Fishery Data Series No. 11-57

Abundance and Distribution of Fish River Coho Salmon *Oncorhynchus kisutch* in 2005 and 2006

by

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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)

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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ABSTRACT

The Niukluk River counting tower has monitored coho salmon *Oncorhynchus kisutch* passage since 2001. This information is used to make inseason harvest decisions for the entire Fish River drainage. A mark–recapture experiment was initiated to estimate the total abundance of coho salmon returning to the Fish River drainage and assess using the Niukluk River tower escapement as an index for drainagewide coho salmon escapement.

Radiotelemetry was used in 2005 and 2006 to estimate the abundance of coho salmon returning to the Fish River drainage. The total coho salmon abundance was estimated using a 2-event mark–recapture experiment where coho salmon were captured in the lower Fish River and recaptured with a stationary receiver at the Niukluk River counting tower. Coho salmon were marked with external radio tags in 2005 and with esophageal radio tags in 2006. A total of 140 coho salmon were tagged in 2005 and 243 coho salmon were tagged in 2006

An estimated 6,876 and 25,328 coho salmon returned to the Fish River drainage in 2005 and 2006. In 2005 a total of 2,718 coho salmon were counted past the Niukluk River counting tower while 11,106 coho salmon were counted in 2006. Coho salmon passage at the counting tower represented 39.5% and 43.8% of the total Fish River return in 2005 and 2006. The consistency between years supports the use of the Niukluk River counting tower as an index of Fish River drainage coho salmon abundance.

The Niukluk River counting tower may provide a dependable index of the total Fish River coho salmon return however this project was only conducted for 2 years. A mark–recapture study should be conducted over the entire generation of coho salmon to validate the consistency of the proportion of coho salmon migrating past the Niukluk River counting tower.

Key words: coho salmon, *Oncorhynchus kisutch*, mark–recapture, radiotelemetry, escapement, Fish River, Niukluk River, Golovnin Bay, Norton Sound.

INTRODUCTION

The Fish River drainage is approximately 6,200 km^2 and enters Golovnin Lagoon, Golovnin Bay, and then Norton Sound (Figure 1). The Fish River drainage supports coho *Oncorhynchus kisutch*, Chinook *O. tshawytscha*, chum *O. keta*, pink *O. gorbuscha*, and a small run of sockeye salmon *O. nerka*. There are also resident populations of Dolly Varden *Salvelinus malma*, Arctic grayling *Thymallus arcticus*, whitefish species *Coregonus* spp., and burbot *Lota lota*. The Niukluk River is the largest tributary of the Fish River.

Fish River drainage coho salmon stocks support a substantial subsistence fishery. The average number of coho salmon caught in the subsistence fishery was 944 (1998–2007), about 53% of the coho salmon harvest. The sport fishery harvest of Fish River coho salmon was smaller, averaging 675 (1998–2007), about 39% of the coho salmon harvest. Until recently, few coho salmon were harvested in saltwater commercial fisheries in Subdistrict 2, the Golovnin Bay subdistrict. The average commercial catch was 168 (1998–2007), about 8% of the coho salmon harvest (Soong et al. 2008).

Escapement goals are used to manage Fish River coho salmon populations. Aerial surveys enumerating coho salmon were conducted on the Fish River in 21 years from 1984 to 2006 and in only 7 years on the Niukluk River over that same time period. Aerial surveys are not an effective way to assess coho salmon escapement because they have been inconsistent due to high water levels, low visibility, and inclement weather.

A counting tower was installed on the Niukluk River in 1995 to enumerate pink and chum salmon. Since 2001, the counting tower has operated through most of the coho salmon run (Kohler 2003; Todd et al. 2005) and is currently used as an index of Fish River drainagewide coho salmon escapement for inseason harvest management. The combined sustainable escapement goal (SEG) of 950–1,900 coho salmon based on aerial surveys in the Niukluk River and Ophir Creek, large tributary of Niukluk River, was established in 1999 by the Alaska Board of Fisheries (BOF; ADF&G 2004). At the 2007 BOF meeting, ADF&G recommended discontinuing the aerial survey goal for Niukluk River and Ophir Creek because of the unpredictability of aerial surveys and recommended using the Niukluk River tower SEG of 2,400 to 5,900 coho salmon (Brannian et al. 2006).

The Fishery Disaster Relief Program for Norton Sound, part of Norton Sound Initiative (NSI), provided funding for 2 years of radiotelemetry studies to evaluate the appropriateness of using Niukluk River counting tower estimates as an index of Fish River drainagewide coho salmon escapement.

