

**A Mark-Recapture Experiment to Estimate the
Escapement of Chinook Salmon in the Unuk River,
2014.**

by

Todd Johnson

June 2014

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)		General		Mathematics, statistics	
centimeter	cm	Alaska Administrative Code	AAC	<i>all standard mathematical signs, symbols and abbreviations</i>	
deciliter	dL	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	alternate hypothesis	H_A
gram	g	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	base of natural logarithm	e
hectare	ha	at	@	catch per unit effort	CPUE
kilogram	kg	compass directions:		coefficient of variation	CV
kilometer	km	east	E	common test statistics	(F, t, χ^2 , etc.)
liter	L	north	N	confidence interval	CI
meter	m	south	S	correlation coefficient	
milliliter	mL	west	W	(multiple)	R
millimeter	mm	copyright	©	correlation coefficient (simple)	r
		corporate suffixes:		covariance	cov
Weights and measures (English)		Company	Co.	degree (angular)	$^\circ$
cubic feet per second	ft ³ /s	Corporation	Corp.	degrees of freedom	df
foot	ft	Incorporated	Inc.	expected value	E
gallon	gal	Limited	Ltd.	greater than	>
inch	in	District of Columbia	D.C.	greater than or equal to	\geq
mile	mi	et alii (and others)	et al.	harvest per unit effort	HPUE
nautical mile	nmi	et cetera (and so forth)	etc.	less than	<
ounce	oz	exempli gratia		less than or equal to	\leq
pound	lb	(for example)	e.g.	logarithm (natural)	ln
quart	qt	Federal Information Code	FIC	logarithm (base 10)	log
yard	yd	id est (that is)	i.e.	logarithm (specify base)	log ₂ , etc.
		latitude or longitude	lat. or long.	minute (angular)	'
Time and temperature		monetary symbols (U.S.)	\$, ¢	not significant	NS
day	d	months (tables and figures): first three letters	Jan, ..., Dec	null hypothesis	H_0
degrees Celsius	°C	registered trademark	®	percent	%
degrees Fahrenheit	°F	trademark	™	probability	P
degrees kelvin	K	United States (adjective)	U.S.	probability of a type I error (rejection of the null hypothesis when true)	α
hour	h	United States of America (noun)	USA	probability of a type II error (acceptance of the null hypothesis when false)	β
minute	min	U.S.C.	United States Code	second (angular)	"
second	s	U.S. state	use two-letter abbreviations (e.g., AK, WA)	standard deviation	SD
Physics and chemistry				standard error	SE
all atomic symbols				variance	
alternating current	AC			population sample	Var
ampere	A			sample	var
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				

REGIONAL OPERATIONAL PLAN SF.1J.2014.07

**A MARK-RECAPTURE EXPERIMENT TO ESTIMATE THE
ESCAPEMENT OF CHINOOK SALMON IN THE UNUK RIVER, 2014.**

by

Todd Johnson

Alaska Department of Fish and Game, Division of Sport Fish, Ketchikan

Alaska Department of Fish and Game
Division of Sport Fish

June 2014

The Regional Operational Plan Series was established in 2012 to archive and provide public access to operational plans for fisheries projects of the Divisions of Commercial Fisheries and Sport Fish, as per joint-divisional Operational Planning Policy. Documents in this series are planning documents that may contain raw data, preliminary data analyses and results, and describe operational aspects of fisheries projects that may not actually be implemented. All documents in this series are subject to a technical review process and receive varying degrees of regional, divisional, and biometric approval, but do not generally receive editorial review. Results from the implementation of the operational plan described in this series may be subsequently finalized and published in a different department reporting series or in the formal literature. Please contact the author if you have any questions regarding the information provided in this plan. Regional Operational Plans are available on the Internet at: <http://www.adfg.alaska.gov/sf/publications/>

*Todd Johnson,
Alaska Department of Fish and Game, Division of Sport Fish,
2030 Sea Level Drive, Suite 205
Ketchikan, AK 99901*

This document should be cited as:

Johnson, T. A. 2014. A mark-recapture experiment to estimate the escapement of Chinook salmon in the Unuk River, 2014. Alaska Department of Fish and Game, Regional Operational Plan No. SF.IJ.2014.07, Anchorage.

The Alaska Department of Fish and Game (ADF&G) administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act (ADA) of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility please write:

ADF&G ADA Coordinator, P.O. Box 115526, Juneau, AK 99811-5526

U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042, Arlington, VA 22203

Office of Equal Opportunity, U.S. Department of the Interior, 1849 C Street NW MS 5230, Washington DC 20240

The department's ADA Coordinator can be reached via phone at the following numbers:

(VOICE) 907-465-6077, (Statewide Telecommunication Device for the Deaf) 1-800-478-3648,

(Juneau TDD) 907-465-3646, or (FAX) 907-465-6078

For information on alternative formats and questions on this publication, please contact:

ADF&G, Division of Sport Fish, Research and Technical Services, 333 Raspberry Rd, Anchorage AK 99518 (907) 267-2375

SIGNATURE/TITLE PAGE

Project Title: A mark-recapture experiment to estimate the escapement of Chinook salmon in the Unuk River, 2014

Project leader(s): Todd Johnson, Fishery Biologist II

Division, Region and Area: Sport Fish, Region I, Ketchikan

Project Nomenclature: Governor's Chinook Initiative Fund

Period Covered: June–September, 2014

Field Dates: June 1–September 15, 2014

Plan Type: Category III

Approval

Title	Name	Signature	Date
Project Leader	Todd Johnson		3/12/14
Area Management Biologist *	Kelly Piazza <small>Robert Chodwick</small>		3/12/14
Biometrician	David Evans		3/12/14
Research Coordinator	JEFF NICHOLS		6/15/14
Regional Supervisor	Brian Frenette		5.20.14

* Note- Regional Management Biologist Signed for Area Management Biologist

Chinook Salmon Research Initiative Approval

Title	Name	Signature	Date
Fish and Game Coordinator	Ed Jones		5.20.14
Fisheries Scientist	Robert Clark		3/12/14
Fisheries Scientist	Eric Volk		3/12/14

TABLE OF CONTENTS

	Page
LIST OF TABLES.....	ii
LIST OF FIGURES.....	ii
LIST OF APPENDICES.....	ii
ABSTRACT.....	1
PURPOSE.....	1
BACKGROUND.....	1
OBJECTIVES.....	6
Secondary Objectives.....	7
METHODS.....	7
Study Design.....	7
Event 1-Marking.....	7
Event 2-Recapturing.....	10
Mark-Recapture Sample Sizes.....	11
Age Composition.....	11
Estimation of Coded Wire Tag Marked Fraction in the 2007–2011 Broods.....	12
Data Collection.....	13
Event 1 - Marking.....	13
Event 2 - Recapturing.....	14
Age-Sex-Length Sampling.....	14
Coded Wire Tag Sampling.....	15
Data Reduction.....	16
Data Analysis.....	16
Abundance-Medium or Large.....	16
Abundance-Small.....	18
Abundance-All.....	19
Age and Sex Composition of Escapement.....	20
Expansion Factor.....	21
Estimation of Fraction of Adults Bearing Coded Wire Tags.....	21
SCHEDULE AND DELIVERABLES.....	22
RESPONSIBILITIES.....	22
REFERENCES CITED.....	24
APPENDIX A.....	26
APPENDIX B.....	34
APPENDIX C.....	41
APPENDIX D.....	45
APPENDIX E.....	49

LIST OF TABLES

Table		Page
1.	Peak survey counts, mark-recapture estimates of abundance, expansion factors, and associated statistics for large (>660 mm mid eye to fork of tail (MEF)) Chinook salmon in the Unuk River in 1994, 1997, 2009 and 2011, and the 1997-2009 and 2011 average.....	5
2.	Ranking of spawning sites and historical peak survey dates for Unuk River tributaries in Southeast Alaska.....	11

LIST OF FIGURES

Figure		Page
1.	Behm Canal area in Southern Southeast Alaska (inset), showing major Chinook salmon systems and hatcheries.....	2
2.	Unuk River area in Southeast Alaska, showing major tributaries, barriers to salmon migration, and location of ADF&G research sites (SN1 = set net site).....	4
3.	Location of the set gillnet site (SN1) on the lower Unuk River.	8
4.	Depiction of the net placement used at the set gillnet site (SN1) on the lower Unuk River.....	8
5.	Age errors encountered when comparing differences between coded wire tag (CWT) and scale ages from fish gathered on the Unuk River in Southeast Alaska, 1996–1998.....	12

LIST OF APPENDICES

Appendix		Page
A1.	Numbers of Unuk River Chinook salmon fall fry and spring smolt captured and tagged with coded wire tags, 1992 brood year to present.....	27
A2.	Numbers of adult Unuk River Chinook salmon examined for adipose finclips, sacrificed for coded wire tag sampling purposes, valid coded wire tags decoded, percent of the marked fraction carrying germane coded wire tags, percent adipose clipped, and estimated fraction of the sample carrying valid coded wire tags, 1992 brood year to present.	30
B1.	Unuk River spawning ground survey form, 2014.	35
B2.	Unuk River set gillnet recording form, 2014.....	36
B3.	Unuk River set gillnet age-sex-length form, 2014.....	37
B4.	Coded wire tag anadromous stream numbers, coded wire tag sample numbers, and age-sex-length stream codes for the Unuk River and its tributaries.	38
B5.	Coded wire tag sampling form.	39
B6.	Unuk River spawning grounds age-sex-length form, 2014.	40
C1.	Predicting escapement from index counts using an expansion factor.	42
E1.	Tests of consistency for the Petersen estimator (from Seber 1982, page 438).	50

ABSTRACT

This plan describes a two-event mark-recapture experiment to estimate large (>660 mm MEF) adult Chinook salmon (*Oncorhynchus tshawytscha*) returning to the Unuk River in 2014. Fish will be captured during the first event on the lower Unuk River using set gillnets from approximately June 11 through August 4. Each apparently healthy fish will be marked with a numbered solid-core spaghetti tag and two secondary batch marks in the form of an upper-left operculum punch and removal of the left axillary appendage. In the second event, fish will be examined on the spawning grounds throughout August. All fish captured will be sampled for spaghetti tags, secondary batch marks, adipose clips and age, sex, and length information. A subsample of observed adipose clipped fish will also be sampled for coded wire tags. These data will be used to estimate the fraction of the escapement marked with a spaghetti tag (used in a modified Petersen estimate of adult abundance) and the fraction of each brood marked with a coded wire tag and adipose fin clip (used in harvest and smolt abundance estimation, respectively). A separate project will conduct standardized peak survey counts of 6 systems, including the Unuk River. Future Unuk River peak survey counts will be expanded by multiplication with a historical average ratio of mark-recapture estimates of abundance to peak survey counts. The Alaska Department of Fish and Game uses these data to make local and regional management decisions, and the Pacific Salmon commission uses the data for coastwide management and stock assessment through the Chinook Technical Committee.

Key words: Chinook Salmon, *Oncorhynchus tshawytscha*, escapement, Unuk River, peak survey count expansion factor, age, sex length composition, mark tag fraction, coded wire tag, adipose fin, Southeast Alaska, Petersen estimator, mark-recapture.

PURPOSE

The primary goals of this and a companion study (see separate operational plan: Chinook Salmon Coded Wire Tagging on the Unuk River, 2013–2014) are to estimate inriver run size, total run size, marine harvest rate and distribution, marine exploitation rate, smolt and parr abundance, marine survival (smolt-to-adult) and overwinter survival (parr-to-smolt) of Unuk River Chinook salmon (*Oncorhynchus tshawytscha*). This study provides crucial components required to meet these goals, namely estimates of spawning escapement, age-sex composition, and the coded wire tag (CWT) and adipose-finclip marked fractions for adults in the escapement. The Alaska Department of Fish and Game (ADF&G) uses these data to make regional management decisions, and the Pacific Salmon Commission (PSC) uses these data for coastwide management and stock assessment through the Chinook Technical Committee (CTC).

The Unuk is 1 of 12 stocks chosen by the ADF&G as an indicator stock for the Chinook salmon initiative research (CSIR) projects. These projects were chosen to help address issues of production for Chinook salmon statewide. The recent downturn in Chinook production initiated a look at production statewide and an analysis of gaps within our knowledgebase. Juvenile information was identified as missing. The Unuk River is 1 of 2 projects state wide that provides information on the parr and smolt abundances and freshwater survival from parr to smolt. This study is important as it provides age-structured production and return rate of CWT tagged fish, which is critical for calculating juvenile Chinook salmon production and survival estimates.

BACKGROUND

The Unuk, Chickamin, Blossom, and Keta rivers are located on the mainland and traverse the Misty Fjords National Monument in southern Southeast Alaska (SEAK). The Unuk and Chickamin rivers produce the largest natural runs of Chinook salmon in this area and flow into Behm Canal near Ketchikan (Figure 1). These four rivers are “index streams” for the escapement estimation program for Chinook salmon in SEAK (Pahlke 1993).

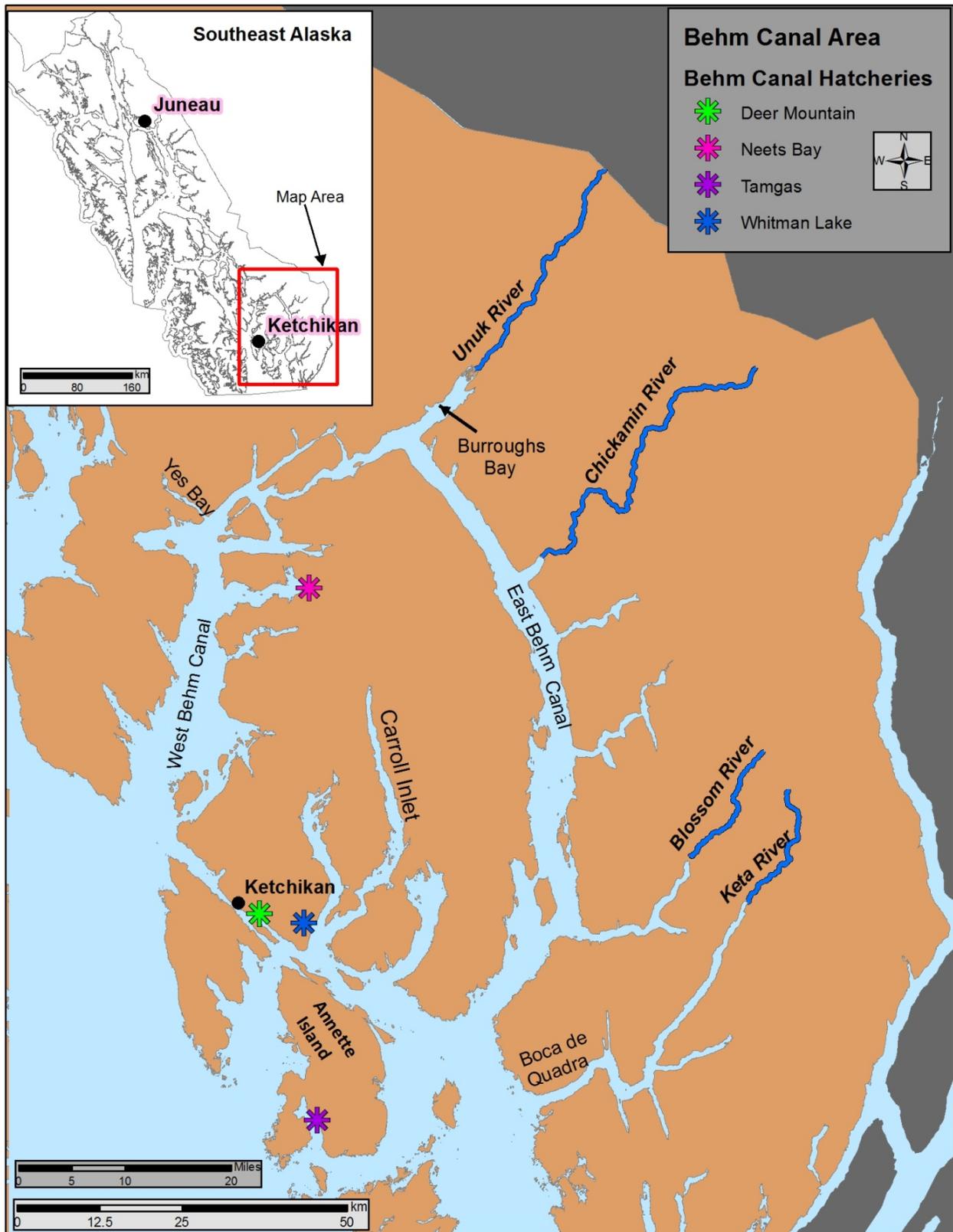


Figure 1.–Behm Canal area in Southern Southeast Alaska (inset), showing major Chinook salmon systems and hatcheries.

