Regional Operational Plan SF.3F.2014.04

Chinook Salmon Escapement in the Chena, Salcha, and Goodpaster Rivers and Coho Salmon Escapement in the Delta Clearwater River, 2014–2015

by

James W. Savereide

March 2015

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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SIGNATURE/TITLE PAGE

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Approval

Title	Name	Signature	Date
Project leader	James Savereide		
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Regional Supervisor	Don Roach		3/2/15

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Salmon enumeration projects in the Tanana River drainage were conducted by the Alaska Department of Fish and Game (ADF&G) on the Chena and Delta Clearwater rivers. The enumeration projects on the Salcha and Goodpaster rivers were conducted by Bering Sea Fishermen's Association (BSFA) and Tanana Chiefs Corporation (TCC), respectively. The primary purpose of these projects is to determine whether or not the established escapement goals for these 3 rivers are met. There is no escapement goal for the Goodpaster River. Chinook salmon *Oncorhynchus tshawytscha* escapement for the Chena, Salcha, and Goodpaster rivers was estimated using tower-counting techniques and coho salmon O. kisutch escapement in the Delta Clearwater River was estimated by visual boat survey at peak escapement. This report details work to be conducted by ADF&G on the Chena and Delta Clearwater rivers.

Key words: Chinook salmon, *Oncorhynchus tshawytscha,* chum salmon, *O. keta*, coho salmon, *O. kisutch*, Chena River, Delta Clearwater River, Salcha River, Goodpaster River, counting tower, escapement.

PURPOSE

The Yukon River is 1 of 12 indicator stocks chosen by the ADF&G in the *Chinook Salmon Stock Assessment and Research Plan* (ADFG Chinook Research Team 2013) as a stock for which additional information on stock productivity is desired. Age-structured production models that are widely used to understand a stock's dynamics require information about processes like escapement, recruitment, and mortality. The Chena and Salcha rivers support the largest spawning populations of Chinook salmon *Oncorhynchus tshawytscha* in the Alaskan side of the Yukon River drainage, while the Delta Clearwater River supports the largest spawning population of coho salmon *O. kisutch* in the Yukon River drainage.

The primary purpose of this project is to determine whether or not the established escapement goals on these 3 rivers are met. To accomplish this objective counting tower techniques are used to enumerate the Chinook salmon escapements in the Chena and Salcha rivers whereas visual boat surveys are used to estimate coho salmon escapement in the Delta Clearwater River (DCR). The monitoring programs provide information on run magnitude and timing, which allows managers to modify fishing regulations to achieve the established escapement goals.

BACKGROUND

The Chena and Salcha rivers support significant spawning populations of Chinook salmon and the Delta Clearwater River (DCR) supports a significant spawning population of coho salmon. The Goodpaster, Chatanika, and Nenana rivers also support important spawning populations of Chinook and coho salmon.

In 2001 the Alaska Board of Fisheries (BOF) adopted escapement goals for the Chena, Salcha, and Delta Clearwater rivers. Biological escapement goals (BEGs) of 2,800–5,700 Chinook salmon in the Chena River and 3,300–6,500 in the Salcha River were established to provide for maximum sustained yield. A sustainable escapement goal (SEG) of 5,200–17,000 coho salmon in the Delta Clearwater River (DCR) was established because the spawner-recruit information required to establish a BEG is not available.

Escapement monitoring projects are conducted annually on the Chena, Salcha, Goodpaster, and Delta Clearwater rivers to evaluate whether escapement goals are met and to provide information to fisheries managers on run magnitude and timing. Counting tower techniques are used on the Chena, Salcha, and Goodpaster rivers to estimate escapement of Chinook salmon. Boat survey counts are used to enumerate escapement of coho salmon in the Delta Clearwater. Enumeration of Chinook salmon on the Chena River has been conducted by ADF&G since 1986. Enumeration of Chinook salmon on the Salcha River has been conducted since 1987. Enumeration of Chinook salmon on the Goodpaster River has been conducted since 2004. The Salcha River counting tower project was originally operated by ADF&G, but since 1999 has been operated by the Bering Sea Fishermen's Association (BSFA). The Goodpaster River counting tower is run by Tanana Chiefs Corporation (TCC) along with BSFA. BSFA will provide the count data for both projects to ADF&G and ADF&G will conduct the abundance estimation and reporting.

This operational plan describes the procedures for the Chena River Chinook salmon and Delta Clearwater River coho salmon projects for the 2014–2015 field seasons. The counting and analytical procedures for the Salcha and Goodpaster River Chinook projects are the same as those described for the Chena River without any sonar enumeration.

OBJECTIVES

The objectives for 2014–2015 are to:

1. estimate the total escapement of Chinook salmon in the Chena River using tower-counting techniques such that the half-width of the 95% confidence interval to be calculated is ≤ 15% of the point estimate and the potential for bias is minimized.
2. estimate age and sex compositions of the escapement of Chinook salmon in the Chena River such that estimated proportions are within 0.06 of the true proportions 95% of the time; and,
3. count coho salmon in the Delta Clearwater River from a drifting river boat during peak spawning to estimate minimum escapement.
4. deploy and maintain two dual-frequency identification sonars (DIDSON produced by Sound Metrics Corp.) in the Chena River to assess passing salmon during periods of high-water when tower counts cannot be completed; and,
5. count chum salmon in the Chena River throughout the duration of the Chinook salmon run.

METHODS

Study Area and Sampling Design

Chena River Chinook Salmon

Daily escapements of Chinook and chum salmon will be estimated by visually counting fish as they pass over white fabric panels located on the river bottom on the upstream side of the Moose Creek Dam on the Chena River (Figure 1). Personnel will stand on the deck of the dam and count all salmon passing upstream and downstream for 20-min intervals every hour over the course of the run. Lights will be suspended over the panels to provide illumination during periods of low ambient light. Counting will begin on or about 25 June and will continue until there are 3 continuous days with no net upstream passage of Chinook salmon (typically around July 31). The majority of Chinook salmon spawning occurs upstream of this site and no harvest of salmon is allowed, so final estimates represent the total escapement.

