Fishery Data Series No. 06-71

A Mark-Recapture Experiment to Estimate the Escapement of Sockeye Salmon in the East Alsek River, 2005

by

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and

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December 2006

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

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Weights and measures (metric)	
centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm
Weights and measures (English)	
cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd
Time and temperature	
day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s
Physics and chemistry	
all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

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

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

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A MARK-RECAPTURE EXPERIMENT TO ESTIMATE THE ESCAPEMENT OF SOCKEYE SALMON IN THE EAST ALSEK RIVER, 2005

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December 2006

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

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This document should be cited as:
Smith, J. J., D. Reed, M. Tracy, and J. H. Clark. 2006. A Mark-Recapture Experiment to Estimate the Escapement of Sockeye Salmon in the East Alsek River, 2005. Alaska Department of Fish and Game, Fishery Data Series No. 06-71 Anchorage.

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

ABSTRACT

This was the third year of a study to estimate the abundance of sockeye salmon *Oncorhynchus nerka* returning to spawn in the East Alsek River located near Yakutat, Alaska. The abundance of sockeye salmon in 2005 was estimated using a two-event mark-recapture experiment. Biological data were collected during both sampling events. Fish were captured during Event 1 in the lower East Alsek River using a beach seine from 26 July through 17 August. Each fish was marked with an opercle punch and removal of the adipose fin, and 50 of the marked fish received a gastrically implanted radio transmitter. In Event 2, fish carcasses were collected and examined for marks on the spawning grounds in three different sections of the river from 19 September through 19 October. A total of 5,000 sockeye salmon were captured, marked, and released during Event 1. Based on radiotelemetry results, we estimate that 80.4% (SE = 5.6%) of these marked fish successfully moved upstream into the Event 2 area and remained as valid marks. In Event 2, 999 sockeye salmon were sampled and of these, 70 were recaptures that had been previously marked in Event 1. Using Chapman's modification of the Petersen estimator, abundance of sockeye salmon in the East Alsek River in 2005 was estimated to total 56,652 fish (SE = 7,716). The peak aerial survey of sockeye salmon in the East Alsek River in 2005 was 50,400 fish on 14 August. The expansion factor calculated from dividing the estimated escapement by the peak aerial survey count was 1.12 (SE = 0.15). The age classes represented during Event 2 sampling were age-0.1 (0.9%), age-0.2 (18.9%), age-0.3 (69.6%), age-1.2 (4.4%), and age-1.3 (6.2%). Brood years from 2000 through 2003 contributed to the 2005 escapement. Freshwater age-0 fish represented 89.4% (SE = 2.0%) of the 2005 escapement. Evaluation of results from peak counts and mark-recapture estimates of sockeye salmon abundance in the years 2003-2005 revealed that annual peak aerial surveys of abundance of sockeye salmon in the East Alsek River may provide a minimum estimate of abundance but may not be a reliable tool to track abundance trends across years nor be reliably used with an expansion factor to provide a precise estimate of total spawning abundance.

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

INTRODUCTION

The East Alsek River system is located southeast of Yakutat, Alaska (Figure 1). The East Alsek River was formed when the transboundary Alsek River changed channels about a century ago. The Alsek River now enters the ocean about 5 km to the northwest of the mouth of the East Alsek River. Inter-gravel flow from the glacially occluded Alsek River feeds clear water through a gravel berm into the East Alsek River. Hence, the East Alsek River is simply a portion of the old Alsek River channel with clear running water and no direct interconnection with the Alsek River itself. The Alsek River is a large river system draining approximately 20,400 km^2 including portions of the Yukon Territory in Canada and the southeastern Alaska panhandle. The East Alsek River, on the other hand, is a minor river with a small drainage area and the river is only about 15 km in length before entering an estuary lagoon and the Gulf of Alaska.

Early in the 20th century, anadromous salmon invaded the newly created clear waters of the East Alsek River thus utilizing the river's unique spring-type habitat for spawning and rearing phases of their life history. The East Alsek River provides spawning and rearing habitat for sockeye salmon *Oncorhynchus nerka*, coho salmon *O. kisutch*, and chum salmon *O. keta*, and pink salmon *O. gorbuscha* stocks that are commercially utilized and support minor subsistence and sport fisheries. The East Alsek River was not, historically, a major sockeye salmon producing river system; it was primarily considered to be a chum salmon producer. In addition, in the latter parts of the fall season, runs of coho salmon returning to the river system were harvested.

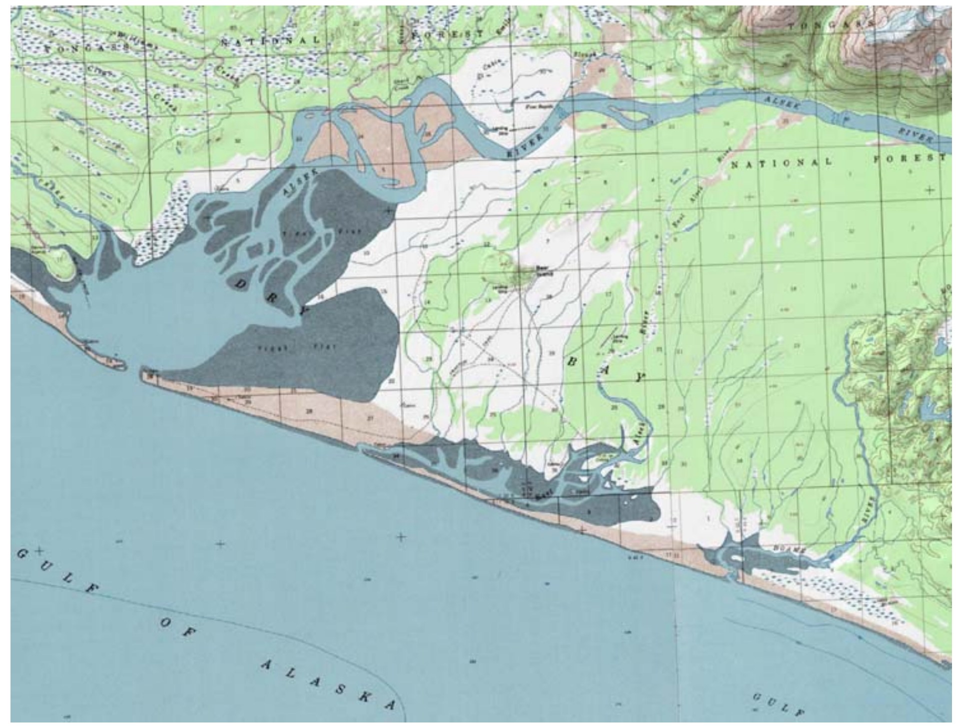

Figure 1.–Map depicting Alaska and showing the location of the East Alsek River southeast of Yakutat, Alaska.

Historically, small family groups of commercial fishermen made wages on the sockeye salmon run, and were then joined by other commercial fishermen for the larger magnitude chum salmon fishery. From 1947 through 1970, the highest annual commercial catch reported for sockeye salmon was 17,000 fish in 1954, and from 1956 through 1968, the highest catch was 6,500 sockeye salmon in 1962. In most of those years, sockeye salmon harvests did not exceed 3,000 fish.