They represent four of the 50 “escapement indicator” stocks used annually by the CTC to judge stock status and management performance in Chinook salmon fisheries in the geographic area covered by the PSC (CTC 2001).

The Unuk River originates in a heavily glaciated area of northern British Columbia and flows for 129 km until it empties into Burroughs Bay approximately 85 km northeast of Ketchikan, Alaska. Only the lower 39 km of the river are in Alaska (Figure 2). Pahlke et al. (1996) estimated that 86% of all Chinook salmon spawning in 1994 occurred in U.S. tributaries, including Cripple, Gene's Lake (inlet creek), Kerr, Clear, and Lake creeks, and the Eulachon River. Analysis of radio telemetry data collected in 2009 showed that 77.9 % of the spawning population occurred in these U.S. tributaries (Weller and Evans 2012). It is likely that a majority of the juvenile Chinook salmon rear in the U.S portion of the Unuk River.

Aerial surveys of Cripple, Gene's Lake, Clear, Kerr, and Lake creeks, and the Eulachon River have been conducted annually since 1977. Average distribution of peak survey counts in the Unuk River tributaries from 1977 to 2007, and 2009 to 2013 (2008 surveys were incomplete) was as follows: Cripple Creek (36.1%), Gene's Lake Creek (32.6%), Eulachon River (14.0%), Clear Creek (9.6%), Kerr Creek (4.2%), and Lake Creek (3.5%). All index areas are surveyed by helicopter, and due to heavy canopy cover Gene's Lake Creek and Cripple Creek, surveys are supplemented with foot surveys as needed.

A drop in the indices of escapement (peak survey counts) in each of these four systems in the late 1980s raised conservation concerns for these stocks, and historical data was reviewed to evaluate their status. During this review, the Division of Sport Fish (DSF) agreed to begin a more intensive stock assessment program on the Unuk River. This revised stock assessment program consists of 2 components: 1) an annual mark-recapture tagging project to estimate total escapement; and 2) an annual coded wire tag (CWT) project to estimate marine harvest and survival. Implementation of the recent CSIR means that this stock assessment program will continue into the near future. Spawning abundance of large Chinook salmon was first estimated for the Unuk River in 1994, and then in 1997 through 2009 and 2011 using mark-recapture experiments. Estimating the annual escapements using mark-recapture methods is a substantial improvement over aerial surveys for population assessment and modeling (Jones III et al. 1998a).

Concurrent estimation of escapement and peak survey counts also allows us to calculate an expansion factor that can be used to expand past and future survey counts when there are no mark-recapture estimates (e.g., 2010, 2012 and 2013) to estimate the spawning escapement. Mark-recapture experiments were not successful in 2010, 2012 and 2013. In 2010, the diagnostic tests described in Appendix E suggested a partially stratified estimator be used; stratification efforts were unsuccessful, however, and no mark recapture estimate was produced. In 2012 and 2013, expanded peak counts were used because poor runs and high water levels resulted in low sample numbers and insufficient (5 and 0, respectively) recoveries for the mark-recapture experiment. From 1997 through 2009 and in 2011 the average mark-recapture abundance estimate of large Chinook salmon was 5,185 fish and ranged from 2,970 in 1997 to 10,541 fish in 2001 (Table 1; Jones et al. 1998b; Jones and McPherson 1999, 2000, 2002; Pahlke et al. 1996; Weller and McPherson 2003a-b, 2004, 2006a-b; Weller and Evans 2009, 2012).

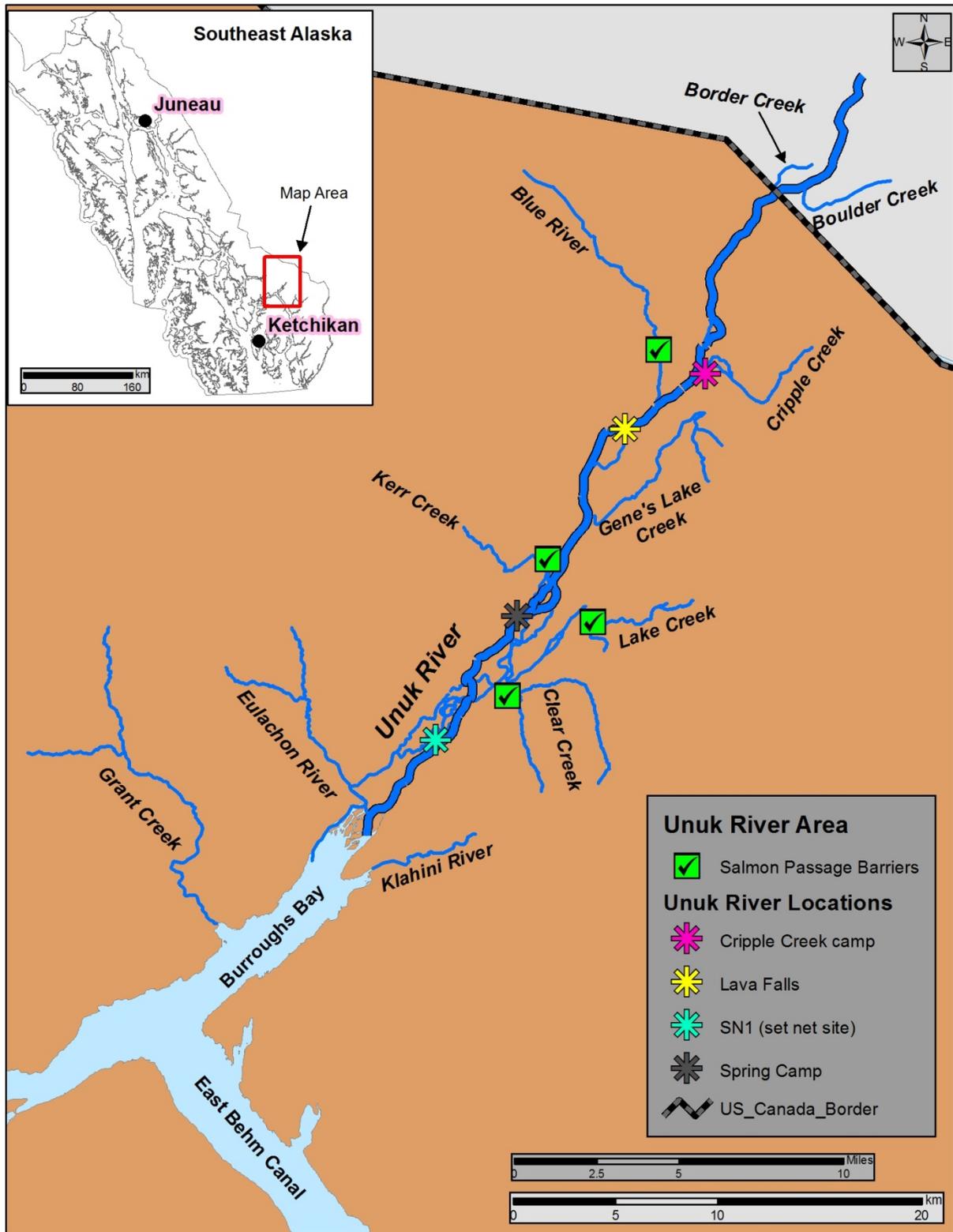


Figure 2.—Unuk River area in Southeast Alaska, showing major tributaries, barriers to salmon migration, and location of ADF&G research sites (SN1 = set net site).

Table 1.—Peak survey counts, mark-recapture estimates of abundance, expansion factors, and associated statistics for large (≥ 660 mm mid eye to fork of tail (MEF)) Chinook salmon in the Unuk River in 1994, 1997–2009 and 2011, and the 1997–2009 and 2011 average.

Year	Survey count	Mark-recapture (M-R) estimate	SE (M-R)	Survey count/M-R, %	CV (M-R), %	95% RP (M-R)	Expansion factor (EF)	SE (EF)	CV (EF), %	95% RP (EF), %	95% CI (M-R)	Estimated bias, %
1994	711	4,623	1,266	15.4	27.4	53.7	6.50	1.78	27	54	2,992–9,425	ND
1997	636	2,970	277	21.4	9.3	18.3	4.67	0.44	9	18	2,499–3,636	0.1
1998	840	4,132	413	20.3	10.0	19.6	4.92	0.49	10	20	3,433–4,974	0.6
1999	680	3,914	490	17.4	12.5	24.5	5.76	0.72	13	25	3,110–5,071	1.5
2000	1,341	5,872	644	22.8	11.0	21.5	4.38	0.48	11	21	4,848–7,347	1.1
2001	2,019	10,541	1,181	19.2	11.2	22.0	5.22	0.58	11	22	8,665–13,541	1.0
2002	897	6,988	805	12.8	11.5	22.6	7.79	0.90	12	23	5,775–8,845	0.6
2003	1,121	5,546	433	20.2	7.8	15.3	4.95	0.39	8	15	4,814–6,530	0.0
2004	1,008	3,963	325	25.4	8.2	16.1	3.93	0.32	8	16	3,406–4,684	0.5
2005	929	4,742	396	19.6	8.4	16.4	5.10	0.43	8	16	4,094–5,579	0.5
2006	940	5,645	506	16.7	9.0	17.6	6.01	0.54	9	18	4,094–5,579	0.5
2007	709	5,668	446	12.5	7.9	15.4	7.99	1.32	17	32	4,900–6,685	0.3
2009	687	3,157	354	21.8	11.2	22.0	4.60	0.52	11	22	2,568–4,012	1.3
2011	431	3,195	655	13.5	20.5	40.2	7.41	1.52	21	40	1,911–4,479	ND
Average	971	5,494	567	17.7	10.6	20.8	5.89	0.83	14	28	4,470–6,65	0.59

Note: RP = relative precision.

There are 14 years of relatively precise total escapement estimates and associated survey counts that were used to develop a predictive mean expansion factor (EF) of 5.89 for this stock (Eq. 6 in Appendix C1). The 2008, 2010, 2012 and 2013 data are excluded from the calculation. In 2008, peak survey counts were incomplete and the mark recapture studies of 2010, 2012 and 2013 failed to produce reliable estimates of escapement. The predictive mean EF enables us to predict Chinook salmon escapement of total large spawners for the 1977–1996 calendar years from the peak survey counts.

Harvest estimates are necessary in order to estimate total production, exploitation rates, and survival rates. A CWT program is used to estimate harvest parameters. A previous study on the Unuk River implanted CWTs in Chinook salmon juveniles from the 1982–1986 broods (Pahlke et al. 1996). Indications from this research were that harvest rates on the Unuk River Chinook salmon stock (over all age classes: age-1.1 to age-1.5 fish) ranged from 14% to 24%, although low relative precision associated with these harvest estimates contributes to some uncertainty.

In 1993, ADF&G resumed a CWT project on the Unuk River. Fish were marked at a much higher rate than was done previously. From 1993 to 2013, a total of 636,883 Chinook salmon (fall) parr have been tagged, with an annual average of 31,844 and a range of 13,656 (2012) to 61,905 (Pahlke et al. 1996; Jones III et al. 1998b; Jones III and McPherson 1999, 2000, 2002; Weller and McPherson 2003a-b, 2004, 2006a-b; Weller and Evans 2012). Smolt tagging efforts commenced in the spring of 1994 and a total of 188,218 smolt have since been tagged for an annual average of 9,411 and a range of 2,642 smolt in 1994 to 17,119 smolt tagged in 1998 (Appendix A1). The first significant returns from this effort (age-1.3 fish from the 1992 brood year) returned in 1997. Escapement was estimated in 1994 and in 1997 through 2013, and will continue in years when CWT-tagged fish return to allow estimation of total run size, exploitation rates, and harvest distribution (CWT marked fractions are determined from sampling during the mark-recapture study).

A biological escapement goal (BEG) of 650–1,400 large fish counted in surveys was developed for this stock in 1997 from analysis of smolt and adult spawner-recruit data from 1977 to 1995 (McPherson and Carlile 1997); the BEG range was expressed as a peak count because the expansion factor was unknown at that time. A spawner-recruit analysis of the 1977–2004 data utilizing an expansion factor of 4.83 was used to revise the BEG (Hendrich et al. 2008). The revised BEG of 1,800 to 3,800 large spawners (375 to 800 in peak survey counts) was approved in 2008 by ADF&G (McPherson et al. 2008).

OBJECTIVES

The research objectives for 2014 are to:

1. Estimate the abundance of large (≥ 660 mm MEF) Chinook salmon in the Unuk River such that the estimate is within 30% of the true abundance 95% of the time.
2. Estimate the age and sex compositions of large Chinook salmon in the Unuk River such that estimates are within 5 percentage points of the true values 95% of the time.
3. Estimate the reciprocal of the fraction of each brood stock ($1/\theta$) marked with a CWT such that each estimate for a completed brood year has a coefficient of variation (CV) $\leq 10\%$.

