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A Mark–Recapture Experiment to Estimate the Spawning Escapement of Sockeye Salmon in the Akwe-Italio Rivers, 2004

by

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April 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 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. 06-18

A MARK-RECAPTURE EXPERIMENT TO ESTIMATE THE SPAWNING ESCAPEMENT OF SOCKEYE SALMON IN THE AKWE-ITALIO RIVERS, 2004

by

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ABSTRACT

This study estimated the total spawning abundance of sockeye salmon *Oncorhynchus nerka* in the Akwe and Italio river systems located near Yakutat, Alaska. The abundance of sockeye salmon in 2004 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 Akwe River using a beach seine from 30 June through 24 July. Each fish was marked with an opercle punch, and 116 of the marked fish received a gastrically implanted radio transmitter. A total of 1,169 sockeye salmon were captured, marked, and released during Event 1. Based on radio telemetry results, we estimate that 69% of these marked fish successfully moved upstream into the Event 2 area and remained as valid marks. Two methods were used to collect samples for Event 2: carcass sampling on the spawning grounds of both river systems, and beach seining for live fish in the Italio River drainage. In Event 2, 1,573 sockeye salmon were sampled and of these, 34 were recaptures that had been previously marked in Event 1. Using a modification of Chapman's Petersen-type estimator, the total abundance of sockeye salmon that reached the spawning areas in the combined Akwe and Italio rivers in 2004 was estimated to be 36,398 (SE = 6,704). The estimated abundance of spawners in the Akwe River was 28,835 (SE = 5,624) and in the Italio River was 7,563 (SE = 2,155). Aerial survey counts peaked at 1,200 sockeye salmon in the Akwe River on 10 August and 20 August, and peaked at 4,000 sockeye salmon in Italio Lake on 1 September. The expansion factor calculated from dividing the estimated escapement by the peak aerial survey count was 24.03 (SE = 4.69) for the Akwe River and 1.89 (SE = 0.54) for the Italio River. The age classes represented in the 2004 Akwe River escapement during Event 2 sampling were age-0.1 (0.7%), age-0.2 (20.0%), age-0.3 (76.6%), age-0.4 (0.7%), age-1.2 (0.7%), and age-1.3 (1.4%). In the 2004 Italio River escapement, age classes represented were age-1.2 (35.2%), age-1.3 (41.8%), age-2.2 (5.7%), and age-2.3 (17.2%).

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

INTRODUCTION

The Akwe and Italio river systems drain into the Gulf of Alaska approximately 30 km southeast of Yakutat, Alaska (Figure 1). This area of Alaska is geologically active with rivers changing course periodically. Many of these rivers form lagoons with water that flows westward inside the beach for several miles before entering the ocean. In December of 1986, the Italio River changed course and broke through and into the Akwe River lagoon. The Akwe River is larger than the Italio River and unlike the Italio River, it is glacially influenced.

Targeted commercial and subsistence set gillnet fishing for both the Akwe and Italio sockeye salmon stocks has taken place. In the years prior to 1987, fishermen set gillnets in the Akwe lagoon and presumably harvested predominantly the Akwe stock of sockeye salmon. And similarly, fishermen set gillnets in the Italio lagoon and presumably harvested predominantly the Italio stock of sockeye salmon. Prior to the fishing season in 1987, the Alaska Department of Fish and Game (ADF&G) redefined set gillnet fishing boundaries in response to the Italio River changing course during the prior winter. The lower boundary of the Akwe fishing area was moved upstream above the confluence of the two rivers. And likewise, the lower boundary of the Italio fishing area was moved upstream above the confluence of the two rivers. Management intent was to continue to allow fishing, but at the same time preserving the management objective of allowing fishing only on target stocks to the extent practical while minimizing interception of non-target stocks.

Annual harvests of sockeye salmon in the Akwe fishery were as high as about 28,700 fish in 1980 and averaged about 8,000 fish during the 15-year period of 1972 to 1986 (Figure 2). Since 1987, annual harvests of sockeye salmon in the Akwe fishery were as high as about 21,000 fish in 2000 and have averaged about 7,000 fish in the 15-year period of 1987 to 2001. Thus, there has not been much difference in the Akwe fishery harvests before and after the change in the Italio River's course. Annual harvests of sockeye salmon in the Italio fishery were as high as about 7,500 fish in 1984 and averaged about 1,800 fish per year during the 16-year period from 1972 to 1987 (Figure 3).

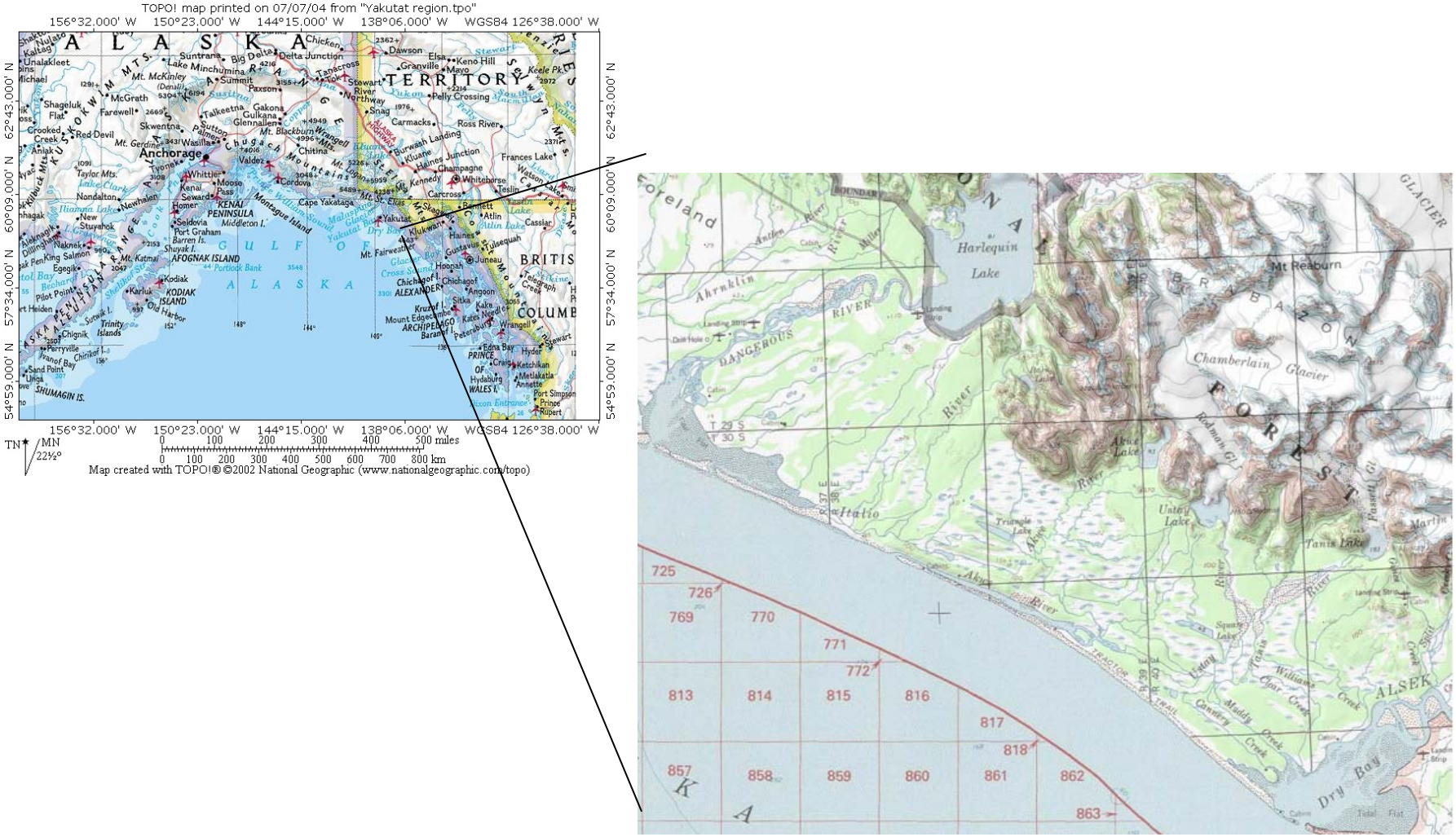

Figure 1.–Map showing the location of the Akwe and Italio rivers southeast of Yakutat, Alaska.

