Fishery Data Series No. 05-61

Mark-Recapture Experiments to Estimate the Abundance of Sockeye Salmon in the Lost River in 2003 and 2004

by

David L. Waltemyer,

Daniel Reed,

Michael Tracy,

and

John H. Clark

November 2005

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

FISHERY DATA REPORT NO. 05–61

A MARK-RECAPTURE EXPERIMENT TO ESTIMATE THE ESCAPEMENT OF SOCKEYE SALMON IN THE LOST RIVER, 2003-2004

by
David L. Waltemyer,
Division of Commercial Fisheries, Soldotna,
Daniel Reed,
Division of Sport Fish, Fairbanks,
Michael Tracy,
Division of Commercial Fisheries, Yakutat,
and
John H. Clark,
Division of Commercial Fisheries, Juneau

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

November 2005

Development and publication of this manuscript were partially financed by the Southeast Sustainable Salmon Fisheries Fund under Project 45215.

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

David L. Waltemyer
Alaska Department of Fish and Game, Division of Commercial Fisheries
43961 Kalifornsky Beach Road, Suite B, Soldotna, AK 99669-8367, USA

Daniel Reed
Alaska Department of Fish and Game, Division of Sport Fish
1300 College Road, Fairbanks, AK 99701-1599, USA

Michael Tracy
Alaska Department of Fish and Game, Division of Commercial Fisheries
PO Box 49, Yakutat, AK 99689-0049, USA

and

John H. Clark
Alaska Department of Fish and Game, Division of Commercial Fisheries
1255 W. 8th Street, PO Box 25526, Juneau, AK 99802-5526, USA

This document should be cited as:
Waltemyer, D. L., D. Reed, M. Tracy, and J. H. Clark. 2005. Mark–Recapture experiments to estimate the abundance of sockeye salmon in the Lost River in 2003 and 2004. Alaska Department of Fish and Game, Fishery Data Series No.05-61, Anchorage.

The Alaska Department of Fish and Game 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 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, or if you desire further information please write to ADF&G, P.O. Box 25526, Juneau, AK 99802-5526; U.S. Fish and Wildlife Service, 4040 N. Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or O.E.O., U.S. Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-6077, (TDD) 907-465-3646, or (FAX) 907-465-6078.

TABLE OF CONTENTS

Page

LIST OF TABLES ii

LIST OF FIGURES ii

LIST OF APPENDICES ii

ABSTRACT 1

INTRODUCTION 1

METHODS 2

Capture and Marking (Event 1) 2
Recovery on Spawning Grounds (Event 2) 4
Abundance Estimation 4
Peak Survey to Total Escapement Expansion Factor 6
Age, Sex, and Length Composition 6

RESULTS 6

Tagging, Recovery and Abundance 6
2003 6

2004 7

Expansion Factor 9
Estimates of Age, Sex and Length Composition 9

DISCUSSION 9

CONCLUSIONS AND RECOMMENDATIONS 10

ACKNOWLEDGMENTS 11

REFERENCES CITED 11

APPENDIX A 12

LIST OF TABLES

Table **Page**

1. Fates of sockeye salmon in the mark–recapture experiment. 5
2. Number of sockeye salmon marked in Event 1 and inspected for marks on the spawning grounds by location in Event 2, Lost River, 2003. 6
3. Number of sockeye salmon marked in Event 1 and inspected for marks on the spawning grounds by location in Event 2, Lost River, 2004 7
4. Summary of Kolmogorov-Smirnov (K-S) test results for size frequency distributions observed in marked (M), captured (C), and recaptured (R) samples, 2004. 8
5. Survey counts of sockeye salmon escapement in the Lost River/Tawah Creek drainage, 2003. 9

LIST OF FIGURES

Figure **Page**

1. Map depicting Alaska and showing location of the Lost River southeast of Yakutat, Alaska. 3

LIST OF APPENDICES

Appendix **Page**

A. 1. Detection of size-selectivity in sampling and its effects on estimation of size composition. 13
A. 2. Summary of beach seine sets made, number of sockeye salmon caught, and type of mark employed by date and location, Lost River, 2003. 14
A. 3. Event 2 summary of number of sockeye salmon inspected and number of recaptures by date and location, Lost River, 2003. 15
A. 4. Summary statistics and graphs for the K-S tests comparing marks (M) to recaptures (R) and marks (M) to captures (C) of sockeye salmon in the Lost River, 2003. 16
A. 5. Results of “consistency tests” for the Lost River sockeye salmon experiment, 2003. 17
A. 6. Summary of beach seine sets made by location, number of sockeye salmon caught, and type of mark employed by date and location, Lost River, 2004. 18
A. 7. Event 2 summary of number of sockeye salmon inspected and number of recaptures by date and location, Lost River, 2004. 19
A. 8. Summary of contingency tests for breakdown of size strata with regard to temporal affects in sampling Lost River, 2004. 21
A. 9. Summary of strata estimates of abundance of sockeye salmon using Chapman’s modification of the Petersen estimator, Lost River, 2004. 22
A. 10. Age and sex composition of sockeye salmon escapement in Ophir Creek, Lost River, 2003. 23
A. 11. Age and sex composition of sockeye salmon escapement in Ophir Creek, Lost River, 2004. 24

ABSTRACT

This was the first endeavor as part of a planned 3-year study to estimate the abundance of sockeye salmon *Oncorhynchus nerka* returning to spawn in the Lost River located near Yakutat, Alaska. The abundance of sockeye salmon in 2003 and 2004 was estimated using 2-event mark–recapture experiments. Biological data were collected during both sampling events. Fish were initially captured during Event 1 at the confluence of the Tawah Creek and Lost River in 2003, but subsequently moved to sections of Tawah Creek for the majority of sampling in 2003 and 2004 using a beach seine from July 12 through August 11 in 2003 and from August 4 through September 7 in 2004. Each fish was marked by removal of the adipose fin and given a secondary batch mark in the form of an opercle punch or removal of an axillary appendage. In Event 2, fish carcasses were collected and examined for marks on the spawning grounds in 3 different sections of the Tawah Creek drainage from September 20 through October 27 in 2003 and in 4 different sections of the drainage from September 22 through November 17 in 2004. In 2003, a total of 312 sockeye salmon were captured, marked, and released during Event 1. In Event 2, 745 sockeye salmon were sampled and of these, 40 were recaptures that had been previously marked in Event 1. In 2004, a total of 444 sockeye salmon were captured, marked and released during Event 1. In Event 2, 226 sockeye salmon were sampled and of these, 47 were recaptures.

In 2003, a battery of hypothesis tests suggested that stratification of mark–recapture estimates by temporal strata and/or fish size was unnecessary. An estimate of the abundance of sockeye salmon was produced using a Chapman modification of the Petersen estimator. Abundance of sockeye salmon in the Lost River in 2003 was estimated to total 5,978 fish (SE = 861). The peak survey of sockeye salmon in the Lost River in 2003 was 3,057 fish on September 14. The expansion factor calculated from dividing the estimated escapement by the peak survey count was 1.95 (SE = 0.281). The age classes represented in the 2003 escapement during Event 2 sampling were age-1.1 (2.0%), age-0.3 (2.8%), age-1.2 (44.4%), age-1.3 (50.3%), age-2.2 (0.3%), and age-2.3 (0.3%). Brood years from 1997 through 2000 contributed to the 2003 escapement.

In 2004, the same battery of hypothesis testing suggested that stratification of mark–recapture estimates by temporal strata and/or fish size was necessary. An estimate of the abundance of sockeye salmon was produced using the Chapman modification of the Petersen estimator after a thorough evaluation of using the Darroch estimator for a size stratum. Abundance of sockeye salmon in the Lost River in 2004 was estimated to total approximately 2,406 fish (SE = 386). The peak survey of sockeye salmon in the Tawah Creek drainage in 2004 was 1,123 fish (Summit Lake only) on September 1. The expansion factor calculated from dividing the estimated escapement by the peak survey count was 2.14 (SE = 0.343). The age classes represented in the 2004 escapement during Event 2 sampling were age-1.1 (4.5%), age-1.2 (35.2%), age-2.2 (1.3%), age-1.3 (54.7%), and age-2.3 (4.2%). Brood years from 1998 through 2001 contributed to the 2004 escapement.

