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Enumeration of Chilko River Chinook Salmon Escapement (Mark-Recapture) 2011.

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 summer-run (age 1.3 Stock Group) Chinook salmon (*Oncorhynchus tshawytscha*) escapement to the Chilko River in 2011 was generated using a two event mark-recapture and helicopter-based peak count salmon escapement estimation methods. Marks were applied to 731 adult Chinook salmon, and 386 of them were recovered from a total recovery sample of 4,070 males and female carcasses. No jack estimate was calculated as none of the 3 marks applied to jacks were recovered from a total recovery of 2 jacks. Spatial bias was detected in the application and recovery samples for females; therefore, the application and recovery data were stratified spatially. For males, spatial bias was detected in the application sample and temporal bias was detected in the recovery sample; therefore, the application data was stratified spatially and the recovery data was stratified temporally. The Stratified Population Analysis System (SPAS) was employed and showed inconsistent recovery probabilities and an unequal ratio of marked to unmarked between the strata for both sexes; therefore, the maximum likelihood (ML) Darroch method was recommended as the most reliable escapement estimation model. The ML Darroch estimate of escapement was 8,396 adult Chinook salmon (lower 95% CI=7,523; upper 95% CI=9,269). Sex-specific escapement estimates were 3,515 males (lower 95% CI=2,781; upper 95% CI=4,249) and 4,881 females (lower 95% CI=4,410; upper 95% CI=5,353). The estimated escapement based on aerial counts and the Fraser River Chinook peak count expansion factor was 7,526; 10% less than the ML Darroch estimate.

INTRODUCTION

The Wild Salmon Policy required the creation of conservation units in order to manage fisheries in a way that will preserve genetic diversity. 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) Catch and Escapement Report (PSC 2002; 2011). 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 requires estimates of survival 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. Survival and exploitation rate indicator stocks are required for each Chinook aggregate in the Fraser River, thus programs are required 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 stock be assessable by a high precision method (usually mark recapture) to yield: (a) reliable estimates of escapement by age and by sex annually and (b) carcass sampling rates that are high enough to produce precise CWT estimates. In order to produce precise CWT 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 study of 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 (1991-2010) of 10,197 (4,366-21,625) 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 2011). 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 aggreagates importance in fisheries facilitates 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 2011, while providing an opportunity to investigate spawning behavior and evaluate study designs. 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 and additional Chilko River Chinook salmon studies are planned for 2012-2013. If the ongoing studies indicate that it is feasible to generate high precision estimates of escapements to the Chilko River annually and sufficient carcass sampling rates, then it may be feasible to develop an indicator stock program on the Chilko to represent 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.

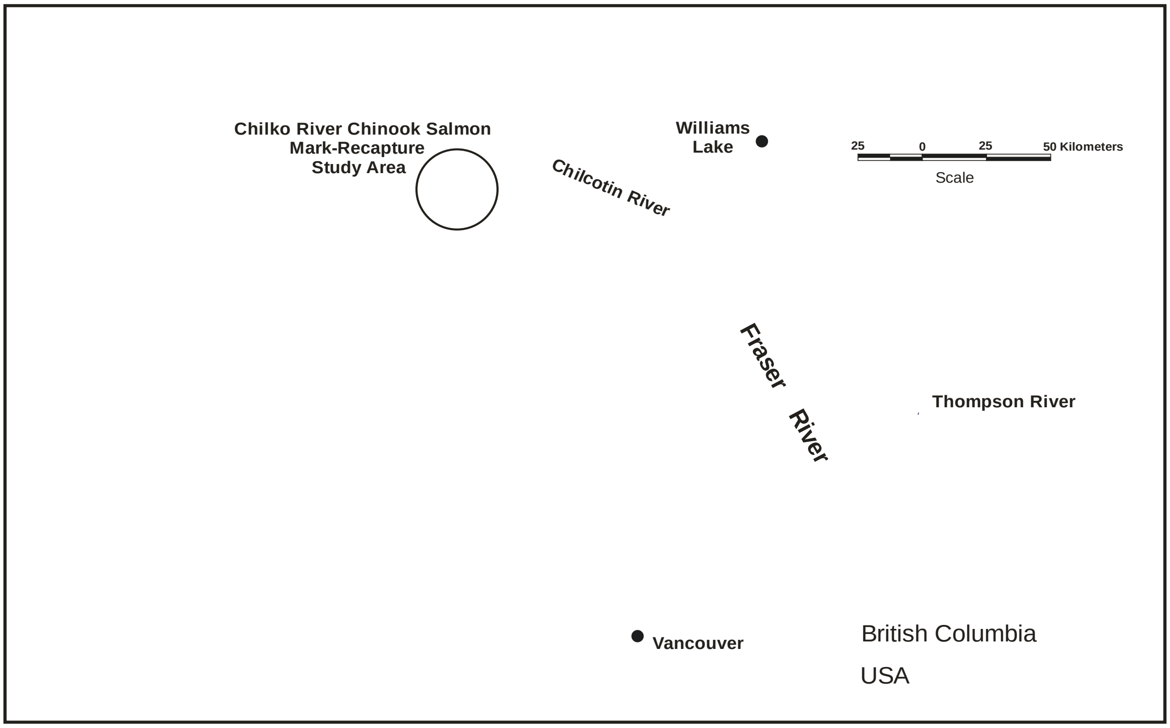

Figure 1. The Chilko River is located about 135 km west of Williams Lake and about 300 km north of Vancouver, B.C.

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 mid-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 weeks since adult Chinook salmon first appear in the Chilko River during early 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& 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.

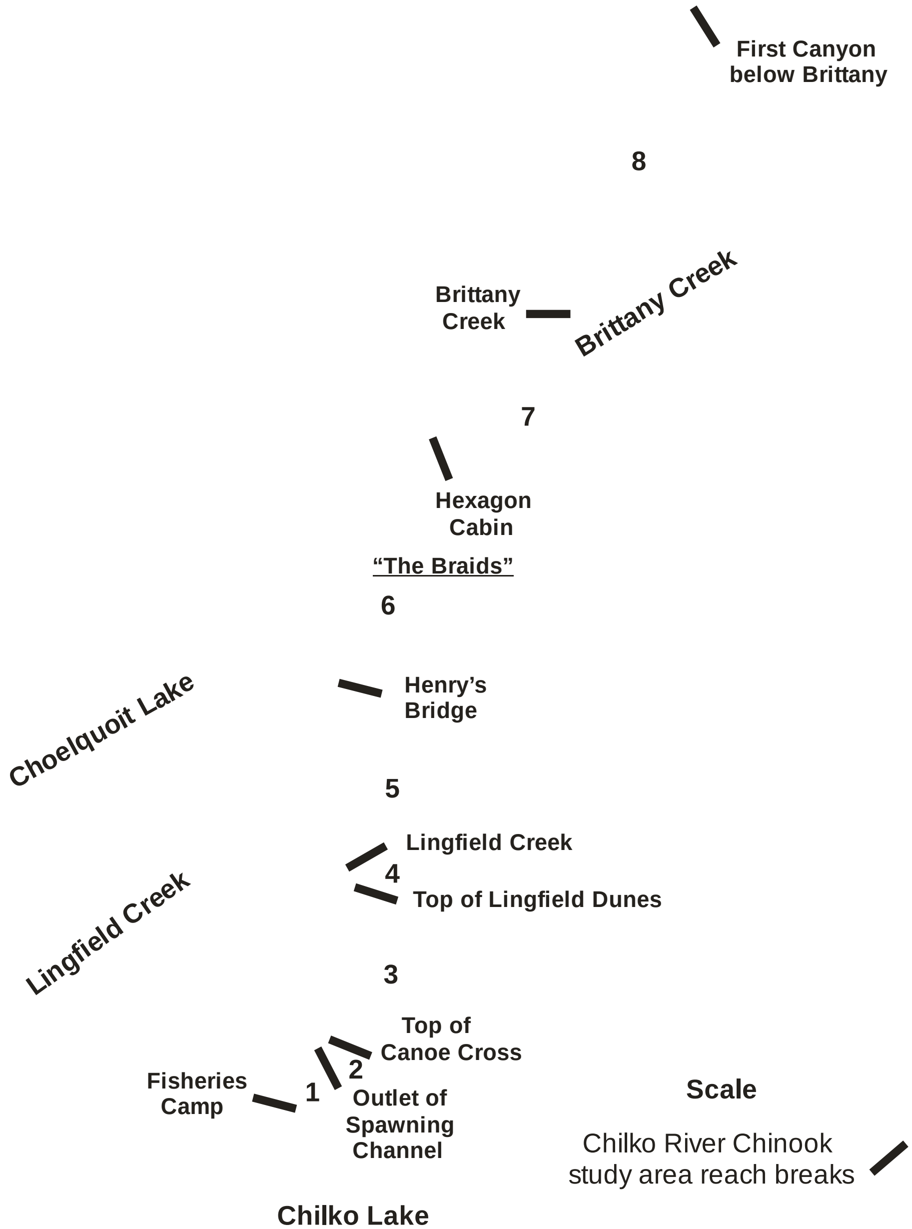

Figure 2. The Chilko River study area with reach breaks, tributaries, seining location and other sites referred to in this report.

