Moyeha River Chinook Salmon (*Oncorhynchus tschawytscha*) escapement and composition in 2010

Prepared for:

Pacific Salmon Commission
Sentinel Stocks Program

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EXECUTIVE SUMMARY

Moyeha River chinook salmon (*Oncorhynchus tschawytscha*) contribute to the southeast Alaska, northern British Columbia and west coast of Vancouver Island (WCVI) Aggregate Abundance Based Management fisheries managed under the Pacific Salmon Treaty. The Moyeha River is located in Strathcona Park, Clayoquot Sound, on the West Coast Vancouver Island (WCVI). It was chosen as a Sentinel Stock candidate for the following four reasons: Habitat in the Moyeha River watershed is pristine and untouched by development; the population has never been purposely enhanced by hatchery supplementation; the stock contributes to the PSC eleven-stream WCVI chinook salmon escapement index; and, Moyeha chinook belong to the South West Vancouver Island (SWVI) chinook Conservation Unit (CU), while the Burman and Kaouk populations belong the Nootka-Kyuquot CU (Holtby and Ciruna 2007). Prior to the Sentinel Stocks program, AUC_{index} surveys from 2000 to 2009 indicated an escapement average of 130 individuals (Figure 1). The objectives of the project were to (1) estimate total escapement of age-3 and older chinook salmon; (2) estimate the proportions of age-3 and older chinook salmon by age, sex, size and origin; and (3) compare this result to the normative AUC_{index} developed annually using snorkel survey methods.

Summary of Methods

The goal of this project was to estimate chinook salmon using a two event mark-recapture experiment focused on age-3 and older chinook salmon. In order to capture and tag chinook, a seine net was deployed in the Moyeha River approximately 1.75km and 2.00km upriver within staging pools using a 12ft aluminium boat and then a 14ft flat-bottom boat, both powered by a 9.9hp motor. Chinook were tagged in both opercula with numbered Kurl-lock tags and biological samples were obtained. Chinook were visually identified by gender and post-orbital hypural (POH) lengths were measured to the nearest 5mm. Scales were obtained for ageing. A mutilation mark was applied in the right or left operculum depending on when the salmon was tagged. Tissue samples were preserved to contribute to the coast-wide GSI database. Chinook recovered live by beach seine that have been previously tagged were recorded along with any other species captured.

Carcass surveys were conducted over the entire anadromous reach from river km 13.5 to the river mouth. Biological samples included otoliths for origin determination. There were only 12 samples obtained and one sample was destroyed in the lab resulting in loss of accuracy in representation of origin. The gender of each chinook was also identified along with the POH lengths to the nearest 5mm. Egg retention in females was estimated to assess handling stress.

A Peterson estimate could not be developed as no marked carcasses were recovered. (objective 1). Therefore, an estimate was developed using the sequential Bayesian methods of

Gazey and Staley (1986) using data obtained from the marking events, carcass surveys, and re-sight information from the tagged chinook observed in the DFO swim surveys. The assumption of a closed population was made, although this was not verified through the use of radio tags.

Summary of Results

The Bayesian analysis estimate using exclusively adult data (removing jacks) produced a modal population estimate located at 684– 692 (95% highest probability density) and there was a 95% probability that the escapement was at least 440 individuals. Although the data was sparse, this represents a direct probability statement of population size. The potential for introduction of bias through failure to assess tag loss (no marked carcasses were recovered) was addressed by simulation of tag loss rates. In the most extreme case assessed, assuming the loss of 29% of tags, less than a 3% reduction in population resulted. It is reasonable to conclude that bias from unequal capture probabilities through mark loss was not a substantive source of error in the estimate of escapement.

Out of the 27 fish caught during the seining events, 3 were live recaptures. There were 14 samples obtained from the carcass surveys with no recaptures. The ratio of males to females sampled was 1.88:1.00 during the seining event and 2.50:1.00 for the carcass recoveries and pooled to get a ratio of 2.08:1.00 (objective 2). The age structure proportions were 0.33 (SE = 0.08, CI = 0.17 – 0.55) age-3, 0.21 (SE = 0.07, CI = 0.10 – 0.43) age-4, and 0.45 (SE = 0.09, CI = 0.28 – 0.64) age-5. Origin proportions determined from otolith examination (n =11) were 0.46 (SE = 0.16, CI = 0.17 – 0.78) naturally spawned salmon and 0.55 (SE = 0.16, CI = 0.23 – 0.82) hatchery strays from the Conuma Hatchery and were predominantly 3-year old males. Lengths were similar between chinook caught during the seining events and obtained in the carcass surveys (D, = 0.182, P = 0.985).

The normative area-under-the curve index (AUC_{index}) from the snorkel surveys provided by DFO was 185 large chinook with a peak observation of 162 individuals. We were not able to develop an expansion factor to the Peterson estimate but the expansion factor between the AUC_{index} estimate to the Bayes 0.95 probability minimum estimate was 2.38 (objective 3).

Future Estimates of Escapement

Considerably more effort is required to mark sufficient fish to generate a reliable estimate of escapement using the Petersen method in the future. An increase in marking effort employing additional capture methods and increased carcass recovery effort is required to achieve the Chinook Technical Committee standards of a CV of <15%. Larger origin and age sample sizes are required to estimate proportions more precisely.

Sentinel Stocks Program Financial Support

The Moyeha River Sentinel Stocks project provided $159,478.00 for the 2010 project, in which $10,285 of those funds were provided to DFO for oversight. The total funds expended for the 2010 project by the Nuu-chah-nulth Tribal Council was $94,500.22. The funds remaining are $54,712.78.

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INTRODUCTION

The Sentinel Stocks Program was established in 2009 in the Pacific Salmon Treaty to improve escapement estimates of chinook salmon (*Oncorhynchus tschawytscha*) from selected indicator stocks located in Washington, Oregon and British Columbia. The Moyeha River Sentinel Stocks Project (SSP) is one of three projects that were conducted on the west coast of Vancouver Island (WCVI) in 2010 to determine accurate chinook salmon escapement to this river. The other two SSP projects on Vancouver Island were the Burman River and Kaouk River. The Moyeha River project had similar methods and project design as the Burman River project.

The Moyeha River population belongs to the South West Vancouver Island (SWVI) Conservation Unit (Holtby and Ciruna 2007). This population is represented in the eleven-stream WCVI Chinook escapement index reported by the Joint Chinook Technical Committee in the annual catch and escapement reports.

This was the first attempt at a mark-recapture experiment on the Moyeha River. Since 1995, the Department of Fisheries and Oceans (DFO) have estimated escapement with an $\text{AUC}_{\text{index}}$ method on using multiple visual snorkel surveys. This population is relatively small with maximum escapements estimated at 362 and averaging 130 individuals over the past 10 years (Figure 1).

The objectives for the Moyeha River project were threefold. The first objective was to estimate the total escapement of age 3.0 and older chinook salmon in the Moyeha River to the data standard (CV <15%, on average) using a two-event Petersen closed population mark-recapture experiment using nets for capture and marking and carcass surveys to recover marked fish. The second objective was to estimate the proportions of age 3.0 and older chinook by age, sex, size and origin (hatchery & wild) with a 95% probability of detecting a 5% change in the largest component between years. And the third objective was to compare the escapement estimate result to the normative DFO area-under-the-curve ($\text{AUC}_{\text{index}}$) snorkel survey result.

Study Area

The Moyeha River is a pristine watershed situated in the middle of the west coast of Vancouver Island in British Columbia, Canada. This river is located in Strathcona Park at the end of Herbert Inlet, Clayoquot Sound (Figure 2). The mouth of Moyeha River is located 49° 25’ 07”N, 125° 54’ 30”W and the main stem is 28km in length. A migration barrier to chinook, consisting of a cascade, is located at river km 11 according to Brown et al (1979) but DFO personnel indicate that the barrier is located at river km 13.5 (D. Palfrey, personal communication, September 2010) (Figure 3). For the purpose of this report, we will use river km 13.5. No roads exist in the watershed so access is limited to foot, boat or air travel. This river experiences flood events during the late summer through the fall season. August had very little precipitation and access to the river was relatively easy while assessing the study area. Precipitation increased from mid-September through to November, which made access problematic and difficult (Figure 4).

The Moyeha River has a gradient of 0.25% to 0.50% from the river mouth up to 6.4km and 0.50% to 0.75% from 6.4km to 11.0km up river (Brown et al. 1979). The potential spawning habitat for salmon is 264,000m² with a maximum salmon density of 0.026 salmon/m² (Reimchen et al. 2002, Brown et al. 1979). According to Brown et al.'s report (1979), the majority of the river accessible to salmon consists of course material (50.9mm – 256mm). Chinook salmon are capable of spawning in larger course material compared to other salmon species because of their size (Kondolf and Wolman 1993). Fish can spawn in gravels up to about 10% of their body length. Salmon, such as chinook, may choose to spawn in smaller gravels which often have to do with spawning habitat availability (Kondolf and Wolman 1993).

Moyeha River chinook salmon are ocean-type fall chinook. Chinook begin to arrive in Clayoquot Sound in late July to early August and move to the head of Herbert Inlet, entering the river during the first elevation of stream discharge in autumn. Some of the fish hold in pools at the upper level of tidal influence, usually until near the end of September. During the first significant freshet, fish move upstream and distribute themselves throughout the river up to an impassable barrier at river kilometre 13.5. Peak spawning occurs during the last week of September and first week of October. Small numbers of fish continue to enter the system with each subsequent rainfall until mid to early October. Chinook spawning is usually complete prior to the last week in October or first week of November. Other salmon species observed in this river are coho (*O. kisutch*), sockeye (*O. nerka*), pink (*O. gorbuscha*), chum (*O. keta*) and trout species such as steelhead, rainbow trout (*O. mykiss*) and cutthroat (*O. clarki*).