Key words: sockeye salmon, *Oncorhynchus nerka*, spawning abundance, Lost River, mark–recapture, peak survey count, expansion factor, age, sex, length composition, Yakutat Alaska

INTRODUCTION

The Lost River is a small stream located 11 km southeast of Yakutat, Alaska (Figure 1). Portions of the drainage include Ophir Creek, Tawah Creek, and Coast Guard (Summit) Lake. Alaska Department of Fish and Game (ADF&G) staff count spawning and/or migrating sockeye salmon and coho salmon in the Lost River system during foot, and boat based escapement surveys. The annual peak survey counts are used as indices of the annual escapement strengths for these 2 stocks of salmon.

The Lost River system drained into its own lagoon before entering the Gulf of Alaska prior to the winter of 1999–2000. In that winter, the Lost River changed channels and now empties into the Situk-Ahrnklin lagoon. A commercial set gill net fishery took place in the Lost River lagoon prior to the year 2000. Prior to 2000, it is believed that virtually all of the salmon harvest that took place in the Lost River lagoon were fish of Lost River origin. The Situk-Ahrnklin

stocks of sockeye and coho salmon are much more abundant than the Lost River stocks of sockeye and coho salmon. The Situk-Ahrnklin lagoon fishery targets Situk and Ahrnklin origin fish. Although there is no scientific based catch allocation methodology in place for that fishery, it is assumed that some Lost River origin sockeye and coho salmon were harvested in the Situk-Ahrnklin lagoon fishery in the years from 2000 to 2002.

From 1972 to 1999, harvests of sockeye salmon in the Lost River lagoon commercial fishery averaged about 2,800 fish. A small sport fishery takes place in the Lost River; only a few sockeye salmon are harvested by anglers. Sporadic, but minor subsistence harvests of sockeye salmon in the Lost River system have also taken place over the past 30 years.

Successfully implemented peak annual counts of sockeye salmon in the Lost River system have previously been assumed to represent about two-thirds of the total annual abundance. This assumption is based entirely on professional opinion; a scientifically based total estimate of the abundance of sockeye salmon in the Lost River system has never taken place. Assuming the professional based expansion factor is correct, total escapement of sockeye salmon in the Lost River system since 1972 has averaged about 3,700 fish. And thus, total run strength has averaged somewhere between 6,000 and 7,000 sockeye salmon over the past 30 years.

In 1995, ADF&G adopted an escapement goal range of 1,000 to 2,300 sockeye salmon counted during a peak survey of the Lost River based upon the technical recommendations of Clark, Burkholder, and Clark (1995). Peak annual counts of sockeye salmon in the Lost River system from 1998 to 2002 averaged 1,700 fish. Based upon the assumption that peak surveys represent about two-thirds of the total escapement, the total escapement of sockeye salmon in the Lost River from 1998 to 2002 was about 2,500 fish.

Improvements in the annual stock assessments for Lost River sockeye salmon have been recommended in past technical reports and they are needed. This specific stock assessment study is planned and primarily intended to provide direct estimates of total abundance of sockeye salmon in the Lost River. Intent was to continue these efforts for a minimum of 3 years so that the annual average and inter-annual variance for the relationship between peak survey counts and total escapements can be scientifically determined for sockeye salmon. The objectives for the sockeye salmon stock assessments in 2003–2004 were: (1) to estimate the total abundance of sockeye salmon in the Lost River; (2) to estimate the expansion factor (abundance estimate divided by the peak survey count); and (3) to estimate the age composition of the escapement of sockeye salmon in the Lost River.

METHODS

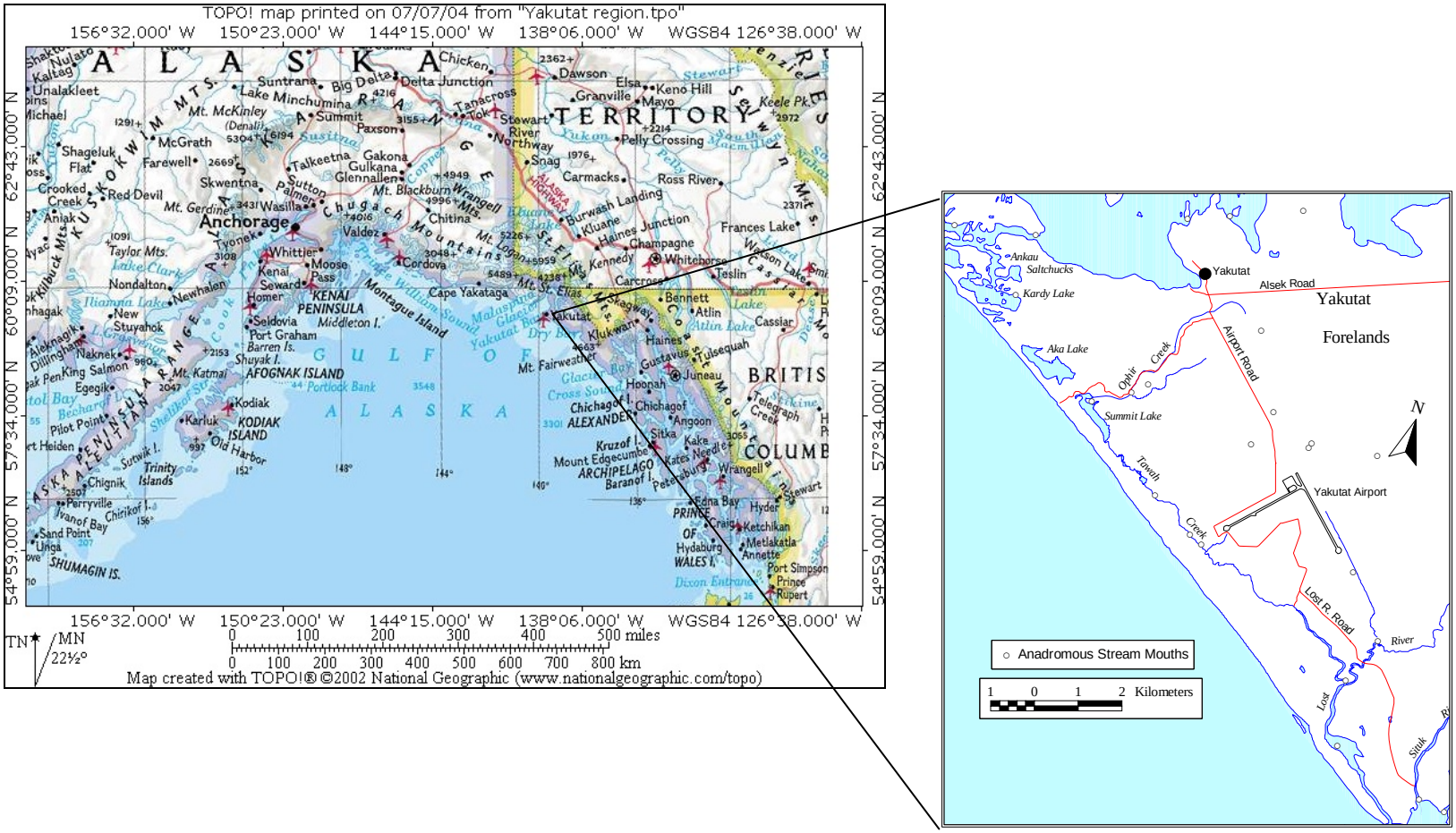
Two-event mark–recapture experiments for a closed population (Seber 1982) were conducted to estimate abundance of sockeye salmon in the Lost River in 2003 and 2004.

CAPTURE AND MARKING (EVENT 1)

Immigrating sockeye salmon were caught in the vicinity of the Tawah Creek and the Lost River confluence and within the Tawah Creek drainage itself. A 30 m × 4 m (mesh 2.2 cm) beach seine was used to capture fish during Event 1 from July 12 to August 11, 2003 and from August 4 to September 7, 2004. The number of beach seine sets each day and the resultant catch per set were recorded on field data forms.