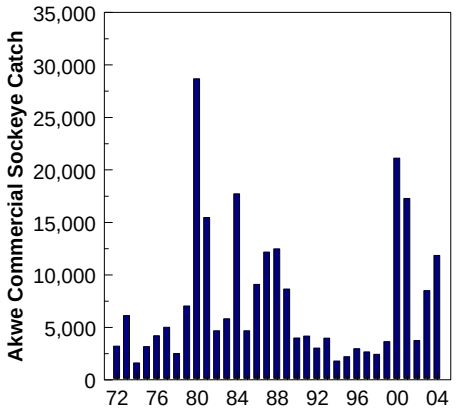

Figure 2.–Commercial catch of sockeye salmon from the Akwe set gillnet fishery, 1972–2004.

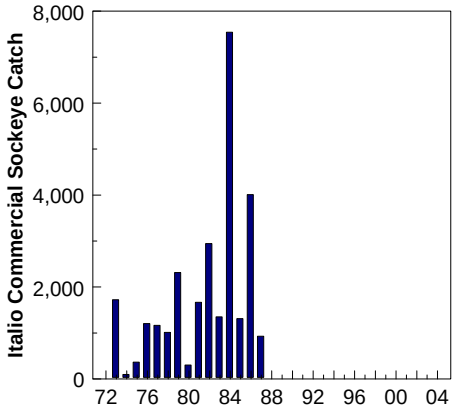

Figure 3.–Commercial catch of sockeye salmon from the Italio set gillnet fishery, 1972–2004 (since 1987, the catch totaled 5 sockeye salmon in 1988, 1 sockeye salmon in 1993, and 24 sockeye salmon in 1995).

However, in almost all of the years since 1987, there has been no directed fishery in the Italio for sockeye salmon and harvests have only averaged about two fish in the 14-year period from 1988 to 2001. Thus, there is a large difference (an average of only about 4% of the historic harvest) in the before and after fishery harvests associated with the change in the Italio River's course. The new (1987 to present) Italio fishing boundaries were defined and intended to target Italio salmon stocks. But, due to the limited geographic area available, the change resulted in a fishing area that is fairly small with typical water currents causing problems and difficulties for fishing set gillnets. As a result, only minor levels of commercial and subsistence fishing effort have been exerted in this area since 1987.

The distribution of sockeye salmon spawners in the Akwe and Italio river systems has not been well documented. The moderately sized population of Akwe River sockeye salmon is believed to spawn primarily in tributaries to Akwe Lake. Presumably, the lake provides limited rearing habitat for juveniles and the majority of the sockeye salmon smolt leave fresh water as age-0 fish or as "zero-checks" (Geiger et al. 2003). Italio River sockeye salmon are believed to spawn in Italio Lake, in small tributaries to the lake, and in the mainstem Italio River and its tributaries. A falls located about 800 m below Italio Lake has historically caused some difficulty with upstream salmon migration. In the late 1970s, ADF&G and the U. S. Forest Service made some in-stream improvements at the falls to reduce water velocity and hence improve upstream migratory success for salmon. Although adult sockeye salmon have historically demonstrated that they can successfully migrate past this high velocity stretch of river, it is almost certain that sockeye salmon fry hatching in the river downstream of this area cannot successfully migrate upstream to rear in the lake.

The stock assessment program for the Akwe and Italio sockeye salmon populations has historically consisted of flying aerial surveys to count spawners as well as collecting and tabulating fish tickets and subsistence catch reports. Minor sport fishing also occurs and is accounted for by the Statewide Harvest Postal Survey. Annual sampling of the commercial catches and the escapements for age, sex, and length information has been limited.

A geological change in 1985 resulted in a larger portion of the Ustay River entering the Akwe River. The Ustay River is a glacial stream that splits and subsequently feeds into both the Alsek and the Akwe rivers. As a result, water clarity and the ability to observe salmon during aerial-based surveys in the Akwe River have deteriorated since 1985. In the years from 1973 to 1984, prior to the increased impact of Ustay River waters on survey conditions, peak survey counts were assumed to represent about one half of the total escapement. Since then, surveys have been assumed to represent only about a tenth of the total escapement. These

survey expansion assumptions have been based entirely on professional judgment of ADF&G staff who have conducted the surveys and are discussed by Clark et al. (1995). ADF&G has often been unable to evaluate escapements in the Akwe system in recent years (1992, 1997–2000, and 2002–2003) due to poor water visibility (Figure 4).

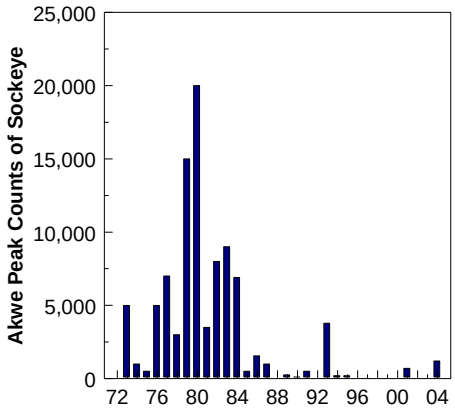

Figure 4.–Peak survey counts of sockeye salmon in the Akwe River, 1972–2004 (counts not obtained in 1992, 1997–2000, and 2002–2003; counts since 1984 negatively affected due to Ustay River glacial water influence).

The Italio River is considered the most difficult stream in the Yakutat area to survey from the air. While the water is clear, the river follows a very convoluted course and flows through deep forest. Deep shadows often exist along extensive sections of the river. Prior to 2005, professional opinion (Clark et al. 1995) was that under good/normal conditions, about one-half of the total number of sockeye salmon in the river system were counted. While there has been virtually no fishery in the Italio since 1987, the peak counts of sockeye salmon spawning have also greatly decreased (Figure 5).

The Akwe and the Italio commercial fisheries are designed for active management, whereas only passive management (fishery monitoring) of the subsistence and sport fisheries occurs. The active management of these commercial fisheries is accomplished through periodic aerial surveys of spawning escapements and adjustment of weekly openings for harvest opportunity. Due to the lack of observations of spawners in the past several years, ADF&G fishery managers have had to rely completely upon catch per unit of effort statistics from the commercial fishery.

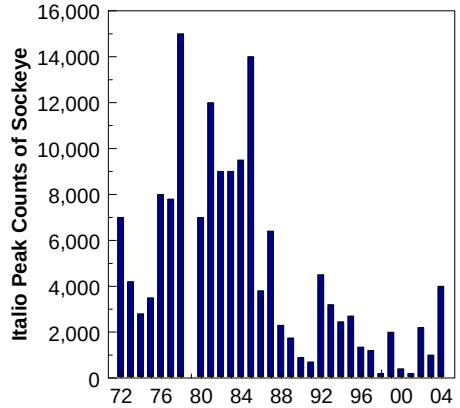

Figure 5.–Peak survey counts of sockeye salmon in the Italio River, 1972–2004 (count not obtained in 1979; commercial fishery virtually nonexistent since 1987).

