Enumeration of Chilko River Chinook Salmon Escapement (Mark-Recapture) 2013

Completion Report

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As requested by local First Nation Communities:

NOTICE TO READERS REGARDING CONTENT AND ABORIGINAL TITLE AND RIGHTS

WHEREAS existing Aboriginal and treaty rights are recognized and affirmed in section 35(1) of the *Constitution Act*, *1982*;

AND WHEREAS in entering into agreement to undertake this collaborative work, the Parties are not seeking to determine the existence, nature or scope of Aboriginal or treaty rights but rather are seeking to collaborate in aquatic resource management;

AND WHEREAS the Parties confirm their commitment to a relationship based on mutual respect and understanding;

(a) This cooperative research study:

- (i) does not, and is not intended to, define or extinguish any Aboriginal or treaty rights and is not evidence of the nature or extent of any Aboriginal or treaty rights;
- (ii) is made without prejudice to the positions taken by either Party with respect to Aboriginal or treaty rights;
- (iii) does not affect any Aboriginal or treaty rights of any other Aboriginal group.

The Parties agree that participation in this cooperative study is not, and shall not be construed as, evidence that the Tsilhqot'in National Government nor its member Bands acknowledge or consent to Crown jurisdiction or any infringement of the Aboriginal title within areas subject to Aboriginal title, including the area under consideration of BC Supreme Court in Tsilhqot'in Nation v. Canada, 2007 BCSC 1700 and November 2010 BC Supreme Court of Appeals.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

The 2013 escapement of Summer-Run Chinook Salmon to the Chilko River was estimated using a two event mark-recapture study, and the Peak Count method based on concurrent aerial visual surveys. Petersen tags and sex-specific secondary marks were applied to 735 female and large male Chinook Salmon captured using a combination of seining and angling of which 391 were recovered. A total of 2,093 female and large male carcasses were recovered. There were 45 small males sampled during carcass recovery and of the 21 tags applied to small males, three were recovered.

The results of the bias testing indicated that measurable sources of stress including holding time, marking, and number of times recaptured, and release condition did not have a significant impact on the subsequent behaviour of the marked fish. The mark-recapture assumption of closure was likely met based on the mark-recapture field observations, aerial survey data, and the 2010 radio telemetry study. There was no evidence of temporal or spatial bias in the application or recovery samples for large males. However, there was evidence of temporal and spatial bias in the application and recovery samples for females. The Stratified Population Analysis System (SPAS) results showed no evidence of an unequal ratio of marked to marked between temporal application strata for males; therefore, stratification was not required and the Petersen method was used. For females, spatial and temporal biases were detected in the application and recovery. Escapement estimate using the maximum likelihood (ML) Darroch for females could only be generated in SPAS using temporally stratified application data and spatially stratified recovery data, as the other tests failed to generate estimates. The total estimate of escapement for large males and females was 4,200 Chinook Salmon (lower 95% CI=3,645; upper 95% CI=4,754). Sex-specific escapement estimates were 2,138 large males (Petersen, lower 95% CI=1,926; upper 95% CI=2,350) and 2,062 females (Darroch, lower 95% CI=1,719; upper 95% CI=2,404). The estimated escapement based on aerial counts and the Fraser River Chinook peak count expansion factor was 5,186; approximately 17% more than the mark-recapture estimate. The small sample size of marked recoveries of small males precluded the use of a Peterson mark-recapture estimate. The small male estimate was 192, based on an expansion of small male carcasses recovered by one half the recovery rate of the large males. The age composition of the recovery sample was 9% age 3, 55% age 4, 35% age 5, and 1% age 6. The vast majority of samples showed a two-year freshwater growth pattern (sub2).

INTRODUCTION

For the purposes of management under the Pacific Salmon Treaty, Fraser River Chinook Salmon (*Oncorhynchus tshawytscha*) have been grouped into five stock aggregates on the basis of life history, migration timing and ocean distribution. Summed aggregate escapements are reported annually for the Fraser River stock aggregates in the Chinook Technical Committee (CTC) Annual Catch and Escapement Report (PSC 2002; 2013). Aggregate escapements consist of summed estimates for the constituent streams, and individual estimates vary in quality; however, collectively they represent long term indices of abundance. Estimates are often derived from visual survey data, although some are produced from direct counts (e.g. at a fishway or as they pass an electronic resistively counter).

In addition to spawning ground escapement estimates, preseason forecasting and management of the stock aggregates require time series of estimates of survivals and exploitation rates. Over a number of years, an indicator study can be used to generate these aggregate-specific estimates of survival and exploitation. Indicator studies are ongoing for three of the five Fraser River Chinook Salmon aggregates; Lower Shuswap (Fraser 0.3 Summer), Nicola (Fraser 1.2 Spring) and Harrison (Fraser 0.3 Fall) rivers. Ultimately, survival and exploitation rate indicator stock programs are required for each Chinook aggregate in the Fraser River, thus programs are needed for the Fraser River 1.3 Spring and 1.3 Summer Chinook Salmon aggregates.

To develop a survival and exploitation indicator program requires that the candidate stock be assessable by a high precision method (usually mark recapture) to yield: (a) reliable annual estimates of escapement by age and sex and (b) carcass sampling rates that are high enough to yield precise estimates of return by CWT code. In order to produce precise CWT return estimates, indicator stocks require substantial annual releases of CWT'd juveniles to provide stock and age specific markers for subsequent identification in fisheries and escapement. Annual provision of marked juveniles may be achieved by hatchery supplementation or by extensive juvenile trapping and tagging programs. However, prior to initiation of any CWT program, a stock should first be assessed to determine whether it is feasible to determine accurate and precise estimates of escapement annually and to measure carcass sampling rates.

Chilko River has been identified as the preferred system for development of an indicator program to represent the Fraser River 1.3 Summer Chinook Salmon stock aggregate, based on historical escapement data, physical characteristics of the river, importance of the stock to fisheries, and historical CWT data during the CTC base period. The Chilko River is one of the largest of the Summer-run age 1.3 populations in the Fraser River watershed with a recent mean annual escapement (1991-2013) of 9,600 (3,845-21,625) based on peak count escapement estimation methods (Bailey *et al*. 2000, Parken *et al*. 2003). Last year (2012) had the lowest annual escapement recorded since 1989. The total estimated escapement to the stock aggregate has ranged between 10,000 and 45,000 since 1975 (PSC 2013). The Fraser River Summer-Run 1.3 stock aggregate contributes catch to AABM and ISBM fisheries from SEAK to Washington, and returning Chilko River Chinook Salmon are significant contributors to First Nations and recreational fisheries within the Fraser River. The aggregates importance in fisheries could facilitate the recovery of CWT information and the production of exploitation rates.

The Sentinel Stocks Program (SSP) was created as a part of the 2008 Pacific Salmon Treaty Agreement. The SSP was created to provide additional sources of high quality escapement information for stocks with five geographic areas that are of particular importance to the Pacific Salmon Commission (PSC), thus strengthening the biological basis of the Chinook regime, increasing confidence in management, and better informing the development of future regimes.

Funding for this project was provided by the SSP to estimate the Chinook Salmon escapement to the Chilko River in 2013, while providing an opportunity to investigate in-river behavior and evaluate the study design for possible future use. The primary objectives of this study were:

1) To produce an estimate of the spawning abundance by age and sex that meets or exceeds the CTC data standard for escapement indicator stocks;

2) To produce an estimate of an annual calibration factor to correct for biases in peak count salmon escapement estimates in the Chilko River and other Fraser River tributaries that have similar visual counting conditions.

The design of the Chilko River Chinook Salmon mark-recapture study was similar to that used on the Harrison River (Farwell et al. 1998) and Nicola River (Farwell *et al*. 1999). The project was also conducted in 2010, 2011 and 2012; and an additional Chilko River Chinook Salmon study is planned for 2014. The results of the study from 2010 to 2013 indicate that it is feasible to generate high precision estimates of escapements to the Chilko River annually and it has sufficient carcass sampling rates. The implementation of CWT'd juveniles is still required for this program to function as the indicator stock of the Fraser River Summer-run Age 1.3 Chinook aggregate.

STUDY AREA

The Chilko River is a large (stream order 7) tributary of the Chilcotin River located on the eastern edge of the Coast Mountain Range in Central British Columbia (Figure 1). The river flows from Chilko Lake northeast for 82 km before entering the Chilcotin River, 106 km upstream of the Fraser River.

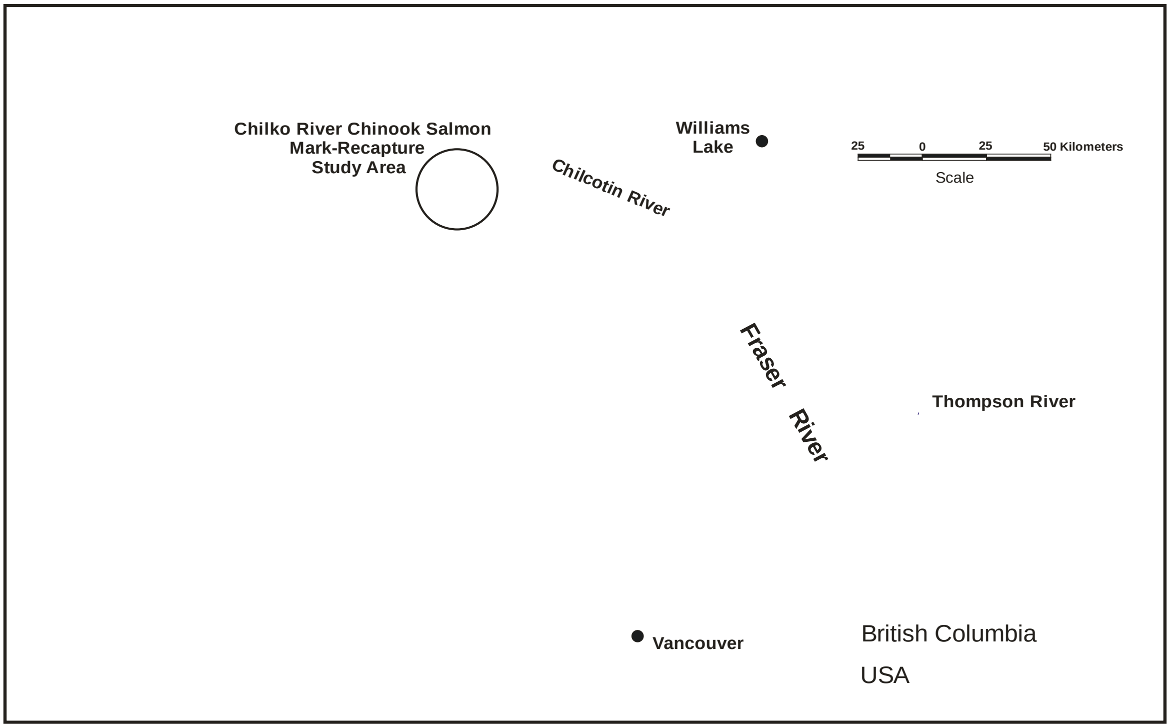

Figure 1. The Chilko River is located about 135 km west of Williams Lake and about 300 km north of Vancouver, B.C.

