Enumeration of Chilko River Chinook Salmon Escapement (Mark-Recapture) 2014

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.

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ABSTRACT

The 2014 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 1617 female and large male Chinook Salmon, captured using a combination of seining and angling. Of these 1617 marks, 650 were recovered. A total of 5063 female and large male carcasses were recovered. There were three small males sampled during carcass recovery and of the two tags applied to small males, none 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 bias in the application or recovery samples for large males or females. There also was no evidence of spatial bias in the application or recovery samples for large males. 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 bias was detected in the recovery sample. Escapement estimate using the ML Darroch for females were generated in SPAS using spatially stratified application and recovery data. The total estimate of escapement for large males and females was 13,246 Chinook Salmon (lower 95% CI=11,969; upper 95% CI=14,523). Sex-specific escapement estimates were 7,130 large males (Petersen, lower 95% CI=6,436; upper 95% CI=7,825) and 6,116 females (Darroch, lower 95% CI=5,534; upper 95% CI=6,699). The estimated escapement based on aerial counts and the Fraser River Chinook peak count expansion factor was 11,283; approximately 15% less than the mark-recapture estimate. Additional paired estimates are required to develop a more stable calibration factor for the aerial survey program. The small sample size of marked recoveries of small males precluded the use of a Peterson mark-recapture estimate. The small male estimate was 20 based on an expansion of small male carcasses recovered by one half the recovery rate of the large males. The age composition of the male recovery sample was 0% age 3, 52% age 4, 46% age 5, and 1% age 6. The female recovery sample was 0% age 3, 34% age 4, 66% age 5, and 1% age 6. All 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). 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 2014, 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 annually from 2010-2013. There is currently no additional Chilko River Chinook Salmon study planned for 2015. The results of the study from 2010 to 2014 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.

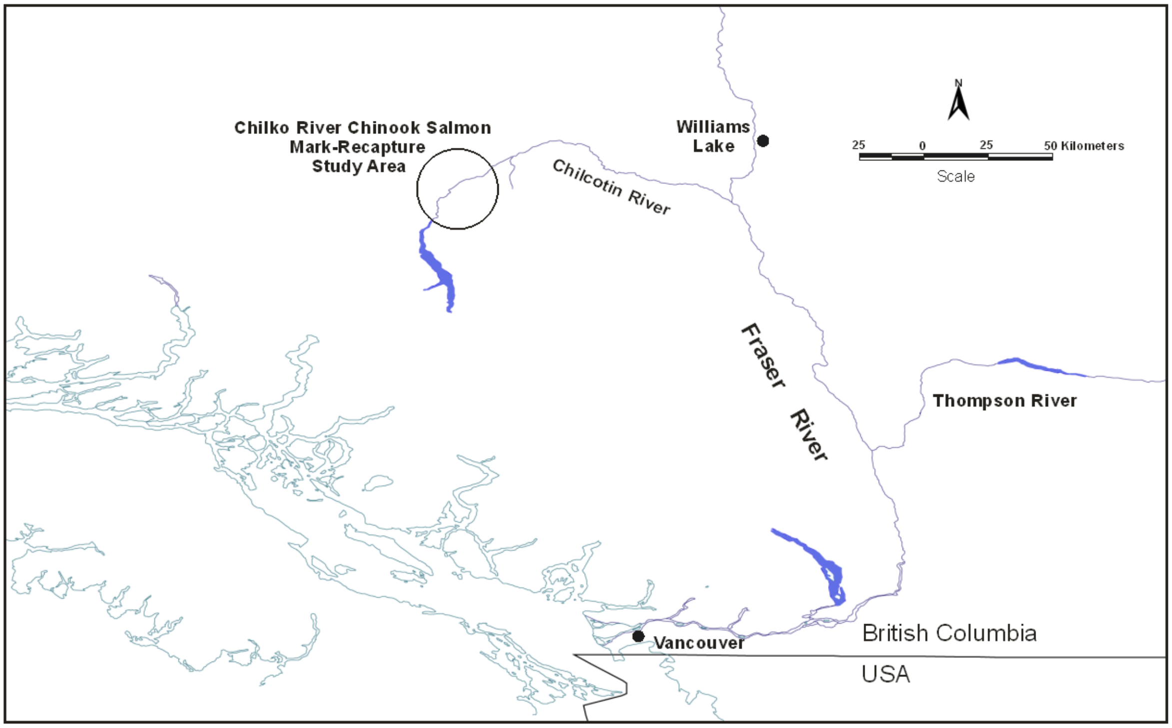

Figure 1. The Chilko River is located about 135 km west of Williams Lake and about 300 km north of Vancouver, B.C.

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.