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 2011, discharge base don preliminary data ranged from 68-136 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. During the study period, the discharge steady decreased except for a small increased in late August. The flows started to increase again in late-September at the end of recovery (27 September 2011). Water temperatures ranged from 10-13°C with a mean of 11.6°C during the 2011 application period.

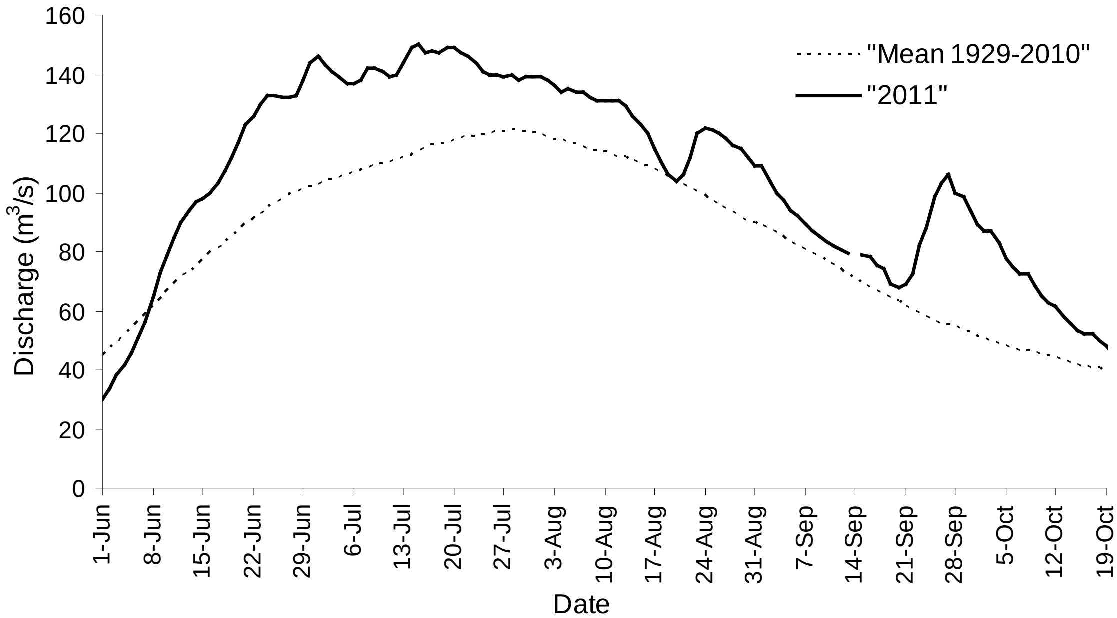

Figure 3. Preliminary mean daily discharge (m^3/s) for 2011 and the final mean daily discharge for 1928-2010 for Chilko River from June – October using Environment Canada's Water Survey Station information near the outlet of Chilko Lake (Lynne Campo, pers. comm., Environment Canada, unpublished data).

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 pikeminnows (*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 3 August 2011 to 3 September 2011. 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 6 locations downstream of Henry's Bridge throughout reaches 6-8 (Figure 4).

Figure 4. Chilko River Chinook angling locations, 2011.

Fish were caught on single barbless hooks of sizes 3/0 or 4/0 that were baited with roe (salmon eggs) treated with procure and borax, and fish were 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. 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 and noted where the fish was hooked, later categorized as either critical (roof of mouth, gills, tongue, or eye) or non-critical (all other locations).

A 350’ long X 100 meshes deep seine net constructed with 3.5” mesh was set by powerboat 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 (~50m) 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 captured Chinook salmon (Farwell *et al*. 1999). One Petersen disk tag was uniquely coded with a 5 digit number and the other was a blank transparent disk. These tags were placed on the fish using a 7.7cm 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, 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; or 3: required ventilation) were recorded. The date, person tagging, tagging location and time were also recorded. After tagging and data collection, the seine captured fish were released over the net; however, angled fish were quickly passed from the river to the onboard tagging tray supported in knotless mesh landing nets, and from the tagging tray back to the river and into the flow-through holding tubes. 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 6 September 2011 and continued until 27 September 2011, when no further carcasses were found. Recovery effort occurred in strata 1 to 8 on a two day cycle with each stratum surveyed 11 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 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 adult in every reach; the 5th unmarked adult fish (changed to every 10th unmarked adult on 19 September 2011); 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, 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 (AFC) 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 gaff) were recorded for each carcass recovered. Scales were collected from every sampled fish and 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

Sampling biases were only evaluated for adult males and females because the jack (fish less than 50 cm FL) sample size was too small.

Tagging 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; 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 using a chi-square test (Sokal and Rohlf 1981). Samples were stratified by sex prior to testing.

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. Samples were stratified by sex before testing.

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 stratifying by sex and comparing the rate of marks recovered 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 adult application and recovery samples for 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 strata, adult males, females, and small males, because other Fraser River Chinook salmon escapement programs repeatedly find significant sampling selectivity among these strata, 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 adult 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. If one or both of the above mentioned tests are true (p>0.05) then it is appropriate to use the pooled Petersen method, otherwise the Darroch/Plante maximum likelihood (ML) method produces the most accurate population estimate (Arnason *et al*. 1996).

Escapement by Age

Escapement by age was determined by applying the estimated age composition of the recovery sample to the estimate of escapement based on the ML Darroch estimator. As sex specific escapement estimates were calculated, age data was also stratified by sex.

PEAK COUNT ESCAPEMENT ESTIMATION

Aerial counts were performed at low levels (50-80 m above the ground) in a Bell 206B helicopter 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, and 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 as a carcass. 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 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 Estimate of Escapement

For the peak count method, one calculates annual escapement 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 used to estimate escapement. The expansion factor used for Fraser River Chinook salmon estimation, 1.54, 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).

RESULTS

Mark-Recapture

Fish Capture and Mark Application

Seven hundred and thirty seven (737) Chinook salmon were captured for mark application between 11 August and 3 September 2011 (Appendix 1). Of those, 382 were captured by seine net and 355 by angling. There was a single mortality observed during the angling portion of application. This produced an instant mortality rate for angling of 0.3%. Heavy bleeding from hooking injuries was observed on 8 fish, moderate bleeding was observed on 9 fish and slight bleeding was observed on 81 fish. Three marked females (mark numbers: 95117, 96091, 96131) were recovered in native fisheries and were subsequently removed from bias testing and escapement estimates.

Mark application was conducted in four of the eight reaches (Figure 2 & 4). Over half of the marks (52%) were applied in reach 4 at the Lingfield seine site. The remaining tags were applied by angling in reaches 6, 7 and 8. Of the 355 marks applied by angling 200 (56%) were applied at the Below Brittany application site. The application sites Rob's Run and Above Kye's resulted in 66 (19%) and 50 (14%) marks applied respectively. The final 39 (11%) marks were applied at the Rogers Bar, Magic Mile and Dead Spruce application sites. Peak angling application in the lower river was 38 Chinook on 25 August 2011. Peak seining application in the upper river was 122 Chinook on 2 September 2011.

Within the mark application sample, males averaged 86.4 cm FL (range 51.5 to 107.0 cm; Figure 6) while females averaged 82.9 FL (range 62.5 to 96.1 cm; Figure 5) and jacks averaged 44.2 cm FL (range 43.7 to 45.0 cm; Figure 6; Appendix 1).

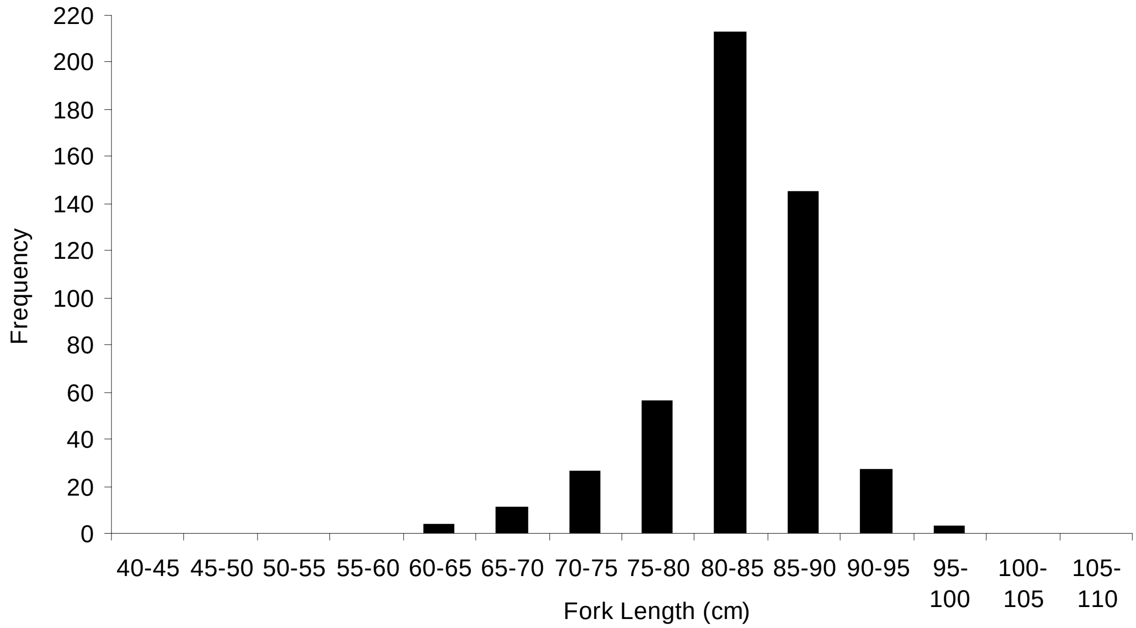

Figure 5. The fork length distribution of female Chinook salmon captured during mark application at Chilko River 2011.