Biological escapement goals (BEG) were established for both systems by ADF&G in 1995 (Clark et al. 1995). For the Akwe River, a BEG of 600 to 1,500 peak aerial survey counts of sockeye salmon was adopted. However, in 2006, ADF&G recommended the goal be dropped because of difficulties in annually assessing escapement (Der Hovanisian and Geiger 2005). Current harvest levels on Akwe sockeye stocks appear to be similar to historic levels; however, escapement strength in recent years is often undocumented. It may be that Italio sockeye salmon stocks are harvested in the Akwe fishery in appreciable numbers since the Italio River changed course. If so, harvest comparisons may be a poor stock-assessment tool.

A BEG of 2,500 to 7,000 peak survey counts was adopted for Italio sockeye stocks in 1995 based on a stock-recruit analysis using data from brood years 1972 to 1981 (Clark et al. 1995). Little fishing effort has been expended in the commercial Italio set gillnet fishery since 1987, so only minor effort has been required to implement the active management program. However, even though annual harvests were minor, escapement objectives were not achieved from 1996 through 2002. In 2003, the escapement goal was dropped because the productivity of this system had so obviously declined from that observed in brood years 1972 to 1989 (Geiger et al. 2003). The escapement goal for the Italio River will not be revised until better population dynamics information becomes available (Geiger et al. 2003). Based upon the very limited information

that is available to date, the situation with Italio sockeye salmon stocks is that exploitation is likely near zero, but annual aerial counts of escapements are typically below historic levels.

The purpose of this study was to improve the annual assessments for Akwe River and Italio River sockeye salmon stocks and augment stock assessment information available for management of fisheries in the Yakutat area. Objectives for the 2004 stock assessments were:

(1) To estimate the total escapements of sockeye salmon in the Akwe and Italio rivers;
(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 both systems.

Funding for this study was obtained via a grant from the National Oceanic and Atmospheric Administration through the Southeast Sustainable Salmon Fund.

METHODS

A two-event mark–recapture experiment for a closed population (Seber 1982) was conducted to estimate abundance of sockeye salmon in the Akwe and Italio rivers in 2004.

CAPTURE AND MARKING (EVENT 1)

Immigrating sockeye salmon were caught from 20 June through 24 July 2004 in a 900-m section of the lower Akwe River between the river mouth and the confluence of the Akwe and Italio rivers (Figure 6). This section of the river was downstream from the lower boundary of the Akwe commercial set gillnet fishing district in an area where Akwe and Italio sockeye salmon stocks are mixed. A 61-m (2.2-cm mesh) beach seine was used to capture fish from 30 June to 8 July. A 46-m beach seine (3.8-cm mesh) was used from 9 July to 24 July. Due to tidal influences in the lower river, sets were typically made in the hours

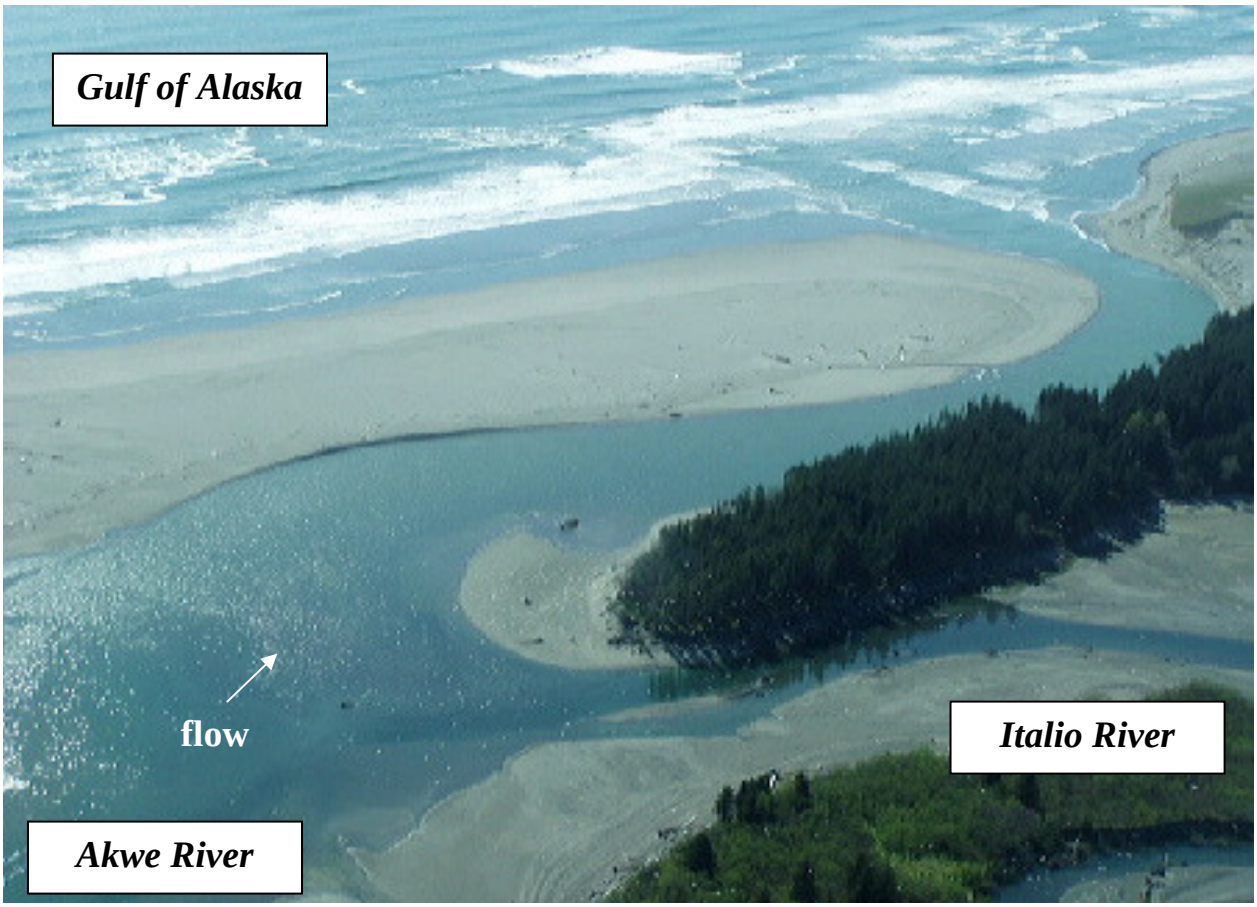

Figure 6.–Aerial photograph showing the confluence of the Akwe and Italio rivers, 2004

prior to an incoming tide. 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 released. Fish with deep wounds, damaged gills, or in a lethargic condition were not sampled, and were released without being marked. 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 opercle (LUOP) if the fish was caught from 30 June through 10 July; or a hole punched in the upper one-third of the right opercle (RUOP) if the fish was caught from 13 July through 24 July.

The secondary marks were used to ensure that when a fish was examined on the spawning grounds up to two months later, the time period when the fish was marked and released during Event 1 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 (Isanti, MN). 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 deployment, the frequency and code for each radio tag was checked, verified, and noted on the field data form. The radio tags used in 2004 included 60 distinct frequencies (150–153 MHz range) with two codes per frequency. Using catch statistics for the 2002 Akwe River fishery, radio tags were deployed over the season in proportion to the projected sockeye salmon abundance in the lower river. Tracking of the radio-tagged fish occurred weekly through ground surveys and aerial surveys using a fixed wing aircraft.