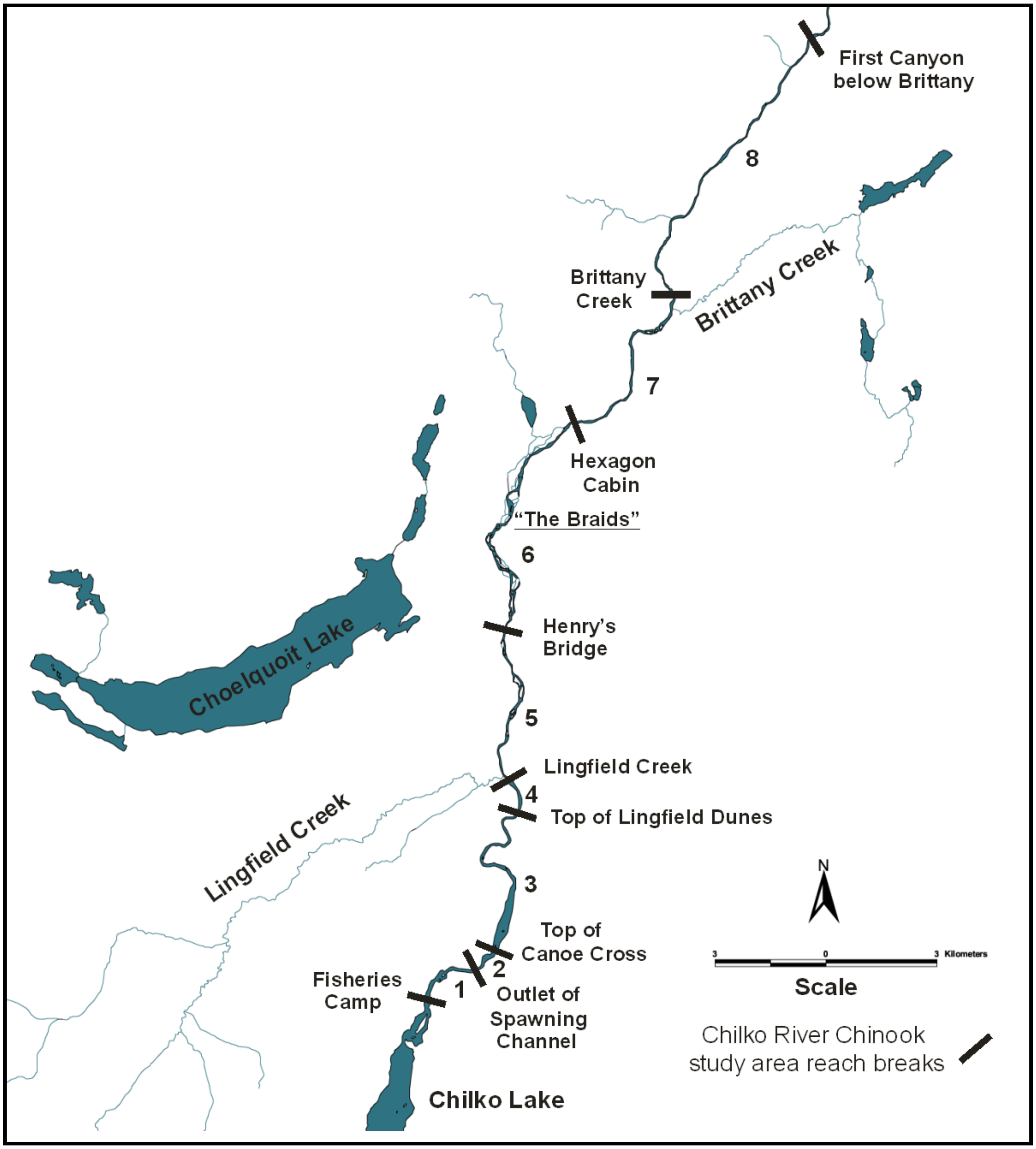

Figure 2. Chilko River study area with reach breaks, tributaries, seining location and other sites referred to in this report.

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 2014, discharge based on preliminary data ranged from 41.0-106 m^3/s during the project (August-October; Figure 3). Historical maximum flows approach 205 m^3s^{-1} and occur in late July or 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 2014, the discharge steadily decreased throughout the study period and water temperatures ranged from 13-17.5°C with a mean of 15.6°C during the application period.

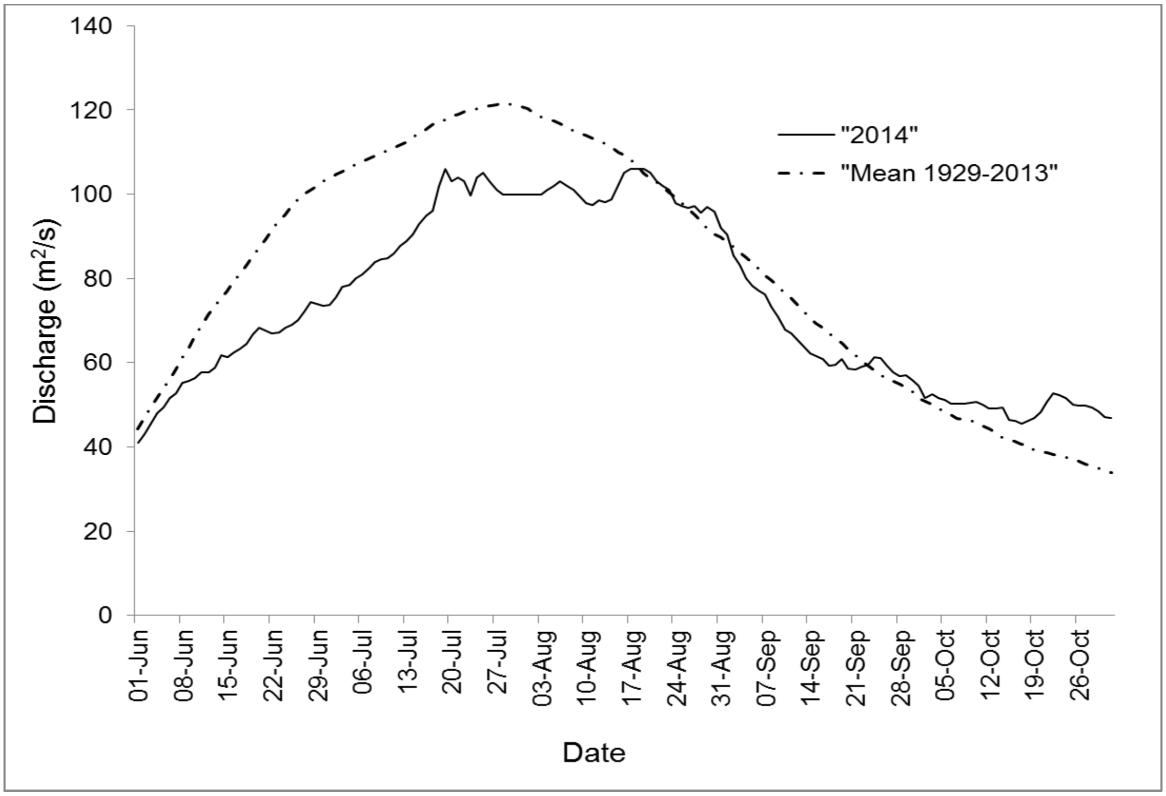

Figure 3. Preliminary mean daily discharge (m^3/s) for 2014 and the mean daily discharge for 1929-2013 for Chilko River from June - October using Environment Canada's Water Survey Station information near the outlet of Chilko Lake (Lynne Campo, pers. comm., Environment Canada, unpublished data).

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 29 July 2014 to 6 September 2014. 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 15 locations downstream of Henry's Bridge throughout reaches 6-8 (Figure 4).

Figure 4. Chilko River Chinook Salmon angling locations, 2014.

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 chainsaw-mounted 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 2014 and continued until 7 October 2014. Recovery effort occurred in reaches 1 to 8 on a two day cycle with a day off each Sunday. Reaches 1-5 were surveyed 12 times while reaches 6-8 were surveyed 11 times. Recovery crews of three to five 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 20th 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). Scales were collected from every third marked fish and every unmarked fish that was sampled. Five 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 the Kolmogorov-Smirnov two sample tests (Sokal and Rohlf 1981). 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. Both samples were stratified by sex prior to performing these tests.

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 (chi-square test). In addition, age composition between males and females in the recovery sample was compared using a chi-square test.

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

If biases were detected, population estimates were generated using the Stratified Population Analysis System (SPAS), a statistical software package developed by Arnason *et al*. (1996). This software package performs a number of statistical tests and generates the Darroch maximum likelihood estimate of escapement. The study area was stratified by pooling animals that exhibited approximately homogeneous capture and migration encounters. The data were entered into SPAS according to the directions in 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).

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.

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

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.

PEAK COUNT ESCAPEMENT ESTIMATION

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 was 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 Estimate of Escapement

For the Peak Count method, the annual escapement was calculated 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 used for Fraser River Chinook Salmon escapement estimation, 1.5385, 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). Escapement is estimated as:

$$N_{PeakCount} = \frac{Total\ fish\ observed}{0.65}$$

Where $N_{PeakCount}$ was the estimated spawner population size for the stream using the Peak Count method. Jack Chinook are not included in the estimates as they are too small to count from helicopters and they are a highly variable component of the spawning escapement from one year to the next.

PEAK COUNT VERSUS MARK-RECAPTURE COMPARISONS: 2010 – 2014

Since 2010, both aerial surveys and mark-recapture studies have been conducted annually. Five years of paired estimates were examined using linear regression analysis and Studentized Deleted residual diagnostics.

Expansion factors were calculated annually:

$$\pi = \frac{E_{HPE}}{N_{PeakCount}}$$

where:

E_{HPE} = the high precision mark-recapture escapement estimate (Petersen or ML Darroch)

$N_{PeakCount}$= estimated spawner population using the Peak Count expansion method.

And the linear regression relationship was determined:

$$y = mx + b$$

where:

m = slope of the linear regression relationship,
x = peak count escapement estimate and
b = intercept of the linear regression.

