Enumeration and Calibration of Chinook Salmon Escapements to Two Clear B.C. Interior Streams, 2007

Prepared for:
Pacific Salmon Commission:
Southern Boundary Restoration and Enhancement Fund

Prepared by:
M. Chamberlain[1] & C. Parken[2]

Fisheries & Oceans Canada
Science Branch, Pacific Region

[1]985 McGill Place
Kamloops, British Columbia.
V2C 6X6

[2]Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, British Columbia
V9T-6N7

April 2008

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In the BC Interior, spawner indices for chinook are chiefly generated from visual surveys conducted at or near the peak of spawning activity. Little information exists from this area to convert spawner indices to total estimates of escapement. Since rivers can be grouped by common visual counting conditions that influence the accuracy of counts (e.g. river size and water clarity), we used known statistical property enumeration data collected on the summer run (4_1) chinook salmon occupying the Lower and Middle Shuswap rivers to calculate stream-specific expansion factors and average-stream expansion factors for chinook in large clear rivers. 2007 was the second year in which paired enumeration activities were conducted in the Middle Shuswap River and the eighth time paired enumeration activities were conducted on the Lower Shuswap River.

It is hoped that with this information, we will be able to predict biases in escapement estimates from applying an average-stream expansion factor and to assess those biases against standard guidelines currently being developed by the Chinook Technical Committee (CTC). Expansion factors collected from the Middle Shuswap River is to be compared to those collected from the larger Slower Shuswap River dataset. Data will also be analysed in a Regional meta-analysis to make the best use of available information.

For this project we used Peterson mark-recapture methods on the Middle and Lower Shuswap Rivers to develop the high precision escapement estimates against which the visual counts will be evaluated. Spawning escapements to other Fraser River tributary areas have been estimated by the Petersen mark-recapture method. This estimation technique has the advantage that confidence limits about the population estimate can be determined (Seber 1982). The validity of escapement estimates derived by such mark-recovery projects is influenced by several assumptions underlying the mark-recovery method (Seber 1982). The Petersen method will produce an accurate estimate of the actual population size if several criteria are met. These criteria are that: the population is closed; all animals are equally vulnerable to capture in the application sample; mark application does not affect subsequent catchability; the recovery sample is taken at random; marks are not lost; and all marks are reported (Seber 1982). Extensive bias testing was done in both investigations to evaluate if the mark-recapture assumptions were met.

Funding for the Middle Shuswap River portion of this project was provided by the Southern Boundary Restoration and Enhancement Fund.

STUDY AREA

The Lower and Middle Shuswap Rivers are part of a complex system in the North Okanagan that drains a mountainous watershed in southern interior British Columbia.

The Middle Shuswap River initially flows south and then west from Sugar Lake for 32 kilometres, before flowing north for a further 22 kilometres before draining into Mabel Lake (Figure 1). Water flow within the Middle Shuswap is regulated by two dams within the system, the first, the Peers dam, is located at the outlet of Sugar Lake and the second, the Wilsey dam, is located at Shuswap Falls, approximately 22 kilometres upstream of Mabel Lake. Wilsey dam is a barrier to the upstream migration of fish from the lower reaches of the Shuswap River system. The mark-recapture investigation on the Middle Shuswap River chinook was conducted on that portion of the river located between Wilsey dam and Mabel Lake. The study area was divided in five strata.

The Lower Shuswap River flows southwest from Mabel Lake for approximately 40km until it reaches the town of Enderby. The flow then changes to a northerly direction until the river enters Mara Lake and ultimately Shuswap Lake at Sicamous. The total length of the lower Shuswap River is approximately 80km. The study area includes the section from the upper river terminus at Mabel Lake downstream to the BC Hydro power lines just east of Enderby and is approximately 35km in length (Figure 1). For mark-recapture and aerial escapement estimation purposes, this study area is divided into nine strata.

The Middle and Lower Shuswap Rivers supports populations of four species of Pacific salmon; chinook, coho (*O. kisutch*), sockeye (*O. nerka*), and pink (*O. gorbuscha*).

