**3.5925**
0501030231	3.5925	/ (	200	/	200	) =	**3.5925**
					6. H_{Final}	=	**475.0081**

Appendix A-3. Comparison of estimated escapement with and without the supplementation program in the upper Sacramento River for 2003.

Methods and Equations

To determine the number of hatchery winter Chinook salmon returning at each age (H_{Age}), we multiplied the estimated total hatchery adults (H_{Final}) by the expected proportions returning at each age (Hallock and Fisher 1985):

$$H_{Age} = H_{Final} \times A_P. \tag{11}$$

We can then compare our estimated returns in absence of the supplementation program to returns with the existing program.

Data and Calculations

Age (yr)	$\mathbf{H_{Age}}$		H_{Final}		A_P
2 (from year 2000 adults)	**118.7520**	=	475.0081	×	0.25
3 (from year 1999 adults)	**318.2554**	=	475.0081	×	0.67
4 (from year 1998 adults)	**38.0006**	=	475.0081	×	0.08

Comparison of Appendix A-1 and A-2

Age (year)	Natural	Hatchery	Percent Increase
2	15	119	702
3	63	318	404
4	6	38	505
Total	**84**	**475**	**464**

An estimated 84 fish would have returned without the supplementation program (Appendix A-1), however, an estimated 475 hatchery fish returned in 2003. Offspring of the winter Chinook salmon adults used as broodstock for propagation at Livingston Stone NFH returned at a rate 464% greater than the estimated escapement if these adults had been allowed to spawn naturally.

Appendix B. Genetic results of fin tissues collected from Chinook salmon carcasses during the 2003 upper Sacramento River winter Chinook salmon carcass survey. Data presented includes sample collection date, sample number assigned by the Service, LOD score determined by the Bodega Marine Laboratory (University of California-Davis), and the genetic call (LOD > 0 for winter).