Strathcona Park was established in 1911 and protects some of the last unspoiled wilderness on Vancouver Island, including the Moyeha Valley (Strathcona Park Master Plan 1993). The Moyeha River Valley is the only completely protected coastal watershed on Vancouver Island and covers 184km^2 (Tripp et al 2010) as a major drainage system. In the Moyeha watershed, approximately 92% of the forest is classified as old age forest and reaching ages from 141 years to 251+ years.

BC Parks relies on zoning that divides the park into logical units to apply uniform and consistent management objectives such as Wilderness Conservation Zones, Recreational Zones, Natural Environment Zones and Special Feature Zones (Strathcona Park Master Plan 1993). Moyeha River Valley is a part of the Wilderness Conservation Zone and Special Feature Zone. The objective of the Wilderness Conservation Zone is to protect a remote, undisturbed natural landscape and to provide unassisted back country recreational opportunities dependant on a pristine environment. The Special Feature Zone has the objective to preserve and protect significant natural or cultural resources, features or processes because of their special character, fragility or heritage value.

The Moyeha River is also located within the Ahousaht First Nations traditional territory. Strathcona Park is located in a number of First Nations territories located on the west coast, east coast and Great Central Lake and Sproat Lake areas (Strathcona Park Master Plan 1993).

METHODS

Marks

This mark-recapture project required chinook salmon to be captured by seining or gillnetting and recaptured by carcass recovery sampling (objective 1). A 50 fathom knotted beach seine that was 200 meshes deep was deployed in pools located in sections 3.5 and 4.0 (1.75km and 2.00km upriver respectively) from a 12ft aluminium boat and then by a 14ft Jon boat powered by a 9.9hp motor. The 50 foot gillnet with 7”mesh size was used on a few occasions. The goal was to set three times per pool each day. Seining effort started September 13th, 2010 and ended October 21st, 2010.

All species captured in the seine net were recorded then carefully released back into the river. Live captured chinook salmon were marked with individually numbered and coloured Kurl-lock aluminium tags (Ketchum Manufacturing Inc., Brockville, Ontario, Canada K6V 7N5). These tags were applied on both opercula and a secondary mutilation mark by hole-punch was applied on the left or right operculum depending on which week the salmon was tagged. The hole punch helped in identifying tagged chinook that may have lost their Kurl-lock tags and the location of the hole punch identified when the salmon was tagged. Silver tags were applied from September 17th to 22nd, 2010and yellow tags from September 30th to October 7th, 2010. We switched to yellow tags when we noticed a new batch of chinook salmon or salmon that did not obtain tags in the tagging pool.

Biological samples were obtained from all chinook salmon to determine age composition (objective 2). Five scales were obtained from the preferred area of each salmon and placed in labelled scale booklets. Genetic samples were obtained by collecting the tissue(s) from the hole-punch that was applied to the operculum. Tissue samples were preserved in vials containing 95% ethanol. The scale and tissue samples were sent to the Pacific Biological Station, Nanaimo, British Columbia for age and genetic analysis. The post-orbital hypural (POH) length was also measured from each salmon to the nearest 5mm using a fibreglass tape measure.

Gender was determined by visually assessing the maturity characteristics of the salmon such as kype pronouncement, mouth and abdominal size.

Recaptures

Carcass surveys were conducted from the migration barrier at rkm 13.5 to the estuary by two crews of two persons. One crew surveyed from rkm 13.5 to rkm7.0. The second crew would collect carcasses from rkm7.0 to the estuary. Surveyors used a hook and line to obtain carcasses from deeper water areas. The banks were also searched for carcasses that may have been pulled from the river by predators or washed ashore.

Biological samples such as scales, otoliths and tissue samples were obtained from every chinook carcass encountered to determine age and origin (objective 2). Otoliths were placed in numbered vials. All samples were sent to the Pacific Biological Station for further analysis. Post orbital hypural (POH) lengths were measured to the nearest 5mm and the abdomen was dissected to not only check for gender but to also assess egg retention for females. The carcass was then cut in half to prevent double counting.

Abundance

Chinook salmon abundance was to be determined by using a two-event Petersen closed population mark-recapture experiment (Seber 1982):

$$\hat{N} = \frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} - 1 \qquad (1)$$

where n_1 is the number of fish marked, n_2 is the total number of fish recovered of which m_2 are marked. The variance of the population is determined by:

$$\mathrm{Var}(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)} \qquad (2)$$

The assumptions for the 2-event Petersen estimate are that (a) the population is closed; (b) every fish has equal probability of being captured and all marked fish mix with unmarked fish; (c) tagging and handling does not affect catch ability or survival of an individual; (d) the second sample is a simple random sample; (e) fish do not lose their marks; (f) all marked fish recovered are reported and not overlooked; and (g) double sampling does not occur.

We did not test for closure (a) with radio telemetry but assumed the population is closed. There was a First Nations chum food fishery occurring near the river entrance of the Moyeha at the end of Herbert Inlet. This fishery is conducted by the Ahousaht First Nation and occurs once a week starting in October. According to the Ahousaht fisheries guardian, no chinook salmon have been captured in this fishery indicating that most of the chinook have migrated into the Moyeha River by that time. To satisfy assumption (b), we fished with the same gear and effort in each tagging pool and attempted to apply marks proportionally throughout the entire run. Unfortunately, no marked carcasses were recovered to test for assumptions (c) to (f) although for assumption (e) fish tagged also obtained a mutilation mark and we had two crew members examining carcasses encountered to satisfy assumption (f). The carcasses were cut in half to prevent double sampling for assumption (g).

Bayesian sequential estimate

Chinook salmon were captured in nets and marked and were to be recaptured by carcass recoveries. Unfortunately, no marked carcasses were recovered and the recapture sample size was too small to establish a Petersen estimate. Therefore, a sequential Bayesian analysis (Gazey and Staley 1986) was conducted to determine chinook salmon escapement. The Gazey and Staley (1986) method was developed for situations with few recaptures in a closed population situation.

The probability model is based on the binomial distribution, therefore the probability of recovering Rt marked individuals from a total of Mt in a sample of Ct for a particular population size (Ni) is given by equation 3:

$$P(R_t \mid N_i) = \binom{C_t}{R_t}\left(\frac{M_t}{N_i}\right)^{R_t}\left(1-\frac{M_t}{N_i}\right)^{C_t-R_t} \tag{3}$$

The prior distribution is represented by a “non-informative” discrete uniform distribution since *a priori* we do not know the distribution of the population size.

$$P(N_i) = \frac{1}{K} \tag{4}$$

where K is the number of population levels that are considered to be possible, bounded at the lower level by the number of tags released (i.e. Ni ≥ max Mt). Combining the prior with the sampling distribution provides the probabilities associated with the various population sizes as:

$$P\left(N_{i|} \mid R_1R_2...R_T\right)=\frac{\prod_{i=1}^{T}\left(\frac{1}{N_i}\right)^{R_t}\left(1-\frac{M_t}{N_i}\right)^{C_t-R_t}}{\sum_{i=1}^{K}\prod_{t=1}^{T}\left(\frac{1}{N_i}\right)^{R_t}\left(1-\frac{M_t}{N_i}\right)^{C_t-R_t}} \qquad (5)$$

The likelihood function (numerator) alone dictates the posterior distribution, while the denominator acts as a normalizing constant that ensures proportionality with the true distribution due to the effect of the prior distribution.

Population estimates were derived from temporal sub-sets of the mark-recapture data using the sequential Bayesian approach (Gazey and Staley 1986). This method determines the posterior distribution of probabilities associated with population size from the joint probabilities of mark recovery rates. Calculated population parameters include 95% Highest Probability Density (HPD) and the mode, a maximum likelihood estimate of the sampling distribution. It should be noted that, while the former has equivalence to a confidence interval, it forms a direct probability statement about population size (Gazey and Staley 1986). The mode is generally reported as a value range, representing its location in the posterior distribution: a single value denotes that each integer between the population bounds has been evaluated.

Live counts of chinook from swim surveys were combined with carcass survey data to form the analytical data set. These data were provided as Excel files by Uu-a-thluk Fisheries; ancillary data in the form of swim cards was also provided. Since jacks were tagged, an initial data set was compiled to include these smaller, less visible fish. However, since no tagged jacks were recovered in swims or during carcass surveys, a second data set was constructed, eliminating jacks from mark totals and also from swim counts. These data minimize bias resulting from unequal probabilities of resighting/recovery between the two size classes of chinook and have been used to estimate adult escapement to Moyeha River.

Assumptions for using a sequential Bayes algorithm are that a) the population is closed, so the population size does not change over the period of the experiment; b) The probability of capturing a marked individual at any given time is equal to the proportion of marked members in the population at that time; c) marked individuals do not lose their marks over the period of the study; and d) all marks are reported on recovery.

For assumption a) the population is assumed to be closed; to satisfy assumption b) marked and unmarked individuals were equally available for capture by fishing with the same effort throughout the project; c) marked individuals also obtained a mutilation mark that would be visible upon inspection if the Kurl-lock tags were to be lost; and to satisfy assumption d) at least two individuals would inspect carcasses encountered to ensure marks were not overlooked.

Area-under-the curve estimation

The normative area-under-the curve (AUC) estimation procedure employed by DFO on the WCVI employs five to six swim surveys to estimate the number of spawners over time over a standardized reach. The visual observations are adjusted for the swimmers estimate of observation efficiency and a technician estimates survey life. This is done by estimating the length of time fish spend in the survey area (survey life) and the proportion of fish counted relative to the number in the stream during the survey (Korman et al. 2002). The number of fish observed on each survey is expanded by the observer efficiency and plotted against the survey date. The AUC estimate is determined by dividing the integral of the escapement curve by the average residence time (survey life) of fish in the survey area (English et al. 1992).