METHODS

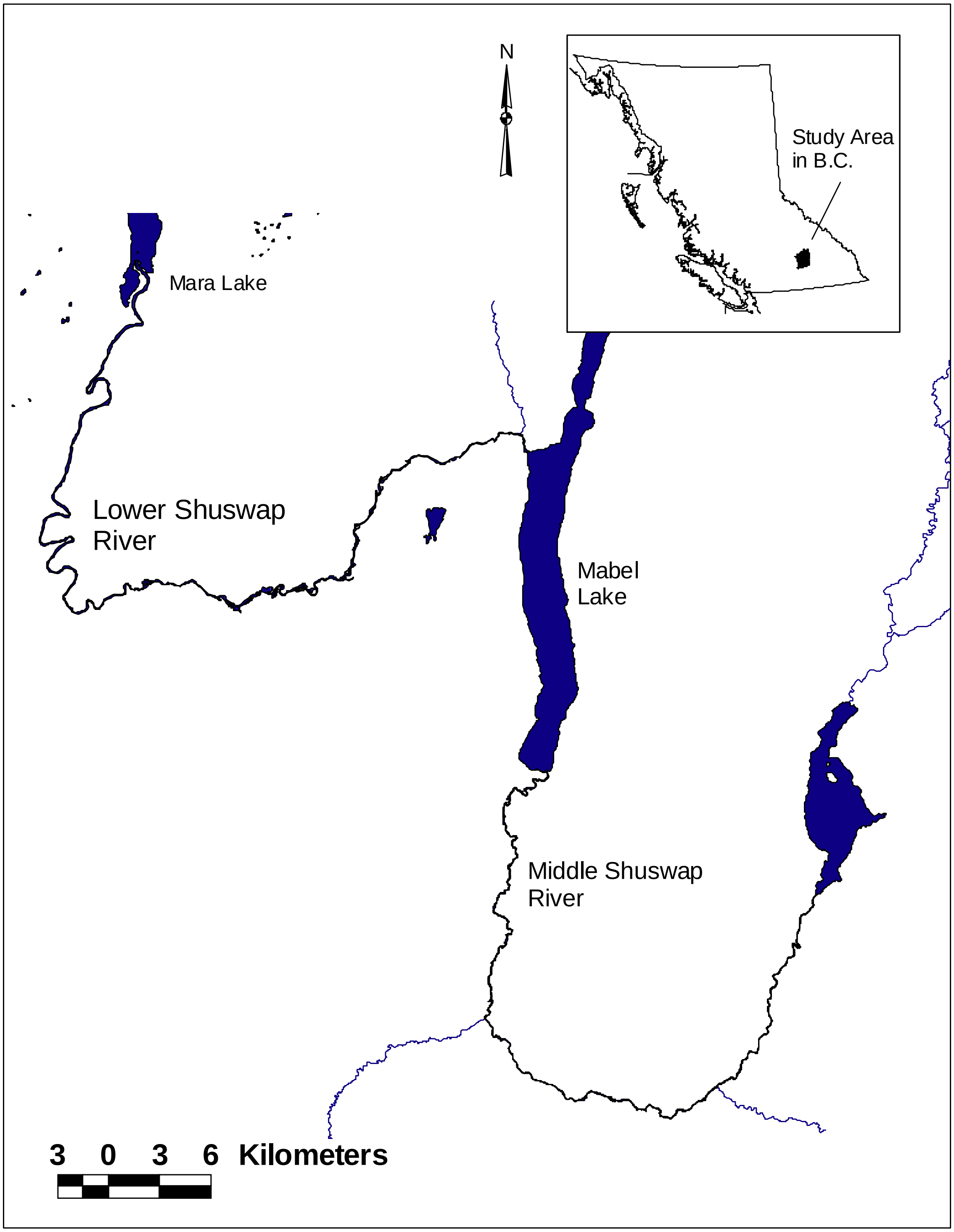
MARK-RECAPTURE

A two-event mark-recapture experiment was used to estimate abundance of chinook salmon spawners at Middle and Lower Shuswap Rivers. During the first event, a representative sample of chinook salmon were captured by beach seining and/or angling throughout the entire river and run, and subsequently tagged and released. Fish were sampled for marks during event two, a carcass recovery conducted throughout each system. Data analyses includes several statistical tests to assess weaknesses in the study design by examining size, temporal, spatial, and sex sampling biases.