Collection Date	Sample Number	LOD Score	GeneticCall
5/7/2003	03-25002	1.01	Non-Winter
5/7/2003	03-25003	5.56	Winter
5/9/2003	03-22001	5.53	Winter
5/9/2003	03-22002	-6.58	Non-Winter
5/9/2003	03-25005	-5.26	Non-Winter
5/10/2003	03-25007	5.79	Winter
5/12/2003	03-22003	4.41	Winter
5/12/2003	03-22004	5.03	Winter
5/12/2003	03-22005	4.13	Winter
5/12/2003	03-22007	9.11	Winter
5/12/2003	03-22008	8.52	Winter
5/12/2003	03-22009	8.56	Winter
5/12/2003	03-22011	-6.62	Non-Winter
5/12/2003	03-25008	-6.98	Non-Winter
5/12/2003	03-25010	4.53	Winter
5/12/2003	03-25012	8.25	Winter
5/12/2003	03-25016	6.29	Winter
5/15/2003	03-22013	5.46	Winter
5/15/2003	03-22014	4.46	Winter
5/15/2003	03-22015	4.05	Winter
5/15/2003	03-22016	7.38	Winter
5/15/2003	03-22017	0.68	Non-Winter
5/15/2003	03-22018	5.28	Winter
5/15/2003	03-22019	5.98	Winter
5/15/2003	03-22020	-7.80	Non-Winter
5/16/2003	03-25020	7.11	Winter
5/16/2003	03-25021	3.92	Winter
5/16/2003	03-25022	-5.82	Non-Winter
5/16/2003	03-25023	4.68	Winter
5/18/2003	03-22022	4.83	Winter
5/18/2003	03-22023	5.68	Winter
5/18/2003	03-22024	7.32	Winter
5/18/2003	03-22025	5.71	Winter
5/18/2003	03-22026	1.60	Non-Winter
5/18/2003	03-22027	4.59	Winter
5/18/2003	03-25024	5.42	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
5/18/2003	03-25025	3.72	Winter
5/18/2003	03-25026	7.38	Winter
5/18/2003	03-25027	No Data	No call
5/18/2003	03-25029	6.23	Winter
5/18/2003	03-25030	6.98	Winter
5/18/2003	03-25031	4.18	Winter
5/18/2003	03-25032	6.59	Winter
5/21/2003	03-22029	6.86	Winter
5/21/2003	03-22030	1.75	Non-Winter
5/21/2003	03-22031	4.93	Winter
5/21/2003	03-22032	5.03	Winter
5/21/2003	03-22033	-5.03	Non-Winter
5/21/2003	03-22034	5.92	Winter
5/21/2003	03-22035	5.73	Winter
5/21/2003	03-22036	6.83	Winter
5/21/2003	03-22037	7.14	Winter
5/21/2003	03-22038	7.24	Winter
5/21/2003	03-22040	3.06	Winter
5/21/2003	03-25034	3.14	Winter
5/22/2003	03-22041	-5.31	Non-Winter
5/22/2003	03-25037	3.16	Winter
5/22/2003	03-25039	-5.72	Non-Winter
5/24/2003	03-22042	5.20	Winter
5/24/2003	03-22043	4.83	Winter
5/24/2003	03-22044	5.38	Winter
5/24/2003	03-22045	3.92	Winter
5/24/2003	03-22046	7.47	Winter
5/24/2003	03-22047	4.17	Winter
5/24/2003	03-22048	No Data	No call
5/24/2003	03-25040	6.42	Winter
5/24/2003	03-25041	4.29	Winter
5/24/2003	03-25043	7.46	Winter
5/24/2003	03-25044	5.76	Winter
5/24/2003	03-25046	3.60	Winter
5/25/2003	03-22049	4.84	Winter
5/25/2003	03-22050	7.14	Winter
5/25/2003	03-25047	6.11	Winter
5/25/2003	03-25049	4.38	Winter
5/25/2003	03-25050	No Data	No call
5/27/2003	03-22051	5.30	Winter
5/27/2003	03-22052	5.63	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
5/27/2003	03-22053	4.65	Winter
5/27/2003	03-22054	9.76	Winter
5/27/2003	03-22055	No Data	No call
5/27/2003	03-22057	4.85	Winter
5/27/2003	03-22058	3.93	Winter
5/27/2003	03-22059	5.74	Winter
5/27/2003	03-25052	6.86	Winter
5/27/2003	03-25053	4.65	Winter
5/27/2003	03-25056	7.97	Winter
5/27/2003	03-25057	6.81	Winter
5/27/2003	03-25060	6.77	Winter