The area under the curve plotted from the adjusted count data was calculated using the trapezoidal approximation:

$$A\hat{U}C = 0.5 * \sum_{i=2}^{n} (t_i - t_{i-1}) * (p_i + p_{i-1}) \qquad (6)$$

where t_i is the time of sampling measured from the day that fish entered the system, p_i is the count of live fish in the system on swim i and n is the number of observations + 2.

Escapement was calculated by division of the AUC by a survey life of 18 days in 2010.

$$\hat{N}_{AUCindex} = \frac{A\hat{U}C}{\hat{S}} \qquad (7)$$

where $\hat{S}$ is the survey life estimate or period the fish were available to be counted in the river counting sections.

Calibration of the AUC estimate

The AUC_{index} escapement estimate was compared to the Bayesian estimate to determine the expansion factor using:

$$\text{Expansion factor} = \frac{\hat{N}_{Bayesian}}{\hat{N}_{AUCindex}} \qquad (8)$$

Where $\hat{N}_{Bayesian}$ is the Bayesian estimate of population size and $\hat{N}_{AUCindex}$ is the AUC population estimate.

Age, sex, origin and tag loss proportions

The proportions of age 3 chinook and older, origin of hatchery and wild, and male and female chinook were estimated as follows:

$$P_{age,\ sex,\ origin} = a_i/n \tag{9}$$

where $P_{age,\ sex,\ origin}$ is the estimated proportions of males, females or origin by age i, a_i is the number of males, females or origin by age i, n is the total number of males, females or origin samples and i is the age (3,4,5). The variance can be estimated by:

$$Var(P_{age,\ sex,\ origin}) = [P_{age,\ sex\ origin}\ (1 - P_{age,\ sex,\ origin})]\ /\ n - 1 \tag{10}$$

The abundance of males, females, of age and origin were estimated with:

$$\hat{N}i = \sum P_i\hat{N}_{Bayesian} \tag{11}$$

where $\hat{N}_{Bayesian}$is the Bayesian estimate and the combined variances were estimated with:

$$Var(\hat{N}_i) = \sum \hat{N}^2*var(P_i)+var(\hat{N})*P_i^2 - var(\hat{N})*var(P_i) \tag{12}$$

The proportion of tags lost could not be determined because there were no recaptures during the carcass surveys.

RESULTS

Marks

A total of 24 chinook salmon were captured by seine, sampled, tagged, and released in the Moyeha River from September 17th to October 7th, 2010. Excluding the two jacks captured gives a total of 22 adult chinook marked (M = 22). The main seining events occurred in section 4 (2.00km up river) with some sets occurring just below section 4 (approximately 1.75km up river). Seining effort started September 13th, 2010 and ended October 21st, 2010 with an average catch-per-unit of effort (CPUE) of 3.38 per day per pool (table 1). No chinook were collected on September 13th & 14th, 2010 even though chinook were observed in the tagging pool. Peak catch (CPUE of 4.50) occurred on September 17th-22nd, 2010 when a motorized boat was used to set the seine net. A motorized boat allowed for quicker movement to set the net, which gave the salmon less of a chance of escaping. Access to the river to seine became more difficult in late September through October because of high flows (figure 5). River flow was low in early to mid-September and slightly increased near the end of September but access was relatively easy throughout this month because of the dry conditions throughout the summer. As precipitation increased from the end of September throughout October, seining effort was limited to specific days after river flows decreased. Since we were no longer seeing or catching any fish, we discontinued seining after October 21st, 2010.

Recaptures

There were three live recaptures during the seining events that give a recapture rate of 11.1% (table 2). None of the three fish had lost tags but they were not at large for long prior to recapture. Carcass surveys conducted from September 14th to November 3rd, 2010 recovered 14 carcasses. None of the carcasses had tags or secondary mutilation marks (0.0% recapture rate). The total recapture rate, including the seining events and carcass recoveries, is 7.3%. As with the seining events, carcass surveys were limited by access to the river with the exception of the carcass survey conducted on November 3rd, 2010 (figure 6). Considering the high water and flows at that time, and that there were no chinook carcasses found on October 20th and 21st, 2010, and for future reference, it would be best to not survey in November.

Visual recaptures by the swim survey crew recorded a total of three chinook salmon obtaining tags (R = 3). These visual recaptures were used to determine the Bayes sequential estimate. Two chinook were observed on October 7th, 2010 with one in section 4 and the other in section 5. Another tagged salmon was observed on October 20th, 2010. A total of 258 chinook were examined during the seining, carcass and swim events (C = 258) with 22 marked adults (M = 22).

Age composition

Five scales were collected from each of the 38 salmon sampled to determine the age composition (objective 2). The samples include the 24 samples obtained from the live fish and the 14 samples obtained from the carcasses. Out of the 38 scale samples collected, 25 samples were successfully aged (65.8%), 9 were partially aged and regenerated (23.7%), 3 were regenerated (7.89%) and 1 was undetermined (2.63%). The partially read samples were included in the results considering that there were no stream-type chinook found in the completely read samples and the chinook jack was removed from the final results (n = 33). The proportion of age-3 chinook salmon were 0.33 (SE = 0.08, CI = 0.18 – 0.55), age-4 was 0.21 (SE = 0.07, CI = 0.10 – 0.43) and age-5 was 0.45 (SE = 0.09, CI = 0.28 – 0.64) (table 3).

Origin

Thirteen otoliths were recovered out of the fourteen carcasses sampled to assess the proportions of wild and hatchery strays (objective 2). Out of the thirteen otolith samples obtained, twelve were read because one otolith sample was misplaced. Out of the twelve samples analyzed at the lab, one otolith was destroyed (n = 11), six were identified as originating from Conuma hatchery (0.55; SE = 0.16, CI = 0.23 – 0.82) and five otoliths did not obtain any marks (0.46; SE = 0.16, CI = 0.17 – 0.78) (table 4) indicating natural origin. Genetic samples had not been analyzed at the time of writing this report. Chinook originating from Conuma hatchery were predominately age-3 (n = 4) with one age-4 and one age-5. The wild chinook were predominately age-5 (n = 4) with one regenerated scale.

Lengths

Post-orbital hypural (POH) lengths measured from salmon captured during the seining events were compared to POH lengths measured from carcasses recovered (figure 7a& 7b) (objective 2). The majority of salmon captured during the seining events ranged from 600mm to 800mm (figure 7a). The average POH length for chinook captured in the seine net (n = 24) was 667mm (SE = 23; 95% CI = 621 – 712). The average POH length for chinook obtained in the carcass surveys (n = 14) was 703mm (SE = 27; 95% CI = 649 – 756). Carcasses had a similar length distribution compared to chinook obtained in the seine net. Chinook salmon obtained in the seine net was slightly smaller compared to salmon obtained during the carcass surveys (figure 7b). The Kolmogorov-Smirnov test results suggest the lengths from both data sets were normally distributed and were not different (*D,* = 0.182, *P* = 0.985). The sample size was too small to compare lengths by sex and there were no marked recaptures during the carcass surveys.

Sex

The ratio of males and females was 1.88:1.00 for chinook salmon captured in the seine net and the ratio for salmon captured in the carcass recoveries is 2.50:1.00 (table 5). The ratio of males and females encountered during the seining events and carcass surveys were not significantly different (X^2 = 0.238, *df* = 1, *P* = 0.625) and pooled to provide a ratio of males (25) to females (12) of 2.08:1.00.

Abundance

A Petersen estimate could not be generated because there were no recaptures in the carcass surveys to generate a usable estimate to satisfy objective 1. Consequently, we applied a Bayesian methodology, specifically designed to address problems associated with sparse data

(Gazey and Staley 1986), to generate an escapement estimate by using live counts of chinook salmon from the swim surveys, combined with the carcass survey data.

Bayesian sequential estimate

In all cases, the posterior probability distribution was constructed from 801 discrete population levels between bounds of 40 – 3,240 individuals. The data set including jacks, produced a modal population estimate for large adults and jacks of 760– 768 (95% highest probability density 352– 2,192, 2.5% and 97.5% quantiles 448- 2,480). The exclusively adult data produced a modal population estimate located at 684– 692 (95% highest probability density 312– 2,008, 2.5% and 97.5% quantiles 400- 2,308). Sequential plots of the latter posterior distribution with time are illustrated in Fig. 8. The bounds on the estimate are wide, due to the sparse data. Consequently, the level of precision attained was poor, with the limits of error for the estimate, as indicated by the probability distribution, approximately 62% of the mode with 95% probability.

The swim survey data was obtained under excellent conditions, with all swims in clear conditions with water levels at normal or better with one exception. On 21 September levels were above normal following moderate rainfall in the previous week (data from Tofino station A http://www.climate.weatheroffice.gc.ca). At this time the nearby Burman River hydrograph was not elevated, suggesting that the effect on the survey was not appreciable and the recorded efficiency for chinook was noted to be 95%.

A sizeable number of adult chinook were examined in the course of the program (249), but unfortunately with few marked fish noted. Invariably, low numbers of recaptures have a substantial effect on the precision of the estimate. It would have been preferable to have initiated tagging prior to the first swim survey, to maximize the level of effort available for visual tag recovery. However, the project was not initially designed for a Bayesian estimate.