The radio tags were used to estimate the portion of fish marked in Event 1 that successfully moved into the Event 2 sampling area rather than being caught in upstream fisheries, dying from handling, or moving elsewhere. This provided a means to adjust the number of marks used in the abundance estimation process. Secondly, the proportion of radio-tagged fish that migrated into the Akwe and Italio rivers was used as part of the calculation needed to estimate the number of fish in each respective river system. Lastly, the location of radio-tagged fish on the spawning grounds in each of the two river systems was used to assist with sampling during Event 2.

RECOVERY ON SPAWNING GROUNDS (EVENT 2)

Event 2 sampling was conducted by collecting and inspecting sockeye salmon for marks on or near the spawning grounds of the Akwe and Italio river systems. In the upper Akwe River, a beach seine was used to collect live fish on 25 August at the mouths of two major spawning tributaries located 3.0 and 4.5 km downstream of Akwe Lake. From 24–26 August, carcass surveys throughout the mainstem Akwe River were also conducted. Three visits to the Italio River system were made in 2004. From 23–24 July, a float survey of the mainstem Italio River was conducted to track radio-tagged fish and count live sockeye salmon. On 21 August, live fish were collected and sampled using a beach seine at the falls located 1.6 km downstream of Italio Lake. Beach seining was subsequently conducted in Italio Lake from 15–16 September. The numbers of marked and unmarked fish from each sampling location examined during Event 2 were compared to determine if marking rates were relatively constant across the entire spawning grounds. To avoid double-sampling, live fish were marked with a partial dorsal fin clip before release and carcasses were marked with a slash on the left side of the fish.

ABUNDANCE ESTIMATION

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

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

where $\hat{N}$ = estimated abundance of sockeye salmon; $\hat{M}_e$ = 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:

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

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 successfully migrated upstream into the Event 2 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 successfully migrated upstream into 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) 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 unit effort statistics during Event 1 sampling. Event 1 sampling effort was sporadic with anywhere from one to six beach-seine sets per day over a 25-day period of time. Meeting the second condition depended primarily upon survey coverage. Event 2 sampling took place during two main periods (late August and mid-September) and throughout the main spawning grounds of both systems. Meeting the third condition depended primarily upon behavior of fish marked in 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, time of marking was independent of if and when/where recovery occurred during Event 2. 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. Determination of whether all length categories of the sockeye salmon population were subject to similar probabilities of capture during sampling in Events 1 and 2 was based upon the Kolmogorov-Smirnov (K-S) test (Conover 1980). Procedures are described in Appendix A1 as well as corrective measures (stratification) based on diagnostic test results to minimize bias in estimates of abundance and size composition. The diagnostic test hypotheses were evaluated using the test criterion of $\alpha = 0.10$.

The basis for meeting the fourth condition (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 Event 2 sampling. Thus marked fish were unable to lose their marks as sometimes occurs with tagged fish (condition 5).

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) 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 300,000 (B) times.

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 never seen on the spawning grounds
4. Unmarked and inspected on the spawning grounds

Radio-tagged Salmon
1. Marked LUOP (t = 1) and spawned in Akwe River
2. Marked LUOP and spawned in Italio River
3. Marked LUOP and did not reach spawning grounds
4. Marked RUOP (t = 2) and spawned in Akwe River
5. Marked RUOP and spawned in Italio River
6. Marked RUOP and did not reach spawning grounds

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

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

The estimated fraction ($\hat{q}_{ak}$) of those fish surviving and choosing the Akwe River as their spawning destination was:

$$\hat{q}_{ak} = m_{ak}/m \qquad (5)$$

where m_{ak} is the subset of m fish located in the Akwe River. Note that the estimated fraction of fish choosing the Italio River is $1-\hat{q}_{ak}$. The estimated number of fish from the Akwe River in the run is:

$$\hat{N}_{ak} = \hat{q}_{ak}\hat{N} \qquad (6)$$

The estimated number of fish from the Italio River in the run is:

$$\hat{N}_{it} = (1-\hat{q}_{ak})\hat{N} \qquad (7)$$

Harvest rate (U) in the Akwe River commercial, subsistence and sport fisheries was estimated as:

$$\hat{U}_{ak} = H_{ak}/\left(H_{ak} + \hat{N}_{ak}\right) \qquad (8)$$

where H_{ak} was the documented or estimated number of sockeye salmon harvested in the commercial, subsistence, and sport fisheries.

Variance estimates for $\hat{N}_{ak}$, $\hat{N}_{it}$, and $\hat{U}_{ak}$ were calculated using bootstrap procedures similar to those described for $\hat{N}$ above (see equation 4).

AERIAL SURVEY TO TOTAL ESCAPEMENT EXPANSION FACTOR

The expansion factors for the peak counts of sockeye salmon from the Akwe and Italio surveys in 2004 and their sample variances were estimated as follows:

$$\hat{\pi}_{2004} = \hat{N}/I_{2004} \qquad (9)$$

$$\hat{var}(\hat{\pi}_{2004}) = \hat{var}(\hat{N})I_{2004}^{-2} \qquad (10)$$

where π was the expansion factor and I the peak count of several surveys conducted in 2004. The variance in equation (10) 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 from 267 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 objective criteria developed by the ADF&G, Commercial Fisheries Division scale-aging group in Douglas, Alaska. 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 the Akwe and Italio rivers independently, age composition by gender 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 for the proportions' variance (Cochran 1977):

$$\hat{p}_{ij} = n_{ij} / n \qquad (11)$$

$$var(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1-\hat{p}_{ij})}{n_j - 1} \qquad (12)$$

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

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

RESULTS

TAGGING, RECOVERY AND ABUNDANCE

In Event 1, a total of 1,169 sockeye salmon were captured, sampled, and released with primary and secondary marks between 30 June and 24 July 2004 (Table 2; Appendix A2). Of these, 684 fish (58.5%) were marked from 30 June to 10 July and received a hole punch in the left opercle, and 485 fish (41.5%) were marked from 11–24 July and received a hole punch in the right opercle. Of the 1,169 marked sockeye salmon, 116 fish (9.9%) were systematically tagged with uniquely identifiable radio transmitters.

From 21 August through 16 September 2004, a total of 1,573 sockeye salmon were inspected for marks in Event 2 (Table 2; Appendix A3, A4). Of these, 34 fish (2.2%) were observed with marks. All marked fish had their primary tag identification which was an adipose fin clip. Of the 116 radio-tagged fish, 8 fish were censored from the analyses; 2 fish were never detected following tagging (indicating possible radio failure) and relocation and recovery data for 6 radio tags indicated probable regurgitation (Table 2). Twenty-three radio-tagged fish were harvested in the set gillnet commercial fishery in the lower Akwe River and six fish migrated upstream of the tagging site (and commercial fishing district) but did not recruit to the spawning grounds. Of the latter six radio-tagged fish, four fish were last detected in the lower Akwe River during an aerial survey on 20 August, one fish was last detected in the lower Italio River during the same aerial survey, and one fish was recovered in the mid-Italio River during a boat survey. Additionally, two fish were detected at or near the confluence of the two rivers more than two weeks after tagging and were considered to represent mortalities.

Table 2.–Number of sockeye salmon marked in Event 1 and inspected for marks on the spawning grounds in Event 2, Akwe and Italio rivers, 2004.