5/27/2003	03-25063	5.07	Winter
5/27/2003	03-25064	7.66	Winter
5/27/2003	03-25065	5.50	Winter
5/27/2003	03-25066	4.52	Winter
5/28/2003	03-22060	4.76	Winter
5/28/2003	03-25054	5.91	Winter
5/28/2003	03-25071	No Data	No call
5/28/2003	03-25072	2.46	Winter
5/30/2003	03-22061	6.22	Winter
5/30/2003	03-22062	3.79	Winter
5/30/2003	03-22063	8.31	Winter
5/30/2003	03-22064	1.95	Non-Winter
5/30/2003	03-22065	5.48	Winter
5/30/2003	03-22066	5.47	Winter
5/30/2003	03-22067	7.86	Winter
5/30/2003	03-22068	3.15	Winter
5/30/2003	03-22069	0.38	Non-Winter
5/30/2003	03-22070	6.77	Winter
5/30/2003	03-22071	7.11	Winter
5/30/2003	03-22072	6.10	Winter
5/30/2003	03-22073	5.98	Winter
5/30/2003	03-22074	5.46	Winter
5/30/2003	03-22075	7.89	Winter
5/30/2003	03-25055	4.31	Winter
5/30/2003	03-25068	6.05	Winter
5/30/2003	03-25069	5.39	Winter
5/30/2003	03-25074	1.22	Non-Winter
5/30/2003	03-25075	4.63	Winter
5/30/2003	03-25076	4.69	Winter
5/30/2003	03-25077	3.16	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
5/31/2003	03-22076	5.02	Winter
5/31/2003	03-25079	7.27	Winter
6/2/2003	03-22078	2.75	Winter
6/2/2003	03-22087	1.50	Non-Winter
6/2/2003	03-25087	No Data	No call
6/5/2003	03-22107	4.27	Winter
6/5/2003	03-22113	1.70	Non-Winter
6/5/2003	03-25102	3.59	Winter
6/6/2003	03-22121	4.32	Winter
6/8/2003	03-22124	5.86	Winter
6/8/2003	03-22133	5.91	Winter
6/8/2003	03-22139	5.09	Winter
6/8/2003	03-25125	5.29	Winter
6/9/2003	03-25139	3.47	Winter
6/11/2003	03-22156	4.91	Winter
6/11/2003	03-22163	7.25	Winter
6/11/2003	03-25140	9.06	Winter
6/12/2003	03-22175	5.34	Winter
6/12/2003	03-22176	9.40	Winter
6/14/2003	03-20030	2.96	Winter
6/14/2003	03-22185	3.95	Winter
6/14/2003	03-25160	5.32	Winter
6/14/2003	03-25167	7.53	Winter
6/14/2003	03-25171	6.24	Winter
6/14/2003	03-25176	4.96	Winter
6/15/2003	03-22201	6.05	Winter
6/15/2003	03-25189	7.70	Winter
6/17/2003	03-22209	7.73	Winter
6/17/2003	03-22210	3.47	Winter
6/17/2003	03-22215	6.12	Winter
6/17/2003	03-22219	4.34	Winter
6/17/2003	03-25193	7.51	Winter
6/18/2003	03-25219	7.51	Winter
6/18/2003	03-25221	7.74	Winter
6/20/2003	03-22243	6.12	Winter
6/20/2003	03-22246	7.33	Winter
6/20/2003	03-22251	7.64	Winter
6/20/2003	03-22255	6.08	Winter
6/20/2003	03-22261	8.07	Winter
6/20/2003	03-22273	8.56	Winter
6/20/2003	03-25245	2.48	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
6/21/2003	03-22284	3.81	Winter
6/21/2003	03-25256	5.10	Winter
6/23/2003	03-22297	6.95	Winter
6/23/2003	03-22311	5.88	Winter
6/23/2003	03-22312	4.45	Winter
6/23/2003	03-22315	6.63	Winter
6/23/2003	03-22323	4.52	Winter
6/23/2003	03-25260	5.20	Winter
6/23/2003	03-25274	5.60	Winter
6/23/2003	03-25276	4.01	Winter
6/23/2003	03-25301	7.94	Winter
6/24/2003	03-22332	0.67	Non-Winter
6/24/2003	03-22336	6.25	Winter
6/24/2003	03-25308	3.68	Winter
6/26/2003	03-22350	No Data	No call
6/26/2003	03-22356	3.56	Winter
6/26/2003	03-22362	No Data	No call
6/26/2003	03-22375	8.65	Winter
6/26/2003	03-22391	6.82	Winter
6/26/2003	03-25321	8.00	Winter