Upon retrieval of the beach seine, sockeye salmon were carefully removed from the net for sampling. Sockeye salmon captured and in good condition were measured from mid-eye to fork of tail (MEF) to the nearest 5 mm, sex determined by visual examination of external anatomy, fish were doubly marked, and color phase and condition of each fish was noted and then the fish were released.

The primary mark was an adipose fin clip. The secondary mark was a 6-mm diameter hole punched in the upper one-third of the left (LUOP) or right (RUOP) opercle with a paper punch, or a left (LAUX) or right (RAUX) auxiliary fin clip, or a double RUOP. The secondary mark was used to designate the time strata when a fish was tagged in the first-event releases.


TOPO! map printed on 07/07/04 from "Yakutat region.tpo"
156°32.000' W 150°23.000' W 144°15.000' W 138°06.000' W WGS84 126°38.000' W
62°43.000' N
60°09.000' N
57°34.000' N
54°59.000' N
A L A S K A
TERRITORY
Anchorage
Yakutat
Cordova
Valdez
Whittier
Seward
Homer
Kodiak
Juneau
Sitka
Ketchikan
Wrangell
Petersburg
Haines
Skagway
Cape Yakataga
Cordova
Dawson
Whitehorse
Teslin
Carcross
Bennett
Atlin
Cassiar
Stewart
Hyder
Craig
Prince Rupert
Port Simpson
Metlakatla
Annette
Hydaburg
Edna Bay
Kake
Angoon
Hoonah
Tulsequah
Gustavus
Klukwan
Mt. Fairweather
Mt. Kennedy
Mt. St. Elias
Mt. Logan
Mt. McKinley (Denali)
Mt. Blackburn
Mt. Gerdine
Mt. Katmai
Mt. Fairweather
Kenai Peninsula
Montague Island
Prince William Sound
Yakutat Bay
Glacier Bay
Cross Sound
Chichagof I.
Baranof I.
Kruzof I.
Mount Edgecumbe
ALEXANDER ARCHIPELAGO
PRINCE OF WALES I.
Dixon Entrance
Portlock Bank
Shumagin Is.
Kodiak Island
Afognak Island
Kenai Peninsula
Aleutian Range
Alaska Peninsula
Alaska Range
Wrangell Mts.
Chugach Mountains
Kuskokwim Mts.
Yukon
Susitna
Copper
Tanana
Kuskokwim
Nulato
Kaltag
Unalakleet
Shageluk
Flat
Crooked Creek
Red Devil
Anvik
Taylor Mts.
Nondalton
Newhalen
New Stuyahok
Naknek
King Salmon
Egegik
Pilot Point
Port Heiden
Dillingham
Aleknagik
Chignik
Perryville
Ivanof Bay
Sand Point
Unga
Chirikof I.
Trinity Islands
Karluk
Old Harbor
Sutwik I.
Shuyak I.
Barren Is.
Port Graham
Seldovia
Middleton I.
Homer
Seward
Kenai
Moose Pass
Whittier
Tyonek
Wasilla
Palmer
Sutton
Talkeetna
Gakona
Glennallen
Gulkana
Skwentna
Farewell
McGrath
Paxson
Summit
Lake Minchumina
Big Delta
Delta Junction
Tok
Tanacross
Northway
Stewart River
Snag
Carmacks
Ross River
Pelly Crossing
Mayo
Keno Hill
Elsa
Granville
Chicken
Burwash Landing
Kluane
Haines Junction
Champagne
Frances Lake
Watson Lake
Teslin Lake
Atlin Lake
Tatlatui Lake
Iliamna Lake
Lake Clark
Kilbuck Mts.
Ahnak
Creek
Hagemeister Strait
Cook Inlet
Shelikof Strait
Bristol Bay
Becharof Lake
Ugashik Lake
Naknek Lake
Kamishak Bay
Kachemak Bay
Prince William Sound
Yakutat Bay
Glacier Bay
Cross Sound
Chatham Strait
Stikine
Telegraph Creek
Dixon Entrance
Skeena
Nahanni
Mackenzie
Keele Pk.
Stewart
Macmillan
Pelly
Yukon
Alaska Highway
Alaska Peninsula
Aleutian Range
Kuskokwim Mts.
Wrangell Mts.
Chugach Mountains
Alaska Range
Kilbuck Mts.
Cook Inlet
Shelikof Strait
Kachemak Bay
Prince William Sound
Yakutat Bay
Glacier Bay
Cross Sound
Chatham Strait
Stikine

The secondary marks were used to ensure that when a fish was examined on the spawning grounds, anywhere from 2 weeks to 3 months later, the time period when the fish was marked and released could be determined. Further, this ensured that we could conduct appropriate tests of these data when calculating the mark–recapture estimate. Temporal marks are necessary to conduct diagnostic tests of model assumptions and to select the most appropriate model to estimate abundance.

RECOVERY ON SPAWNING GROUNDS (EVENT 2)

Event 2 sampling was conducted by seining and inspecting sockeye salmon for marks throughout the spawning grounds of the Tawah Creek drainage from September 20 to October 27, 2003 and from September 22 to November 17, 2004. In order to assess mixing of marked and unmarked segments of the spawning population, Tawah Creek was sampled in 4 sections on the spawning grounds. The numbers of marked and unmarked fish examined during Event 2 sampling in these sections of creek were discretely recorded and compared to determine if marking rates were relatively constant across the entire spawning grounds.

Sampling crews consisted of 2 to 4 persons that traversed Ophir and Tawah Creeks spawning grounds by foot or with the use of canoe. Once a fish was examined and to ensure that these fish were not sampled again (without replacement), a slash mark was made on the left side of any carcass or a dorsal fin hole punch was made on live fish.

ABUNDANCE ESTIMATION

In 2003, we used Chapman's modification of the Petersen Method (Seber 1982) to estimate abundance of sockeye salmon as:

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \qquad (1)$$

where:

$\hat{N}$ = estimated abundance of sockeye salmon;

M = number of marked sockeye released in Event 1 that were available for sampling during Event 2;

C = number of sockeye inspected for marks during Event 2; and

R = number of sockeye with marks in samples during Event 2.

The conditions for accurate use of this methodology are:

1) all sockeye salmon have an equal probability of being marked; or
2) all sockeye salmon have an equal probability of being inspected for marks; or
3) marked fish mixed completely with unmarked fish between events; and
4) there is no recruitment to the population between events; and
5) there is no mark-induced mortality; and
6) fish do not lose their marks and all marks are recognizable.

Meeting the first condition depended upon entry pattern, how long these fish remained in the area where netting occurred, and the fishing effort that took place during Event 1. Residence time at the first event sampling site is unknown and only limited inference can be gleaned concerning entry pattern based on catch per effort statistics during event 1 sampling. Event 1 sampling effort was sporadic with anywhere from 1 to 4 beach seine sets per day over a 31 day period of time. Meeting the second condition depended primarily upon survey coverage. Second event sampling took place over a 38-day period and throughout the spawning grounds. Meeting the third condition depended primarily upon behavior of fish marked during Event 1.

Three consistency tests described by Seber (1982) were used to test for temporal and/or spatial violations of conditions 1–3. Contingency table analyses were used to test 3 null hypotheses: 1) the probability that a marked fish was recovered during Event 2 was independent of when it was marked; 2) the probability that a fish that was inspected during Event 2 was marked was independent of

when/where it was caught during Event 2; and 3) time of marking was independent of whether and where/when a marked fish was recovered during Event 2. Failure to reject at least 1 of these 3 hypotheses is sufficient to conclude that at least 1 of conditions 1–3 was satisfied.

Assumptions 1–3 could also be violated if size-selective sampling occurred. Meeting these conditions was tested through a series of hypothesis tests (Appendix A.1). Determination of whether the sockeye salmon sampled in Event 1 had similar length distributions to fish sampled in Event 2 was based upon the Kolmogorov-Smirnov (K-S) test. The test hypotheses were that fish of different lengths were captured with equal probability during Events 1 and 2 using the test criterion level of $\alpha = 0.05$.