It was not until the late 1970s and early 1980s that sockeye salmon catches started climbing exponentially. Commercial harvests of sockeye salmon in the East Alsek set gill net fishery averaged about 22,000 fish in the 1970s, about 90,000 fish in the 1980s, about 120,000 fish in the early 1990s, and dropped to about 20,000 fish in the late 1990s. Peak annual harvests in excess of 180,000 sockeye salmon occurred in 1986 and 1993. From the mid-1990s to the present, the numbers of returning sockeye salmon dropped to the point that there was not a commercial opening for sockeye salmon in the East Alsek fishery from 1999 to 2001.

Sockeye salmon use the East Alsek River system for spawning, but only for very short-term rearing. The river, with its crystal clear water, favorable water temperatures, spawning substrate, and favorable flows provided exceptional spawning habitat through the 1970s and 1980s. As a result, the sockeye salmon stock quickly grew to a magnitude of up to a quarter million fish in some years. The stock is unique in that most of the East Alsek River sockeye salmon are “zero checks.” These fish migrate to sea the year they hatch, more similar in life history patterns to chum and pink salmon, rather than to typical sockeye salmon that rear in fresh water for one to three years after hatching. Adaptation of sockeye salmon with this unique life history characteristic and the exceptional spawning habitat in the East Alsek River allowed this stock to explode in magnitude from the mid-1970s through the early 1990s.

The available data demonstrates an approximately 25-year sockeye salmon “event.” The joining of the East Alsek River and the Doame River waters in 1966 is a likely contributing factor that added a large amount of rearing habitat in the lagoon. Basically, the lagoon provides some of the function of a lake as found in more traditional sockeye salmon producing systems. An earthquake in 1959 was likely responsible for several phenomenon that resulted in: (1) the eastward shift of portions of the Alsek River channel, (2) tectonic plate movement including upheaval, and (3) the expansion of Alsek Lake from glacial fracture and retreat. Flow of the Alsek River was shifted from a westerly to an easterly course. An examination of the geography of the Yakutat area shows that all rivers in the Yakutat area to the southeast of the Tsiu River[1] break out into the Gulf of Alaska to the west. Some of these rivers, like the East Alsek River and the Akwe River, flow westward inside the beach for several kilometres before actually breaking out into the ocean. With the Alsek River migrating eastward, more water was probably available for upwelling in the East Alsek River. With elevated channelization of the Alsek River, the extent that flood stage would be attained at less extreme water levels would produce a condition that would prevail until the Alsek River channel was lowered through normal channel attrition. The expansion of Alsek Lake promoted deposition of water-borne sediments in the lake and accelerated channel attribution downstream, a phenomenon that occurs when a reservoir is created by the imposition of a dam; sediment deposition upstream and channel incisement downstream. The Alsek River channel below the lake is now well incised and reaches bedrock in some places.

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[1] In the Yakutat Management Area, the Tsiu River is the river located the farthest northwest in the area.

Likely of more importance were major flood events in the Alsek River itself. From 1964 to 1983, there were four major flood events in the Alsek River. During each of these flood events, the Alsek River overran its banks and poured down the East Alsek River. These flood events scoured the spawning gravel and cleaned out the emergent vegetation growing in the East Alsek River. The last time the Alsek River overflowed its banks and flooded the East Alsek River was in 1981 and it was a minor event lasting about 24 hours. Even the 2002 record volume of 178,000 cubic feet per second did not crest the banks and flood the East Alsek River. No subsequent flood in the Alsek River has overflowed and scoured the East Alsek River, because the Alsek River by the early 1980s had resumed its migration to the west. In 1997, the Alsek River had a 100-year flood event. No one in living memory had seen the Alsek River so high, and it took out a cabin that had been on the river for over 60 years. That flood did not overflow into the East Alsek River.

East Alsek commercial fishermen have had to contend with the algae produced on the sockeye salmon spawning grounds in the upper East Alsek River. Even on an incoming tide, fishermen have to continuously shake their net to clean it, and the river is all but impossible to fish on an outgoing tide. As soon as the tide turns, all nets are wrapped up to the cork line to allow the algae to pass freely under the net. By itself, the East Alsek River, even in flood stage, is not powerful enough to scour the algae. It takes the physical force of an overflowing Alsek River to scour the emergent vegetation out of the East Alsek River. For the past decade, the upper East Alsek River has been choked with vegetation, and it is believed that a substantial portion of the spawning gravel is no longer accessible to sockeye salmon.

Thus, we believe that the major factor responsible for the East Alsek River 25-year sockeye salmon “event” was the periodic (about every 5 years) flushing of the gravel beds in the East Alsek River by flood events in the much larger transboundary Alsek River. The last flood event of this type occurred in 1981; and by the early 1990s, the spawning habitat of the East Alsek River had deteriorated considerably. Although sockeye salmon escapements in the early 1990s were within the range of what was predicted to provide for excellent production, those escapements produced few recruits in subsequent years. Emergent vegetation and the silting in of the gravel beds have greatly deteriorated the quality of the spawning habitat. We think the history of the magnitude of sockeye salmon in the East Alsek River includes the following:

1. invasion in the early 1900s;
2. adaptation to the unique environment with a subsequent unique life history feature;
3. population explosion in the 1970s and 1980s; and
4. lesser abundance since the early 1990s due to deteriorating spawning habitat.

The ongoing ADF&G stock assessment program for the East Alsek-Doame River system consists of flying aerial surveys of both the East Alsek River (Figure 2) and the Doame River to count spawners, collection and tabulation of fish tickets and subsistence catch reports, and monitoring of the sport fishery through a postal questionnaire. Annual sampling of the commercial catch and periodic annual sampling of the East Alsek River escapement for age, sex, and length information has also taken place.

The commercial fishery is actively managed whereas more passive management (fishery monitoring) of the subsistence and sport fisheries has typically occurred since statehood. Run timing for the two sockeye salmon spawning populations has always been considered to be different, with Doame River sockeye salmon entering the terminal fishery from early June through mid-July, and East Alsek River sockeye salmon entering the fishery from late July into September. Active management of the commercial fishery consists of weekly aerial surveys of spawning escapements and variable openings of the commercial fishery on a weekly basis. In many years through active management, the East River commercial fishery was either curtailed or closed during the early weeks to provide additional protection for the smaller Doame River sockeye salmon population. In these same years, the more dominant East Alsek River sockeye salmon population was more heavily exploited later on in the season. The commercial harvest of less than 6,000 sockeye salmon in 1998 represented the smallest harvest since the population explosion of the 1970s and 1980s. Commercial openings for target fishing on sockeye salmon did not occur from 1999 to 2002. In 2001, the sport fishery for sockeye salmon was also closed through emergency order. Commercial harvesting has been allowed since 2002.