SECONDARY OBJECTIVES

1. Estimate mean length-at-age and sex for the spawning population.
2. Refine the expansion factor for converting peak survey counts to escapement.
3. Estimate the age-sex composition of medium (≥ 400 to < 660 mm MEF) and small (< 400 mm MEF) Chinook salmon spawning in the Unuk River.
4. Estimate the abundance of medium Chinook salmon in the Unuk River using mark-recapture techniques. If mark-recapture data are insufficient to estimate the abundance of medium fish, abundance will be estimated based on the proportion of medium fish sampled on the spawning grounds.
5. Estimate the abundance of small Chinook salmon in the Unuk River based on the proportion of small fish sampled on the spawning grounds.

METHODS

STUDY DESIGN

Event 1-Marking

Total immigration of Chinook salmon into the Unuk River in 2014 will be estimated using a two-event closed population mark-recapture experiment. Chinook salmon will be tagged at a set gillnet site (SN1, Figure 3) as they immigrate into the Unuk River. This site is located approximately 3 km (2 mi) upstream on the south channel or “mainstem” of the lower Unuk River, well below all known spawning tributaries, with the exception of the Eulachon River. Fishing effort will be applied uniformly in time to promote catching fish destined for each spawning location within the Unuk River drainage in proportion to their abundance.

The set gillnets will be 37-m (120 ft) long by 4-m (14 ft) deep with 18-cm (7¼ in) stretch mesh hung loosely at a ratio of about 2.2:1. Two set gillnets will be fished at SN1 as described in Jones and McPherson (2000). One net will be attached to the shore and stretched directly across a small slough to a fixed buoy placed just downstream of a small island (i.e., perpendicular to the main flow of the Unuk River). Another net will be attached to the same fixed buoy and allowed to trail downstream (Figure 4). This net configuration produced catch rates that averaged 10.1% of the estimated abundance of large fish (all fish > 660) during 1997–2007, 2009, and in 2011.

Previous studies (Jones III et al. 1998a; Jones and McPherson 1999, 2000, 2002; Pahlke et al. 1996; Weller and McPherson 2003a-b, 2004, 2006a-b; Weller and Evans 2012) have shown that few returning adult Chinook salmon enter the Unuk River before June 10. Furthermore, on average, only 2% of the set gillnet catch occurred before June 15 in the 12 previous years of this mark-recapture project. From 1997 to 2012, the immigration into the lower river was largely ($> 97\%$) complete by August 1; however in 2007 and 2008 the return extended well into the first week of August.

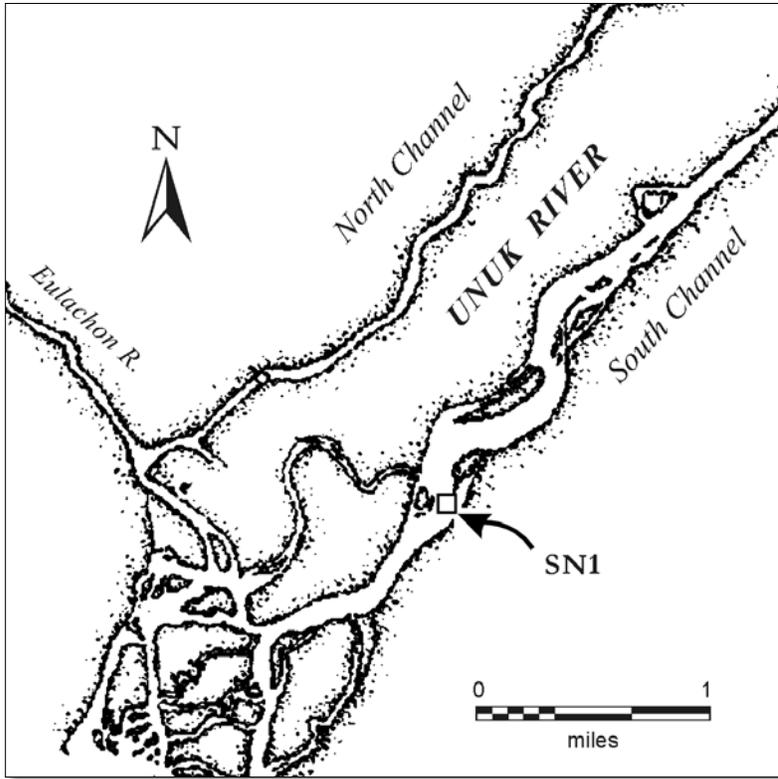


Figure 3.—Location of the set gillnet site (SN1) on the lower Unuk River.

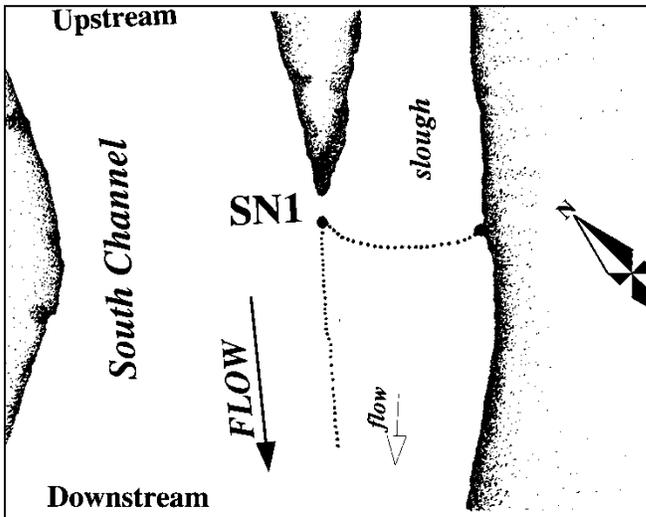


Figure 4.—Depiction of the net placement used at the set gillnet site (SN1) on the lower Unuk River.

An orientation, logistics, and training meeting will take place at the Ketchikan ADF&G office on June 5. The crew will go into the field on approximately June 6, where there will be camp repairs and preparation for the setnet site. Fishing will begin as soon as possible or by June 11. Fishing will cease when the Chinook salmon immigration is considered negligible (<1% of the cumulative catch to date for 3 consecutive days) or by August 4, whichever comes first. The net will be attended to at all times to ensure that fish are immediately removed from the net, sampled, and released.

Two 2-person crews will fish exclusively at SN1. One crew, deemed C1, will fish in the mornings (i.e., approximately 0500 to 1000) and the other crew, deemed C2, will fish in the afternoons (approximately 1001 to 1501) 6 days per week. Crews will alternate days off to ensure that fishing occurs each and every day. Ideally, nets will be repaired while fishing is taking place (i.e., it should be possible to repair nets while watching for bobbing corks). Each crew will fish 5 hours per day (soak time). This time does not include process time (i.e., the time involved handling, marking, and releasing fish) and this is why each crew is scheduled for 7.5 hours during the morning or evening shift (in addition to soak time, this includes data entry, sampling preparations, and travel to and from the setnet site). Every fish captured, including Chinook salmon, will add 1 minute of process time. Additional time may be required if it is not possible to repair nets while fishing, and the crew leader will adjust this accordingly. This also means that overtime may be required at times to adequately perform this project. As in 2013, we will maintain the reduction in soak time from 6 to 5 hours to minimize overtime hours and to compensate for reductions in operational budgets. This reduction will result in an approximate loss of 98 hours of fishing time through event 1, while saving approximately 196 hours of overtime on the budget. We expect to see a reduction of catch at the net and in the marked fraction of approximately 17%. This reduction will make it more difficult for us to realize our objective criteria. The work schedules are as follows:

C1 = set gillnet crew 1 X1 = C1 day off
 C2 = set gillnet crew 2 X2 = C2 day off

Shift	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon
Morning	X1	C1	C1	C1	C1	C1	C1	X1	C1	C1	C1	C1	C1	C1	X1
Evening	C2	C2	C2	X2	C2	C2	C2	C2	C2	C2	X2	C2	C2	C2	C2

Days off will be staggered approximately 7 days apart for each crew and 3 days apart between crews. This schedule will ensure that if a sudden surge of fish immigrates into the river, at least one crew will be fishing at that time and at no time will back-to-back days be taken off. The time that the set gillnet is more than 50% in the water and effectively fishing will be recorded to calculate CPUE. This value will be considered the EFFORT (in net hours) required to attain the CATCH. Thus, the actual time spent working the nets will vary slightly day to day. If more than 1/2 hour is missed on a given day, every attempt will be made to make it up the following day.

Every apparently healthy Chinook salmon captured, without regard to size, will be given 3 separate marks: a primary mark consisting of a uniquely numbered solid core spaghetti tag, a left axillary appendage (LAA) clip, and a 5-mm diameter upper left operculum punch (ULOP). The two secondary batch marks (LAA and ULOP) will be applied to increase the probability of correctly identifying fish that have lost their primary mark. Regardless of health, every captured fish will also be sampled prior to release to determine age (from scales), sex, and length (ASL, See Age-Sex-Length Sampling section below), condition, and presence or absence of an adipose fin (See Coded Wire Tag Sampling section).

Each set gillnet crew will consist of a motor operator and a set gillnet operator. The motor operator is responsible for safe operation of the skiff, collecting scales, and recording all field data. The set gillnet operator is responsible for setting and retrieving the set gillnet, species identification, tagging fish, determining gender, and measuring length. Captured fish will be

retrieved immediately after entanglement. All fish will be immediately and carefully untangled or cut loose and removed from the set gillnet.

Event 2-Recapturing

Spawning ground sampling will begin approximately 26 July or after completion of the Event 1 marking and continue as long as sampling is effective (approximately August 24–31). The goal of sampling is 5-fold: 1) to estimate the fraction of fish marked at SN1; 2) to estimate the fraction of fish marked with adipose fin clips and CWTs; 3) to estimate ASL composition; 4) to report the numbers of fish seen; and 5) gather data to allow assumption testing.

All Chinook salmon found or captured on the spawning grounds, regardless of size, will be counted and examined for spaghetti tags, LAAs, ULOPs, ASL, and adipose fin clips. Presence or absence of each of these marks will be recorded for each fish inspected. Note that any fish not suitable for sampling (head or tail missing, mangled beyond accurate length measurement, etc.) will be ignored and not sampled (See Age-Sex-Length Sampling and Coded Wire Tag Sampling sections below).

A variety of gear including dip nets, rod and reel snagging gear, short sections of netting, and spears (for dead fish) will be used to collect fish for sampling. Studies have shown this approach is effective at collecting an unbiased sample for age and sex composition (Jones III et al. 1998a; Jones and McPherson 1999, 2000, and 2002; McPherson et al. 1997). To prevent double sampling of fish on the spawning grounds, every live and dead fish sampled will be given a lower left operculum punch (LLOP) on the lower one-third (ventral side) of the left operculum. Additionally, every dead fish sampled will be slashed several times through the preferred area on the left side using a knife. Effort will be adjusted according to the relative number of fish present in each of the tributaries (i.e., those tributaries with more fish will have more effort, and vice-versa) to prevent compensatory sampling. Initial spawning ground surveys will focus on sampling live fish; later surveys will focus on dead and dying fish as they become more available. Historical peak spawning dates from Kissner (1984) and from surveys in 1997–2001 (see Table 2) suggest the likely timing of events. Actual survey dates in 2014 will be adjusted by observed abundance and environmental conditions to maximize the number of fish sampled. Surveys will be conducted as follows:

Cripple and Gene's Lake creeks: 2 surveys each of large live and dead fish approximately 1 week apart near the peak of spawning. Crews will walk upstream through the index area and count large fish in route. Crews will then sample carcasses and live fish of all sizes as usual on the trip back downstream. Fish observed in the lake outlet (Gene's Lake) will also be counted.

Eulachon River and Clear, Lake, Boundary, and Kerr creeks: Live and dead large fish observed at each location will be counted while inspecting fish of all sizes for marks and collecting ASL samples.

All survey counts will be recorded on a Spawning Grounds Survey Form (Appendix B1).

Table 2.—Ranking of spawning sites and historical peak survey dates for Unuk River tributaries in Southeast Alaska.

Location	Importance as spawning site (rank)	Historical survey date			Index area
		1 st	2 nd	Peak	
Cripple Creek	1	8/2	8/8	8/6	Y
Gene's Lake Creek	2	8/6	8/13	8/15	Y
Eulachon River	3	8/17	8/25	8/18	Y
Clear Creek	4	8/10	8/17	8/15	Y
Lake Creek	5	8/5	8/12	8/5–8/25	Y
Kerr Creek	5	8/16	8/23	8/17	Y
Boundary Creek	5	8/4	8/9	8/6	N

Mark-Recapture Sample Sizes

Expected precision is based on assumptions concerning population size in 2014 and past performance (Table 1). For our purposes, Chinook salmon ≥ 660 mm MEF are considered large and generally consist of brood year returns of age-1.3 to age-1.5. Based on a sibling analysis of the 1992–2010 brood year returns of age-1.2 to -1.4 Chinook salmon to the Unuk River, an estimated 2,824 age-1.3 and 1,540 age-1-4 fish are predicted to return in 2014. The average marine harvest rate from the 1992–2007 broods was 25% and 24% of age-1.3 and age-1.4 fish, respectively. Assuming an average marine harvest, we expect an inriver escapement of 2,118 age-1.3 and 1,170 age-1.4 fish to the Unuk River in 2014. On average, an estimated 37 age-1.5 fish returned to spawn in the Unuk River from 1997 to 2013. We therefore expect an inriver escapement of 3,325 large Chinook salmon in the Unuk River in 2014.

Catch rates at the setnet site from 1997–2011 (excluding 2008, 2010, 2012 and 2013) have averaged 10.1% of the estimated abundance of large fish and 14.1% have been examined on the spawning grounds (again excluding 2008, 2010, 2012 and 2013). Should these averages pertain to the study in 2014, our expectation for 2014 is that we will capture and tag 279 (accounting for reduced sampling time at the net) large fish in the lower river using set gillnets ($0.101 \times 3,325 \times (1-0.17) = 277$) and sample 469 ($0.141 \times 3,325 = 481$) on the spawning grounds. In the context of Petersen's estimator, the 95% relative precision (RP) is within 30% when the abundance of large fish is 3,325, number marked is 279, and number sampled on the spawning grounds is 481 (Robson and Regier 1964). Thus, the criterion for large fish in Objective 1 will be short of the sample size by approximately 12 fish. We feel that if the run and catch success is close to predicted we should be able to sample 481 with a small increase in effort. It is important to note that expected precision of the abundance estimate is based on historical data on the Unuk River. Over the last few years the mark-recapture experiment has been compromised by small runs, high water flows, reduction in effort and natural changes to the river/setnet site that has affected its productivity. If degradation of the setnet site continues in 2014, effort will be put into exploratory fishing to find an area that is conducive to catching and marking more fish; this effort may include shifting to different methods or gear.

Age Composition

Age compositions for fish in the lower river set gillnets and in each escapement sampling location (spawning tributary) will initially be estimated separately. Data for separate spawning

tributaries will be pooled when compositions for large fish are not statistically different ($\alpha = 0.1$) as determined by contingency table analysis. Details of the analysis are given in the data analysis section.