The basis for meeting condition 4 (no recruitment) is based on the timing of the tagging event, observations of salmon abundance at the tagging site throughout Event 1, and surveys. The timing of the tagging event coincided with the commercial fishery which gave an indication that 99% of the harvest had been taken during the tagging event. During float/foot surveys of the Ophir/Tawah Creeks drainage newly arriving sockeye salmon have not been observed after the month of September. Further, catches of sockeye salmon in the commercial fishery in the month of August quickly decline and instead coho salmon are harvested. Consequently, there is reason to believe that little to no recruitment to the population occurred prior to or following completion of event 1 sampling.

Anytime salmon are caught and handled, there is potential for mark-induced mortality (condition 5). Periodic visual examinations of the area where Event 1 sampling occurred failed to document dead marked sockeye salmon. However, this provides only limited testing of this important assumption

Each marked fish received a primary mark and a secondary mark to insure that marks were recognizable during second-event sampling. Thus marked fish were unable to lose their marks as sometimes occurs with tagged fish (condition 6).

An estimate of the variance for $\hat{N}$ was obtained through bootstrapping (Efron and Tibshirani 1993) by adapting methods described by Buckland and Garthwaite (1991). The fate of the estimated $\hat{N}$ in the experiment was divided into capture histories (Table 1) to form an empirical probability distribution (*epd*). A bootstrap sample of size $\hat{N}$ was drawn from the *epd* with replacement. From the resulting collection of resample capture histories, R^*, C^*, and M^* were tallied, and then $\hat{N}^*$ was calculated. The bootstrap procedure was repeated one million (B) times.

Table 1.–Fates of sockeye salmon in the mark–recapture experiment.

1.	Marked and not seen during Event 2
2.	Marked and recaptured on the spawning grounds during Event 2
3.	Unmarked and not seen during Event 2
4.	Unmarked and inspected on the spawning grounds during Event 2

Using these bootstrap results, the approximate variance was calculated as:

$$\hat{\text{var}}(\hat{N}) = \frac{\sum_{b=1}^{B} (\hat{N}_b^* - \hat{\bar{N}}^*)^2}{B-1} \qquad (2)$$

where $\hat{\bar{N}}^*$ is the average of the $\hat{N}_b^*$.

In 2004, the experiment was designed to estimate sockeye salmon abundance using a 2-sample mark–recapture experiment. Under ideal conditions, Chapman's modification of the Petersen Method (Seber 1982) would be used to estimate sockeye salmon abundance. The same conditions or assumptions apply, as stated earlier, for appropriate use of this methodology.

This experiment was designed so that these conditions could either be ensured by field procedures or the conditions could be evaluated with diagnostics testing, and the appropriate model for estimating abundance could be selected. In the case when size-bias sampling was detected by diagnostic tests, stratification of data by size category (Appendix A.1) was used to eliminate potential bias prior to estimating

abundance. Where temporal violations of the equal probability of capture assumptions were detected using the contingency table analyses described above, the partially stratified estimator described by Darroch (1961) was utilized to estimate abundance. The software package Stratified Population Analysis System (SPAS; Arnason et al. 1996) was employed to calculate a Darroch-type estimate and approximate variance.

PEAK SURVEY TO TOTAL ESCAPEMENT EXPANSION FACTOR

The expansion factor for the peak count of sockeye salmon from the surveys in 2003 and 2004 and its' variances were estimated as follows:

$$\hat{\pi}_i = \hat{N}_i / I_i \tag{3}$$

$$v\hat{a}r(\hat{\pi}_i) = v\hat{a}r(\hat{N}_i) I_i^{-2} \tag{4}$$

where π_i was the expansion factor for year i and I_i the peak count of several surveys conducted in year i. The variance in equation 4 represents sampling-induced variation from the mark–recapture experiment, and accordingly represents the same precision attained with the estimate of abundance from the experiment.

AGE, SEX, AND LENGTH COMPOSITION

Scales were collected from sockeye salmon sampled during Event 2 and the methods of Thompson (1987) were used to determine minimum sample size. Fish scales were taken from the left side of the salmon approximately 2 rows above the lateral line on the diagonal row that extends down from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Koo 1955). Scales were mounted on gum cards and impressions made in cellulose acetate as prescribed by Clutter and Whitesel (1956). Ages of sockeye were determined by visual examination of scale impressions under moderate magnification (40X) using a microfiche viewer. Age was determined based on criteria established by Mosher (1969). Ages were recorded in European notation (Koo 1962). Sex and length were recorded for all specimens sampled. Sex of the fish was determined by morphological characteristics. Length in millimeters was measured from mid-eye to fork-of-tail (MEF) in 5-mm increments.

For each size stratum, age and sex composition was estimated as a series of proportions p_{ij} defining a multinomial distribution. The marginal proportion was estimated for each combination of age and sex along with estimates of the proportions' variance (Cochran 1977):

$$\hat{p}_{ij} = n_{ij} / n \tag{5}$$

$$\mathrm{var}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n-1} \tag{6}$$

where n was the sample size and n_{ij} the number in the sample of age i sex j.

RESULTS

TAGGING, RECOVERY AND ABUNDANCE

2003

A total of 312 sockeye salmon were captured, sampled and released with primary and secondary marks between July 12 and August 11 2003 (Table 2).

Table 2.–Number of sockeye salmon marked in Event 1 and inspected for marks on the spawning grounds by location in Event 2, Lost River, 2003.

Event 1:	
Released with marks (M)	312
Event 2:	
Captured (C)	
Ophir Creek Bridge	189
Upper Ophir Creek	555
Total	744
Recaptured (R)	
Ophir Creek Bridge	5
Upper Ophir Creek	33
Total	38

Detailed information, including the beach seine sets made, number of sockeye salmon caught, and type of mark employed by date and location is presented in Appendix A.2. From September 20 through October 27 of 2003, we inspected a total of 744 fish from Ophir Creek during Event 2 (Table 2, Appendix A.3). Of these, a total of 38 fish were observed with marks and were used to represent the total number of recaptured fish in Event 2 for the Lost River. Five of the marked

fish were captured at the Ophir Creek bridge, and the remaining 33 fish were captured in Upper Ophir Creek. All marked fish recovered during Event 2 possessed their primary adipose fin clip and secondary marks.

Diagnostic testing for size-bias sampling was conducted according to methods described in Appendix A.1. The length frequency distribution of all fish marked (M) during Event 1 did not differ significantly from that of those marked fish recaptured (R) during Event 2 (K-S = 0.190, p = 0.135); Appendix A.4) thus, we failed to reject the null hypothesis indicating no evidence of size-bias sampling during Event 2. The direct test for Event 1 length bias between captures (C) and recaptures (R) indicated no statistical difference (K-S = 0.143, p = 0.424). For the M-C test, a K-S test statistic of 0.084 with a p-value of 0.079 was calculated indicating that we fail to reject the null hypothesis indicating no evidence of size bias during Event 1. Based on the prescription of detecting no differences in both tests, we determined we had a Case I experiment with no size bias resulting in a singe unstratified abundance estimate, and concluded lengths, sexes, and ages from all sampling events could be pooled to estimate composition.

Temporal violations of the first conditions (equal probability of sampling or complete mixing) were examined using contingency table analyses (Seber 1982, Appendix A.5). The null hypothesis that the probability that a marked fish was inspected for marks during Event 2 was independent of the time during the run that it was marked in Event 1 was rejected (χ^2 = 3.905, p = 0.048) indicating probability of capture during Event 2 was not consistent over time. A summary of the number of sockeye salmon inspected and number with marks observed during Event 2 is shown in Appendix A.3. The null hypothesis that the probability that an Event 2 fish was marked was independent of the time interval during Event 2 when the fish was sampled was not rejected (χ^2 = 3.308, p = 0.346) when 4 approximately equal size lots of Event 2 fish were compared over time. By inspection, marked to unmarked ratios of fish examined during October were very uniform and potentially different from those examined during September. However, no significant difference was detected between fish examined in September vs. October (χ^2 = 3.169, p = 0.075) indicating probability of capture during Event 1 was consistent over time. The null hypothesis that the time a fish was marked (July vs. August) was independent of whether or when (September vs. October) a marked fish was recovered was not rejected (χ^2 = 4.595, p = 0.101). Failure to reject the null hypothesis for any one of these 3 tests is sufficient to conclude that at least one of conditions 1–3 was satisfied and a partially stratified model for abundance estimation did not need to be employed.