Five technicians will be assigned to enumerate the salmon escapement in the Chena River. Each day will be divided into three 8.0-h shifts. Shift I begins at 0000 (midnight) and ends at 0759; Shift II begins at 0800 and ends at 1559; Shift III begins at 1600 and ends at 2359. Salmon will be counted for 20 min of every hour. The start time for all counts will begin between the top of the hour and 10 minutes past.

A DIDSON sonar used to enumerate migrating fish will be deployed upstream of the white fabric panels on both sides of the river to estimate the number of migrating salmon during periods of high-water (> 2 consecutive days) when tower counts cannot be completed. In 2007, a DIDSON was deployed near this site and a mixture model based on length was used to allocate the total count of salmon passing the sonar into numbers of Chinook and chum salmon. Results were compared to actual tower counts and suggested this methodology is an appropriate means

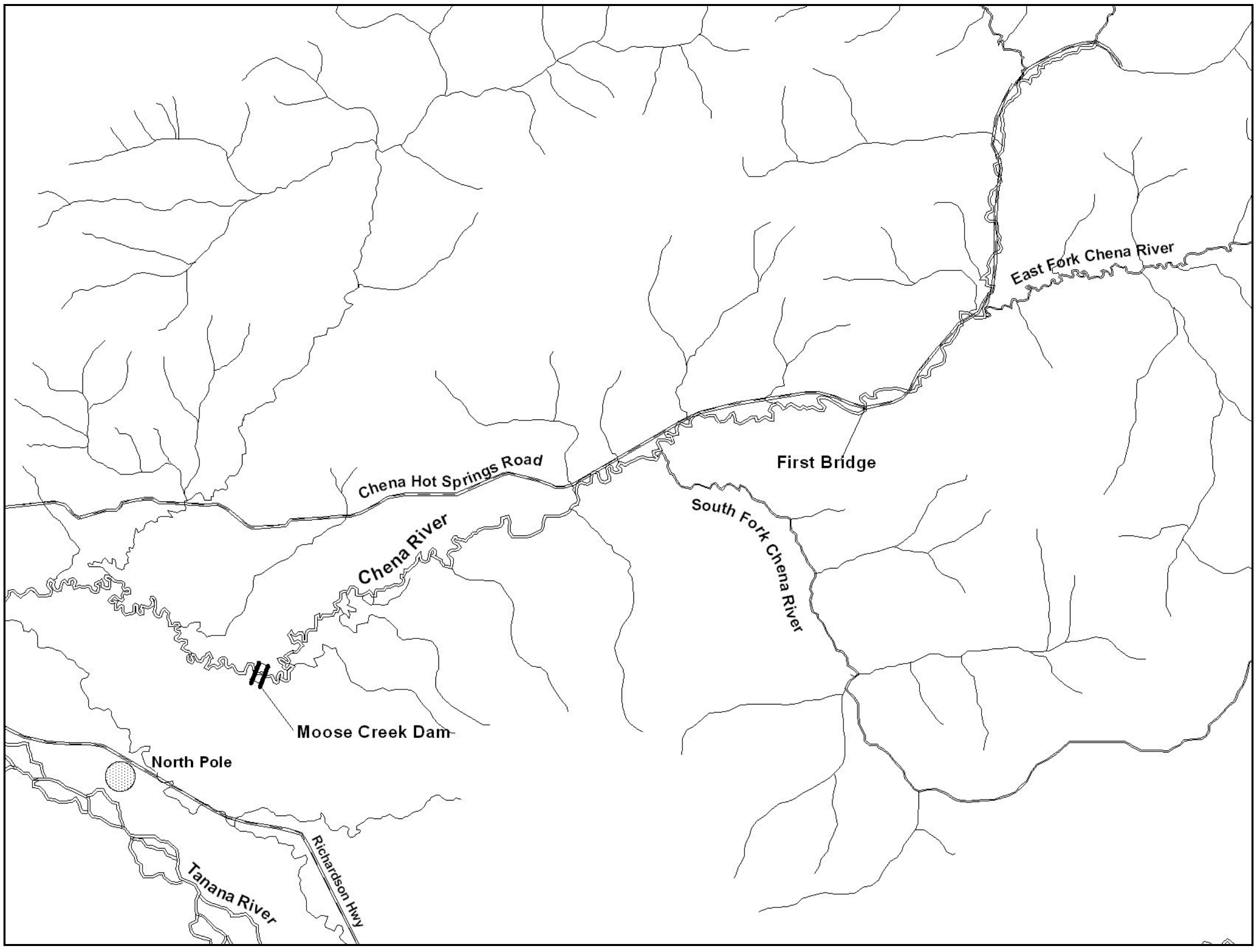

Figure 1.–Map of the Chena River demarcating the Moose Creek Dam (river km 72) and the first bridge on Chena Hot Springs Road (river km 161).

to estimate passage when conditions prohibit tower counts. The objective is to position each sonar so it can record images from each half of the river, 24 hours a day, 7 days a week. Previous tower counts have shown the majority of the Chinook salmon migrate up the north side of the river at the tower site due to a deeper channel located on that side of the river. On the both sides, the DIDSON will be mounted to a portable aluminum stand that is moved manually to adjust for water depth. Small weir structures will be deployed at each site to ensure migrating salmon pass through the sonar beam.

In addition to the tower counts and sonar site, carcasses of spawned-out Chinook salmon will be collected during the last week of July through the first 2 weeks of August from river km 72 to 161 (Figure 1) to estimate age and sex composition of the escapement. Ages will be determined from scale patterns as described by Mosher (1969). Three scales will be removed from the left side of the fish approximately 2 rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Welander 1940). If no scales are present in the preferred area due to decomposition, scales will be removed from the same area on the right side of the fish or if necessary, from any location other than along the lateral line where there are any scales remaining. Scales will be stored in coin envelopes and mounted on gum cards in the lab. Sex will be determined from external and internal characteristics.