The posterior distributions depict a decreasing trend (Fig 8) in adult population levels following the first marked chinook recapture (sighting). Generally, convergence of the distribution around a single value indicates a stable population size (Gazey and Staley 1986) and is indicative of closure in the population (assumption of stability). Even though losses through mortality, predation etc. are present, as long as these affect both marked and unmarked chinook equally, then the mark/unmarked ratio is stable and the posterior distribution is not greatly affected. However, the final sets of iterations are moving towards a smaller escapement size, suggesting that mortality rates were not equivalent between tagged and untagged chinook. Or it could suggest that unmarked fish had entered the system without being proportionally marked. Generally, bias towards losses of tagged fish, resulting in lower probability of recovery, produces a reduction in population size. The degree to which this may have biased the estimates was assessed by manipulating the marked fish totals for the sampling occasions after 7th October. Three data sets were evaluated with progressively greater reductions. In the final run, the 110 actual marks (22 corresponding to the five iterations of the posterior) were reduced to 78, by the reduction of 2,3,6,9 and 12 marks. This produced mark totals of 22,21,18,15 and 12 in the final five iterations. The result on the estimate was small as illustrated in Fig 9. In the final trial (29% mark loss) the mode was reduced to 660-668 chinook (95% HPD 300 – 1,956) a reduction of < 3%. Therefore, it is reasonable to conclude that bias from unequal capture probabilities through mark loss was not a significant error in the estimate of escapement.

The degree of precision associated with minimum population levels is depicted in Fig 10. There was a 0.95 probability that the escapement of chinook to the Moyeha River was at least 440 individuals. Allowing for the hypothetical reduction in marked chinook described above (29% level), the minimum escapement is reduced to 432, again illustrating the small bias associated with potential mark loss.

Area-under-the curve estimation

The AUC_{index} result for the swim surveys conducted by the Department of Fisheries and Oceans was 185 with a peak of 162 individuals (figure 11). There were a total of six swim surveys conducted on the Moyeha River starting September 2, 2010 and ending November 22,2010.

Calibration of AUC escapement

The expansion factor from the AUC_{index} escapement to the Bayesian estimate to develop an expansion factor (objective 3) was 2.38.

DISCUSSION

This was the first year that a mark-recapture project was conducted in this system. This project provided an insight on the river characteristics such as the flood events and an understanding of salmon behaviour and staging areas within this system. With this background knowledge, we will be able to plan ahead of the chinook migration to set up seining stations at preferred locations within the river and focus our marking before the major flood events.

For the two-event Petersen mark-recapture experiment we assumed the population was closed. To ensure that every fish had equal probability of being captured we fished with the same gear and same effort throughout the project. We assumed that both marked and unmarked fish experienced the same mortality. Information on the frequency distribution on sizes of chinook marked with those captured and those with marks recovered would have been beneficial to ensure our captures were not size selective. We were able to test the lengths of fish obtained in the seining events to the carcasses recovered that were not marked and the lengths appeared to be similar. Chinook also obtained a mutilation mark to ensure that tags were not lost. All carcasses encountered were examined by two crew members to ensure tags were not overlooked. Carcasses were then cut in half to prevent double sampling.

We were able to obtain an escapement estimate of at least 440 individuals from the Bayesian analysis approach and compared this to the normative AUC_{index} approach. In order to satisfy the assumptions for this approach we assumed a closed population. We fished with the same gear and effort throughout the project. As with the Peterson estimate, a mutilation mark was applied to each chinook to ensure no tag loss and two crew members examined carcasses to ensure marks were not overlooked.

We were also able to obtain partial information for age structure, lengths, and origin. From the scale samples obtained, there were more age-5 chinook and the otolith samples indicated wild chinook dominating this age class. Age-3 chinook were the next most abundant with hatchery fish dominating this age class. It was believed that there were no hatchery influences to the Moyeha River, but after receiving the analysis from the otolith lab, this may not be the case. However, the finding of a high proportion of hatchery strays should be questioned because of the small sample size analyzed (n = 11). Further investigation of hatchery contribution is in process and results from genetic samples taken during the seining events, carcass surveys, and swim surveys (n = 40) will be analyzed to provide better representation of hatchery strays. Further investigation and more samples will need to be taken in future years in order to conclude that Moyeha River chinook have been significantly impacted by hatchery strays.

There were no stream-type chinook found in the samples successfully aged. The small sample size obtained possibly contributes to this result along with the small proportion of stream-type chinook that may contribute to this population. According to Healey (1983), there is a distinct difference in distribution and behaviour of the two life history types of ocean-type and stream-type chinook. Stream-type chinook dominate the upper reaches of North America with Alaska obtaining nearly 100%. This percentage decreases in stream-type chinook as latitude decreases in which ocean-type dominate approximately below 55-56°N latitude (Healey 1983). Moyeha chinook, along with other Vancouver Island chinook populations, have predominately ocean-type chinook.

CONCLUSION AND RECOMMENDATIONS

Working with a small population in a mark-recapture experiment is difficult, particularly given the unpredictable stream flows on the WCVI in autumn. Recommendations for future projects on this system include substantially increasing effort on marking and recovering carcasses; and incorporating and evaluating additional, possibly more effective capture methods such as angling and tangle netting or including other methods such as the Korman (2002) AUC method for consideration for assessing smaller populations. The Bayesian analysis took into account the small sample size and could be used to assess populations such as the Moyeha River chinook if methods to assess closure were incorporated in the future. Alternative or back-up methods that might be incorporated in the sampling design without compromising other objectives, such as Korman's AUC method or mark-resight methods, should be considered.

ACKNOWLEDGEMENTS

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Figure 1. Moyeha River chinook escapement from 2000 to 2010.

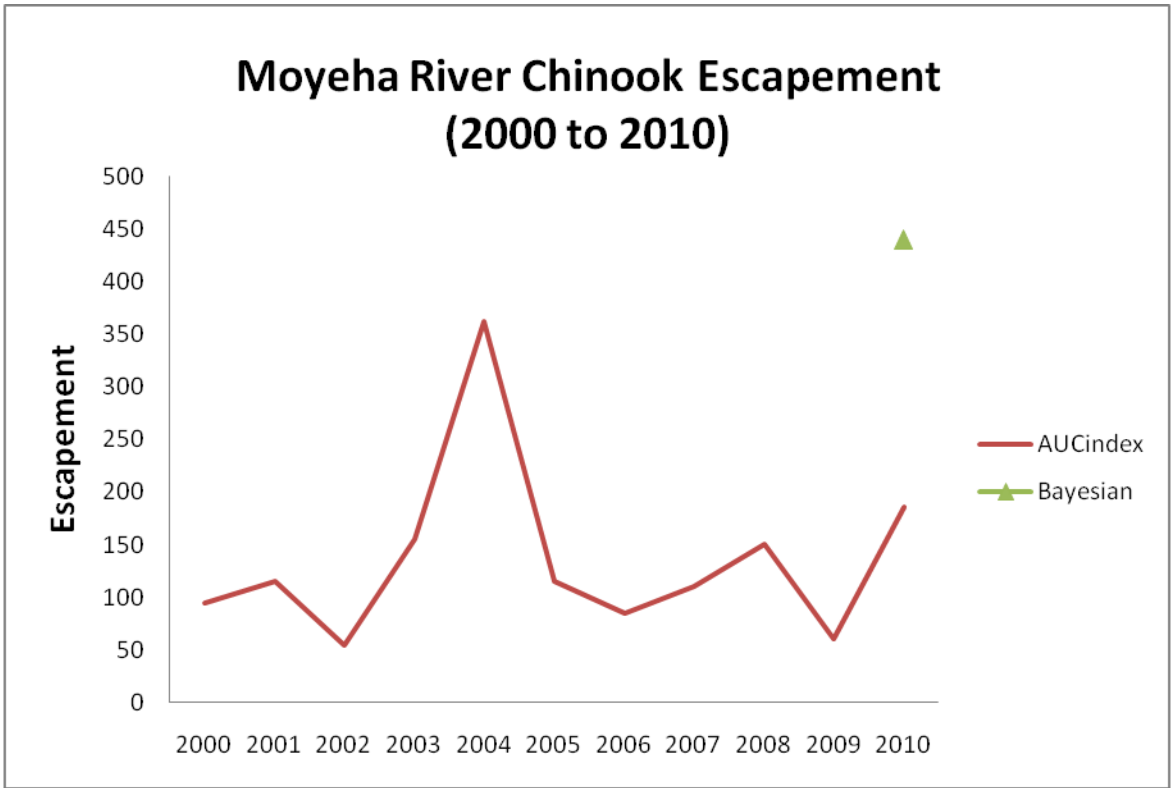
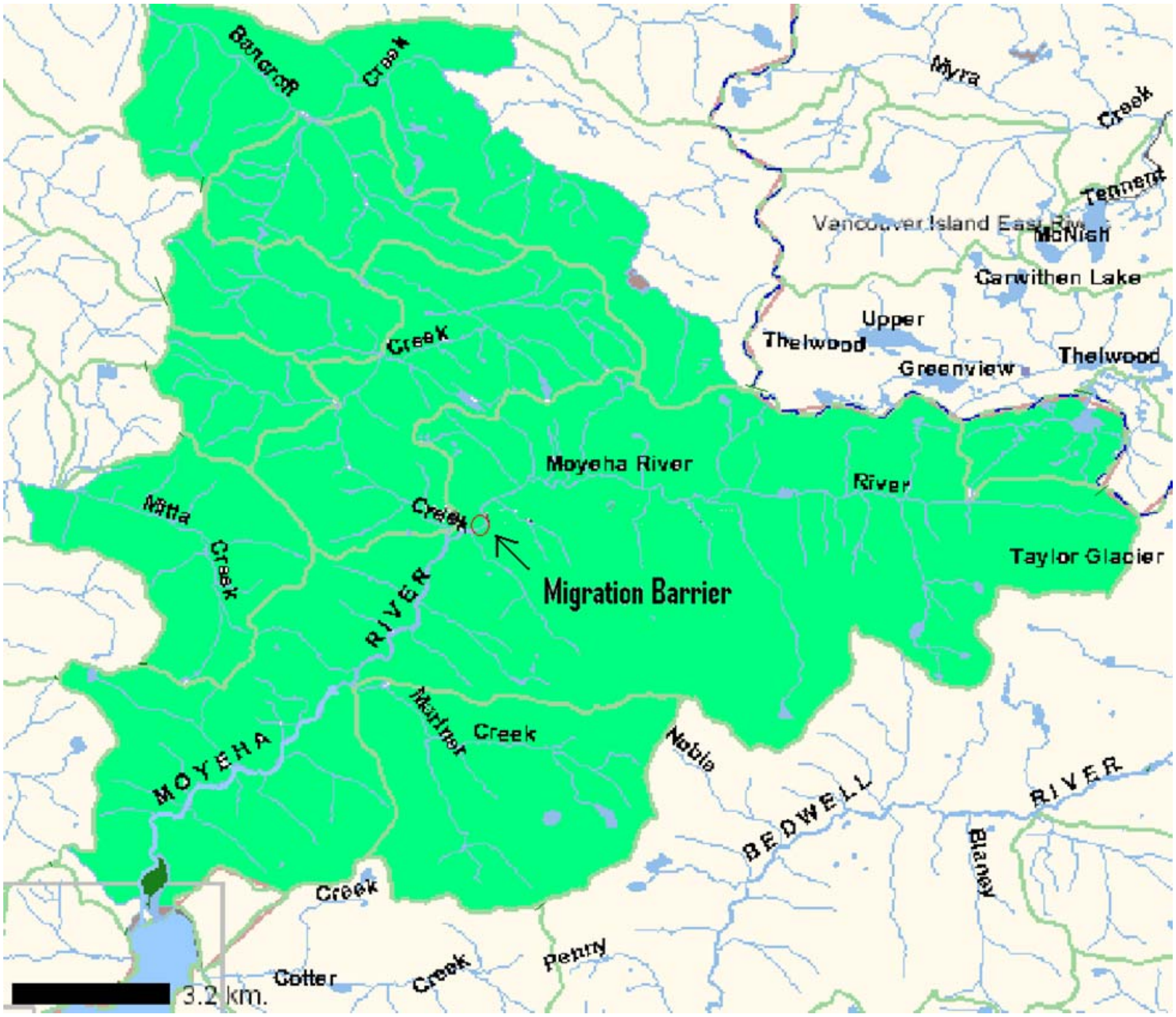