We were able to use the Chapman modification of the Petersen estimator which gives a point estimate of 5,978 fish with a SE of 861. The 95% CI is 4,639 to 8,098 fish based on the bootstrap analysis.

2004

A total of 444 sockeye salmon were captured, sampled, and released with primary and secondary marks between August 4 and September 7, 2004 (Table 3, Appendix A.6). From September 22 through November 17 of 2004, a total of 226 fish were inspected during Event 2, of these 47 fish were observed with marks (Table 3, Appendix A.7). All marked fish had their primary adipose fin clip.

Table 3.–Number of sockeye salmon marked in Event 1 and inspected for marks on the spawning grounds by location in Event 2, Lost River, 2004.

Event 1:	
Released with marks (M)	444
Event 2:	
Captured (C) Ophir Creek	226
Recaptured (R) Ophir Creek	47

As a part of the abundance estimate, testing for size bias sampling was conducted. Length frequencies were plotted and compared, and found to differ statistically between fish marked (M) in Event 1 and those marked fish recaptured (R) on the spawning grounds in Event 2 (Table 4). Similarly, length-frequency distributions differed statistically for all fish marked (M) during Event 1 and those captured (C) during Event 2 (K-S = 0.215, p < 0.001; Table 4). Based on these initial tests, we had a Case IV

experiment (see Appendix A.1) and needed to stratify our data by size and then estimate abundance for each size stratum independently. Inspection of length frequencies and diagnostic tests indicated the most severe discrepancies were accommodated by stratifying the data into size categories of 281–485 mm, 486–550 mm, and 551–640 mm (Table 4) and further testing for size bias was conducted within these 3 strata. For each size category, the null hypotheses of no differences in size distributions of M-R and M-C were not rejected. This left us with a Case I experiment for each stratum. Therefore, it was necessary to stratify our data by size and then estimate abundance for each size category.

Table 4.– Summary of Kolmogorov-Smirnov (K-S) test results for size-frequency distributions observed in marked (M), captured (C), and recaptured (R) samples, 2004.

Size Category	K-S Statistic	Probability Level	Hypothesis Test
All fish			
M-R	0.236	0.011	Reject
M-C	0.215	<0.001	Reject
281-485 mm interval			
M-R	0.373	0.512	Accept
M-C	0.159	0.327	Accept
486-550 mm interval			
M-R	0.186	0.309	Accept
M-C	0.162	0.083	Accept
551-640 mm interval			
M-R	0.162	0.864	Accept
M-C	0.102	0.472	Accept

Diagnostics were also directed at detecting significant temporal violations of the first 3 "or" assumptions of the estimator. Using the entire data set, we tested the null hypothesis that the probability of a fish being inspected for marks was independent of the time during the run when it was marked in Event 1. The Chi-square (χ^2) Test statistic for all fish combined was 9.8488 with a p-value of 0.0198 indicating a rejection of the null hypothesis and that temporal stratification was necessary (Appendix A.8). A second temporal test was conducted for testing the null hypothesis that the probability that an Event 2 fish was marked was independent of the time during Event 2 when a fish was caught and inspected. The χ^2 was equal to 9.524 with a p-value of 0.0085, so we rejected the null hypothesis. A third χ^2 test for mixing could not be conducted using the same temporal strata as the previous 2 tests because expected values for contingency table cells were too small for valid testing. However, when not dissimilar adjacent rows and columns were pooled, the χ^2 was 6.565 with a p-value of 0.0375, which rejects the null hypothesis of complete mixing between sampling events. Following size stratification, in size categories 281–485 mm and 551–640 mm, we failed to reject the null hypotheses indicating a Petersen-type estimate was appropriate for unbiased abundance estimation within these strata. However, in the size category 486–550 mm, we again rejected all 3 of the null hypotheses indicating the Petersen estimate was biased and a Darroch-type estimator was appropriate for estimating abundance. We appear to have different size fish showing up at different times in the experiment and it is plausible and likely that the temporal/geographic problems are confounded to some extent with the size bias problems we observed.

It appears that the size of fish observed during the second event varied significantly between September, October and November. Also, it appears that fish marked during the first 2 marking periods were different size than those marked during the second 2 marking periods, but we didn't detect any difference between the cumulative distribution frequencies (CDFs) for the first 2 marking periods and we didn't detect any differences between the CDFs for the last 2 marking periods.

In order to develop the least biased estimate of abundance, it was critical that size stratification and an appropriate estimator were used. Chapman's modification of the Petersen method was used to estimate abundance in the 281–486 mm and 551–640 mm strata, and we attempted to use Darroch's partially stratified estimator for the 486–550 mm size stratum. Unfortunately, when the Darroch estimator was used, the transition matrix (a result of the probabilities of capture over time during both events) that reflects the most obvious choice of estimator does not yield a plausible estimate of abundance. Thus, if we estimated abundance on all 3 strata

using Chapman's estimator, the overall abundance estimate is 2,406 fish with a SE of 386 (Appendix A.9). The estimates of abundance based on the size categories 281–485 mm and 551–640 mm were 835 fish and 1,157 fish, respectively, for an unbiased estimate of 1,992 fish (SE=382) in these 2 size strata. The 486–550 mm size stratum contributes a biased estimate of 414 fish (SE=55) to this total. The 95% CI is 1,649 to 3,162 fish based on all 3 strata combined.

EXPANSION FACTOR

During 2003, there were 5 boat surveys of the Lost River/Tawah Creek drainage when sockeye salmon were counted (Table 5).

Table 5.–Survey counts of sockeye salmon in the Lost River/Tawah Creek drainage, 2003.

Date	Count
7/16	52
7/24	119
7/31	168
8/19	2,942
9/14	3,057

The peak survey occurred on September 14 and the count was 3,057 sockeye salmon. The survey expansion factor (the ratio of the total abundance estimate of salmon to the peak survey count) for 2003 was 1.95 (SE = 0.281).

In 2004, there were 10 float surveys of the Lost River/Tawah Creek drainage for enumerating sockeye escapement (Table 6).

Table 6.–Survey counts of sockeye salmon in the Lost River/Tawah Creek drainage, 2004.

Date	Count
7/14[a]	0
7/21[a]	13
7/28[a]	19
8/2[b]	191
8/8[a]	210
8/12[b]	245
8/19[b]	342
9/1[c]	1,123
9/28	609
9/29[d]	39

[a] Cannon Beach to confluence
[b] Summit Lake to confluence
[c] Summit Lake only
[d] East Ophir

The peak survey count was observed on September 1 with a count of 1,123 sockeye salmon. However, this count only included Summit Lake. Thus, this count would reflect a minimum for a system-wide total. The maximum survey expansion factor (the ratio of the total abundance estimate of salmon to the peak survey count) for 2004 was 2.14 (SE = 0.343).

ESTIMATES OF AGE, SEX AND LENGTH COMPOSITION

The age composition of fish sampled in 2003 in the Lost River was comprised of 6 age classes ranging from age-1.1 to age-2.3 that represented 4 brood years (2000, 1999, 1998, and 1997) that returned in 2003 as 3, 4, 5 and 6 year old fish (Appendix A.10). There were 2 age classes (both sexes combined) age-1.2 (44.4%) and age-1.3 (50.3%) that made up a majority of the spawning population. Age-1.1 (2.0%), age-0.3 (2.8%), age-2.2 (0.3%), and age-2.3 (0.3%) comprised the remainder. Overall, males represented 38.7% and females represented 61.3% of the escapement.