Two riverboats with 3 people in each boat (1 operator and 2 people collecting carcasses) will be used to collect Chinook salmon carcasses. Chinook salmon carcasses will be speared from the boats and collected along banks and gravel bars. All deep pools and eddies that can be safely explored will be inspected to find and sample as many Chinook salmon carcasses as possible. After collection, the carcasses will be placed in a large tub onboard the boat. Once the tub is full, the boat will land on a gravel bar and the carcasses will be laid out in rows of 10 with their left sides facing up.

A mark-recapture experiment (Appendix A1) to estimate escapement will be undertaken only if tower counts are not conducted for 10 or more days between 5–25 July and:

1. escapement is projected to be greater than 13,000 Chinook salmon;
2. escapement estimates were not obtained during the preceding two consecutive years (regardless of projected run size in the current year); or,
3. an escapement of more than 13,000 Chinook salmon was observed 5 years (dominant age class in the brood-year return) prior to this year.

These criteria were established to balance the risks associated with exposing salmon adults and eggs, as well as all other organisms, to potentially damaging levels of electricity during the mark-recapture experiment and a desire to maintain the integrity of the time series of escapement data. The current Chena River Chinook salmon BEG is based on 15 pairs of spawner-return estimates (for brood years 1986–2000) with a spawning contrast of 4.90 (estimates range from 2,730–13,390; Evenson and Reed *In prep*). Estimates of escapement that fall within the middle of the range of previous estimates have little effect on the estimate of optimal spawning escapement which is used to determine the BEG. However, extremely large or small escapements (outside the observed range) will improve the spawning contrast and provide for more certainty in the estimate of optimal spawning escapement.

Criterion 1 is evaluated using a series of projected total escapements that are produced by correlating daily cumulative escapement estimates during the current year with a “typical” passage pattern derived from historical patterns of Chinook salmon passage. Criterion 2 does not apply because escapement estimates were obtained in 2012 and 2013. Criterion 3 does not apply for age 5 salmon because the 2009 escapement estimate was within the 3,000 to 13,000 interval.

If a mark-recapture experiment is required, additional age-sex-length (ASL) samples will be collected during the marking event and data collected in either one or both sampling events from that study will be used to estimate ASL composition (Appendices A1, A2 & A3).

Using the study design described under adequate counting conditions, approximately 33% of the Chena River Chinook salmon run will be counted. Relative precision (95%) of escapement estimates since 2003 have ranged from 9% to 15% when 15% to 33% of the run was sampled (Savereide *In prep*).

Objective criteria for age and sex compositions were established to maintain the integrity of the spawner-recruit data used to set the BEG. Spawner-recruit analyses based on the abundance of female Chinook salmon instead of total escapement are subject to the error around the estimates of total escapement and sex composition. Simulation studies indicate that measurement error in stock size (for spawner-recruit analysis) is rarely much of a problem until the coefficient of variance (CV) approaches 20% or higher (S. Fleischman, ADF&G, *personal communication*), but to minimize the effects of this error on the estimate of optimal escapement, precise estimates of the sex composition are required. To estimate age compositions with the desired level of precision and accuracy a minimum of 416 Chinook salmon carcasses will be sampled for scales assuming 15% data loss due to unreadable scales (Thompson 1987). Assuming an average run of 5,000 salmon is estimated to pass the counting site and Objective 1 is achieved, a sample size of 416 to estimate sex composition from carcass surveys will provide an estimate of female escapement with a CV < 25%, after adjusting for bias in the carcass samples (see Data Analysis), if the percent female is no lower than 7%. If the percent female is 50%, the CV of the estimate of female escapement will be about 19%.

Delta Clearwater River Coho Salmon

Previous aerial surveys of the Delta Clearwater River drainage have shown that an average of 20% of the coho escapement is found in areas inaccessible to a boat survey; therefore, counts of adult coho salmon will be conducted to obtain a minimum estimate of escapement. This estimate will be used to evaluate whether or not the SEG was met.

Two persons (a boat operator and a counter) will conduct the survey from a drifting river boat equipped with a 5 ft elevated platform. The survey is typically done during peak spawning times over the course of 1 to 2 days. The survey will be conducted along the lower 18 miles of the Delta Clearwater River to within 1.0 mile of the Clearwater Lake outlet (Figure 2). The total number of coho salmon observed (both dead and alive) will be recorded every mile at mile markers posted on the river bank. The sum of the section counts equals the estimate of minimum escapement.

Data Collection

Chena River Chinook Salmon

The numbers of Chinook and chum salmon and water clarity rating (Table 1) will be recorded on field forms (Appendix B) at the end of each hourly count. At the end of each shift the counting technician will evaluate and record the overall weather and river stage height from a staff gauge mounted on the dam. Only counts with a rank of 3 or higher will be used in the estimate of escapement. A count with a rank of 4 or 5 is considered as no count. Each day, the data sheets from the previous day will be returned to the project leader at the end of Shift 1.

All recorded images from the DIDSON will be stored on an external hard drive capable of holding large data files. The technicians will ensure the sonar is running at the end of every 20-min tower count and that the proper sonar angle has been maintained. They will be responsible for any adjustments necessary due to water level and/or debris.

All fish collected during carcass surveys will be sampled for age, sex, and length (ASL). After sampling, all carcasses will be cut in a distinctive manner through the left orbit to avoid resampling and returned to the river.

Table 1.–Water clarity ratings.