6/26/2003	03-25331	4.35	Winter
6/26/2003	03-25345	5.51	Winter
6/26/2003	03-25346	8.79	Winter
6/26/2003	03-25347	6.56	Winter
6/26/2003	03-25348	No Data	No call
6/26/2003	03-25353	4.79	Winter
6/26/2003	03-25356	3.48	Winter
6/27/2003	03-22704	No Data	No call
6/27/2003	03-25377	4.11	Winter
6/27/2003	03-25379	5.08	Winter
6/27/2003	03-25381	4.02	Winter
6/29/2003	03-22402	No Data	No call
6/29/2003	03-22405	3.71	Winter
6/29/2003	03-22408	3.59	Winter
6/29/2003	03-22414	5.76	Winter
6/30/2003	03-22434	7.64	Winter
6/30/2003	03-25423	7.74	Winter
6/30/2003	03-25426	3.46	Winter
7/2/2003	03-22444	3.81	Winter
7/2/2003	03-22456	6.17	Winter
7/2/2003	03-25435	6.07	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
7/2/2003	03-25440	6.19	Winter
7/2/2003	03-25441	8.98	Winter
7/2/2003	03-25481	5.86	Winter
7/2/2003	03-25485	6.08	Winter
7/2/2003	03-25491	No Data	No call
7/2/2003	03-25500	3.38	Winter
7/3/2003	03-22462	3.69	Winter
7/3/2003	03-22467	6.54	Winter
7/3/2003	03-22473	5.00	Winter
7/3/2003	03-22479	No Data	No call
7/3/2003	03-25446	3.64	Winter
7/5/2003	03-22487	7.17	Winter
7/5/2003	03-22498	3.58	Winter
7/5/2003	03-25605	5.54	Winter
7/6/2003	03-25609	6.30	Winter
7/6/2003	03-25617	6.97	Winter
7/6/2003	03-25619	4.94	Winter
7/6/2003	03-25627	4.31	Winter
7/8/2003	03-22805	6.83	Winter
7/8/2003	03-22813	1.16	Non-Winter
7/8/2003	03-25484	5.40	Winter
7/8/2003	03-25632	6.17	Winter
7/8/2003	03-25643	6.23	Winter
7/8/2003	03-25654	3.62	Winter
7/9/2003	03-22821	3.22	Winter
7/9/2003	03-22823	8.77	Winter
7/9/2003	03-22836	5.61	Winter
7/9/2003	03-25669	No Data	No call
7/9/2003	03-25676	6.42	Winter
7/11/2003	03-22849	5.72	Winter
7/11/2003	03-22852	5.16	Winter
7/11/2003	03-25645	3.15	Winter
7/11/2003	03-25650	3.99	Winter
7/11/2003	03-25682	7.05	Winter
7/11/2003	03-25686	6.98	Winter
7/11/2003	03-25705	6.29	Winter
7/12/2003	03-22863	6.22	Winter
7/12/2003	03-22864	5.58	Winter
7/12/2003	03-25722	6.25	Winter
7/14/2003	03-22725	7.65	Winter
7/14/2003	03-25501	5.30	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
7/14/2003	03-25507	5.59	Winter
7/14/2003	03-25512	8.59	Winter
7/14/2003	03-25692	6.84	Winter
7/15/2003	03-22733	5.47	Winter
7/15/2003	03-22735	3.37	Winter
7/15/2003	03-25517	5.76	Winter
7/17/2003	03-25530	5.21	Winter
7/17/2003	03-25594	6.12	Winter
7/17/2003	03-25595	No Data	No call
7/17/2003	03-25700	6.10	Winter
7/18/2003	03-22746	2.72	Winter
7/18/2003	03-25539	7.59	Winter
7/20/2003	03-22765	2.53	Winter
7/20/2003	03-25543	No Data	No call
7/20/2003	03-25545	2.44	Winter
7/20/2003	03-25546	3.32	Winter
7/21/2003	03-22766	4.59	Winter
7/21/2003	03-22770	6.10	Winter
7/21/2003	03-22777	-1.92	Non-Winter
7/23/2003	03-22781	5.72	Winter
7/23/2003	03-22786	6.82	Winter
7/23/2003	03-25568	3.41	Winter
7/23/2003	03-25571	No Data	No call
7/24/2003	03-25585	No Data	No call
7/24/2003	03-25587	6.51	Winter
7/24/2003	03-25588	5.31	Winter
7/26/2003	03-22887	3.01	Winter
7/26/2003	03-22888	5.53	Winter
7/27/2003	03-22905	6.39	Winter
7/29/2003	03-22915	6.37	Winter