Most Chinook salmon scales are readable: an average of 86% of the scales collected from 1995 to 2004 were successfully aged by ADF&G technicians, with a range of 83% in 2003 to 91% in 1998 (Jones III et al. 1998a; Jones and McPherson 1999, 2000, 2002; Weller and McPherson 2003a-b, 2004, 2006a). Also, comparing ages based on scales to known-age fish determined using decoded CWTs shows that aging fish from scales on the Unuk River is accurate (Figure 5).

Assuming no selectivity by sex, scale samples must be collected from 592 large fish (scale regeneration = 14%, no finite population correction) according to Thompson (1987). Because scales from 748 (469 + 279) large fish should be collected during the experiment, the criterion for large fish in Objective 2 should be met. All scales will be processed to determine age.

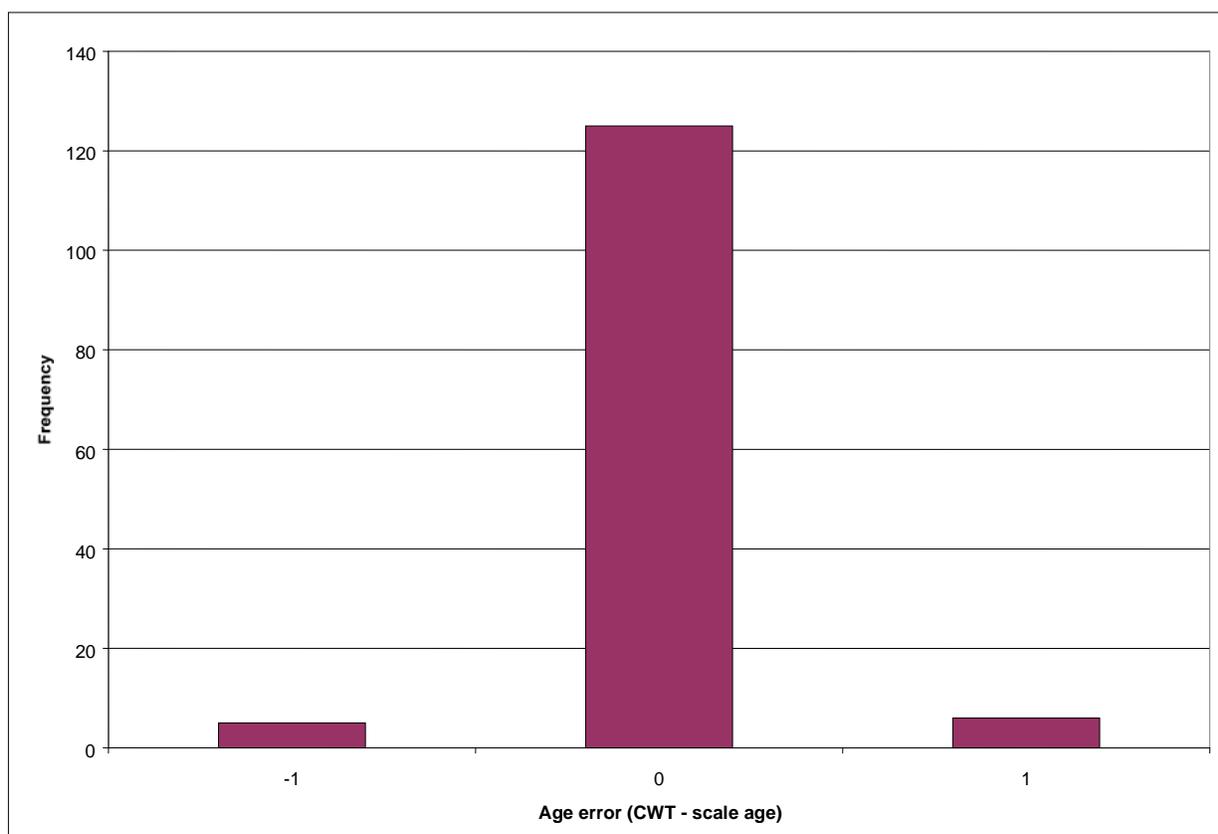


Figure 5.—Age errors encountered when comparing differences between coded wire tag (CWT) and scale ages from fish gathered on the Unuk River in Southeast Alaska, 1996–1998.

Estimation of Coded Wire Tag Marked Fraction in the 2007–2011 Broods

Harvest contributions of Unuk River Chinook salmon have been or will be estimated from recovery of Chinook salmon with CWTs sampled from fisheries. This estimation requires assessment of the CWT marked fraction by brood year. In 2014, ages 1.1 through 1.5 fish will be sampled from the Unuk inriver run originating from brood years 2007 through 2011. These tags were placed in parr in the fall of 2008 through 2012 and in smolt in the spring of 2009 through 2013. Note that the marked fraction for CWTs (θ) is unknown until returning adults can be

sampled inriver. As part of the sampling for the mark-recapture estimate in 2014, each captured fish will be inspected for the presence or absence of an adipose fin. Sampling of adipose-clipped fish is described in the Coded Wire Tag Sampling section. Brood year-specific marked fractions will then be estimated as described in the Data Analysis section (Eq. 15). Estimates of θ for a given brood year will be updated as its age class returns. Between 1997 and 2010, this project sampled an average of 1,429 adults per brood year for adipose clips (brood years 1992–2006, Appendix A2). Given that we have tagged an average of about 8% of the outmigration for each brood year, a simulation shows that the CV of our estimate of the inverse of the marked fraction ($1/\theta$) should be about 9%, within the prescribed precision of Objective 3. The average CV of estimates of $1/\theta$ for brood years 2000 through 2006 is 12%. Previously assumed tagging and precision requirements, and adult sampling goals are described in separate operational plan titled “Chinook Salmon Coded Wire Tagging on the Unuk River, Southeast Alaska”. These precision calculations are subject to the caveats described for the precision calculations for the mark-recapture estimate; i.e. small runs, high water and changing setnet site conditions may reduce the historical catch rates at the setnet site, and small runs will reduce event-2 sampling. These reductions will conspire to lower the number of adults inspected for adipose fin clips. Should these conditions persist, we will adjust our expectations of precision of the estimate of the marked CWT fraction.

DATA COLLECTION

Event 1 - Marking

Effort and catch during set gillnet fishing at SN1 will be recorded daily on a Set Gillnet Recording Form (Appendix B2). Date, location, the initials of the crewmembers working, river height and temperature, start and end time, and other comments will be recorded on this form. Water level will be measured at a staff gauge permanently affixed to a structure in the main channel of the lower Unuk River, at an accessible site near camp. Water temperature, measured to the nearest 1°C, and depth will be measured at the same time (approximately 0800 hours) each day. The number of fish caught and the processing time for sampling fish or cleaning nets, etc. will also be recorded. Fishing effort will equal the difference between the start and end times minus processing time (i.e., 1 minute additional for each fish captured regardless of species and other delays such as net cleaning, taking lunch, or photos).

Regardless of size, each healthy Chinook salmon captured will be given 3 different marks: a primary mark consisting of a uniquely numbered solid core spaghetti tag, and the 2 batch marks (LAA and the ULOP). Each fish captured, regardless of health, will be sampled for ASL and CWTs (see Age-Sex-Length Sampling and Coded Wire Tag Sampling sections below). Data from Chinook salmon captured with set gillnets will be recorded on the Set Gillnet Age-Sex-Length Form (Appendix B3). This form includes the fish #, date, time caught, sex, length (mm MEF), spaghetti tag #, adipose clip cinch #, presence of sea lice, age, AEC (age error code), stream code (see Appendix B4), comments, and card #. Wounds, marks, and atypical circumstances will be recorded in the comment section. Tagged fish will be sequentially numbered, beginning with “1”; untagged fish will not be numbered. A Coded Wire Tag Sampling Form (Appendix B5) summarizing each day's set gillnet sampling must also be completed. We anticipate that approximately 9 fish will be sacrificed in the lower river set gillnets, of which nearly 100% will be age-.1 or -.2 males (see Coded Wire Tag Sampling section below).

Event 2 - Recapturing

All Chinook salmon found or captured on the spawning grounds, regardless of size and that are suitable for sampling, will be counted and sampled for spaghetti tags, LAA, ULOP and lower left operculum (LLOP) punches, ASL, and adipose fin clips (see Coded Wire Tag Sampling section below for details on CWT recovery). Dip nets, rod and reel snagging gear, hands, short sections of netting, and spears (for dead fish) will be used to capture fish. In order to prevent double sampling of fish on the spawning grounds, every newly sampled fish will be given a LLOP. Additionally, each dead fish sampled will also be slashed several times with a knife through the preferred area.

Emphasis during spawning grounds surveys will be on inspecting fish for marks and collecting ASL data. Also, a count will be made of the total number of large fish seen by observers traversing an area on a single day; this count will be recorded on the Spawning Grounds Survey Form (Appendix B1) each day a survey count is made (see Study Design above for more details). The location, date, stream code (Appendix B4), survey #, surveyors, all water and weather conditions, total number of large fish, etc. will be recorded on this form. The percentage of fish the observer(s) believed were counted and why they thought so will also be recorded.

Data from fish sampled on the spawning grounds will be recorded on the Spawning Grounds Age-Sex-Length Form (Appendix B6). A Coded Wire Tag Sampling Form (Appendix B5) for each day's spawning grounds sampling for each location (e.g., Cripple Creek, Kerr Creek, etc.) must also be completed.

Age-Sex-Length Sampling

All Chinook salmon caught in the lower river set gillnets and sampled on the spawning grounds will be sampled for ASL. Age compositions for the lower river set gillnet sampling and each escapement sampling location (tributary) will be tabulated separately using the Set Gillnet Age-Sex-Length and Capture Form (Appendix B3) and the Spawning Grounds Age-Sex-Length Form (Appendix B6). For age composition sampling, it is imperative that good scale samples be taken.

Five scales will be removed from the preferred area on the left side accordingly: 3 scales from 2 to 3 rows above the lateral line taken 1 inch apart, and 2 scales 4 to 5 rows up and ½ inch from one of the lower 3 scales (Welander 1940). In some cases the preferred area on the left side of the fish may be devoid of scales. In such instances, the preferred area on the right side of the fish should be sampled for scales and if this is devoid of adequate samples, then samples should be taken from the areas near the dorsal or anal fins on the left side of the fish. All scales will be carefully cleaned, mounted on scale gum cards, 5 per column, using methods described in ADF&G (*unpublished*)¹. The gum cards will be labeled completely at the time of sampling, or shortly thereafter. Scale cards are sequentially numbered by sampling location, beginning with 001 at each sampling location. The correct ASL stream code (Appendix B4) should also be recorded on each card. Gender will be determined from secondary maturation characteristics and length will be taken to the nearest 5 mm MEF. Secondary maturation characteristics can include predominant snouts and compressiform bodies for males, while females may display abraded

¹ ADF&G (Alaska Department of Fish and Game). *Unpublished*. Length, sex, and scale sampling procedure using the ADF&G adult salmon age-length mark-sense form version 3.0. Division of Commercial Fisheries, Douglas, AK.

caudal fins (i.e., white tails) and prominent bellies. Scales will be cleaned and mounted neatly, without excess water, sand, or mucus. If it is not possible to mount the scales in this manner on site, then the scales will be stored in numbered plastic slide pockets and then mounted later that evening at camp with care taken to clean them properly and to label the gum cards completely, including last names of all samplers for that location for that day. If scales are not collected from a fish for any reason, note that in the comment column on the ASL form and make sure to skip that column on the gum card.

MOST IMPORTANTLY:

- 1) sample every Chinook salmon encountered on the spawning grounds, regardless of size, and record all data for each fish on the appropriate form;
- 2) check every fish for the presence or absence of all marks (i.e., spaghetti tags, ULOP, LLOP, LAA, adipose fin);
- 3) collect clean, readable scales from the preferred area (or other areas if necessary); and
- 4) collect heads and scales from all adipose-finclipped fish that are dead, post spawn, or <700 mm MEF.

Coded Wire Tag Sampling

All fish sampled in the study will be inspected for adipose fin clips and sampled for ASL. The brood year of all fish sampled (with and without adipose fins) will therefore be known and estimation of brood-year specific adipose-finclipped fractions will be possible. The large sample sizes and high value of θ (~0.1) would lead to excessive mortality if all live, adipose-finclipped fish were sacrificed to verify the presence of a valid Unuk River CWT. Therefore, only fish \leq 700 mm MEF without adipose fins will be sacrificed to retrieve CWTs; this practice will be followed regardless of where or when these fish are encountered (i.e., in Event 1 or Event 2). This size limit for sampling live Chinook salmon will include almost all individuals through age-1.2 fish, a group that is almost exclusively male. All live, unspawned fish >700 mm MEF missing their adipose fin will be noted and released after sampling. Heads of all spawned-out fish >700 mm MEF, alive or dead, will be taken if the adipose fin is missing. Heads so collected will be given a uniquely numbered cinch strap obtained from the Division of Commercial Fisheries (DCF) Mark, Tag, and Age Laboratory, and will be attached to each head. The head will then be sent to the Mark, Tag, and Age Laboratory for dissection and decoding of tags. Results from the adipose fin clip, scale, and direct CWT sampling will be used to:

- estimate the CWT marked fraction by brood year, θ (using adipose fin clip, scale, and decoded CWT data); this fraction will be used to estimate marine harvest;
- compare ages derived from tags to ages determined from scales taken from the tagged fish (using scale and decoded CWT data);
- determine the incidence (if any) of strays from other tagged stocks (decoded CWT data);
- detect loss of CWTs (adipose fin clip and CWT data), and
- estimate abundance, return, and survival rates of smolts and juveniles when combined with other project data analyses (adipose fin clip, scale, and decoded CWT data).

DATA REDUCTION

It is the responsibility of the field crew leader to insure that all data are recorded on a daily basis. Data forms will be kept up to date at all times. If a computer is available in the field, data will be transferred from field forms to EXCEL^{®2} spreadsheet files. Otherwise, this will be performed later in the office. After these steps have been completed, the original field forms will be compared with the electronic files and error checked.

Inspection for errors will follow; common issues include: incorrect dates, transposed nonsensical lengths (i.e., 470 mm when the fish was actually 740 mm), correct length measurement method used (i.e., MEF or postorbit of eye-to-hypural (POH)), etc. Scale cards will be checked to ensure that scales are clean and mounted correctly, and that the cards are correctly and completely labeled and matched up with the corresponding ASL data form. Data will be sent to the ADF&G office at regular intervals and inspected for accuracy and compliance with sampling procedures. Data will be transferred from field forms to EXCEL[®] spreadsheet files. Scales will be pressed and ages estimated in the scale aging lab in Juneau. Scale ages will be entered into the spreadsheet files. When input is complete, data lists will be obtained and checked against the original field data. This will be performed two times to insure that data are error free.