The Chilko River Chinook Salmon population returns to the mouth of the Fraser River from late June to early August, with a peak in migration during mid-July (Parken et al. 2008). The time for this summer-run stock to migrate from the Fraser River mouth to the spawning grounds has not been measured directly, but the migration may take about three to five weeks since Chinook Salmon first appear in the Chilko River during late July. Chinook Salmon spawning occurs from late August to late September.

Virtually all Chinook Salmon spawn in the Chilko River between the outlet of Chilko Lake and a canyon below its confluence with Brittany Creek; approximately 30 km downstream of the lake. The Chilko River downstream of the Brittany Creek confluence is very high gradient and constrained within a lava bedrock canyon. Based on previous assessment studies, the study area was divided into eight reaches, from the lake outlet to the upper end of Bidwell Canyon (Figure 2 and Table 1). This study area was selected because it is where virtually all the Chinook Salmon spawn. Lingfield Creek and Brittany Creek are minor tributaries that enter the Chilko River study area (Figure 2), and there is no reported spawning of Chinook Salmon in either one.

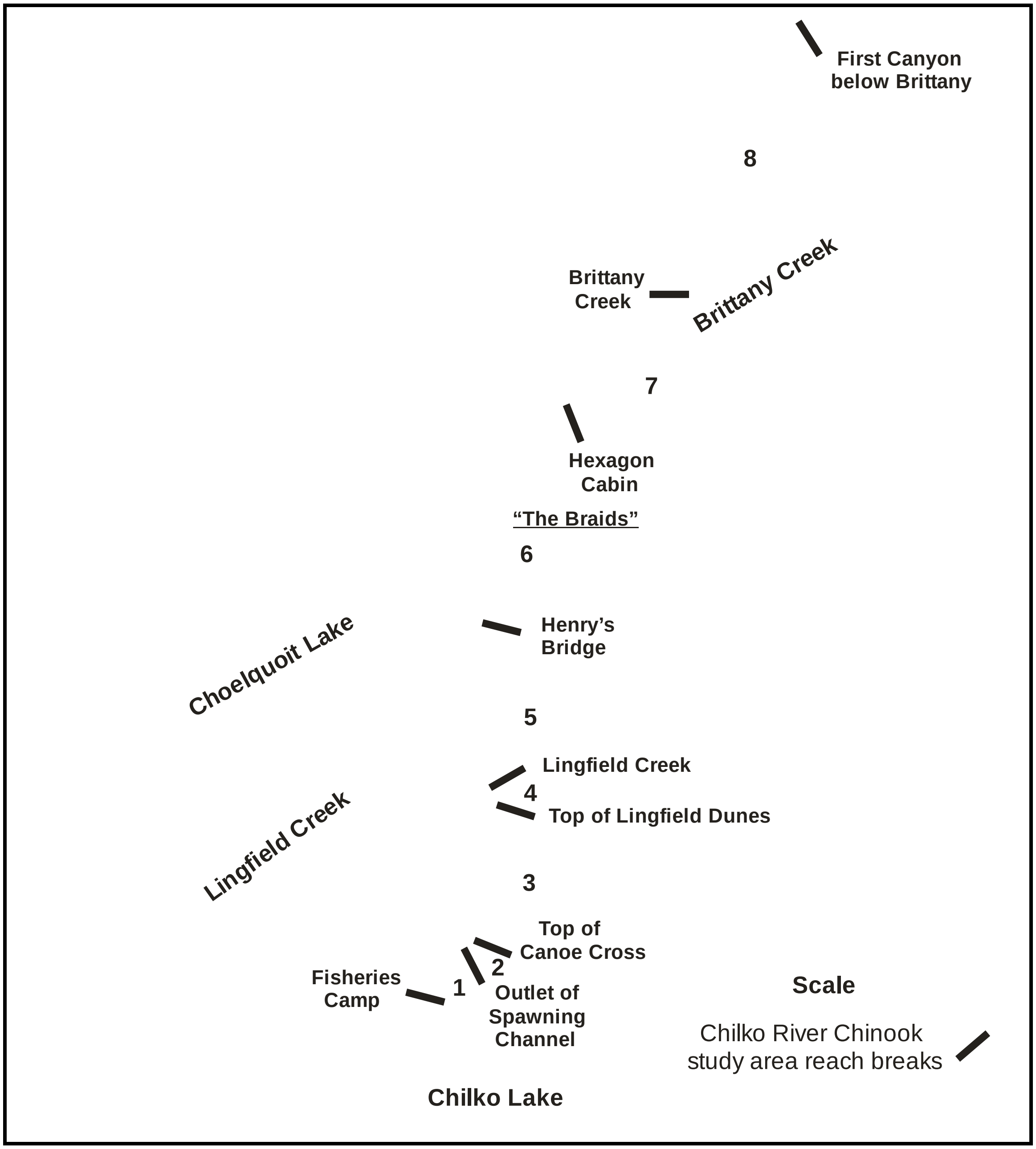

Figure 2. Chilko River study area with reach breaks, tributaries, seining location and other sites referred to in this report.

Table 1. Chilko River reaches, coordinates, associated reach designations and length.

Reaches	Upstream Coordinates[a]	Reach Number	Reach Length (km)
Fisheries Cabin to Outlet of Spawning Channel	51 37 34 N 124 08 32 W	1	1.6
Outlet of Spawning Channel to Top of Canoe Cross	51 37 55 N 124 07 27 W	2	1.0
Top of Canoe Cross to Top of Lingfield Dunes	51 38 26 N 124 06 48 W	3	5.3
Top of Lingfield Dunes to Lingfield Creek	51 40 09 N 124 06 19 W	4	0.9
Lingfield Creek to Henry's Bridge	51 40 43 N 124 06 35 W	5	4.5
Henry's Bridge to Hexagon Cabin (Kye's)	51 42 55 N 124 06 25 W	6	7.0
Hexagon Cabin (Kye's) to Brittany Creek	51 45 46 N 124 04 25 W	7	4.4
Brittany Creek to First Canyon Below Brittany Creek	51 47 22 N 124 02 22 W to 51 51 15 N 123 58 45 W	8	9.3

a. NAD83 map datum.

The greatest densities of Chinook Salmon spawners are in the "Lingfield Dunes" directly upstream of Lingfield Pool (reach 4) and in the "Braids" below Henry's Crossing (reach 6; Figure 2).

Annual and spawning season mean discharge data (m^3s^{-1}) were estimated for Chilko River by Environment Canada (Lynne Campo, pers. comm., Environment Canada, unpublished data). In 2013, discharge based on preliminary data ranged from 45.6-106 m^3/s during the project (August-October; Figure 3). Historical maximum flows approach 205 m^3s^{-1} and occur in early-August, but a secondary peak can occur later in the summer when sudden warming causes rapid melting of high elevation snow and glaciers. In 2013, the discharge steadily decreased throughout the study period and water temperatures ranged from 14-18°C with a mean of 16.4°C during the application period.

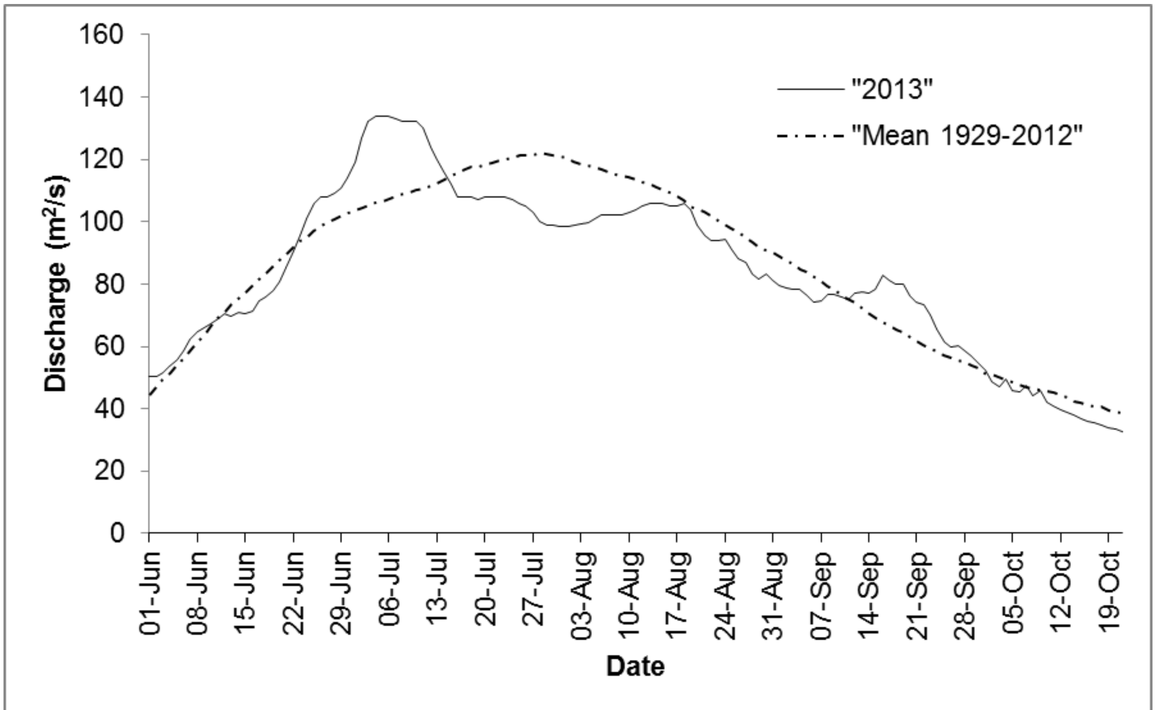

Figure 3. Preliminary mean daily discharge (m^3/s) for 2013 and the mean daily discharge for 1929-2012 for Chilko River from June - October using Environment Canada's Water Survey Station information near the outlet of Chilko Lake (Lynne Campo, pers. comm., Environment Canada, unpublished data).