7/29/2003	03-25746	5.17	Winter
7/29/2003	03-25748	3.42	Winter
7/30/2003	03-25750	4.45	Winter
8/1/2003	03-22920	5.80	Winter
8/1/2003	03-22921	4.29	Winter
8/1/2003	03-22922	6.90	Winter
8/1/2003	03-22923	No Data	No call
8/1/2003	03-22924	No Data	No call
8/1/2003	03-22926	6.93	Winter
8/1/2003	03-22927	1.38	Non-Winter
8/1/2003	03-22928	4.81	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
8/1/2003	03-22929	6.39	Winter
8/1/2003	03-22930	5.22	Winter
8/1/2003	03-22931	6.96	Winter
8/1/2003	03-22934	6.15	Winter
8/1/2003	03-22935	7.01	Winter
8/1/2003	03-25698	No Data	No call
8/1/2003	03-25699	No Data	No call
8/1/2003	03-25752	7.29	Winter
8/1/2003	03-25754	5.75	Winter
8/1/2003	03-25755	4.83	Winter
8/1/2003	03-25756	1.81	Non-Winter
8/1/2003	03-25757	8.24	Winter
8/1/2003	03-25758	7.49	Winter
8/1/2003	03-25759	5.42	Winter
8/1/2003	03-25761	4.82	Winter
8/1/2003	03-25762	7.42	Winter
8/1/2003	03-25764	3.41	Winter
8/2/2003	03-22936	4.62	Winter
8/2/2003	03-25765	6.43	Winter
8/2/2003	03-25766	4.27	Winter
8/2/2003	03-25767	5.82	Winter
8/4/2003	03-22937	8.72	Winter
8/4/2003	03-22938	3.09	Winter
8/4/2003	03-22939	7.93	Winter
8/4/2003	03-22941	7.93	Winter
8/4/2003	03-22942	3.68	Winter
8/4/2003	03-22943	5.50	Winter
8/4/2003	03-22944	6.66	Winter
8/4/2003	03-22945	6.30	Winter
8/4/2003	03-22946	3.95	Winter
8/4/2003	03-22947	8.13	Winter
8/4/2003	03-22948	5.30	Winter
8/4/2003	03-22950	6.72	Winter
8/4/2003	03-25770	3.72	Winter
8/4/2003	03-25773	4.35	Winter
8/4/2003	03-25774	7.16	Winter
8/4/2003	03-25776	7.04	Winter
8/4/2003	03-25777	6.29	Winter
8/4/2003	03-25778	6.24	Winter
8/4/2003	03-25779	1.73	Non-Winter
8/4/2003	03-25780	3.29	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
8/4/2003	03-25781	1.73	Non-Winter
8/4/2003	03-25782	1.73	Non-Winter
8/4/2003	03-25783	5.21	Winter
8/4/2003	03-25784	5.43	Winter
8/4/2003	03-25791	1.72	Non-Winter
8/4/2003	03-25792	3.41	Winter
8/4/2003	03-25794	3.83	Winter
8/4/2003	03-25795	5.09	Winter
8/4/2003	03-25796	6.87	Winter
8/5/2003	03-25769	8.32	Winter
8/5/2003	03-25902	8.92	Winter
8/7/2003	03-22951	4.68	Winter
8/7/2003	03-22952	7.24	Winter
8/7/2003	03-22953	3.56	Winter
8/7/2003	03-22961	4.80	Winter
8/7/2003	03-22962	4.65	Winter
8/7/2003	03-22963	7.55	Winter
8/7/2003	03-22964	5.99	Winter
8/7/2003	03-22966	9.06	Winter
8/7/2003	03-25797	3.10	Winter
8/7/2003	03-25903	3.88	Winter
8/7/2003	03-25904	7.03	Winter
8/7/2003	03-25905	4.83	Winter
8/7/2003	03-25906	8.33	Winter
8/7/2003	03-25907	7.87	Winter
8/7/2003	03-25908	7.05	Winter
8/7/2003	03-25909	-8.98	Non-Winter
8/7/2003	03-25910	3.19	Winter
8/7/2003	03-25912	4.78	Winter
8/8/2003	03-25914	7.21	Winter
8/10/2003	03-22968	4.84	Winter
8/10/2003	03-22969	7.02	Winter
8/10/2003	03-22970	3.98	Winter
8/10/2003	03-22971	4.47	Winter
8/10/2003	03-25915	1.50	Non-Winter
8/10/2003	03-25916	6.68	Winter
8/10/2003	03-25917	4.81	Winter
8/10/2003	03-25919	3.73	Winter
8/11/2003	03-22972	5.80	Winter
8/11/2003	03-25920	2.76	Winter
8/11/2003	03-25921	6.80	Winter