The DCF Mark, Tag, and Age Laboratory is the clearinghouse for all information on CWTs within the state of Alaska. All CWT data (sampled fish, decoded tags, location, data type, samplers, etc.) are archived and accessible on a permanent ADF&G statewide database and once per year are provided to the permanent coastwide database at the Pacific States Marine Fisheries Commission. Completed CWT tagging summary and release information will be sent to the DCF Mark, Tag, and Age Laboratory, after first being given to the project leader and error checked using computer software.

A final, edited copy of the data, along with a data map, will be sent to DSF Research and Technical Services in Anchorage for electronic archiving when the report is submitted.

DATA ANALYSIS

Abundance-Medium or Large

Data collected in past studies (Jones III et al. 1998a; Jones and McPherson 1999, 2000, 2002; Pahlke et al. 1996) show that the marked fraction in samples collected in tributaries at the lower end of the drainage tends to be higher than in those collected from upper reaches (χ^2 test of data pooled across years, $P < 0.001$, $df = 1$). We assume this result occurs because fish bound for lower river locations spend more time milling in the lower river (where the gillnet is located) than fish bound for upriver spawning areas, and are therefore subjected to a higher probability of capture. However, analysis of data pooled over years also shows that fish marked during the early, middle, and late segments of the immigration are equally likely to be recovered on the spawning grounds. Thus, we expect to estimate abundance using Chapman's (1951) nearly unbiased modification of the Petersen estimator (Seber 1982, p. 60); if the case of unequal recapture probabilities occurs in 2014, the Darroch estimator (Seber 1982, p. 433) will be used.

² This product name is included for a complete description of the process and does not constitute product endorsement.

The abundance of large spawning Chinook salmon will be estimated using Chapman's modification of the Peterson estimator. Chinook classed as 'Medium' (≥ 400 mm and < 660 mm MEF) will also be estimated with a Petersen estimator if a sufficiently large number of such sized fish are tagged and recovered; otherwise the proportionality method, as described for fish classed 'small' (< 400 mm MEF) will be used. The abundance for fish of size class k ($k = L$ (≥ 660 mm) or $k = M$ (≥ 400 to < 660 mm)) will be estimated:

$$\hat{N}_k = \frac{(n_{1k} + 1)(n_{2k} + 1)}{(m_{2k} + 1)} - 1 \quad (1)$$

with variance estimated as:

$$\text{var}(\hat{N}_k) = \frac{(n_{1k} + 1)(n_{2k} + 1)(n_{1k} - m_{2k})(n_{2k} - m_{2k})}{(m_{2k} + 2)(m_{2k} + 1)^2} \quad (2)$$

where n_{1k} is the number of adults of size class k marked and released at SN1, n_{2k} is the number of adults of size class k inspected for marks upstream, and m_{2k} is the number in the subset of n_{2k} inspected comprised of adults marked at SN1.

The conditions for accurate use of this methodology are:

- a. every fish has an equal probability of being marked in event 1, or every fish has an equal probability of being captured in event 2, or marked fish mixed completely with unmarked fish in the population between events; and
- b. there is no recruitment to the population between sampling events; and
- c. there is no mark induced mortality; and
- d. fish do not lose their marks in the time between the two events; and
- e. all marked fish are recognized.

Several tests will be used to investigate assumption a. Size selectivity will be evaluated using two Kolmogorov-Smirnov (KS) tests ($\alpha = 0.1$, Appendix D1). If there is no size selectivity during either or both sampling events, then no stratification in estimates beyond large and medium fish is needed. If size selectivity is indicated during both sampling events for either large or medium fish, then the estimate will be further stratified for large or medium fish.

Sampling data for the experiment will be summarized and analyzed by the computer program Stratified Population Analysis System (SPAS; Arnason et al. 1996). Data will be stratified by marking period (early, middle, and late) and recovery area (combinations of spawning grounds) in SPAS. Pooling data over all marking and recovery strata leads to a pooled Petersen estimator, which is desired if experimental assumptions of the estimator are met. Two chi-square tests for adequacy of a pooled Petersen estimator are provided for in SPAS: 1) that immigrants marked in the different initial strata are recaptured with equal probability (the "Mixing Test" as described in Arnason et al. 1996); and 2) that marked fractions are similar in each recovery strata (the "Equal Proportions Test", as described in Arnason et al. 1996). These tests are presented in Appendix D. If either of these tests yields nonsignificant results, the pooled Petersen estimator is appropriate (Arnason et al. 1996). A meta-analysis of data collected between 1997 and 2000 (as noted above) suggests the Petersen estimator has been appropriate for this experiment. If a stratified model is

necessary, partial pooling of strata may be used to improve fit, provide admissible estimates, or to overcome numerical estimation problems. Goals in this case are always that animals within the pooled stratum should be as homogeneous as possible with respect to capture, migration, and recapture (Arnason et al. 1996). The estimated proportions of marked fish in each area and the physical proximity of the areas will guide partial pooling of recovery strata. Pooling of marking strata will be used to break trends in the fractions marked over time and will be guided by the size and length of the strata and environmental conditions on the river (river stage height and rainfall). A Goodness of Fit (GOF) test (provided in SPAS) that compares the observed and predicted statistics will indicate the adequacy of a stratified model. In general, pooling would be manipulated to yield admissible (non-negative) estimates, reduce the number of estimated parameters, and increase precision while finding no evidence of lack of fit. Sex selectivity will also be investigated using chi-square test equivalents of the size-selectivity tests described in Appendix D1 ($\alpha = 0.1$).

The life history of Chinook salmon isolates fish returning to the Unuk River, so recruitment into the population is not expected (assumption b). For assumption c, we assume tagged and untagged fish experience similar mortality or emigration due to natural causes. From a review of past studies in rivers of SEAK where Chinook salmon were marked, approximately 3% were found to be affected (Phil Richards, Fishery Biologist, ADF&G, Sport Fish Division, Juneau, personal communication); therefore it appears that effect of spaghetti tagging on survival is minimal. Also note that the estimates are germane to the time of tagging, not recapture.

Fish will be tripled marked, so any tag loss will be accounted for (assumption d). Each fish captured in the set gillnet will be checked carefully for the presence or absence of a primary mark and 2 secondary marks, and careful inspection of each fish on the spawning grounds will ensure detection of at least one of the marks (assumption e).

Bootstrapping (Efron and Tibshirani 1993), following the methods in Buckland and Garthwaite (1991), will be used to derive (potentially asymmetric) confidence intervals for the abundance estimates. The fate of the estimated \hat{N}_k in the experiment will be divided into capture histories (see below) to form an empirical probability distribution (*epd*). A bootstrap sample of \hat{N}_k will be drawn from the *epd* with replacement. From the resulting collection of resampled capture histories, n_{1k}^* , n_{2k}^* , m_{2k}^* , and \hat{N}_k^* will be calculated. A large number (B) of bootstrap samples will be so drawn. The percentile method will be used to estimate 95% confidence intervals for abundance.

Fates of Chinook salmon in the mark-recapture experiment.

1. Marked and never seen again
2. Marked and recaptured in tributaries
3. Unmarked and unseen upstream
4. Unmarked and inspected in tributaries

Abundance-Small

The abundance of small-sized fish (<400 mm; $k = S$; \hat{N}_S), will be estimated indirectly:

$$\hat{N}_S = \hat{N}_L \frac{\hat{\phi}_S}{\hat{\phi}_L} \quad (3)$$

where $\hat{\phi}_k$ is the estimated fraction of k -sized (small or large) fish in the Chinook salmon spawning population:

$$\hat{\phi}_k = \frac{n_k}{n_{sp}} \quad (4)$$

where,

n_{sp} = number of fish sampled on the spawning grounds

n_k = number of k -sized fish found in n_{sp} ,

with variance estimated as:

$$\text{var}(\hat{\phi}_k) = \frac{\hat{\phi}_k(1-\hat{\phi}_k)}{n_{sp}-1} \quad (5)$$

The variance of the abundance of small fish will be estimated:

$$\text{var}(\hat{N}_S) = \hat{N}_L^2 \text{var}\left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right) + \left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right)^2 \text{var}(\hat{N}_L) - \text{var}\left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right) \text{var}(\hat{N}_L) \quad (6)$$

where by the delta method (note that $C\hat{ov}(\hat{\phi}_S, \hat{\phi}_L) = -\frac{\hat{\phi}_S \hat{\phi}_L}{n_{sp}}$),

$$\text{var}\left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right) \approx \left(\frac{\hat{\phi}_S}{\hat{\phi}_L}\right)^2 \left(\frac{\text{var}(\hat{\phi}_S)}{\hat{\phi}_S^2} + \frac{\text{var}(\hat{\phi}_L)}{\hat{\phi}_L^2} + \frac{2}{n_{sp}} \right) \quad (7)$$

Equations 3–7 will also be used to estimate the abundance of medium fish, with appropriate substitutions, if we recapture an insufficient number of medium fish to allow a robust mark-recapture estimate.

Abundance-All

The abundance of all Chinook salmon will be estimated as:

$$\hat{N}_{ALL} = \sum_k \hat{N}_k \quad (8)$$

If medium fish are estimated using mark recapture techniques, then:

$$\text{var}(\hat{N}_{ALL}) = \sum_k \text{var}(\hat{N}_k) \quad (9)$$

If medium fish are estimated using the proportionality method, then:

$$\text{var}(\hat{N}_{ALL}) = \text{var}(\hat{N}_L) \left[\frac{1}{\hat{\phi}_L} \right]^2 + \hat{N}_L^2 \text{var} \left[\frac{1}{\hat{\phi}_L} \right] - \text{var}(\hat{N}_L) \text{var} \left[\frac{1}{\hat{\phi}_L} \right] \quad (10)$$

where,

$$\text{var} \left(\frac{1}{\hat{\phi}_L} \right) \approx \left[\frac{1}{\hat{\phi}_L} \right]^4 \text{var}(\hat{\phi}_L) \quad (11)$$

Age and Sex Composition of Escapement

Age and sex composition will be estimated separately for large, medium, and small fish. Fish ages will be determined from scales according to the procedures in (Olsen 1992). Methodology for estimation of age and sex composition will depend on whether the mark-recapture abundance estimators require further stratification beyond the large, and medium designations (i.e., further stratification within the ‘large’ or ‘medium’ size groups), as described in Appendix D1 (chi-square equivalents of the KS tests will be used to assess sex selectivity).

If the mark-recapture abundance estimators do not need to be further stratified by size (within the ‘large’ or ‘medium’ size groups), proportions by age (or by sex) for the large and medium size classes will be estimated from the appropriate sampling event(s) in which there is no evidence of selectivity. Proportions by age (or by sex) within the small size class will be estimated from the spawning ground samples. These fish are rarely caught by the set gill nets in the marking event.

The proportion of the inriver run composed of a given age c within a size class k (large (≥ 660 mm) medium (≥ 400 to < 660) or small (< 400 mm)) will be estimated as a binomial variable:

$$\hat{p}_{kc} = \frac{n_{kc}}{n_k}, \quad (12)$$

$$\text{var}(\hat{p}_{kc}) = \frac{\hat{p}_{kc}(1 - \hat{p}_{kc})}{n_k - 1} \quad (13)$$

where n_{kc} is the number of Chinook salmon of age c of size group k in n_k , the number of Chinook salmon sampled of size group k . Numbers of fish by age will be estimated as the sum of the products of estimated age composition and estimated abundance within a size category:

$$\hat{N}_c = \sum_k (\hat{p}_{kc} \hat{N}_k) \quad (14)$$

The \hat{N}_k in Eq. 8 are correlated. \hat{N}_S (and possibly \hat{N}_M if insufficient recaptures are found) is estimated from \hat{N}_L by Eq 3. The $\text{var}(\hat{N}_c)$ will therefore be estimated by simulation. The stochastic components in the simulation will be: $\hat{N}_L \sim N(\hat{N}_L, \hat{\sigma}_{\hat{N}_L})$, $\hat{\phi} \sim \text{multinomial}(n_{sp}, \hat{\phi}) / n_{sp}$, and the vector of age-sex proportions for the k^{th} size group as $\hat{p}_k \sim \text{multinomial}(n_k, \hat{p}_k) / n_k$. The above equations will be applied to each set of simulated values. The simulated variance of \hat{N}_c will be taken as the sample variance of the simulated \hat{N}_c ’s.

The proportion of the inriver run (overall size classes) composed of a given age will be estimated as:

$$\hat{p}_c = \frac{\hat{N}_c}{\hat{N}_{ALL}} \quad (15)$$

The $\text{var}(\hat{p}_c)$ will be estimated as the sample variance of the \hat{p}_c generated in the simulation described above.

Sex composition and age-sex composition for the entire spawning population and its associated variances will be estimated using the above equations by first redefining the binomial variables in samples to produce estimated proportions by sex \hat{p}_g , where g denotes gender (male or female), such that $\sum_g \hat{p}_g = 1$, and by age-sex \hat{p}_{cg} , such that $\sum_{cg} \hat{p}_{cg} = 1$.

If selectivity is evident in both the gillnetting and spawning ground samples for either the large or medium abundance estimates in 2014, such that stratification is recommended, but the experiment fails to recapture enough marked fish on the spawning grounds to allow stratification, then the techniques of Pahlke et al. (1996, their Appendix E2) will be used to estimate age and sex composition.

Standard sample summary statistics will be used to calculate estimates of mean length at age and its variance (Cochran 1977).

Expansion Factor

An expansion factor will be calculated to expand past survey counts in the Unuk River when no other escapement estimate was available. The methods used in Appendix C1 will be used for this purpose.

Estimation of Fraction of Adults Bearing Coded Wire Tags

Experience has shown that estimates of the proportion of adults from a given brood year with CWTs does not change appreciably over return years, and thus the fraction of adults from brood year i that are marked with a CWT will be estimated from pooled data as:

$$\hat{\theta}_i = \frac{\sum_{j=1}^L a_j \hat{p}_j}{\sum_{j=1}^L n_j} \quad (16)$$

where

$a_j =$ number of adipose fin clips observed in returning adults in year j ;

$\hat{p}_j = \frac{x_j}{s_j} =$ estimated proportion of sacrificed adults with adipose fin clips in year j (s_j) that also possess a valid CWT (x_j);

$n_j =$ number of adults examined for adipose fin clips in year j ; and

$L =$ number of years over which fish from a given brood year return (maximum = 5).

The variance of $\hat{\theta}_i$ will be estimated by simulation. For each year of recovery j :

- Adipose fin clips will be generated: $a_j^* \sim \text{binomial}(n_j, a_j/n_j)$
- CWTs will be generated: $x_j^* \sim \text{hypergeometric}(m = \hat{\rho}_j a_j^*, n = a_j^* - \hat{\rho}_j a_j^*, k = a_j^* s_j/a_j)$; parameter notation (m, n, and k) is as described in R (The R Foundation for Statistical Computing).