The Chilko River supports populations of three species of Pacific salmon; Chinook, Coho (*O. kisutch*), and Sockeye (*O. nerka*). Other salmonid fish species inhabiting the Chilko River include Rainbow/Steelhead Trout (*O. mykiss*), Rocky Mountain Whitefish (*Prosopium williamsoni*), and Bull Trout (*Salvelinus confluentus*). Non-salmonid fish include suckers (*Catastomus* spp.), Peamouth Chub (*Mylocheilus caurinus*), sculpins (*Cottus* spp.), and Northern Pikeminnow (*Ptychocheilus oregonensis*.

METHODS

MARK-RECAPTURE FIELD STUDY

The initial study design was developed to meet Petersen mark-recapture assumptions; including closure, and equal application and recovery probabilities.

Fish Capture and Mark Application

Chinook Salmon were captured for mark application by beach seining and angling from 8 August 2013 to 27 August 2013. Seining was conducted at Lingfield Pool (Reach 4), the only suitable holding pool identified for seining (Figure 2). Other seining sites were investigated and found to be unsuitable due to flows, substrate types, and/or a lack of holding fish. Fish were successfully angled at 9 locations downstream of Henry’s Bridge throughout reaches 6-8 (Figure 4).

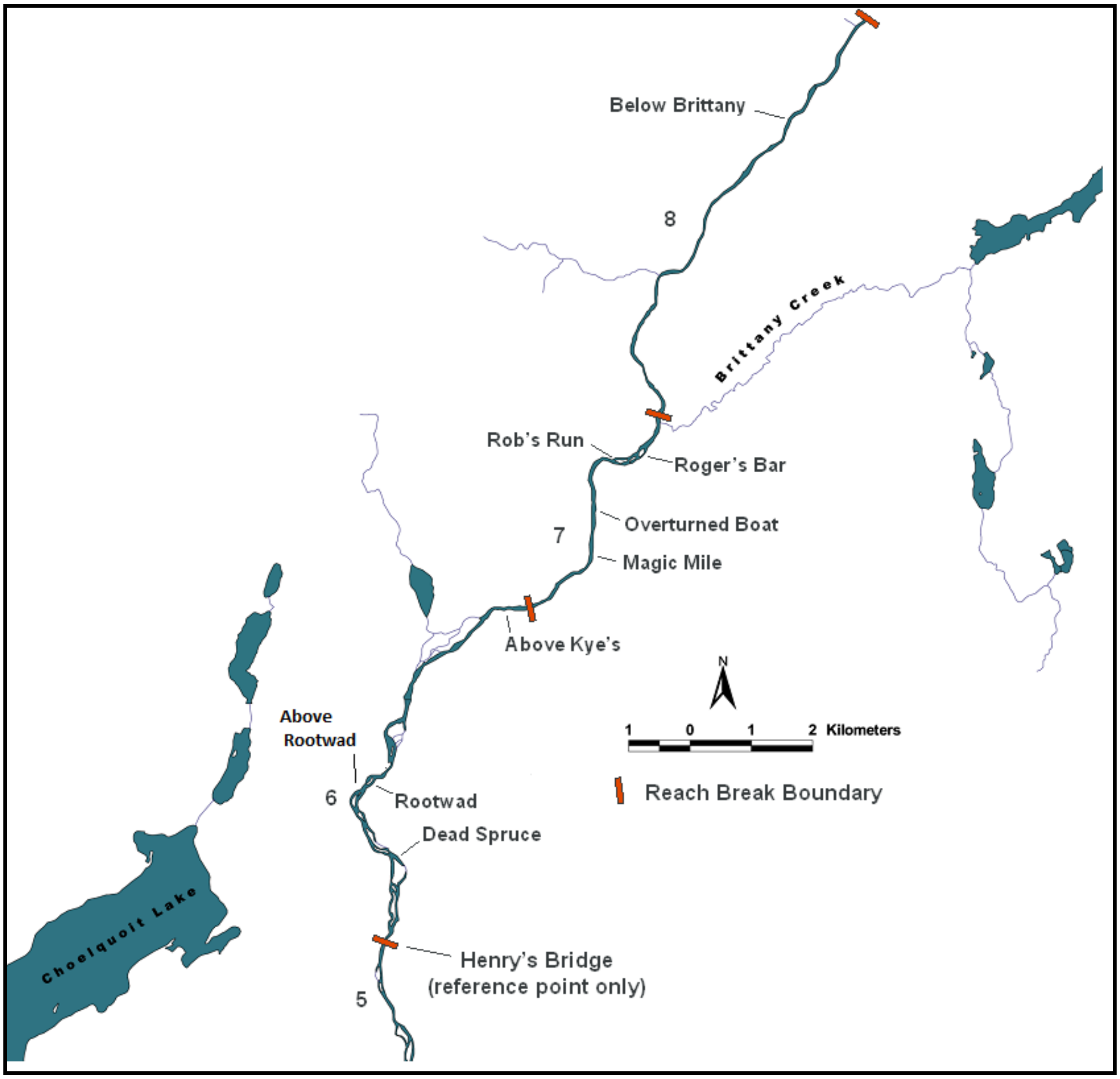

Figure 4. Chilko River Chinook Salmon angling locations, 2013.

Fish were caught on single barbless hooks of sizes 3/0 or 4/0 that were baited with roe (salmon eggs) treated with Pro-Cure and borax, and fish were also caught on spinners and spoons equipped with equal sized hooks. Chinook Salmon were landed into a dip net, processed (marked) immediately in an onboard marking tray with flowing water or portable marking tray placed in the water, and held for up to 15 min in 1.25 m x 0.3 m diameter vinyl flow-through holding tubes that were anchored instream in a manner that permitted suitable water flow before being released back into the river. Hooking location and amount of bleeding from the hook wound were recorded. The relative amount of bleeding from the area of the hook wound was recorded as none, slight, moderate, or heavy. The location where the fish was hooked was recorded and later categorized as either critical (roof of mouth, gills, tongue, or eye) or non-critical (all other locations).

For seining, an 80 m long X 100 meshes deep seine net constructed with 9 cm mesh was set by jet boat in a downstream crescent using a long upstream lead line and drawn from the river to enclose a portion of water along the riverbank. Once the seine and lead line (~50 m) were set in an arc they were withdrawn from the river until it enclosed a small area of water along the shore to allow quick capture of the fish for mark application. The upstream lead line was retrieved using a hydraulic winch and the downstream line was retrieved manually. Captured salmon were held in the net in relatively deep water until mark application (Farwell *et al*. 1999).

During mark application, fish were placed in the canvas cradle of the marking tray. The portable marking tray was placed in flowing water and an onboard tray was also used. Onboard trays were mounted in vessels and were supplied with flowing water, pumped from the river during marking operations. Two Peterson tags, 2.2 cm diameter clear cellulose acetate disks, were applied to the captured Chinook Salmon (Farwell *et al*. 1999). One Petersen disk tag was uniquely coded with a five or six digit number and the other was a blank transparent disk. These tags were placed on the fish using a 7.7 cm steel pin inserted through the dorsal musculature and pterygiophore bones approximately 1.5 cm below the insertion of the dorsal fin with the disk arranged one on each side of the fish, and the buffer disk on the pin head side. Petersen disk tags were held tightly against the fish by twisting the pin into a knot. Sex specific operculum punches 0.6 cm in diameter (used as secondary marks), were applied on the left operculum for seined fish and the right for angled fish: two punches for a female and one for a male. Each fish's mark number, fork length (FL, ± 0.1 cm), sex (female (F), large male >50 cm FL (M) and small male <50 cm FL (J)), adipose fin clip status (adipose fin present or absent), scarring, type of secondary mark, and release condition (1: swam away rapidly; 2: swam away slowly; 3: required ventilation; or 4: died) were recorded. The date, person tagging, tagging location and time were also recorded. After tagging and data collection, seine captured fish were released over the net. During mark application, any previously marked Chinook Salmon and all other fish species captured were recorded and released (Farwell *et al*. 1999).

Carcass Recovery

Carcass sampling began on 4 September 2013 and continued until 6 October 2013. Recovery effort occurred in reaches 1 to 8 on a two day cycle with each reach surveyed 16 times. Recovery crews of five to seven people recovered carcasses from river shores and pools in a downstream direction using a combination of gaffing from boats and walking side channels and the shoreline.