In 2004, the age composition of fish sampled in the Ophir Creek drainage was comprised of 5 age classes ranging from age-1.1 to age-2.3 that represented 4 brood years (2001, 2000, 1999, and 1998) that returned in 2004 as 3-, 4-, 5- and 6-year-old fish (Appendix A.11). Two age classes, age-1.2 (35.2%) and age-1.3 (54.7%), made up a majority of the spawning population. Age-1.1 (4.5%), age-2.2 (1.3%), and age-2.3 (4.2%) comprised the remainder.

DISCUSSION

This study has provided an opportunity to understand the dynamics of estimating population sizes relative to underlying assumptions that have to be met in order to use specific estimators. In 2003, we initially were hoping to use Chapman's modification of the Petersen method. And through a battery of tests for determining if size or temporal affects are present, we were able to conclude that the Chapman estimator was the model of choice. We collected data such that we could directly address the 3 "or" assumptions and length selectiveness through a series of statistical tests

or diagnostics. Based on the results of the K-S tests, size characteristics of the marked fish in Event 1 and subsequent recaptured fish in Event 2 were not significantly different, and were not different between the marked fish of Event 1 and the captured fish of Event 2. This resulted in a Case I scenario of calculating 1 unstratified abundance estimate.

The necessity of using an abundance estimator such as the Darroch (which is a partially stratified Petersen estimator) to minimize bias is based the results of diagnostic tests to evaluate the appropriateness of a Petersen type estimator. Testing of the first 3 conditions for satisfying equal probability of capture in either sampling event or that mixing occurred provided diagnostic results that directed us toward a stratified approach in 2004. This necessitated breaking the sampling in Events 1 and 2 into periods of fairly homogeneous proportions based on released and recaptured fish in each stratum. Unequal probabilities of capture between different sizes of fish during Events 1 and 2 were confounded with differences in probability of capture over time during these events. The size of fish looked at during the second event varied significantly between September, October and November. Also, fish marked during the first 2 marking periods were different size than those marked during the second 2 marking periods, but we did not detect any difference between the CDFs for the first 2 marking periods and we did not detect any difference between the CDFs for the last 2 marking periods. Thus, a Chapman modification of the Petersen was used to estimate abundance in the smallest and largest size strata and a partially stratified Petersen estimator—a Darroch estimator was applied to the intermediate size group.

However, in applying the Darroch estimator to the intermediate size group, the transition matrix (a result of the probabilities of capture over time during both events) that is the most obvious choice for using the Darroch model did not yield a plausible estimate of abundance. We had some non-sensical probabilities of capture and estimates of negative fish. Thus the only choice we had was to use the Chapman model for all 3 strata, knowing that for the intermediate size group there would be some bias.

The Chapman estimator when summing the 3 size categories produced an overall abundance estimate of 2,406 fish. If the intermediate size stratum contributed a biased estimate of 414 fish to the total, and if we believe the estimate is at least the correct order of magnitude, we conclude that we still have a fair amount of confidence in how many fish this stratum contributes. We know that 191 fish were handled between the 2 events, so there are at least that many accounted for. The nature of the bias (high or low) of the abundance estimate of 414 is unknown and the estimate of variance is very likely biased low. The estimates of the other 2 size strata are sound, so the relative effects of these biases on the overall estimate is relatively much smaller than for the middle size stratum itself.

We estimated that the portions of sockeye salmon observed during the peak surveys were approximately 51% and 47% of the estimated abundance in 2003 and 2004, respectively. This value is lower than was previously thought. Prior opinions concerning this proportion generally centered on the belief that the peak surveys accounted for about two-thirds of the total.

CONCLUSIONS AND RECOMMENDATIONS

Estimating the total abundance is important information for assessment and management of the Lost River/Tawah Creek sockeye salmon stocks. Use of a 2-event mark–recapture abundance estimator provided a relatively accurate estimate of abundance of sockeye salmon in 2003 for the Lost River. The abundance estimate for sockeye salmon in 2004 was not as simple a matter.

Multiple years are critical to determining annual variation and an appropriate average for application of expansion factors to historic peak surveys for run reconstruction efforts. Three years of useable abundance estimates and companion expansion factors should be collected. This should provide the data needed to improve historic run reconstructions and improve information for better understanding of productivity and estimation of an appropriate escapement goal for this stock of salmon.

ACKNOWLEDGMENTS

We thank Alyssa Caracciolo, Matt Caterson, Ann Crane, Mike Freeman, Nicole Miller, and Greg Vaughn for conducting the field work and data collection. We thank Gordon Woods for providing support and logistics associated with the field work. Gordie Woods and Mike Freeman conducted surveys for this study. Iris Frank completed the aging of sockeye salmon scales collected during the project. We thank Andrew McGregor and an anonymous peer reviewer for reviewing this report and providing helpful suggestions. We thank Amy Carroll for help in formatting and finalization of this report. Funding for this project was provided by the Southeast Sustainable Salmon Fishery Fund under Project 45215.

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 2106:36 pp.

Buckland, S. T. and P. H. Garthwaite. 1991. Quantifying precision of mark–recapture estimates using the bootstrap and related methods. Biometrics 47:255–268.

Clark, J. H., A. Burkholder, and J. E. Clark. 1995. Biological escapement goals for five sockeye salmon stocks returning to the Yakutat area of Alaska. Regional Information Report Number 1J95-16, Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development. Douglas, Alaska 56 pp.

Clutter, R., and L. Whitesel. 1956. Collection and interpretation of sockeye salmon scales. Bulletin International Pacific Salmon Fisheries Commission, No. 9, New Westminster, B.C.

Cochran, W. G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons, Inc. New York. 428 pp.

Darroch, J. N. 1961. The two-sample capture-recapture census when tagging and sampling are stratified. *Biometrika* 48, 241–60.

Efron, B., and R. J. Tibshirani. 1993. An introduction to the bootstrap. Chapman Hall, New York. 436 pp.

Koo, T. S. Y. 1955. Biology of the red salmon, Oncorhynchus nerka (Walbaum), of Bristol Bay, Alaska as revealed by a study of their scales. Doctoral dissertation, University of Washington, Seattle.

Koo, T. S. Y. 1962. Age Determination in Salmon. Pages 37–48. *In* Studies of Alaska Red Salmon, T.S.Y. Koo, editor. University of Washington Press, Seattle.

Mosher, K. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. United States Department of the Interior, Circular 317, Washington, D.C.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters. 2nd. ed. Charles Griffin and Sons, Ltd., London. 654 pp.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. American Statistician. 41-42-46.

APPENDIX A

Appendix A1.–Detection of size-selectivity in sampling and its effects on estimation of size composition.

Results of Hypothesis Tests (K-S and χ^2) on lengths of fish MARKED during the First Event and RECAPTURED during the Second Event	Results of Hypothesis Tests (K-S and χ^2) on lengths of fish CAPTURED during the First Event and CAPTURED during the Second Event
Case I:	
"Accept" H_o	"Accept" H_o
There is no size-selectivity during either sampling event.	
Case II:	
"Accept" H_o	Reject H_o
There is no size-selectivity during the second sampling event but there is during the first.	
Case III:	
Reject H_o	"Accept" H_o
There is size-selectivity during both sampling events.	
Case IV:	
Reject H_o	Reject H_o
There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

Case I: Calculate 1 unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate 1 unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data (p. 17).

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Use lengths, ages, and sexes from only the second sampling event to estimate proportions in compositions, and apply formulae to correct for size bias to the data from the second event.

Whenever the results of the hypothesis tests indicate that there has been size-selective sampling (Case III or IV), there is still a chance that the bias in estimates of abundance from this phenomenon is negligible. Produce a second estimate of abundance by not stratifying the data as recommended above. If the 2 estimates (stratified and unbiased vs. biased and unstratified) are dissimilar, the bias is meaningful, the stratified estimate should be used, and data on compositions should be analyzed as described above for Cases III or IV. However, if the 2 estimates of abundance are similar, the bias is negligible in the UNSTRATIFIED estimate, and analysis can proceed as if there were no size-selective sampling during the second event (Cases I or II).