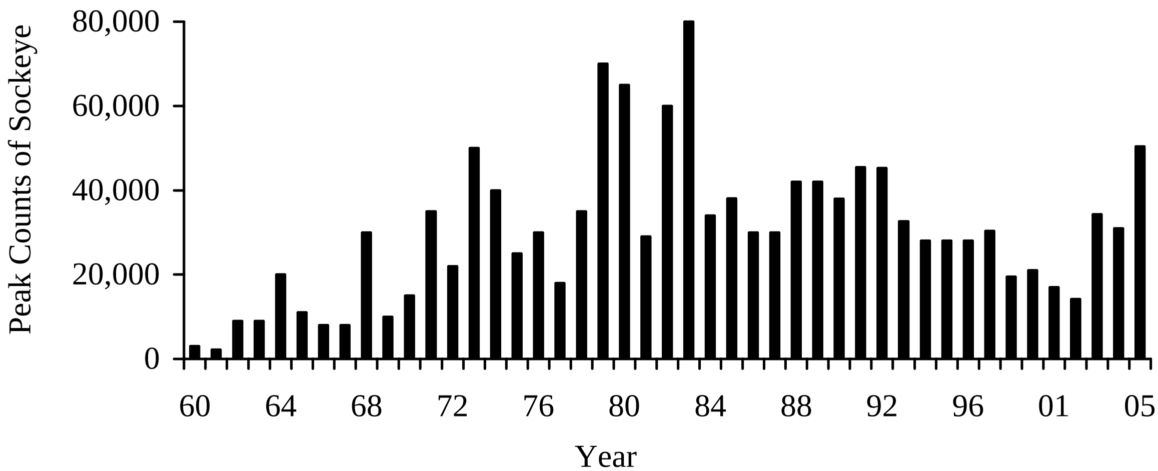

Figure 2.–Peak aerial survey counts of sockeye salmon in the East Alsek River, 1960-2005.

In 1995, the Alaska Department of Fish and Game (ADF&G) adopted an escapement goal of 26,000 to 57,000 sockeye salmon counted during a peak survey of the East Alsek-Doame River system on an annual basis (Clark et al. 1995). The data used in this analysis was primarily from the 1970s and 1980s when the population was at very high levels. By the late 1990s, it became very apparent that productivity of the stock had significantly declined and the issue of the appropriateness of the existing escapement goal for this stock came into question. Stock-recruit analysis in the fall of 2002 confirmed that a significant drop in productivity had occurred. In the spring of 2003, ADF&G revised the escapement goal to 13,000 to 26,000 sockeye salmon counted during a peak survey of the East Alsek-Doame River system on an annual basis (Clark et al. 2003). In addition to recommending a reduction in the escapement goal for the stock, the authors recommended that research be funded to estimate total abundance of sockeye salmon in the East Alsek River with the intent to determine what portion of that total abundance is represented by peak aerial counts. Further, they recommended that these efforts be maintained for a minimum of three years so that annual variation in the peak aerial surveys could be documented.

In the fall of 2002, funding was obtained from the Southeast Sustainable Salmon Fisheries Fund to augment stock assessment information available for management of sockeye and coho salmon fisheries in the Yakutat Area. An important aspect of this overall stock assessment effort was to provide improved information concerning total escapements of sockeye salmon returning to the East Alsek River system. This report documents work aimed at estimating abundance of sockeye salmon in the East Alsek River in 2005. Objectives for the East Alsek River sockeye salmon stock assessments in 2005 were: (1) to estimate the total number of sockeye salmon in the East Alsek River; (2) to estimate the expansion factor (escapement estimate divided by the peak survey count); and (3) to estimate the age and sex composition of the escapement of sockeye salmon in the East Alsek River.

METHODS

A two-event mark-recapture experiment for a closed population (Seber 1982) was conducted to estimate abundance of sockeye salmon in the East Alsek River in 2005.

CAPTURE AND MARKING (EVENT 1)

Once immigrating sockeye salmon were above the upper boundary of the East Alsek commercial set gill net fishing district in an area known as "the lake", sampling commenced. A 60 m × 4 m (2.2 cm mesh) beach seine was used to capture fish from 26 July to 17 August. 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, sexed, doubly marked, and color phase and condition of each fish was noted and then the fish was released. Fish with deep wounds, damaged gills or in a lethargic condition were not sampled, but were released without being marked.

1. The primary mark was an adipose fin clip. The secondary mark was:
2. a 6-mm diameter hole punched in the upper one-third of the left opercle (LUOP) with a paper punch if the fish was caught from 26 July to 5 August;
3. a 6-mm diameter hole punched in the upper one-third of the right opercle (RUOP) with a paper punch if the fish was caught from 15 August to 17 August; and
4. two 6-mm diameter holes punched in the middle one-third of the right opercle (RM2OP) with a paper punch if the fish was caught from 6 August to 14 August.

The secondary marks were used to ensure that when a fish was examined on the spawning grounds, anywhere from two weeks to up to two months later, the time period when the fish was marked and released could be determined. Temporal marks were needed to conduct diagnostic tests of model assumptions and to select the most appropriate model to estimate abundance.

A subset of fish captured in Event 1 were fitted with a radio transmitter tag and then released. The radio tags used were purchased from Advanced Telemetry Systems (ATS). The tags were 51 mm long and necked from a diameter of 19 to 15 mm. The tag was positioned in the mouth and manually inserted through the esophagus into the stomach with a tag plunger. Prior to deploying each radio transmitter, the frequency was checked, verified, and noted on the field data form. Once the radio transmitter was in place and measures taken to ensure that the tag would not be regurgitated, the fish was released. The radio transmitters were used to examine assumptions associated with the mark-recapture experiment to verify that marked fish moved into the Event 2 sampling area rather than dying or moving elsewhere. This provided a means to adjust the number of marks used in the abundance estimation process. Tracking of the radio-tagged fish occurred weekly through ground surveys and/or aerial surveys using a fixed-wing airplane.

RECOVERY ON SPAWNING GROUNDS (EVENT 2)

Event 2 sampling was conducted by collecting and inspecting sockeye salmon for marks throughout the spawning grounds of the East Alsek River. In order to assess mixing of marked and unmarked segments of the spawning population, the East Alsek River was split into three sections at approximately 2.4 km, 4.8 km, and 11.0 km upriver on the spawning grounds. The numbers of marked and unmarked fish examined during Event 2 sampling in these three sections of river were discretely recorded and compared to determine if marking rates were relatively constant across the entire spawning grounds. Sampling crews consisting of 2 to 4 persons walked the East Alsek River spawning grounds and gathered carcasses between 19 September and 19 October. 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 the fish.

ABUNDANCE ESTIMATION

We used Chapman's modification of the Petersen Method (Seber 1982) to estimate abundance of the sockeye salmon escapement as:

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

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

$\hat{M}$ = estimated number of marked sockeye salmon released in Event 1 that were available for sampling during Event 2;

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

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

The number of valid marked salmon in the experiment was estimated by correcting the total number of salmon marked during Event 1 using the estimated proportion ($\hat{p}_v$) of radio-tagged salmon that remained in the study area:

$$\hat{M} = M\hat{p}_v = M\sum_{t=1}^{3}\frac{M_t}{M}\hat{p}_t \qquad (2)$$

where M_t was the total number of salmon marked with a unique secondary mark during marking period t ($\sum M_t = M$) and p_t was the proportion of fish marked during period t that remained in the study area and were available for sampling during Event 2. These proportions were estimated using radio-tagged fish:

$$\hat{p}_t = v_t / r_t \qquad (3)$$

where r_t was the number of radio-tagged fish marked during period t and v_t were those members of r_t that remained in the study area.

The conditions for accurate use of this methodology were:

1. all sockeye salmon had an equal probability of being marked; or
2. all sockeye salmon had an equal probability of being inspected for marks; or

3. marked fish mixed completely with unmarked fish between events; and
4. there was no recruitment to the population between events; and
5. there was no mark-induced mortality; and
6. fish did not lose their marks and all marks were 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 0 to 3 beach-seine sets per day over a 22-d period of time. Meeting the second condition depended primarily upon survey coverage. Event 2 sampling took place over a 30-d 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 three 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 the second event; and (3) for all marked fish recovered during Event 2, time of marking was independent of if and when/where recovery occurred. Failure to reject at least one of these three hypotheses is sufficient to conclude that at least one of conditions 1-3 was satisfied.

