2001 Winter Chinook Salmon Carcass Survey Annual Report

A USFWS Report

U.S. Fish and Wildlife Service
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Introduction

In 2001 the US Fish and Wildlife Service (Service) and the California Department of Fish and Game (CDFG) conducted a carcass survey for winter Chinook salmon in the upper Sacramento River. Primary objectives of this survey are to estimate the abundance of winter Chinook salmon, and to collect information on several important life history attributes of this population including age and sex composition of the spawner population, pre-spawning mortality rate, and temporal and spatial distribution of spawning activities. An additional primary purpose of this survey is to collect data useful to evaluate the winter Chinook hatchery supplementation program conducted at the Livingston Stone National Fish Hatchery (LSNFH).

The Service and CDFG have conducted the Sacramento River winter Chinook carcass survey since 1996. The 2001 survey season was the first that was funded through CALFED (since renamed as the California Bay-Delta Authority). The following report is submitted to satisfy annual reporting requirements for those portions of this survey that fall within the Service's responsibilities, including: an evaluation of the winter Chinook salmon hatchery program at LSNFH and genetic characterization of the spawning population. An annual report of work performed on this project by CDFG during 2001, including an estimate of spawner abundance, was finalized in August 2002 (Snider et al.).

Background

The Sacramento River supports four distinct "runs" of Chinook salmon: fall Chinook, late-fall Chinook, spring Chinook, and winter Chinook. Winter Chinook usually return from the ocean in an immature reproductive state and enter the San Francisco Bay from November through June. They move upstream quickly, and hold in deep cool waters of the Sacramento River for extended periods before spawning from May to August. Sacramento River winter Chinook spawn between Red Bluff and Keswick Dam (the upper limit of migration). Most winter Chinook spawn as three year olds (~65%), with the remainder spawning as two (25%) and four (8%) year olds (Hallock and Fisher 1985, Fisher 1994). Virtually all of the two year olds are precocious males, commonly known as "jacks".

In 1989, due to low abundance of returning adults and a declining population trend, Sacramento River winter Chinook salmon were listed as threatened under the California Endangered Species Act. In November of 1990, the National Fisheries Service (NMFS) finalized an emergency rule that listed winter Chinook salmon as threatened under the federal Endangered Species Act (ESA). In the following years adult returns of winter Chinook salmon continued to decline, and in January of 1994 NMFS reclassified winter Chinook salmon as federally endangered. The NMFS cited the following reasons for the reclassification, 1) the continued decline and increased variability of the population since its listing as a threatened species in 1989 (Figure 1), 2) the expectation of weak returns in certain future years as the result of two small year classes (1991 and 1993), and 3) continuing threats to the population.

In 1989, in order to supplement natural production and to protect against extinction, the Service developed an artificial propagation program for winter Chinook salmon. The propagation program was located at the Coleman National Fish Hatchery, on Battle Creek, a tributary of the Sacramento River. In 1998, because of concerns about adults imprinting on Battle Creek instead of the mainstem Sacramento River, the program was moved to a new facility at the base of Shasta Dam: Livingston Stone National Fish Hatchery (Figure 2).

In 1997, a draft recovery plan for Sacramento River Chinook salmon was developed. The de-listing criteria identified in the recovery plan required a mean annual spawning abundance over 13 consecutive years of 10,000 females, and a cohort replacement rate, over the same 13 year period, greater than 1. The recovery plan also stipulated that in order to evaluate progress toward these delisting goals, a monitoring system must be in place to estimate spawner abundance with an estimation error less than 25%. At that time, estimates of winter Chinook escapement were based on passage counts through the ladders at the Red Bluff Diversion Dam (RBDD). However, estimates of annual escapement based on sampling at RBDD were determined to have an approximate error of about 100%. Therefore, beginning in 1996 the Service and CDFG and began cooperation on annual escapement surveys of the upper Sacramento River as an alternative methodology to produce more precise estimates of abundance for winter Chinook salmon.

Whereas the Service and the CDFG work side-by-side and cooperate fully on all field tasks associated with the winter Chinook carcass survey, the two agencies have clearly distinct and identifiable responsibilities in regards to analysis and reporting of the information generated on this survey. The responsibilities of the CDFG include: 1) estimating the abundance of adult winter Chinook salmon and, 2) collecting information on important life history attributes of winter Chinook salmon (e.g., age, sex, pre-spawn mortality). These information and analyses for the 2001 survey are reported by Snider et al. (2002). The responsibilities of the Service include: 1) recovering coded-wire tags from hatchery-origin fish and, 2) collecting tissue samples for genetic analyses. One of the Service’s primary goals associated with the carcass survey is to provide information to evaluate the efficacy of the winter Chinook supplementation program at the LSNFH in assisting recovery of this endangered species. This report is intended to meet the Service’s reporting responsibilities for the first year of the investigation, including: an evaluation of the winter Chinook salmon hatchery program at Livingston Stone National Fish Hatchery (LSNFH) and genetic characterization of the spawning population.

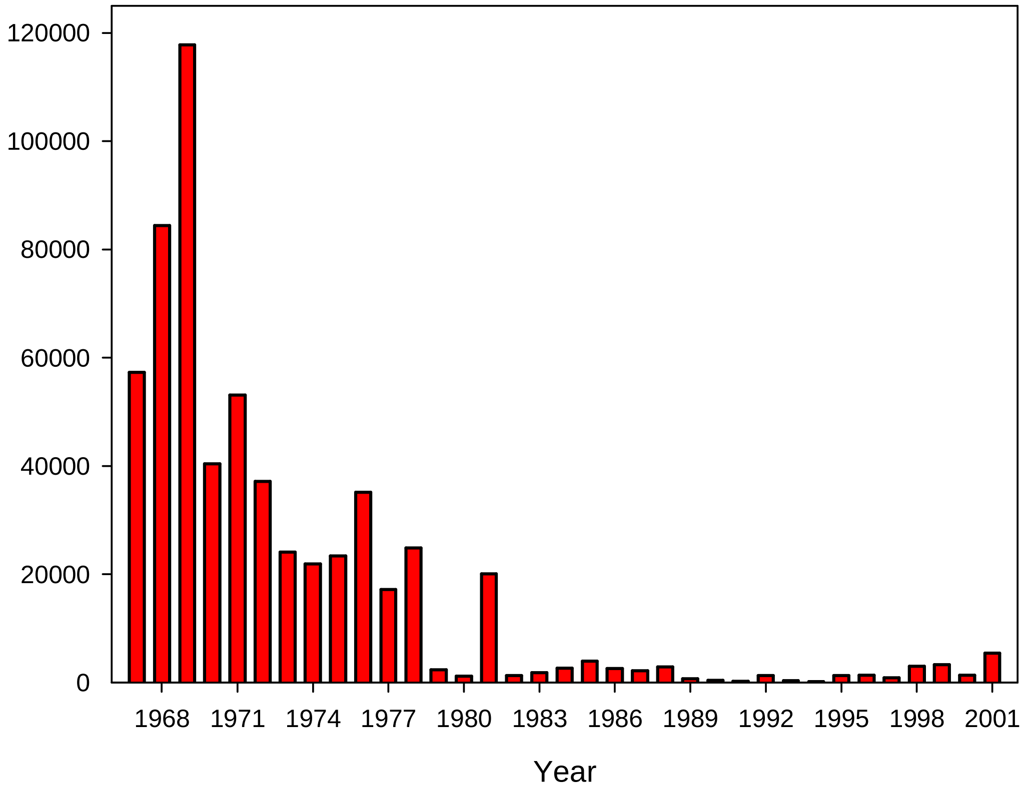

Figure 1 Population estimates for Sacramento River winter Chinook salmon 1967-2001

Methods

Similar to recent years (i.e. since 1997), the 2001 winter Chinook carcass survey was designed to encompass the primary spawning areas and entire spawn timing of winter Chinook salmon. The survey area was divided into two 7-mile reaches (Figure 2): Reach 1 extended from Keswick Dam (RM [river mile] 302) to the Cypress Street Bridge in Redding (RM 295); reach 2 comprised the area between the Cypress Street Bridge (RM 295) and the Redding Water Treatment Plant (RM 288).

We conducted our surveys in 3-day survey cycles, with the upper reach (reach 1) surveyed on the first day, the lower reach (reach 2) surveyed on the second day, and no survey conducted on the third day. The 2001 survey comprised 40 survey cycles with each cycle repeated approximately 2.5 times per week.

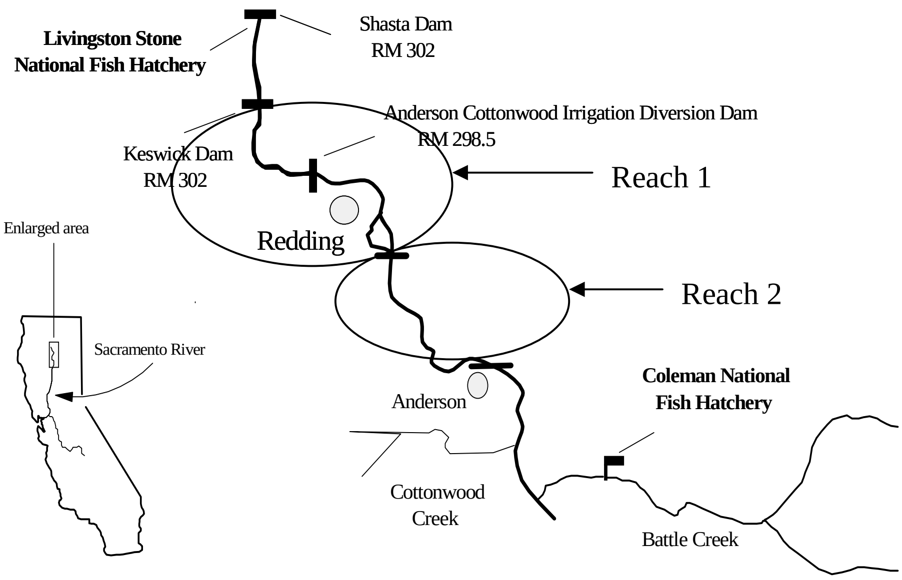

Figure 2 Upper Sacramento River and carcass survey area

The survey was conducted from two boats, each having two observers. Each boat usually surveyed the area between one shoreline and the middle of the river. Most observed carcasses were collected using a five-pronged gig, and were then sexed (females are evaluated for their spawning status; males are categorized as "unknown"), measured, tagged, and returned to the river. For a description of the mark-recapture methodologies, see Snider et al (2002).