Collection Date	Sample Number	LOD Score	GeneticCall
8/13/2003	03-22973	3.76	Winter
8/13/2003	03-25786	5.39	Winter
8/13/2003	03-25787	4.84	Winter
8/13/2003	03-25923	3.45	Winter
8/13/2003	03-25924	4.70	Winter
8/13/2003	03-25925	7.58	Winter
8/16/2003	03-22974	3.92	Winter
8/16/2003	03-22975	5.10	Winter
8/16/2003	03-22976	6.99	Winter
8/16/2003	03-22977	5.71	Winter
8/16/2003	03-25926	6.22	Winter
8/19/2003	03-22900	2.84	Winter
8/19/2003	03-25927	3.03	Winter
8/23/2003	03-22978	6.09	Winter
8/25/2003	03-22979	-5.30	Non-Winter
9/3/2003	03-22988	-6.36	Non-Winter

Appendix C. Recovery information for carcasses containing a coded wire tag (CWT) collected during the 2003 upper Sacramento River winter Chinook salmon carcass survey. Data includes river mile (RM) of recovery and carcass gender, fork length (FL, mm), condition (see text [Methods] for description), and spawn status. All fish were winter Chinook salmon originating from Livingston Stone National Fish Hatchery.

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
5/15/2003	0501030107	296.5	Female	790	Non-Fresh	Unknown
5/15/2003	0501030107	298	Male	860	Fresh	Unknown
5/19/2003	0501030404	294	Female	720	Non-Fresh	Spawned
5/21/2003	0501030205	297	Female	800	Fresh	Spawned
5/27/2003	0501030403	296.5	Female	760	Non-Fresh	Spawned
6/2/2003	0501030408	301	Female	720	Fresh	Spawned
6/2/2003	0501030403	296.5	Female	710	Fresh	Spawned
6/2/2003	0501030404	296.5	Female	750	Fresh	Spawned
6/5/2003	0501030705	299	Male	540	Fresh	Unknown
6/5/2003	0501030406	296.5	Female	780	Non-Fresh	Spawned
6/8/2003	0501030107	296.5	Female	740	Fresh	Spawned
6/12/2003	0501030406	289	Male	750	Fresh	Unknown
6/14/2003	0501030803	296.5	Male	420	Non-Fresh	Unknown
6/17/2003	0501030408	297	Female	710	Fresh	Spawned
6/17/2003	0501030207	297	Female	720	Fresh	Spawned
6/17/2003	0501030208	299	Female	720	Non-Fresh	Spawned
6/18/2003	0501030405	294	Female	700	Non-Fresh	Spawned
6/23/2003	0501030108	299	Female	660	Fresh	Spawned
6/23/2003	0501030405	299	Female	770	Fresh	Spawned
6/23/2003	0501030306	296.5	Female	710	Fresh	Spawned
6/24/2003	0501030301	289	Male	750	Non-Fresh	Unknown
6/27/2003	0501030206	288	Male	860	Fresh	Unknown
6/29/2003	0501030705	299	Male	550	Fresh	Unknown
6/29/2003	0501030401	296.5	Female	690	Fresh	Spawned
6/29/2003	0501030307	297	Female	670	Non-Fresh	Spawned
6/29/2003	0501030404	298	Female	740	Fresh	Spawned
6/29/2003	0501030405	299	Female	750	Fresh	Spawned
6/29/2003	0501030307	301	Female	740	Fresh	Spawned
6/29/2003	0501030802	299	Male	420	Fresh	Unknown
6/29/2003	0501030306	299	Female	800	Non-Fresh	Spawned
6/29/2003	0501030208	299	Female	750	Fresh	Spawned
7/2/2003	0501030305	299	Female	770	Fresh	Spawned
7/2/2003	0501030309	301	Female	740	Fresh	Spawned
7/2/2003	0501030209	298	Female	700	Fresh	Spawned
7/2/2003	0501030302	298	Female	720	Non-Fresh	Spawned
7/2/2003	0501030206	299	Female	870	Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
7/2/2003	0501030402	296.5	Male	760	Non-Fresh	Unknown
7/2/2003	0501030203	296.5	Female	730	Fresh	Spawned
7/2/2003	0501030402	298	Male	840	Non-Fresh	Unknown
7/2/2003	0501030404	296.5	Female	780	Fresh	Spawned
7/3/2003	0501030705	294	Male	540	Fresh	Unknown
7/5/2003	0501030108	299	Male	750	Fresh	Unknown
7/5/2003	0501030108	299	Female	700	Fresh	Spawned
7/5/2003	0501030208	299	Female	650	Fresh	Spawned
7/5/2003	0501030203	296.5	Female	730	Fresh	Spawned
7/6/2003	0501030903	289	Male	520	Fresh	Unknown
7/6/2003	0501030207	291	Female	630	Fresh	Spawned
7/6/2003	0501030408	291	Female	720	Fresh	Spawned
7/8/2003	0501030409	299	Female	730	Fresh	Spawned