The absolute and relative error were determined by comparing the peak count estimate to the high precision estimate (mark-recapture). The absolute and relative error were calculated annually as:

$$\text{Absolute Error} = x_{peak\ count} - x_{mark\text{-}recapture}$$

$$\text{Relative Error} = \frac{x_{peak\ count} - x_{mark\text{-}recapture}}{x_{mark\text{-}recapture}}$$

where:

$x_{peak\ count}$ = peak count escapement estimate and
$x_{mark\text{-}recapture}$ = high precision mark-recapture.

Survey Life

A survey life was calculated 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.

BROOD STOCK COLLECTION & CWT PILOT

As a component of the evaluation of the potential to use the Chilko River as a CWT indicator for Fraser 1.3 Summer Chinook, a pilot brood stock capture was undertaken in 2014.The brood stock capture and egg takes were conducted on September 8, 2014 and September 16, 2014. Adult Chinook salmon were captured from the Lingfield Dunes section of the Chilko River (Figure 2) using tangle nets. Gametes were removed from 90 fish and transported to the Spius Creek Hatchery using trucks or helicopter. All Petersen disk-tagged salmon retained for broodstock were removed from the mark application sample. Unmarked fish taken for broodstock were not included in the mark-recapture experiment, and were chopped in half to prevent subsequent sampling.

RESULTS

MARK-RECAPTURE

Fish Capture and Mark Application

One thousand six hundred eighty nine (1689) Chinook Salmon were captured for mark application between 29 July and 6 September 2014 (Appendix 1). Of those, 854 were captured by seine net and 823 by angling. Tags were applied to 833 large male, 809 female and 2 small male Chinook Salmon. There were 14 mortalities observed during the angling portion of application (5 large male, 5 female, and 4 sex not recorded). The angling mortalities resulted in an estimated instantaneous mortality rate for angling of <2%. Heavy bleeding from hooking injuries was observed on 22 fish; these fish were released untagged. Moderate bleeding was observed on 18 fish and slight bleeding was observed on 203 fish. Fish with moderate and slight bleeding were tagged and released. One marked female (mark number: 121260) was recovered in the First Nation fishery and removed from the application data set. Eighteen tagged fish (7 large males and 11 females) were removed for broodstock, these tags were also removed from the application data set. Furthermore, two large males and four females were removed from the application data set due to errors in the data recording. After removals there were 802 large males tagged, 815 females tagged, and two small males tagged that were used for data analysis. Subsequent values are reported with the aforementioned tags removed.

Mark application was conducted in four of the eight reaches (Figure 1). Over half of the marks (52%) 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 784 marks applied by angling, 203 (26%) were applied at the Roger's Bar application site. The application site Root Wad resulted in 202 (26%) marks applied. The other 379 (48%) marks were applied at the Above Kye's, Rob's Run, Overturned Boat, Dead Spruce, Above Root Wad, Magic Mile application, Below Brittany, Below Ernie's, Bob's Bar, DH Bar, Grizzly, Jumping Spring Bar, and MSG sites. Peak angling application in the lower river was 46 Chinook Salmon on 15 August 2014 and again on 20 August 2014. Peak seining application in the upper river was 277 Chinook Salmon on 16 August 2014.

Within the mark application sample, females averaged 81.5 cm FL (range 52.7 to 94.0 cm; Figure 5) while large males averaged 77.5 cm FL (range 54.2 to 105.6 cm; Figure 6) and small males averaged 46.4 cm FL (range 45.4 to 47.3 cm; Appendix 1).

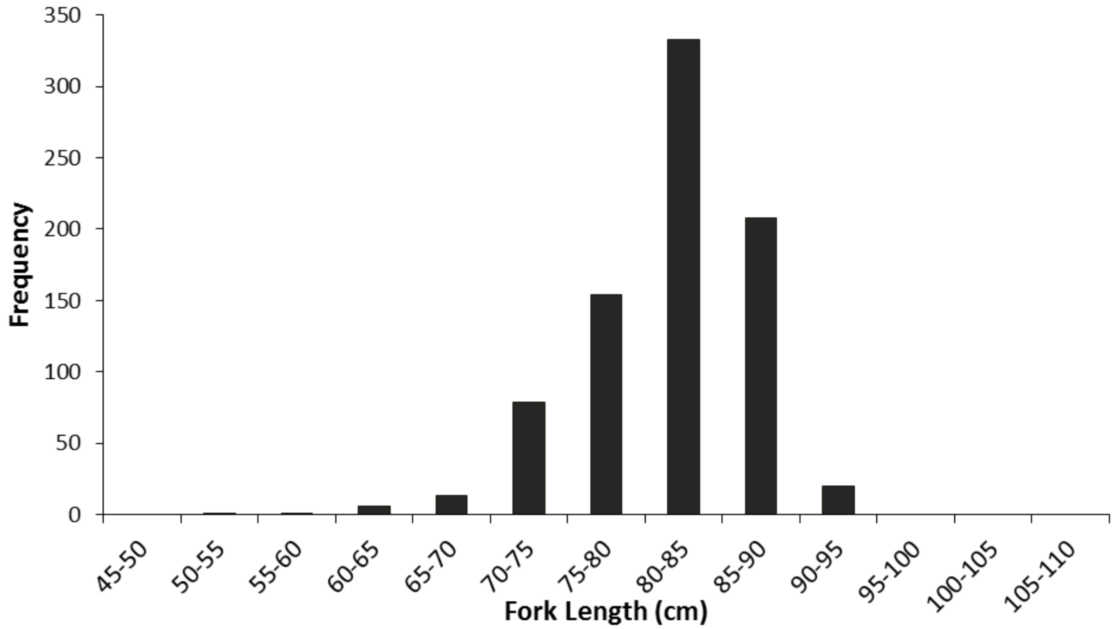

Figure 5. The fork length distribution of female Chinook Salmon captured during mark application at Chilko River 2014.

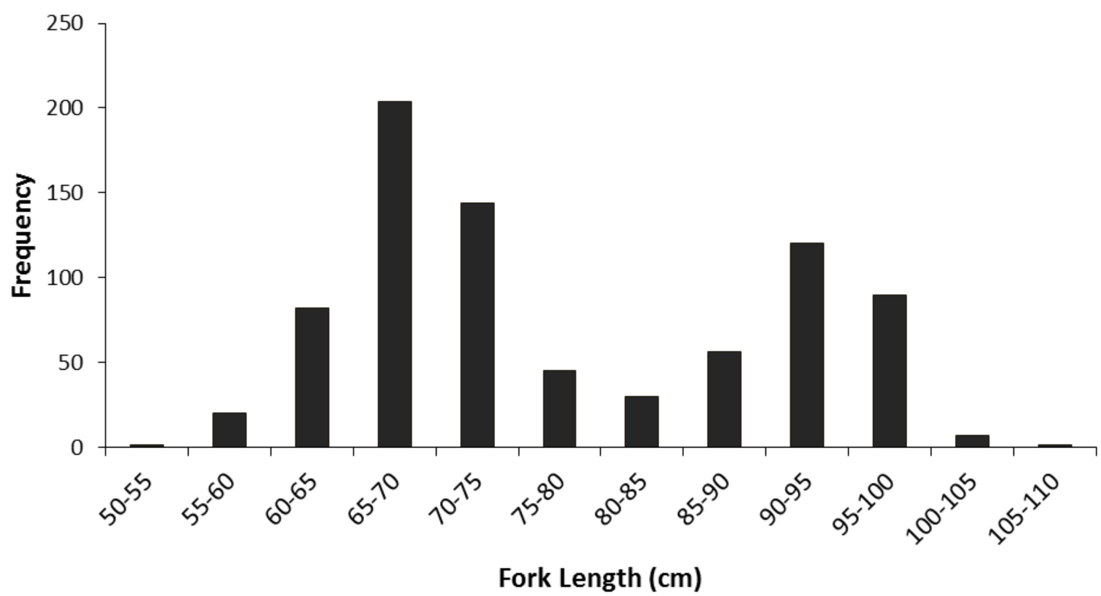

Figure 6. The fork length distribution of large male Chinook Salmon captured during mark application at Chilko River 2014.