Carcasses were also checked for adipose-fin clips. A missing adipose fin indicates that the Chinook carcass is of hatchery origin. The head was removed and retained from all adipose-fin clipped carcasses. Coded wire tags were later extracted and read at the Red Bluff FWO, providing the brood year and other information about individual fish.

Fin-tissue samples were taken from a portion of the carcasses that were deemed to have sufficient fin-tissue suitable for testing. Tissue samples were not collected from extremely decayed carcasses because their fin-tissues are not usable for genetic analysis. On days in which the number of carcasses suitable for sampling was expected to be less than 100, all suitable carcasses were sampled. On days in which the number of carcasses suitable for sampling was expected to exceed 100, a sub-sample ratio (e.g. 1:3) was assigned at the start of the day. For example, if the ratio was set at 1:3, every third carcass with suitable fin tissue was sampled.

A subset of fin-tissue samples was sent to the UC Davis Genetics laboratory at Bodega Bay (BML) for analysis. A systematic subsample of tissues was analyzed for collections made during the primary spawn timing (i.e. June and July). We hypothesized that nearly all samples collected from the primary spawn timing would be genetically identified as winter Chinook salmon. All samples collected during the early and late segments of the run were genetically analyzed (i.e. May and August) because we hypothesized a higher proportion of these fish would be identified as non-winter Chinook salmon. The results of genetic analyses provide information on the number of winter Chinook salmon among carcasses recovered on the spawning grounds, and aid in the development, implementation, and validation of a population genetic model for assessing the effect of the hatchery program on the effective size and genetic diversity of the winter Chinook population.

Results

Carcass Recoveries

The winter Chinook carcass survey was conducted from May 2 through August 29 in 2001. Two thousand two hundred and thirty five fresh and 2,910 decayed (5,145 total) carcasses were observed. One hundred and fifty five carcasses with clipped adipose fins were collected in 2001 (115 fresh, 35 non-fresh, and 5 without information on condition).

Spatial distribution

The distribution of salmon carcasses was highly variable throughout the survey area, with pools and eddies below spawning grounds typically showing a higher concentration of carcasses compared to areas of strong current. More carcasses were found in Turtle Bay (River mile 296.5) than any other location. Adipose fin-clipped carcasses were recovered in similar proportions, by river mile, to unmarked carcasses (Figure 3).

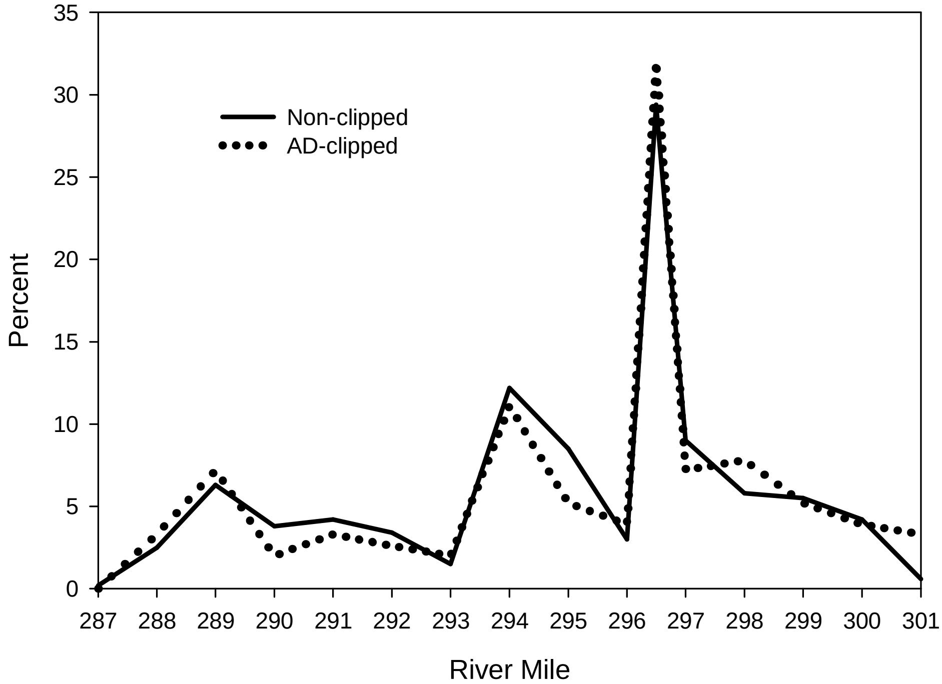

Figure 3 Percentage of adipose fin-clipped and unmarked carcasses recovered by river mile in 2001

Temporal distribution

In 2001 we observed a fairly normal (bell-shaped) temporal distribution of carcass recoveries. The majority of both adipose fin-clipped and unmarked carcasses were recovered in June and July. The temporal distribution of adipose fin-clipped carcass recoveries was similar to that of unmarked carcasses (Figure 4).

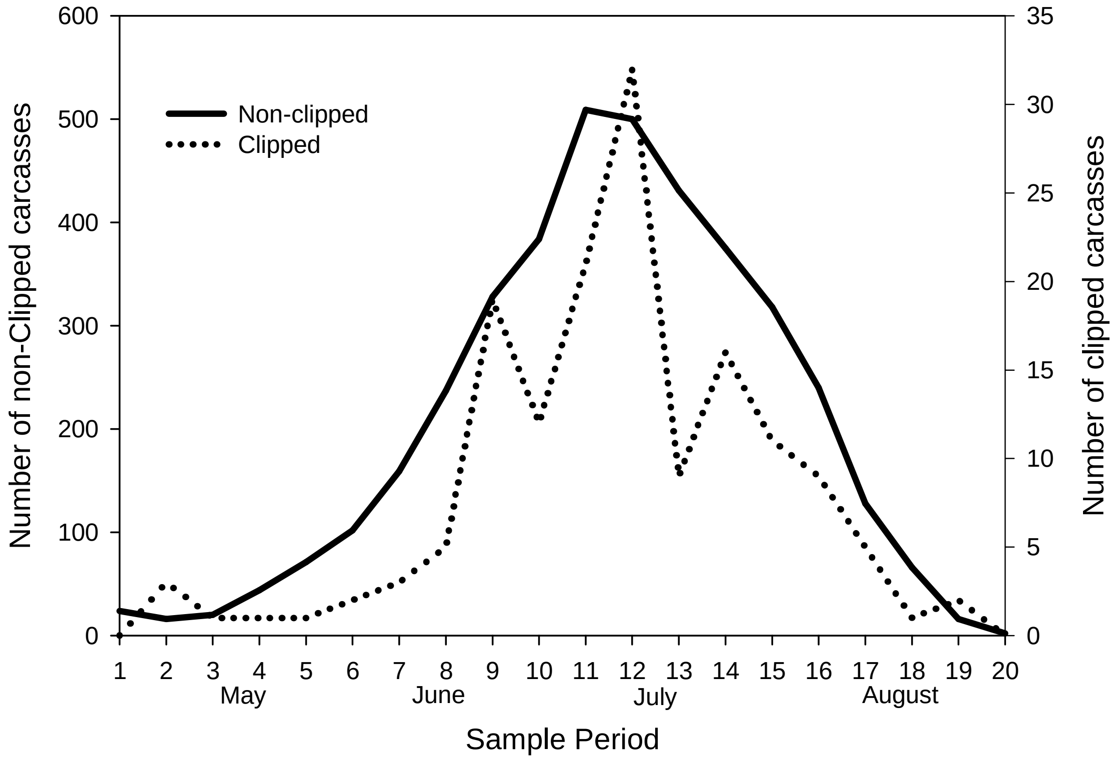

Figure 4 Temporal distributions of adipose fin-clipped and unmarked carcass recoveries

CWT recoveries

Coded wire tags (CWT) were recovered from 117 of the adipose fin-clipped carcasses. A tag was not recovered and decoded from a total of 38 of the collected heads. Failure to recover and decode tags was attributable to the following reasons: a tag was not detected in 31 of the heads collected, two heads were lost prior to tag excision, and five tags were found but lost during processing. All coded wire tagged carcasses were from the brood years (BY) 1998 and 1999 winter Chinook salmon that were reared at LSNFH and released at Lake Redding Park (Figure 5, Table 1). BY 1998 winter Chinook (n = 147,392) were released on January 28, 1999, and BY 1999 winter Chinook (n = 30,840) were released on January 27, 2000.