OBJECTIVES

1. Estimate escapement of coho salmon in the Fish River drainage.
2. Estimate the proportion of Fish River drainage coho salmon that migrate above the Niukluk River counting tower.
3. Estimate the age, sex, and length composition of coho salmon in the Fish River drainage escapement.
4. Determine tributary distribution and major spawning locations as represented by radiotagged salmon tracked to their final spawning location.

METHODS

Radiotelemetry and mark–recapture studies were used to estimate abundance and spawning distribution of coho salmon in the Fish River drainage. The abundance of coho salmon was estimated using a Petersen 2-sample mark–recapture experiment with Chapman modification for a closed population (Seber 1982). The first sample consisted of coho salmon captured and marked with radio tags on the lower Fish River (LFR), below the confluence with the Niukluk River (FNC). The second sample was the coho salmon abundance estimate from the Niukluk River counting tower. The marked fish in the second event were the radiotagged coho salmon that passed the Niukluk River counting tower. Age, sex, and length (ASL) samples were taken from all radiotagged coho salmon in the lower Fish River and from a sample of coho salmon that passed the Niukluk River counting tower. The mark–recapture assumptions of equal probability of capture by size, sex, and time were tested using the length distributions of radiotagged coho salmon and coho salmon that passed the Niukluk counting tower.

CAPTURE

A seine net, 45 m long with 2¼ in mesh, was used to capture coho salmon in the lower Fish River, approximately 3–8 km upriver from White Mountain (Figure 2). After the seine was complete, the pursed seine net served as a net pen for holding coho salmon prior to tagging. Alternatively, a 25 m gillnet with 5½ in stretched mesh was used when the number of coho salmon caught with the seine net was less than one coho salmon per attempt. The gillnet was deployed and allowed to drift with the current while one person walked along shore holding a rope connected to the float line. When a fish was caught, the onshore person anchored the end and pulled the net to shore. When necessary, net bars were cut to release the fish and reduce stress and incidental mortality.

TAGGING

All captured coho salmon were sampled for ASL and their adipose fins were clipped. Cradles, modified from Larson (1995) to include a sliding meter stick attached on the outside and deeper side notches, were used to sample and tag fish. Three scales were taken from the primary growth area, three scale 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 (Clutter and Whitesel 1956). Fish age was determined based on criteria established by Mosher (1969). Ages were recorded in European notation (Koo 1962). Sex of the fish was determined by external morphological characteristics and length was measured mideye to tail fork (METF, to the nearest 5 mm). All fish, tagged and untagged, were released at the capture site.

From the captured coho salmon, randomly selected fish that appeared healthy were radiotagged. Tags were deployed proportional to the historical coho salmon run timing past the Niukluk River counting tower (Figure 3).

In 2005, ATS model F2110[1] pulse-coded external mount radio tags were used. The tags were mounted on each coho salmon on the left side near the posterior edge of the dorsal fin. Each tag weighed approximately 15 g, had an expected operational life in excess of 45 days, and was equipped with a mortality switch that became active when the fish remained motionless for more than 4 hours. There were 150 unique tags in 15 tag frequencies (150–150.1 MHz) and 10 pulse codes.

In 2006, ATS model F1835b esophageal implant pulse-coded tags were used. Tags were inserted through the mouth and then implanted into the fish's stomach just below the esophagus with a tagging tube (Wuttig 1998). The outer portion of the tagging tube was slightly larger than the diameter of the tag with a cut in the side for the tag antennae. To insert the tag, the inner portion of the tube was pushed through the outer tube so the tag was placed into the fish's gastrointestinal tract. Each tag weighed approximately 13 g, had a warranted life of 48 days, an expected battery life of 96 days, and was equipped with a mortality switch. There were 250 unique tags in 17 frequencies (150–150.1 MHz) and 15 pulse codes.

Each deployed radio tag's frequency, pulse code, date, and time were recorded at the tagging site. Sequentially numbered Peterson disk tags were placed between pterygiophore bones near the posterior edge of the dorsal fin as secondary marks (Barton 1992; Winter 1978).

The number of coho salmon to be marked was estimated using the Tortora (1978) method for simultaneous 95% confidence intervals within 10% of the true range:

$$n = 1 + \mathrm{int}\left(\frac{N \cdot 0.25 \cdot z^2_{a/2k}}{(N-1)\cdot d^2 + s^2 \cdot z^2_{a/2k}}\right) \tag{1}$$

where n was the necessary sample size for N, the true population size, $z^2_{a/2k}$ was the upper $\alpha/2$ portion of the normal distribution, d was the allowable deviation from the true mean population, k was the number of categories, and s^2 was the maximum variance at $a = 0.05$, d = 10, $s^2 = 0.25$,

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

and k = 1. The minimum sample size was 150 fish. The actual target sample size was set at 175, to allow for 14%–15% tag loss.