Carcass Recovery

A total of 5083 carcasses were examined between 5 September 2014 and 7 October 2014 (Appendices 2 & 3). Of this sample, 5063 were of known sex and used in the mark-recapture data analysis. Within this recovery sample, 650 Chinook Salmon carcasses were marked and 4413 were unmarked (Table 2). Within the marked group, there were 248 large males, 402 females and 0 small males (Appendix 1). The mean elapsed time (days out) between mark application and the subsequent mark recovery was 36 days (Appendix 1).

Table 2. Summary of carcass recovery for Chinook Salmon in the Chilko River, 2014.

Sex	Total Carcasses	Primary Mark	Secondary Mark Only	Marked Total
Large Male	2151	234	14	248
Female	2909	393	9	402
Small Male	3	0	0	0
Unknown	20	3	0	3
Total	5083	630	25	653

Reach 6 had the most carcasses recovered (23%) while reach 1 and 2 had the fewest (0%). Peak recovery occurred on the recovery cycle from 23 September to 24 September, when 1024 carcasses were recovered. Of the 5060 sexed adult carcasses examined, 43% were males and 57% were females.

Within the recovery sample, females averaged 67.6 POHL (range 52.6 to 79.0; Figure 7 and Appendix 3) while large males averaged 64.2 cm POHL (range 47.7 to 84.6 cm; Figure 8 and Appendix 3) and small males averaged 41.1 cm POHL (range 38.4 to 44.1 cm; Appendix 3).

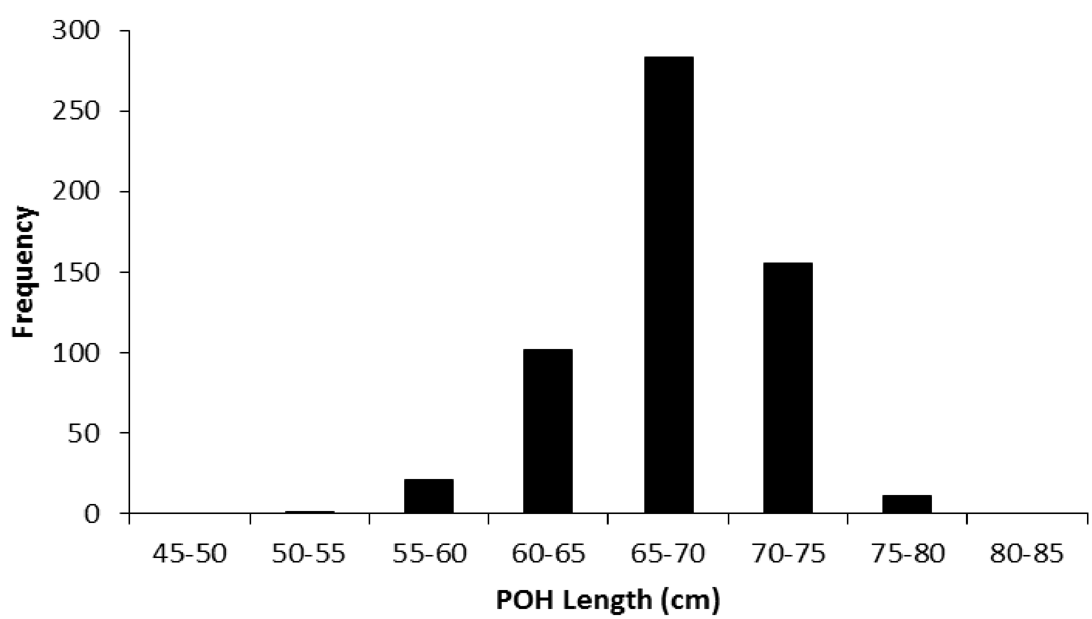

Figure 7. The post-orbital to hypural plate (POH) length distribution of female Chinook Salmon sampled during carcass recovery at Chilko River 2014.

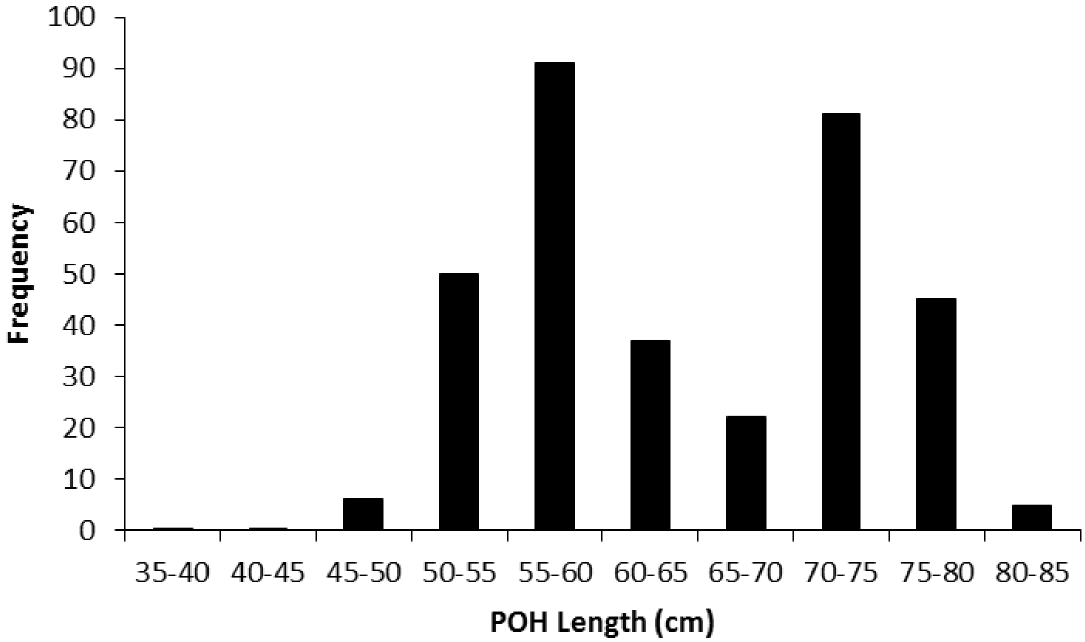

Figure 8. The post-orbital to hypural plate (POH) length distribution of large male Chinook Salmon sampled during carcass recovery at Chilko River 2014.

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 1.3. Table 3 shows the age composition by sex of the scale sub-sample with complete ages.