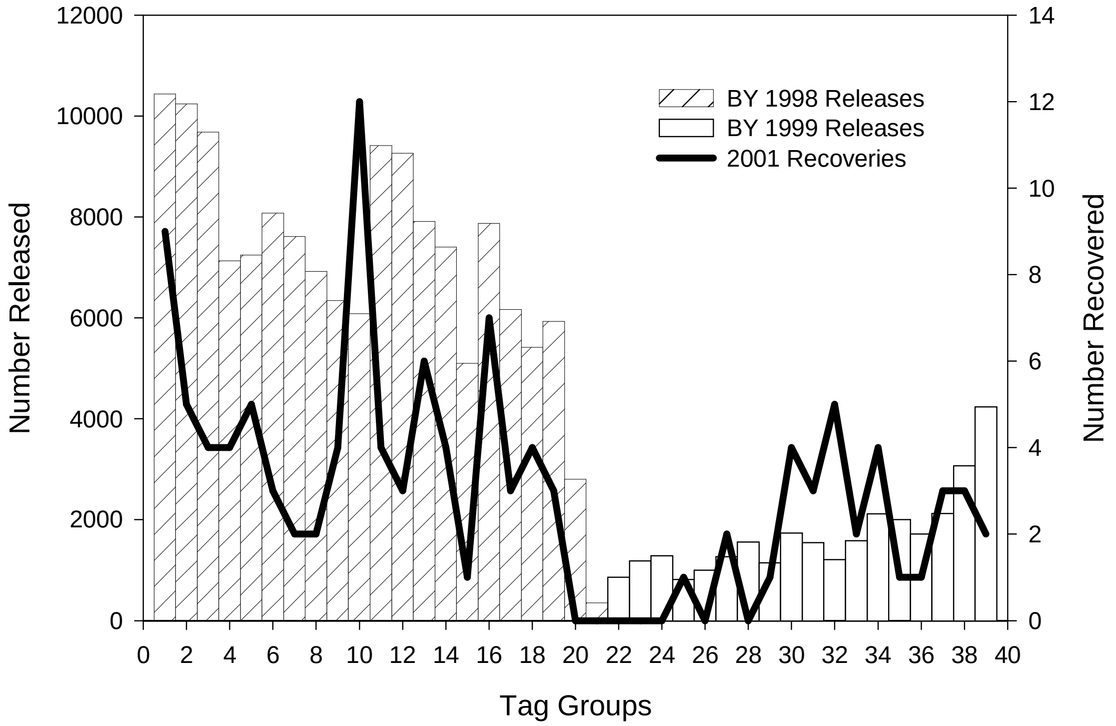

Figure 5 Number of juvenile winter Chinook released by tag code (each tag group corresponds to an individual tag code) and numbers of carcass recoveries by tag code in 2001.

BY1998 Tag codes	Recoveries	BY1999 Tag codes	Recoveries
0501020811	9	0501021205	0
0501020812	5	0501021206	0
0501020813	4	0501021207	0
0501020814	4	0501021208	1
0501020815	5	0501021209	0
0501020901	3	0501021210	2
0501020902	2	0501021211	0
0501020903	2	0501021212	1
0501020904	4	0501021213	4
0501020905	12	0501021214	3
0501020906	4	0501021215	5
0501020907	3	0501021301	2
0501020908	6	0501021302	4
0501020909	4	0501021303	1
0501020910	1	0501021304	1
0501020911	7	0501021305	3
0501020912	3	0501021306	3
0501020913	4	*0501021307	2
0501020914	3	*captive brood	
0501020915	0		
0501021001	0		

Table 1 Numbers of coded-wire tags recovered during the winter Chinook escapement survey in 2001. Recoveries are reported by brood year (BY) and tag code.

Age and sex composition
Of the recovered adipose fin-clipped carcasses that contained a CWT, 27.4% were two year olds and 72.6% were three year olds. Of the unmarked carcasses that were scale-aged (by CDFG), 10.3% were two year olds, 85.5% were three year olds, and 4.1% were four year olds. The absence of four year olds among hatchery origin carcasses during the 2001 survey season is explained by the fact that releases from the supplementation program at LSNFH began only three years prior, in 1998.

Among the adipose fin-clipped carcasses, 43% were males and 57% were females; among the unmarked carcasses, 34% were males and 66% were females.

Spawning status
All of the 85 female carcasses collected with clipped adipose fins in 2001 were classified as completely spawned. Of the unclipped carcasses, a total of 1,198 females were examined for egg retention, with 1,190 (99.4%) being completely spawned, three (0.2%) carcasses identified as partially spawned, and five (0.4%) were unspawned (Snider et al. 2002).

Body Size

Note: Analysis of body size for marked and unmarked winter Chinook salmon collected on the 2001 carcass survey was conducted by the CDFG, whose results are reported below.

Age of unmarked carcasses was determined by CDFG by examining length frequency distributions, and corroborated by conducting a scale pattern analysis on a subset of fresh, unmarked carcasses (Snider et al. 2002). Age of adipose-fin clipped carcasses was determined through examination of coded-wire tags. Figures 6-9 show the length-frequency distributions of male and female scale-aged unmarked carcasses and adipose-fin clipped carcasses. Body sizes of adipose fin-clipped carcasses recovered in 2001 were compared with those of unmarked carcasses of the same age. The results are as follows: No statistical difference exists between the average length of two-year-old adipose-fin clipped males (mean = 535 mm, range = 390-650 mm) and two-year-old unmarked males (mean = 620 mm, range = 450-650 mm; ANOVA, $F = 1.91$, $df = 194$, $p>0.15$). The average length of three-year-old adipose-fin clipped males (mean = 810 mm, range = 690-820 mm) was smaller than that of unmarked males (mean = 860 mm, range = 720-110 mm; ANOVA, $F = 1.91$, $df = 547$, $p<0.0001$). There were too few two-year-old females to compare statistically. Three-year-old adipose fin-clipped females (mean = 725 mm, range = 550-910 mm) were statistically smaller than three-year-old unmarked females (mean = 760 mm, range = 650-1010 mm; ANOVA, $F = 15.65$, $df = 1,329$, $p<0.0001$).

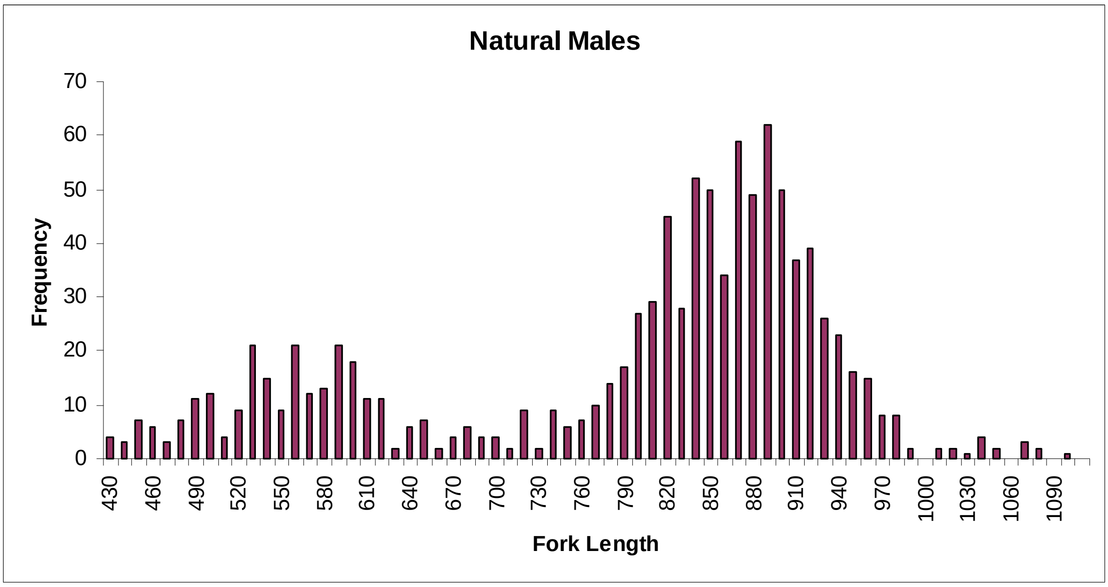

Figure 6 Length-frequency distribution of unmarked male winter Chinook collected during the 2001 carcass survey

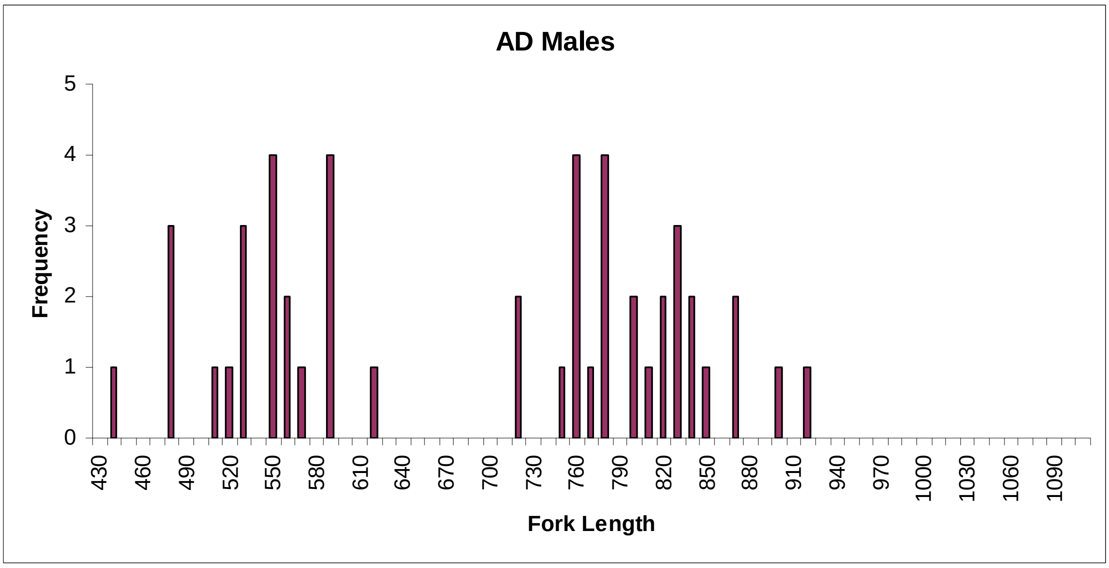

Figure 7 Length-frequency distribution of adipose-fin clipped male winter Chinook collected during the 2001 carcass survey