Rating	Description	Salmon Viewing	Water Condition
1	Excellent	All passing salmon are observable	Virtually no turbidity or glare, “drinking water” clarity; all routes of passage observable
2	Good	All passing salmon are observable	Minimal to moderate levels of turbidity or glare; all routes of passage observable
3	Fair	Possible, but not likely, that some passing salmon may be missed	Moderate to high levels of turbidity or glare; a few likely routes of passage are partially obscured
4.	Poor	Likely that some passing salmon may be missed	Moderate to high levels of turbidity or glare; some-many likely routes of passage are obscured
5	Un-observable	Passing fish are not observable	High level of turbidity or glare; ALL routes of passage obscured

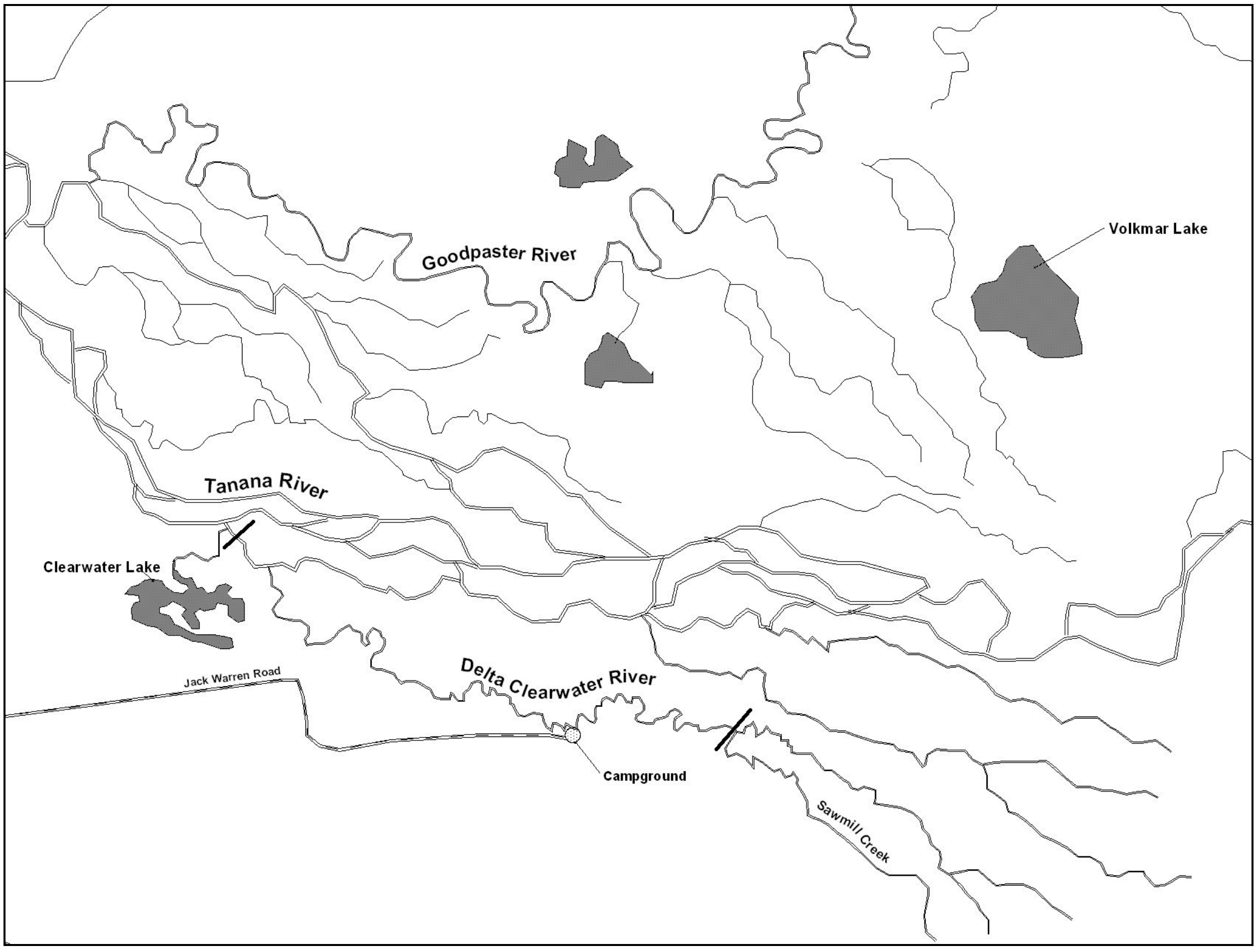

Figure 2.–Map of the Delta Clearwater River demarcating the survey area (bold lines).

Delta Clearwater River Coho Salmon
The person counting coho salmon will stand on the elevated platform and count fish along each mile section of river. The observer will wear polarized glasses to facilitate viewing into the water and record the number of coho salmon on tally counters. The numbers of coho salmon will be recorded at the end of each mile section and the tally counters will be zeroed out at the start of the next section. The survey conditions will also be recorded.

Data Reduction

Chena River Chinook Salmon
Recorded data will be entered into a Microsoft Excel® spreadsheet for data analysis. The spreadsheet calculates daily estimates of Chinook salmon escapement and the associated variance plus summary tables documenting counting effort and daily and cumulative Chinook and chum salmon passage.

Recorded data from the DIDSON will be stored and a total count of all salmon migrating upstream and downstream will be completed when 2 or more consecutive days are missed due to high-water.

When all data are compiled in the spreadsheet, a copy of the file and the scale cards will be sent to CFD in Anchorage. The scale cards will be imprinted on acetate cards, aged, and the ages entered into the spreadsheet listing the sex and length for each fish. The completed file will be used by CFD for assessment and reporting purposes, and a copy returned to Fairbanks for final analysis, contribution to the final FDS report, and archiving. Final copies of the spreadsheet file will be provided with the completed report when it is submitted for review to be archived in the Sport Fish Division Docushare repository.

Delta Clearwater River Coho Salmon
Field notebooks and raw survey data will be archived in the Delta Junction area office. Results will be reported to the project leader and they will be presented in the annual FDS Report.