Conditions 1-3 could also be violated if length selective sampling occurred. Meeting these conditions was tested through a series of hypothesis tests (Appendix A1). Determination of whether sockeye salmon sampled in Event 1 had length distributions similar to fish sampled in Event 2 was based upon the Kolmogorov-Smirnov (K-S) test. The test hypothesis was that fish of different lengths were captured with equal probability using the test criterion of $\alpha = 0.1$.

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 aerial surveys.

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. This assumption was tested more thoroughly through the tracking of radio-tagged sockeye salmon. Adjustments to the number of marked fish were made in accordance with findings from aerial and ground surveys of radio tag distribution.

Each marked fish received a primary mark and a secondary mark to ensure 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 $\hat{N}$ was drawn from the *epd* with replacement. From the resulting collection of resample capture histories, R^*, C^*, and M^* were tallied. Similarly, the fates of the M_t radio-tagged fish (t = 1, 2, 3) were sampled with replacement to yield a bootstrap sample of size M_t and the observations from these bootstrap samples were combined using equation 2 to calculate $\hat{M}^*$, and then $\hat{N}^*$ was calculated. The bootstrap procedure was repeated one million (B) times.

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

$$\hat{\text{var}}(\hat{N}) = \frac{\sum_{b=1}^{B}(\hat{N}_b^* - \bar{\hat{N}}^*)^2}{B-1} \tag{4}$$

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

Table 1.–Fates of sockeye salmon in the mark-recapture experiment and fates of radio-tagged salmon.

Sockeye Salmon
1. Marked and never seen again
2. Marked and recaptured on the spawning grounds
3. Unmarked and not seen on the spawning grounds
4. Unmarked and inspected on the spawning grounds
Radio-tagged Sockeye Salmon
1. Marked LUOP (t = 1) and spawned in East Alsek River
3. Marked LUOP and did not reach spawning grounds
4. Marked RUOP (t = 2) and spawned in East Alsek River
6. Marked RUOP and did not reach spawning grounds
7. Marked 2RMOP (t=3) and spawned in East Alsek River
8. Marked 2RMOP and did not reach spawning grounds

AERIAL SURVEY TO TOTAL ESCAPEMENT EXPANSION FACTOR

The expansion factor for the peak count of sockeye salmon from the survey in 2005 and its variance was estimated as follows:

$$\hat{\pi}_{2005} = \hat{N} / I_{2005} \tag{5}$$

$$v\hat{a}r(\hat{\pi}_{2005}) = v\hat{a}r(\hat{N}) I_{2005}^{-2} \tag{6}$$

where π was the expansion factor and I the peak count of several surveys conducted in 2005. 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 that experiment.

AGE, SEX, AND LENGTH COMPOSITION

Scales were collected and sampled from 227 sockeye salmon during Event 2. Fish scales were taken from the left side of the salmon approximately two 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 salmon 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):

$$\hat{p}_{ij} = n_{ij} / n \tag{7}$$

$$\text{var}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n-1} \tag{8}$$

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

Length composition was estimated using standard sample summary statistics for each combination of age and sex (Cochran 1977).

RESULTS

TAGGING, RECOVERY AND ABUNDANCE

A total of 5,000 sockeye salmon were captured, sampled, and released with primary and secondary marks between 27 July and 17 August 2005 (Table 2, Appendix A2). In addition, 50 fish or 1.0 percent were systematically tagged with radio transmitters during Event 1.

Table 2.–Number of sockeye salmon marked in Event 1 and inspected for marks on the spawning grounds by location in Event 2, East Alsek River, 2005.

Sample Size			
Event 1: Released with marks (M)			5,000
Released with radio tags			50
Event 2: Captured (C)			
Lower section		304	
Middle section		574	
Upper section		148	
Total			999
Recaptured (R)			
Lower section		27	
Middle section		39	
Upper section		4	
Total			70
Radio tags			
Unavailable		10	
Never detected	2		
Mortalities	4		
Never recruited	4		
Recruited to spawning grounds			
Lower section		3	
Middle section		25	
Upper section		12	
Total			50

From 19 September through 19 October 2005, we inspected a total of 999 fish from the lower, middle, and upper sections of the East Alsek River during Event 2 (Table 2, Appendix A3). Of these, 70 fish were observed with marks. All marked fish had their primary tag identification that was an adipose fin clip. Of the 50 radio-tagged fish, 10 fish were noted as unavailable (Table 2). Two radio-tagged fish were never detected after release. Three fish were last detected as mortalities in the lower section and 1 fish was detected as a mortality in the middle section. Four fish were last detected as live fish in the lower river but were not considered available for recovery in Event 2. Thus, 40 of the radio-tagged fish were designated as having moved or recruited into the lower, middle, or upper spawning areas (Table 2). A detailed summary of tag deployment and recovery designation is found in Appendix A4.

Testing for size bias sampling was conducted. To evaluate the null hypothesis of equal probability sampling during Event 2, the length frequency distribution of fish marked during Event 1 (M) was compared to that of marked fish recaptured during Event 2 (R). We failed to reject the null hypothesis (K-S = 0.140, p = 0.131; Figure 3). To evaluate the null hypothesis of equal probability sampling during Event 1, the length frequency distribution of fish inspected during Event 2 (C) was compared to that of marked fish recaptured (R). We failed to reject this null hypothesis (K-S = 0.130, p = 0.190; Figure 3). Based on these two tests, we concluded that we had a Case I experiment (see Appendix A1) and that stratification was not necessary prior to estimating abundance.

Diagnostic tests were also conducted to detect spatial or temporal violations of conditions 1-3. To evaluate equal probability of capture during Event 2, we tested the null hypothesis that the probability of a fish being inspected for marks during Event 2 was independent of the time during the run that it was marked in Event 1. The Chi-square (χ^2) Test statistic was 7.11 with a p-value of 0.029; thus we rejected the null hypothesis, indicating that equal probably of capture during Event 2 was not realized. To evaluate equal probability of capture during Event 1, we tested the null hypothesis that the probability that an Event 2 fish was marked was independent of the time (September or October) during Event 2 when the fish was caught and inspected. The χ^2 was equal to 3.23 with a p-value of 0.072, so we failed to reject the null hypothesis. To further evaluate equal probability of capture during Event 1, we also tested the null hypothesis that the probability of an Event 2 fish was marked was independent of where in the river (lower, middle, or upper sections) it was caught and inspected. The χ^2 statistic was 5.86 with a p-value of 0.053, so again we failed to reject the null hypothesis. As the null hypothesis was not rejected during either of these Event 1 tests, a partially stratified model for abundance estimation did not need to be employed.

Radiotelemetry results indicated that an estimated 80.4% (SE = 5.6%) of the fish moved into the East Alsek River. This proportion was used to adjust the number of marked fish for estimating abundance. Individual radio-tagged fish were distributed in the lower (7.5%), middle (62.5%), and upper (30.0%) sections. The estimates of abundance taking into account the adjustment for the number of marks was 56,654 fish (SE = 7,716). The 95% CI is 43,660 to 73,900 fish based on the bootstrap analysis.