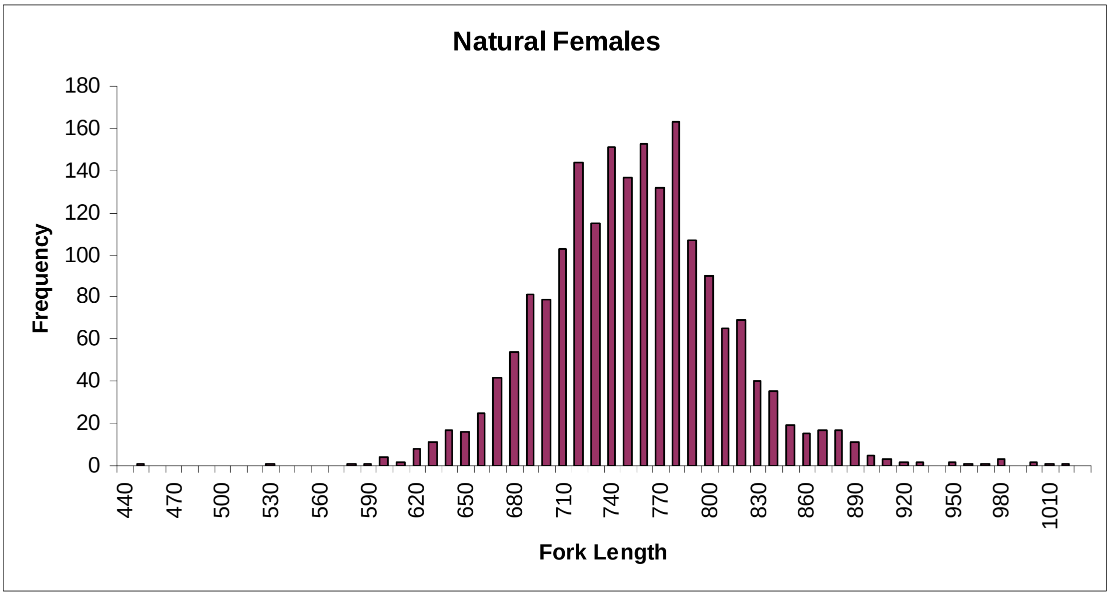

Figure 8 Length-frequency distribution of unmarked female winter Chinook collected during the 2001 carcass survey

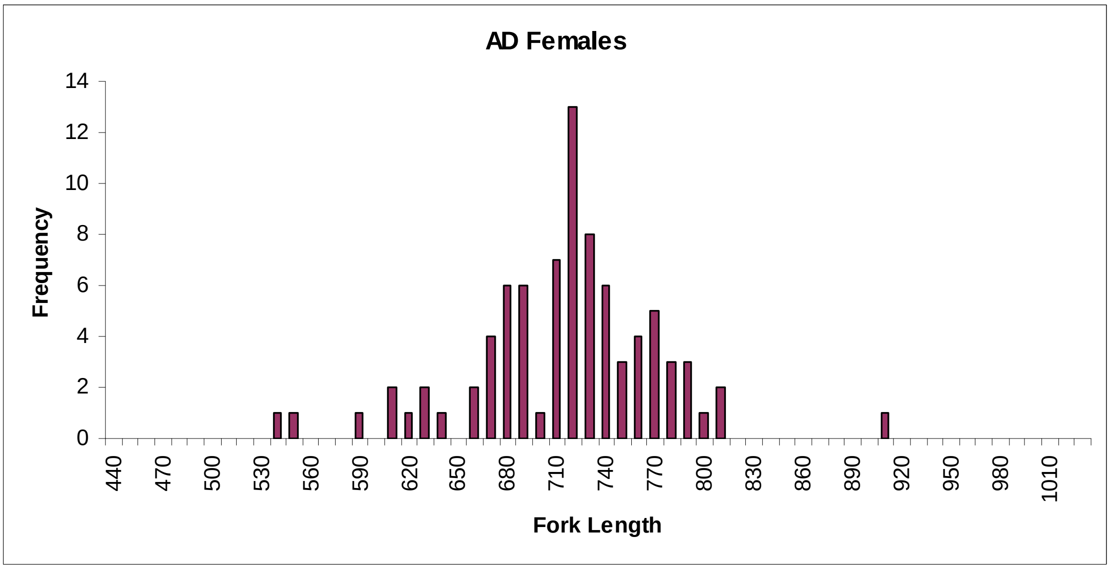

Figure 9 Length-frequency distribution of adipose-fin clipped female winter Chinook collected during the 2001 carcass survey

Tissue samples
Tissue samples were collected from 3,167 carcasses in 2001. Of these, 633 were sent to BML, with 452 (71.4%) amplifying at sufficient loci to undergo genetic run-call analysis. The genetic results data for the 2001 winter Chinook carcass survey were reported by Hedgecock et al. (2002), and are reprinted in appendix A of this report.

Differences between the two LOD score thresholds are not large. We utilized LOD>0 scores since this threshold is the most inclusive for winter Chinook; accordingly, 96% of the 452 samples analyzed are identified as winter Chinook (Figure 10). Over 97% of sub-samples collected in June, July and August were identified as winter Chinook, whereas 89% of the samples collected in May were identified as winter Chinook.

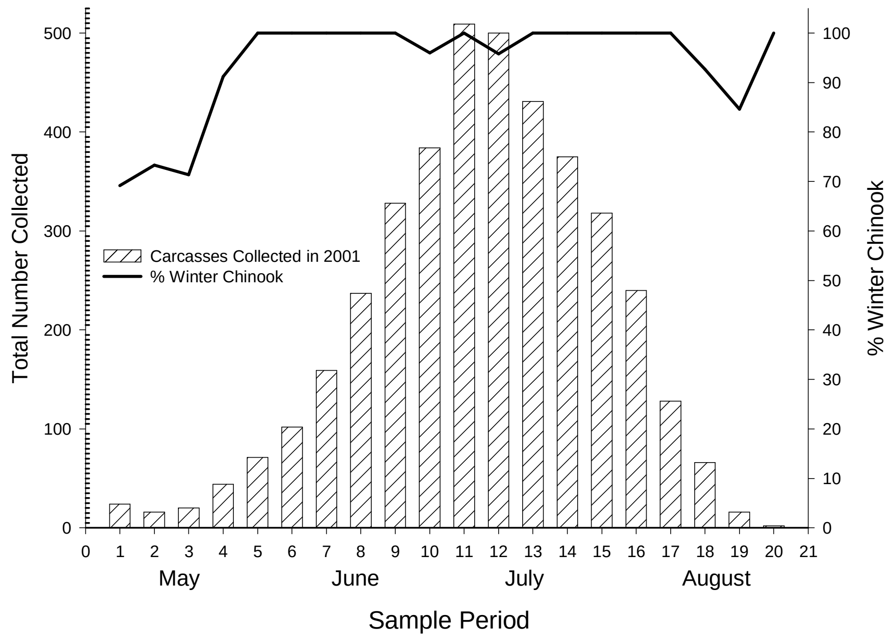

Figure 10 Number of carcasses collected and percentage of tissue samples identified as winter Chinook in 2001, LOD<0

Discussion

Recruitment of Hatchery Origin Fish

One of the most important criteria we can use to evaluate the supplementation program at LSNFH is to determine whether removing adult spawners from the wild and spawning them in the hatchery environment results in an increase of adult returns to spawning areas in the Upper Sacramento River. To determine if this is the case with the winter Chinook supplementation program in 2001, we compared the estimated recruitment of hatchery produced winter Chinook salmon in 2001 with the estimated number of naturally produced adults that would have returned in 2001 had the propagation program not removed some adults from the naturally spawning population for use as broodstock. We estimated the size of the hatchery origin population that returned in 2001 by expanding coded-wire tag recoveries based on the winter Chinook population estimate (Snider et al 2002). We then estimated the number of naturally produced adults that would have returned in 2001, had some adults not been removed from the naturally spawning population for use as hatchery broodstock, based on age-specific cohort replacement rates and considering the number of adults that were used as hatchery broodstock (Appendix B). For our calculations, we used the winter Chinook population estimates based on the Peterson mark-recapture method, because that estimator was valid for every age-class.

Based on this analysis, we estimate that 513 hatchery-produced winter Chinook salmon returned in 2001. We estimate that the Chinook adults used as broodstock would have produced 188 adult returns had they been allowed to reproduce naturally. The results of our analysis indicate that the winter Chinook supplementation program conducted at the Livingston Stone NFH resulted in an increase of winter Chinook escapement to the upper Sacramento River in 2001 by 325 fish, an increase of 273% above the number of winter Chinook salmon that would have been produced naturally by the broodstock. Based on our calculations, it appears the supplementation program succeeded in demographically enhancing the winter Chinook population in 2001, and is aiding in increasing abundance of this endangered species.

Carcass Recoveries

One of the primary reasons for moving the winter Chinook hatchery program to LSNFH at the base of Shasta Dam was to increase the number of hatchery-origin adults returning to the spawning areas in the upper mainstem of the Sacramento River. When the program was located at Coleman National Fish Hatchery on Battle Creek, many hatchery produced winter Chinook adults returned to Battle Creek. Because the program was intended to supplement production in the Sacramento River (rather than in Battle Creek), the winter Chinook supplementation program was moved to LSNFH in 1998. By incubating eggs and rearing juveniles in Sacramento River waters, hatchery-origin adults would be much more likely to return to the spawning areas in the mainstem Sacramento River. 2001 was the first year in which hatchery-origin adults reared at LSNFH returned in numbers (as 3 year-olds) sufficient to evaluate the efficacy of the move.

The 2001 survey season marked the first year in which a substantial number of adipose fin-clipped carcasses were recovered (n=155) on the winter Chinook Carcass survey. Recoveries in the Sacramento River during previous years were relatively rare, with 5 fin-clipped carcasses recovered in 1997, 4 in 1998 and 1999, and 3 in 2000. This large increase in the recovery of fin-clipped winter Chinook is significant in that it indicates that moving the winter Chinook hatchery program to LSNFH was successful in regards to imprinting juvenile hatchery-origin winter Chinook to return to spawning areas in the mainstem Sacramento River.

Spatial Distribution

As shown in figure 3, adipose fin-clipped carcasses were found in the same areas as unmarked carcasses during 2001, suggesting that hatchery produced winter Chinook returned to the same areas and commingled with their natural origin counterparts.