Appendix A2.–Summary of beach seine sets made, number of sockeye salmon caught, and type of mark employed by date and location, Lost River, 2003.

Date	Start Time	Caught	Marked	Mark[a]	Cumulative Marks	Comments	Location[a]
7/12	11:30	2	2	RUOP	2		1
7/16	12:30	11	11	RUOP	13		1
7/24	12:37	19	19	RAUX	32		3
7/24	14:05	9	9	RAUX	41		2
7/31	11:30	37	37	LAUX	78		4
7/31	13:20	14	14	LAUX	92		3
8/3	13:10	16	16	LUOP	108		2
8/7	12:44	41	41	LUOP	149		4
8/7	15:20	68	68	LUOP	217		5
8/7	16:43	30	30	LUOP	247		5
8/11	13:20	26	26	LUOP	273		4
8/11	15:00	5	5	LUOP	278		2
8/11	15:10	34	34	LUOP	312		2

Sample Days 7, Sample Period 31 days

[a]Location designations: 1 – Tawah Creek/Lost River confluence (N 59° 28.051', W 139° 36.855')

2 – Tawah Creek middle (N 59° 29.131', W 139° 41.299')

3 – Tawah Creek upper (N 59° 29.272', W 139° 41.624')

4 – Cannon Beach Bridge (N 59° 29.753', W 139° 43.336')

5 – Summit Lake outlet (N 59° 30.261', W 139° 45.112')

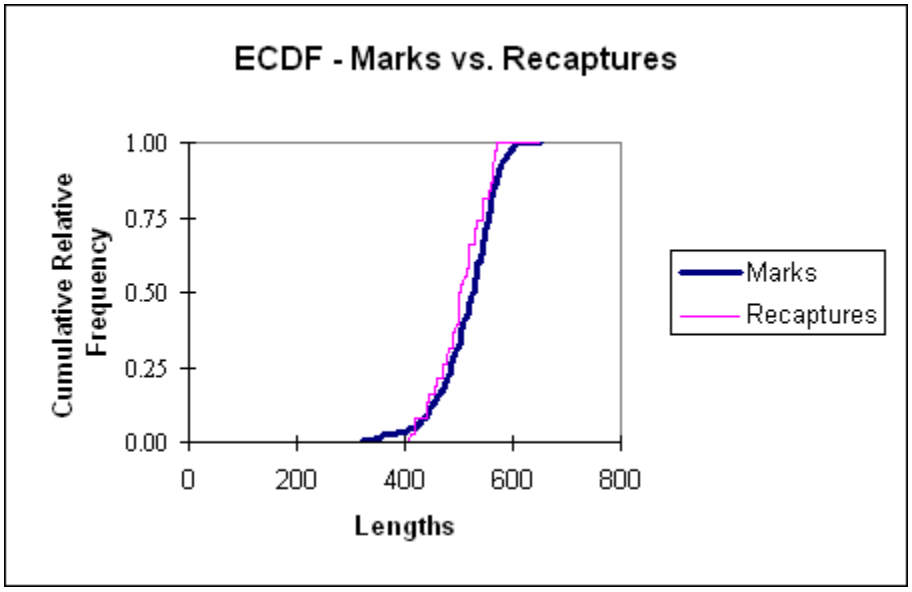
Appendix A3.–Event 2 summary of number of sockeye salmon inspected and number of recaptures by date and location, Lost River, 2003.

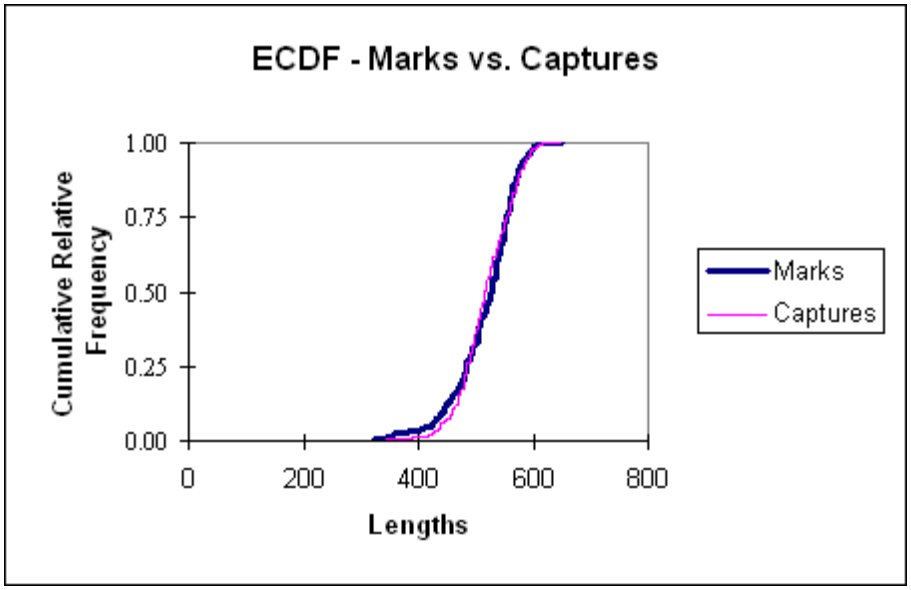
	Number Recovered			Number Marked		
Date	Ophir Creek Bridge	Upper Ophir	Total	Ophir Creek Bridge	Upper Ophir	Total
9/20	23		23			
9/21	85		85	1 – LUOP		1
9/22						
9/23						
9/24						
9/25	62		62	4 – LUOP		4
9/26						
9/27						
9/28						
9/29	19		19			
9/30						
10/1		163	163		9 – LUOP 1 – LAUX	10
10/2		24	24		2 – LUOP	2
10/3						
10/4		35	35		2 – LUOP 1 – RUOP	3
10/5						
10/6		124	124		4 – LUOP	4
10/7						
10/8						
10/9		20	20		2 – LUOP 1 – LAUX	3
10/10		33	33		2 – LUOP 1 – LAUX	3
10/11			40		1 – RAUX 1 – LUOP	2
10/12						
10/13						
10/14						
10/15		2	2			
10/16		31	31		1 – LUOP	1
10/17						
10/18						
10/19						
10/20						
10/21						
10/22		64	64		1 – RAUX 1 – LUOP	2
10/23						
10/24						
10/25						
10/26						
10/27		19	19		3 – LUOP	3
Total			744			38
Sample Days	15					
Sample Period	38	days				

Appendix A4.–Summary statistics and graphs for the K-S tests comparing marks (M) to recaptures (R) and marks (M) to captures (C) of sockeye salmon in the Lost River, 2003.

	M/C	R/C	R/M
Test Statistic 'D'	0.084	0.143	0.190
P-value	0.079	0.424	0.135

Minimum	320
Maximum	650
Mark C	312
Capture C	744
Recapture C	38





Appendix A5.–Results of "consistency tests" for the Lost River sockeye salmon experiment, 2003.

Condition 1:
H_o: Probability of finding a marked fish during second event is independent of time of initial tagging.
Or equal probability of capture during second event.

	July (other)		August (LUOP)		
First Event	Observed	Expected	Observed	Expected	Totals
Released & Recaptured	6	11	32	27	38
Released & Not Recaptured	86	81	188	193	274
Totals	92		220		312
	Cont. to X^2		Cont. to X^2		
Released & Recaptured	2.4179		1.0111		
Released & Not Recaptured	0.3353		0.1402		
	Statistic	3.905	*P*-Value	0.0482	

Reject H_o at α 0.05

Condition 2:
H_o: Probability that a second event fish was marked was independent of time during the second event when the fish was caught and inspected.

	Sept		Oct		
Second Event	Observed	Expected	Observed	Expected	Totals
Unmarked	184	179	522	527	706
Marked	5	10	33	28	38
Totals	189		555		744
	Cont. to X^2		Cont. to X^2		
Unmarked	0.1207		0.0411		
Marked	2.2430		0.7638		
	Statistic	3.169	*P*-Value	0.075	

Fail to reject H_o at α 0.05

Time Period	Unmarked	Marked
September 20–29	184	5
October 1–2	175	12
October 4–9	169	10
October 10–27	178	11
	Chi^2 (Pearson's)	3.308243
	df	3
	P-value	0.346497
	Error report	No errors encountered

Fail to reject H_o at α 0.05

Appendix A6.–Summary of beach seine sets made by location, number of sockeye salmon caught, and type of mark employed by date and location, Lost River, 2004.