The spawning ground surveys and carcass recovery methods were similar to those used at the Harrison River (Farwell *et al*. 1999). During recovery, Chinook Salmon carcasses were removed from the river using peughs or gaffs and were placed on the riverbank for subsequent examination. Complete sample information was collected from marked fish; adipose-absent fish; the 1st unmarked large male or female in every reach; every subsequent 4th unmarked large male or female fish; and all unmarked small males (less than 50 cm FL) encountered. Complete sample information consisted of the sampling date, recovery crew members, reach number, sex (female (F), large male >50 cm FL (M) and small male <50 cm FL (J)), Petersen disk tag presence and number, post-orbital to hypural plate (POH) length (± 0.1 cm), secondary mark status, female percent spawn (0% when a pre-spawning mortality, 50% when partially spent, or 100% when virtually no eggs remaining), carcass condition (1: fresh when gills red or mottled; 2: moderately fresh when gills white but flesh still firm; 3: moderately rotten when body intact but soft; or 4: rotten when only skin and bones remaining), adipose fin clip status (present or absent), adipose fin clip condition (categorized as 1: complete clip with clip flush with dorsal surface; 2: incomplete clip with a nub of adipose tissue present; and 3: questionable clip that appears to be clipped but fungus or decomposition has obscured the area), number of eyes, and recovery method (shore/beach or pool/gaff) were recorded for each carcass recovered. Scales were collected from every sampled fish and 5 scales from each side of the carcass were placed into scale books. Scale samples were read at the Pacific Biological Station Sclerochronolgy lab in Nanaimo, B.C. Ages were recorded using the Gilbert-Rich and European coding systems. All carcasses examined for the presence of tags were cut in half using a machete to prevent re-counting.

ANALYTICAL PROCEDURES

Sex Identification Correction

Sex identification errors occurred at mark application because sexually dimorphic traits were not fully developed at the time of marking and internal examinations were not possible until carcasses were examined during recovery. For the purposes of estimating sex specific population sizes, the mark application data was corrected for sex identification error using the method described by Staley (1990).

Tests for Sampling Selectivity

All samples were pooled by sex (large male (M), female (F) and small male (J)) before testing. Sampling biases were only evaluated for large males and females because the small male sample size was too small.

Marking Stress

Mark application stress was assessed in a number of ways: by comparing the apparent spawning success for the marked and unmarked females in the carcass recovery sample; by comparing the rates of mark recovery from fifteen minute hold time increments; by comparing the rates of mark recovery from release condition categories; by comparing the rates of mark recovery by bleed code; by comparing the rates of mark recovery by hook location; and by comparing the recovery rates of fish that were captured once to those captured two or more times. As tags were only applied by angling in the lower spatial strata and seining in the upper, the test of recovery rate by application method cannot be differentiated from the spatial test. All of the above mentioned tests were performed using chi-square tests.

Period

Temporal bias was assessed in both the application and recovery samples, using chi-square tests. Application sample bias was examined by comparing the mark incidence among recovery periods. Recovery sample bias was examined by comparing the mark recovery rate among application periods (Sokal and Rohlf 1981).

Location

Spatial bias was assessed in both the application and recovery samples, using chi-square tests. Application bias was assessed by comparing the differences in mark incidence among spatial recovery strata. Recovery bias was assessed by comparing the proportion of marks recovered among the spatial application strata.

Size

Size related bias was assessed in both the application and recovery samples using SPSS to run Mann-Whitney and two-sample Kolmogorov-Smirnov tests. Application bias was assessed by comparing POH length frequency distributions in marked and unmarked fish in the recovery sample. Recovery bias was assessed by comparing fork length frequency distributions in the recovered and not recovered portions of the tag application sample.

Sex

Sex related bias was assessed in both application and recovery samples, using chi-square tests. Application bias was assessed by stratifying by sex and comparing the differences in mark incidence in the recovery sample. Recovery bias was assessed by comparing the rate of marks recovered by sex in the application sample. In addition, sex specific differences in tag loss were assessed.

Age

Application bias was assessed by comparing the age composition in the marked and unmarked scale samples taken during recovery using SPSS to run Pearson chi-square tests. In addition, age composition between large males and females in the recovery sample was compared.

Bias Summary

Bias testing results of the application and recovery samples for large males and females were summarized into one table to inform a decision on the appropriate method to be used to calculate the mark-recapture estimation of escapement.

MARK-RECAPTURE ESTIMATION OF ESCAPEMENT

The mark-recapture study design was planned around three estimation pools (large males, females, and small males) because other Fraser River Chinook Salmon escapement programs repeatedly find significant sampling selectivity among these pools; age-specific maturation patterns differ between males and females; and in order to facilitate comparison with past or similar studies.

Petersen Estimator

If no biases were detected, then the Chinook Salmon population within the Chilko River study area can be estimated using Chapman's modification of the Petersen estimator (Ricker 1975).

Darroch Estimator

Stratified Petersen Analysis System (SPAS) is a statistical software package developed by Arnason *et al*. (1996). The SPAS program uses a "complete mixing" test, to determine whether all animals have an equal probability of recovery across all strata, and an "equal proportions" test, to determine whether the ratio of marked to unmarked animals is equal across all strata. Passing either of these tests ($p>0.05$) is sufficient for the validity of full pooling; thus it is appropriate to use the pooled Petersen method. Otherwise the Darroch/Plante maximum likelihood (ML) method should be used to produce the most accurate population estimate (Arnason *et al*. 1996).

Schwarz (2013) recently developed SPAS (SPAS-2) in R, which allows for a richer set of models to be fit and allows for model comparison of different pooling strategies using AIC. The data were entered into SPAS and SPAS-2 according to the directions in Arnason *et al*. (1996) and Schwarz (2013). The mark-recapture data was stratified by pooling animals that exhibited approximately homogeneous capture and migration encounters. Based on bias test results, various models including the Petersen were fit to the data in SPAS-2 and the escapement estimate generated from the best fit model was selected for reporting. Historically, we have found requirements for sex-specific models with spatial and temporal stratifications. As SPAS-2 is still under development, the software was not able to generate standard errors (se) for some population estimates; therefore, the se from SPAS was used in the absence of a SPAS-2 se.

Small Male Estimator

If the small male sample size was statistically too small to provide a reliable Petersen estimate then the estimate was produced using ½ the recovery rate of large males to expand the number of small males recovered.

$$\text{Small Male Escapement} = \frac{\text{Total Small Male Recoveries}}{0.5 * (\text{Total Large Male Recoveries}/\text{Large Male Escapement})}$$

Escapement by Age

Escapement by age was determined by applying the estimated age composition of the recovery sample to the escapement estimate. As sex specific escapement estimates were calculated, age data were also pooled by large male, female and small male.

VISUAL SURVEY STUDY & SURVEY LIFE

Aerial Count Procedures

Aerial counts were performed at low levels (50-80 m above the ground) using a Bell 206B helicopter, flown at slow speeds (10-40 km hr^{-1}). The helicopter flew in a downstream direction to minimize scattering of spawners and glare. Fish counting was carried out by two experienced observers each wearing polarized glasses and seated on the opposite side of the helicopter from the pilot. The helicopter was flown slowly in a “crab” style to provide observers with the best view of the fish. Observers used tally counters for their individual counts of Chinook Salmon. Fish were recorded as spawners, holders, or carcasses by stratum. Spawners were observed in the shallow water and clearly associated spawning habitat, whereas holders were observed in pools or migrating through areas not associated with spawning habitat. Where carcasses had been cut in two by the recovery crew, only posterior sections including tails were counted carcasses. At lower densities, fish were counted individually. However, as the density increased, fish were counted or estimated in groups of five or 10.

For each stratum, observers discussed the groups of fish that were being counted and noted when a fish or group was counted by only one observer. At the end of each stratum count, the observers recorded their individual tallies, discussed their observations, and determined the best count for the stratum. Frequently, but not exclusively, the best count was the higher count of the two observations because it is assumed that the observer with the highest count observed the most fish (typically front seat). This methodology is used at many locations throughout the Fraser River watershed (Faulkner and Ennevor 1995; Bailey *et al*. 2000; Parken *et al*. 2003; Trouton 2004).

Peak Count Estimator

The Peak Count (PC) method is used to determine the annual escapement estimate based on the aerial surveys. The PC estimate of escapement is generated by multiplying the maximum total daily count of spawners, holders and carcasses by the species- and area-specific expansion factor to account for fish not observed (McPherson *et al*. 1999). The maximum total daily count usually occurs closest to the peak of spawning (comparatively few holding fish or carcasses; most of the fish actively spawning). Visual surveys were conducted throughout the spawning period with two or three surveys scheduled as close to the predicted time of peak spawning as possible (Parken *et al*. 2003). The survey with the maximum daily count of spawners, holders and carcasses was then multiplied by 1.5385 to generate an estimate of the escapement. The expansion factor of 1.5385 used for Fraser River Chinook Salmon estimation, assumes that observers count 65% of the true population when that count occurs at or very close to the peak of spawning (Dickson in Farwell *et al*. 1999).

Survey Life

A survey life was determined by determining the total number of spawner days based on the aerial survey data and dividing that number by the total population based on the mark-recapture estimate.

RESULTS

MARK-RECAPTURE

Fish Capture and Mark Application

Seven hundred and sixty five (765) Chinook Salmon were captured for mark application between 8 August and 27 August 2013 (Appendix 1). Of those, 507 were captured by seine net and 258 by angling. Tags were applied to 344 large male, 394 female and 21 small male Chinook Salmon. There were seven mortalities observed during the angling portion of application (3 large male and 4 female). The angling mortalities resulted in an estimated instantaneous mortality rate for angling of <3%. Heavy bleeding from hooking injuries was observed on two fish, moderate bleeding was observed on 8 fish and slight bleeding was observed on 69 fish. One marked large male (mark number: 95722) was recovered in the First Nation fishery and removed from the application data set. Two large male heavy bleeders (mark numbers: 95708 and 102562 (died in the brood tube)) were also removed from the application data set prior to analysis. Subsequent values are reported with these 3 marked large male removals.