Temporal Distribution

As shown in figure 4, adipose fin-clipped carcass recoveries showed a similar temporal distribution to the recoveries of unmarked carcasses, indicating that in 2001 hatchery produced winter Chinook returned at the same time as their naturally produced counterparts.

Coded-wire Tag Recoveries

All of the CWT's recovered during the 2001 carcass survey were from the 1998 and 1999 brood year releases (Figure 5). Figure 5 also shows that nearly all of the tag codes from both 1998 and 1999 were represented in the recoveries. Because each tag code represents an individual family group (a family group is defined as the progeny of an individual female x male cross) or a cluster of family groups, the recovery of many tag codes in 2001 provides an indication that the hatchery population in 2001 maintained the genetic diversity of their parent stock.

Age and Sex Composition

In 2001, the proportion of adipose-fin clipped winter Chinook that were recovered as two-year-olds was higher than unmarked winter Chinook recoveries. Two-year-old fish were almost exclusively male which may explain the higher proportion of males among recoveries of adipose fin-clipped carcasses. Higher proportions of adults returning as two year olds is not uncommon among hatchery programs, and is also likely not a genetic trait but rather a result environmental influences caused by differing rearing conditions.

Spawning Status

All 85 of the adipose-clipped female carcasses were completely or nearly void of eggs, providing a very good indication that returning hatchery-origin winter Chinook adults are spawning.

Body Size

Three-year-old male and female hatchery origin winter Chinook are statistically smaller than their natural origin counterparts. Lengths of hatchery origin two-year-old males were not significantly different than natural origin two-year-old males; however that analysis was based on small sample sizes (natural origin = 13, hatchery origin = 28).

Tissue Samples

Greater than 96% of the tissue samples tested in 2001 were genetically identified as winter Chinook providing a very good indication that the carcasses encountered on the winter Chinook escapement survey are indeed primarily winter Chinook. This information coupled with temporal aspect of carcasses collected (i.e. normally distributed and very few carcasses collected at the tail-end of the survey period), indicates that the carcass survey is adequately covering the winter Chinook spawning season.

Conclusions

Based on data collected on the Sacramento River winter Chinook carcass survey, adult escapement of winter Chinook salmon was increased in 2001 as a result of the propagation program at Livingston Stone NFH. Hatchery produced winter Chinook returned to the same spawning areas as naturally produced fish and spawned at the same times as naturally produced fish. Recoveries of fin-clipped carcasses included several CWT codes, indicating that hatchery produced winter Chinook contained several different family groups and maintained the genetic diversity of their parent stock. Body size differences existed between hatchery and naturally produced winter Chinook, and hatchery fish did seem to return more as two-year-olds when compared to their natural origin counterparts. Whether or not these differences are merely statistical, the result of small sample sizes, or are a reflection of actual biological differences will hopefully be established with the accumulation of more data from subsequent survey years.

The results of genetic analyses conducted on tissue samples collected on the 2001 survey indicate that we are indeed focusing our survey efforts on the winter Chinook population in the upper Sacramento River. That, coupled with the temporal distribution of carcass collection, indicates that we are adequately covering the entire spawning season for upper Sacramento River winter Chinook salmon.

Notes on apparent inconsistencies between the winter Chinook Carcass Survey and fish trapping at the Keswick Dam

Winter Chinook 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 propagation program. Broodstock collection activities for winter Chinook are conducted according to an Adult Collection Plan, which 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 are returned to the Sacramento River either at Bonnyview Road boat ramp (RM 292) or Caldwell Park boat ramp (RM 299), depending on flow levels. Before fish are released back into the river, they are floy tagged for identification.

Comparison of fin-clip rates between the winter Chinook carcass survey and broodstock collections at the Keswick Dam Fish Trap

During 2001, adipose fin-clipped winter Chinook carcasses comprised 40% of the total Chinook trapped at the Keswick Dam fish trap, whereas fin-clipped carcasses represented only 7% of the total fresh carcasses recovered on the carcass survey. This discrepancy may result if hatchery winter Chinook have a tendency to return to the uppermost reaches of the Sacramento River. Because winter Chinook are incubated and reared at LSNFH, located at the base of Shasta Dam (RM 314), they imprint on waters released from Shasta Lake. Therefore, hatchery winter Chinook from LSNFH *may* have a tendency to return to the uppermost parts of the free-flowing section of the Sacramento River, immediately below Keswick Dam. This hypothesis is supported by the high proportion of fin-clipped winter Chinook captured at the Keswick Dam fish trap. However, we did not find evidence of this through our winter Chinook carcass survey, wherein adipose fin-clipped Chinook salmon were dispersed throughout the upper Sacramento River in a pattern very similar to unclipped Chinook.

Recoveries of Floy-Tagged Fish Released from the Keswick Dam Fish Trap

During 2001, a total of 91 genetically identified winter Chinook were captured at the Keswick Dam fish trap, floy tagged, and then released back into the Sacramento River. One of these tagged fish was subsequently recovered[1] on the escapement survey, for a recovery rate of 1%. This fish was trapped on April 4, 2001, released at Bonnyview Road boat ramp on April 10 and recovered on the carcass survey on May 8, at river mile 296.5 (reach 1). This recovery rate of 1% for fish released from the Keswick Dam fish trap compares to a recovery rate of greater than 50% for winter Chinook salmon that were tagged as part of the carcass survey mark-and-recapture estimate. During the 2001 carcass survey, 4,019 adult carcasses were tagged, of which 2,136 were subsequently recovered giving a recovery rate of 53%. Considering only fresh carcasses, the recovery rate was slightly higher, with 1,146 recoveries out of a total of 2,017 fresh carcasses tagged, for a recovery rate of 57%.

Several hypotheses have been proposed to explain the discrepancy between recovery rates for fish released from the Keswick Dam trap and carcasses tagged as part of the mark-and-recapture survey; these include 1) live fish released from the Keswick Dam trap may shed their floy tags during spawning activities, or post-spawing as their body condition deteriorates, 2) the fish released from the Keswick Dam trap 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) due to the stress of being captured, transported, tissue sampled, tagged and released, the fish released from the Keswick Dam trap may fall back below the survey areas.

Recommendations

In order to address these apparent inconsistencies between the Keswick Dam fish trap and the winter Chinook carcass survey, we recommend that additional research be conducted to assess the abundance and composition of that segment of the winter Chinook population that returns in the uppermost section of the Sacramento River, between the Anderson-Cottonwood Irrigation District (ACID) Diversion Dam and the Keswick Dam. We believe that the fish ladders at the ACID 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 track and document the post-release movements of winter Chinook salmon in the upper Sacramento River. Each of these studies has the potential to provide valuable insights into possible biases associated with winter Chinook population estimates in the upper Sacramento River based on the mark-and-recapture methods.

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[1] Five floy-tagged Chinook from the Keswick Dam fish trap were subsequently recaptured at Keswick Dam, and all 5 were re-released back into the Sacramento River.

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Appendix A

Tissue Sample Results

Appendix A. Sample identification number, date of collection, LOD score, and run assignment for tissues collected during the carcass survey on the upper Sacramento River, 2001. LOD scores (based on 7 loci) are given for each sample, and the number of winter fish tallied for LOD>0, and 1. Samples that were not able to be amplified at sufficient loci to undergo WHICHRUN analysis were excluded.