ρ_j^* will then be calculated as $\rho_j^* = \frac{x_j}{s_j/a_j a_j^*}$, and $\hat{\theta}_i^*$ as:

$$\hat{\theta}_i^* = \frac{\sum_{j=1}^L a_j^* \rho_j^*}{\sum_{j=1}^L n_j} \quad (17)$$

Many values of $\hat{\theta}_i^*$ will be simulated and the variance of $\hat{\theta}_i^*$ estimated as the sample variance of the simulated values.

SCHEDULE AND DELIVERABLES

Adult tagging efforts will begin approximately June 11 and end approximately 1 August. Spawning grounds work is scheduled from late July through August. Raw field data will be entered and error checked by 30 November 2014. An ADF&G-DSF, Fishery Data Series (FDS) report will be prepared by 1 June 2015 summarizing adult spawning abundance and age, sex and length composition for the Unuk River Chinook salmon run in 2014.

RESPONSIBILITIES

Todd Johnson, Fisheries Biologist II (project leader)

Duties: This position is responsible for supervising all aspects of the project, including planning, budget, sample design, permits, equipment, personnel, and training. Supervises Dreyer, Sanguinetti, and the three vacant technician positions; will adjust field operations with their consultation. Maintains regular contact with field crew. Will track budget and stay within allocations. Will analyze all smolt and harvest contribution data and will be the lead author on reports. May assist with fieldwork and will arrange logistics with field crew and Sanguinetti. Will conduct a start-of-project meeting with the field crew and Sanguinetti. Follows departmental and state policy in all matters.

David Evans, Biometrician III

Duties: Provides input to and approves the sampling design. Reviews and provides biometric support for operational plan, data analysis, and final report.

Philip Richards, FB III

Duties: Supervises Johnson. Will oversee or assign aerial Chinook salmon index surveys and may assist with field work.

Ed Jones, Salmon Research Coordinator

Duties: This position is the Salmon Research Coordinator for salmon stock assessment and provides program and budget planning oversight. Also reviews the operational plan, data analysis, and final report.

Micah Sanguinetti, Fish and Wildlife Technician IV (project expeditor)

Duties: This position serves as the assistant project leader and is responsible for expediting project activities from Ketchikan, from June 1 through the end of the project. Responsible for daily radio call, arranging logistics with field crew and project leader, purchasing supplies, loading and unloading supply planes, proper conduct in the public's eye, and following department guidelines supplied by the project leader. Responsible for supervising field crew in absence of Johnson, assists with field operations as necessary, makes recommendations on logistics to the project leader, adjusts personnel hours and schedules as appropriate. Enters field data into spreadsheets and edits and summarizes data.

David Dreyer, Fish and Wildlife Technician IV (crew leader)

Duties: This position is responsible for directing all field aspects of the project under directions from the project leader. Will ensure that all crew members are trained in the proper operation of all aspects of the project including boating safety, fish handling, data collection and recording, conduct in the public's eye, and adherence to department policies. Position will be responsible for equipment maintenance and proper operation, fieldwork schedules, scheduling of flights with Sanguinetti, and submitting data accurately and timely. With the project leader and Sanguinetti, will attempt to resolve as many personnel and administrative items as is possible and is responsible for submitting inventories at the end of the season to Sanguinetti. This position is also responsible for reports to be submitted to the project leader weekly, and daily satellite phone calls or emails to Sanguinetti and Johnson. Position functions as lead technician on the morning set net crew. Follows departmental and state policy in all matters.

Nathan Frost, Fish and Wildlife Technician III.

Duties: This position is responsible for assisting in all aspects of escapement spawning grounds sampling including safe operation of riverboats and all other equipment and various data collection and conduct in the public's eye. Follows departmental and state policy in all matters.

Mike Enders, Fish and Wildlife Technician III.

Duties: This position is responsible for assisting in all aspects of escapement spawning grounds sampling including safe operation of riverboats and all other equipment and various data collection and conduct in the public's eye. Follows departmental and state policy in all matters.

Alanna Gottshall, Fish and Wildlife Technician II.

Duties: This position is responsible for assisting in all aspects of adult tagging and escapement spawning grounds sampling including safe operation of riverboats and all other equipment and various data collection, and conduct in the public's eye. Follows departmental and state policy in all matters.

REFERENCES CITED

- Arnason, A. N., C. W. Kirby, C. J. Schwarz, and J. R. Irvine. 1996. Computer analysis of data from stratified mark-recovery experiments for estimation of salmon escapements and other populations. Canadian Technical Report of Fisheries and Aquatic Sciences. 2106: 37 p.
- Buckland, S. T. and P. H. Garthwaite. 1991. Quantifying precision of mark-recapture estimates using the bootstrap and related methods. *Biometrics* 47:255–268.
- Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publication Station 1:131–160.
- Chinook Technical Committee (CTC). 2001. Catch and escapement of Chinook salmon under Pacific Salmon Commission jurisdiction, 1997–2000. Pacific Salmon Commission Joint Chinook Committee Report TCCHINOOK (01)-1, Vancouver, B.C.
- Cochran, W. G. 1977. *Sampling Techniques*, third edition, Wiley and Sons, New York.
- Conover, W. J. 1980. *Practical nonparametric statistics* 2nd ed. John Wiley & Sons, New York. 493pp.
- Efron, B. and R. J. Tibshirani. 1993. *An introduction to the bootstrap*. Chapman and Hall, New York.
- Jones III, E. L., T. J. Quinn and B. W. Van'Alen. 1998a. Observer accuracy and precision in aerial and foot survey counts of pink salmon in a Southeastern Alaska stream. *North American Journal of Fisheries Management*, 18(4), 832–846.
- Hendrich, C. F., J. L. Weller, S. A. McPherson and D. R. Bernard. 2008. Optimal Production of Chinook salmon from the Unuk River. Alaska Department of Fish and Game, Fishery Manuscript No. 08-03, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms08-03.pdf>
- Jones III, E. L., S. A. McPherson, and D. L. Magnus. 1998b. A mark-recapture experiment to estimate the escapement of Chinook salmon in the Unuk River, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-33, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms98-33.pdf>
- Jones III, E. L. and S. A. McPherson. 1999. A mark-recapture experiment to estimate the escapement of Chinook salmon in the Unuk River, 1998. Alaska Department of Fish and Game, Fishery Data Series No. 99-14, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms99-14.pdf>
- Jones III, E. L. and S. A. McPherson. 2000. A mark-recapture experiment to estimate the escapement of Chinook salmon in the Unuk River, 1999. Alaska Department of Fish and Game, Fishery Data Series No. 00-22, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms00-22.pdf>
- Jones III, E.L. and S.A. McPherson. 2002. A mark-recapture experiment to estimate the escapement of Chinook salmon in the Unuk River, 2000. Alaska Department of Fish and Game, Fishery Data Series No. 02-17, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms02-17.pdf>
- Kissner, P. D. Jr. 1984. A study of Chinook salmon in southeast Alaska. Alaska Department of Fish and Game, Sport Fish Division. Annual report 1983–84, Project F-9-16, 25 (AFS-41).
- McPherson, S. A., D. R. Bernard, M. S. Kelley, P. A. Milligan, and P. Timpany. 1997. Spawning abundance of Chinook salmon in the Taku River in 1996. Alaska Department of Fish and Game, Fishery Data Series No. 97-14, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms97-14.pdf>
- McPherson, S., J. H. Clark, D. R. Bernard, J. A. Der Hovanisian, E. Jones, K. Pahlke, P. Richards, J. Weller, T. Johnson, R. Chapell, B. Elliott, and C. Hendrich. 2008. Chinook salmon status and escapement goals for stocks in Southeast Alaska. Alaska Department of Fish and Game, Special Publication No. 08-18, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/SP08-18.pdf>
- Mood, A.M., F.A. Graybill and D.C. Boes. 1974. *Introduction to the theory of statistics*, 3rd ed. McGraw-Hill Book Co. New York. 564pp.
- Neter, J. and W. Wasserman. 1990. *Applied Linear Statistical Models*. Richard D Irwin, Inc. Homewood, Ill. 1181 pp.

REFERENCES CITED (continued)

- Olsen, M. A. 1992. Abundance, age, sex and size of Chinook salmon catches and escapements in Southeast Alaska in 1987. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-07, Juneau. . <http://www.adfg.alaska.gov/FedAidpdfs/tfr.92-07.pdf>
- Pahlke, K. A. 1993. Escapements of Chinook salmon in Southeast Alaska and transboundary rivers in 1992. Alaska Department of Fish and Game, Fishery Data Series No 93-46, Juneau. <http://www.adfg.alaska.gov/FedAidPDFs/fms93-46.pdf>
- Pahlke, K. A., S. A. McPherson, and R. P. Marshall. 1996. Chinook salmon research on the Unuk River, 1994. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 96-14, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms96-14.pdf>
- Robson, D. S., and H. A. Regier. 1964. Sample size in Peterson mark-recapture experiments. Transactions of the American Fisheries Society 93:215–226.
- Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters. 2nd. ed. Charles Griffin and Sons, Ltd., London. 654 p.
- Thompson, S. K. 1987. Sample size for estimating multinomial proportions. American Statistician. 41:42–46.
- Welander, A. D. 1940. A study of the development of the scale of the Chinook salmon (*Oncorhynchus tshawytscha*). Master's thesis, University of Washington, Seattle.
- Weller, J. L. and S. A. McPherson. 2003 a. Estimation of the escapement of Chinook salmon in the Unuk River in 2001. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 03-13, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms03-13.pdf>
- Weller, J. L. and S. A. McPherson. 2003 b. Estimation of the escapement of Chinook salmon in the Unuk River in 2002. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 03-15, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms03-15.pdf>
- Weller, J. L. and S. A. McPherson. 2004. Estimation of the escapement of Chinook salmon in the Unuk River in 2003. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 04-10, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms04-10.pdf>
- Weller, J. L. and S. A. McPherson. 2006 a. Estimation of the escapement of Chinook salmon in the Unuk River in 2004. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 06-07, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms06-07.pdf>
- Weller, J. L. and S. A. McPherson. 2006 b. Estimation of the escapement of Chinook salmon in the Unuk River in 2005. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 06-59, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms06-59.pdf>
- Weller, J. L. and D. G. Evans. 2009. Estimation of the Escapement of Chinook salmon in the Unuk River in 2006. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 09-02, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms09-02.pdf>
- Weller, J. L. and, D. G. Evans. 2012. Production of Unuk River Chinook salmon through 2009 and 1992–2005 broods. Alaska Department of Fish and Game, Division of Sport Fish, Fisheries Data Series No. 12-85, Anchorage. <http://www.adfg.alaska.gov/FedAidPDFs/fms12-85.pdf>

APPENDIX A

Appendix A1.—Numbers of Unuk River Chinook salmon fall fry and spring smolt captured and tagged with coded wire tags, 1992 brood year to present.

Brood year	Year tagged	Fall/ spring	Tag code	Dates tagged	Number of Chinook salmon released with adipose clips	Estimated number of Chinook salmon released with valid CWTs and adipose clips
1992	1993	Fall	04-38-03	10/13–10/22/93	10,304	10,263
1992	1993	Fall	04-38-04	10/25/93	439	433
1992	1993	Fall	04-38-05	10/16–10/21/93	3,192	3,093
1992	1994	Spring	04-42-06	5/05–5/23/94	2,642	2,642
1992 brood year total					16,577	16,431
1993	1994	Fall	04-33-49	10/07–10/24/94	1,706	1,700
1993	1994	Fall	04-33-50	10/07–10/22/94	11,152	11,139
1993	1994	Fall	04-35-57	10/22–11/01/94	7,688	7,687
1993	1995	Spring	04-42-13	4/10–5/05/95	3,227	3,227
1993 brood year total					23,773	23,753
1994	1995	Fall	04-35-56	10/07–10/10/95	11,537	11,476
1994	1995	Fall	04-35-58	10/11–10/16/95	11,645	11,645
1994	1995	Fall	04-35-59	10/17–10/24/95	11,100	10,825
1994	1995	Fall	04-42-31	10/25–10/26/95	6,324	6,260
1994	1996	Spring	04-42-07	4/13–4/23/96	6,099	6,099
1994	1996	Spring	04-42-08	4/23–4/27/96	1,357	1,357
1994 brood year total					48,062	47,662
1995	1996	Fall	04-47-12	9/30–9/15/96	24,224	24,224
1995	1996	Fall	04-42-36	10/16–10/19/96	11,200	11,200
1995	1996	Fall	04-42-18	10/20–10/21/96	3,753	3,753
1995	1997	Spring	04-38-29	3/31–4/18/97	12,517	12,517
1995 brood year total					51,694	51,694
1996	1997	Fall	04-47-13	10/04–10/11/97	24,303	24,176
1996	1997	Fall	04-47-14	10/06–10/11/97	22,975	22,583
1996	1997	Fall	04-47-15	10/11–10/20/97	15,396	15,146
1996	1998	Spring	04-46-46	3/29–4/05/98	11,188	11,134
1996	1998	Spring	04-43-39	4/08–4/13/98	5,987	5,987
1996 brood year total					79,849	79,026
1997	1998	Fall	04-01-39	10/04–10/13/98	22,374	22,366
1997	1998	Fall	04-01-40	10/13–10/23/98	11,640	11,522
1997	1999	Spring	04-01-44	4/08–5/01/99	7,948	7,948
1997 brood year total					41,962	41,836
1998	1999	Fall	04-01-42	10/04–10/17/99	16,661	16,661
1998	2000	Spring	04-02-56	4/01–4/27/00	11,124	11,124
1998	2000	Spring	04-02-57	4/29–5/4/00	2,209	2,209
1998 brood year total					29,994	29,994
1999	2000	Fall	04-03-74	10/06–10/20/00	21,853	21,853
1999	2000	Fall	04-02-88	10/20–10/29/00	10,072	10,072
1999	2001	Spring	04-01-45	4/2–4/23/01	16,561	16,561
1999 brood year total					48,486	48,486