Figure 2. Moyeha River location on Vancouver Island in Strathcona Park.

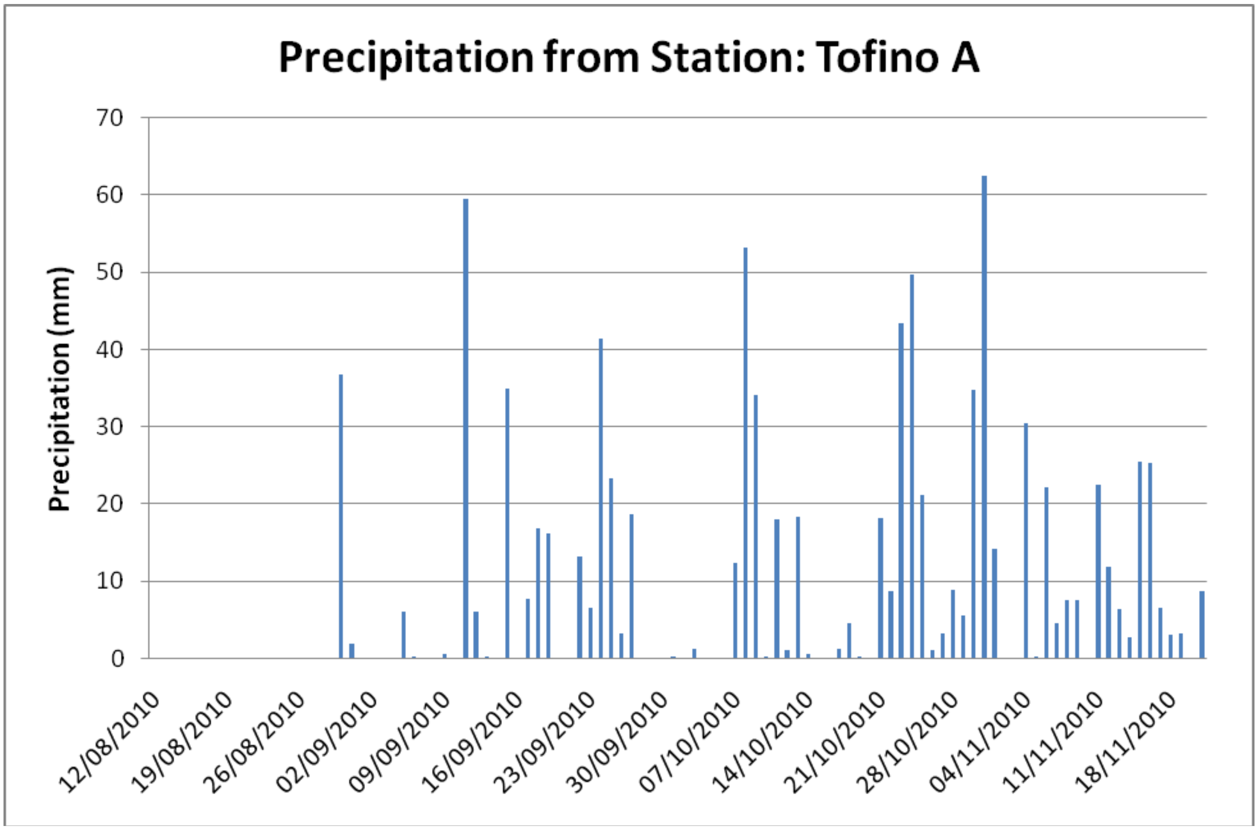
Made on mapster: http://www.pac.dfo-mpo.gc.ca/gis-sig/maps-cartes-eng.htm

Figure 3. Moyeha River watershed and approximate location of migration barrier.



Made on mapster: http://www.pac.dfo-mpo.gc.ca/gis-sig/maps-cartes-eng.htm

Figure 4. Precipitation from Tofino station A from August 12th to November 21st, 2010.



Precipitation information available at: http://www.climate.weatheroffice.gc.ca

Figure 5. Seining effort and precipitation from September 1st to November 10th/2010.

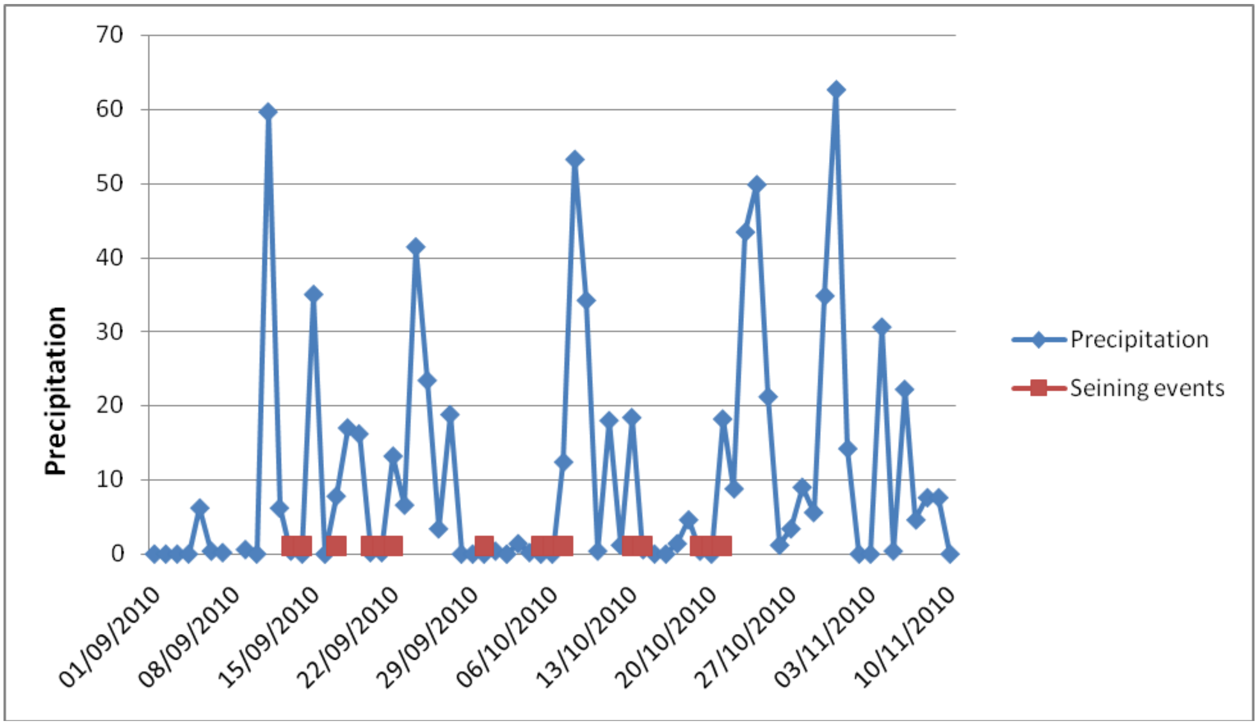


Figure 6. Carcass survey effort and precipitation from September 1st to November 10th/2010.