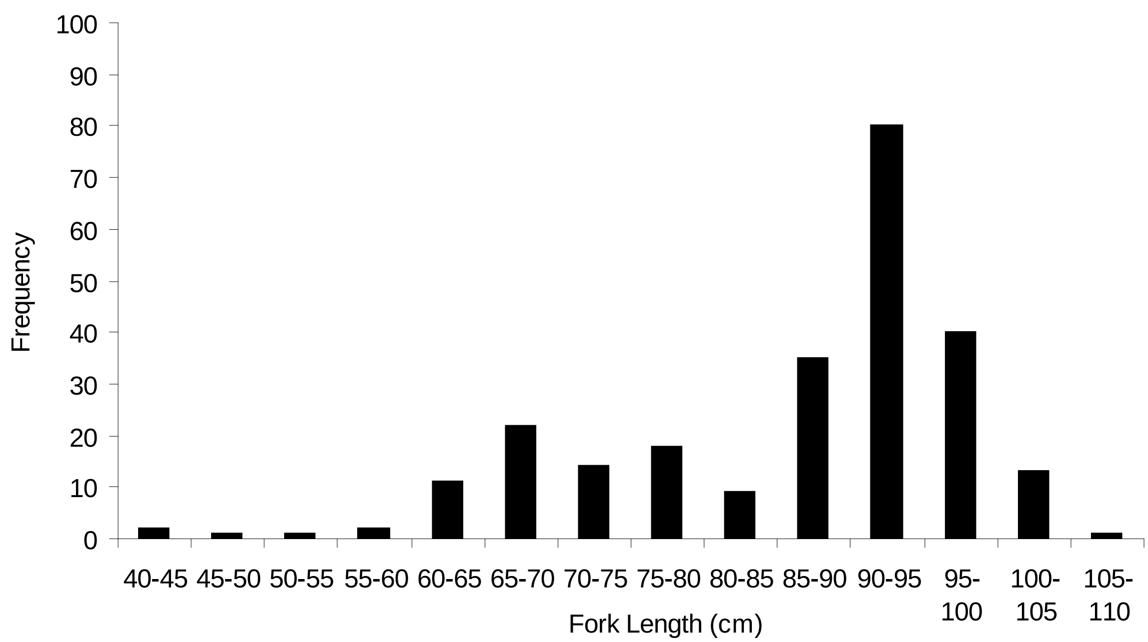

Figure 6. The fork length distribution of male Chinook salmon captured during mark application at Chilko River 2011.

Carcass Recovery

A total of 4,128 carcasses were examined between 6 September 2011 and 27 September 2011 (Appendices 2 & 3). Of this sample, 4,070 were of known sex and used in the mark-recapture data analysis. Within this recovery sample, 386 Chinook salmon were marked and 3,684 were unmarked (Table 2). Within the marked group, there were 126 males and 260 females (Appendices 1& 2). The mean elapsed time (days out) between mark application and the subsequent mark recovery was 22.2 days (Appendix 1).

Table 2. Summary of carcass recovery for Chinook salmon in the Chilko River, 2011.

Sex	Total Carcasses	Primary Mark	Secondary Mark Only	Marked Total
Male	1,466	117	9	126
Female	2,602	256	4	260
Jack	2	0	0	0
Unknown	58	0	0	0
Total	4,128	373	13	386

Reach 6 had the most carcasses recovered (37%) while reach 1 and 2 had the fewest (0%). Peak recovery occurred on the recovery cycle from 20 September 2011 to 21 September 2011. Of the 4,070 sexed adult carcasses examined, 36% were males and 64% were females. Within the recovery sample, males averaged 70.9 cm POHL (range 49.0 to 84.2 cm; Figure 8) while females averaged 69.8 POHL (range 51.2 to 79.6 cm; Figure 7) and small males averaged 43.2 cm POHL (range 38.1 to 48.3 cm; Figure 8).

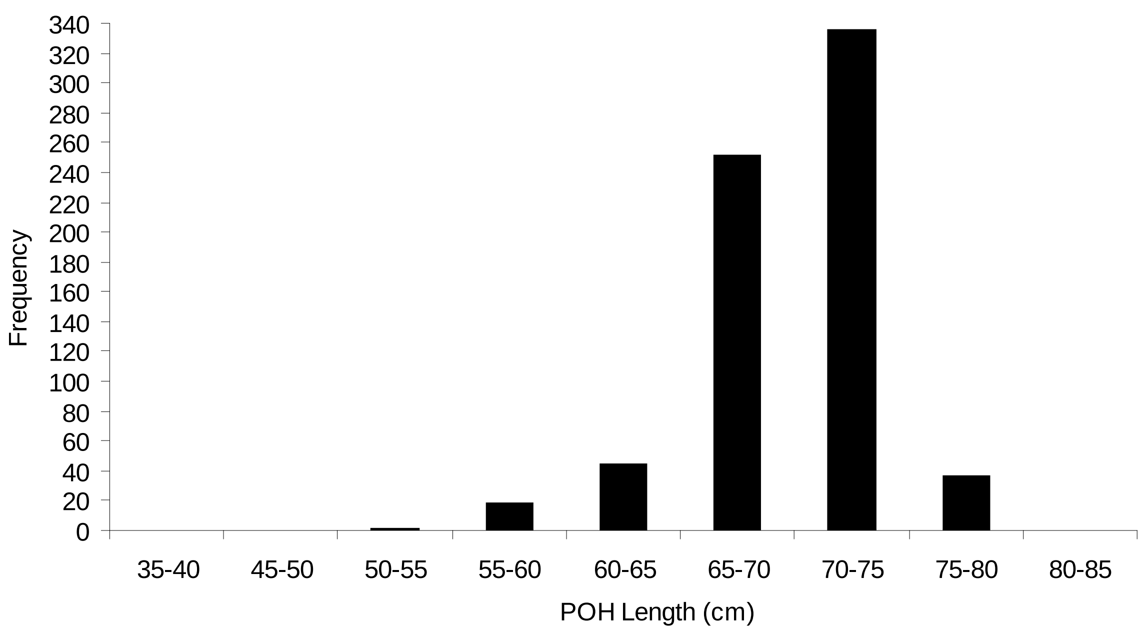

Figure 7. The post-orbital to hypural plate (POH) length distribution of female Chinook salmon sampled during carcass recovery at Chilko River 2011.

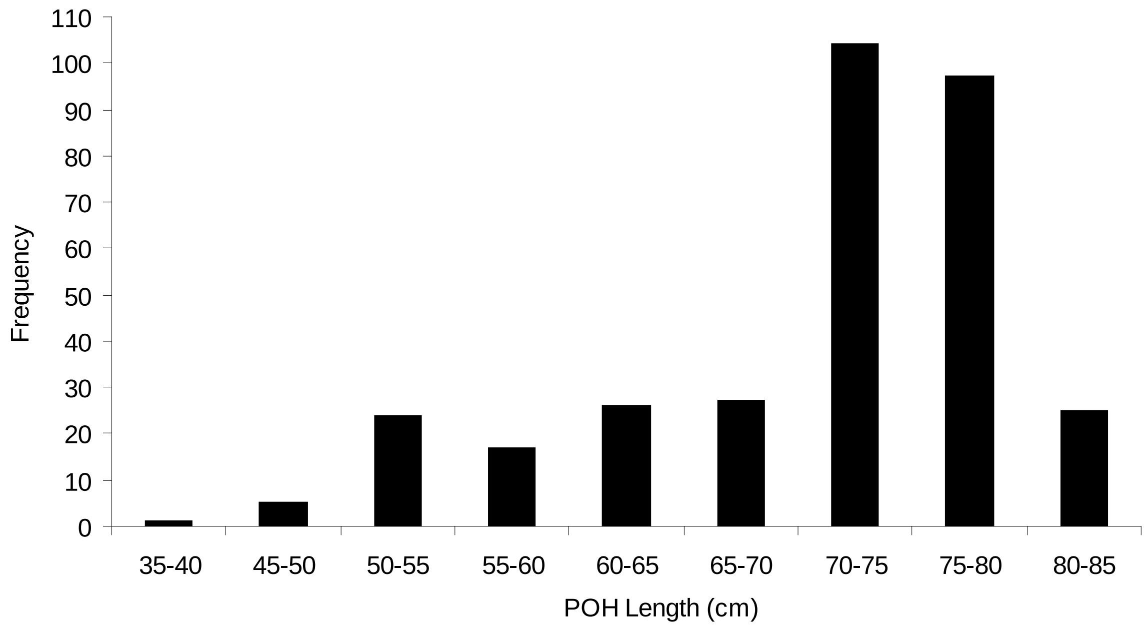

Figure 8. The post-orbital to hypural plate (POH) length distribution of male Chinook salmon sampled during carcass recovery at Chilko River 2011.