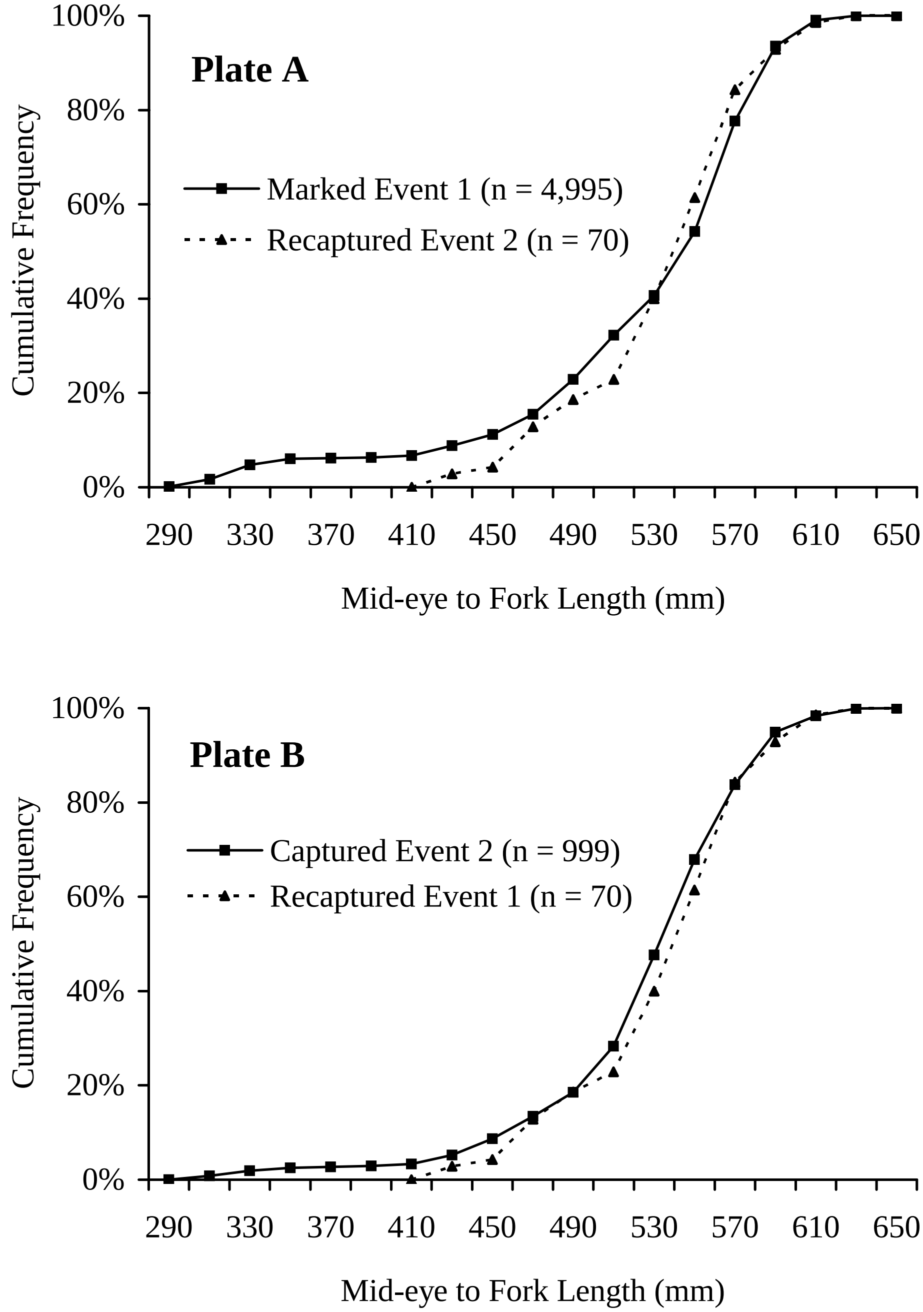

Figure 3.–Cumulative frequency distributions of length of sockeye salmon collected in Events 1 and 2, East Alsek River, 2005.

EXPANSION FACTOR

During 2005, there were 12 aerial surveys of the East Alsek River when sockeye salmon were counted. These counts ranged from 2,500 fish on 12 June to the peak survey of 50,400 sockeye salmon on 14 August. The expansion factor for the 2005 East Alsek River sockeye salmon aerial surveys was calculated as the ratio of the estimate of abundance of sockeye salmon to the peak aerial survey count. The estimated expansion factor for 2005 was 1.12 (SE = 0.15).

ESTIMATES OF AGE, SEX AND LENGTH COMPOSITION

The age composition of fish sampled in the East Alsek River was comprised of five age classes ranging from age-0.1 to age-1.3 that represented four brood years (2003, 2002, 2001, and 2000) that returned in 2005 as 2, 3, 4, and 5 year old fish (Table 3). There were two age classes (both sexes combined) age-0.2 (18.9%) and age-0.3 (69.6%) that made up a majority of the spawning population. Age-0.1 (0.9%), age-1.2 (4.4%), and age-1.3 (6.2%) comprised the remainder. Overall males represented 35.7% and females represented 64.3% of the escapement.

Average length by age for all strata combined in the escapement ranged from 373 mm for age-0.1 to 565 mm for age-1.3 (Table 3). Mean length for all known-age males was 549 mm and for females was 524 mm.

Table 3.–Age and length composition and estimated escapement by age class for East Alsek River sockeye salmon, 2005.

	Brood Year and Age Class					
Sex	2003	2002	2001	2001	2000	
Parameter	0.1	0.2	0.3	1.2	1.3	Total
Male						
Sample Size	2	13	58	2	6	81
Percent	0.9	5.7	25.6	0.9	2.6	35.7
Standard Error	0.6	1.5	2.9	0.6	1.1	3.2
Mean Length (mm)[a]	373	486	569	458	580	529
Length Range (mm)	360–385	410–515	485–615	425–490	515–600	300–630
Female						
Sample Size		30	100	8	8	146
Percent		13.2	44.1	3.5	3.5	64.3
Standard Error		2.3	3.3	1.2	1.2	3.2
Mean Length (mm)		470	541	496	554	521
Length Range (mm)		425–515	480–595	445–525	520–580	400–635
All Fish						
Sample Size	2	43	158	10	14	227
Percent	0.9	18.9	69.6	4.4	6.2	100.0
Standard Error	0.6	2.6	3.1	1.4	1.6	
Mean Length (mm)	373	475	551	489	565	524
Length Range (mm)	360–385	410–515	480–615	425–525	515–600	300–635

[a] Mean Length - represents the mean of 5 mm interval measurements.

DISCUSSION

The Chapman modification of the Petersen estimator was used based on meeting several necessary conditions. We collected data such that we could directly evaluate violations of conditions 1-3 for a Petersen-type estimator and subsequently select the correct models for estimating abundance and composition parameters.

Likewise, we were careful in ensuring we addressed assumption 6 (recognizable marks). Three of the 999 sockeye salmon examined during the second event had adipose clips, but no secondary mark. Review of the data collection during Event 1 sampling identified that several adipose-clipped fish squirmed loose before secondary marks were applied by the sampling crew and hence confirmed that these fish with missing adipose fins were most likely valid recaptures but whose time of marking was indiscernible. These three fish were incorporated into the estimation process.