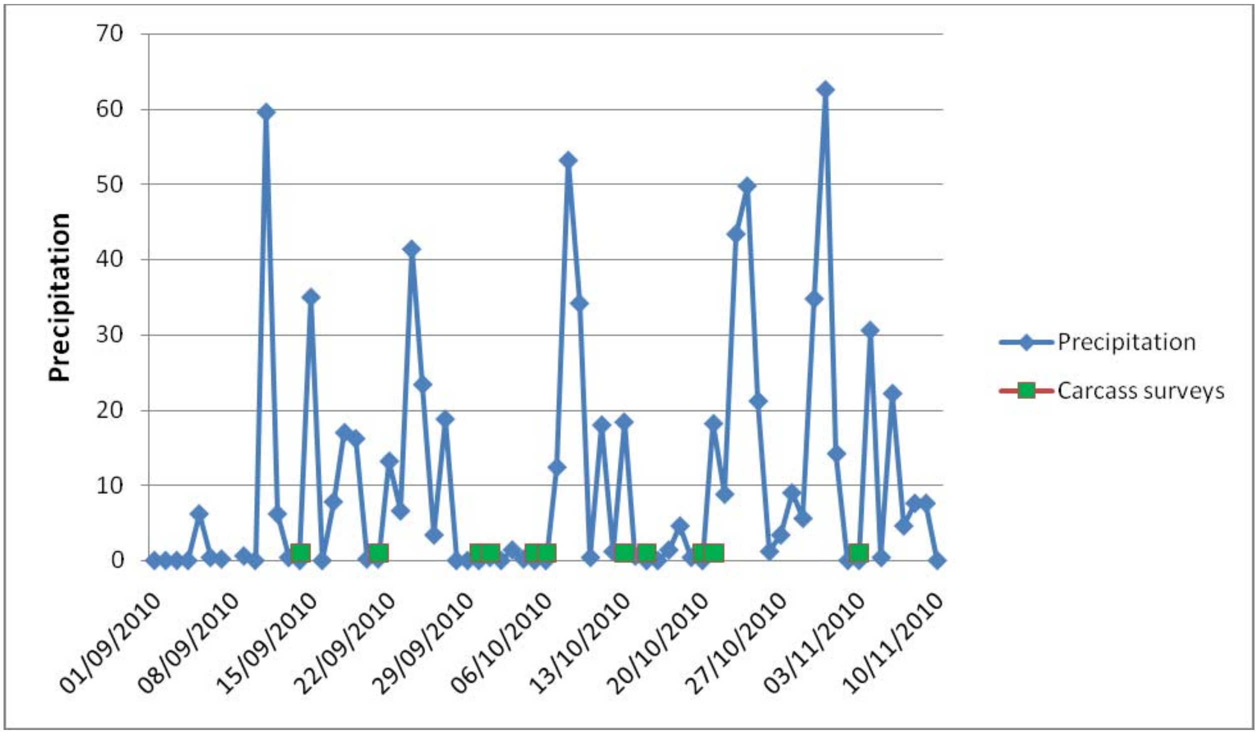


Figure 7a. Length frequency distribution of chinook salmon captured in the Moyeha River by seine and carcass recoveries.

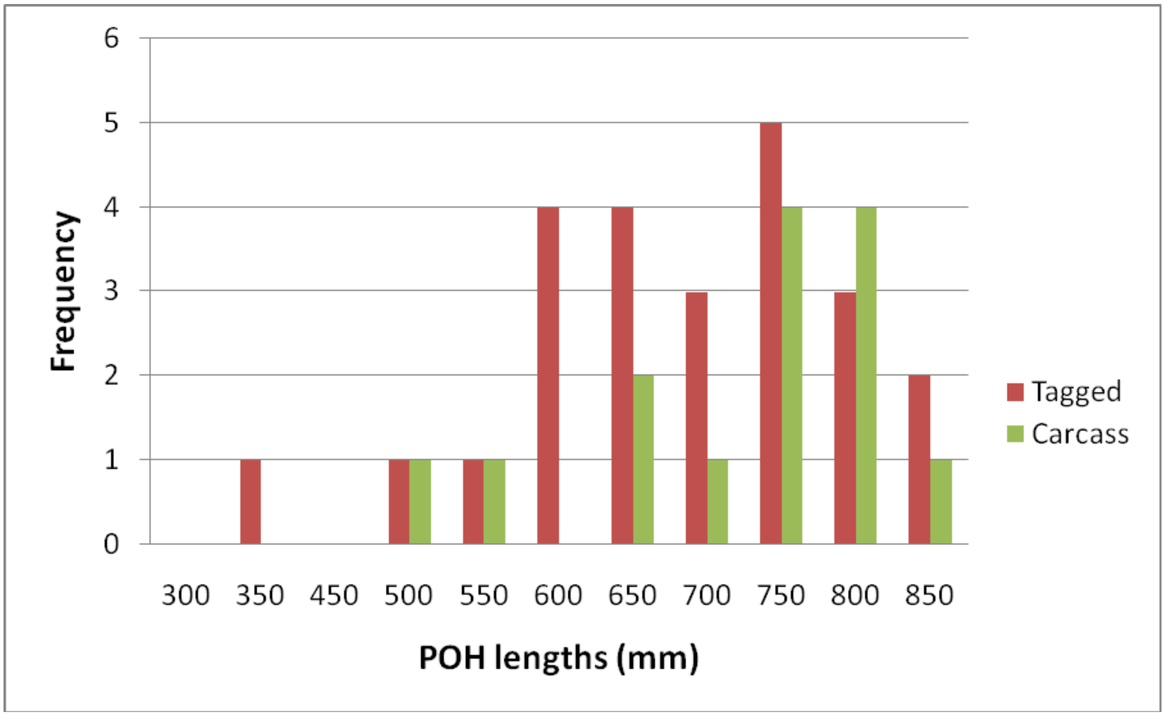


Figure 7b. Cumulative length frequency distribution for chinook salmon obtained in the seine net and during the carcass recoveries.

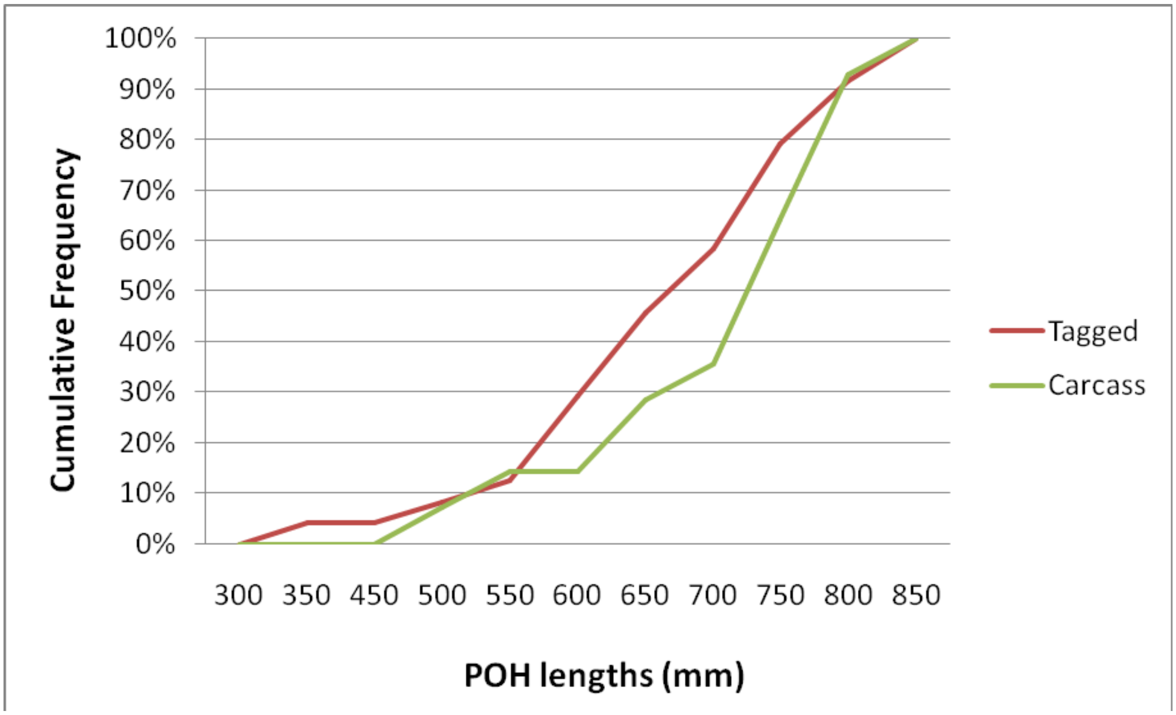


Figure 8. Sequential plots of the posterior distribution of the large adult population estimate.