At carcass recovery, the sub-sample of scale ages showed this population has stream-type life history, and the scales all had one freshwater annulus, with total ages of four to six years (Appendix 3). The Chinook were primarily age 3.1. Table 3 shows the age composition by sex of the scale sub-sample with complete ages.

Table 3. Age structure for adult Chilko River Chinook salmon for 2011, collected during carcass recovery.

Age		Male		Female		Total	
European	Gilbert Rich	Sample Size	Percent	Sample Size	Percent	Sample Size	Percent
1.1	3_2	0	0	0	0	0	0
1.2	4_2	29	23	25	10	54	15
1.3	5_2	95	75	216	88	311	84
1.4	6_2	2	2	4	2	6	2

ANALYTICAL

Sex Identification Correction

Of the 734 marked Chinook salmon in the application sample, 246 were identified as male, 485 as female, and 3 were identified as small male at the time of release (Table 4). There were 12 sex identification errors among recovered marked fish: 2 fish identified as males at mark application were actually females and 10 females were actually males (Appendix 1). After application of the sex identification correction, the corrected mark releases were 265 (36%) males and 466 (64%) females.

Table 4. Marks applied by sex, including Staley's sex correction factors and sex corrected totals, to Chilko River Chinook salmon, 2011.

	Mark Application		
Sex	Total	Sex Correction Factor[a]	Sex Corrected
Male	246	+0.026	265
Female	485	-0.026	466
Jacks	3	0	3

a. Staley's sex correction factor. Adjust application totals by adding/subtracting male/ 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=0.98; Table 5; Appendix 2).

Table 5. Spawning success rates of marked and unmarked female Chinook salmon for Chilko River 2011.

	Unsuccessful	Successful	Percent Successful
Marked	4	249	98.4
Unmarked	36	2268	98.4

There was no evidence detected for stress related to the length of time male or female Chinook salmon were held until marking (p=0.67 and p=0.92, 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, 2011.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
0-30 Minutes	40	87	0	127	82	144	0	226	48.9	60.4	-	56.2
31-90 Minutes	24	66	0	90	44	109	1	154	54.6	60.5	0.0	58.4
Total	64	153	0	217	126	253	1	380	50.9	60.4	0.0	57.1

a. Corrected for sex identification error.

Of the 734 fish marked, the majority (99.5%) swam away rapidly (release condition 1) after mark application and very few (0.5%) swam away slowly (release condition 2 +3; 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 734 fish marked, 380 were captured by seine net and 354 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 (Table 11).

Following release, 48 previously marked adult Chinook were recaptured during subsequent mark application periods (Table 7; Appendix 1). Five Chinook were recaptured multiple times during the application period. There was no evidence of a difference in marked recovery rate between recaptured and non-recaptured fish (p=0.74; chi-square test).

Table 7. Effect of recapture on recoverability by sex for Chilko River Chinook salmon, 2011.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Times Recap'd	M	F	J	Total	M	F	J	Total	M	F	J	Total
0x	114	233	0	347	251	432	3	686	45.5	53.9	0.0	50.6
1-4x	3	23	0	26	14	34	0	48	21.1	68.1	-	54.2
Total	117	256	0	373	265	466	3	734	44.2	54.9	0.0	50.8

a. Corrected for sex identification error.

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 numbers of carcass recoveries, each stratum contained between 4 and 17 days. The greatest amount of pooling (17 days) was in the first period when sample sizes were smallest. The mean mark incidence was 8.6% (range 5.6% to 10.1%) for males and 10.0% (range 9.3% to 11.1%) for females (Table 8). There was evidence of a difference in mark incidence throughout time for males (p=0.02), as tag incidence increased over time. There was no evidence of a difference in mark incidence throughout time for females (p=0.42).

Table 8. Incidence of primary or secondary marks in Chilko River Chinook salmon, by recovery period and sex, 2011.

	Marked Recoveries				Total Recoveries				Mark Incidence (%)			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
31-Aug	25	67	0	92	450	687	1	1138	5.6	9.8	0.0	8.1
17-Sep	48	91	0	139	493	820	0	1313	9.7	11.1	-	10.6
21-Sep	53	102	0	155	523	1095	1	1619	10.1	9.3	0.0	9.6
Total	126	260	0	386	1466	2602	2	4070	8.6	10.0	0.0	9.5

Temporal bias in the recovery sample was examined by comparing recovery rates among application periods. When the period was stratified to contain approximately equal numbers of marks applied, each stratum contained between 4 and 16 days. The greatest amount of pooling (16 days) was in the early period when daily sample sizes were smallest. The mean percentage recovered was 44.2% for males and 54.9% for females (Table 9). There was no evidence of a difference in recovery rate among periods for both males and females (p=0.17 and p=0.30).

Table 9. Primary marks applied and recovered in Chilko River Chinook salmon, by application period and sex, 2011.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
11-Aug	36	68	0	104	80	134	2	216	45.3	50.6	0.0	48.2
27-Aug	39	94	0	133	75	158	0	233	52.0	59.5	-	57.1
31-Aug	42	94	0	136	110	174	1	285	38.1	54.1	0.0	47.7
Total	117	256	0	373	265	466	3	734	44.2	54.9	0.0	50.8

a. Corrected for sex identification error.

Location

Spatial bias in the application sample was examined by comparing mark incidences among reaches 2 to 8, since no carcasses were recovered in reach 1. Reaches were pooled into two strata: the lower stratum consisted of reaches six, seven and eight; and the upper stratum consisted of reaches two through five. The mark incidence in the lower stratum was 8.2% for males and 8.5% for females (Table 10). The mark incidence in the upper stratum was 9.9% for males and 12.0% for females. There was no evidence of a difference between male mark incidence in the upper and lower spatial recovery strata (p=0.39). There was evidence of a higher mark incidence in the upper versus the lower spatial strata for females (p<0.01).

Table 10. Incidence of primary or secondary marks in Chilko River Chinook salmon, by recovery strata and sex, 2011.

	Marked Recoveries				Total Recoveries				Mark incidence (%)			
Stratum	M	F	J	Total	M	F	J	Total	M	F	J	Total
Lower	92	127	0	219	1122	1489	2	2613	8.2	8.5	0.0	8.4
Upper	34	133	0	167	344	1113	0	1457	9.9	12.0	-	11.5
Total	126	260	0	386	1466	2602	2	4070	8.6	10.0	0.0	9.5

Spatial bias in the recovery sample was examined by comparing the recovery rate between different spatial application strata (Table 11). 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 can be divided into application method (angling, seining). There was evidence of a difference in the percentage of marked fish that were recovered between application method strata for males and females (p<0.05 and p=0.01).

Table 11. Primary marks applied and recovered in Chilko River Chinook salmon, by application method and sex, 2011.

	Marked Recoveries				Marks Applied [a]				Percent Recovery			
Stratum	M	F	J	Tota	M	F	J	Total	M	F	J	Total
Angling	53	103	0	156	139	213	2	354	38.1	48.4	0.0	44.1
Seining	64	153	0	217	126	253	1	380	50.9	60.4	0.0	57.1
Total	117	256	0	373	265	466	3	734	44.2	54.9	0.0	50.8

a. Corrected for sex identification error.

Size

Size-related bias in the application sample was examined by comparing the POH length-frequency distributions (Figure 9, 10, 11, & 12) 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 both males and females (p=0.65 and p=0.37).