Event 1:	
Released with marks (M)	1,169
Released with radio tags	116
Event 2:	
Captured (C)	
Akwe River	1,043
Italio river	117
Total	1,160
Recaptured (R)	
Akwe River	22
Italio River	12
Total	34
Radio Tags	
Unavailable	
Censored – never detected	6
Censored – probable regurgitation	2
Harvested in commercial fishery	23
Never recruited	8
Recruited to Spawning Grounds	
Akwe River	61
Italio River	16

Testing for size bias sampling was conducted. 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 during Event 2 (R) using the K-S test. We failed to reject the null hypothesis (K-S = 0.058, p = 0.999; Figure 7). 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 = 0.168, p = 0.316; Figure 7). In contrast, length frequency distributions differed statistically for all fish marked (M) during Event 1 and those captured (C) during Event 2 (K-S = 0.162, $p < 0.001$; Figure 7). To the extent that size biased sampling may have occurred, it was most likely during Event 2. The test statistics for the M/R and M/C tests were similar in magnitude and location on the length axis Figure 7); and the M/C test is more powerful due to the large sample sizes. The significant result of the M/C test may have been the result of:

1) A difference in the size distribution of sockeye salmon spawning in the Akwe and Italio river systems; and
2) The logistical difficulty in maintaining uniform Event 2 sampling effort across both systems.

When we compared the length–frequency distribution of fish sampled during Event 2 in the Akwe River with the distribution of fish sampled in the Italio River, we found a significant difference (K-S = 0.260, $p < 0.001$). No diagnostic tests were available for these data to indicate whether or not size-biased sampling occurred during Event 2 sampling within either the Akwe or Italio river systems. To further evaluate the hypothesis of equal probability sampling during the first event, we conducted separate R/C tests using only Akwe River and only Italio River Event 2 samples. Not surprisingly, we failed to reject the null hypothesis in either case (Akwe K-S = 0.145, p = 0.773; Italio K-S = 0.211, p = 0.665). Based on these test results, size stratification was not necessary prior to calculating an unbiased estimate of abundance.

Diagnostic tests were conducted to detect spatial or temporal violations of conditions 1–3. We tested the null hypothesis that the probability of a fish being inspected for marks was independent of the time during the run that it was marked in Event 1. The 1 df Chi-square (χ^2) test statistic was 0.001 with a p-value of 0.970, thus we failed to reject the null hypothesis and no temporal stratification was necessary. A second temporal test was conducted for testing the null hypothesis that the probability that an Event 2 fish was marked was independent of which of eight Event 2 sampling events that the fish was caught and inspected. The seven df χ^2 test statistic was 8.079 with a p-value of 0.326, so we failed to reject the null hypothesis. We also tested the null hypothesis that the probability of an Event 2 fish was marked was independent of where (Akwe River or Italio River) it was caught and inspected. The one df χ^2 statistic was 0.040 with a p-value of 0.842, so again we failed to reject the null hypothesis. Failure to reject the null hypothesis for these tests is sufficient to conclude that a least one of conditions 1–3 were satisfied and a partially stratified model for abundance estimation did not need to be employed.

Sockeye salmon were observed during aerial surveys in the Italio River prior to the initiation of Event 1. A total of 500 fish were counted on 20 June and 300 were counted on 27 June. 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.

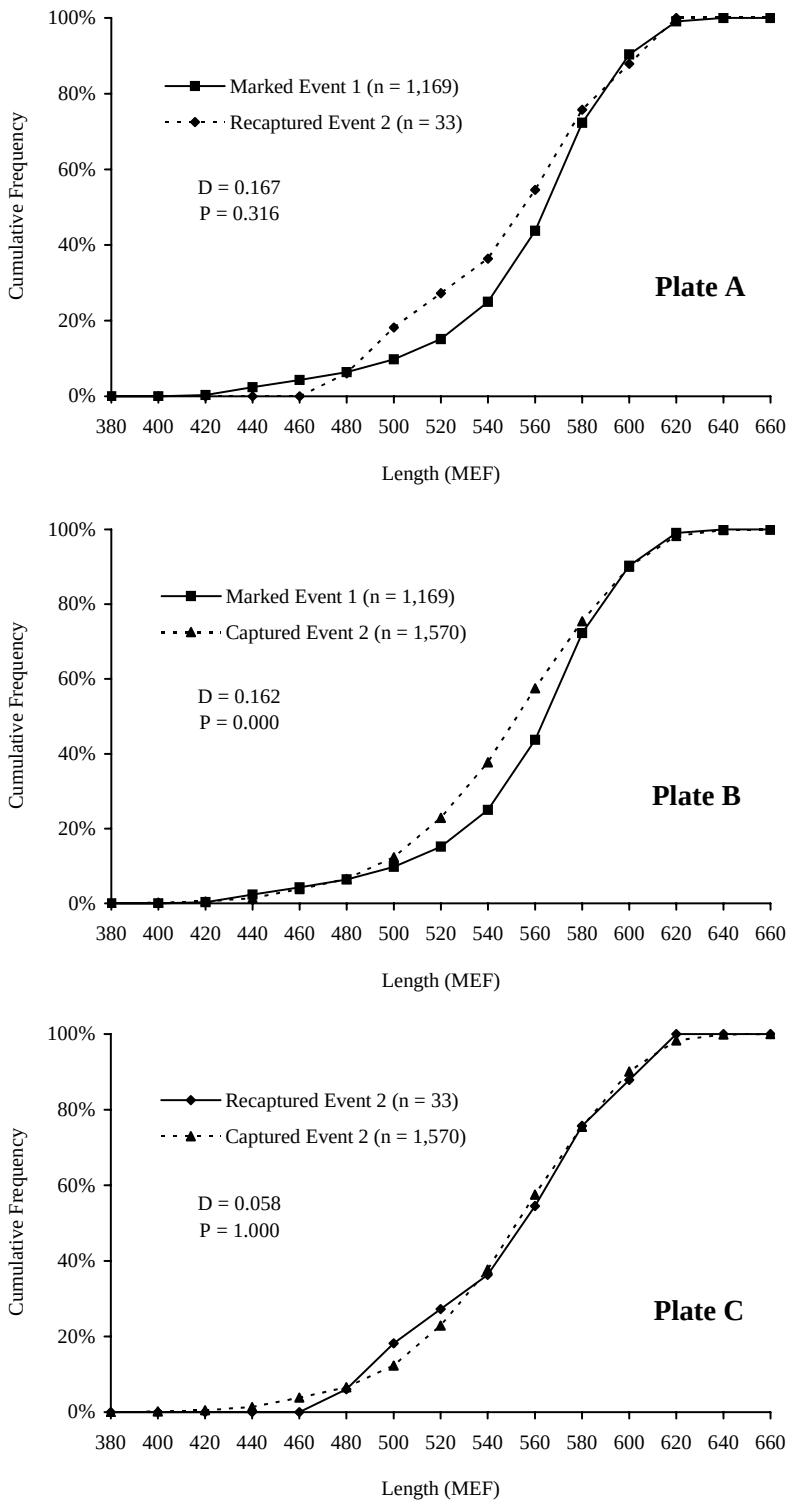

Figure 7.–Cumulative length frequency distributions and K-S tests comparing marks (M) to recaptures (R), marks (M) to captures (C), and captures (C) to recaptures (R) for sockeye salmon in the Akwe and Italio rivers, 2004.

Radio telemetry results indicated that an estimated 77 of the 108 uncensored radio-tagged fish recruited into either the Italio River (16 fish) or upstream of the commercial fishing district in the Akwe River (61 fish) and were assumed to have spawned successfully. This proportion was used to adjust the number of marked fish for estimating abundance. The estimate of abundance based on the adjustment for the number of marks was 36,398 fish (SE = 6,704). The 95% CI was 26,280 to 52,460 fish based on the bootstrap analysis.