Tag Application

Chinook were captured by angling in the Middle Shuswap River between 23 August and 21 September, 2007. Capture and marking was attempted in the strata one to four in areas utilized by pre-spawning chinook. Anglers used size 3 single barbless hooks (Eagle Claw L183F) baited with salmon eggs treated with borax. Chinook were landed and either processed immediately, or held for up to

Figure 1. Lower and Middle Shuswap River's chinook calibration study area.



15 minutes in large recovery pens, anchored instream in a manner to permit suitable water flow prior to processing.

In the Lower Shuswap River, chinook salmon were captured for tag application by beach seining from 12 September to 6 October, 2007. Stream morphology and the absence of adequate chinook holding water restricted seining to strata 1, 2, 4, 5 and 8. The seine net was set by powerboat in a downstream or upstream crescent and drawn from the river to enclose a portion of water along the riverbank. Once the seine was set in an arc it was withdrawn from the river until it enclosed a small area of water along the shore to allow quick capture of the fish for tag application. Two sizes of seine nets with 2” mesh were used: 150’ x 28’ and 220’x 30’. Captured salmon were held in the water until being moved to the tray for tag application (Farwell et al. 1999).

In both systems, after capture, fish were placed in the canvas cradle of the tagging tray in shallow, flowing water close to shore. Two Peterson tags, 2.2 cm diameter clear cellulose acetate disks, were applied to every chinook salmon (Farwell et al. 1999). One Petersen disk was uniquely coded with a 5 digit number and the other was a blank transparent disk. The Petersen 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. Disks were held tightly against the fish by twisting the pin into a knot. Sex specific operculum punches 0.6cm in diameter, as secondary marks, were applied on the left operculum of every tagged fish: two punches for a female and one for a male. Each fish’s tag number, fork length (± 0.5 cm), sex, adipose fin clip status (presence or absence), scarring, type of secondary mark, and release condition were recorded. For angled fish the relative amount of bleeding from the area of the hook as where the fish was hooked were also recorded. The hooking location was later categorized as either critical (roof of mouth, gills, tongue, or eye) or non-critical. The date, person tagging, tagging location and time were also recorded. During tag application, any previously tagged chinook salmon and all other fish species captured were recorded and released.

Carcass Recovery

Sampling of chinook carcasses in the Middle Shuswap River commenced on 24 September and continued until the 17 of October. In the Lower Shuswap River, carcasses sampling commenced on 1 October and continued until 29 October. Carcass recovery activities ended after the peak of die off when few if any carcasses were available for recovery.

To recover carcasses, daily surveys of both river shores and pools were conducted from late September to late October. In a downstream direction, four recovery crews of two-people processed carcasses from the river banks and near shore areas by foot wherever water depth permitted and rafts when water was too deep. Two additional two-people crews used powerboats and gaffs to recover and process carcasses from deep areas along cutbanks, pools, and midstream areas. The spawning ground surveys and carcass recovery operations were similar to those used on the Harrison River and are described in Farwell et al. (1999).

During recovery, chinook carcasses were removed from the river using peughs or gaffs and were placed on the riverbank for examination. Complete sample information was collected from marked fish; adipose-absent fish; the 20th unmarked, adult fish; and the 5th unmarked jack encountered. Complete sample information consisted of the date, recovery crew members, strata number, sex, Petersen disk tag presence and number, post-orbital to hypural plate (POH) length ($\pm$ 0.5 cm), secondary mark status, female percent spawn, carcass condition, adipose fin clip status (present or absent), adipose fin clip (AFC) condition, number of eyes, and recovery method (shore/beach or gaff) were recorded for each carcass recovered. Heads and complete sample information were taken from all AFC fish and an individual head identification code was applied and recorded. Heads are to be sent to the Vancouver lab for coded wire tag removal and decoding. Scales were collected and placed in scale books, and are being aged by the Biological Station in Nanaimo. Examined carcasses were cut in half using a machete to prevent re-counting.