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-2502	05/02/01	6.10	Winter	Winter
01-2503	05/02/01	10.86	Winter	Winter
01-2504	05/02/01	4.79	Winter	Winter
01-2505	05/02/01	1.12	Winter	Winter
01-2508	05/03/01	5.89	Winter	Winter
01-2509	05/03/01	-5.45	Non Winter	Non Winter
01-2511	05/05/01	8.24	Winter	Winter
01-2512	05/05/01	7.34	Winter	Winter
01-2513	05/05/01	5.69	Winter	Winter
01-2514	05/05/01	-9.82	Non Winter	Non Winter
01-2515	05/05/01	-6.28	Non Winter	Non Winter
01-2516	05/08/01	8.59	Winter	Winter
01-2518	05/09/01	-5.72	Non Winter	Non Winter
01-2519	05/09/01	4.82	Winter	Winter
01-2522	05/11/01	-8.27	Non Winter	Non Winter
01-2523	05/11/01	5.08	Winter	Winter
01-2524	05/11/01	-7.01	Non Winter	Non Winter
01-2527	05/14/01	8.30	Winter	Winter
01-2528	05/14/01	6.18	Winter	Winter
01-2531	05/15/01	8.52	Winter	Winter
01-2532	05/15/01	4.48	Winter	Winter
01-2533	05/15/01	4.48	Winter	Winter
01-2535	05/17/01	-1.57	Non Winter	Non Winter
01-2536	05/17/01	8.29	Winter	Winter
01-2539	05/18/01	5.55	Winter	Winter
01-2541	05/20/01	-2.93	Non Winter	Non Winter
01-2542	05/20/01	-2.18	Non Winter	Non Winter
01-2543	05/20/01	6.97	Winter	Winter
01-2544	05/20/01	2.54	Winter	Winter
01-2545	05/20/01	-8.41	Non Winter	Non Winter
01-2548	05/21/01	9.82	Winter	Winter
01-2549	05/21/01	-4.55	Non Winter	Non Winter
01-2550	05/23/01	2.74	Winter	Winter
01-2551	05/23/01	2.65	Winter	Winter
01-2553	05/23/01	4.63	Winter	Winter
01-2554	05/23/01	6.43	Winter	Winter
01-2555	05/23/01	8.56	Winter	Winter
01-2556	05/23/01	6.82	Winter	Winter
01-2557	05/23/01	7.33	Winter	Winter
01-2558	05/24/01	5.41	Winter	Winter
01-2559	05/24/01	4.99	Winter	Winter
01-2561	05/24/01	1.10	Winter	Winter
01-2564	05/24/01	7.64	Winter	Winter
01-2565	05/24/01	7.03	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-2566	05/24/01	8.72	Winter	Winter
01-2567	05/26/01	10.08	Winter	Winter
01-2568	05/26/01	6.62	Winter	Winter
01-2569	05/26/01	6.82	Winter	Winter
01-2570	05/26/01	9.49	Winter	Winter
01-2571	05/26/01	6.36	Winter	Winter
01-2572	05/26/01	4.07	Winter	Winter
01-2574	05/26/01	2.70	Winter	Winter
01-2575	05/26/01	2.78	Winter	Winter
01-2577	05/27/01	2.23	Winter	Winter
01-2578	05/27/01	11.11	Winter	Winter
01-2579	05/27/01	12.42	Winter	Winter
01-2580	05/27/01	8.92	Winter	Winter
01-2581	05/27/01	9.09	Winter	Winter
01-2582	05/27/01	8.55	Winter	Winter
01-2583	05/27/01	5.63	Winter	Winter
01-2584	05/29/01	4.50	Winter	Winter
01-2585	05/29/01	7.02	Winter	Winter
01-2586	05/29/01	6.59	Winter	Winter
01-2587	05/29/01	5.14	Winter	Winter
01-2588	05/29/01	8.12	Winter	Winter
01-2589	05/29/01	5.77	Winter	Winter
01-2592	05/29/01	7.94	Winter	Winter
01-2594	05/29/01	6.72	Winter	Winter
01-2595	05/29/01	8.98	Winter	Winter
01-2596	05/29/01	7.16	Winter	Winter
01-2597	05/30/01	9.84	Winter	Winter
01-2599	05/30/01	3.35	Winter	Winter
01-2600	05/30/01	7.08	Winter	Winter
01-2601	05/30/01	3.54	Winter	Winter
01-2602	05/30/01	4.91	Winter	Winter
01-2603	05/30/01	8.29	Winter	Winter
01-2610	06/01/01	6.74	Winter	Winter
01-2630	06/02/01	6.68	Winter	Winter
01-2640	06/04/01	7.37	Winter	Winter
01-2650	06/04/01	4.27	Winter	Winter
01-2660	06/05/01	5.68	Winter	Winter
01-2670	06/05/01	7.35	Winter	Winter
01-2680	06/05/01	6.97	Winter	Winter
01-2700	06/07/01	8.32	Winter	Winter
01-2710	06/08/01	4.02	Winter	Winter
01-2720	06/08/01	5.39	Winter	Winter
01-2740	06/10/01	4.83	Winter	Winter
01-2750	06/10/01	4.30	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-2760	06/11/01	5.64	Winter	Winter
01-2770	06/11/01	8.20	Winter	Winter
01-2780	06/11/01	3.26	Winter	Winter
01-2790	06/16/01	8.13	Winter	Winter
01-2810	06/13/01	5.52	Winter	Winter
01-2820	06/13/01	10.72	Winter	Winter
01-2840	06/14/01	5.45	Winter	Winter
01-2850	06/14/01	2.37	Winter	Winter
01-2880	06/16/01	6.07	Winter	Winter
01-2900	06/16/01	3.74	Winter	Winter
01-2910	06/17/01	6.23	Winter	Winter
01-2980	06/19/01	3.05	Winter	Winter
01-2990	06/20/01	4.92	Winter	Winter
01-3010	06/20/01	5.69	Winter	Winter
01-3030	06/22/01	5.20	Winter	Winter
01-3040	06/22/01	2.47	Winter	Winter
01-3060	06/22/01	3.82	Winter	Winter
01-3070	06/22/01	4.39	Winter	Winter
01-3100	06/23/01	8.90	Winter	Winter
01-3120	06/23/01	6.32	Winter	Winter
01-3130	06/25/01	6.14	Winter	Winter
01-3140	06/25/01	4.53	Winter	Winter
01-3150	06/25/01	0.74	Winter	Non Winter
01-3160	06/26/01	2.88	Winter	Winter
01-3190	06/26/01	3.29	Winter	Winter
01-3210	06/23/01	8.16	Winter	Winter
01-3240	06/25/01	4.26	Winter	Winter
01-3270	06/25/01	7.01	Winter	Winter
01-3320	06/26/01	5.88	Winter	Winter
01-3340	06/28/01	5.98	Winter	Winter
01-3370	06/28/01	-0.21	Non Winter	Non Winter
01-3390	06/28/01	3.00	Winter	Winter
01-3400	06/28/01	6.11	Winter	Winter
01-3410	06/28/01	5.48	Winter	Winter
01-3430	06/28/01	3.10	Winter	Winter
01-3440	06/28/01	5.47	Winter	Winter
01-3450	07/23/01	7.21	Winter	Winter
01-3480	07/24/01	6.81	Winter	Winter
01-3504	05/08/01	4.70	Winter	Winter
01-3508	05/14/01	10.14	Winter	Winter
01-3509	05/15/01	5.84	Winter	Winter
01-3510	05/15/01	10.30	Winter	Winter
01-3512	05/20/01	6.73	Winter	Winter
01-3514	05/20/01	10.53	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-3515	05/21/01	8.29	Winter	Winter
01-3516	05/21/01	9.16	Winter	Winter
01-3517	05/23/01	7.93	Winter	Winter
01-3518	05/23/01	10.54	Winter	Winter
01-3519	05/24/01	8.19	Winter	Winter
01-3520	05/24/01	7.33	Winter	Winter
01-3521	05/24/01	6.47	Winter	Winter
01-3522	05/24/01	10.53	Winter	Winter
01-3524	05/27/01	5.63	Winter	Winter
01-3525	05/29/01	10.08	Winter	Winter
01-3526	05/29/01	6.89	Winter	Winter
01-3527	05/29/01	10.21	Winter	Winter
01-3528	05/29/01	6.13	Winter	Winter
01-3529	05/29/01	6.05	Winter	Winter
01-3531	05/30/01	10.14	Winter	Winter
01-3532	05/30/01	5.48	Winter	Winter
01-3533	05/30/01	9.28	Winter	Winter
01-3534	05/30/01	4.50	Winter	Winter
01-3535	05/30/01	6.72	Winter	Winter
01-3536	05/30/01	8.23	Winter	Winter
01-3550	06/07/01	4.81	Winter	Winter
01-3560	06/07/01	9.96	Winter	Winter
01-3580	06/10/01	6.77	Winter	Winter
01-3600	06/14/01	7.00	Winter	Winter
01-3620	06/16/01	6.46	Winter	Winter
01-3650	06/19/01	1.93	Winter	Winter
01-3660	06/19/01	5.45	Winter	Winter
01-3670	06/19/01	7.10	Winter	Winter
01-3690	06/20/01	9.61	Winter	Winter
01-3710	06/28/01	6.73	Winter	Winter
01-3730	06/29/01	9.09	Winter	Winter
01-3740	06/29/01	4.43	Winter	Winter
01-3750	07/01/01	7.16	Winter	Winter
01-3760	07/01/01	9.07	Winter	Winter
01-3770	07/01/01	6.26	Winter	Winter
01-3780	07/01/01	6.75	Winter	Winter
01-3790	07/01/01	5.70	Winter	Winter
01-3800	07/01/01	7.05	Winter	Winter
01-3810	07/01/01	8.43	Winter	Winter
01-3820	07/02/01	7.85	Winter	Winter
01-3830	07/02/01	8.75	Winter	Winter
01-3840	07/05/01	6.62	Winter	Winter
01-3850	07/05/01	7.05	Winter	Winter
01-3870	07/05/01	5.91	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-3880	07/05/01	9.01	Winter	Winter
01-3890	07/05/01	4.73	Winter	Winter
01-3900	07/05/01	1.18	Winter	Winter
01-3920	06/29/01	4.80	Winter	Winter
01-3930	06/29/01	9.62	Winter	Winter
01-3940	06/29/01	5.96	Winter	Winter
01-3960	07/01/01	9.72	Winter	Winter
01-3970	07/01/01	4.47	Winter	Winter
01-3980	07/01/01	7.28	Winter	Winter
01-3990	07/01/01	7.34	Winter	Winter
01-4000	07/01/01	8.98	Winter	Winter
01-4010	07/01/01	6.90	Winter	Winter
01-4020	07/02/01	8.69	Winter	Winter
01-4030	07/02/01	7.90	Winter	Winter
01-4060	07/02/01	5.15	Winter	Winter
01-4070	07/02/01	2.31	Winter	Winter
01-4080	07/02/01	7.21	Winter	Winter
01-4090	07/05/01	3.82	Winter	Winter
01-4100	07/05/01	5.08	Winter	Winter
01-4110	07/05/01	10.52	Winter	Winter
01-4130	07/05/01	9.63	Winter	Winter
01-4140	07/05/01	7.46	Winter	Winter
01-4170	07/05/01	5.63	Winter	Winter
01-4180	07/05/01	5.62	Winter	Winter
01-4210	07/05/01	3.35	Winter	Winter
01-4220	07/05/01	7.39	Winter	Winter
01-4230	07/05/01	6.15	Winter	Winter
01-4240	07/05/01	9.42	Winter	Winter
01-4250	07/05/01	5.40	Winter	Winter
01-4270	07/05/01	6.16	Winter	Winter
01-4280	07/06/01	2.86	Winter	Winter
01-4290	07/06/01	11.91	Winter	Winter
01-4320	07/06/01	8.47	Winter	Winter
01-4330	07/06/01	5.81	Winter	Winter
01-4340	07/06/01	7.48	Winter	Winter
01-4430	07/08/01	6.88	Winter	Winter
01-4440	07/08/01	10.62	Winter	Winter
01-4460	07/08/01	-0.08	Non Winter	Non Winter
01-4470	07/08/01	2.95	Winter	Winter
01-4480	07/08/01	5.68	Winter	Winter
01-4540	06/22/01	7.72	Winter	Winter
01-4550	06/22/01	7.56	Winter	Winter
01-4560	06/22/01	7.51	Winter	Winter