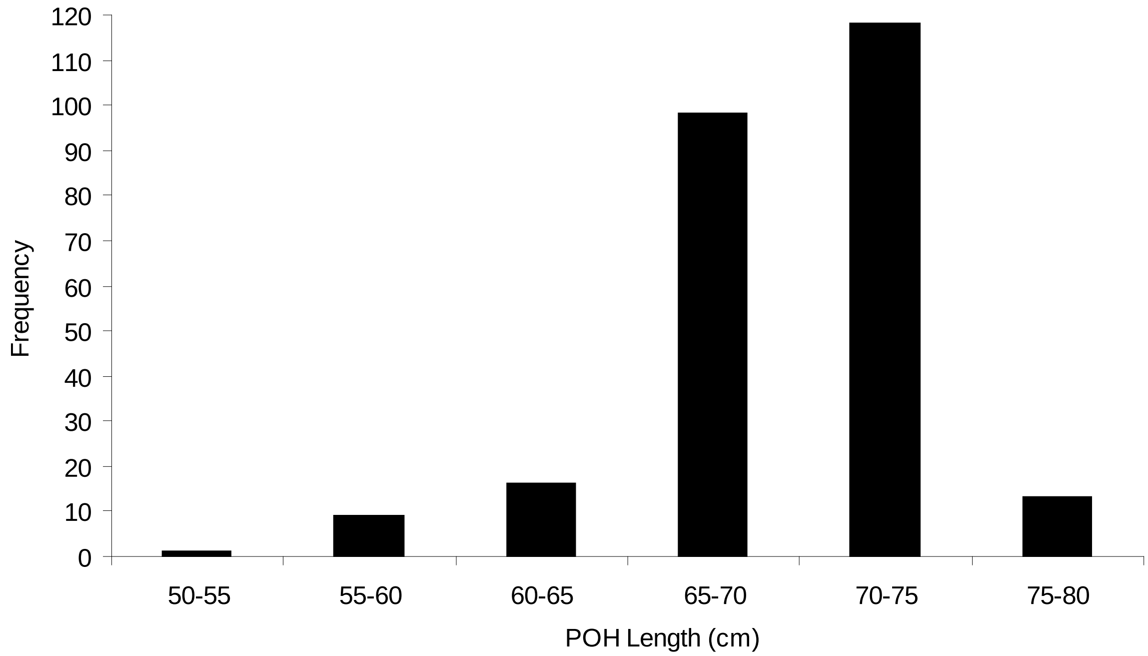

Figure 9. The POH length distribution of female Chinook salmon sampled during carcass recovery at Chilko River 2011 that were marked.

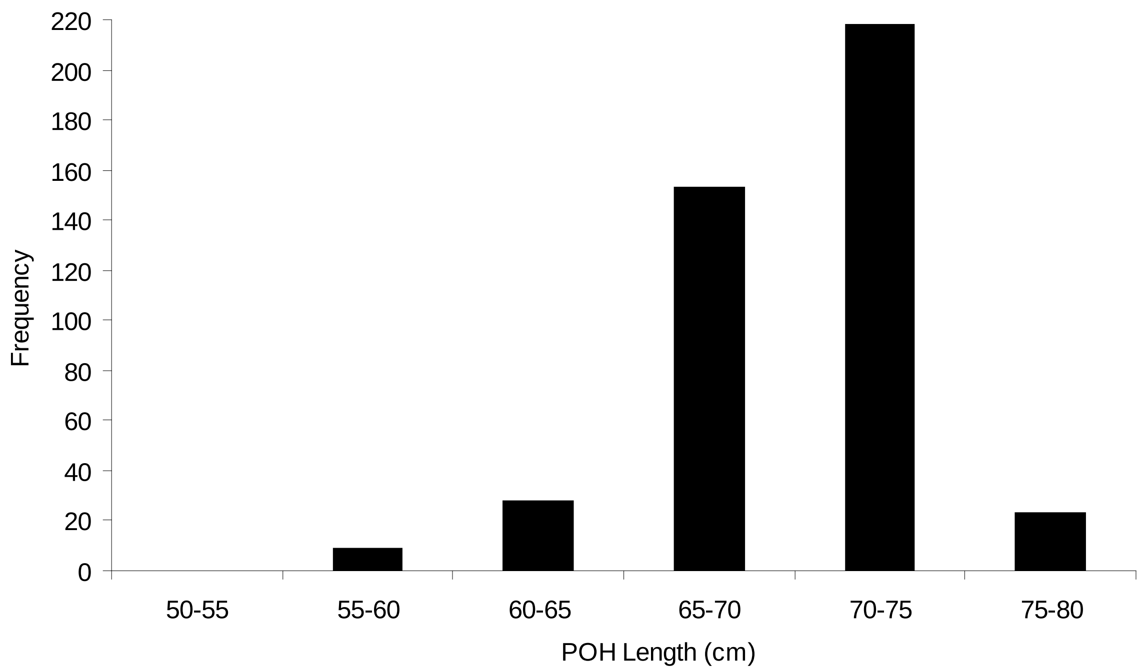

Figure 10. The POH length distribution of female Chinook salmon sampled during carcass recovery at Chilko River 2011 that were unmarked.

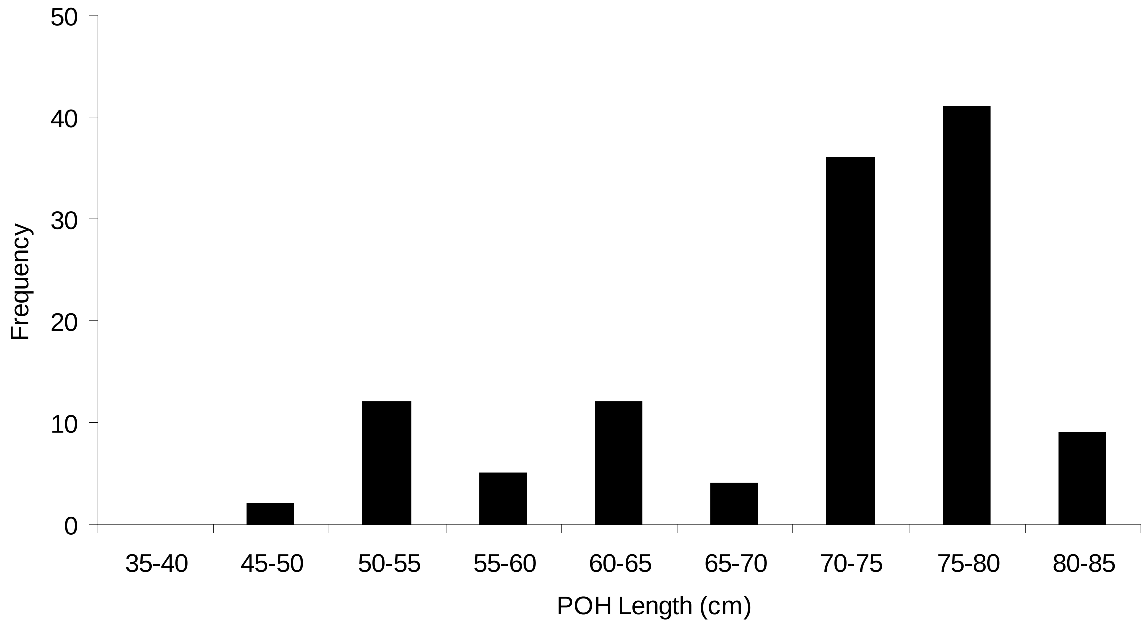

Figure 11. The POH length distribution of male Chinook salmon sampled during carcass recovery at Chilko River 2011 that were marked.

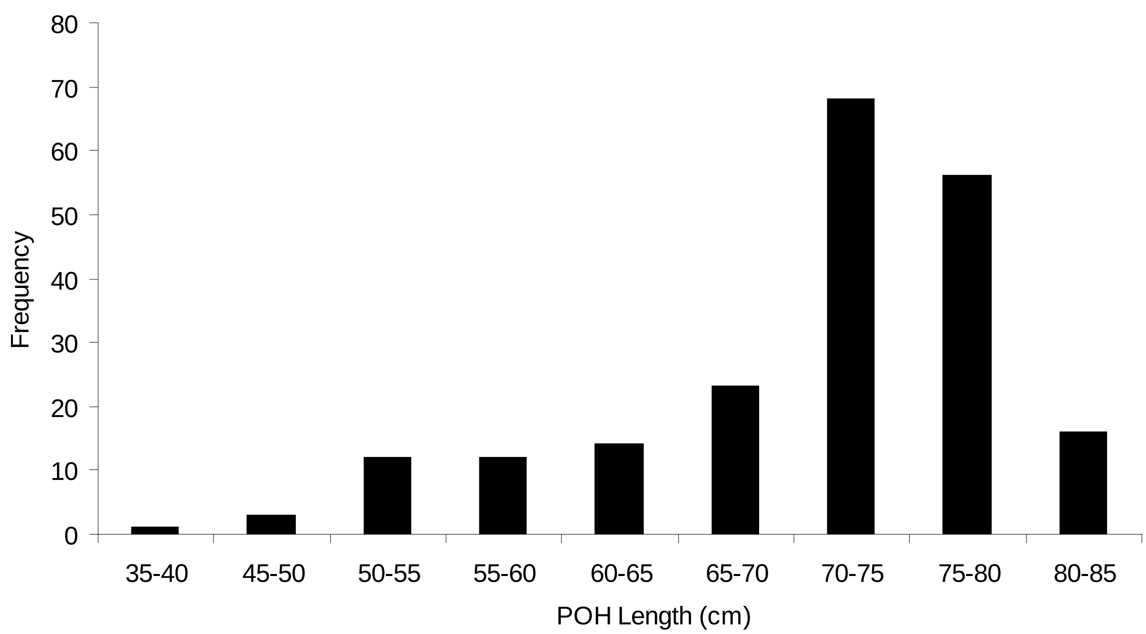

Figure 12. The POH length distribution of male Chinook salmon sampled during carcass recovery at Chilko River 2011 that were unmarked.