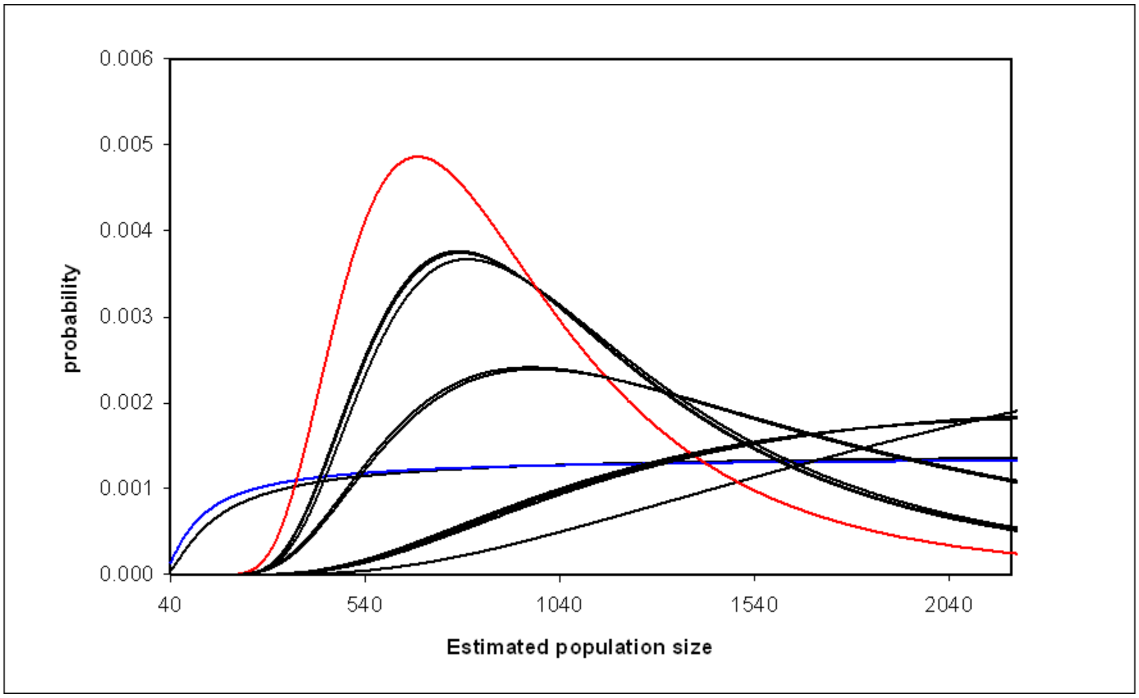


Figure 9. Reduction in escapement size for various losses of marks in late sampling stages.

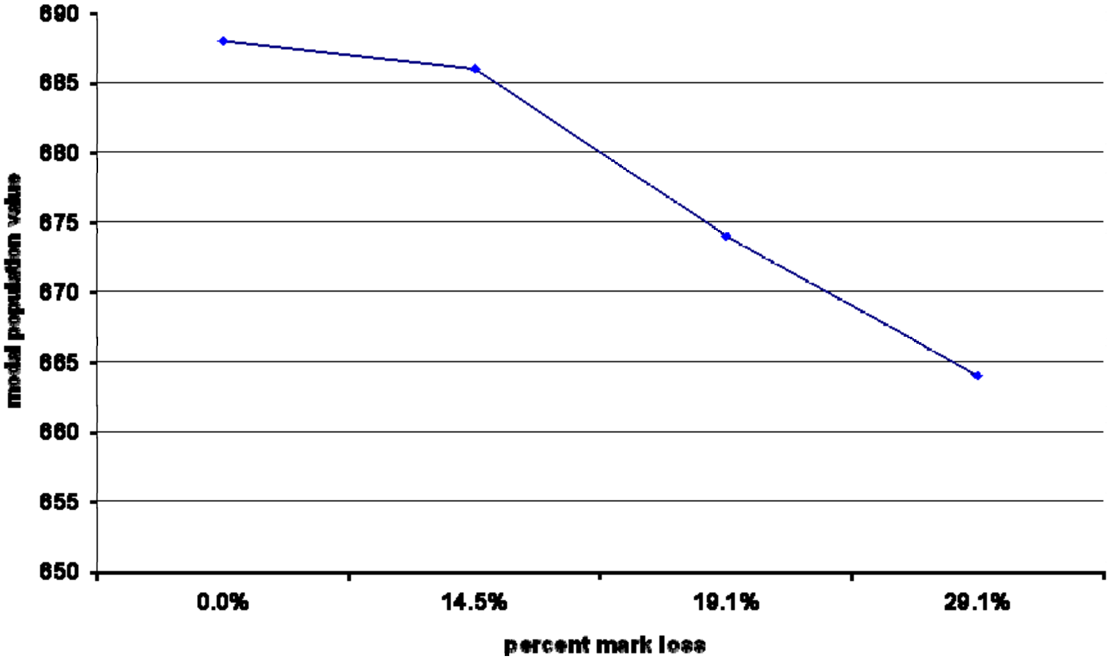


Figure 10. Minimum population estimates for levels of probability.

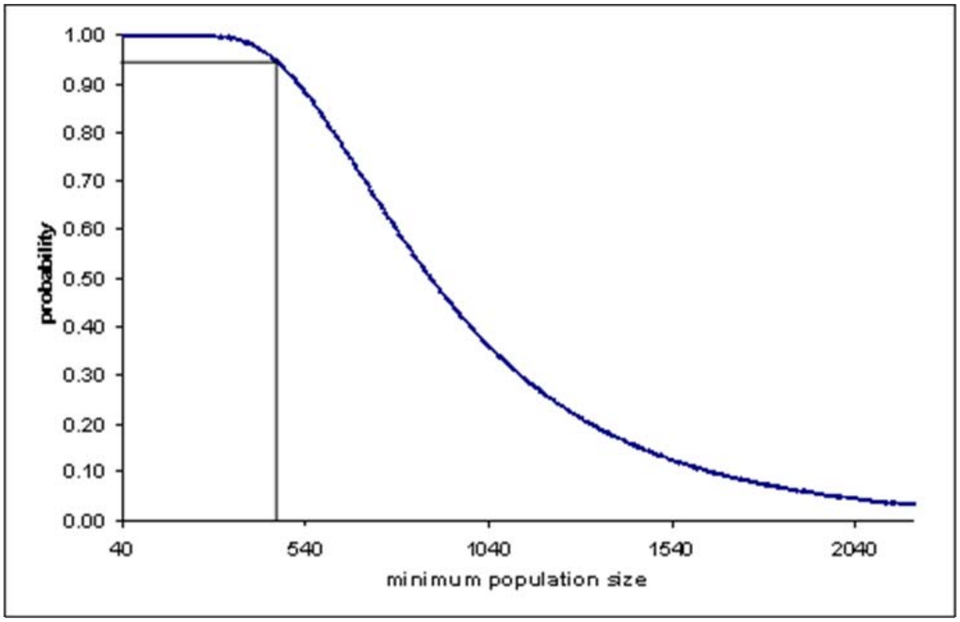


Figure 11. Moyeha River chinook escapement curve for 2010.

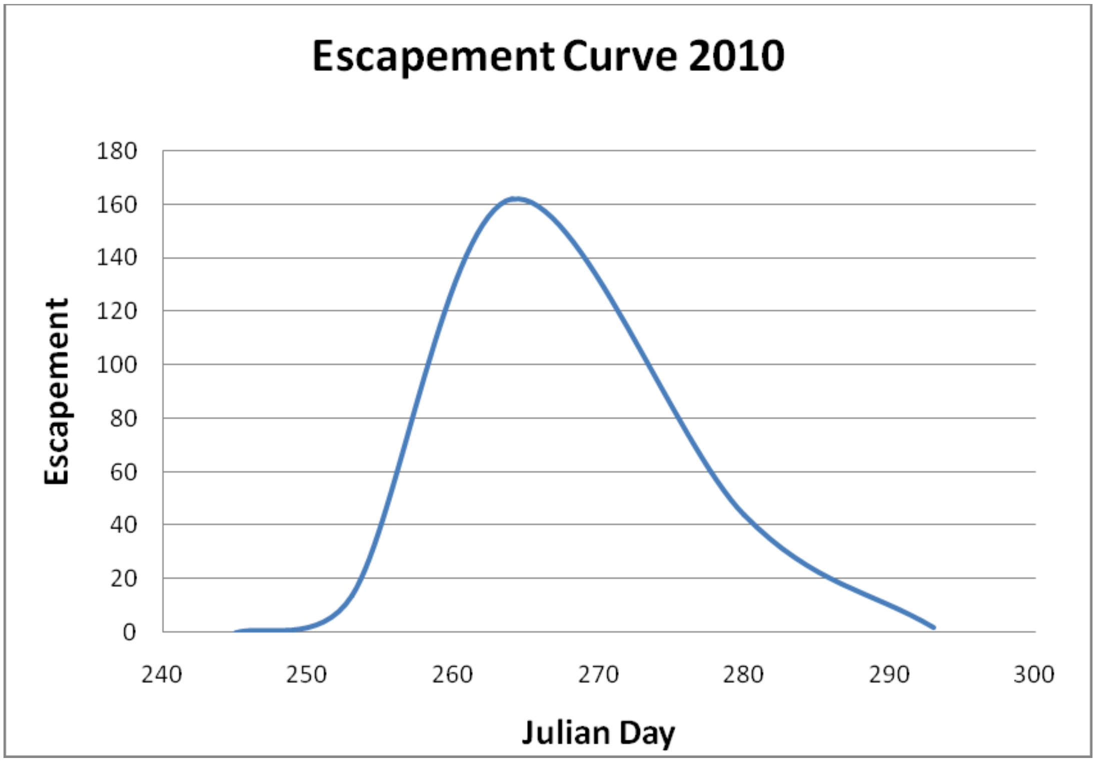


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Table 1. Seining catch-per-unit of effort (CPUE)

Date (2010)	Visual assessment	Chinook catch	CPUE	Comments
Sept. 13th - Sept. 14th	Chinook in pool	0	0	Difficulty setting net
Sept. 17th - Sept. 22nd	Chinook in pool	18	4.50	Peak catch
Sept. 30th - Oct. 7th	Chinook in pool	9	2.25	Decrease in catch
Oct. 13th - 21st	very little (1-3 fish)	0	0	No catch
Average			**3.38**	

Note: Average =(4.50 + 2.25)/2

Table 2. Recapture rate of chinook salmon captured by seine and during the carcass surveys within the river.

	Seine	Carcass	Total
Marked	3	0	3
Unmarked	24	14	38
Total captured	27	14	41
Recovery rate	0.11	0	0.07

Table 3. Age 3 and older chinook salmon in the Moyeha River 2010.