Mark application was conducted in four of the eight reaches (Figure 1). Over half of the marks (67%) were applied by seining in reach 4 at the Lingfield Creek seine site. The remaining tags were applied by angling in reaches 6, 7 and 8. Of the 249 marks applied by angling 102 (41%) were applied at the Root Wad application site. The application site Roger's Bar resulted in 95 (38%) marks applied. The final 52 (21%) marks were applied at the Above Kye's, Rob's Run, Overturned Boat, Dead Spruce, Above Root Wad, Below Brittany, and Magic Mile application sites. Peak angling application in the lower river was 23 Chinook Salmon on 10 August 2013. Peak seining application in the upper river was 256 Chinook Salmon 27 August 2013.

Within the mark application sample, females averaged 78.5. cm FL (range 55.2 to 93.9 cm; Figure 5) while large males averaged 73.2 cm FL (range 50.4 to 103.1 cm; Figure 6) and small males averaged 44.6 cm FL (range 36.6 to 49.2 cm; Figure 6; Appendix 1).

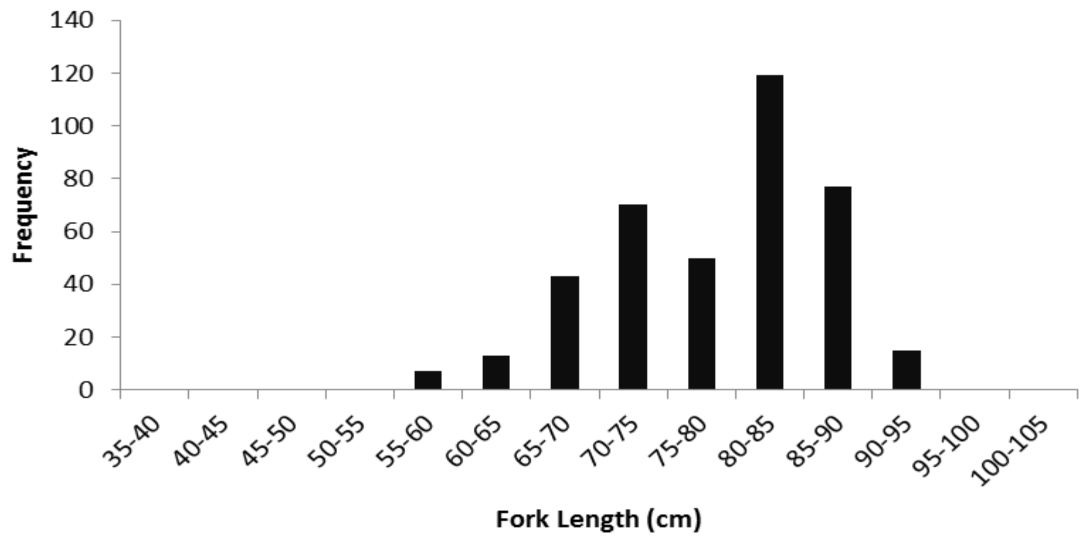

Figure 5. The fork length distribution of female Chinook Salmon captured during mark application at Chilko River 2013.

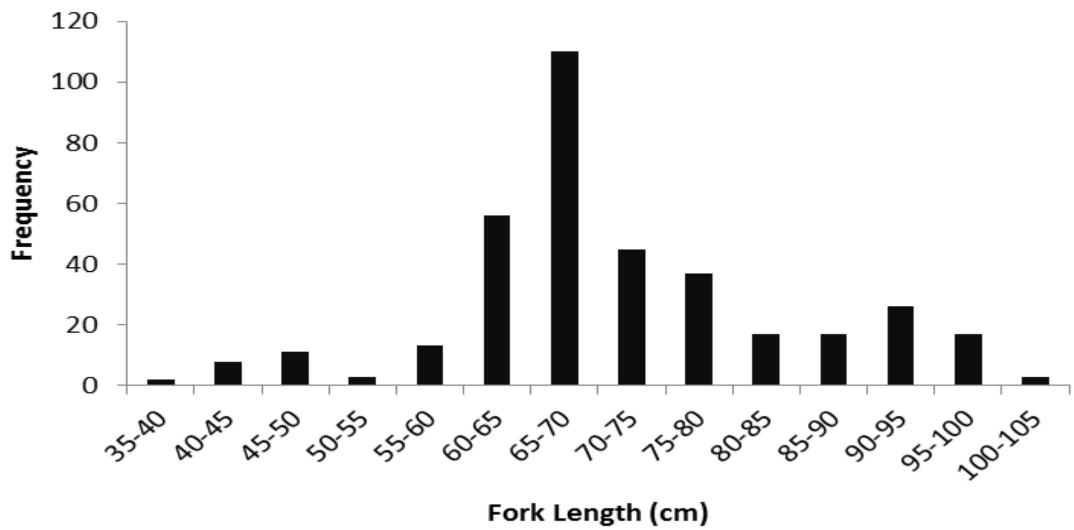

Figure 6. The fork length distribution of male Chinook Salmon captured during mark application at Chilko River 2013.

Carcass Recovery

A total of 2156 carcasses were examined between 4 September 2013 and 6 October 2013 (Appendices 2 & 3). Of this sample, 2138 were of known sex and used in the mark-recapture data analysis. Within this recovery sample, 394 Chinook Salmon carcasses were marked and 1744 were unmarked (Table 2). Within the marked group, there were 171 large males, 220 females and 3 small males (Appendix 1). The mean elapsed time (days out) between mark application and the subsequent mark recovery was 33 days (Appendix 1).

Table 2. Summary of carcass recovery for Chinook Salmon in the Chilko River, 2013.

Sex	Total Carcasses	Primary Mark	Secondary Mark Only	Marked Total
Large Male	1000	170	1	171
Female	1093	217	3	220
Small Male	45	3	0	3
Unknown	18	3	1	4
Total	2156	393	5	398

Reach 4 had the most carcasses recovered (35%) while reach 1 and 2 had the fewest (0%). Peak recovery occurred on the recovery cycle from 22 September to 23 September. Of the 2138 sexed carcasses examined, 49% were males and 51% were females.

Within the recovery sample, females averaged 65.7 POHL (range 43.8 to 79.0; Figure 7 and Appendix 3) while large males averaged 61.6 cm POHL (range 47.0 to 82.1 cm; Figure 8) and small males averaged 36.7 cm POHL (range 29.2 to 44.1 cm; Figure 8).

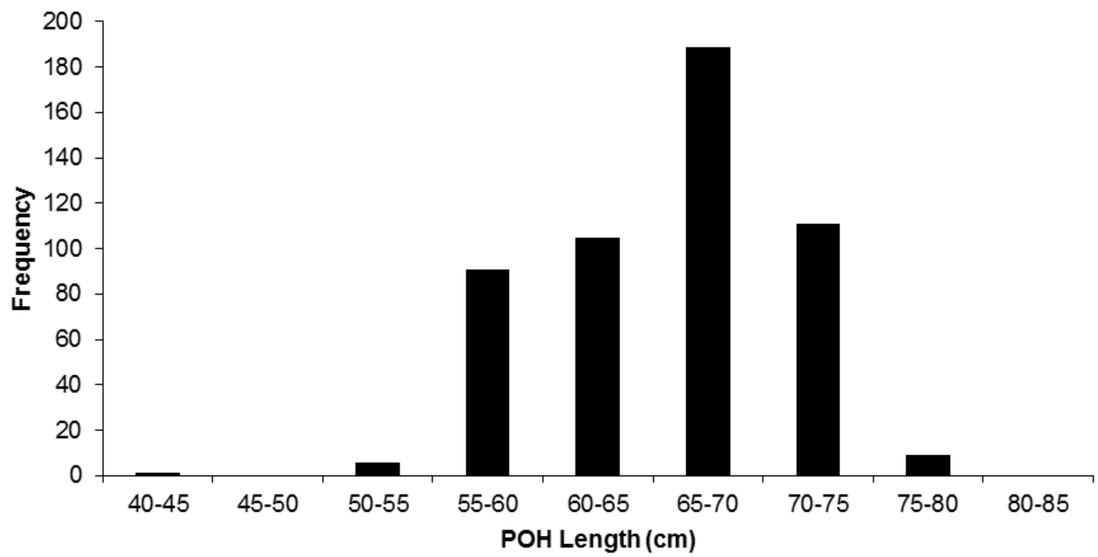

Figure 7. The post-orbital to hypural plate (POH) length distribution of female Chinook Salmon sampled during carcass recovery at Chilko River 2013.

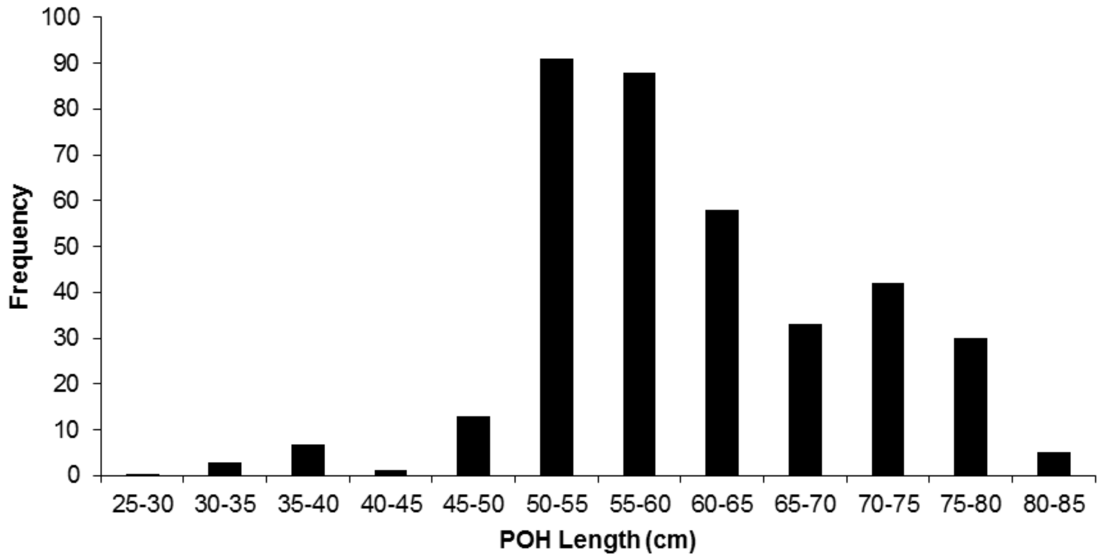

Figure 8. The post-orbital to hypural plate (POH) length distribution of male Chinook Salmon sampled during carcass recovery at Chilko River 2013.