Recruitment was only a possibility if fish entered the system before or after Event 1 sampling. In 2005, there was evidence to suggest that condition 4 (no recruitment) was not met. Sockeye salmon were caught in the 2005 commercial fishery (District 182) prior to the initiation of Event 1. A total of 2,679 fish or 53% of the annual catch occurred during openings from 10 July to 22 July 2005. Fish that passed the tagging site prior to Event 1 had zero probability of being marked. However, the failure to detect significant differences in marked to unmarked ratios during Event 2 sampling during tests for spatial or temporal violations of conditions 1-3 indicates that marked fish mixed sufficiently with unmarked fish prior to Event 2 sampling. The entry of these early fish to the system (with zero probability of capture) affects the experiment similar to a violation of condition 4, effectively resulting in recruitment “between” sampling events. In this situation, given sufficient mixing of marked and unmarked fish prior to Event 2, the abundance estimate will be germane to the timing of the second sampling event.

Event 1 sample sizes were larger than expected in 2005 despite encountering heavy rains which precluded sampling effort from 12-14 August. A total of 5,000 sockeye salmon were marked in 2005 which was 67% more than the preseason minimum target (3,000 fish). At least part of this increase was due to fishing at a relatively productive site that had not been used in previous years. In contrast, Event 2 sample sizes in 2005 (999 fish) were considerably smaller than expected. This was largely attributed to a 12-d breach in Event 2 sampling from 30 September to 12 October due to heavy rains and high water levels. Even with the smaller than expected Event 2 sample sizes, the number of fish sampled was above the minimum number of fish necessary for providing statistical reliability in the project objectives.

The assumption that marked fish may have a greater mortality rate than unmarked fish (assumption 5) because capturing, handling, and marking sockeye salmon may induce mortality or delay their upstream migration was tested. Fish were tagged with radio transmitters to ascertain capture and handling-induced mortality. Two transmitters were recovered in-season near the tagging site (one without an accompanying carcass) suggesting the fish had expired. Six transmitters were detected live at least once after release, but were either not detected again or were detected as mortalities downstream of spawning areas. Two transmitters were never detected after deployment, possibly representing fish that “nosed-in” and later left to spawn in other nearby river systems. Therefore, the worst-case scenario is that 10 out of 50 fish died before spawning or did not recruit to the spawning grounds. Consequently, a weighted estimate of the number of marks was applied to take into account this mortality and an estimate of abundance generated.

We believe that the abundance estimate of 56,652 sockeye salmon derived from the mark-recapture experiment in 2005 was a relatively unbiased estimate of the actual abundance of sockeye salmon that returned to the spawning grounds of the East Alsek River. As a result, the portion of sockeye salmon observed during the peak aerial survey in 2005 was approximately 89% of the actual abundance.

Prior opinions concerning the proportion of total escapement counted during surveys of sockeye salmon in the East Alsek River generally centered on the belief that the peak aerial surveys accounted for about two-thirds of the total (Clark et al. 2003). In 2004, a two-event mark-recapture experiment was conducted to estimate abundance of the East Alsek River escapement of sockeye salmon (Waltemyer et al 2005b). Abundance in 2004 was estimated at 46,878 fish (SE = 6,470; CV = 14%), the peak aerial survey counted 31,000 fish, the estimated expansion factor in 2004 was about 1.5, and 77% of the radio-tagged fish marked during Event 1 moved upstream into the Event 2 capture area. In 2003, a two-event mark-recapture experiment was conducted to estimate abundance of the East Alsek River escapement of sockeye salmon (Waltemyer et al 2005a); however, unlike the experiments in 2004 and 2005, fish were not released with radio tags to adjust the number of marked fish released during Event 1. Abundance in 2003 was estimated at 122,037 fish (SE = 15,360; CV = 13%), the peak aerial survey counted 31,000 sockeye salmon, the estimated expansion factor in 2004 was 3.9. Adjustment of the 2003 estimate to account for the average portion of fish marked from radio tag experiments in 2004 (77%) and 2005 (80%) that moved upstream into the Event 2 capture area results in a revised 2003 estimate of abundance of about 96,000 sockeye salmon and a revised expansion factor estimate for the 2003 aerial survey of about 3.1.

Escapement trends for sockeye salmon in the East Alsek River from 2003-2005 based upon the abundance estimates versus the peak aerial surveys shows different trends (Figure 4). Abundance estimates indicate a substantial reduction in escapement between 2003 and 2004 followed by a small increase in 2005 while aerial survey counts indicate similar escapements in 2003 and 2004 followed by an increase in 2005. These data demonstrate that the relationship between abundance estimates and aerial survey counts is poor. The three abundance estimates are relatively precise with coefficients of variation of 13%, 14%, and 14% in 2003, 2004, and 2005, respectively. The relationship between peak annual aerial survey counts and abundance estimates of sockeye salmon in the East Alsek River in the years 2003, 2004, and 2005 was evaluated (Appendix A.5) and resulted in 1.97 as the appropriate expansion factor for use in converting peak survey counts into total abundance estimates. The expansion factor has a standard error of 1.06. These data indicate that estimating annual escapements of sockeye salmon in the East Alsek River based upon peak aerial surveys will result in very imprecise annual estimates. While the peak aerial survey counts can likely be reliably counted upon to provide a minimum estimate of escapement, they may not accurately track trends in annual escapement strength. Actual annual abundance of sockeye salmon in the East Alsek River may be close to the number counted during peak annual surveys or could be several fold higher.

Age composition information collected in 2005 was within the ranges of past escapements (Clark et al. 2003). The Age-4 component of the escapement has continued to be the predominant age group.

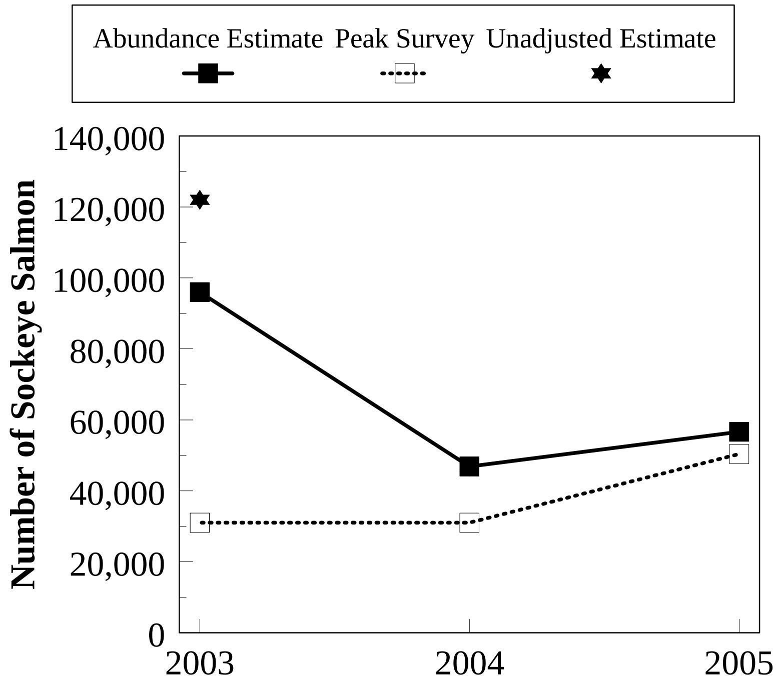

Figure 4.–Abundance estimates for spawning sockeye salmon in the East Alsek River from 2003-2005 and peak aerial survey counts in each of the three years.