-continued-

Brood year	Year tagged	Fall/ spring	Tag code	Dates tagged	Number of Chinook salmon released with adipose clips	Estimated number of Chinook salmon released with valid CWTs and adipose clips
2000	2001	Fall	04-02-92	9/29–10/05/01	10,950	10,950
2000	2001	Fall	04-04-57	10/05–10/09/01	11,231	11,231
2000	2001	Fall	04-04-58	10/09–10/14/01	11,223	11,200
2000	2001	Fall	04-04-60	10/14–10/23/01	10,990	10,990
2000	2002	Spring	04-05-38	4/4–4/24/02	10,904	10,904
2000	2002	Spring	04-05-39	4/25–4/26/02	1,067	1,067
2000 brood year total					56,365	56,342
2001	2002	Fall	04-05-23	9/28–10/05/02	11,402	11,402
2001	2002	Fall	04-05-24	10/05–10/13/02	11,538	11,538
2001	2002	Fall	04-05-25	10/13–10/17/02	11,778	11,778
2001	2002	Fall	04-05-26	10/17–10/20/02	11,425	11,425
2001	2002	Fall	04-46-52	10/20–10/25/02	8,403	8,403
2001	2003	Spring	04-08-07	4/8–5/10/03	11,354	11,354
2001	2003	Spring	04-08-03	5/10/2003	483	483
2001 brood year total					66,383	66,383
2002	2003	Fall	04-08-42	9/29–10/10/03	23,255	23,255
2002	2003	Fall	04-08-10	10/10–10/14/03	11,464	11,464
2002	2003	Fall	04-04-61	10/14–10/18/03	9,779	9,779
2002	2004	Spring	04-09-75	03/29–04/10/04	11,666	11,666
2002	2004	Spring	04-09-76	04/10–04/17/04	2,730	2,730
2002 brood year total					58,894	58,894
2003	2004	Fall	04-09-77	9/19–10/03/04	11,789	11,789
2003	2004	Fall	04-09-78	10/03–10/19/04	11,417	11,417
2003	2004	Fall	04-09-81	10/19–10/21/04	3,923	3,923
2003	2005	Spring	04-09-80	4/10–4/28/05	8,618	8,585
2003 brood year total					35,747	35,714
2004	2005	Fall	04-11-55	9/24–10/18/05	23,330	23,330
2004	2005	Fall	04-11-56	10/18/05	941	941
2004	2006	Spring	04-11-52	4/2–4/23/06	16,371	16,269
2004 brood year total					40,642	40,540
2005	2006	Fall	04-13-05	10/3–10/12/06	23,406	23,406
2005	2006	Fall	04-11-51	10/12–10/19/06	9,393	9,393
2005	2007	Spring	04-12-81	4/9–4/27/07	4,731	4,721
2005 brood year total					37,530	37,520
2006	2007	Fall	04-12-82	9/30–10/03/07	11,777	11,777
2006	2007	Fall	04-12-83	10/03–10/07/07	11,716	11,716
2006	2007	Fall	04-12-84	10/07–10/13/07	11,756	11,756
2006	2007	Fall	04-12-85	10/13–10/21/07	9,840	9,840
2006	2008	Spring	04-14-62	4/19–4/27/08	10,489	10,489
2006 brood year total					55,578	55,578
2007	2008	Fall	04-14-65	10/03–10/21/08	16,595	16,595
2007	2009	Spring	04-14-63	4/17–5/02/09	5,578	5,573
2007 brood year total					22,173	22,168

-continued-

Appendix A1.–Page 3 of 3.

Brood year	Year tagged	Fall/ spring	Tag code	Dates tagged	Number of Chinook salmon released with adipose clips	Estimated number of Chinook salmon released with valid CWTs and adipose clips
2008	2009	Fall	04-13-87	9/28–10/01/09	10,963	10,933
2008	2009	Fall	04-13-88	10/02–10/05/09	11,289	11,289
2008	2009	Fall	04-13-89	10/05–10/09/09	11,556	11,556
2008	2009	Fall	04-13-85	10/09–10/14/09	11,149	11,149
2008	2010	Spring	04-13-86	4/9–4/24/10	8,190	8,190
2008 brood year total					53,147	53,117
2009	2010	Fall	04-13-90	9/26–10/17/10	11,630	11,619
2009	2010	Fall	04-09-95	10/17–10/22/10	4,117	4,115
2009	2011	Spring	04-09-99	4/11–4/27/11	10,216	10,216
2009 brood year total					25,963	25,950
2010	2011	Fall	04-09-93	10/05–10/09/09	11,466	11,466
2010	2011	Fall	04-09-94	10/09–10/14/09	2,211	2,211
2010	2012	Spring	04-14-66	4/16–4/28/12	3,942	3,942
2010 brood year total					17,619	17,619
2011	2012	Fall	04-09-91	10/03–10/08/12	10,364	10,364
2011	2012	Fall	04-14-67	9/27–10/10/12	3,292	3,292
2011	2013	Spring	04-09-90	4/13–4/25/13	6,176	6,140
2011 brood year total					19,832	17,796

^a Note: An en-dash (–) indicates the data were not available at the time of plan preparation.

Appendix A2.—Numbers of adult Unuk River Chinook salmon examined for adipose finclips, sacrificed for coded wire tag sampling purposes, valid coded wire tags decoded, percent of the marked fraction carrying germane coded wire tags, percent adipose clipped, and estimated fraction of the sample carrying valid coded wire tags, 1992 brood year to present (2010 return year).

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags			Valid	Percent	Marked fraction (q)	
						Fall	Spring	Total	adipose clips (%)	adipose clips (%)	Valid (%)	Event
1992	1.2	1996	33	0	0	0	0	0	—	0.0	—	1&2
1992	1.3	1997	436	11	11	10	1	11	100.0	2.5	2.5	1&2
1992	2.2	1997	1	0	0	0	0	0	—	0.0	—	1&2
1992	1.4	1998	324	15	11	4	4	8	72.7	4.6	3.4	1&2
1992	1.5	1999	1	0	0	0	0	0	—	0.0	—	1&2
1992 brood year total			795	26	22	14	5	19	86.4	3.3	2.8	1&2
1993	1.1	1996	4	1	1	1	0	1	100.0	25.0	25.0	1&2
1993	1.2	1997	300	35	35	28	3	31	88.6	11.7	10.3	1&2
1993	1.3	1998	736	63	48	36	8	44	91.7	8.6	7.8	1&2
1993	2.2	1998	1	0	0	0	0	0	—	0.0	—	1&2
1993	1.4	1999	325	34	19	14	4	18	94.7	10.5	9.9%	1&2
1993	1.5	2000	9	0	0	0	0	0	—	0.0	—	1&2
1993 brood year total			1,375	133	103	79	15	94	91.3	9.7	8.8	1&2
1994	1.1	1997	56	4	4	2	2	4	100.0	7.1	7.1	1&2
1994	1.2	1998	311	31	28	14	11	25	89.3	10.0	8.9	1&2
1994	2.1	1998	1	0	0	0	0	0	—	0.0	—	1&2
1994	1.3	1999	421	45	14	6	5	11	78.6	10.7	8.4	1&2
1994	1.4	2000	247	12	7	3	3	6	85.7	4.9	4.2	1&2
1994	1.5	2001	4	0	0	0	0	0	—	0.0	—	1&2
1994 brood year total			1,040	92	53	25	21	46	86.8	8.8	7.7	1&2
1995	1.1	1998	81	15	14	8	5	13	92.9	18.0%	17.2	1&2
1995	0.2	1998	1	0	0	0	0	0	—	0.0	—	1&2
1995	1.2	1999	462	54	45	29	16	45	100.0	11.7	11.7	1&2
1995	1.3	2000	742	77	20	9	7	16	80.0	10.4	8.3%	1&2
1995	1.4	2001	512	53	19	12	7	19	100.0	10.4	10.4%	1&2
1995	1.5	2002	6	1	1	1	0	1	100.0	16.7	16.7	1&2
1995	2.4	2002	1	0	0	0	0	0	—	0.0	—	1&2
1995 brood year total			1,805	200	99	59	35	94	94.9	11.1	10.5	1&2
1996	0.1	1998	2	0	0	0	0	0	—	0.0	—	1&2
1996	1.1	1999	65	6	6	4	1	5	83.3	9.2	7.7	1&2
1996	1.2	2000	541	69	49	33	14	47	95.9%	12.8	12.2	1&2
1996	1.3	2001	1,177	137	43	27	11	38	88.4	11.6	10.3	1&2
1996	1.4	2002	551	58	15	11	4	15	100.0	10.5	10.5	1&2
1996	1.5	2003	7	1	0	0	0	0	—	14.3	—	1&2
1996 brood year total			2,343	271	113	75	30	105	92.9	11.6	10.7	1&2

-continued-

Appendix A2.–Page 2 of 4.

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags			Valid adipose clips (%)	Percent adipose clips (%)	Marked fraction (q)	
						Fall	Spring	Total			Valid (%)	Event
1997	1.1	2000	12	1	1	0	1	1	100.0	8.3	8.3	1&2
1997	1.2	2001	189	26	23	12	5	17	73.9	13.8	10.2	1&2
1997	0.4	2002	1	0	0	0	0	0	–	0.0	–	1&2
1997	1.3	2002	598	56	7	4	3	7	100.0	9.4	9.4	1&2
1997	2.2	2002	1	0	0	0	0	0	–	0.0	–	1&2
1997	1.4	2003	379	31	6	4	0	4	66.7	8.2	5.5	1&2
1997	1.5	2004	6	2	0	0	0	0	–	33.3	–	1&2
1997 brood year total			1,186	116	37	20	9	29	78.4	9.8	7.7	1&2
1998	1.1	2001	31	3	3	0	3	3	100.0	9.7	9.7	1&2
1998	1.2	2002	419	26	21	12	9	21	100.0	6.2	6.2	1&2
1998	0.4	2003	1	0	0	0	0	0	–	0.0	–	1&2
1998	1.3	2003	1,112	117	28	11	17	28	100.0	10.5	10.5	1&2
1998	2.2	2003	1	0	0	0	0	0	–	0.0	–	1&2
1998	1.4	2004	542	51	1	1	0	1	100.0	9.4	9.4	1&2
1998	1.5	2005	6	1	0	0	0	0	–	16.7	–	1&2
1998 brood year total			2,112	198	53	24	29	53	100.0	9.4	9.4	1&2
1999	0.2	2002	1	0	0	0	0	0	–	0.0	–	1&2
1999	1.1	2002	3	0	0	0	0	0	–	0.0	–	1&2
1999	1.2	2003	147	15	13	7	5	12	92.3	10.2	9.4	1&2
1999	1.3	2004	396	49	3	2	1	3	100.0	12.4	12.4	1&2
1999	2.3	2005	4	0	0	0	0	0	–	0.0	–	1&2
1999	1.4	2005	200	15	6	1	3	4	66.7	7.5	5.0	1&2
1999	1.5	2006	1	0	0	0	0	0	–	0.0	–	1&2
1999 brood year total			752	79	22	10	9	19	86.4%	10.5	9.1	1&2
2000	1.1	2003	72	4	4	2	2	4	100.0%	5.6	5.6	1&2
2000	1.2	2004	804	62	52	29	22	51	98.1%	7.7	7.6%	1&2
2000	2.2	2005	1	1	1	1	0	1	100.0	100.0	100.0	1&2
2000	1.3	2005	1,158	107	15	10	3	13	86.7	9.2	8.0	1&2
2000	1.4	2006	529	46	2	2	0	2	100.0%	8.7	8.7	1&2
2000	2.3	2006	1	0	0	0	0	0	–	0.0	–	1&2
2000	1.5	2007	8	0	0	0	0	0	–	0.0	–	1&2
2000 brood year total			2,573	220	74	44	27	71	95.9%	8.6%	8.2%	1&2
2001	1.1	2004	36	7	7	5	2	7	100.0	19.4	19.4	1&2
2001	1.2	2005	186	20	17	11	5	16	94.1	10.8	10.1	1&2
2001	1.3	2006	618	57	7	5	1	6	85.7	9.2	7.9	1&2
2001	2.2	2006	1	0	0	0	0	0	–	0.0	–	1&2
2001	1.4	2007	272	29	4	2	2	4	100.0	10.7	10.7	1&2
2001	2.3	2007	2	0	0	0	0	0	–	0.0	–	1&2
2001	1.5	2008	4	1	1	0	0	0	0.0	25.0	0.0	1&2
2001 brood year total			1,119	114	36	23	10	33	91.7	10.2	9.3	1&2

-continued-

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags			Valid adipose clips (%)	Percent adipose clips (%)	Marked fraction (q)	
						Fall	Spring	Total			Valid (%)	Event
2002	1.1	2005	70	5	5	1	1	2	40.0	7.1	2.9	1&2
2002	1.2	2006	794	58	46	21	14	35	76.1	7.3	5.6	1&2
2002	1.3	2007	1,266	120	19	10	4	14	73.7	9.5	7.0	1&2
2002	1.4	2008	423	48	4	3	0	3	75.0	11.3	8.5	1&2
2002	1.5	2009	4	1	0	0	0	0	–	25.0	–	1&2
2002 brood year total			2,557	232	74	35	19	54	73.0	9.1	6.6	1&2
2003	1.1	2006	28	2	2	1	1	2	100.0	7.1	7.1	1&2
2003	1.2	2007	218	22	21	8	10	18	85.7	10.1	8.7	1&2
2003	2.1	2007	1	0	0	0	0	0	–	0.0	–	1&2
2003	1.3	2008	324	30	2	1	1	2	100.0	9.3	9.3	1&2
2003	1.4	2009	151	14	3	1	2	3	100.0	9.3	9.3	1&2
2003	2.3	2009	1	0	0	0	0	0	–	0.0	–	1&2
2003	1.5	2010	3	0	0	0	0	0	–	0.0	–	1&2
2003 brood year total			726	68	28	11	14	25	89.3	9.4	8.4	1&2
2004	0.2	2007	1	0	0	0	0	0	–	0.0	–	1&2
2004	0.2	2007	1	0	0	0	0	0	–	0.0%	–	1&2
2004	1.1	2007	38	5	5	2	3	5	100.0	13.2	13.2%	1&2
2004	0.3	2008	1	0	0	0	0	0	–	0.0	–	1&2
2004	1.2	2008	216	18	14	4	4	8	57.1	8.3	4.8	1&2
2004	1.3	2009	581	57	15	4	5	9	60.0%	9.8	5.9	1&2
2004	2.3	2010	1	0	0	0	0	0	–	0.0	–	1&2
2004	1.4	2010	161	7	2	1	1	2	100.0	4.3	4.3	1&2
2004	1.5	2011	1	0	0	0	0	0	–	0.0	–	1&2
2004 brood year total			1,000	87	36	11	13	24	66.7	8.7	5.8	1&2
2005	0.1	2007	1	0	0	0	0	0	–	0.0	–	1&2
2005	1.1	2008	25	2	2	2	0	2	100.0	8.0	8.0	1&2
2005	1.2	2009	582	44	43	20	16	36	83.7	7.6	6.3	1&2
2005	2.2	2010	1	0	0	0	0	0	–	0.0	–	1&2
2005	1.3	2010	663	51	7	5	1	6	85.7	7.7	6.6	1&2
2005	1.4	2011	143	16	2	2	0	2	100.0	11.2	11.2	1&2
2005	1.5	2012	0	0	0	0	0	0	–	–	–	1&2
2005 brood year total			1,415	113	54	29	17	46	85.2%	8.0%	6.8%	1&2
2006	1.1	2009	20	2	2	1	0	1	50.0	10.0	5.0	1&2
2006	0.3	2010	1	0	0	0	0	0	–	0.0	–	1&2
2006	1.2	2010	222	13	12	7	3	10	83.3	5.9	4.9	1&2
2006	1.3	2011	354	17	5	5	0	5	100.0	4.8	4.8	1&2
2006	1.4	2012	44	4	3	2	1	3	100.0	9.1	9.1	1&2
2006	1.5	2013	–	–	–	–	–	–	–	–	–	1&2
2006 brood year total			641	36	22	15	4	19	86.4%	5.6%	4.9%	1&2
2007	1.1	2010	23	1	1	1	0	1	100.0	4.3	4.3	1&2
2007	1.2	2011	172	5	5	3	1	4	80.0	2.9	2.3	1&2
2007	1.3	2012	199	8	2	1	1	2	100.0	4.0	4.0	1&2
2007	1.4	2013	–	–	–	–	–	–	–	–	–	1&2
2007	1.5	2014	–	–	–	–	–	–	–	–	–	1&2

-continued-

Appendix A2.–Page 4 of 4.