At carcass recovery, the sub-sample of scale ages showed this population has predominantly stream-type life history, and the vast majority of the scales had one freshwater annulus, with total ages of three to six years (Appendix 3). The Chinook were primarily age 1.2. Table 3 shows the age composition by sex of the scale sub-sample with complete ages. There were seven samples that showed no freshwater annulus and one sample with 2 freshwater annuli. These samples were not included below as scale age re-reading has been requested and the results are pending.

Table 3. Scale age sample size and proportions for Chilko River Chinook Salmon from 2013, collected during carcass recovery.

Age		Large Male		Female		Small Male	
European	Gilbert Rich	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent
1.1	3_2	32	9.7%	5	0.7%	39	93.1%
1.2	4_2	217	65.2%	234	51.8%	3	6.9%
1.3	5_2	71	24.5%	215	46.1%	0	0%
1.4	6_2	1	0.5%	6	1.4%	0	0%

ANALYTICAL

Sex Identification Correction

Of the 756 marked Chinook Salmon in the application sample, 341 were identified as large male, 394 as female, and 21 were identified as small male at the time of release (Table 4). There were 19 sex identification errors among recovered marked fish: four fish identified as large males at mark application were actually females and 15 females were actually large males (Appendix 1). After application of the sex identification correction, the corrected mark releases were 367 (50%) large males and 368 (50%) females.

Table 4. Marks applied by sex, including Staley's sex correction factors and sex corrected totals, to Chilko River Chinook Salmon, 2013.

	Mark Application		
Sex	Total	Sex Correction Factor[a]	Sex Corrected
Large Males	341	+0.035	367
Females	394	-0.035	368
Small Males	21	0	21

a. Staley's sex correction factor. Adjust application totals by adding or subtracting the male or female factors for each of the total male and female marks applied.

Sampling Selectivity

Small males, less than 50 cm FL, identified as jacks in the field were not analyzed due to inadequate sample sizes.

Marking Stress

There was no evidence of a difference in spawning success between marked and unmarked female recovery samples (p=0.20; Table 5; Appendix 2).

Table 5. Spawning success rates of marked and unmarked female Chinook Salmon for Chilko River 2013.

	Unsuccessful	Successful	Percent Successful
Marked	6	208	97.2%
Unmarked	12	851	98.6%

There was no evidence detected for stress related to the length of time large male or female Chinook Salmon were held until marking (p=0.24 and p=0.08, respectively; Table 6; Appendix 1).

Table 6. Proportion of marks recovered by sex and hold time strata during seining mark application of Chilko River Chinook Salmon, 2013.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
0-15 Minutes	26	34	0	60	51	52	1	104	51%	65%	0%	58%
16-30 Minutes	33	32	1	66	54	53	2	109	61%	60%	50%	61%
31-45 Minutes	23	34	0	57	52	43	2	97	44%	80%	0%	59%
46-60 Minutes	16	26	1	43	35	34	3	72	45%	77%	33%	60%
61+ Minutes	26	46	1	73	62	58	5	125	42%	80%	20%	58%
Total	124	172	3	299	254	240	13	507	49%	72%	23%	59%

a. Corrected for sex identification error.

Of the 756 fish marked, the majority 754 (99.7%) swam away rapidly (release condition 1) and two (0.3%) swam away slowly (release condition 2; Appendix 1). The sample size of Chinook that swam away slowly was too small to use chi-square tests. Even if a bias did exist within that group, the small sample size would make any possible effects to the estimate negligible.

There was no evidence of difference detected for stress related to bleeding for female or large male Chinook Salmon (p=0.84 and p=0.06; Table 7; Appendix 1).

Table 7. Proportion of marks recovered by bleeding condition strata during angling mark application of Chilko River Chinook Salmon, 2013.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Bleeding	11	13	0	24	43	34	0	77	26%	38%	-	31%
No Bleeding	35	32	0	67	70	94	8	172	50%	34%	0%	39%
Total	46	45	0	91	112	129	8	249	41%	35%	0%	37%

a. Corrected for sex identification error.

Of the 249 fish marked during angling, 29 were hooked in a critical location, 193 in a non-critical location and 27 in an unknown location. There was no evidence of difference detected for stress related to hook location for large male or female Chinook Salmon (p=0.99 and p=0.41, respectively; Table 8; Appendix 1).

Table 8. Proportion of marks recovered by sex and hook location strata during angling mark application of Chilko River Chinook Salmon, 2013.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Critical	6	3	0	9	16	13	0	29	37%	23%	-	31%
Non-Critical	37	39	0	76	90	99	4	193	41%	39%	0%	39%
Total	43	42	0	85	106	112	4	222	41%	37%	0%	38%

a. Corrected for sex identification error.

Following release, 69 previously marked large male and female Chinook Salmon were recaptured during subsequent mark application periods (Table 9; Appendix 1). Four of these were recaptured twice during the application period. There was no evidence of a difference in marked recovery rate between recaptured and non-recaptured fish for large males or females respectively (*p*=0.36 *and p*=0.17; chi-square test).

Table 9. Effect of recapture on recoverability by sex for Chilko River Chinook Salmon, 2013.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Times Recap'd	M	F	J	Total	M	F	J	Total	M	F	J	Total
0x	158	198	3	359	344	324	19	687	46%	61%	16%	52%
1-2x	13	22	0	35	22	45	2	69	58%	49%	0%	51%
Total	171	220	3	394	367	368	21	756	47%	60%	14%	52%

a. Corrected for sex identification error.

Of the 756 fish marked, 507 were captured by seine net and 249 were captured by angling. The test to determine differences between the marked recovery rates of capture methods (angling versus seining) was the same as the spatial recovery test.

Period

Temporal bias in the application sample was examined by comparing mark incidences among two recovery periods. When the period was stratified to contain approximately equal recovery periods, the first stratum contained 18 days and the second stratum contained 15 days. The mean mark incidence was 17% (range 15% to 20%) for large males and 20% (range 16% to 27%) for females (Table 10). There was no evidence of a difference in mark incidence throughout time for large males (*p*=0.06). There was evidence of a difference in mark incidence throughout time for females (*p*<0.01).

Table 10. Incidence of primary or secondary marks in Chilko River Chinook Salmon, by recovery period and sex, 2013.

	Marked Recoveries				Total Recoveries				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
04-Sep	77	107	2	186	384	396	14	794	20%	27%	14%	23%
22-Sep	94	113	1	208	616	694	31	1,344	15%	16%	3%	15%
Total	171	220	3	394	1,000	1,093	45	2,138	17%	20%	7%	18%

Temporal bias in the recovery sample was examined by comparing recovery rates among two application periods. When the period was stratified to contain approximately equal application periods, each stratum contained 10 days. The mean percentage recovered was 46% for large males and 59% for females (Table 11). There was no evidence of a difference in recovery rate throughout time for large males (p=0.72). There was evidence of a difference in recovery rate throughout time for females (p<0.01). The recovery rate in the late period was higher than the early period for females.

Table 11. Primary marks applied and recovered in Chilko River Chinook Salmon, by application period and sex, 2013.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
08-Aug	62	73	1	136	129	162	8	299	48%	45%	13%	45%
18-Aug	108	144	2	254	237	207	13	457	45%	70%	15%	56%
Total	170	217	3	390	367	368	21	756	46%	59%	14%	52%

a. Corrected for sex identification error.

Location

Spatial bias in the application sample was examined by comparing mark incidences among reaches two to eight, as no carcasses were recovered in reach one. Reaches were pooled into two strata: the upper stratum consisted of reaches two through five and the lower stratum consisted of reaches six, seven and eight. The mark incidence in the lower stratum was 18% for large males and 16% for females (Table 12). The mark incidence in the upper stratum was 16% for large males and 22% for females. There was no evidence of a difference between mark incidence in the upper and lower spatial recovery strata for large males (p=0.53). There was evidence of a difference between mark incidence in the upper and lower spatial recovery strata for females (p=0.02).

Table 12. Incidence of primary or secondary marks in Chilko River Chinook Salmon, by recovery strata and sex, 2013.

	Marked Recoveries				Total Recoveries				Mark incidence			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Lower	82	53	2	137	455	336	26	817	18%	16%	8%	17%
Upper	89	167	1	257	545	757	19	1321	16%	22%	5%	19%
Total	171	220	3	394	1000	1093	45	2138	17%	20%	7%	18%

Spatial bias in the recovery sample was examined by comparing the recovery rate between different spatial application strata. All marks were applied by seining in the upper reaches and angling in the lower reaches. Due to this application procedure, the spatial application strata cannot be separated from application method (angling and seining). There was no evidence of a difference in the percentage of marked fish that were recovered between application method strata for large males (p=0.20). There was strong evidence that seined females were recovered at a higher rate than those angled (p<0.01; Table 13).