Table 3. Scale age sample size and proportions for Chilko River Chinook Salmon from 2014, 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	1	0.7%	0	0.0%	1	100.0%
1.2	4_2	88	57.5%	99	35.7%	0	0%
1.3	5_2	62	40.5%	177	63.9%	0	0%
1.4	6_2	2	1.3%	1	0.4%	0	0%

ANALYTICAL

Sex Identification Correction

Of the 1619 marked Chinook Salmon in the application sample, 802 were identified as large male, 815 as female, and 2 were identified as small male at the time of release (Table 4). There were 11 sex identification errors among recovered marked fish: three fish identified as large males at mark application were actually females and 8 females were actually large males (Appendix 1). After application of the sex identification correction, the corrected mark releases were 824 (51%) large males and 793 (49%) females.

Table 4. Marks applied by sex, including Staley's sex correction factors and sex corrected totals, to Chilko River Chinook Salmon, 2014.

	Mark Application		
Sex	Total	Sex Correction Factor[a]	Sex Corrected
Large Males	802	+0.014	824
Females	815	-0.014	793
Small Males	2	0	2

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=0.19; Table 5; Appendix 2).

Table 5. Spawning success rates of marked and unmarked female Chinook Salmon for Chilko River 2014.

	Unsuccessful	Successful	Percent Successful
Marked	2	397	99.5%
Unmarked	31	2,454	98.7%

There was no evidence detected for stress related to the length of time large male or female Chinook Salmon were held until marking when fish held for 0-90 minutes were compared to fish held over 90 minutes (p=0.15 and p=0.35, 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, 2014.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
0-15 Minutes	40	54	0	94	92	72	2	166	43%	75%	0%	57%
16-30 Minutes	24	47	0	71	69	84	0	153	35%	56%	-	46%
31-45 Minutes	17	45	0	62	59	71	0	130	29%	63%	-	48%
46-60 Minutes	13	36	0	49	41	66	0	107	31%	55%	-	46%
61-90 Minutes	11	50	0	61	60	94	0	154	18%	53%	-	40%
91+ Minutes	16	38	0	54	70	56	0	126	23%	68%	-	43%
Total	121	270	0	391	391	443	2	836	31%	61%	0%	47%

a. Corrected for sex identification error.

Of the 1,619 fish marked, the majority, 1,589 (99.6%) swam away rapidly, (release condition 1) six (0.4%) swam away slowly (release condition 2; Appendix 1), and 24 did not have a release condition recorded (release condition NR; 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.

Of the 784 fish marked during angling, 764 had a bleed code recorded. In this sample, 18 had moderate bleeding; 203 had slight bleeding, and 543 had no bleeding. Due to small sample sizes, slight and moderate bleeders were grouped for comparison to fish with no bleeding. There was no evidence of difference detected for stress related to bleeding for large male (p=0.48; Table 7; Appendix 1) or female Chinook Salmon (p=0.76; Table 7; Appendix 1).

Table 7. Proportion of marks recovered by bleeding condition strata during angling mark application of Chilko River Chinook Salmon, 2014.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Bleeding	34	35	0	69	118	103	0	221	29%	34%	-	31%
No Bleeding	77	85	0	162	309	234	0	543	25%	36%	0%	30%
Total	111	120	0	231	427	337	0	764	26%	36%	0%	30%

a. Corrected for sex identification error.

Of the 784 fish marked during angling, 40 were hooked in a critical location, 706 in a non-critical location and 38 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=0.59 and p=0.99, 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, 2014.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Critical	4	6	0	10	22	19	0	40	19%	32%	-	25%
Non-Critical	102	110	0	212	390	315	2	706	26%	35%	0%	30%
Total	106	116	0	222	411	333	2	746	26%	35%	0%	30%

a. Corrected for sex identification error.

Following release, 181 previously marked large male and female Chinook Salmon were recaptured during subsequent mark application periods (Table 9; Appendix 1). Seventeen 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=0.738 *and* p=0.922; chi-square test).

Table 9. Effect of recapture on recoverability by sex for Chilko River Chinook Salmon, 2014.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Times Recap'd	M	F	J	Total	M	F	J	Total	M	F	J	Total
0x	225	353	0	578	742	694	2	1438	30%	51%	0%	40%
1-2x	23	49	0	72	82	99	0	181	28%	50%	-	40%
Total	248	402	0	650	824	793	2	1619	30%	51%	0%	40%

a. Corrected for sex identification error.

Of the 1,619 fish marked, 835 were captured by seine net and 784 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 three recovery periods. When the period was stratified to contain approximately equal recovery periods, the first stratum contained 14 days, the second stratum contained 9 days, and the third stratum contained 11 days. The mean mark incidence was 12% (range 11% to 13%) for large males and 14% (range 13% to 15%) for females (Table 10). There was no evidence of a difference in mark incidence throughout time for large males (p=0.82) or females (p=0.23).

Table 10. Incidence of primary or secondary marks in Chilko River Chinook Salmon, by recovery period and sex, 2014.

	Marked Recoveries				Total Recoveries				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
04-Sep	7	15	0	22	56	101	0	157	13%	15%	-	14%
18-Sep	171	216	0	387	1452	1456	3	2911	12%	15%	0%	13%
27-Sep	70	171	0	241	643	1352	0	1995	11%	13%	-	12%
Total	248	402	0	650	2151	2909	3	5063	12%	14%	0%	13%

Temporal bias in the recovery sample was examined by comparing recovery rates among three application periods. When the period was stratified to contain approximately equal application periods, the first stratum contained 14 days while the second and third stratum each contained 13 days. The mean percentage recovered was 28% for large males and 50% for females (Table 11). There was no evidence of a difference in recovery rate throughout time for large males (p=0.41) or females (p=0.09).

Table 11. Primary marks applied and recovered in Chilko River Chinook Salmon, by application period and sex, 2014.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
29-Jul	55	79	0	134	169	140	0	309	33%	57%	-	43%
12-Aug	112	199	0	311	412	398	2	812	27%	50%	0%	38%
25-Aug	67	115	0	182	243	255	0	498	28%	45%	-	37%
Total	234	393	0	627	824	793	2	1619	28%	50%	0%	39%

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 12% for large males and 12% for females (Table 12). The mark incidence in the upper stratum was 11% for large males and 15% for females. There was no evidence of a difference between mark incidence in the upper and lower spatial recovery strata for large males (p=0.83). There was evidence of a difference between mark incidence in the upper and lower spatial recovery strata for females (p=0.03).

Table 12. Incidence of primary or secondary marks in Chilko River Chinook Salmon, by recovery strata and sex, 2014.

	Marked Recoveries				Total Recoveries				Mark incidence			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Lower	109	113	0	222	927	962	1	1890	12%	12%	0%	12%
Upper	139	289	0	428	1224	1947	2	3173	11%	15%	0%	13%
Total	248	402	0	650	2151	2909	3	5063	12%	14%	0%	13%

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=0.09). 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, 2014.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Angling	113	123	0	236	438	344	2	784	26%	36%	0%	30%
Seining	121	270	0	391	386	449	0	835	31%	60%	-	47%
Total	234	393	0	627	824	793	2	1619	28%	50%	0%	39%

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=10119; p=0.13; Kolmogorov-Smirnov Z=1.07; p=0.20). There was no evidence of a difference in POH length between marked and unmarked recoveries for females (Mann-Whitney U=32895; p=0.22; Kolmogorov-Smirnov Z=0.90; p=0.39).