Data Analysis

Chena River Chinook Salmon
Taras and Sarafin (2005) demonstrated that interpolating for undercounts (a rank of 4 or 5) using a diel migratory pattern, where the majority of salmon migration takes place in the evening and early morning hours, yielded more accurate estimates of daily escapement than using a direct expansion of the successful counts within 8-h shifts for that day. To ensure the most appropriate method was used, the cumulative proportion of Chinook salmon migration by hour of day was determined for 2006–2009; there was no apparent diel migratory pattern (J. Savereide, ADF&G, Fairbanks, unpublished data).

Estimates of Chinook salmon escapement will be stratified by day and daily estimates will be summed to estimate total escapement. Daily escapement will be estimated one of four ways depending on the frequency of successful counts. The following criteria will determine the methods used to estimate the daily escapement and its variance and reference equations 1-13 below:

1. when 2 or more 8-hr shifts per day are considered complete, escapement will be estimated with equation 3 and variance will be estimated using equation 6;
2. when counts are only conducted during one 8-hr shift on a given day, but all 8 counting periods were sampled, escapement will be estimated using equation 3 and variance will be estimated using equation 11;
3. when no 8-hr shifts are considered complete on a given day, interpolation techniques described in equations 12 and 13 will be used to estimate escapement and equation 11 will be used to estimate variance. This approach will only be used when one or two consecutive days of counting are incomplete; and,
4. when all 8-hr shifts on 3 or more but less than 10 consecutive days are incomplete, daily escapement will be assessed using a mixture model that apportions the DIDSON sonar counts of salmon by species (Huang 2012).

Daily estimates of escapement will be considered a two-stage direct expansion where the first stage is 8-h shifts within a day and the second stage is 20 min counting periods within a shift. The second stage is considered systematic sampling because the 20 min counting periods were not chosen randomly.

The formulas necessary to calculate escapement from counting tower data are taken directly or modified from those provided in Cochran (1977). The expanded shift escapement on day *d* and shift *i* will be calculated by:

$$Y_{di} = \frac{M_{di}}{m_{di}} \sum_{j=1}^{m_{di}} y_{dij} . \tag{1}$$

The average shift escapement for day *d* will be:

$$\overline{Y}_d = \frac{\sum_{i=1}^{h_d} Y_{di}}{h_d} . \tag{2}$$

A minimum of 4 counting periods per shift will be required for a shift to be considered complete. Counts will be conducted during all scheduled counting periods unless water clarity conditions prohibit counts.

The expanded daily escapement will be:

$$\hat{N}_d = \overline{Y}_d H_d . \tag{3}$$

The period sampled is systematic because a period is sampled every hour in a shift. The sample variance associated with periods will be approximate using the successive difference approach:

$$s_{2di}^2 = \frac{1}{2(m_{di}-1)}\sum_{j=2}^{m_{di}}\left(y_{dij} - y_{di(j-1)}\right)^2 . \tag{4}$$

All shifts will be sampled unless water clarity conditions prohibit counts. If 2 or more shifts are not sampled then the moving average technique (described below) will be used to estimate the daily passage and its variance. If 1 shift is not sampled then the between shift sample variance will be calculated as:

$$s_{1d}^2 = \frac{1}{h_d - 1}\sum_{i=1}^{h_d}\left(Y_{di} - \overline{Y}_d\right)^2 . \tag{5}$$

The variance for the expanded daily escapement will be estimated by:

$$\hat{V}\left(\hat{N}_d\right) = \left[(1 - f_{1d})H_d^2\frac{s_{1d}^2}{h_d}\right] + \left[\frac{1}{f_{1d}}\sum_{i=1}^{h_d}\left((1 - f_{2di})M_{di}^2\frac{s_{2di}^2}{m_{di}}\right)\right] \tag{6}$$

where:

$$f_{1d} = \frac{h_d}{H_d}\text{; and,} \tag{7}$$

$$f_{2di} = \frac{m_{di}}{M_{di}} \tag{8}$$

and

d = day;

i = *8-h shift;*

j = *20-min counting period;*

y_{dij} = *observed sum of 20-min period counts;*

Y_{di} = *expanded shift escapement;*

m_{di} = *number of 20-min counting periods sampled within a shift;*

M_{di} = *total number of possible 20-min counting periods within a shift;*

h_d = *number of 8-h shifts sampled within a day;*

H_d = *total number of possible 8-h shifts within a day; and,*

D = *total number of possible days.*

Total escapement and variance estimates are the sum of all daily estimates:

$$\hat{N} = \sum_{d=1}^{D} \hat{N}_d \text{ ; and,} \tag{9}$$

$$\hat{V}\left(\hat{N}\right) = \sum_{d=1}^{D} \hat{V}(\hat{N}_d) \text{ .} \tag{10}$$

Equation 5, the sample variance across shifts, requires data from more than 1 shift per day. In the event that water conditions and/or personnel constraints do not permit at least 2 shifts during a day, a coefficient of variation (CV) will be calculated using all days when more than 1 shift was worked. The average CV will then be used to approximate the daily variation for those days when fewer than 2 shifts were worked. The coefficient of variation is used because it is independent of the magnitude of the estimate and is relatively constant throughout the run (Evenson 1995). The daily *CV* is calculated as:

$$CV_d = SE_d \big/ \hat{N}_d \text{ .} \tag{11}$$

When k consecutive days are not sampled due to adverse viewing conditions, the moving average estimate for the missing day i will be calculated as:

$$\hat{N}_i = \frac{\sum_{j=i-k}^{i+k} I(day\, j \;\; was\, sampled)\hat{N}_j}{\sum_{j=i-k}^{i+k} I(day\; j\, was\, sampled)} \tag{12}$$

where:

$$I(\cdot) = \begin{cases} 1 & when\, the\, condition\, is\, true \\ 0 & otherwise \end{cases} \tag{13}$$

is an indicator function. The moving average procedure will only be applied for data gaps that do not exceed 2 days (6 consecutive 8-hr shifts). Data gaps that exceed 2 days will be assessed using a mixture model (J. Huang, ADF&G, Fairbanks, unpublished data) applied to the DIDSON sonar data. The files from the DIDSON sonar will provide the data required to determine a total count of migrating salmon during times of high-water when tower counts cannot be completed. The sonar files will be processed by DIDSON Control and Display, a pre-programmed software by Sound Metric Corporation, and displayed on computer screens as video-like footages. All of the sonar files will be viewed and a tally of all migrating salmon will be recorded. The total count of salmon will be considered a census because the sonar will be recording continually throughout the salmon run.