CONCLUSIONS AND RECOMMENDATIONS

Estimating total escapement is important information for assessment and management of the East Alsek River sockeye salmon stock. Use of a two-event mark-recapture abundance estimator provided an accurate estimate of about 57,000 fish as the 2005 escapement of sockeye salmon in the East Alsek River. The peak aerial survey of 50,400 fish on 14 August in 2005 represented about 90% of the actual abundance of sockeye salmon on the spawning grounds in the East Alsek River. Brood years 2000 to 2003 contributed to the 2005 run. Evaluation of the results from 2003-2005 revealed that annual peak aerial surveys of abundance of sockeye salmon in the East Alsek River may provide a minimum estimate of abundance but may not be a reliable tool to track trends across years nor be reliably used with an expansion factor to provide a precise estimate of total spawning abundance.

ACKNOWLEDGMENTS

We thank Alyssa Caracciolo, Matt Caterson, Ann Crane, and Chet Woods for conducting the field work and data collection while operating from the Dry Bay/East Alsek field camp. We thank Gordon Woods for providing support and logistics associated with the field work. Gordon Woods and Mike Freeman conducted aerial surveys for this study. Iris Frank completed the aging of sockeye salmon scales collected during the project. We thank David Bernard for assistance with development of average expansion factors and associated variances. We thank Amy Carroll for help in formatting and finalizing this report. This project was funded by the Southeast Sustainable Salmon Fund under Project 45215.

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APPENDIX A

Appendix A1.–Detection of size or sex selective sampling during a 2-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first 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), 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, comparing M and C, is conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

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

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o
There is no size/sex selectivity detected during either sampling event.		
Case II:		
Reject H_o	Fail to reject H_o	Reject H_o
There is no size/sex selectivity detected during the first event but there is during the second event sampling.		
Case III:		
Fail to reject H_o	Reject H_o	Reject H_o
There is no size/sex selectivity detected during the second event but there is during the first event sampling.		
Case IV:		
Reject H_o	Reject H_o	Reject H_o
There is size/sex selectivity detected during both the first and second sampling events.		
Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

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

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

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

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

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

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

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

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

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

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

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

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;

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

Appendix A2.–Summary of beach seine sets made, number of sockeye salmon caught, and type of mark employed by date and location, East Alsek River, 2005.

Set #	Date	Water Temp (^{o}C)	Start Time	Marks Applied Daily	Marks Applied Cum.	Secondary Mark [a]	Radio Tags	Comments
1	26-Jul	14	14:05	342	342	LUOP	4	
2	27-Jul	11	10:47	310	652	LUOP	5	
3	28-Jul	12	12:00	427	1,079	LUOP	3	
4	30-Jul	12	10:48	420	1,499	LUOP	5	
5	31-Jul	11	10:13	168	1,667	LUOP	3	Heavy rain
6	1-Aug	12	12:30	0	1,667	LUOP	2	
7	1-Aug		15:22	129	1,796	LUOP		
8	2-Aug	10	11:21	325	2,121	LUOP	3	
9	3-Aug	9	10:30	239	2,360	LUOP	3	Heavy rain
10	3-Aug		13:30	0	2,360	LUOP		
11	3-Aug		14:49	89	2,449	LUOP		
12	7-Aug	12	11:32	120	2,569	RUOP	2	
13	8-Aug	13	13:44	188	2,757	RUOP	4	
14	8-Aug		16:13	68	2,825	RUOP		
15	9-Aug	11	10:53	218	3,043	RUOP	4	
16	9-Aug		15:10	90	3,133	RUOP		
17	10-Aug	10	10:24	207	3,340	RUOP	4	
18	10-Aug		13:36	144	3,484	RUOP		
19	11-Aug	11	10:25	225	3,709	RUOP	2	
20	11-Aug		13:52	116	3,825	RUOP		
21	15-Aug	11	11:09	420	4,245	RM2OP	3	
22	16-Aug	10	10:33	241	4,486	RM2OP	2	
23	16-Aug		13:50	174	4,660	RM2OP		
24	17-Aug	10	10:18	200	4,860	RM2OP	1	
25	17-Aug		13:45	140	5,000	RM2OP		
				5,000			50	

[a] LUOP - left upper opercle; RUOP - right upper opercle; RM2OP - 2 holes in right middle opercle.
All sets were made at "Schumacher's" using a 200-ft beach seine (7/8" mesh).

Appendix A3.–Number of sockeye salmon inspected and the number of recaptures by date and location during Event 2, East Alsek River, 2005.

	Number Inspected [a]				Number Recaptures			
Date	Lower	Middle	Upper	Total	Lower	Middle	Upper	Total
19-Sep	89			89	12			12
20-Sep		91		91		8		8
21-Sep								
22-Sep		71		71		4		4
23-Sep			11	11				
24-Sep	63			63	4			4
25-Sep								
26-Sep	23	43		66	1	4		5
27-Sep	23			23	3			3
28-Sep		55		55		4		4
29-Sep	27			27	2			2
30-Sep								
1-Oct								
2-Oct								
3-Oct								
4-Oct								
5-Oct								
6-Oct								
7-Oct								
8-Oct								
9-Oct								
10-Oct								
11-Oct								
12-Oct		37		37		5		5
13-Oct			75	75			2	2
14-Oct		114		114		8		8
16-Oct	52	37		89	3	2		5
17-Oct		39	8	47		1		1
18-Oct	27	21		48	2	1		3
19-Oct		39	54	93		2	2	4
Total	304	547	148	999	27	39	4	70
Days	7	10	4	16	7	10	2	15
Period	30							

[a] River sections designated as Lower (2.4 km upriver), Middle (4.8 km upriver), and Upper (11.0 km upriver).

Appendix A4.–Detection history and fates of radio-tagged sockeye salmon, sorted by location where last detected, East Alsek River, 2005.