7/8/2003	0501030203	297	Female	720	Fresh	Spawned
7/8/2003	0501030308	296.5	Female	700	Fresh	Spawned
7/8/2003	0501030409	297	Female	760	Fresh	Spawned
7/8/2003	0501030408	298	Female	750	Fresh	Spawned
7/8/2003	0501030401	299	Female	740	Fresh	Spawned
7/8/2003	0501030206	299	Female	680	Fresh	Spawned
7/8/2003	0501030206	299	Female	770	Fresh	Spawned
7/8/2003	0501030203	299	Female	690	Fresh	Spawned
7/8/2003	0501030406	301	Female	740	Fresh	Spawned
7/8/2003	0501030204	300	Female	690	Fresh	Spawned
7/8/2003	0501030402	296	Female	780	Non-Fresh	Spawned
7/9/2003	0501030401	288	Female	700	Fresh	Spawned
7/9/2003	0501030306	292	Female	730	Non-Fresh	Spawned
7/9/2003	0501030403	294	Male	880	Fresh	Unknown
7/11/2003	0501030206	299	Female	810	Non-Fresh	Spawned
7/11/2003	0501030202	296	Female	680	Fresh	Spawned
7/11/2003	0501030304	296.5	Female	740	Non-Fresh	Spawned
7/11/2003	0501030204	296.5	Female	690	Fresh	Spawned
7/11/2003	0501030205	298	Female	720	Fresh	Spawned
7/11/2003	0501030206	299	Male	790	Fresh	Unknown
7/11/2003	0501030202	298	Female	750	Non-Fresh	Spawned
7/11/2003	0501030401	298	Female	670	Fresh	Spawned
7/11/2003	0501030301	298	Male	760	Fresh	Unknown
7/11/2003	0501030203	299	Female	750	Fresh	Spawned
7/12/2003	0501030402	289	Male	910	Non-Fresh	Unknown
7/14/2003	0501030408	296.5	Female	680	Fresh	Spawned
7/14/2003	0501030802	298	Male	450	Fresh	Unknown
7/14/2003	0501030202	296.5	Female	800	Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
7/14/2003	0501030203	296.5	Female	700	Fresh	Spawned
7/14/2003	0501030204	299	Male	860	Fresh	Unknown
7/17/2003	0501030207	296.5	Female	790	Fresh	Spawned
7/17/2003	0501030207	298	Female	770	Fresh	Spawned
7/17/2003	0501021305	300	Female	820	Fresh	Spawned
7/17/2003	0501030204	299	Female	780	Non-Fresh	Spawned
7/18/2003	0501030307	294	Female	730	Fresh	Spawned
7/20/2003	0501030206	299	Female	770	Non-Fresh	Spawned
7/20/2003	0501030202	299	Female	650	Non-Fresh	Spawned
7/20/2003	0501030203	299	Female	680	Fresh	Spawned
7/20/2003	0501030304	299	Female	650	Fresh	Spawned
7/20/2003	0501030705	297	Male	560	Fresh	Unknown
7/20/2003	0501030202	296.5	Female	680	Fresh	Spawned
7/20/2003	0501030302	298	Female	760	Non-Fresh	Spawned
7/21/2003	0501030204	294	Male	830	Non-Fresh	Unknown
7/23/2003	0501030308	301	Female	690	Fresh	Spawned
7/23/2003	0501030107	296.5	Female	730	Non-Fresh	Spawned
7/23/2003	0501030401	296.5	Female	690	Non-Fresh	Spawned
7/23/2003	0501030209	296.5	Female	700	Non-Fresh	Spawned
7/23/2003	0501030302	297	Female	750	Fresh	Spawned
7/23/2003	0501030303	296.5	Female	790	Fresh	Spawned
7/23/2003	0501030206	296.5	Female	710	Fresh	Spawned
7/24/2003	0501030806	288	Male	580	Fresh	Unknown
7/24/2003	0501030705	293	Male	470	Fresh	Unknown
7/24/2003	0501030404	294	Female	720	Fresh	Spawned
7/26/2003	0501030109	296.5	Female	680	Non-Fresh	Spawned
7/26/2003	0501030303	299	Female	740	Non-Fresh	Spawned
7/26/2003	0501030408	299	Female	640	Non-Fresh	Spawned
7/29/2003	0501030207	296.5	Female	720	Fresh	Spawned
7/29/2003	0501030404	296.5	Female	720	Non-Fresh	Spawned
7/29/2003	0501030206	299	Female	700	Non-Fresh	Spawned
7/29/2003	0501030306	298	Female	770	Fresh	Spawned
7/29/2003	0501030201	298	Female	710	Non-Fresh	Spawned
7/29/2003	0501030307	299	Female	710	Non-Fresh	Spawned
7/30/2003	0501030209	289	Female	660	Fresh	Spawned
8/1/2003	0501030406	299	Female	690	Fresh	Spawned
8/1/2003	0501030406	301	Female	710	Non-Fresh	Spawned
8/1/2003	0501030302	299	Female	710	Fresh	Spawned
8/1/2003	0501030705	296.5	Male	550	Fresh	Unknown
8/4/2003	0501030408	299	Female	710	Fresh	Spawned
8/4/2003	0501030304	298	Female	720	Fresh	Spawned