Gender bias has been noted when comparing sex ratios of Chinook salmon collected during carcass surveys with those collected by electrofishing (Stuby 2001). To adjust for this bias, an analysis of data from previous years when both sampling procedures were used was completed to determine an adjustment factor. The adjustment factor is based on paired electrofishing and carcass survey data from the Chena River (1989–1992, 1995–1997, and 2000).

The escapement estimate will be apportioned by sex prior to apportioning by age categories within each sex. Estimates of the proportion of females and males in the escapement based on carcass surveys will be adjusted to estimate what would have been observed from an electro-fishing sample. The estimated proportions of males and females from carcass surveys will be calculated using (Cochran 1977):

$$\hat{p}_{sc} = \frac{y_{sc}}{n_c}; \tag{14}$$

with variance:

$$\hat{V}[\hat{p}_{sc}] = \frac{\hat{p}_{sc}(1-\hat{p}_{sc})}{n_c - 1}; \tag{15}$$

where y_{sc} is the number of salmon of sex s observed during carcass surveys and n_c is the total number of salmon of either sex observed during carcass surveys for $s = m$ or f.

The adjustment factor necessary to compensate for the gender bias when no electro-fishing is conducted is $\hat{R}_p$ = 0.708 with $\hat{V}(\hat{R}_p)$ = 0.018.

The bias-corrected estimate and variance (Goodman 1960) of the proportion of females, $\tilde{p}_{fe}$, is:

$$\tilde{p}_{fe} = \hat{p}_{fc}\hat{R}_p \text{ with } \hat{V}(\tilde{p}_{fe}) = \hat{p}^2_{fc}\hat{V}(\hat{R}_p) + \hat{R}^2_p\hat{V}(\hat{p}_{fc}) - \hat{V}(\hat{R}_p)\hat{V}(\hat{p}_{fc}). \tag{16}$$

The estimate and variance of the proportion of males observable during electrofishing are:

$$\tilde{p}_{me} = 1 - \tilde{p}_{fe} \text{ and } \hat{V}(\tilde{p}_{me}) = \hat{V}(\tilde{p}_{fe}).$$

Escapement of each sex is then estimated by:

$$\hat{N}_s = \tilde{p}_{se}\hat{N} \tag{17}$$

The variance for $\hat{N}_s$ in this case is (Goodman 1960):

$$\hat{V}(\hat{N}_s) = \hat{V}(\tilde{p}_{se})\hat{N}^2 + \hat{V}(\hat{N})\tilde{p}^2_{se} - \hat{V}(\tilde{p}_{se})\hat{V}(\hat{N}). \tag{18}$$

The proportion of fish at age k by sex s for samples collected solely for age, sex, and length will be calculated as:

$$\hat{p}_{sk} = \frac{y_{sk}}{n_s} \tag{19}$$

where: $\hat{p}_{sk}$ = the estimated proportion of Chinook salmon that are age k; y_{sk} = the number of Chinook salmon sampled that are age k; and, n_s = the total number of Chinook salmon sampled.

The variance of this proportion will be estimated as:

$$\hat{V}[\hat{p}_{sk}] = \frac{\hat{p}_{sk}(1-\hat{p}_{sk})}{n_s - 1} \tag{20}$$

Escapement at age *k* for each sex is then estimated by:

$$\hat{N}_{sk} = \hat{p}_{sk}\hat{N}_s \tag{21}$$

The variance for $\hat{N}_{sk}$ in this case is (Goodman 1960):

$$\hat{V}(\hat{N}_{sk}) = \hat{V}(\hat{p}_{sk})\hat{N}_s^{\,2} + \hat{V}(\hat{N}_s)\hat{p}_{sk}^2 - \hat{V}(\hat{p}_{sk})\hat{V}(\hat{N}_s). \tag{22}$$

DCR Coho Salmon

The minimum escapement of coho salmon will be estimated by:

$$E_{\min} = \sum_{i=1}^{s} C_i \tag{23}$$

where: C_i = count of coho salmon in each mile section and s = mile sections.

SCHEDULE AND DELIVERABLES

Results from this project will be summarized annually in a Fishery Data Series Report for which a draft will be submitted to the Research Supervisor by 1 March each year. The FDS report will satisfy annual report requirements from the funding source (AKSSF). Annual performance reports will also be completed by December each year. Probable dates for sampling activities are summarized below.

Sampling = (S), Mobilization = (M), Demobilization = (D), Analysis = (A), FDS Report = (R)

Date	Chena Tower	Chena Mark - Recapture [a]	Chena Carcass	DCR Coho	Data Analysis/Reports
June 13–26	M				
June 27–July 3	S				
July 4–10	S	M			
July 11–17	S	S			
July 18–24	S	S			
July 25–July 31	S	S	S		
August 1–August 7	S/D	S	S		
August 8–August 14			S		
October–November					A
October 24–November 6				M/S	
December					R
March					R

[a] The Chena River M-R experiment will only be conducted under a limited set of circumstances (see Study Area and Sampling Design section for the Chena River).

RESPONSIBILITIES

Project Staff and Primary Assignments

James Savereide, *Fisheries Biologist III*. Project Leader. Responsible for supervision of all aspects of the Chena River Chinook salmon counting tower project, managing the project budget, and writing the final report.