AERIAL ENUMERATION

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}).

In the Middle Shuswap River the helicopter flew in a downstream direction and on the Lower Shuswap River the helicopter flew in an upstream direction, flight direction was determined by the ability to achieve the optimal viewing conditions. 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 machine was flown slowly in a “crab” style to provide observers with the best view of the fish. Observers used tally counters to keep track of their individual counts of chinook salmon. Fish were recorded as either live or dead by stratum. Live fish were counted in two categories: spawning if they were on the shallows and clearly associated spawning habitat, and holding if they were holding in pools and not associated with spawning habitat (Faulkner and Ennvor, 1995).

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’s or 10’s. This is the standard method used by DFO and partners to count Upper Fraser chinook and coho salmon.

At the end of each strata count, the observers recorded their individual tallies, discussed their observations, and determined the best count for the strata. 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. A study of chinook salmon escapement on the Nechako River also uses the same system, the maximum count obtained by the two observers in each section was used in calculations to estimate escapement as it was considered to most accurately reflect the subsequent actual population present (Faulkner and Ennevor, 1995).

Flight dates were scheduled to occur prior to and during the expected peak of spawning activity. In 2007, on the Middle Shuswap River flights were conducted 18, 21 and 27 September; and 1 and 4 October. On the Lower Shuswap River flights were conducted on 27 September and on 1, 4, and 9 October.

Aerial flight data was expanded using both the Peak Count and AUC method.

ANALYTIC PROCEDURES

Tests for Sampling Selectivity

In order to meet the criteria for a statistical valid mark-recapture investigation application and recovery data is tested to ensure one of the five principles needed to conduct a successful mark-recapture experiment are not violated.

Bias testing procedures on the mark-recapture data for both Shuswap systems was presented in Chamberlain and Parken 2006, and is not presented in this report.

ESTIMATION OF SPAWNER POPULATION

Mark-Recovery Escapement

The adult chinook salmon populations within the Middle and Lower Shuswap River study areas were estimated using the Chapman modification of the Petersen estimator (Ricker 1975). In anticipation of significant sex related differences in the data, and in order to facilitate comparison with past or similar studies, the escapement was calculated by sex. The escapement to the river (N_t) was the sum of the male (N_m) and female (N_f) escapements. Male escapement was estimated by:

$$N_m = \frac{(M_m + 1)(n_m + 1)}{(m_m + 1)} - 1$$

where:

M_m = number of males released with primary and secondary marks corrected for sex identification errors;

m_m = number of primary and/or secondary marked male carcasses recovered; and

n_m = number of male carcasses examined for marks.

Standard error (square root of the variance) of the male escapement estimate was calculated as:

$$SE_m = \sqrt{\frac{(M_m + 1)(n_m + 1)(M_m - m_m)(n_m - m_m)}{(m_m + 1)^{\wedge 2}\,(m_m + 2)}}$$

and the 95% upper and lower confidence limits on the male estimate were calculated as:

$$N_m \pm 1.96\ SE_m$$

The female spawning escapement (N_f) and its confidence limits were calculated in an analogous manner. Confidence limits around the total escapement were calculated from the square root of the summed male and female variances.

Sex Identification Correction

Identification errors occurred because sexually dimorphic traits were not fully developed at the time of marking and internal examinations were not possible until the carcass survey. For determination of sex specific population sizes, tag application data were corrected for sex identification error using the method described by Staley (1990).

Adipose Fin Clipped Escapement

The spawning escapement of AFC chinook was calculated for the Lower Shuswap River only. The number of AFC chinook in the escapement was calculated from the AFC incidence in the Lower Shuswap River carcass recovery sample only. This sample was the larger of the two samples and reflected the incidence of AFC fish remaining after removal of hatchery brood stock. The AFC incidence in the recovery sample was tested for differences (chi-square test) related to clip condition. If significant differences were noted, questionable clips were removed from further analysis. AFC escapement was the product of the sex specific AFC incidence and the sex specific Petersen population estimate. Differences in AFC incidence by sex were tested for significance. Ninety-five percent confidence limits on the AFC escapement were not calculated.