Table 13. Primary marks applied and recovered in Chilko River Chinook Salmon, by application method and sex, 2013.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Angling	46	45	0	91	112	129	8	249	41%	35%	-	37%
Seining	124	172	3	299	254	240	13	507	49%	72%	23%	59%
Total	170	217	3	390	367	368	21	756	46%	59%	14%	52%

a. Corrected for sex identification error.

Size

Size-related bias in the application sample was examined by comparing the POH length-frequency distributions in the measured sample of marked and unmarked carcasses in the recovery sample. There was no evidence of a difference in POH length between marked and unmarked recoveries for large males (Mann-Whitney U=14339; p=0.07; Kolmogorov-Smirnov Z=1.15; p=0.14). There was no evidence of a difference in POH length between marked and unmarked recoveries for females (Mann-Whitney U=31079; p=0.50; Kolmogorov-Smirnov Z=0.69; p=0.73).

Size related bias in the recovery sample was examined by comparing the male and female fork length frequency distributions of recovered and not recovered fish marked at application. There was evidence of a difference in fork length between recovered and not recovered samples for large males (Mann-Whitney U=10865; p<0.01; Kolmogorov-Smirnov Z=2.16; p<0.01). There was weak evidence of a difference in fork length between recovered and not recovered samples for females (Mann-Whitney U=16680; p=0.05; Kolmogorov-Smirnov Z=1.24; p=0.09).

Sex

Sex bias in application was assessed by comparing mark incidence between large males and females in the recovery sample. Mark incidence was 17% for large males and 20% for females (Table 14). There was no evidence of a difference between male and female mark incidence (p<0.09); therefore, there was no sex bias at application.

Table 14. Percent recovery and mark incidence of secondary only and primary marks recovered by sex for the 2013 Chilko River Chinook Salmon mark-recapture project.

Sex	Marks Applied[a]	Secondary Marked Recoveries[b]	Total Marked Recoveries[c]	Total Recoveries	Percent Recovery	Mark Incidence
Large Male	367	1	171	1000	46%	17%
Female	368	3	220	1093	60%	20%
Small Male	21	0	3	45	14%	7%
Total	756	4	394	2138	52%	18%

a. Corrected for sex identification error.
b. Carcasses recovered with secondary mark only.
c. Total marked recoveries (primary and secondary only).

Sex bias in recovery was assessed by comparing percent recovery between large males and females in the application sample. There was strong evidence of a sex bias in the recovery sample (p<0.01), the percent recovery of large males was 46% and of females was 59% (Table 14).

Primary mark loss was <1% for large males and 1% for females, these estimates were not materially different.

Age

Age bias on application was assessed by comparing the age composition of the marked and unmarked recovery sample. Due to small sample sizes, age 3_2 and 6_2 were removed for female analysis and 6_2 were removed for large male analysis. There was no evidence of a difference in age composition between marked and unmarked samples for large males or females (p=0.25 and p=0.45). Table 15 shows the age composition by sex for scale samples with complete ages that were collected during the recovery sample.

Age composition between large males and females in the recovery sample was compared. Due to small sample sizes, age 3_2 and 6_2 were removed. There was evidence of a difference in age composition between the large males and females (p<0.01). Large males were composed of a lower proportion of age 5_2 than 4_2.

Table 15. Comparison of age samples taken from marked and unmarked large male and female Chinook Salmon during recovery in the Chilko River, 2013.

		Large Male		Female	
	Age	Sample Size	Percent[a]	Sample Size	Percent[a]
Marked	3_2	16	10%	4	2%
	4_2	110	71%	93	48%
	5_2	28	18%	93	48%
	6_2	0	0%	2	1%
Unmarked	3_2	16	10%	1	0%
	4_2	107	64%	141	53%
	5_2	43	26%	122	46%
	6_2	1	1%	4	1%

a. Percentages do not sum to 100% due to rounding errors.

Bias Summary

Bias testing results of the application and recovery samples for large males and females are summarized in Table 16.

Table 16. Results of statistical tests for bias in the 2013 Chilko River Chinook Salmon escapement estimation study.

Bias type	Application sample [a]	Recovery sample [a]
Stress	n/a	No bias
Period	Female bias	Female bias
Location	Female bias	Female bias
Fish size	No bias	Large male bias, Weak female bias
Fish sex	No bias	Higher recovery rate for females
Fish age	n/a	Large male/female age bias

a. No bias indicates that bias was not detected; undetected bias may be present.

MARK-RECAPTURE ESTIMATE OF ESCAPEMENT

The mark-recapture study design was planned around three estimation pools (large males, females, and small males) because other Fraser River Chinook Salmon escapement programs repeatedly find significant sampling selectivity among these pools.

Large Males: Petersen Estimate

Due to no evidence of temporal or spatial bias within the large male application or recovery data, a pooled Petersen estimator was used to calculate escapement. As SPAS results showed evidence of complete mixing and equal proportions between temporal strata for males (p=0.16 and 0.25), the Petersen estimator was used. The

2013 large male spawning escapement of Chilko River Chinook Salmon was estimated to be 2138 ± 212 (Table 17).

Table 17. Large male escapement estimate derived from 2013 mark-recovery data using a Petersen estimator for Chilko River Chinook Salmon.

	Large Males
Carcasses Sampled	1,000
Marks Applied [a]	367
Marks Recovered	171
Total Percent Recovered	47%
Population Size	2,138
Coefficient of Variation	5%
Lower 95% Confidence Limit	1,926
Upper 95% Confidence Limit	2,350

a. Corrected for sex identification error.

Females: Darroch Estimate

There was spatial and temporal bias at recovery and application for females. The recovery data were stratified into early and late recovery periods based on equal recovery periods. The early period for recovery data was 4 September 2013 to 21 September 2013 and the late period was 22 September 2013 to 6 October 2013. For spatial stratification the recovery data was divided into upper and lower segments of the river. The application data were stratified into early and late periods based on equal application periods. For temporal stratification at application, the early period was 8 August 2013 to 17 August 2013 and the late period was from 18 August 2013 to 27 August 2013. For spatial stratification the application data was stratified into marks applied in the upper river at the seine site and marks applied in the lower river by angling.

SPAS-2 ranked the temporal application and spatial recovery (2x2) ML Darroch model the highest, 90% of the weight relative to the other 4 models; however, se's were not generated. The SPAS results showed strong evidence of incomplete mixing and unequal proportions between temporal strata for females ($p<0.01$, $p=0.02$). These results further support the use of the ML Darroch estimator for females instead of the Petersen estimator. The 2013 female spawning escapement of Chilko River Chinook Salmon was estimated to be 2,062 ± 343 using the ML Darroch estimator in SPAS (Table 18).

Table 18. Female escapement estimate derived from 2013 mark-recovery data using the ML Darroch estimator for Chilko River Chinook Salmon.

	Females
Carcasses Sampled	1093
Marks Applied [a]	394
Marks Recovered	220
Total Percent Recovered	52%
Population Size	2,062
Coefficient of Variation	8%
Lower 95% Confidence Limit	1,719
Upper 95% Confidence Limit	2,404

a. Corrected for sex identification error.

Small Males: Recovery Rate Expansion

There was insufficient data to generate an estimate of small male escapement using a mark-recapture method, as only three marked small males were recovered from a total of 21 marks applied. Forty-five small male carcasses were recovered (Table 19). The 2013 small male spawning escapement of Chilko River Chinook Salmon was estimated to be 192 using the large male recovery rate expansion.

Table 19. The small male escapement estimate derived from 2013 mark-recovery data using the large male recovery rate expansion.

	Small Males
Total Large Male Carcasses Sampled	1000
Large Male Escapement Estimate	2138
Large Male Recovery Rate	46.8%
Small Male Recovery Rate (1/2 Large Male Rate)	23.4%
Total Small Male Carcasses Sampled	45
Population Size	192

Combined Total

The 2013 total large male and female spawning escapement of Chinook Salmon to Chilko River was 4,200 ± 431 (Table 20).

Table 20. The total large male and female escapement estimate derived from 2013 Chilko River Chinook Salmon mark-recovery data using the Petersen estimator for large males and the ML Darroch estimator for females.

	Total
Carcasses Sampled	2,093
Marks Applied [a]	735
Marks Recovered	391
Percent Recovered	49%
Population Size	4,200
Coefficient of Variation	5%
Lower 95% Confidence Limit	3,645
Upper 95% Confidence Limit	4,754

a. Corrected for sex identification error.

Escapement by Age

The majority of Chinook Salmon returning to the Chilko River in 2013 were age 1.2 (Table 21). The total Chinook Salmon escapement estimate by age consisted of 401 age 1.1, 2496 age 1.2, 1486 age 1.3 and 40 age 1.4.

Table 21. Escapement estimates by sex and age for 2013 Chilko River Chinook Salmon.

Age		Escapement Estimate[a]			
European	Gilbert Rich	Large Male	Female	Small Male	Total
1.1	3_2	207.8	14.1	178.8	401
1.2	4_2	1,396.9	1,085.8	13.2	2,496
1.3	5_2	522.7	963.5	0	1,486
1.4	6_2	10.6	29.6	0	40

PEAK COUNT ESCAPEMENT ESTIMATE AND SURVEY LIFE

In 2013, three aerial surveys were conducted on September 6, 15, and 21. The highest spawner count (3058) occurred on the 15 September 2013 flight. The peak count of Chinook Salmon was 3371 (3058 spawners, 257 holders and 56 carcasses) also on 15 September 2013. The expanded peak count estimate was 5,186. The survey life was 11.9 days.

DISCUSSION

Properly designed, executed and analyzed mark-recapture studies produce reliable estimates of escapement (Nelson et al. 2000). A high precision mark-recapture estimate can be achieved by applying a large number of marks and by implementing an appropriate recovery effort to recover a large number of those marks (Schwarz *et al*. 1993). During the 2013 Chilko River Chinook Salmon mark-recapture study, large numbers of marks were applied and recovered producing a CV of 5% for the total spawner abundance, and it is likely that the CTC data standard for precision should be attainable in the future. To account for differences in tag incidence, recovery rate, and length distribution between large males, females and small males, the estimation of the spawning population was stratified by sex.