Collection Date	CWT Code	RM	Sex	FL	Condition	Spawn Status
8/4/2003	0501030209	296.5	Female	800	Non-Fresh	Spawned
8/4/2003	0501030307	299	Female	720	Fresh	Spawned
8/7/2003	0501030409	296.5	Female	690	Non-Fresh	Spawned
8/7/2003	0501030308	299	Female	740	Non-Fresh	Spawned
8/7/2003	0501030303	299	Female	750	Non-Fresh	Spawned
8/7/2003	0501030406	299	Female	740	Non-Fresh	Spawned
9/1/2003	0501030302	296.5	Female	720	Non-Fresh	Spawned

Appendix D. Winter Chinook salmon tag code groups released from Livingston Stone National Fish Hatchery during brood years (BY) 1999, 2000, and 2001. All fish were released at Lake Redding Park. Coded wire tag (CWT) codes 0501021307 and 0501030705 were used for the progeny of captive broodstock held at the University of California-Davis Bodega Marine Laboratory. Average fork length (FL) is reported in millimeters and average weight in grams. Number released for each CWT is reported as (1) number released with an adipose fin clip (C) and CWT (T), (2) C and no CWT (NT), (3) No adipose fin clip (NC) and a T, and (4) NC and NT.

					Number Released			
BY	CWT Code	FL	Weight	Release Date	C/T	C/NT	NC/T	NC/NT
1999	0501021205	75	395	1/27/2000	860	4	4	0
1999	0501021206	74	440	1/27/2000	1,180	18	6	0
1999	0501021207	74	479	1/27/2000	1,283	20	7	0
1999	0501021208	76	522	1/27/2000	809	12	0	0
1999	0501021209	84	669	1/27/2000	1,000	21	10	0
1999	0501021210	79	570	1/27/2000	1,258	26	20	0
1999	0501021211	98	1054	1/27/2000	1,549	8	0	0
1999	0501021212	103	1341	1/27/2000	1,145	0	0	0
1999	0501021213	89	892	1/27/2000	1,730	26	0	0
1999	0501021214	92	968	1/27/2000	1,545	0	0	0
1999	0501021215	96	1108	1/27/2000	1,199	6	0	0
1999	0501021301	101	1275	1/27/2000	1,574	57	0	0
1999	0501021302	98	1171	1/27/2000	2,115	65	0	0
1999	0501021303	100	1255	1/27/2000	1,993	0	10	0
1999	0501021304	101	1231	1/27/2000	1,716	0	0	0
1999	0501021305	89	808	1/27/2000	2,125	21	0	0
1999	0501021306	98	1305	1/27/2000	3,054	46	0	0
1999	0501021307	69	370	1/27/2000	4,232	65	22	0
2000	0501030107	81	587	2/1/2001	8,023	124	83	41
2000	0501030108	82	601	2/1/2001	5,284	220	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released			
					C/T	C/NT	NC/T	NC/NT
2000	0501030109	77	507	2/1/2001	5,550	172	0	0
2000	0501030201	72	408	2/1/2001	5,429	347	0	0
2000	0501030202	81	595	2/1/2001	5,241	395	0	0
2000	0501030203	81	580	2/1/2001	6,403	164	0	0
2000	0501030204	80	556	2/1/2001	5,586	203	0	0
2000	0501030205	82	602	2/1/2001	6,166	158	0	0
2000	0501030206	75	475	2/1/2001	6,901	70	0	0
2000	0501030207	78	528	2/1/2001	6,013	0	0	0
2000	0501030208	79	551	2/1/2001	5,381	54	0	0
2000	0501030209	77	510	2/1/2001	5,634	147	88	0
2000	0501030301	81	580	2/1/2001	5,500	56	0	0
2000	0501030302	79	534	2/1/2001	5,747	59	59	0
2000	0501030303	76	479	2/1/2001	5,966	91	0	0
2000	0501030304	77	516	2/1/2001	5,829	29	29	0
2000	0501030305	76	491	2/1/2001	5,333	27	0	0
2000	0501030306	83	631	2/1/2001	5,325	137	0	0
2000	0501030307	83	639	2/1/2001	5,007	102	0	0
2000	0501030308	72	413	2/1/2001	5,268	108	0	0
2000	0501030309	83	627	2/1/2001	4,798	48	0	0
2000	0501030401	80	561	2/1/2001	5,126	131	0	0
2000	0501030402	86	709	2/1/2001	4,826	98	0	0
2000	0501030403	84	645	2/1/2001	5,319	164	0	0
2000	0501030404	86	710	2/1/2001	4,439	161	0	0
2000	0501030405	84	656	2/1/2001	5,435	168	0	0
2000	0501030406	85	685	2/1/2001	4,763	73	0	0
2000	0501030407	81	582	2/1/2001	4,603	23	47	0

BY	CWT Code	FL	Weight	Release Date	Number Released C/T	C/NT	NC/T	NC/NT
2000	0501030408	81	590	2/1/2001	4,666	23	0	0
2000	0501030409	87	730	2/1/2001	2,637	110	0	0
2001	0501020507	70	0	1/30/2002	4,285	0	0	22
2001	0501030705	75	0	1/30/2002	61,462	623	104	104
2001	0501030706	71	0	1/30/2002	37,287	892	427	194
2001	0501030707	85	0	1/30/2002	15,106	0	0	0
2001	0501030708	78	0	1/30/2002	6,077	675	0	0
2001	0501030709	77	0	1/30/2002	6,104	678	0	0
2001	0501030801	72	0	1/30/2002	5,281	109	54	0
2001	0501030802	80	0	1/30/2002	5,521	352	0	0
2001	0501030803	84	0	1/30/2002	4,901	426	0	0
2001	0501030804	78	0	1/30/2002	5,942	734	0	0
2001	0501030805	85	0	1/30/2002	4,726	146	0	0
2001	0501030806	77	0	1/30/2002	6,270	400	0	0
2001	0501030807	75	0	1/30/2002	4,529	140	0	0
2001	0501030808	73	0	1/30/2002	4,853	24	0	0
2001	0501030809	74	0	1/30/2002	5,213	217	0	0
2001	0501030901	78	0	1/30/2002	4,514	393	0	0
2001	0501030902	77	0	1/30/2002	4,696	326	0	0
2001	0501030903	77	0	1/30/2002	4,950	180	0	0
2001	0501030904	77	0	1/30/2002	5,361	254	28	0
2001	0501030905	76	0	1/30/2002	5,528	386	30	0
2001	0501030906	76	0	1/30/2002	5,173	363	56	0
2001	0501030907	76	0	1/30/2002	4,802	507	27	0
2001	0501030908	76	0	1/30/2002	5,755	575	32	32
2001	0501030909	75	0	1/30/2002	6,074	528	0	0

BY	CWT Code	FL	Weight	Release Date	Number Released			
					C/T	C/NT	NC/T	NC/NT
2001	0501040101	71	0	1/30/2002	4,634	23	0	0
2001	0501040102	73	0	1/30/2002	4,967	25	0	0
2001	0501040103	69	0	1/30/2002	4,709	49	97	0
2001	0501040104	69	0	1/30/2002	4,819	0	49	0