RESULTS

FISH CAPTURE AND MARK APPLICATION

In the Middle Shuswap River, 57 individual chinook salmon were captured by angling, between 23 August and 6 September. A further seven chinook salmon were captured on 19 September by beach seining. A total of 64 chinook salmon were Peterson disc tagged and released into the Middle Shuswap River. Of those fish marked, one was harvested by local First Nations; five were recaptured and used for brood stock at the Middle Shuswap River Hatchery. All six fish were removed from the application sample.

Of the 58 marked chinook salmon within the Middle Shuswap River application sample, 32 were identified as male, and 26 were identified as female. Analysis of the recovery sample indicated that no sex identification errors were observed at time of application. For the purpose of this report jacks were not included in the bias testing or the population estimation analysis (Table 1).

	At Mark Application		Corrected for identity errors	
Sex	Total	Adipose fin absent[a]	Total	Adipose fin absent[a]
Male	32	0	32	0
Female	26	0	26	
Total	58	0	58	0

a. Included in total.

Table 1. Marks applied, by sex and adipose fin status, and sex identity errors in Middle Shuswap River chinook salmon, 2007.

In the Lower Shuswap River, 1,423 individual chinook salmon were captured through beach seining between 12 September and 6 October 2007. At total of 1,423 chinook salmon were Peterson disc tagged are released into the Lower Shuswap River. Of those marked fish, two were collected for brood stock and four had questionable data associated with their recovery. All six fish were subsequently removed from the application sample.

Of the 1,417 marked chinook salmon within the Lower Shuswap River application sample, 610 were identified as male, 727 were identified as female and 80 were identified as jacks. Analysis of the recovery sample indicated that there was a slight sex-identification error at the time of application. The sex corrected application sample was 627 males and 710 females. As with the

Middle Shuswap River investigation, jacks were not included in the bias testing or the population estimation analysis (Table 2).

	At Mark Application		Corrected for identity errors		
Sex	Total	Adipose fin absent[a]	Error Rate (%)	Total	Adipose fin absent[a]
Male	610	9	9 (0.98)	627	9
Female	727	5	3 (0.01)	710	5
Total	1417	14		1417	14

a. Included in total.

Table 2. Marks applied, by sex and adipose fin status, and sex identity errors in Lower Shuswap River chinook salmon, 2007.

CARCASS RECOVERY

Carcass recovery was carried out on the Middle Shuswap River from 24 September to 17 October. A total of 328 carcasses were examined during the recovery period of which all were suitable for inclusion in the mark-recovery samples. Of the 328 sexed carcasses, there were 18 chinook that were either primary or secondary marked and 310 unmarked fish (Table 3). Of the carcasses there were 9 and 9 marked males and females, and 98 and 212 unmarked males and females, respectively.

		Primary Mark			Adipose Fin	
Sex	Total Carcasses	Peterson Disc	Secondary Mark only	Total	Absent	Present
Male	107	9	0	9	0	107
Female	221	9	0	9	0	221
Total	328	18	0	18	0	328

Table 3. Carcass recovery and marked carcasses by sex and adipose fin status in the Middle Shuswap River, 2007.

On the Lower Shuswap River carcass recovery was carried out on the Lower Shuswap River from 1 to 29 October. A total of 7,918 carcasses (excluding jacks) were examined and included in the mark-recovery samples. Of the 7,918 sexed carcasses, there were 671 chinook that were either primary or secondary marked and 7,247 unmarked fish (Table 4). Of the carcasses there were 267 and 404 marked males and females, and 3,175 and 4,072 unmarked males and females, respectively.

		Primary Mark			Adipose Fin	
Sex	Total Carcasses	Peterson Disc	Secondary Mark only	Total	Absent	Present
Male	3,442	248	19	267	34	3,408
Female	4,476	397	7	404	28	4,448
Total	7,918	645	26	671	62	7,856

Table 4. Carcass recovery and marked carcasses by sex and adipose fin status in the Lower Shuswap River, 2007.