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 no evidence of a difference in fork length between recovered and not recovered samples for large males (Mann-Whitney U=60994; p=0.12; Kolmogorov-Smirnov Z=1.03; p=0.24). There was no evidence of a difference in fork length between recovered and not recovered samples for females (Mann-Whitney U=80662; *p*=0.49; Kolmogorov-Smirnov Z=0.79; *p*=0.56).

Sex

Sex bias in application was assessed by comparing mark incidence between large males and females in the recovery sample. Mark incidence was 12% for large males and 14% for females (Table 14). There was evidence of a difference between male and female mark incidence (*p*=0.02); therefore, there was sex bias at application.

Table 14. Percent recovery and mark incidence of secondary only and primary marks recovered by sex for the 2014 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	824	14	248	2151	30%	12%
Female	793	9	402	2909	51%	14%
Small Male	2	0	0	3	0%	0%
Total	1619	23	650	5063	38%	13%

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 30% and of females was 51% (Table 14).

Primary mark loss was 6% for large males and 2% for females. The p-value of a chi-square test comparing the rate of tag loss between large males and females was 0.04 strongly indicating there was a significant difference between large male and female tag loss.

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 analysis. There was no evidence of a difference in age composition between marked and unmarked samples for large males or females (*p*=0.08 and *p*=0.27). 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 strong 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, 2014.

		Large Male		Female	
	Age	Sample Size	Percent[a]	Sample Size	Percent[a]
Marked	3_2	1	1%	0	0%
	4_2	49	64%	51	39%
	5_2	25	33%	79	61%
	6_2	1	1%	0	0%
Unmarked	3_2	0	0%	0	0%
	4_2	39	51%	48	39%
	5_2	37	48%	98	60%
	6_2	1	1%	1	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 2014 Chilko River Chinook Salmon escapement estimation study.

Bias type	Application sample [a]	Recovery sample [a]
Stress	n/a	No Bias
Period	No Bias	No Bias
Location	Female bias	Female bias
Fish size	No bias	No Bias
Fish sex	Bias	Higher recovery rate for females
Fish age	No Bias	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. The complete mixing and equal proportions tests in SPAS support the use of the Petersen estimator showing no necessity to use the Darroch estimator. The 2014 large male spawning escapement of Chilko River Chinook Salmon was estimated to be 7,130 ± 695 (Table 17).

Table 17. Large male escapement estimate derived from 2014 mark-recovery data using a Petersen estimator for Chilko River Chinook Salmon.

	Large Males
Carcasses Sampled	2,151
Marks Applied [a]	824
Marks Recovered	248
Total Percent Recovered	30%
Population Size	7,130
Coefficient of Variation	5%
Lower 95% Confidence Limit	6,436
Upper 95% Confidence Limit	7,825

a. Corrected for sex identification error.

Females: Darroch Estimate

There was spatial bias at application and recovery for females. For spatial stratification at application, application data was stratified into marks applied in the upper river at the seine site and marks applied in the lower river by angling. For spatial stratification at recovery, recovery data was divided into carcasses examined in the upper and the lower segments of the river. The upper segment of the river consisted of reaches 1-5 and the lower segment consisted of reaches 6-8.

For spatially stratified application and recovery data, the program SPAS reported evidence of an unequal ratio of marked to unmarked females between strata (p=0.02). These results further support the use of the ML Darroch estimator for females instead of the Petersen estimator. The 2014 female spawning escapement of Chilko River Chinook Salmon was estimated to be 6,116 ± 582 using the Darroch estimator in SPAS (Table 18).

Table 18. Female escapement estimate derived from 2014 mark-recovery data using the ML Darroch estimator for Chilko River Chinook Salmon.

	Females
Carcasses Sampled	2,909
Marks Applied [a]	792
Marks Recovered	402
Total Percent Recovered	48%
Population Size	6,116
Coefficient of Variation	4.9%
Lower 95% Confidence Limit	5,534
Upper 95% Confidence Limit	6,698

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 no marked small males were recovered from a total of 2 marks applied. Three small male carcasses were recovered (Table 19). The 2014 small male spawning escapement of Chilko River Chinook Salmon was estimated to be 20 using the large male recovery rate expansion.

Table 19. The small male escapement estimate derived from 2014 mark-recovery data using the large male recovery rate expansion.

	Small Males
Total Large Male Carcasses Sampled	2,151
Large Male Escapement Estimate	7,130
Large Male Recovery Rate	30%
Small Male Recovery Rate (1/2 Large Male Rate)	15%
Total Small Male Carcasses Sampled	3
Population Size	20

Combined Total

The 2014 total large male and female spawning escapement of Chinook Salmon to Chilko River was 13,246 ± 1,277 (Table 20).

Table 20. The total large male and female escapement estimate derived from 2014 Chilko River Chinook Salmon mark-recovery data using the Petersen estimator for large males and the ML Darroch estimator for females.

	Total
Carcasses Sampled	5,060
Marks Applied [a]	1,617
Marks Recovered	650
Percent Recovered	38%
Population Size	13,246
Coefficient of Variation	3%
Lower 95% Confidence Limit	11,969
Upper 95% Confidence Limit	14,523

a. Corrected for sex identification error.

Escapement by Age

The majority of Chinook Salmon returning to the Chilko River in 2014 were age 1.3 (Table 21). The total Chinook Salmon escapement estimate by age consisted of 67 age 1.1, 6,287 age 1.2, 6,797 age 1.3 and 115 age 1.4.

Table 21. Escapement estimates by sex and age for 2014 Chilko River Chinook Salmon.

Age		Escapement Estimate			
European	Gilbert Rich	Large Male	Female	Small Male	Total
1.1	3_2	47	0	20	67
1.2	4_2	4,101	2,186	0	6,287
1.3	5_2	2,889	3,908	0	6,797
1.4	6_2	93	22	0	115

PEAK COUNT ESCAPEMENT ESTIMATE AND SURVEY LIFE

In 2014, three aerial surveys were conducted on September 8, 16, and 22. The highest spawner count (7,145) occurred on the 16 September 2014 flight. The peak count of Chinook Salmon was 7,334 (7,145 spawners, 160 holders and 29 carcasses) also on 16 September 2014. The expanded peak count estimate was 11,283. The survey life was 9.1 days (CV=1%).

PEAK COUNT VERSUS MARK-RECAPTURE COMPARISONS: 2010 - 2014

The peak count estimates were lower than the mark-recapture estimates in 4 of the 5 years and the relative error ranged from -23% to 15% annually (Table 22). There was a strong correlation between the paired peak count and mark-recapture estimates (Figure 9). The Studentized Deleted residual diagnostic showed one significant outlier; however, the residuals were normally distributed and no point had high leverage.

Four of the paired estimates were in the low escapement range (<10,000) and only one of the paired estimates was in the moderate range (10,000-15,000). None of the paired estimates have been in the high escapement range (>15,000).

Table 22. Relative error between the peak count and the mark-recapture estimates for Chilko River Chinook Salmon, 2010-2014.