Based on the 77 radio-tagged fish that moved upstream and reached the spawning areas of either river, we estimated that the run was comprised of 79% Akwe River stocks and 21% Italio River stocks. Estimated returns to each system were 28,835 fish (SE = 5,624) for the Akwe River and 7,563 fish (SE = 2,155) for the Italio River.

In 2004, documented commercial and subsistence sockeye salmon harvests in Akwe River fisheries were 11,860 and 36 fish respectively. An estimated 23 (SE not available) sockeye salmon were harvested in the Akwe River sport fishery. The estimated utilization rate of Akwe River sockeye salmon stocks, based on a combined harvest of 11,919 salmon from all three fisheries, was 0.292 (SE = 0.038). No commercial or subsistence harvest was documented in 2004 for Italio River stocks and the estimated sport harvest was 23 (SE = 23) (Jennings et al. *In prep*).

Of the 61 radio-tagged fish recruited to the Akwe River, 2 fish were last detected in the lower river, 10 fish were last detected in mid-river, 46 fish were last detected in the upper river, and 2 fish were last detected near Akwe Lake. Of the 16 radio-tagged fish recruited to the Italio River, 10 fish were detected in Italio Lake, 3 were detected in the Italio River at the falls, and 2 were detected in the upper Italio River below the falls.

EXPANSION FACTOR

During 2004, there were two aerial surveys of the Akwe River and eight aerial surveys of the Italio River drainage when sockeye salmon were counted (Appendix A5). Similar counts (1,200 fish) were obtained on 10 August and 20 August for the Akwe River. Peak counts of sockeye salmon in the Italio River drainage occurred on 1 September when 4,000 fish were observed in Italio Lake. The expansion factors for each system were calculated as the ratio of the estimate of abundance of sockeye salmon to the peak aerial survey count. The estimated expansion factors for 2004 were 24.03 (SE = 4.69) for the Akwe River and 1.89 (SE = 0.54) for the Italio River.

ESTIMATES OF AGE, SEX AND LENGTH COMPOSITION

The age composition of fish sampled in the Akwe River was comprised of six age classes ranging from age-0.1 to age-1.3 that represented four brood years (1999, 2000, 2001, and 2002) that returned in 2004 as 2-, 3-, 4-, and 5-year-old fish (Appendix A6). Age-0.2 (20.0%) and age-0.3 (76.6%) fish (both sexes combined) made up a majority of the Akwe River spawning population. Ninety-eight percent of fish sampled were freshwater age-0 ("zero-checks"), or fish that migrated to sea in the same year they hatched. Two percent of the samples were freshwater age-1 fish ("one-checks") that hatched and subsequently spent the next year in the river system before migrating to sea. Males represented 37.2% and females represented 62.8% of the Akwe River escapement. Average length composition by age in the Akwe River escapement ranged from 395 mm for age-0.1 to 598 mm for age-1.3.

Returns to the Italio River were comprised of four age classes ranging from age-1.2 to age-2.3 that represented three brood years (1998, 1999, and 2000) that returned in 2004 as 4-, 5-, and 6-year-old fish (Appendix A7). Age-1.2 (35.2%) and age-1.3 (41.8%) fish (both sexes combined) made up a majority of the spawning population. Seventy-seven percent of fish were freshwater age-1 and 23% of fish were freshwater age-2. Males represented 48.4% and females represented 51.6% of the Italio River escapement. Average length composition by age in the Italio River escapement ranged from 505 mm for age-1.2 fish to 598 mm for age-2.3 fish.

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.

Recruitment was only a possibility if fish entered the system before or after Event 1 sampling. In 2004, there was evidence to suggest that assumption 4 (no recruitment) was not met. For example, there were 96 sockeye salmon captured in the first beach seine set of Event 1 (30 June), which indicated that fish had already started to move upstream of the tagging site prior to the onset of sampling. Sockeye salmon were also observed in the Italio River during aerial surveys several days prior to the onset of tagging (500 fish on 20 June, 300 fish on 27 June). In addition, there were 16 sockeye salmon captured on the last day of Event 1 sampling (24 July) in 2004, suggesting that some fish continued to immigrate after the termination of Event 1 sampling. Despite these observations, marked to unmarked ratios during Event 2 were not significantly different, indicating there was sufficient mixing of marked and unmarked fish between events. Hence, we believe that the abundance estimate derived in 2004 was not biased due to recruitment, but was germane to the timing of the second sampling event.

Event 2 sample sizes were larger than expected in 2004 as a result of low water levels and larger numbers of spawners than expected. Sockeye salmon tended to congregate in the mainstem near the mouths of major spawning tributaries for longer than usual and were thus more easily captured in beach seine sets. In the Akwe River, 1,043 fish were sampled during Event 2 over a 3-day period (24–26 August), while 530 fish were sampled in the Italio River over a 3-day period (21 August, 15–16 September). Similarly, Event 1 sample sizes were larger (nearly double) than expected during planning the 2004 experiment. While the numbers of fish observed or collected exceeded the minimum numbers of fish indicated during planning to achieve our precision criteria (C.V. $\leq$ 20%), the experiment was planned for an expected abundance of approximately 11,000 spawners, less than 1/3 the number of spawners eventually estimated. The field effort during sampling was approximately appropriate, however, because first and second event samples sizes were sufficient to allow us to meet the precision criteria for the combined estimate of abundance and for the Akwe River estimate.

The assumption that marked fish may have a greater mortality rate than unmarked fish (condition 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. Of the 116 radio tags released, 2 tags were never detected after release, 6 tags were regurgitated near the tagging site, and 23 tags were recovered in the commercial fishery. Eight radio-tagged fish appeared to succumb before reaching the spawning grounds. Therefore, the worst-case scenario is that 8 out of 85 radio-tagged 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 estimates of 28,835 fish in the Akwe River and 7,563 fish in the Italio River derived from the mark–recapture experiment in 2004 were relatively unbiased estimates of the actual abundance of sockeye salmon that returned to the spawning grounds. As a result, the portion of sockeye salmon observed during the peak aerial surveys was approximately 4% and 53% of the actual Akwe River and Italio River abundances, respectively. Clark et al. (1995), using professional judgment, assumed a two-fold expansion factor for sockeye salmon survey counts in the Akwe River for the years 1973–1984 but a larger factor for later years due to decreased visibility. This study provides no insight into accuracy of that assumption for the years 1973–1984. Clark et al. (1995) assumed a 10-fold expansion for Akwe River sockeye salmon surveys for later years and this study indicates that even that level of expansion was likely too low. It seems likely to

us that such a small percentage of the sockeye salmon spawning population in the glacial waters of the Akwe River can be counted during a survey that once the survey count is expanded, the resulting escapement estimate is so imprecise as to have little biological meaning. Clark et al. (1995), using professional judgment, assumed a two-fold expansion factor for sockeye salmon counts in the Italio River. This study indicates that the professional judgment based assumption used by Clark et al. (1995) was reasonably close to the expansion factor scientifically estimated in 2004.