AERIAL ENUMERATION

Middle Shuswap River

Five aerial enumeration flights were undertaken between 18 September and 4 October. The highest live count (681) occurred on the 27 September flight. The 27 September count was 50% higher than the live count (344) on 21 September. During the peak count on 18 September, 88% were actively spawning, and 12% were holding. Seven days earlier, 61% of the chinook were spawning while three days later 100% of the fish were spawning. (Table 5)

Lower Shuswap River

Four aerial enumeration flights were undertaken between 27 September and 9 October. The highest live count (9,400) occurred on the 4 October flight, however the date with the highest proportion of spawning chinook salmon was 9 October (92% of 7,307) (Table 5).

Date	System	Chinook Observed			
		Holding	Spawning	Carcasses	Total
27-Sep-07	Lower Shuswap	6,020	369	3	6,392
1-Oct-07	Lower Shuswap	4,765	3,312	11	8,088
4-Oct-07	Lower Shuswap	1,941	7,459	30	9,430
9-Oct-07	Lower Shuswap	600	6,707	183	7,490
18-Sep-07	Middle Shuswap	479	73	0	552
21-Sep-07	Middle Shuswap	132	212	15	359
27-Sep-07	Middle Shuswap	85	596	14	695
1-Oct-07	Middle Shuswap	0	486	54	540
4-Oct-07	Middle Shuswap	0	309	65	374

Table 5. Summary of aerial chinook enumeration, Lower and Middle Shuswap Rivers, 2007.

ESTIMATION OF SPAWNER POPULATIONS

Mark-Recovery Escapement

For both systems, the mark-recovery data used to calculate spawning population size was comprised of the number of marks released and available for recovery (corrected for sex identification errors), the number of carcasses examined within the study area, and the number of marks recovered within the study. The data were stratified by sex.

The 2007 spawning escapement of 954 Middle Shuswap River chinook salmon was calculated by summing the sex specific Petersen population estimates (Table 6). Lower and upper 95% confidence limits on this estimate were 512 and 1,396, respectively. The male escapement was estimated to be 355 (37%) while the female estimate was 598 (63%).

	Sex		
	Male	Female	Total
Carcasses Sampled	107	221	328
Marks Applied	32	26	58
Marks Recovered	9	9	18
Percentage Recovered	28%	35%	31%
Population Size	355	598	954
Lower 95% Confidence Limit	188	324	512
Upper 95% Confidence Limit	523	873	1396
Precision	47%	46%	46%
AFC Incidence d	0%	0%	0%
AFC Population size	-	-	-

Table 6. Escapement estimates derived from mark-recovery data for Middle Shuswap River chinook salmon, by sex, 2007.

The 2007 spawning escapement for the Lower Shuswap River was 15,926 chinook salmon (Table 7). The estimated, calculated by summing the sex specific Petersen population estimates had lower and upper 95% confidence limits of 14,747 and 17,105, respectively. The male escapement was estimated to be 8,070 (51%) while the female estimate was 7,856 (49%).

	Sex		
	Male	Female	Total
Carcasses Sampled	3,442	4,476	7,918
Marks Applied	627	710	1,337
Marks Recovered	267	404	671
Percentage Recovered	43%	57%	50%
Population Size	8,070	7,856	15,926
Lower 95% Confidence Limit	7,368	7,378	14,747
Upper 95% Confidence Limit	8,771	8,334	17,105
Precision	9%	6%	7%
AFC Incidence	1%	1%	1%
AFC Population size	34	28	91

Table 7. Escapement estimates derived from mark-recovery data for Lower Shuswap River chinook salmon, by sex, 2007.

Aerial Escapement

On the Middle Shuswap River the highest aerial count (including carcasses), recorded on 27 September (695) and expanded by the traditional 0.65 expansion factor, resulted in an estimate of the spawning population size of 1,069 chinook. The mark-recovery estimate was 954 indicating that the traditional expansion factor produced an estimate which nearly equal to the mark-recapture estimate. A more accurate expansion factor for the 2007 data would be 1.37 or 0.73 of the total population.