Size related bias in the recovery sample was examined by comparing the male and female fork length frequency distributions (Figure 13, 14, 15, & 16) 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 both males and females (p=0.98 and p=0.76).

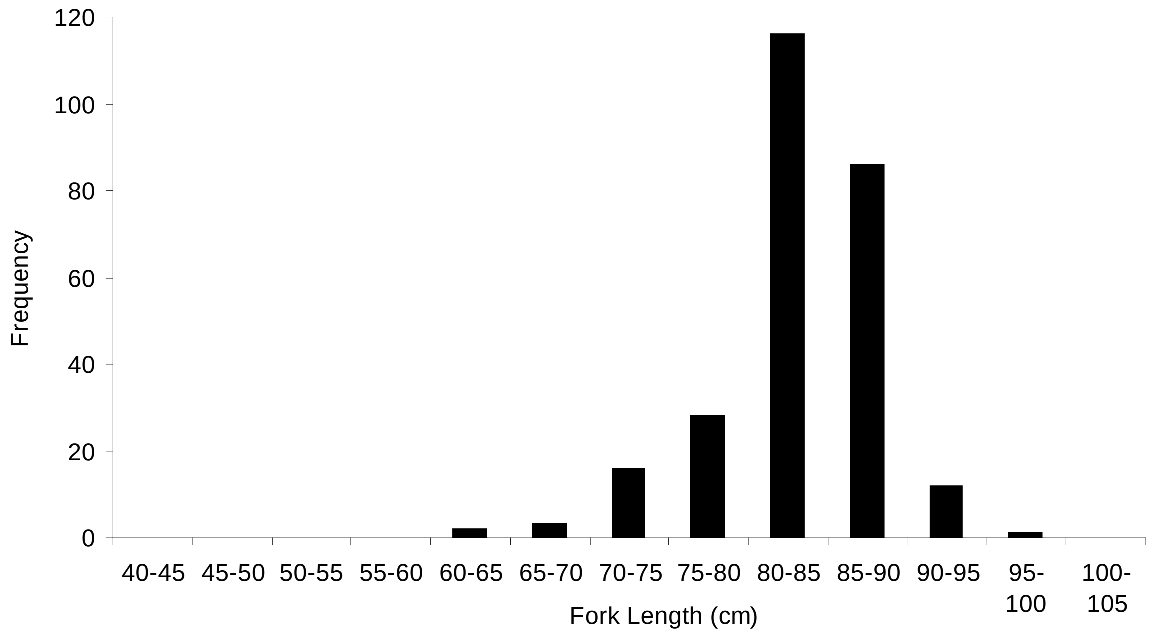

Figure 13. The fork length distribution of female Chinook salmon marked that were recovered at Chilko River 2011.

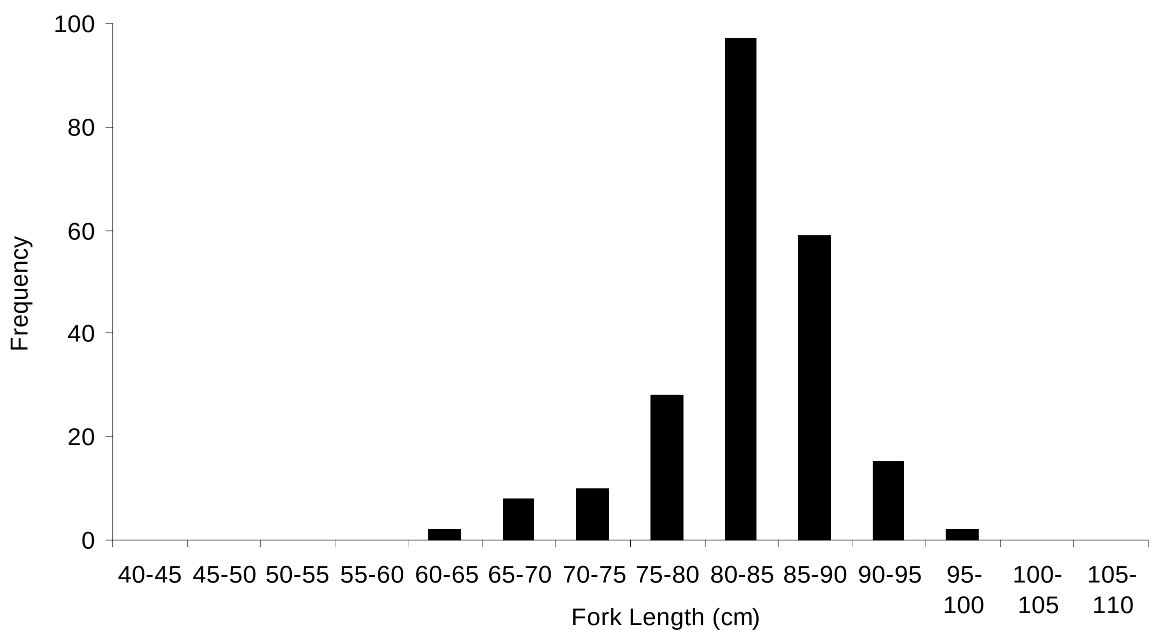

Figure 14. The fork length distribution of female Chinook salmon marked that were not recovered at Chilko River 2011.

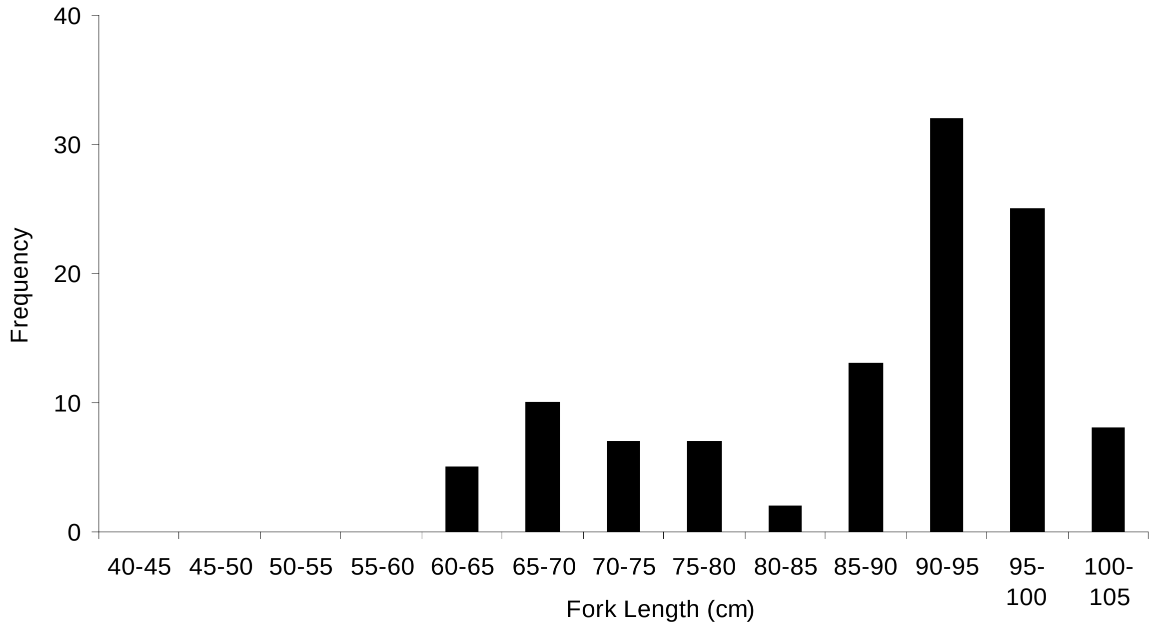

Figure 15. The fork length distribution of male Chinook salmon marked that were recovered at Chilko River 2011.