Historical age composition sampling for the Akwe River escapements of sockeye salmon only occurred in the five years of 1982–1986 (Clark et al. 1995); age composition during those five years averaged 61% age-4, 27% age-3, 10% age-5, 1% age-6, and 1% age-2. In 2004, age composition was 77% age-4, 20% age-3, 2% age-5, and 1% age-2 (Appendix A8). The 2004 age composition was similar to that documented in 1982–1986 in that age-4 fish dominated, followed by age-3 fish, then age-5 fish, but was different in that age-6 fish were not present. Age composition information collected in 2004 for the Italio River suggests similarities to past (1982–1985) escapements (Clark et al. 1995). However, the age-5 component only accounted for 48% of the escapement in 2004, whereas historically it represented 58%. In contrast, the age-6 component represented 17% of the Italio River escapement in 2004, whereas it historically represented only 2% of the escapement.

There was a substantial difference in the freshwater age composition of samples collected on the spawning grounds of the Akwe and Italio river systems in 2004. Ninety-eight percent of the 2004 Akwe River escapement samples consisted of freshwater age-0 fish, whereas none of the Italio River escapement samples consisted of freshwater age-0 fish. Historically, age composition of sockeye salmon in the Akwe River system has been heavily weighted towards freshwater age-0 fish, with this life-history type representing 85% of the escapements sampled (1982–1986, n =1,472; (Appendix A8) and 74% of the harvests sampled (1982–2003, n = 9,745; Appendix A9). In contrast, freshwater age-0 fish have historically only represented 6% of the escapements sampled in the Italio River system (1982–1985, n = 1,453; Appendix A10) and 54% of the harvests sampled in the Italio River (1982–1987; n = 2,766; Appendix A11). Differences in the life-history pattern of sockeye salmon in the two systems may explain some of this variation. From 1982–1985, ADF&G staff collected escapement samples from Italio Lake and in the Italio River below the lake, but above the falls. Escapements of sockeye spawning below the falls were not sampled. It seems likely that progeny of sockeye salmon spawning above the falls in the Italio River system rear in Italio Lake and thus have a typical sockeye-type life-history pattern. Progeny of sockeye salmon elsewhere in the systems do not have easy access to a lake environment and likely migrate to sea as freshwater age-0 fish. Based on this information, it is possible that Italio River escapement age compositions are biased and the actual proportion of freshwater age-0 fish in the escapements is higher than the samples indicate.

In addition, there was a large difference in the proportion of freshwater age-1 fish in the 2004 Akwe River escapement samples (2%) and the historical harvest samples (26%). It is possible that Italio River sockeye salmon, which are comprised of a larger proportion of freshwater age-1 fish than Akwe River stocks, were intercepted in the Akwe River set gillnet fishery and contributed to the observed differences. It is also possible that the proportion of freshwater age-1 fish sampled in the Akwe River escapement in 2004 was biased low. For example, 15% of 1982–1985 escapement samples in the Akwe River were comprised of freshwater age-1 fish. Ultimately, to better explain the differences in age composition between the Akwe and Italio river systems, as well as between escapement and harvest samples, it is recommended that additional age composition data be collected during any future studies.

CONCLUSIONS AND RECOMMENDATIONS

Estimating total escapement is important information for assessment and management of the Akwe and Italio river sockeye salmon stocks. Use of a two-event mark–recapture abundance estimator provided estimates of about 28,835 and 7,563 fish in the Akwe and Italio systems, respectively. The peak aerial survey of 1,200 fish in the Akwe River drainage and 4,000 fish in the Italio River drainage represented about 4% and 53% of the actual abundance of sockeye salmon on the spawning grounds in each system, respectively. In 2004, brood years 1999 to 2002 contributed to the Akwe River run and brood years 1998 to 2000 contributed to the Italio River run.

Multiple years of abundance estimates are important in determining annual variation and an appropriate average for application of expansion factors to historic peak aerial surveys for run reconstruction efforts. Three years of useable abundance estimates and companion expansion factors should be collected. However, funding was not available to continue these stock assessment efforts in 2005 and 2006 and may be difficult to obtain in future years.

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APPENDIX A

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

Size-selective sampling: The Kolmogorov-Smirnov two-sample test (Conover 1980) is used to detect significant evidence that size-selective sampling occurred during the first 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^2-test) is generally used to detect significant evidence that sex-selective sampling occurred during the first of 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.

-continued-

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:

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

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

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, Akwe River, 2004.

			Number of Sockeye Salmon					
				Marks Applied				
Date	No. of Sets	Start Fishing Time	Caught	Fin clip & Punch	Radio Tag & Punch	Total	Cum.	Punch Location[a]
30-Jun	1	10:15	96	92	4	96	96	LUOP
1-Jul	2	10:45	27	22	5	27	123	LUOP
2-Jul	3	10:15	36	30	6	36	159	LUOP
3-Jul	5	10:00	29	22	7	29	188	LUOP
6-Jul	4	11:45	67	55	11	66	254	LUOP
7-Jul	3	11:15	87	76	11	87	341	LUOP
8-Jul	3	10:00	87	75	12	87	428	LUOP
9-Jul	3	09:45	144	130	14	144	572	LUOP
10-Jul	4	11:15	112	100	12	112	684	LUOP
13-Jul	3	10:00	38	34	4	38	722	RUOP
14-Jul	4	09:40	38	34	4	38	760	RUOP
15-Jul	5	08:45	97	93	4	97	857	RUOP
16-Jul	4	08:30	83	79	4	83	940	RUOP
17-Jul	5	10:30	30	26	4	30	970	RUOP
20-Jul	6	09:10	57	55	2	57	1,027	RUOP
21-Jul	6	08:30	56	51	3	54	1,081	RUOP
22-Jul	1	08:30	0	0	0	0	1,081	RUOP
23-Jul	5	08:45	72	66	6	72	1,153	RUOP
24-Jul	3	09:00	16	13	3	16	1,169	RUOP
Total	70		1,172	1,053	116	1,169		

[a] LUOP - left upper opercle; RUOP = right upper opercle.

Appendix A3.–Summary of the number of sockeye salmon inspected for marks and the number marked by date and location, Akwe River, 2004.

				Number Marked				
	Number inspected			Seine		Carcass		
Date	Seine	Carcass	Total	LUOP	RUOP	LUOP	RUOP	Total
24-Aug	241		241			4	3	7
25-Aug	339	373	712	4	7	2	2	15
26-Aug	90		90					
Total	670	373	1,043	4	7	6	5	22

Appendix A4.–Summary of the number of sockeye salmon inspected for marks and the number marked by date and location, Italio River, 2004.

					Number Marked						
	Number Inspected				Falls		Lake				
	Falls	Lake			Seine		Seine		Carcass		
Date	Seine	Seine	Carcass	Total	LUOP	RUOP	LUOP	RUOP	LUOP	RUOP	Total
21-Aug	117			117	1						1
15-Sep			23	23					1		1
16-Sep		87	303	390			1		7	2	10
Total	117	87	326	530	1		1		8	2	12

Appendix A5.–Sockeye salmon counts during aerial surveys of the Akwe and Italio rivers, 2004.

Date	Akwe River	Italio River	Italio Lake	Total
20-Jun		500		500
27-Jun		300		300
3-Jul		1,200		1,200
11-Jul		2,200	500	2,700
18-Jul		3,900	0	3,900
25-Jul		1,500	1,200	2,700
10-Aug	1,200		3,200	4,400
20-Aug	1,200			1,200
1-Sep			4,000	4,000

Appendix A6.–Age, length, and sex composition of sockeye salmon escapement in the Akwe River, 2004.