Radio Transmitter	Release Date	Aerial Survey 29-Aug	Aerial Survey 26-Sep	Aerial Survey 17-Oct	Date Tag Recovered	Last Detected	Comment
151.412-24[a]	26-Jul					unknown	Never detected
151.612-24[a]	3-Aug					unknown	Never detected
153.122-23[a]	15-Aug					unknown	Live 8/18
151.623-23[a]	27-Jul				2-Aug	lake	
151.301-23[a]	30-Jul					lodges	Live 8/6
150.723-24[a]	8-Aug	Mort				lower	near L. Doame R
150.923-24[a]	10-Aug	Mort				lower	Live 8/18
151.512-24[a]	1-Aug	Live			20-Sep	lower	
151.633-24[a]	3-Aug	Mort				lower	Live 8/10
150.942-24[a]	10-Aug	Mort	Mort			middle	Live 8/18
150.742-24	8-Aug	Live	Live			middle	
150.762-24	8-Aug	Live	Live	Live		middle	
150.782-24	8-Aug	Live	Live			middle	
150.804-24	9-Aug	Live	Live	Live		middle	
150.822-24	9-Aug	Live	Live	Live		upper	
150.842-24	9-Aug	Live	Mort			upper	
150.862-24	9-Aug	Live	Live			middle	
150.882-24	10-Aug	Live	Live	Live		middle	
150.903-24	10-Aug	Live	Live			middle	
150.963-24	11-Aug	Live	Live			middle	
150.983-24	11-Aug	Live	Live	Live		lower	
151.063-24	30-Jul	Live	Live	Mort		lower	
151.263-23	30-Jul	Live	Mort			lower	
151.343-23	26-Jul	Live	Live	Mort		lower	
151.403-23	26-Jul	Live	Mort			lower	
151.451-24	26-Jul	Live	Live	Mort		lower	
151.473-24	31-Jul	Live	Mort			lower	
151.492-24	31-Jul	Live	Live	Live		lower	
151.532-24	1-Aug	Live	Live			lower	
151.552-24	31-Jul	Live	Live			lower	
151.571-24	2-Aug	Live	Live			lower	
151.592-24	2-Aug	Live	Live	Live		middle	
151.623-23	2-Aug	Live	Live			middle	
151.653-24	3-Aug	Live	Mort			lower	
151.672-24	7-Aug	Live	Mort			middle	
151.683-23	27-Jul	Live	Live	Live		middle	
151.692-24	7-Aug	Live	Live	Live		middle	
151.803-23	27-Jul	Live	Mort			middle	
151.823-23	27-Jul	Live	Live	Live		middle	
151.883-23	27-Jul	Live	Live	Live		middle	
151.902-23	28-Jul	Live	Live			middle	
151.923-23	28-Jul	Live	Live	Live		middle	
151.943-23	28-Jul	Live	Live	Live		middle	
151.962-23	30-Jul	Live	Live			middle	
151.982-23	30-Jul	Live	Live	Live		middle	
153.063-24	15-Aug	Live	Mort			middle	
153.153-23	15-Aug	Live	Live	Live		middle	
153.183-23	16-Aug	Live	Live			middle	
153.213-23	16-Aug	Live	Live			middle	
153.243-23	16-Aug	Live	Mort			upper	

[a] Fish with radio transmitters that were designated as not recruiting to the spawning grounds.

Appendix A5.–Expansion factor for converting peak aerial survey counts of sockeye salmon in the East Alsek River into estimates of total abundance and associated precision of the so derived estimates.

Based on a simple model without depensation in counts:

$$S_y = qN_y \exp(\lambda_y) \tag{1}$$

where *S* is the peak count in a calendar year *y*, *N* is the actual escapement, *q* is the fraction of the escapement seen (or the reciprocal of the expansion factor π), and λ is a normal random variate with mean 0 and variance σ_λ^2. In a calendar year *t* without a mark-recapture experiment, *N* and its variance could be estimated through expansions:

$$\hat{N}_t = \hat{\pi} S_t \quad \text{var}(\hat{N}_t) = \text{var}(\hat{\pi}) S_t^2 \tag{2}$$

Equation 2 can be linearized and rearranged such that

$$\ln \pi = \ln(1/q) = \ln N_y - \ln S_y + \lambda_y$$

$$(\ln \pi) - \lambda_y = \ln N_y - \ln S_y \tag{3}$$

Note for the purposes of expanding peak counts to escapements, the variance of the expansion factor π is only a function of σ_λ^2. However, *N* in the years 2003, 2004, and 2005 is not perfectly known, instead estimates ($\hat{N}$) from a series of mark-recapture experiments are available such that $\hat{N}_y = N_y \exp(\gamma_y)$ where γ is a random normal variate with mean 0 and variance σ_γ^2 representing measurement error. By using $\hat{N}$ instead of *N* we have the relationship:

$$(\ln \pi) - \lambda_y + \gamma_y = \ln \hat{N}_y - \ln S_y \tag{4}$$

If $\ln \hat{N}_y - \ln S_y \equiv X_y$ in (EQ 4), $\text{Var}(X) = \sigma_\lambda^2 + \sigma_\gamma^2$, an estimate of that variance would be

$$\text{var}(X) = \frac{\sum_{y=2003}^{2005} (X_y - \overline{X})^2}{n-1} \tag{5}$$

and using the delta method an estimate of σ_γ^2 would be

$$\hat{\sigma}_\gamma^2 = \frac{\sum_{y=2003}^{2005} \text{var}(\ln \hat{N}_y)}{n} \cong \frac{\sum_{y=2003}^{2005} cv^2(\hat{N}_y)}{n} \tag{6}$$

making an estimate of σ_λ^2

$$\hat{\sigma}_\lambda^2 = \text{var}(X) - \hat{\sigma}_\gamma^2 \tag{7}$$

The estimate of the expansion factor and an estimate of its variance would then be

$$\hat{\pi} = \exp\left(\Sigma X_y / n + \hat{\sigma}_\lambda^2 / 2\right) \tag{8}$$

$$\text{var}(\hat{\pi}) = \hat{\pi}^2 \left[\exp(\hat{\sigma}_\lambda^2) - 1\right] \tag{9}$$

Application of the approach with data from 2003, 2004, and 2005 mark-recapture studies and peak aerial survey counts of sockeye salmon in the East Alsek River follows:

Year	Peak Aerial Survey	Abundance Estimate (*N*)	Standard Error of Abundance Estimate	Coefficient of Variation (*N*) Squared	Natural Log of Survey	Natural Log of Abundance Estimate	Subtraction of Natural Logs
2003	31,000	96,000	12,000	0.01563	10.34174	11.47210	1.13036
2004	31,000	46,878	6,470	0.01905	10.34174	10.75530	0.41356
2005	50,400	56,652	7,716	0.01855	10.82775	10.94468	0.11694
Avg.							0.55362

Note: Abundance estimate in 2003 was adjusted under the assumption that a similar portion of marked fish moved upstream into the Event 2 capture area as was documented, on average, in 2004 and 2005 through radio telemetry.

These data show that:

1. Estimated variance in the relationship including mark-recapture measurement error = 0.2714697.
2. Estimated variance in the relationship with mark-recapture measurement error removed = 0.2537283.
3. An estimated 6.5% of the observed variation in the relationship between peak aerial surveys and total abundance estimates is measurement error associated with the mark-recapture experiments; the remaining 93.5% of the variation in the relationship is associated with the peak aerial surveys.
4. Estimated expansion factor for converting peak aerial survey counts = 1.97.
5. Estimated standard error of the expansion factor for converting peak aerial surveys without mark-recapture measurement error = 1.06.

As an <u>example</u> of application in a year when 50,000 sockeye salmon were counted during a peak aerial survey and an estimate of the total spawning abundance was desired:

1. Peak aerial survey = 50,000 sockeye salmon.
2. Estimate of total abundance = 98,742 sockeye salmon.
3. Standard error of the abundance estimate = 53,066 sockeye salmon.
4. 90% confidence interval of the abundance estimate:
    a. Square root of estimated variance with mark-recapture measurement error removed = 0.503714.
    b. T-value with 2 degrees of freedom = 2.9; that value times 0.503714 = 1.460772.
    c. Lower value = 0.55362-1.460772 = -0.90715; exponential = 0.403672.
    d. Upper value = 0.55362+1.460772 = 2.01439, exponential = 7.4961639.
    e. Lower value (0. 403672) times 50,000 counted during survey = 20,184 sockeye salmon.
    f. Upper value (7.4961639) times 50,000 counted during survey = 374,808 sockeye salmon.
    g. The 90% confidence interval for a total abundance estimate of 98,742 sockeye salmon spawning in the East Alsek River using the relationship would be 20,184 to 374,808 sockeye salmon, a <u>very imprecise</u> estimate.