For the Lower Shuswap River, the aerial count with the highest number of fish observed, recorded on 4 October (9,430) and expanded by the traditional 0.65 expansion factor, resulted in an estimate of the spawning population size of 14,508 chinook. The peak count expansion produced an escapement estimate which was biased low compared to the more accurate mark recapture estimate. A more accurate expansion factor for the 2007 data would be 1.69 for the count with the highest number of total chinook observed (or 0.59 of the total population).

DISCUSSION

The Pacific Salmon Treaty outlines tasks for the Chinook Technical Committee, which includes establishing MSY or other biologically-based escapement goals. Chinook escapement goals are used in the management Chinook salmon fisheries. Typically MSY escapement goals are calculated from stock-recruitment analyses of several years of spawner escapements and subsequent production. The approach can take 15-20 years to acquire sufficient data and often requires considerable resources. For these and other reasons, many stocks do not have sufficient spawner and production data to estimate optimal spawning escapements. Consequently, habitat-based methods have been developed as low-cost, quick alternatives.

A habitat-based approach to estimate the optimal spawning escapements based on the size of the watershed used by the stock (Parken et. al. 2004). The model was developed from stock-recruitment estimates of optimal spawning escapements for stocks ranging from coastal Oregon to the Yukon drainage in Alaska. The model has been verified with independent estimates of optimal spawner escapements and was used to establish escapement goals for data limited stocks in Alaska.

The habitat model predicts the total number of optimal spawners needed, but most data limited stocks only have indices of abundance and additional information is required to convert the indices to total spawners. To apply the habitat model to data limited systems expansion factors are required to convert the spawner indices into estimates of total escapement. This involves estimating total escapement by mark-recapture or direct count methods while performing the index methods, which are typically peak counts from visual surveys.

The estimation of population size for spring and summer-run chinook salmon present in tributaries to the Fraser and Thompson Rivers has traditionally been done using visual counts from helicopter overflights. Initially, only one flight per year was undertaken on each tributary; however, the current program attempts to estimate escapement on two or more separate days, near the peak of spawning for each system. The overflight program was initiated in the early 1970's and expanded to provide two or more flights per spawning system in 1989.

Visual estimates tend to be inaccurate and frequently underestimate population size (Tschaplinski and Hyatt 1991). The accuracy of aerial counts can be influenced by the physical conditions at the time of counting, with light penetration, turbidity, fish behaviour and weather all influencing fish visibility (Bevan 1961). Other factors influencing aerial estimates include the experience of the pilot and observers, flight scheduling and frequency of counts (Bevan 1961; Neilson and Geen 1981). To increase accuracy, flights occurred when observation conditions were the best available. Also, we used experienced enumerators and a helicopter pilot with prior experience in low level fish enumeration. We have no evidence that the 2007 observations were hampered by weather or observer conditions

The validity of escapement estimates derived by such mark-recovery projects is influenced by several assumptions underlying the mark-recovery method (Seber 1982). The Petersen method will produce an accurate estimate of the actual population size if several criteria are met. These criteria are that: the population is closed; all animals are equally vulnerable to capture in the application sample; mark application does not affect subsequent catchability; the recovery sample is taken at random; marks are not lost; and all marks are reported (Seber 1982). Slight biases were evident in the temporal distribution of tags in both the recovery and application samples in both the Middle and Lower Shuswap Rivers.

The higher precision of the Lower Shuswap mark-recapture estimate compared to the Middle Shuswap estimate is the result of the high numbers of tagged fish with the population and the high carcass sample rate (50 and 34% of the total population for the Lower and Middle Shuswap, respectively). The precision estimate for the Middle Shuswap River, failed to meet the pre-season objectives ($\pm$ 25% of the true value 95% of the time). While was still lower then desired. The precision of the Lower Shuswap River, seven percent, exceeded the pre-season goals considerably. It is expected that increases in both the number of tags applied to chinook and the number of carcasses inspected on the Middle Shuswap River in 2008 will increase precision.