	Brood Year and Age Class						
Sex	2002	2001	2000	2000	1999	1999	
Parameter	0.1	0.2	0.3	1.2	0.4	1.3	Total
Male							
Sample Size	1	1	49	1		2	54
Percent	0.7	0.7	33.8	0.7		1.4	37.2
Standard Error	0.7	0.7	3.9	0.7		1.0	4.0
Mean Length (mm)	395	440	583	510		598	576
Length Range (mm)			550–615			590–605	395–615
Female							
Sample Size		28	62		1		91
Percent		19.3	42.8		0.7		62.8
Standard Error		3.3	4.1		0.7		4.0
Mean Length (mm)		523	553		560		544
Length Range (mm)		500–540	475–615		560–560		475–615
All Fish							
Sample Size	1	29	111	1	1	2	145
Percent	0.7	20.0	76.6	0.7	0.7	1.4	100.0
Standard Error	0.7	3.3	3.5	0.7	0.7	1.0	
Mean Length (mm)	395	520	566	510	560	598	556
Length Range (mm)		440–540	475–615			590–605	395–615

Appendix A7.–Age, length, and sex composition of sockeye salmon escapement in the Italio River, 2004.

	Brood Year and Age Class				
Sex	2000	1999	1999	1998	
Parameter	1.2	1.3	2.2	2.3	Total
Male					
Sample Size	14	28	4	13	59
Percent	11.5	23.0	3.3	10.7	48.4
Standard Error	2.9	3.8	1.6	2.8	4.5
Mean Length (mm)	519	603	536	609	580
Length Range (mm)	460–550	550–645	490–555	560–645	460–645
Female					
Sample Size	29	23	3	8	63
Percent	23.8	18.9	2.5	6.6	51.6
Standard Error	3.9	3.6	1.4	2.3	4.5
Mean Length (mm)	498	571	522	579	536
Length Range (mm)	440–545	515–610	495–535	550–615	440–615
All Fish					
Sample Size	43	51	7	21	122
Percent	35.2	41.8	5.7	17.2	100.0
Standard Error	4.3	4.5	2.1	3.4	
Mean Length (mm)	505	589	530	598	557
Length Range (mm)	440–550	515–645	490–555	550–645	440–645

Appendix A8–Age composition of sockeye salmon sampled on the spawning grounds of the Akwe River, 1982-1986.

	Age								
Year	0.1	0.2	0.3	0.4	1.2	1.3	2.1	2.2	2.3
1982	0.7	16.7	59.7	0.0	5.6	13.2	0.0	1.4	2.8
1983	0.3	28.6	58.5	0.0	1.6	8.4	0.0	1.0	1.6
1984	0.3	8.5	75.9	0.0	1.5	13.8	0.0	0.0	0.0
1985	1.9	45.9	32.9	1.4	9.2	5.8	0.5	1.9	0.5
1986	0.0	35.0	56.7	0.0	1.7	5.6	0.0	0.0	1.0
Avg.	0.6	26.9	56.7	0.3	3.9	9.3	0.1	0.9	1.2

Appendix A9.–Age composition of sockeye salmon sampled in the Akwe River commercial set gill net fishery, 1982–2003.

	Age												
Year	0.2	0.3	0.4	0.5	1.1	1.2	1.3	1.4	2.1	2.2	2.3	2.4	3.2
1982	14.2	44.8	0.6	0.0	0.0	12.5	25.6	0.0	0.0	0.4	1.7	0.0	0.2
1983	15.8	56.5	0.3	0.0	0.0	6.3	20.4	0.2	0.0	0.2	0.3	0.0	0.0
1984	0.2	73.7	0.2	0.0	0.0	0.2	25.8	0.0	0.0	0.0	0.0	0.0	0.0
1985	9.9	55.3	5.2	0.0	0.2	6.4	20.6	0.5	0.0	0.5	1.4	0.0	0.0
1986	24.6	49.0	0.0	0.0	0.0	2.5	19.3	0.1	0.0	1.2	3.3	0.0	0.0
1987	0.7	89.2	0.5	0.0	0.0	0.5	8.3	0.0	0.0	0.3	0.5	0.0	0.0
1988	4.9	77.0	1.0	0.0	0.0	4.1	10.7	0.4	0.0	1.2	0.8	0.0	0.0
1989	6.8	53.4	1.6	0.0	0.0	2.5	31.7	0.3	0.0	0.6	3.1	0.0	0.0
1990													
1991	4.1	43.7	0.4	0.0	0.0	5.2	40.7	0.0	0.0	1.9	4.1	0.0	0.0
1992	13.1	39.3	0.6	0.0	0.0	4.3	41.2	0.0	0.0	0.3	1.2	0.0	0.0
1993	1.9	84.8	0.8	0.0	0.0	2.2	8.2	0.0	0.0	0.3	1.9	0.0	0.0
1994	2.0	80.2	0.8	0.0	0.0	1.6	10.9	0.8	0.0	0.8	2.8	0.0	0.0
1995	30.9	36.6	2.6	0.0	0.0	6.2	18.0	0.0	0.0	0.5	5.2	0.0	0.0
1996	5.1	76.6	0.4	0.0	0.0	2.7	13.1	0.0	0.0	1.1	0.9	0.0	0.0
1997	3.7	77.7	1.4	0.0	0.0	1.4	13.4	0.2	0.0	0.2	2.0	0.0	0.0
1998	4.6	78.6	0.7	0.0	0.0	3.4	9.0	0.2	0.0	0.7	2.7	0.0	0.0
1999	15.9	51.0	0.6	0.2	0.0	14.9	14.4	0.6	0.0	1.3	0.8	0.2	0.0
2000	3.2	75.5	0.4	0.0	0.0	0.0	19.5	0.0	0.0	0.4	1.1	0.0	0.0
2001	1.8	72.1	0.2	0.0	0.0	2.0	23.6	0.0	0.2	0.0	0.2	0.0	0.0
2002	24.6	48.2	1.8	0.0	0.0	7.0	15.4	0.7	0.0	1.5	0.8	0.0	0.0
2003	12.8	73.2	0.2	0.0	0.2	2.3	9.1	0.0	0.0	0.4	1.9	0.0	0.0
Avg.	9.6	63.6	1.0	0.0	0.0	4.2	19.0	0.2	0.0	0.7	1.8	0.0	0.0

Appendix A10.–Age composition of sockeye salmon sampled on the spawning grounds of the Italio River, 1982–1985.[a]

	Age							
Year	0.2	0.3	1.1	1.2	1.3	2.2	2.3	3.3
1982	0.2	0.2	1.0	30.4	59.6	3.2	5.0	0.2
1983	1.1	0.6	0.6	14.5	81.5	0.9	0.9	0.0
1984	1.3	5.5	2.3	32.6	54.4	1.0	2.6	0.3
1985	12.7	1.5	0.5	55.2	27.0	3.1	0.0	0.0
Avg.	3.9	2.0	1.1	33.2	55.6	2.0	2.1	0.1

[a] ADF&G staff collected these samples from Italio Lake and from the Italio River upstream of the falls.

Appendix A11.–Age composition of sockeye salmon sampled in the Italio River commercial set gill net fishery, 1982–1987.

	Age							
Year	0.2	0.3	0.4	1.2	1.3	1.4	2.2	2.3
1982	3.4	22.3	0.0	16.6	50.9	0.3	2.3	4.2
1983	3.0	41.2	0.0	3.2	51.5	0.0	0.2	0.9
1984	0.5	66.8	0.0	0.2	31.9	0.0	0.2	0.4
1985	9.1	35.6	14.6	11.5	25.7	0.4	2.4	0.8
1986	5.5	35.2	0.4	6.2	49.5	0.3	1.0	1.9
1987	0.9	85.4	0.0	0.9	11.6	0.0	0.6	0.6
Avg.	3.7	47.8	2.5	6.4	36.8	0.2	1.1	1.5