RADIOTRACKING EQUIPMENT AND TRACKING PROCEDURES

Receiver Sites

Three stationary receiver sites were selected based on river morphology, surrounding terrain, and acceptable receiver coverage. To assess receiver coverage at each site water depth was recorded on three transects extending from both banks, located perpendicular to the shore, upriver, and downriver from each receiver site. A tagged fish was then simulated at each transect using 2–3 radio tags suspended 20–30 cm above the river bottom (McCleave et al. 1978; Solomon 1982). A site was deemed suitable when it had adequate receiver coverage.

ATS model R4500C receivers were used at all receiver sites, at the tagging location and during aerial and boat surveys. The receiver operated by scanning through the selected tag frequencies and pulse codes, with the scan and data storing rates individually set for each receiver. The receivers logged the tag frequency and pulse code, GPS coordinates, year, Julian day, hour, minutes, seconds, and signal strength of the radio tag.

Receiver site 1 was located 1 km downriver from White Mountain on a hillside approximately 15 m above the river (Figure 2). Two antennae were installed; one pointed up river and the other down river. This receiver was programmed to scan all frequencies and log and store data continuously. The recorded data were downloaded weekly. Fish detected and recorded at Site 1 and not identified as moving upriver were censored from the data and used to assess mortality. Receiver site 2 was located at the confluence of the Fish and Niukluk rivers, approximately 19 km upriver from the tagging location (Figure 2). Three antennae were installed; one pointed up the Fish River, the second down the Fish Fiver and the third up the Niukluk River. The receiver was set to scan continuously and store individual tag data every 10 min. Recorded data were downloaded to a laptop computer weekly.

Receiver site 3 was at the Niukluk River counting tower site, approximately 8 km upriver from the confluence of the Niukluk and Fish rivers (Figure 2). Two antennae were installed; one pointed up river and the other down river. The receiver was set to scan all frequencies and log and store data continuously.

Aerial and Boat Surveys

Aerial telemetry flights were conducted using a *Piper* Super Cub PA-18. Aerial surveys covered all Fish River and Niukluk River tributaries and were flown at altitudes of 150–300 m. In areas where numerous tagged fish were received at the same time such as the confluence of Fish and Niukluk rivers, surveys were conducted at an altitude of 150 m. In areas where fish were widely dispersed, surveys were conducted at an altitude of 300 m. Two antennae were used during survey flights. Both antennae were mounted perpendicular to the body of the plane with a 30° tilt from the aircraft wing lift strut (Gilmer 1981; Kenward 1987). An aircraft switch box inside the fuselage connected to both antennae allowed the observer to switch between left, right, or both antennae to better receive the transmitted signal from a tagged fish (Winter 1978). When a tag frequency and pulse code were detected and signal strength was greater than in the previous scan cycle river location, tag frequency, pulse code, and the presence of a mortality code were electronically logged on the receiver and hand written in an aerial survey log.

Boat surveys were conducted when the stationary receivers were downloaded. One antenna was held parallel to the ground in the direction of travel. Tag frequency and pulse codes were recorded in the same manner as the aerial surveys. For aerial and boat surveys tag coordinate resolution was within a 0.5 km radius.

DATA ANALYSIS

Tag Fates

Each tagged coho salmon was assigned 1 of 3 fates: Niukluk River above the counting tower, Fish River and tributaries, or censored based on information collected from stationary receiver sites and aerial surveys. A tag was censored if the tag did not move more than 10 km above the tagging location, did not survive more than 7 days, was found below the tagging location and did not move above the tagging location at a later date, or was only found once by aerial surveys or receiver sites.

Migration Rates and Holding Durations

Migration rates and holding time were estimated for coho salmon moving from the tagging location to FNC and from FNC to the Niukluk River counting tower. Migration rates were calculated as the difference between the date/time coho salmon were tagged and the date/time each fish was first recorded at a receiver site by the downriver facing antenna. Records were organized into 4 h time blocks (beginning at midnight) to assess diel migratory timing. Holding duration at a site was calculated as the difference between the upriver antenna and the downriver antenna records. Entry into Niukluk River was computed from the last record on antennae 3 (tributary monitoring) at the Fish-Niukluk River confluence site. Migration rates and holding durations were also computed by final destination.

Mark–Recapture Experiment

For a mark–recapture experiment, the following assumptions need to be satisfied (Seber 1982):

Assumption I: The population is closed to births, deaths, immigration and emigration.