Virgil Davis, *Fish & Wildlife Technician III*. Crew leader. Mobilization, day-to-day project tasks, all aspects of field work, fill in on counting shifts as needed, demobilization.

Vacant, *Fish & Wildlife Technician II*–Mobilization, day-to-day project tasks, all aspects of field work, demobilization.

Vacant, *Fish & Wildlife Technician II*–Mobilization, day-to-day project tasks, all aspects of field work, demobilization.

Allison Martin, *Fish & Wildlife Technician II*–Mobilization, day-to-day project tasks, all aspects of field work, demobilization.

Vacant, *College Intern II*–Mobilization, day-to-day project tasks, all aspects of field work, demobilization.

Brandy Baker, *Fishery Biologist II*. Responsible for conducting boat counts of the Delta Clearwater River coho salmon escapement and updating long - term data sets.

Audra Brase, *Fishery Biologist III*. Responsible for conducting boat counts of the Delta Clearwater River coho salmon escapement and updating long - term data sets.

Jiaqi Huang, *Biometrician III*. Assist with project design and data analysis.

Matt Evenson, *Fishery Biologist IV.* Final report editing and project support.

CFD Staff: Age scales collected from carcass survey and provide these data to the project leader.

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APPENDIX A

TWO-EVENT MARK-RECAPTURE

Objective

1. Estimate the total escapement of Chinook salmon in the Chena River using mark-recapture techniques such that the estimate is within 25% of the true value 95% of the time.

Study Area and Sampling Design

The majority of Chinook salmon spawning in the Chena River occurs from the Moose Creek Dam upriver to the first bridge (Figure 1). This study is designed to estimate the abundance of Chinook salmon escaping to spawn in this area of the Chena River using two-event mark-recapture techniques (Seber 1982). The first event will capture and tag Chinook salmon using electrofishing methods after passage above the dam is considered to be nearly complete. Chinook salmon inspected for marks during carcass surveys will constitute the second event.

A riverboat equipped with electrofishing gear (Clark 1985) will be used to capture adult Chinook salmon during the marking event. The sampling crew will consist of three to four people, with one person driving the boat and two to three people retrieving fish with long handled dip nets. As fish are collected they are placed in an on-board tub filled with circulating fresh water.

Every Chinook salmon captured during the first event will:

1. be marked with an individually numbered jaw tag in the left maxillary;
2. be given a fin clip (secondary mark);
3. be measured to the nearest 5mm MEF;
4. be sexed by external characteristics; and,
5. have 3 scales removed for ageing (Welander 1940).

Date and location of sampling will be recorded for each fish sampled.

During the recapture event Chinook salmon carcasses will be collected and inspected during a complete survey of the study area. A hiatus of 4–10 days will be observed before second event sampling was initiated. Two riverboats will be used during the recapture event. Crews will consist of three people in each boat with one person driving and the other two people collecting carcasses with long handled spears. After the collection tub is full, the boat will land on a gravel bar and the carcasses will be laid out in rows of 10 with their left sides facing up. As in the first event, all fish collected will be sampled for age, sex, and length. All fish will also be examined for jaw tags and fin-clips. After sampling, all carcasses will be cut in a distinctive manner through the left orbit to avoid resampling and returned to the river.

Sample Size

The number of fish to tag and the number of carcasses to examine is determined using an estimate of the total escapement and the desired precision of the estimate. Assuming the number of Chinook salmon returning to the Chena River in 2010 will be ~ 7,000 fish (average estimated escapement for 1986–2007), at least 636 Chinook salmon should be tagged and examined to obtain estimates of escapement with the desired precision and accuracy (Robson and Regier 1964).

Data Analysis

A two-sample mark-recapture model will be used to estimate the total escapement of Chinook salmon. To obtain an unbiased estimate of escapement from a mark-recapture experiment, certain conditions must be met (Seber 1982). These conditions, expressed in the circumstances of this study, along with their respective design considerations and test procedures will be as follows:

1. The population is closed to births, deaths, immigration and emigration.

This assumption will be violated because carcasses tend to drift out of the study area but its likely fish would drift out of the study area at the same rate. In addition, first event sampling will occur when virtually all of the fish have returned to spawn, and any immigration of Chinook salmon into the study area after the marking event will be negligible. Therefore, the estimate of abundance will be unbiased with respect to the time and area of the first event.

2. Marking will not affect the catchability of Chinook salmon during the second event.

There is no explicit test for this assumption because the behavior of unhandled fish can not be observed. The experiment is designed to mark live fish and examine fish for tags after they have died. Therefore, provided marked fish die at the same rate and in the same places as unmarked fish this assumption will be met.

3. Tagged fish would not lose their marks between sampling events.

Jaw tags attached to the maxillary remain attached to the fish and are identifiable even when carcasses are in moderate stages of decomposition. Secondary marks (fin clips) will also allow sampling personnel to determine if a primary mark was lost.

In addition to the previous assumptions, one of the following assumptions must also be met:

1. all Chinook salmon have the same probability of being marked during the first event;
2. all Chinook salmon have the same probability of being sampled in the second event; or,
3. marked fish mix completely with unmarked fish between events.

Equal probability of capture will be evaluated by area, size, and sex. The procedures to analyze sex and length data for statistical bias due to gear selectivity are described in Appendix A2. If different probabilities are indicated, abundance estimates will be stratified by sex and/or within size groups.

To further evaluate the three conditions of this assumption, contingency table analyses recommended by Seber (1982) and described in Appendix A3 will be used to detect significant temporal or geographic violations of assumptions of equal probability of capture.