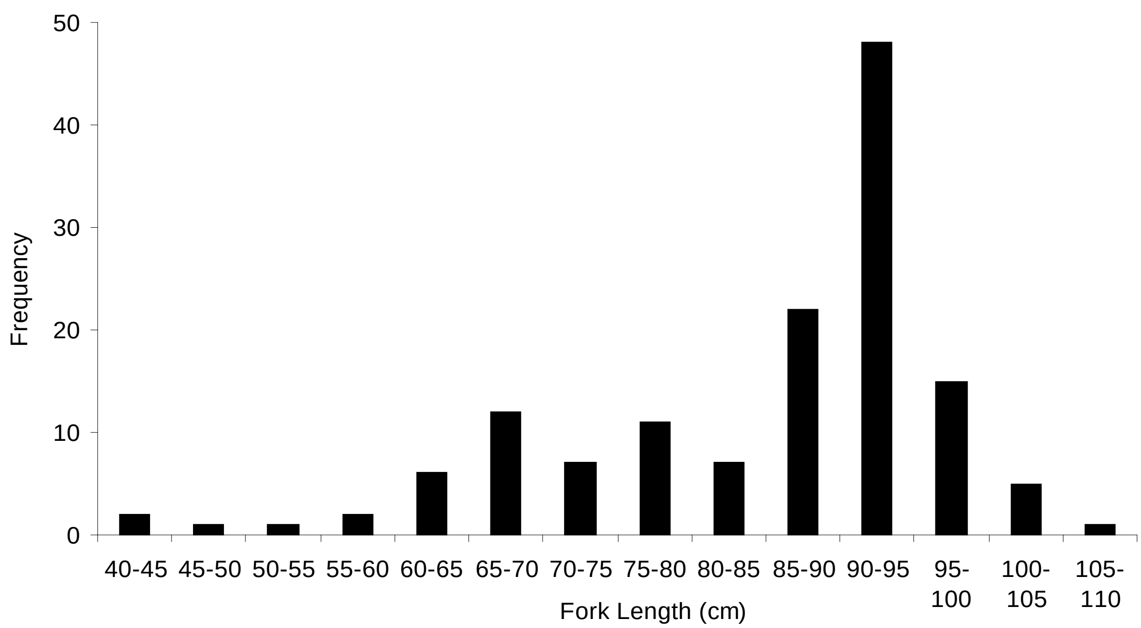

Figure 16. The fork length distribution of male Chinook salmon marked that were not recovered at Chilko River 2011.

Sex

Sex bias in application was assessed by comparing mark incidence between males and females in the recovery sample. Mark incidence was 8.6% for males and 10.0% for females (Table 12). There was no evidence of a difference between male and female mark incidence (p=0.16); therefore, no sex bias at application.

Table 12. Percent mark recovery and incidence of primary or secondary marks between sexes of 2011 Chilko River Chinook salmon.

Sex	Marked Recoveries	Marks Applied[a]	Percent Recovery	Marked Recoveries	Total Recoveries	Mark Incidence (%)
Male	117	265	44.2	126	1466	8.6
Female	256	466	54.9	260	2602	10.0
Total	373	731	51.0	386	4068	9.5

a. Corrected for sex identification error.

Sex bias in recovery was assessed by comparing percent recovery between males and females in the application sample. The percent recovery of males was 44.2% and of females was 54.9% (Table 12). The chi-square test resulted in a p-value of less than 0.01 strongly indicating that there was a sex bias in the recovery sample.

Primary mark loss was 7% for males and 2% for females. The p-value of a chi-square test comparing the rate of tag loss between males and females was 0.01 strongly indicating there was a significant difference between tag loss in males and females.

Age

At carcass recovery, all scale samples showed this population has stream-type life history, and the scales all had one freshwater annulus, with total ages of three to six years (Appendix 3). Table 13 shows the age composition by sex for scale samples with complete ages that were collected during the recovery sample. The one jack sample was a 3_2. Due to small sample sizes, age 3_2 and 6_2 were removed. There was evidence of a difference in age composition between the males and females ($p<0.01$), with a higher percentage of 5_2 for females and 4_2 for males.

Table 13. Age structure for adult Chilko River Chinook salmon for 2011, samples collected during carcass recovery.

	Male		Female	
Age	Sample Size	Percent[a]	Sample Size	Percent[a]
3_2	1	0.4%	0	0.0%

4_2	71	26.2%	69	13.2%
5_2	193	71.2%	448	85.5%
6_2	6	2.2%	7	1.3%

a. Where percentages do not sum to 100, differences are due to rounding error.

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. There was no evidence of a difference in age composition between marked and unmarked samples for males or females (*p*=0.11 and *p*=0.12; Table 14).

Table 14. Comparison of age samples taken from marked and unmarked adult Chinook salmon during recovery in the Chilko River, 2011.

		Male		Female	
	Age	Sample size	Percent	Sample Size	Percent
Marked	3_2	0	0%	0	0%
	4_2	32	32.3%	31	16.3%
	5_2	66	66.7%	158	83.2%
	6_2	1	1.0%	1	0.5%
Unmarked	3_2	1	0.6%	0	0%
	4_2	39	22.7%	38	11.4%
	5_2	127	73.8%	290	86.8%
	6_2	5	2.9%	6	1.8%

Bias Summary

Bias testing results of the adult application and recovery samples for males and females are summarized in Table 15.

Table 15. Results of statistical tests for bias in the 2011 Chilko River Chinook salmon escapement estimation study.

Bias type	Application sample [a]	Recovery sample [a]
Stress	No bias	No bias
Period	No bias	Bias in males
Location	Bias in males and females	Bias in females
Fish size	No Bias	No bias

Fish sex	No bias	Bias
Fish age	n/a	n/a

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

MARK-RECOVERY ESTIMATE OF ESCAPEMENT

Petersen

Due to biases in the application and recovery data, a pooled Petersen estimator was not used to calculate escapement.

Darroch

As there was temporal recovery and spatial application bias in the male data, the data was stratified by both time and space: upper and lower application and early, middle and late recovery strata. The upper application strata consisted of the fish seined at Lingfield while the lower application strata was all the fish angled in reaches 6,7 and 8. The early period for recovery was August 31st to September 15th, the middle period was September 16th to 19th and the late period was from September 20th to 27th. The program SPAS reported strong evidence of incomplete mixing of marked and unmarked males (p=0.01) and an unequal ratio of marked to unmarked males between strata (p=0.01). These results further support the use of the Darroch estimator instead of the Petersen estimator.

Due to evidence of spatial bias in the female application and recovery data, the application and recovery data was stratified spatially. The application data was stratified into upper (marks applied by seining at Lingfield) and lower (marks applied by angling in reaches 6,7 and 8) strata. The recovery data was stratified into upper (fish recovered in reaches 1,2,3,4 and 5) and lower (fish recovered in reaches 6,7 and 8) strata. SPAS reported evidence of incomplete mixing of females (p=0.01) and an unequal ratio of marked to unmarked females between the strata (p<0.01). Considering these results, the maximum likelihood (ML) Darroch model produces the most accurate female estimate (Arnason *et al.* 1996).

Therefore, the 2011 total adult spawning escapement of Chinook salmon to Chilko River was 8,396 with lower and upper 95% confidence limits of 7,523 and 9,269 respectively (Table 16). The male escapement was estimated to be 3,515 ± 734, the female estimate was 4,881 ± 472 (Table 14).

There was insufficient data to generate an estimate of jack escapement using the Darroch estimator (Table 16). A total of 3 tags were applied and 2 carcasses were recovered, none were tagged. Based on that, a minimum of 5 jacks were handled during sampling events. In the future, as the scale sample sizes becomes larger for Chilko River Chinook salmon with fork lengths less than 50cm then a valid estimate of escapement may be generated for these small fish.

Table 16. Escapement estimates derived from 2011 mark-recovery data using a Darroch estimator for Chilko River Chinook salmon, by sex.

	Sex		
	Male	Female	Jack [b]
Carcasses Sampled	1466	2602	2
Marks Applied [a]	265	466	3
Marks Recovered	126	260	0
Percent Recovered	48	56	0
Population Size	3515	4881	na
Coefficient of Variation	11%	5%	na
Lower 95% Confidence Limit	2781	4249	na
Upper 95% Confidence Limit	4410	5353	na

a. Corrected for sex identification error.
b. Insufficient data to generate valid estimate of escapement.

Escapement by Age

The majority of male and female Chinook salmon returning to the Chilko River in 2011 were age 1.3 (Table 17). The male age composition consisted of 0.4% age 1.1, 26.2% age 1.2, 71.2% age 1.3 and 2.2% age 1.4. The female age composition consisted of 0% age 1.1, 13.2% age 1.2, 85.5% age 1.3 and 1.3% age 1.4.

Table 17. Escapement estimates by sex and age for 2011 Chilko River Chinook salmon.

Age		Male			Female		
European	Gilbert Rich	Sample Size	Escapement Estimate	Percent	Sample Size	Escapement Estimate	Percent
1.1	32	1	13	0.4%	0	0	0%
1.2	42	71	921	26.2%	69	643	13.2%
1.3	52	193	2,503	71.2%	448	4,173	85.5%
1.4	62	6	78	2.2%	7	65	1.3%

PEAK COUNT ESCAPEMENT ESTIMATION

In 2011, five aerial surveys were conducted on August 30, September 3, 7, 13, and 19. The highest spawner count (4,415) occurred on the September 13 (Figure 17).