		Age 3	Age 4	Age 5	Total
Seine	Males	5	4	4	13
	proportion	0.25	0.20	0.20	0.65
	Females	1	2	3	6
	proportion	0.05	0.10	0.15	0.30
	Unknown	1	0.0	0.0	1
	proportion	0.05	0.00	0.00	0.05
Total					**20**
Carcass	Males	4	0.0	5	9
	proportion	0.31	0.00	0.38	0.69
	Females	0.0	1	3	4
	proportion	0.0	0.08	0.23	0.31
Total					**13**
Total Males		9	3	9	21
Proportion		0.43	0.14	0.43	1.00
SE		0.11	0.08	0.11	0.0
CI		0.21 - 0.68	0.04 - 0.44	0.22 - 0.67	
Total Females		1	3	6	10
Proportion		0.10	0.30	0.60	1.00
SE		0.10	0.15	0.16	0.00
CI			0.08 - 0.71	0.26 - 0.86	
Total		**11**	**7**	**15**	**33**
Proportion		**0.33**	**0.21**	**0.45**	**1.00**
SE		**0.08**	**0.07**	**0.09**	
CI		**0.18 - 0.55**	**0.10 - 0.43**	**0.28 - 0.64**	

Table 4. Origin of Moyeha River chinook salmon sampled.

Date	Fish #	Origin
21/09/2010	1	H-Conuma R
30/09/2010	2	Wild
01/10/2010	3	Wild
05/10/2010	4	
05/10/2010	5	Wild
06/10/2010	6	
06/10/2010	7	H-Conuma R
06/10/2010	8	H-Conuma R
06/10/2010	9	H-Conuma R
13/10/2010	10	Wild
15/10/2010	11	H-Conuma R
15/10/2010	12	Wild
15/10/2010	13	H-Conuma R
15/10/2010	14	Destroyed
Total		11
Hatchery		6
Proportion		0.55
SE		0.16
CI		0.23 - 0.82
Wild		5
Proportion		0.46
SE		0.16
CI		0.17 - 0.78

Note: Otolith not retrieved from fish #4 and missing vial from fish #6.

Table 5. Ratio of male to female chinook salmon sampled.

	Seine	Carcass	Total
Male	15	10	25
Female	8	4	12
Unknown	1	0	1
Total	24	14	38
Ratio (males:females)	1.88:1.00	2.50:1.00	2.08:1.00

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APPENDIX 1. Seining days and chinook salmon captured and tagged.

Fish #	Date	Set	Section	Sex	Recap.	Tag colour	Tag #1	Tag #2	Punch location	Adipose clip	POH	Scale booklet	Scale #	Genetic sample	Release cond.	Comments	Temp. (°C)
	13/09/2010	1	3.5													No fish caught	
	13/09/2010	2	3.5													No fish caught	
	14/09/2010	1	4.0													No fish caught	10.5
	14/09/2010	2	4.0													No fish caught	
	14/09/2010	3	4.0													No fish caught	
1	17/09/2010	1	4.0	m	no	plain	1	2	ro	n	685	93293	1-41	6599	good		11.0
2	17/09/2010	1	4.0	m	no	plain	3	4	ro	n	610	93293	2-42	6600	good		
3	17/09/2010	1	4.0	m	no	plain	5	6	ro	n	600	93293	3-43	6598	good		
4	17/09/2010	1	4.0	m	no	plain	7	8	ro	n	644	93293	4-44	6597	good		
5	17/09/2010	1	4.0	f	no	plain	9	10	ro	n	835	93293	5-45	6596	good		
6	17/09/2010	1	4.0	m	no	plain	11	13	ro	n	595	93293	6-46	6595	good		
7	17/09/2010	1	4.0	m	no	plain	14	15	ro	n	785	93293	7-47	6594	good		
8	17/09/2010	1	4.0	m	no	plain	16	17	ro	n	530	93293	8-48	6593	good		
9	17/09/2010	1	4.0	m	no	plain	18	19	ro	n	646	93293	9-49	6592	good		
10	20/09/2010	1	4.0	m	no	plain	20	21	ro	n	690	93294	1-41	6521	good		
11	20/09/2010	1	4.0	m	no	plain	22	23	ro	n	580	93294	2-42	6522	good		
12	20/09/2010	1	4.0	m	no	plain	24	25	ro	n	760	93294	3-43	6591	good		
	20/09/2010	1	3.5														
	20/09/2010	2	3.5													No fish caught	
13	21/09/2010	1	4.0	f	no	plain	26	28	ro	n	725	93294	4-44	6515	good		9.0
14	21/09/2010	1	4.0	f	no	plain	29	30	ro	n	740	93294	5-45	6516	good		
15	21/09/2010	1	4.0	f	no	plain	31	32	ro	n	780			6517			
	21/09/2010	2														No fish caught	

	21/09/2010	3														No fish caught	
	22/09/2010	1	4.0	m	yes	plain	20	21	ro								10.0
16	22/09/2010	1	4.0	f	no	plain	33	34	ro	n	690	93300	1-41	6518		Spagettii tag (2006-06-26)	
17	22/09/2010	2	4.0	m	no	plain	36	37	ro	n	740	93294	7-47	6519		Spagettii tag (2006-06-27)	
	22/09/2010	3														No fish caught	
18	30/09/2010	1	4.0	m	no	yellow	1	2	lo	n	746	93295	1-41	4556	good		9.0
19	30/09/2010	1	4.0	f	no	yellow	3	4	lo	n	745	93295	2-42	4508	fair		
	30/09/2010	2	4.0														
	05/10/2010	1														Caught no Chinook	9.0
	05/10/2010	2														Caught no Chinook	
20	05/10/2010	3	4.0	m	no	yellow	7	8	lo	n	618	93294	9-49	4570	good		
21	05/10/2010	3	4.0	f	no	yellow	5	6	lo	n	830	93294	8-48	4534	good		
	06/10/2010	1	4.0		yes	yellow	5	6								Spagettii tag (2006-00629)	
22	06/10/2010	1	4.0		no	yellow	9	10	lo		500	93338	1-41	4584	good	Spagettii tag (2006-00628)	8.0
	06/10/2010	2	4.0													Caught no Chinook	
	06/10/2010	3	4.0		yes		5	6									
23	07/10/2010	1	4.0	m	no	yellow	11	12	lo	n	332	93338	2-42	4520	fair	spawned	
	07/10/2010	2	4.0													Caught no Chinook	
24	07/10/2010	3	4.0	f	no	yellow	13	14	lo	n	595	93338	3-43	4524	good	Spagettii tag (2006-00630)	
	13/10/2010	1	4.0													Caught no Chinook	8.0
	13/10/2010	2	4.0													Caught no Chinook	
	13/10/2010	3	4.0													Caught no	

			Chinook	
14/10/2010	1	4.0	Caught no Chinook	8.0
14/10/2010	2	4.0	Caught no Chinook	
14/10/2010	3	4.0	Caught no Chinook	
19/10/2010	1	3.5	Caught no Chinook	9.0
19/10/2010	2	3.5	Caught no Chinook	
19/10/2010	3	3.5	Caught no Chinook	
20/10/2010	1	3.5	Caught no Chinook	
20/10/2010	2	3.5	Caught no Chinook	
20/10/2010	3	3.5	Caught no Chinook	
21/10/2010	1	3.5	Caught no Chinook	
21/10/2010	2	3.5	Caught no Chinook	

Note: Fish # = Chinook salmon tagged

Each section is 500m apart. Therefore, section 4 = 2000m = 2km

Hole punch: ro = right operculum, lo = left operculum

POH = Post orbital hypural

Other species (chum and coho) were caught on days where chinook was not caught.

APPENDIX 2. Chinook salmon obtained during the carcass recovery surveys

Fish #	Date	Time	Section (km)	Sex	Tagged	POH	Scale booklet	Scale #	Adipose clip	% Eggs retained	Otolith box	Otolith vial	Genetic Sample	Temp. (°C)	Comments
	14/09/2010														No chinook morts
1	21/09/2010		6.0	m	n	606	93339	1-41	n		170	1	6589		
2	30/09/2010		4.0	m	n	820	93339	2-42	n		170	11	4572		Not spawned
3	01/10/2010		5.5	m	n	793	93339	3-43	n		170	9	4599		spawned
4	05/10/2010		5.0	m	n	720	93339	4-44	n		170		4509		could not obtain otolith
5	05/10/2010		5.0	m	n	735	93339	5-45	n		170	15	4574		
6	06/10/2010		5.0	f	n	790	93333	1-41	n		170	8	4591		
7	06/10/2010		5.0	m	n	630	93333	2-42	n		170	7	4573		
8	06/10/2010		5.0	m	n	525	93333	3-43	n		170	19	4516		
9	06/10/2010		5.0	m	n	480	93333	4-44	n		170	12	4512		
10	13/10/2010		7.0	f	n	790	67335	1-21	n	0	170	3	4580		
11	15/10/2010	10:45	15.5	f	n	680	93334	1-41	n	0	170	10	4504	8.0	
12	15/10/2010	12:30	6.0	m	n	750	93334	2-42	n		170	17	4509		
13	15/10/2010	13:35	5.0	f	n	780	93334	3-43	n	0	170	6	4501		
14	15/10/2010			m	n	740	93340	1-41	n		170	18	4515		
	20/10/2010														No chinook morts
	21/10/2010														No chinook morts
	03/11/2010														No chinook morts

Note: Section: 15.5km is between 7km - 13.5km (river surveyed is 13.5km long)

Appendix 3. Chinook salmon recaptured during the seining events

Tagged	Recaptured	Section	Set	Tag Colour	Tag #1	Tag #2
20/09/2010	22/09/2010	4		p	20	21
05/10/2010	06/10/2010	4	1	y	5	6
05/10/2010	06/10/2010	4	3	y	5	6