The appropriate abundance estimator will depend on the results of the aforementioned tests. If stratification is not needed, then the Chapman modification of the Petersen estimator (Chapman 1951; Seber 1982) will be used:

$$\hat{N} = \frac{(n_1+1)(n_2+1)}{m_2+1} - 1 \qquad \text{(A1-1)}$$

$$\hat{V}\left[\hat{N}\right] = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \qquad \text{(A1-2)}$$

where:

$\hat{N}$ = estimated escapement of Chinook salmon in the Chena River;

n_1 = the number of Chinook salmon marked while electrofishing;

n_2 = the number of Chinook salmon carcasses inspected during carcass surveys; and,

m_2 = the number of marked salmon observed during carcass surveys.

Assuming no size or sex selectivity, proportions by age (or proportions by sex) in the samples will be estimated by:

$$\hat{p}_i = \frac{n_i}{n} , \tag{A1-3}$$

$$\hat{V}[\hat{p}_i] = \frac{\hat{p}_i\ (1-\hat{p}_i\ )}{n-1}, \tag{A1-4}$$

where:

p_i = the proportion in the population in age/sex group i;

n = the number in the sample that are successfully aged or sexed; and,

n_i = the subset of n that belong to group i.

To minimize the size selective bias, if detected, the proportion of fish in a length, sex, or age category will be calculated by summing independent escapement estimates for length, sex, or age category and then dividing by the summed escapements for all categories. First the conditional proportions from the sample will be calculated:

$$\hat{p}_{jk} = \frac{n_{jk}}{n_j} \tag{A1-5}$$

where:

n_j = the number sampled from size stratum j in the mark-recapture experiment;

n_{jk} = the number sampled from size stratum j that are in group (sex, age, size) k; and,

$\hat{p}_{jk}$ = the estimated proportion of group k fish in size stratum j.

The variance calculation for $\hat{p}_{jk}$ identical to equation B-4 (with appropriate substitutions).

The estimated abundance of fish in group k in the population will be:

$$\hat{N}_k = \sum_{j=1}^{s} \hat{p}_{jk} \hat{N}_j \tag{A1-6}$$

where:

N_j= the estimated escapement in size stratum j; and,

s = the number of size strata.

The variance for N_k in this case will be estimated using the formulation for the variance of the product of two independent random variables (Goodman 1960):

$$\hat{V}\left[\hat{N}_k\right] = \sum_{j=1}^{s}\left(\hat{V}\left[\hat{p}_{jk}\right]\hat{N}_j^2 + \hat{V}\left[\hat{N}_j\right]\hat{p}_{jk}^2\right) - \hat{V}\left[\hat{p}_{jk}\right]\hat{V}\left[\hat{N}_j\right] \qquad \text{(A1-7)}$$

The estimated proportion of the population in group k will be:

$$\hat{p}_k = \hat{N}_k / \hat{N} \qquad \text{(A1-8)}$$

where: $\hat{N} = \sum_{j=1}^{s} \hat{N}_j$.

Variance of the estimated proportion will be approximated with the delta method (Seber 1982):

$$\hat{V}\left[\hat{p}_k\right] \approx \sum_{j=1}^{s}\left\{\left(\frac{\hat{N}_j}{\hat{N}}\right)^2 \hat{V}\left[\hat{p}_{jk}\right]\right\} + \frac{\sum_{j=1}^{s}\left\{\hat{V}\left[\hat{N}_j\right]\left(\hat{p}_{jk} - \hat{p}_k\right)^2\right\}}{\hat{N}^2} \qquad \text{(A1-9)}$$

Estimates of mean length at age and its variance would be calculated with standard sample summary statistics (Cochran 1977).

Appendix A2.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g. Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event.

Case II:

Reject H_o	Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling.

Case III:

Fail to reject H_o	Reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling.

Case IV:

Reject H_o	Reject H_o	Either result possible

There is size/sex selectivity detected during both the first and second sampling events.

Evaluation Required:

Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ ; and,} \quad \text{(A2-1)}$$

$$\hat{V}\left[\hat{p}_k\right] \approx \frac{1}{\hat{N}_\Sigma^2} \sum_{i=1}^{j} \left(\hat{N}_i^2 \hat{V}\left[\hat{p}_{ik}\right] + \left(\hat{p}_{ik} - \hat{p}_k\right)^2 \hat{V}\left[\hat{N}_i\right] \right). \quad \text{(A2-2)}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size *k* among fish in stratum *i*;

$\hat{N}_i$ = the estimated abundance in stratum *i*; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

Appendix A3.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

Tests of consistency for petersen estimator

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a temporally or geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing[a]

Area/Time Where Marked	Area/Time Where Recaptured				Not Recaptured
	1	**2**	**…**	**t**	(n_1-m_2)
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[b]

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked (n_2-m_2)				

III.-Test for equal probability of capture during the second event[c]

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured (n_1-m_2)				

[a] This tests the hypothesis that movement probabilities (θ) from time or area i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among time or area designations: H_0: $\Sigma_i a_i \theta_{ij} = k U_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among time or area designations: H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

APPENDIX B

CHENA RIVER DAILY COUNT FORM

Date _____________ **Total Salmon = number up <u>minus</u> number down**

	Chinook			Chum			
Time	Up	Down	Total	Up	Down	Total	Vis
0000							
0100							
0200							
0300							
0400							
0500							
0600							
0700							
Total							

Observer: ______________________________

Weather (circle one): Clear - Partly Cloudy - Mostly Cloudy - Rain River Height: ____________

	Chinook			Chum			
Time	Up	Down	Total	Up	Down	Total	Vis
0800							
0900							
1000							
1100							
1200							
1300							
1400							
1500							
Total							

Observer: ______________________________

Weather (circle one): Clear - Partly Cloudy - Mostly Cloudy - Rain River Height: ____________

	Chinook			Chum			
Time	Up	Down	Total	Up	Down	Total	Vis
1600							
1700							
1800							
1900							
2000							
2100							
2200							
2300							
Total							

Observer: ______________________________

Weather (circle one): Clear - Partly Cloudy - Mostly Cloudy - Rain River Height: ____________