The peak count of Chinook salmon was 4,892 (4,415 spawners, 429 holders and 48 carcasses) also on September 13. The expanded peak count estimate was 7,526.

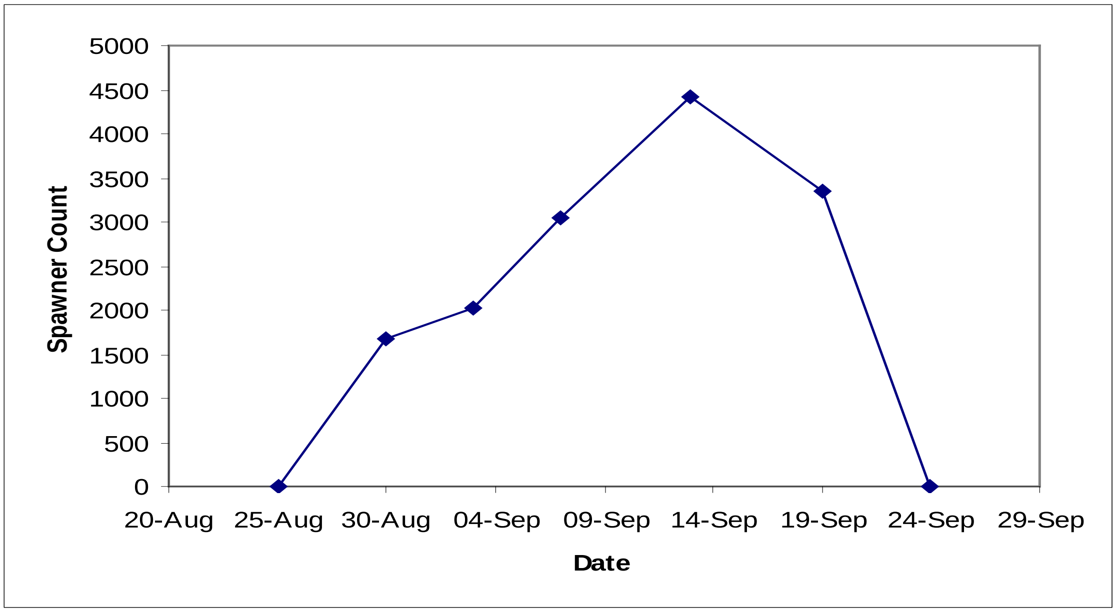

Figure 17**.** Number of Chinook salmon spawners counted by date for the Chilko River, 2011.

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 get a large number of the marks back (Schwarz et al. 1993). During the 2011 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 recovery rate, length distribution and age composition between males and females, the estimation of the spawning population was stratified by sex.

Females were recovered at a higher rate than males, as expected by the behavioural differences between males and females. 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 until 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 Lingfield Dunes and fish were 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, with the latter likely moving downstream for more spawning opportunities. Age composition for 2010 and 2011 showed a higher portion of 4_2 males and 5_2 females. This is consistent with other studies that 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, marking, number of times recaptured, and release condition did not have a significant impact on the subsequent behaviour of the marked fish.

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 2011, we assessed the representativeness of the sampling process by looking for bias in the 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 temporal biases were detected in the application sample for either sex or in recovery sample for females.

There was a significant temporal bias detected in the recovery sample for males, as there was a lower proportion of tagged males recovered in the early period. This bias may have been driven by a delay in the start date of capture by seining; therefore, we recommend starting seining earlier in future studies.

Spatial biases were detected in both the application and recovery samples for female Chinook salmon. There was also weak evidence of a spatial bias at application for males. Spatial biases in the application sample were toward the upper segments for both sexes as the highest mark incidence occurred in the upper segments. For females, the mark recovery rates were also higher in the upper segment. The marks applied in the upper strata were applied by seining at Lingfield Pool. These fish did not distribute evenly from this site and were recovered in and around this area at a higher rate than elsewhere. The majority of the primary holding areas are located in the upper/middle reaches, specifically Canoe Cross and Lingfield Pool (Figure 2). The majority of the spawning habitat is located in Reaches 4 (Lingfield Dunes) & 7 (The Braids; Figure 2). To minimize spatial and temporal biases in future studies we recommend continuing to evenly distribute application effort between the lower strata (angling; strata 6-8) and the upper strata (seining; strata 4) so that the numbers applied reflect the distribution of Chinook salmon throughout time and the Chilko River.

As spatial bias at application and temporal bias at recovery were identified for males, stratifying the application sample by location and the recovery sample by period was recommended. As spatial biases were identified in both the application and recovery samples for females, stratifying both the application and recovery sample by location was recommended. For both males and females, SPAS did not identify a need to use a temporally stratified estimator. For males, SPAS did not identify a need for a spatially stratified estimator. However, SPAS did indicate a requirement to use a spatial by temporal approach for males and a spatially-stratified approach for females. Based on these results, we employed the spatially by temporally stratified ML Darroch for males and a spatially stratified ML Darroch for females to generate escapement estimates of 3,515 males and 4,881 females for a total escapement of 8,396 (CV = 5%).

Based on the 2011 results of the Chilko River Chinook salmon mark-recapture project and data analyses, recommendations 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; 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. Therefore, it is not surprising that the mark-recapture estimate of adult escapement of 8,396 (range 7,522-9,270) exceeded the Peak Count estimate of 7,526; however, they were not materially different. 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 1.78 and 1.72 (2010 and 2011) of the Peak Count were necessary to meet the mark-recovery escapement estimate. The 1995 Nicola River study noted an even 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 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 2011, the Chilko River Chinook salmon estimate was still negatively biased. On the Lower Shuswap River the spawning area and timing of spawn between Chinook and sockeye salmon overlaps; therefore, the ability to count Chinook salmon decreases with the presence of large numbers (>500,000) of sockeye salmon. In 2011, the ability to count Chinook at Chilko River may have been affected by the large return of sockeye and more years with measured expansion factors are necessary to represent average conditions. Until more calibration information is collected, we recommend using the 1.54 expansion factor that is currently used to expand all Fraser Chinook salmon peak count estimates.

The results of the 2011 Chilko Chinook assessment program indicate that the spawning escapement can be estimated with high precision. This study produced precise (CV) escapement estimates for males (11%) and females (5%), which is consistent with the PSC Chinook Technical Committee's (CTC) data standards (CV<15%). Also, a high percentage of male (42%) 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 adult 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 were 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 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 first two 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 2011 was estimated by mark-recapture.

2. Marks were applied to 737 Chinook salmon: 382 of them were captured by seine net and 355 by angling. Three of those marks were applied to jack (<50 cm FL) Chinook salmon: 1 caught by seine net and 2 caught by angling. Three marked females were recovered in First Nation fisheries and were subsequently removed from bias testing and escapement estimates. Therefore, 731 adult marks were used for mark-recapture purposes.

3. After correction for sex identification errors, the application sample consisted of 265 males, 466 females, and 3 jacks.

4. In the recovery sample, 4,128 Chinook carcasses were sampled and 4,070 were identified by sex and 386 had primary or secondary marks.

5. The recovery sample had 1,466 males; 2,602 females; 2 jacks; and 58 that could not be identified for sex. The male age composition consisted of 0.4% age 1.1, 26.2% age 1.2, 71.2% age 1.3 and 2.2% age 1.4. The female age composition consisted of 0% age 1.1, 13.2% age 1.2, 85.5% age 1.3 and 1.3% age 1.4. All 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. Spatial and temporal biases were detected.

7. Based on the radio telemetry from 2010 and aerial survey data from both 2010 and 2011, the mark-recapture assumption of closure was met; however, the 2010 telemetry data as well as the 2010 and 2011 bias testing indicated incomplete mixing, as the majority of male and females spawned and were recovered in the same area that they were released (upper and lower).

8. There was evidence of spatial bias in the application sample for both sexes. There was also evidence of male temporal bias and female spatial bias in the recovery samples. 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 fish in the strata the maximum likelihood (ML) Darroch estimate would be more appropriate than the Petersen estimate for both sexes.

9. The 2011 total adult spawning escapement of Chinook salmon to Chilko River was 8,396 with lower and upper 95% confidence limits of 7,523 and 9,269 respectively. The male escapement was estimated to be 3,515 ± 734; the female estimate was 4,881 ± 472.

10. Aerial surveys of Chinook salmon spawners, holders, and carcasses were conducted between 30 August 2011 and 19 September, 2011. The September 13 flight was the peak count with 4,892 (4,415 spawning, 429 holding, and 48 dead) Chinook salmon observed.

11. The peak count on 13 September 2011 produced an escapement estimate of 7,526 Chinook salmon using the Fraser River Chinook peak count expansion factor (1.54). This escapement estimate was 90% of the mark-recapture escapement estimate. The measured peak count expansion factor was 1.72 based on the peak count and ML Darroch estimate.

12. The residence time was 9.0 days (CV=1%) based on the spawner surveys and the ML Darroch estimate.

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APPENDICES

- Included in separate document -