Year	Peak Count Estimate	Mark-Recapture Estimate	Relative Error
2010	6345	7490	15%
2011	7526	8396	10%
2012	3845	4255	10%
2013	5186	4231	-23%
2014	11283	13246	15%

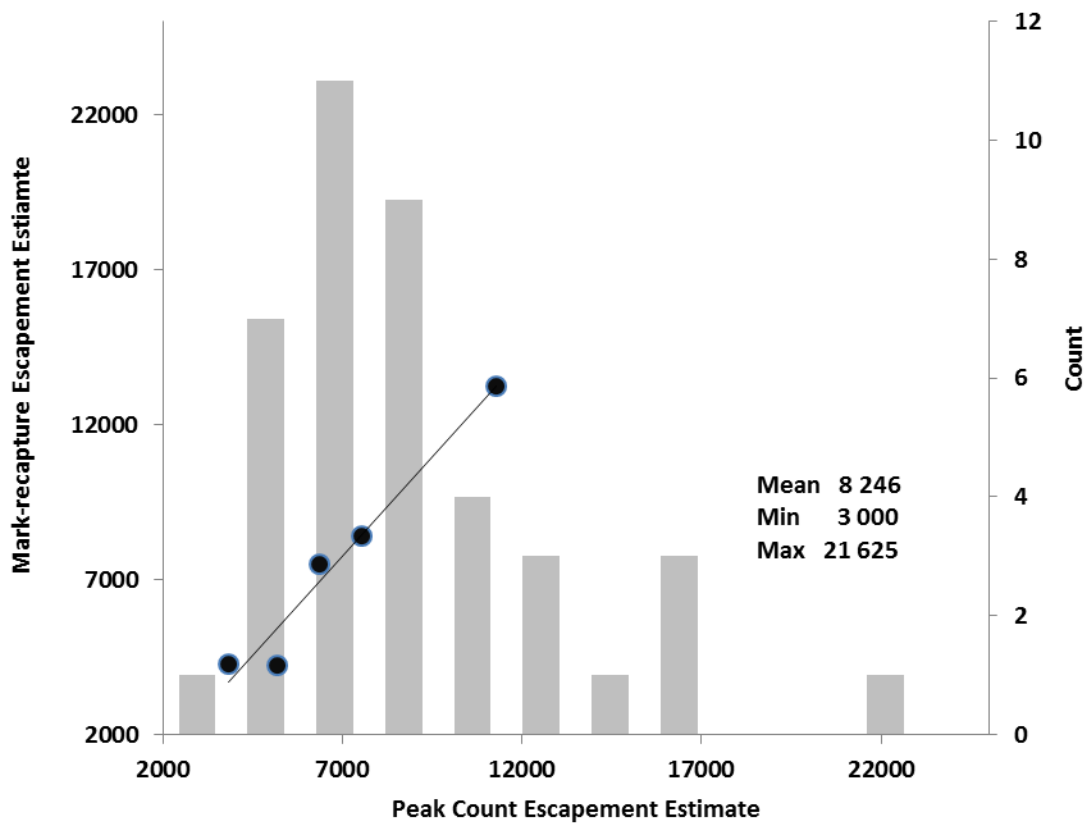

Figure 9. Peak count estimates versus mark-recapture estimates for Chilko River Chinook Salmon, 2010 to 2014 (line). The histogram illustrates the escapement estimate frequency distribution for 40 peak count estimates (1975-2014) in bins of 2000 spawners. The mean, minimum and maximum values are provided for the frequency histogram.

BROOD STOCK COLLECTION & CWT PILOT

Between 8 September 2014 and 16 September 2014, a total of 210 mature male and 252 mature female Chinook salmon were captured of which 44 mature female and 46 mature male Chinook were taken for broodstock. All salmon chosen for broodstock were sacrificed streamside, and gametes collected. Approximately 35,000 eggs, and 11 samples of milt were transported to Spuis Creek Hatchery by helicopter and approximately 115,000 eggs and 34 samples of milt were transported by truck. Ninety six percent survived to the eyed egg stage, and no difference was observed in the survival rate of eggs transported by helicopter versus truck. Egg to fry survival rates were also high, and approximately 144,000 alevins were ponded in spring 2015. Of the ponded alevins, 45,000 were determined to be surplus to available rearing capacity, and were wire tagged in May 2015 and released back to the Chilko River. The remaining 99,000 will be reared to smolt stage, coded-wire tagged and released in spring 2016.

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 2014 Chilko River Chinook Salmon mark-recapture study, large numbers of marks were applied and recovered producing a CV of 3% 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.

Males had a higher tag loss rate than females in 2014, as in 2010 and 2011. Males are more likely to get their teeth and tags caught on the seine net, which may cause immediate or subsequent tag loss.

In 2014, age data indicated a higher proportion of age-5 fish for females and age-4 fish for large males. In 2010 and 2011, there were a higher portion of 4_2 males and 5_2 females. This age composition aligns with the age data from previous years of the Chilko River Chinook Salmon study, with the exception of 2012 and 2013. The 2014 age composition also aligns with other studies that have found Fraser stream-type Chinook Salmon females were most abundant at age 5 and males were most abundant at age 4 (Groot & Margolis 1991).

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 2014, 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 fish size distribution or age composition in application or recovery data. No significant spatial or temporal biases were detected in the application or recovery samples for large males. There was no significant female temporal bias detected at application or recovery; however, females exhibited spatial bias at application and recovery. For females, 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.

As there was evidence of spatial bias at application and recovery for females, the application and recovery samples were stratified by area. SPAS identified a need to use a spatially stratified estimator. Based on these results, we employed the spatially stratified ML Darroch for females to generate an escapement estimate of 6,166 females. As there was no spatial or temporal bias detected for large males, we employed the Petersen estimator to generate an escapement estimate of 7,130 large males. The total escapement estimate is 13,246 (CV = 3%) large males and females. Because only 2 small males were tagged and no small male tags were recovered, a Petersen estimate could not be generated. A recovery rate expansion was used to generate an escapement estimate of 20 small males.

Based on the results of the 2014 Chilko River Chinook Salmon mark-recapture project and data analyses over the last four years, recommendations for future studies include continuing to apply marks evenly in the two spatial strata (upper/seining and lower/angling); apply tags low in the system and early including starting seining earlier; apply tags in primary holding 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 13,246 (range 11,969-14,523) was higher than the peak count estimate of 11,283. 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).

The mean Peak Count expansion factor for Chilko River Chinook Salmon is 1.10 (range 0.81-1.28). The Nicola River Chinook Salmon mark-recapture study noted a much larger mean expansion factor (2.04) of the Peak count aerial estimates over a five year period (1995-1999; Bailey et al. 2000). A large expansion factor for Nicola was reported from abnormally turbid waters during the 1995 enumeration flights and because counts of live fish were not recorded as spawners and holders. Even under optimal counting conditions for all aerial surveys, the Chilko River Chinook Salmon Peak count estimate was still slightly lower than the mark-recapture estimate in all years except 2013. The relative error of the Chilko River Chinook salmon peak count estimates compared to the mark-recapture estimates ranged from -23% to 25% over 5 years (2010-2014). Due to the variation in the relative error, a stable calibration factor is not yet available for Chilko River Chinook Salmon. Using the mean expansion factor of 4 years (1996-1999), peak count estimates of Nicola River Chinook Salmon spawners ranged from -14% to +21% of the mark recapture estimates (Parken et al. 2003). Paired data of escapements in excess of 15,000 Chinook Salmon in the Chilko River have not been observed; thus, the reliability of calibration at higher escapements is unknown. Paired peak count and mark recapture estimates should continue to be conducted annually until the calibration factor stabilizes and paired estimates represent the true range of escapements.