01-4570	06/22/01	11.08	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-4580	06/20/01	3.77	Winter	Winter
01-4590	06/22/01	2.05	Winter	Winter
01-4600	06/22/01	5.51	Winter	Winter
01-4500	07/08/01	1.00	Non Winter	Non Winter
01-4810	07/08/01	4.01	Winter	Winter
01-4820	07/09/01	7.96	Winter	Winter
01-4840	07/09/01	8.13	Winter	Winter
01-4850	07/09/01	5.20	Winter	Winter
01-4860	07/09/01	4.08	Winter	Winter
01-4870	07/09/01	3.35	Winter	Winter
01-4890	07/11/01	8.20	Winter	Winter
01-4900	07/11/01	8.47	Winter	Winter
01-4910	07/08/01	6.23	Winter	Winter
01-4920	07/08/01	6.17	Winter	Winter
01-4940	07/08/01	4.73	Winter	Winter
01-4960	07/08/01	6.29	Winter	Winter
01-5010	07/11/01	7.62	Winter	Winter
01-5020	07/11/01	8.59	Winter	Winter
01-5030	07/12/01	3.92	Winter	Winter
01-5050	07/17/01	3.31	Winter	Winter
01-5060	07/17/01	5.85	Winter	Winter
01-5070	07/17/01	8.16	Winter	Winter
01-5080	07/17/01	4.07	Winter	Winter
01-5100	07/18/01	6.72	Winter	Winter
01-5110	07/11/01	4.70	Winter	Winter
01-5120	07/11/01	6.96	Winter	Winter
01-5130	07/12/01	7.25	Winter	Winter
01-5140	07/12/01	0.16	Winter	Non Winter
01-5150	07/12/01	3.31	Winter	Winter
01-5160	07/18/01	11.56	Winter	Winter
01-5170	07/18/01	2.51	Winter	Winter
01-5180	07/20/01	1.58	Winter	Winter
01-5200	07/20/01	2.88	Winter	Winter
01-5210	07/14/01	4.49	Winter	Winter
01-5220	07/14/01	8.85	Winter	Winter
01-5230	07/15/01	6.09	Winter	Winter
01-5250	07/17/01	9.17	Winter	Winter
01-5260	07/17/01	5.71	Winter	Winter
01-5300	07/20/01	4.38	Winter	Winter
01-5310	07/14/01	6.29	Winter	Winter
01-5330	07/14/01	6.78	Winter	Winter
01-5340	07/14/01	8.84	Winter	Winter
01-5350	07/15/01	10.34	Winter	Winter
01-5370	07/15/01	10.32	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-5380	07/20/01	7.66	Winter	Winter
01-5400	07/26/01	7.67	Winter	Winter
01-5410	07/21/01	8.70	Winter	Winter
01-5420	07/21/01	9.88	Winter	Winter
01-5430	07/23/01	6.46	Winter	Winter
01-5440	07/23/01	6.62	Winter	Winter
01-5450	07/23/01	4.63	Winter	Winter
01-5460	07/23/01	7.55	Winter	Winter
01-5470	07/24/01	9.54	Winter	Winter
01-5490	07/26/01	10.93	Winter	Winter
01-5500	07/26/01	7.79	Winter	Winter
01-5510	07/29/01	4.79	Winter	Winter
01-5520	07/29/01	2.95	Winter	Winter
01-5530	07/29/01	9.03	Winter	Winter
01-5537	08/01/01	4.54	Winter	Winter
01-5538	08/01/01	3.06	Winter	Winter
01-5539	08/01/01	7.84	Winter	Winter
01-5540	08/01/01	10.07	Winter	Winter
01-5541	08/01/01	6.34	Winter	Winter
01-5542	08/01/01	6.08	Winter	Winter
01-5543	08/01/01	5.89	Winter	Winter
01-5544	08/01/01	4.12	Winter	Winter
01-5545	08/01/01	11.71	Winter	Winter
01-5546	08/01/01	4.73	Winter	Winter
01-5547	08/01/01	9.77	Winter	Winter
01-5549	08/01/01	10.35	Winter	Winter
01-5550	08/01/01	9.85	Winter	Winter
01-5551	08/01/01	10.89	Winter	Winter
01-5553	08/02/01	8.17	Winter	Winter
01-5558	08/04/01	3.71	Winter	Winter
01-5562	08/04/01	3.28	Winter	Winter
01-5563	08/04/01	7.52	Winter	Winter
01-5564	08/04/01	6.88	Winter	Winter
01-5565	08/04/01	0.53	Winter	Non Winter
01-5569	08/05/01	10.87	Winter	Winter
01-5572	08/04/01	3.50	Winter	Winter
01-5573	08/04/01	3.91	Winter	Winter
01-5576	08/07/01	2.88	Winter	Winter
01-5577	08/07/01	8.80	Winter	Winter
01-5578	08/07/01	1.67	Winter	Winter
01-5581	08/07/01	5.51	Winter	Winter
01-5585	08/07/01	6.65	Winter	Winter
01-5589	08/08/01	8.46	Winter	Winter
01-5590	08/10/01	10.70	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-5591	08/10/01	11.97	Winter	Winter
01-5592	08/10/01	8.16	Winter	Winter
01-5593	08/11/01	4.64	Winter	Winter
01-5594	08/11/01	4.58	Winter	Winter
01-5599	08/13/01	7.92	Winter	Winter
01-5600	08/13/01	5.73	Winter	Winter
01-5620	07/27/01	4.21	Winter	Winter
01-5630	07/29/01	5.56	Winter	Winter
01-5640	07/29/01	2.78	Winter	Winter
01-5660	08/01/01	4.04	Winter	Winter
01-5661	08/01/01	3.03	Winter	Winter
01-5662	08/01/01	6.15	Winter	Winter
01-5663	08/01/01	12.59	Winter	Winter
01-5664	08/01/01	4.70	Winter	Winter
01-5666	08/01/01	6.74	Winter	Winter
01-5670	08/01/01	2.25	Winter	Winter
01-5671	08/01/01	3.78	Winter	Winter
01-5674	08/01/01	8.55	Winter	Winter
01-5676	08/01/01	3.23	Winter	Winter
01-5680	08/01/01	4.27	Winter	Winter
01-5685	08/02/01	4.76	Winter	Winter
01-5686	08/02/01	5.34	Winter	Winter
01-5689	08/02/01	7.55	Winter	Winter
01-5697	08/04/01	4.31	Winter	Winter
01-5698	08/04/01	6.02	Winter	Winter
01-5699	08/04/01	3.58	Winter	Winter
01-5701	08/04/01	9.89	Winter	Winter
01-5702	08/04/01	8.23	Winter	Winter
01-5703	08/04/01	4.22	Winter	Winter
01-5704	08/04/01	3.94	Winter	Winter
01-5705	08/04/01	4.04	Winter	Winter
01-5706	08/04/01	3.01	Winter	Winter
01-5707	08/04/01	4.64	Winter	Winter
01-5709	08/04/01	5.60	Winter	Winter
01-5710	08/04/01	2.58	Winter	Winter
01-5711	08/04/01	3.62	Winter	Winter
01-5713	08/04/01	3.83	Winter	Winter
01-5714	08/04/01	5.67	Winter	Winter
01-5715	08/04/01	4.90	Winter	Winter
01-5716	08/04/01	5.74	Winter	Winter
01-5717	08/04/01	7.96	Winter	Winter
01-5718	08/05/01	9.02	Winter	Winter
01-5719	08/05/01	6.77	Winter	Winter
01-5721	08/05/01	2.90	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-5722	08/05/01	6.75	Winter	Winter
01-5723	08/05/01	4.58	Winter	Winter
01-5724	08/05/01	5.69	Winter	Winter
01-5726	08/05/01	7.81	Winter	Winter
01-5727	08/05/01	4.93	Winter	Winter
01-5728	08/05/01	9.89	Winter	Winter
01-5730	08/05/01	5.19	Winter	Winter
01-5731	08/05/01	7.92	Winter	Winter
01-5732	08/05/01	8.19	Winter	Winter
01-5734	08/07/01	2.95	Winter	Winter
01-5735	08/07/01	8.23	Winter	Winter
01-5737	08/07/01	8.15	Winter	Winter
01-5739	08/07/01	2.95	Winter	Winter
01-5740	08/07/01	3.54	Winter	Winter
01-5742	08/07/01	6.30	Winter	Winter
01-5743	08/07/01	3.89	Winter	Winter
01-5744	08/07/01	7.83	Winter	Winter
01-5745	08/07/01	3.28	Winter	Winter
01-5746	08/07/01	6.16	Winter	Winter
01-5747	08/07/01	7.77	Winter	Winter
01-5748	08/07/01	7.66	Winter	Winter
01-5750	08/07/01	5.75	Winter	Winter
01-5751	08/07/01	9.97	Winter	Winter
01-5752	08/07/01	3.56	Winter	Winter
01-5753	08/07/01	5.55	Winter	Winter
01-5754	08/07/01	6.48	Winter	Winter
01-5755	08/07/01	4.91	Winter	Winter
01-5757	08/07/01	2.81	Winter	Winter
01-5758	08/08/01	6.04	Winter	Winter
01-5759	08/08/01	8.15	Winter	Winter
01-5760	08/08/01	8.34	Winter	Winter
01-5761	08/08/01	2.33	Winter	Winter
01-5763	08/10/01	8.29	Winter	Winter
01-5764	08/10/01	6.16	Winter	Winter
01-5765	08/10/01	9.95	Winter	Winter
01-5766	08/10/01	0.23	Winter	Non Winter
01-5767	08/10/01	7.39	Winter	Winter
01-5768	08/10/01	9.04	Winter	Winter
01-5769	08/10/01	8.11	Winter	Winter
01-5770	08/10/01	5.74	Winter	Winter
01-5771	08/10/01	6.56	Winter	Winter
01-5772	08/10/01	3.57	Winter	Winter
01-5773	08/10/01	2.34	Winter	Winter
01-5775	08/10/01	4.48	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-5777	08/16/01	2.67	Winter	Winter
01-5778	08/16/01	9.15	Winter	Winter
01-5779	08/16/01	6.26	Winter	Winter
01-5780	08/16/01	6.97	Winter	Winter
01-5781	08/16/01	5.92	Winter	Winter
01-5782	08/16/01	7.15	Winter	Winter
01-5783	08/16/01	4.62	Winter	Winter
01-5784	08/16/01	7.77	Winter	Winter
01-5785	08/16/01	7.03	Winter	Winter
01-5786	08/16/01	5.41	Winter	Winter
01-5787	08/16/01	9.45	Winter	Winter
01-5788	08/19/01	6.89	Winter	Winter
01-5789	08/20/01	7.39	Winter	Winter
01-5800	08/14/01	7.80	Winter	Winter
01-5802	08/13/01	1.76	Winter	Winter
01-5803	08/13/01	5.51	Winter	Winter
01-5806	08/13/01	6.02	Winter	Winter
01-5808	08/13/01	6.36	Winter	Winter
01-5809	08/13/01	9.67	Winter	Winter
01-5810	08/13/01	10.23	Winter	Winter
01-5811	08/13/01	2.86	Winter	Winter
01-5812	08/13/01	8.90	Winter	Winter
01-5813	08/13/01	7.27	Winter	Winter
01-5814	08/13/01	4.66	Winter	Winter
01-5815	08/13/01	9.87	Winter	Winter
01-5823	08/14/01	1.97	Winter	Winter
01-5825	08/16/01	-2.09	Non Winter	Non Winter
01-5826	08/16/01	9.95	Winter	Winter
01-5829	08/16/01	5.70	Winter	Winter
01-5831	08/16/01	8.17	Winter	Winter
01-5832	08/16/01	5.79	Winter	Winter
01-5833	08/16/01	3.09	Winter	Winter
01-5838	08/16/01	5.59	Winter	Winter
01-5839	08/16/01	2.74	Winter	Winter
01-5840	08/16/01	-1.29	Non Winter	Non Winter
01-5842	08/16/01	9.81	Winter	Winter
01-5843	08/16/01	1.88	Winter	Winter
01-5844	08/16/01	2.32	Winter	Winter
01-5845	08/16/01	2.82	Winter	Winter
01-5847	08/16/01	10.32	Winter	Winter
01-5848	08/16/01	4.26	Winter	Winter
01-5849	08/19/01	2.92	Winter	Winter
01-5851	08/19/01	6.38	Winter	Winter
01-5852	08/19/01	4.95	Winter	Winter