For the Middle Shuswap River the expansion factor needed to convert the Peak-Live count from the aerial enumeration to meet the escapement estimate derived from the mark-recapture estimate was 1.37 This expansion indicates that on the peak-live count, observers were able to see 0.76 of the total population. On the Lower Shuswap River the expansion factor need to meet the mark-recapture estimate was 1.69 (or .59 of the total population observed).

The low expansion factor conversions are thought to be related to the optimal visual conditions on the Middle and Lower Shuswap Rivers, and relatively low densities of both chinook and sockeye spawners. This allowed for a greater number of the total population of chinook salmon to be observed in both streams (Table 8).

		Index Method (Peak count)			Calibration Method (Mark-recapture)		
River	Year	Survey type	Total Count	Escapement	Escapement	Calibration Factor	Sockeye Escapement
Lower Shuswap							
	2000	Heli.	13,266	20,409	27,676	2.09	50
	2001	Heli.	11,927	18,349	35,788	3.00	1,071
	2002	Heli.	12,566	19,332	54,219	4.31	780,655
	2004	Heli.	8,730	13,431	16,963	1.94	144
	2005	Heli.	8,405	12,931	17,892	2.13	4,709
	2006	Heli.	18,719	28,790	59,085	3.16	814,023
	2007	Heli.	9,430	14,503	15,926	1.69	5,103
M. Shuswap							
	2006	Heli.	3,483	5,358	4,573	1.31	71,348
	2007	Heli.	695	1,069	954	1.37	324

Table 8. Peak counts, mark-recapture escapements and corresponding calibration factors for the Lower Shuswap River 2000-2007 and for the Middle Shuswap River 2006-2007.

High numbers of sockeye salmon are thought to obstruct the ability to visually count the chinook salmon in the Lower Shuswap River and the high densities and total population of chinook salmon in the Lower Shuswap River is thought to extend the period over which spawning activities are peaking. This creates a plateau of spawning activity which can last over several days instead of a well defined ‘peak’ which tails then tails off into a reduction of the number of spawning fish. In the Middle Shuswap River it is believed that the effects of large sockeye escapements do not influence the ability to visually count chinook as chinook spawning is earlier timed in relation to when sockeye enter the river.

RECOMMENDATIONS

- Conduct calibration activities on the Lower Shuswap River in 2010 to further investigate the effects of high sockeye densities on aerial counts and calibration factors.

- Conduct the calibration activities on the Middle Shuswap River for a minimum of two more years to better understand the inter-annual variability of the calibration factors

- Increased the precision, and strengthen the bias testing of the mark-recapture estimate on the Middle Shuswap River through increasing the number of tags applied and the number of carcasses sampled.

REFERENCES

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

English, K.K., R.C. Bocking, and J.R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. Can. J. Fish. Aquat. Sci. 49:1982-1989.

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.E. Bailey, and B. Rosenberger. 1999. Enumeration of the 1995 Nicola River chinook salmon escapement. Can. Manuscr. Rep. Fish. Aquat. Sci. 2491: 44 p.

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.

Parken, C.K., J.R. Irvine, R.E. Bailey, and I.V. Williams. 2002. Habitat-based methods to estimate spawner capacity for chinook salmon in the Fraser River watershed. Fisheries and Oceans Canada, CSAS. 2002:114.

Perrin, C.J. and J.R. Irvine. 1990. A review of survey life estimates as they apply to the area-under-the-curve method for estimating the spawning escapement of pacific salmon. Can. Tech. Rep. Fish. Aquat. Sci. 1733.

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

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters. Oxford University Press, New York. (Charles Griffin & Co. Ltd., High Wycombe Bucks, England)

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.

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.

Tschaplinski, P.J., and K.D. Hyatt. 1991. A comparison of population assessment methods employed to estimate the abundance of sockeye salmon (*Oncorhynchus nerka*) returning to Henderson Lake, Vancouver Island during 1989. Can. Tech. Rep. Fish. Aquat. Sci. 1798: 101 p.