The results of the Chilko River Chinook Salmon assessment projects over the last five years indicate that the spawning escapement can be estimated with high precision. This study produced precise (CV) escapement estimates for males (5.0%) and females (4.9%), which is consistent with the PSC CTC data standards (CV<15%). Also, a high percentage of male (30%) and female (48%) 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 recovery sample. 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 due to insufficient samples. 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 five 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.

The 2014 broodstock collection was successful, however evaluation of appropriate rearing and release strategies have not yet been accomplished. Progeny from the 2014 broodstock capture may recruit to marine fisheries as early as 2017, and some CWT'd Chinook Salmon could start returning to the Chilko River as three year olds in 2017; however, the majority of returns are expected at ages four and five in 2018 and 2019.

SUMMARY

1. The Chinook Salmon escapement to the Chilko River in 2014 was estimated by mark-recapture.

2. Marks were applied to 1619 Chinook Salmon (excluding removals): 835 of them were captured by seining and 784 by angling. Marks were applied to 802 large male (>50 cm FL) and 815 female Chinook Salmon. Three marks were applied to small male (<50 cm FL) Chinook Salmon.

3. After correction for sex identification errors, the application sample consisted of 824 males, 793 females, and three small males.

4. In the recovery sample, 5,083 Chinook Salmon carcasses were sampled and 5,063 were identified by sex. The recovery sample consisted of 2,151 large male, 2,909 female, 3 small male carcasses and 3 carcasses of undetermined sex. Within this sample, 248 large male, 402 female and zero small male carcasses were recovered with marks.

5. The large male age composition consisted of 0.7% age 1.1, 57.5% age 1.2, 40.5% age 1.3 and 1.3% age 1.4. The female age composition consisted of 0.0% age 1.1, 35.7% age 1.2, 63.9% age 1.3 and 0.4% age 1.4. There was only one small male aged and it was determined to have an age of 1.1. All 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, was assessed in both mark and recovery samples. Spatial biases were detected for females.

7. Based on the radio telemetry from 2010 and aerial survey data from 2010-2014, the mark-recapture assumption of closure was met.

8. There was evidence of spatial bias in the recovery sample for females. Due to this bias, 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. For large males, there was no spatial or temporal bias detected at application or recovery; therefore, a pooled Petersen estimator was used to calculate male escapement.

9. The 2014 total large male and female spawning escapement of Chinook Salmon to Chilko River was 13,246 with lower and upper 95% confidence limits of 11,969 and 14,523 respectively. The male escapement (Petersen) was estimated to be 7,130 ± 695, the female estimate (ML Darroch) was

6,116 ± 582 and the small male escapement (recovery rate expansion) was 20.

10. Aerial surveys of Chinook Salmon spawners, holders, and carcasses were conducted on 8 September 2014 16 September 2014 and 22 September 2014. The 16 September 2014 flight was the peak count with 7,334 (7,145 spawners, 160 holders and 29 carcasses).

11. The peak count on 15 September 2014 produced an escapement estimate of 11,283 Chinook Salmon using the Fraser River Chinook peak count expansion factor (1.5385). This escapement estimate was 85% of the mark-recapture escapement estimate. The measured peak count expansion factor was 1.17 based on the peak count and mark-recapture estimate.

12. The relative error of the peak count estimates compared to the mark-recapture estimates ranged from -23% to 25%. Annual paired peak count and mark-recapture estimates should continue to be generated until the calibration factor stabilizes and these estimates represent the full range of escapements observed back to 1975.

13. The residence time was 9.1 days (CV=1%) based on the spawner surveys and the mark-recapture estimate.

14. There were 46 male and 44 female Chinook Salmon taken for broodstock in 2014. Approximately 150,000 eggs were transported to the Spius Creek Hatchery for rearing. These fish will be coded wire tagged prior to being released back to the Chilko River.

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REFERENCES

Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences 2106.

Bailey, R.E., C.K. Parken, J.R. Irvine, B. Rosenberger, and M.K. Farwell. 2000. Evaluation of utility of aerial overflight based estimates versus mark-recapture estimates of Chinook Salmon escapement to Nicola River, BC. Fisheries and Oceans Canada, CSAS. 2000:152.

Bevan, D.E. 1961. Variability in aerial counts of spawning salmon. J. Fish. Res. Bd. Can. 18: 337-348.

Faulkner, G. and B. Ennevor. 1995. Nechako and Stuart Rivers Chinook spawner enumeration 1994. Fisheries and Oceans Canada. Nechako Fisheries Conservation Program. Data Report No. M94-1.

Farwell, M.K., R. Diewert, L.W. Kalnin, and R.E. Bailey. 1998. Enumeration of the 1995 Harrison River Chinook Salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2453: 32 p.

Farwell, M.K., R.E. Bailey, and B. Rosenberger. 1999. Enumeration of the 1995 Nicola River Chinook Salmon Escapement. Can. Man. Report of Fish. Aquat. Sci. 2491.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press, Vancouver, British Columbia, Canada: 564 pages.

McPherson, S.A, D.R. Bernard, R.J. Yanusz, P.A. Milligan, and P. Timpany. 1999. Spawning abundance of Chinook Salmon in the Taku River in 1998. Alaska Department of Fish and Game, Division of Sport Fish. Fishery Data Series No. 99-26.

Neilson, J.D., and G.H. Geen. 1981. Enumeration of spawning salmon from spawner residence time and aerial counts. Trans. Am. Fish. Soc. 110: 554-556.

Nelson, T.C., R.C. Bocking, and D.E. Miller. 2000. Chinook escapement to the Chuckwalla River 1999: a comparison of mark-recapture and area-under-the-curve estimates based on biotelemetry, aerial surveys, and carcass recoveries. Prepared for the Fisheries and Oceans Canada and Rivers Inlet Restoration Society by LGL Ltd. 83p.

Pacific Salmon Commission. 2002. Catch and escapement of Chinook Salmon under Pacific Salmon Commission jurisdiction 2001. TCCHINOOK (02)-1.

Pacific Salmon Commission Joint Chinook Technical Committee. 2013. Annual report of catch and escapement for 2012. TCCHINOOK (13)-1.

Parken, C.K. J.C. Candy, J.R. Irvine, and T.D. Beacham. 2008. Genetic and coded wire tag results combine to allow more-precise management of a complex Chinook Salmon aggregate. North American Journal of Fisheries Management 28:328-340.

Parken, C.K., R.E, Bailey, and J.R. Irvine. 2003. Incorporating uncertainty into area-under-the-curve and peak count salmon escapement estimation. North American Journal of Fisheries Management 23:78-90.

Ricker, W.E. 1975. Computations and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382 p.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry, the principles and practices of statistics in biological research. Second edition. W.H. Freeman and Company. San Francisco. 859 p.

Staley, M.J. 1990. Abundance, age, size, sex and coded wire tag recoveries for Chinook Salmon escapements of the Harrison River, 1984-1988. Can. Manuscr. Rep. Fish. Aquat. Sci. 2066: 42 p.

Schwarz, C.J., R.E. Bailey, J.R. Irvine and F.C. Dalzeil. 1993. Estimating salmon spawning escapement using capture-recapture methods. Can. J. Fish. Aquat. Sci. 50: 1181-1197.

Trouton, N.T. 2004. An investigation into the factors influencing escapement estimation for Chinook Salmon (*Oncorhynchus tshawytscha*) on the Lower Shuswap River, British Columbia. Simon Fraser University. MSc Thesis.

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APPENDICES

(*see separate document*)