Females were recovered at a higher rate than males, as expected due to the behavioural differences between males and females after spawning. Just before death, spawning males continue to move downstream looking for additional spawning opportunity; therefore, males are more likely to be recovered lower in, or lost completely from, the study area. Females guard their redds while able to maintain position, then move into slower flows close by just before death, subsequently they are more likely to be recovered in close proximity to their spawning location; therefore, females are more likely to be recovered within the study area than males. As females tagged at Lingfield Pool tended to spawn just upstream in the Lingfield Dunes, and they tend to be recovered at a high rate by gaffing at the downstream end of the Lingfield pool, females were recovered at a very high rate in this area compared to males. Males were likely moving downstream in search of more spawning opportunities, and were more likely to get washed out of the study area.

The mark-recovery method will produce an accurate estimate of the actual population size if the capture and tagging process do not significantly influence subsequent fish behaviour (Ricker 1975). The results of the bias testing indicated that measurable sources of stress including holding time, number of times recaptured, hook location, bleeding, and release condition did not have a significant impact on the subsequent behaviour of the marked fish. There was no measurable source of stress between application methods (angling versus seining) for large males. There was a higher recovery rate for females captured by seining than those angled. This difference is discussed in the spatial section as the seining only occurred in the upper portion of the river and the angling only occurred in the lower.

Ricker (1975) stated that an important criterion for producing accurate population estimates from the mark-recovery method is that the mark application and carcass recovery samples should be representative of the population. In 2013, we assessed the representativeness of the sampling process by looking for bias in temporal, spatial, fish size, and sex composition patterns of the application and recovery samples. No biases were detected in the age composition between marked and unmarked recovery samples. No biases were detected in the fish length distribution at application. Biases were detected in the fish length distribution at recovery. No significant spatial biases were detected in the application or recovery for large males. However, a spatial bias in the female application and recovery data was detected. There was a higher rate of recovery in the upper section of the river. As the majority of the spawning occurs in the upper portion of the river at Lingfield Dunes and there is a large pool (Lingfield Pool) immediately downstream that collects many of the carcasses, large numbers of females were recovered at this location. Female carcasses in the lower section of the river may be more likely to drift out of the study area, as there a no large pools for carcasses to collect in.

There was significant temporal and spatial bias detected in the application and recovery sample for females. To minimize these biases in future studies we recommend applying tags sooner to ensure that the early portion of the Chinook migration into the Chilko River is represented. Tags should continue to be applied evenly between the upper and lower portions of the study area.

The application and recovery samples were stratified by period and area, as there was evidence of spatial and temporal bias at application and recovery for females. For males, no temporal or spatial bias was observed. Therefore, we employed the Petersen estimator to generate an escapement estimate of 2,138 large males. For females, SPAS determined incomplete mixing and unequal proportions and SPAS-2 ranked the temporal application and spatial application 2x2 model the highest. Based on these results, we employed the temporally and spatially stratified ML Darroch for females to generate an escapement estimate of 2,062 females. The total only (angling); applying tags throughout time (entire migration) at Lingfield (seining) and ensure that no marks are applied to spawning fish.

Visually derived estimates of spawning escapement throughout the Fraser watershed are generally biased low: Bailey et al. (2000) and Parken et al. (2003) reported negative biases of 5 to 51% during calibration studies in the Nicola watershed. The mark-recapture estimate of large male and female escapement of 4,200 (range 3,645-4,754) was lower than the Peak Count estimate of 5,186. Fish visibility during aerial counts can be influenced by fish behaviour, weather, and the physical conditions at the time of counting such as flow and turbidity (Bevan 1961). Other factors influencing aerial estimates include fish density, the experience of the pilot and observers, flight scheduling and frequency of counts (Bevan 1961; Neilson and Geen 1981).

When we assume that the mark-recapture estimate represents the true population, expansion factors of 1.28, 1.12, 1.11, and 0.81 (2010, 2011, 2012, and 2013 respectively) of the Peak Count were necessary to meet the mark-recovery escapement estimate. Therefore, the mean expansion for Chilko River Chinook Salmon is 1.08 (range 0.81-1.28). The 1995 Nicola River study noted a much larger mean expansion factor (2.04) of the Peak Count aerial estimates over a five year period (Bailey et al. 2000). That large expansion factor was reported from abnormally turbid waters during the 1995 Nicola River enumeration flights and because counts of live fish were not recorded as spawners or holders. Using the mean expansion factor of 4 years, peak count estimates of Nicola River Chinook Salmon spawners ranged from -14% to +21% of the mark recapture estimates (Parken et al. 2003). Even with optimal counting conditions for all aerial surveys in

2010, 2011 and 2012; the Chilko River Chinook Salmon estimate was still slightly lower than the mark-recapture estimate. However, in 2013 the aerial estimate was slightly higher than the mark-recapture. When a large proportion of the Chinook salmon spawn at the peak of spawn and the counting conditions are optimal, observers are likely counting more than the assumed 65% of the population. In this case, an expansion factor of 1.54 is too high and overestimated the population. Continuing to use the 1.54 expansion factor that is currently used to expand raw count data to peak count estimates for Fraser Chinook Salmon is recommended until more calibration information available.

The results of the Chilko Chinook Salmon assessment projects over the last four years indicate that the spawning escapement can be estimated with high precision. This study produced precise (CV) escapement estimates for males (5%) and females (9%), which is consistent with the PSC CTC data standards (CV<15%). Also, a high percentage of male (47%) and female (53%) carcasses were sampled, which indicates there is very good potential to collect sufficient numbers of CWTs on the spawning grounds to represent the ages for large males and females and produce high quality CWT statistics. However, another part of the PSC CTC data standards specifies that the escapement estimates should be asymptotically unbiased, but in this study, sampling biases have been detected in the application and recovery samples. The ML Darroch estimator was used to reduce the influence of the bias, yet further refinement of the study design is needed to produce more representative samples. Also, the abundance of small males that were less than 50 cm could not be estimated with a Petersen mark-recapture test, due to insufficient samples. A recovery rate expansion test was used to determine a small male estimate of 192. A size threshold of 50 cm fork length was based on the results of the Lower Shuswap River mark-recapture program from 2000-2009; however, as more data becomes available from successive studies on the Chilko River the relationship between recovery probabilities and fish length can be evaluated to determine appropriate size stratification. Nonetheless, estimation of the spawning escapement of all ages is a desirable attribute for CWT indicator stock programs. Overall, the results from the four years of the escapement estimation strongly indicate that suitable data can be collected from the Chilko River to support a CWT indicator program, and additional years of study will help refine the study design to improve the quality of escapement estimates.

SUMMARY

1. The Chinook Salmon escapement to the Chilko River in 2013 was estimated by mark-recapture.

2. Marks were applied to 756 Chinook Salmon: 507 of them were captured by seining and 249 by angling. Marks were applied to 341 large male (>50 cm FL) and 394 female Chinook Salmon. Twenty-one marks were applied to small male (<50 cm FL) Chinook Salmon.

3. After correction for sex identification errors, the application sample consisted of 367 males, 368 females, and 21 small males.

4. In the recovery sample, 2,156 Chinook Salmon carcasses were sampled and 2,138 were identified by sex. The recovery sample consisted of 1000 large male, 1093 female, 45 small male carcasses and 18 carcasses of undetermined sex. Within this sample, 171 large male, 220 female and 3 small male carcasses recovered were marked.

5. The large male age composition consisted of 9.7% age 1.1, 65.3% age 1.2, 24.4% age 1.3 and 0.5% age 1.4. The female age composition consisted of 0.7% age 1.1, 51.9% age 1.2, 46.0% age 1.3 and 1.4% age 1.4. The small male age composition consisted of 93.1% age 1.1 and 6.9% age 1.2. The vast majority of the age samples showed the population has stream-type life history, as indicated by a two-year freshwater growth pattern (sub2).

6. Sampling selectivity related to temporal and spatial patterns, as well as fish size and sex, were assessed in both mark and recovery samples. Temporal and spatial biases were detected for females.

7. Based on the radio telemetry from 2010 and aerial survey data from 2010-2013, the mark-recapture assumption of closure was met.

8. There was evidence of temporal and special bias in the application and recovery sample for females. Due to these biases, the Stratified Population Analysis System (SPAS) was used. The results confirmed that due to incomplete mixing and unequal proportions of marked to unmarked females in the strata the maximum likelihood (ML) Darroch estimate would be more appropriate than the Petersen estimate for females. The program SPAS found no evidence of incomplete mixing or an unequal ratio of marked to unmarked males between the strata; therefore, a pooled Petersen estimator was used to calculate male escapement.

9. The 2013 total large male and female spawning escapement of Chinook Salmon to Chilko River was 4,200 with lower and upper 95% confidence limits of 3,645 and 4,754 respectively. The large male escapement (Petersen) was

estimated to be 2,138 ± 212, the female estimate (ML Darroch) was 2,062 ± 343 and the small male escapement (recovery rate expansion) was 192.

10. Aerial surveys of Chinook Salmon spawners, holders, and carcasses were conducted on 6 September 2013, 15 September 2013, and 21 September 2013. The 15 September 2013 flight was the peak count with 3,371 (3,058 spawners, 257 holders and 56 carcasses).

11. The peak count on 15 September 2013 produced an escapement estimate of 5,186 Chinook Salmon using the Fraser River Chinook peak count expansion factor (1.5385). This escapement estimate was 123% of the mark-recapture escapement estimate. The measured peak count expansion factor was 1.26 based on the peak count and mark-recapture estimate.

12. The survey life was 11.9 days (CV=1%) based on the spawner surveys and the mark-recapture estimate.

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APPENDICES

-see separate word document-