Brood year	Age class	Year examined	Number examined	Adipose clips	Number sacrificed	Number of valid tags			Valid adipose clips (%)	Percent adipose clips (%)	Marked fraction (q)	
						Fall	Spring	Total			Valid (%)	Event
2007 brood year total			394	14	8	5	2	7	87.5	3.6	3.1	1&2
2008	1.1	2011	11	0	0	0	0	0	–	–	–	1&2
2008	1.2	2012	117	16	16	5	10	15	93.8	13.7	12.8	1&2
2008	1.3	2013	–	–	–	–	–	–	–	–	–	1&2
2008	1.4	2014	–	–	–	–	–	–	–	–	–	1&2
2008	1.5	2015	–	–	–	–	–	–	–	–	–	1&2
2008 brood year total			128	16	16	5	10	15	93.8	12.5	11.7	1&2
2009	1.1	2012	23	1	1	0	1	1	100.0	4.3	4.3	1&2
2009	1.2	2013	–	–	–	–	–	–	–	–	–	1&2
2009	1.3	2014	–	–	–	–	–	–	–	–	–	1&2
2009	1.4	2015	–	–	–	–	–	–	–	–	–	1&2
2009	1.5	2016	–	–	–	–	–	–	–	–	–	1&2
2009 brood year total			23	1	1	0	1	1	100.0	4.3	4.3	1&2

^a *Note:* An en-dash (–) either indicates that the quantity could not be calculated (division by zero), or the data have not been collected yet.

APPENDIX B

Appendix B1.-Unuk River spawning ground survey form, 2014.

Location Cripple Creek (10175 103002030)

Date August 8, 2014

Survey Number 1st (1st or 2nd, etc.)

Surveyors: Dave Magnus

Water Conditions (Clarity, Water Level, Temp., etc.):

Clear, low, temperature of 40°F

Weather Conditions: Sky partly cloudy, wind calm, sunlight is good for visibility, and tons of bugs

A. Total number of large-size fish counted Counted 72 large fish; saw 12 jacks (also 2 sockeyes, and lots of Dolly's)

B. Rate survey conditions on a scale of 1-10 (10=Best) 8

C. What % of the fish present do you think you counted? 85%

Why? Because the visibility was so good and the fish were spread out and not spooked; the low water helped quite a bit too.

D. Percent of fish counted that were fresh 10%

E. Percent of fish counted that were spawned out 35%

F. Percent of fish counted that were dead 5%

G. Predation There was quite a lot of bear sign including dead fish along the banks; eagles were doing a good job of cleaning up after the bears; Dolly's were everywhere

Other notes and comments: A large pool has formed at the base of a fresh deadfall spruce that fell near the mouth; a few fish were present but likely more will move in.

Appendix B2.–Unuk River set gillnet recording form, 2014.

Date	Location	Crew	Water Temp.	Water Depth	Weather Comments
					<i>Sunny, clear skies, calm wind</i>
7/2	SN1	<i>Magnus, Schantz</i>	8	62"	
Tide/Time	Total Time on Site (start/end)*	Total Process Time (minutes)	Fishing Effort (hrs.)	Number Caught	Fishing Comments: (Numbers and kinds of fish etc)
					<i>6 Chum, 1 pink</i>
16.1'/1148	0940-1547	7	6.1	0	

* = process time + fishing effort

Date	Location	Crew	Water Temp.	Water Depth	Weather Comments
					<i>Mostly cloudy, rain</i>
7/3	SN1	<i>Sanguinetti, Johnson</i>	7	60.5	
Tide/Time	Total Time on Site (start/end)*	Process Time	Fishing Effort (hrs.)	Number Caught	Fishing Comments: (Numbers and kinds of fish etc)
					<i>1 Large Chinook tagged, 14 Chum</i>
16.5'/1134	0540-1115	15	6.25	1	

* = process time + fishing effort

Date	Location	Crew	Water Temp.	Water Depth	Weather Comments
					<i>Rain, calm, foggy</i>
7/4	SN1	<i>Dreyer Duncan</i>	8	73	
Tide/Time	Total Time on Site (start/end)*	Process Time	Fishing Effort (hrs.)	Number Caught	Fishing Comments: (Numbers and kinds of fish etc)
					<i>7 Large Chinook tagged, 1 medium Chinook tagged</i>
16.4'/1121	0545-1202	17	6.3	8	<i>6 Chum, 3 Pinks</i>

* = process time + fishing effort

Date	Location	Crew	Water Temp.	Water Depth	Weather Comments
					<i>Rain, river rising, pulled nets early due to near flood conditions</i>
7/4	SN1	<i>Dreyer, Duncani</i>	7	96"	
Tide/Time	Total Time on Site (start/end)*	Process Time	Fishing Effort (hrs.)	Number Caught	Fishing Comments: (Numbers and kinds of fish etc)
					<i>1 Large Recap Chinook</i>
0.4'/1733	1203-1415	1	2.2	0	

* = process time + fishing effort

Appendix B4.–Coded wire tag (CWT) anadromous stream numbers, coded wire tag sample numbers, and age-sex-length (ASL) stream codes for the Unuk River and its tributaries.

Location	CWT Anadromous Stream #	Sample numbers	ASL stream code
Unuk River	101-75-10300	06930xxx	101-75-030
Boulder Creek	101-75-10300-BOULDER	0693975x	101-75-030-BOULDER
Boundary Creek	101-75-10300-2999	06939xxx	101-75-30B
Chum Creek	101-75-10300-CHUM	069305xx	101-75-030-CHUM
Clear Creek	101-75-10300-2014-3004	06933xxx	101-75-30C
Cripple Creek	101-75-10300-2030	06938xxx	101-75-30Q
Cutthroat Slough	101-75-10300-CUTTHROAT	069325xx	101-75-030-CUTTHROAT
Eulachon River	101-75-10150	06932xxx	101-75-015
Genes Lake Creek	101-75-10300-2022	06937xxx	101-75-30G
Grizzly Slough	101-75-10300-GRIZZLY	069315xx	101-75-030-GRIZZLY
Hell Roaring Creek	101-75-10300-HELLROARING	069395xx	101-75-030-HELLROARING
Kerr Creek	101-75-10300-2019	06936xxx	101-75-30K
Lake Creek	101-75-10300-2014	06934xxx	101-75-30L
Rockface	101-75-10300-ROCKFACE	069335xx	101-75-030-ROCKFACE

APPENDIX C

The expansion factor provides a means of predicting escapement in years where only an index count of the escapement is available, i.e. no weir counts or mark-recapture experiments were conducted. The expansion factor is the average over several years of the ratio of the escapement estimate (or weir count) to the index count.

Systems where escapement is known

On systems where escapement can be completely enumerated with weirs or other complete counting methods, the expansion factor is an estimate of the expected value of the “population” of annual expansion factors (π ’s) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^k \pi_y}{k} \quad (1)$$

where $\pi_y = N_y / C_y$ is the observed expansion factor in year y , N_y is the known escapement in year y , C_y is the index count in year y , and k is the number of years for which these data are available to calculate an annual expansion factor.

The estimated variance for expansion of index counts needs to reflect two sources of uncertainty for any predicted value of π , (π_p). First is an estimate of the process error ($var(\pi)$ -the variation across years in the π ’s, reflecting, for example, weather or observer-induced effects on how many fish are counted in a survey for a given escapement), and second is the sampling variance of $\bar{\pi}$ ($var(\bar{\pi})$), which will decline as we collect more data pairs.

The variance for prediction will be estimated (Neter et al. 1990):

$$v\hat{a}r(\pi_p) = v\hat{a}r(\pi) + v\hat{a}r(\bar{\pi}) \quad (2)$$

where

$$v\hat{a}r(\pi) = \frac{\sum_{y=1}^k (\pi_y - \bar{\pi})^2}{k - 1} \quad (3)$$

and

$$v\hat{a}r(\bar{\pi}) = \frac{\sum_{y=1}^k (\pi_y - \bar{\pi})^2}{k(k - 1)} \quad (4)$$

such that

$$v\hat{a}r(\pi_p) = \frac{\sum_{y=1}^k (\pi_y - \bar{\pi})^2}{k - 1} + \frac{\sum_{y=1}^k (\pi_y - \bar{\pi})^2}{k(k - 1)} \quad (5)$$

Systems where escapement is estimated

On systems where escapement is estimated, the expansion factor is an estimate of the expected value of the “population” of annual expansion factors (π ’s) for that system:

$$\bar{\pi} = \frac{\sum_{y=1}^k \hat{\pi}_y}{k} \quad (6)$$

where $\hat{\pi}_y = \hat{N}_y / C_y$ is the estimate of the expansion factor in year y , \hat{N}_y is the estimated escapement in year y , and other terms are as described above.

The variance for prediction will again be estimated:

$$\hat{var}(\pi_p) = \hat{var}(\pi) + \hat{var}(\bar{\pi}) \quad (7)$$

The estimate of $var(\pi)$ should again reflect only process error. Variation in $\hat{\pi}$ across years, however, represents process error plus measurement error within years (e.g. the mark-recapture induced error in escapement estimation) and is described by the relationship (Mood et al. 1974):

$$V(\hat{\pi}) = V[E(\hat{\pi})] + E[V(\hat{\pi})] \quad (8)$$

This relationship can be rearranged to isolate process error, that is:

$$V[E(\hat{\pi})] = V[\hat{\pi}] - E[V(\hat{\pi})] \quad (9)$$

An estimate of $var(\pi)$ representing only process error therefore is:

$$\hat{var}(\pi) = \hat{var}(\hat{\pi}) - \frac{\sum_{y=1}^k \hat{var}(\hat{\pi}_y)}{k} \quad (10)$$

where $\hat{var}(\hat{\pi}_y) = \hat{var}(\hat{N}_y) / C_y^2$ and $\hat{var}(\hat{N}_y)$ is obtained during the experiment when N_y is estimated.

We can calculate:

$$\hat{var}(\hat{\pi}) = \frac{\sum_{y=1}^k (\hat{\pi}_y - \bar{\pi})^2}{k - 1} \quad (11)$$

and we can estimate $var(\bar{\pi})$ similarly to as we did above:

$$\hat{var}(\bar{\pi}) = \frac{\sum_{y=1}^k (\hat{\pi}_y - \bar{\pi})^2}{k(k - 1)} \quad (12)$$

where both process and measurement errors need to be included.

For large k ($k > 30$), equations (11) and (12) provide reasonable parameter estimates, however for small k the estimates are imprecise and may result in negative estimates of variance when the results are applied as in equation (7).

Because k is typically < 10 , we will estimate $var(\hat{\pi})$ and $var(\bar{\pi})$ using parametric bootstrap techniques Efron and Tibshirani (1993). The sampling distributions for each of the $\hat{\pi}_y$ are modeled using Normal distributions with means $\hat{\pi}_y$ and variances $v\hat{ar}(\hat{\pi}_y)$. At each bootstrap iteration, a bootstrap value $\hat{\pi}_{y(b)}$ is drawn from each of these Normal distributions and the

bootstrap value $\hat{\pi}_{(b)}$ is randomly chosen from the k values of $\hat{\pi}_{y(b)}$. Then, a bootstrap sample of size k is drawn from the k values of $\hat{\pi}_{y(b)}$ by sampling with replacement, and the mean of this bootstrap is the bootstrap value $\bar{\pi}_{(b)}$. This procedure is repeated $B = 1,000,000$ times. We can then estimate $var(\hat{\pi})$ using:

$$v\hat{ar}_B(\hat{\pi}) = \frac{\sum_{b=1}^B (\hat{\pi}_{(b)} - \bar{\pi}_{(b)})^2}{B-1} \quad (13)$$

where

$$\bar{\pi}_{(b)} = \frac{\sum_{b=1}^B \hat{\pi}_{(b)}}{B} \quad (14)$$

and we can calculate $var_B(\bar{\pi})$ using equations (13) and (14) with appropriate substitutions. The variance for prediction is then estimated:

$$v\hat{ar}(\pi_p) = v\hat{ar}_B(\hat{\pi}) - \frac{\sum_{y=1}^k v\hat{ar}(\hat{\pi}_y)}{k} + v\hat{ar}_B(\bar{\pi}) \quad (15)$$

As the true sampling distributions for the $\hat{\pi}_y$ are typically skewed right, using a Normal distribution to approximate these distributions in the bootstrap process will result in estimates of $var(\hat{\pi})$ and $var(\bar{\pi})$ that are biased slightly high, but simulation studies using values similar to those realized for this application indicated that the bias in equation (15) is $< 1\%$.

Predicting Escapement

In years when an index count (C_p) is available but escapement (N_p) is not known, it can be predicted:

$$\hat{N}_p = \bar{\pi} C_p \quad (16)$$

and

$$v\hat{ar}(\hat{N}_p) = C_p^2 v\hat{ar}(\pi_p) \quad (17)$$

APPENDIX D

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 (Chi²-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 than 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 H₀

Fail to reject H₀

Fail to reject H₀

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

Case II:

Reject H₀

Fail to reject H₀

Reject H₀

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

Case III:

Fail to reject H₀

Reject H₀

Reject H₀

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

Case IV:

Reject H_0 Reject H_0 Either result possible

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

Evaluation Required:

Fail to reject H_0 Fail to reject H_0 Reject H_0

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:

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

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

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}_Σ = sum of the \hat{N}_i across strata.

APPENDIX E

Appendix E 1.– 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.-Mixing Test^a

Area/time where marked	Time/area where recaptured				Not recaptured (n ₁ -m ₂)
	1	2	...	t	
1					
2					
...					
s					

II.-Equal Proportions Test (SPAS terminology)^b

	Area/time where examined			
	1	2	...	t
Marked (m ₂)				
Unmarked (n ₂ -m ₂)				

III.-Complete Mixing Test (SPAS terminology) ^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: $H_0: \sum_i a_i \theta_{ij} = k U_j$, 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 . Note that failure to reject H_0 means the Pooled Petersen estimator can be considered consistent only if the degree of closure among tagging strata is constant ($\sum_j \theta_{ij} = \lambda_i$) (Schwarz and Taylor 1998). One way this may be achieved is to sample all or the large majority of spawning areas.

^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: $H_0: \sum_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.