Sample ID	Collection Date	LOD	LOD>0	LOD>1
01-5853	08/20/01	-0.58	Non Winter	Non Winter
01-5860	08/22/01	5.51	Winter	Winter
01-5862	08/22/01	5.09	Winter	Winter
01-5864	08/22/01	7.42	Winter	Winter
01-5865	08/22/01	7.83	Winter	Winter
01-5867	08/22/01	8.92	Winter	Winter
01-5868	08/22/01	-7.15	Non Winter	Non Winter
01-5869	08/22/01	5.90	Winter	Winter
01-5870	08/22/01	5.51	Winter	Winter
01-5871	08/22/01	-6.93	Non Winter	Non Winter
01-5872	08/25/01	6.47	Winter	Winter
01-5873	08/25/01	5.92	Winter	Winter

Appendix B

Differential Recruitment Analysis

Estimating Recruitment in Natural Environment

In order to estimate the recruitment of naturally-produced winter Chinook, we first need to calculate the age composition of the overall population in 2001

$$n_{age-class} = (N_{pop})(P_{age-class}) \tag{1}$$

where:

N_{pop} = Total adult winter Chinook population in 2001 (as estimated by the Peterson method)

$P_{age\text{-}class}$ = Percentage of each age class present in overall population (assumed: 25% age 2, 67% age 3, 8% age 4)

Each age class is then associated with its corresponding brood year, e.g. age-2 fish are the progeny of brood year 1999 adults.

We then calculate the contribution rate for each year ($C_{age\text{-}class}$)

$$C_{age-class} = \frac{n_{age-class}}{N_{brood-year}} \tag{2}$$

where:

$N_{brood\text{-}year}$ = Escapement estimate (Peterson method) for the corresponding brood year

We can then calculate the recruitment of the adults retained for the propagation program ($R_{wild\text{-}spawn}$) had they been allowed to spawn in the wild

$$R_{wild-spawn} = (C_{age-class})(n_{retained}) \tag{3}$$

where:

$n_{retained}$ = Number of adults retained for the propagation program for each year class

2001 Data and Calculations

2001 Total Escapement	**12,120**		
0.25 two year old = 3,030			
0.67 three year old = 8,120			
0.08 four year old = 970			

		Contribution rate	
1999 Escapement	2,262	= 3,030 / 2,262	= 1.3395
1998 Escapement	5,501	= 8,120 / 5,501	= 1.4761
1997 Escapement	2,053	= 970 / 2,053	= 0.4725

Adults taken for broodstock	**Estimated Recruitment**	
1999 = 24	= 24(1.3395)	= 32 adults
1998 = 106	= 106 (1.4761)	= 156 adults
1997 = 0 (moratorium year)	= 0	

CWT Expansion

In order to estimate the number of hatchery fish in the 2001 adult population, we need to expand the number of CWT's recovered in 2001.

To do that, we first need to calculate an expansion factor

To do that, we first need to estimate the number of CWT's from fresh heads ($n_{fresh,cwt}$)

$$n_{fresh,cwt} = \frac{n_{fresh,decoded-cwt}}{(f_a)(f_p)(f_d)(f_c)} \tag{4}$$

Where:

$n_{fresh,decoded\text{-}cwt}$ = Number of tags from fresh heads that were decoded

f_a = Fraction of potential adipose-fin clipped fish that were collected
(Assumed to = 1)

f_p = Fraction of fresh heads that were processed
(= number of fresh head processed / number of fresh heads collected)

f_d = Fraction of CWT's detected in fresh heads
(Assumed to = 1)

f_c = Fraction of CWT's detected that were decoded
(= number of fresh CWT's successfully decoded / number of fresh CWT's detected)

Next we need to estimate the fraction of total fresh heads that have CWT's (f_{cwt})

$$f_{cwt} = \frac{n_{fresh,decoded-cwt}}{n_{fresh-collected}} \tag{5}$$

Where:

$n_{fresh\text{-}collected}$ = Total number of fresh heads collected

We then estimate the total number of CWT's in the population (N_{cwt})

$$N_{cwt} = \frac{N_{pop}}{f_{cwt}} \quad (6)$$

Where:

N_{pop} = Total adult winter Chinook population in 2001 (as estimated by the Peterson method)

** Note: Normally the Jolly-Seber method is considered to be the more accurate estimator because of its more rigorous requirements. However, these requirements have only been met since the 2000 survey season, and as such Jolly-Seber estimates are not available pre-2000. In order to ensure consistency in this exercise, we are therefore using Peterson estimates (which are available for all survey years) throughout.*

We can then generate an expansion factor (F) that we can apply to CWT recoveries

$$F = \frac{N_{cwt}}{N_{decoded}} \quad (7)$$

Where:

$N_{decoded}$ = Total number of CWT's that were decoded (fresh and non-fresh heads)

To estimate the total number of hatchery-produced winter Chinook in the 2001 adult population ($N_{hatchery}$), we then apply this expansion rate (F) to the number of CWT'd winter Chinook observed in 2001 ($N_{cwt\text{-}observed}$).

$$N_{hatchery} = (F)(N_{cwt-observed}) \quad (8)$$

2001 Data and Calculations

	Carcass Survey			
	Fresh	**Decayed**	**Unknown**	**Total**
Potential AD-clip	115	35	5	155
Head not collected	0	0	0	0
Head collected	115	35	5	155

	CWT Processing			
	Fresh	**Decayed**	**Unknown**	**Total**
Heads not processed/lost	2	8	0	10
Head processed	113	27	5	145
cwt not detected	25	12	0	37
cwt detected	93	24	5	122
Not extracted/lost	4	1	0	5
Recovered	89	23	5	117
undecipherable	0	0	0	0
decoded	89	23	5	117
Total heads	**115**	**35**	**5**	**155**

Applying the above to equation (4):

f_a = 1 (assumed)

$$f_p = \frac{\text{number of heads CWT-processed}}{\text{number of fresh heads collected}} = \frac{113}{115} = 0.9826$$

f_d = 1 (assumed)

$$f_c = \frac{\text{number of fresh CWT's successfully decoded}}{\text{number of fresh CWT's detected}} = \frac{89}{93} = 0.9570$$

$$n_{fresh,cwt} = \frac{89}{(1)(0.9826)(1)(0.9570)} = 94.640$$

$$f_{cwt} = \frac{94.640}{2235} = 0.0423$$

$$N_{cwt} = \frac{12120}{0.0423} = 513.25$$

$$F = \frac{513.25}{117} = 4.3867$$

Estimating Recruitment of Hatchery-produced winter Chinook in 2001

Once we have estimated the number of hatchery-produced winter Chinook in the population, we then need to determine the age structure of these fish.

First, we determine that in 2001, 73% (n=85) of the CWT'd were from brood year 1998 (three-year-olds) and 27% (n=32) were from brood year 1999 (two-year-olds).

We can apply these percentages to our estimate of the total number of hatchery-produced winter Chinook to estimate the age composition of the total hatchery-produced population.

513(.73) = 374 from BY1998

513(.27) = 139 from BY 1999

When we compare this with what we estimated had the fish that were taken into the hatchery been allowed to spawn in the wild, we see:

	Wild	**Hatchery**
BY 1998	156	374
BY 1999	32	139
Total	**188**	**513**

Or an increase of **273%**