Date	Location	Start Time	# Marked	Cumulative	Secondary Mark[a]	High Tide(s)	Comments
8/4/2004	Summit Lake	12:15	35	35	LUOP	4:53pm, 9.8 ft.	
8/4/2004	Summit Lake	13:00	49	84	LUOP		
8/8/2004	Cannon Bch. Br.	13:20	21	105	RUOP	8:01am, 6.2 ft. &	
8/8/2004	below Broken Br.	15:55	8	113	RUOP	7:42 pm, 8.5 ft.	
8/8/2004	below Broken Br.	16:30	55	168	RUOP		
8/10/2004	Cannon Bch. Br.	13:30	21	189	RUOP	11:03am, 6.1 ft.	
8/16/2004	Cannon Bch. Br.	10:00	51	240	LAUX	2:48pm, 8.8 ft.	
8/16/2004	Tawah	16:00	35	275	LAUX		
8/25/2004	Cannon Bch. Br.	13:45	12	287	LAUX	10:25 am, 6.7 ft.	
8/25/2004	b/w Broken Br. & Lowell's Bridge	15:34	14	301	LAUX		
8/25/2004	b/w Broken Br. & Lowell's Bridge	16:20	4	305	LAUX		
8/26/2004	below Broken Br.	14:30	9	314	LAUX	11:36 am, 7.4 ft.	
8/28/2004	confluence	14:00	1	315	LAUX	1:11 pm, 8.9 ft.	sockeye caught fishing for coho
8/29/2004	confluence	11:20	2	317	LAUX	1:49 pm, 9.6 ft.	sockeye caught fishing for coho
9/7/2004	confluence	10:30	2	319	RUOP	9:03 am, 6.0 ft.	sockeye caught fishing for coho
9/7/2004	Summit Lake	14:00	125	444	Double RUOP		

[a] Primary mark is removal of the adipose fin. Secondary marks are indicated by removal of the left auxiliary process (LAUX), right auxiliary process (RAUX), or a hole punched in the left upper opercle (LUOP) or right upper opercle (RUOP).

Appendix A7.–Event 2 summary of number of sockeye salmon inspected and number of recaptures by date and location, Lost River, 2004.

	Number Recovered			Number Marked	
Date	Ophir Creek	Daily	Cumulative	Daily	Cumulative
9/22		14	14	2	2
9/23		62	76	13	15
9/24		17	93	3	18
9/25					
9/26					
9/27					
9/28		24	117	1	19
9/29					
9/30					
10/1		9	126	2	21
10/2					
10/3					
10/4					
10/5					
10/6					
10/7		14	140	0	21
10/8		12	152	2	23
10/9					
10/10					
10/11					
10/12					
10/13		2	154	1	24
10/14					
10/15		11	165	3	27
10/16					
10/17					
10/18					
10/19					
10/20					
10/21					
10/22					
10/23					
10/24					
10/25		1	166	1	28
10/26					
10/27					
10/28		7	173	0	28
10/29					
10/31					
10/31					
11/1		37	210	12	40
11/2		10	220	5	45
11/3					
11/4					

-continued-

Appendix A7.–(Page 2 of 2).

	Number Recovered			Number Marked	
Date	Ophir Creek	Daily	Cumulative	Daily	Cumulative
11/5					
11/6					
11/7					
11/8					
11/9					
11/10					
11/11					
11/12					
11/13					
11/14					
11/15					
11/16					
11/17		6	226	2	47
Total			226		47
Sample Days	14				
Sample Period	57				

Appendix A8.–Summary of contingency tests for breakdown of size strata with regard to temporal affects in sampling Lost River, 2004.

1st Event: all fish number marked by type

	LUOP	RUOP	L Aux	2 RUOP	Total
8/4 or LUOP	84				
8/8-10 RUOP		105			
8/16/2029 or Laux			128		
9/7 Double RUOP				127	
					444

2nd Event:

		recaptures	
captured	226	L Aux	15
		2 RUOP	20
		LUOP	2
		RUOP	10
		All	47

Breakdown
Size Category:

		Chi^2	P-value	Significance	Level	rel & recap	rel & not recap	total	unmarked	marked	total
All Fish (281mm–640mm)	1st Event	9.8488	0.0198	sig	<0.05	47	397	444			
	2nd Event	9.5248	0.0085	sig	<0.01				179	47	226
	Mixing	6.5647	0.0375	sig	<0.05		397			47	444
281mm–485mm	1st Event	3.3724	0.3376	n.s.	>0.1	5	79	84			
	2nd Event	1.6572	0.4366	n.s.	>0.1				53	5	58
	Mixing	not valid	too many small #'s				79			5	84
486mm–550mm	1st Event	13.571	0.0035	sig	<0.01	28	95	123			
	2nd Event	7.4473	0.0241	sig	<0.05				68	28	96
	Mixing	13.2354	0.0102	sig	<0.05		95			28	123
551mm–640mm	1st Event	2.0917	0.5535	n.s.	>0.1	14	223	237			
	2nd Event	0.4302	0.8064	n.s.	>0.1				58	14	72
	Mixing	not valid	too many small #'s				223			14	237

Appendix A9.–Summary of strata estimates of abundance of sockeye salmon using Chapman's modification of the Petersen estimator, Lost River, 2004.

Strata	>485mm	486–550mm	>550mm	Total
M=	84	123	237	
C=	58	96	72	
R=	5	28	14	
$\hat{N}$=	835	414	1157	2406
$\hat{var}(\hat{N})$=	83325	3080	62421	148825
$S.E(\hat{N})$=	289	55	250	386
CV	0.3457697	0.134124	0.21589	0.16035

Appendix A10. –Age and sex composition of sockeye salmon escapement in Ophir Creek, Lost River, 2003.

	Brood Year and Age Class						
	2000	1999	1999	1998	1998	1997	
	1.1	0.3	1.2	1.3	2.2	2.3	Total
Statistical Weeks	38–44		(Sept. 14–November 1)				
Male							
Sample Size	7	5	57	68			137
Percent	2.0	1.4	16.1	19.2			38.7
Std. Error	0.7	0.6	1.9	2.1			2.6
Female							
Sample Size		5	100	110	1	1	217
Percent		1.4	28.2	31.1	0.3	0.3	61.3
Std. Error		0.6	2.4	2.4	0.3	0.3	2.6
All Fish							
Sample Size	7	10	157	178	1	1	354
Percent	2.0	2.8	44.4	50.3	0.3	0.3	100.0
Std. Error	0.7	0.9	2.6	2.6	0.3	0.3	

Appendix A11. –Age and sex composition of sockeye salmon escapement in Ophir Creek, Lost River, 2004.

	Brood Year and Age Class					
	2001	2000	1999	1999	1998	
	1.1	1.2	1.3	2.2	2.3	Total
Statistical Weeks		(Sept. 23–November 17)				
Male						
Sample Sizes[a]	3, 0, 0	6, 7, 0	0, 5, 30	0, 3, 0	0, 0, 1	9,15,31
Percent	4.5	10.9	33.4	0.8	1.1	50.6
Std. Error	2.7	3.8	5.3	0.5	1.1	5.2
Female						
Sample Size[a]		13, 18, 0	1, 27, 12	0, 2, 0	0, 4, 2	14,51,14
Percent		24.3	21.4	0.5	3.2	49.4
Std. Error		5.4	4.2	0.4	1.6	5.2
All Fish						
Sample Size[a]	3, 0, 0	19, 25, 0	1, 32, 42	0, 5, 0	0, 4, 3	354
Percent	4.5	35.2	54.7	1.3	4.2	100.0
Std. Error	2.7	6.4	6.6	0.6	1.9	

[a] Sample sizes are presented for each size strata respectively: <486mm, 486–550mm, and >550mm.