This assumption could be violated if harvest occurs between events. However, we assume that the harvest rate of coho salmon returning to the Fish and Niukluk rivers is proportional to their return rates to the Fish and Niukluk rivers.

Assumption II: Marking and handling will not affect the catchability of coho salmon in the second event.

There is no explicit test for this assumption because the behavior of unmarked or uncaptured fish cannot be observed. However, handling time was minimized to attempt to meet this assumption.

Assumption III: Tagged fish did not lose their tags between the tagging site and their spawning destination.

A receiver at the tagging site and boat surveys around the tagging site identified radio tags that were expelled. All tags regurgitated were censored.

Assumption IV: One of the following three conditions will be met:

All coho salmon have equal probability of being captured in the first event;

All coho salmon have equal probability of being captured in the second event; or,

Marked fish mix completely with unmarked fish between events.

The tagging and sampling effort was designed to be proportional to the historical counting tower passage to satisfy the assumption of equal probability of capture for each fish. Additionally, Kolmogorov-Smirnov two sample tests (Zar 1999) were used to detect evidence of length selective sampling during the first or second events (Appendix A1). The chi-square statistic contingency tables (Zar 1999) were used to evaluate sex bias in the two events (Appendix B1) and consistency of capture in the two events for the Peterson estimator (Seber 2002; Appendix B2). Seines were used where possible to minimize bias from gear selectivity.

Niukluk River

The return of coho salmon above the Niukluk River was estimated using the Niukluk River counting tower. The counting tower operated 24 hours a day and salmon passage was monitored for 20 min each hour and expanded to hourly counts. At the time of this project missed hourly counts were determined by averaging the previous and following day's counts for the same hour; if the same hour was missed in two or more consecutive days, then the average incorporated the same number of days preceding and following the missed counts (Kent 2006). Interpolation of missed passage was reevaluated in 2009 and a standard was developed that was used for analysis in this report. Missing counts were interpolated using diurnal fish passage and following the scenarios outlined in Perry-Plake and Antonovich (2009).

As a result of the new interpolation method, Niukluk River tower escapement estimates used in this report are lower than escapement estimates listed in historical reports. Reported Niukluk River escapement estimates were 2,727 coho salmon in 2005 (Banducci et al. 2007) and 11,269 coho salmon in 2006 (Soong et al. 2008). The Niukluk River escapement estimates using the new interpolation methods were 2,718 coho salmon in 2005 and 11,106 coho salmon in 2006.

Fish River Drainage

The total Fish River coho salmon return for a given year was estimated using the Chapman modification to the Petersen estimator (Chapman 1951) for a closed population (Seber 1982):

$$\hat{N}_y = \frac{(m+1)(\hat{c}+1)}{(r+1)} - 1 \qquad (2)$$

where m was the number of marked coho salmon released, not censored, $\hat{c}$ was the estimated number of coho salmon passed the Niukluk River counting tower, r was the number of marked fish from m that were recorded at the Niukluk River counting tower receiver, and y was the study year.

Variance and 95% credibility interval for $\hat{N}_y$ were estimated using empirical Bayesian methods (Carlin and Louis 1997). Using Markov Chain Monte-Carlo techniques, a posterior distribution for $\hat{N}$ was generated by collecting 1,000,000 simulated values of $\hat{N}_y$ calculated using equation (2) from simulated values of equation parameters. Simulated values were modeled from observed data using the following distributions:

$$\text{Observed } r \sim \text{binomial } (q, m)$$

where q was the probability that a radiotagged salmon passed the Niukluk River counting tower and was recaptured; and

$$\hat{c} \sim \text{Normal } (E, var(E))$$

where E was the estimated escapement past the Niukluk River counting tower and $var(E)$ is the sampling variance for the escapement estimate.

At the end of the iterations, the following statistics were calculated:

$$\overline{N} = \frac{\sum_{b=1}^{1,000,000} \hat{N}_{(b)}}{1,000,000} \text{ and,} \tag{3}$$

$$v\hat{a}r(\hat{N}) = \frac{\sum_{b=1}^{1,000,000} (\hat{N}_{(b)} - \overline{N})^2}{1,000,000 - 1} \tag{4}$$

where $\hat{N}_{(b)}$ is the b^{th} simulated value of $\hat{N}_y$.

Age, Sex, and Length Composition and Spawning Proportions

The proportion of each combination of fish age and sex was:

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

with variance (Cochran 1977):

$$\text{v}\hat{\text{a}}\text{r}(\hat{p}_{ij}) = \frac{\hat{p}_{ij}(1 - \hat{p}_{ij})}{n - 1} \tag{6}$$

where n was the sample size and n_{ij} the number in the sample of age i and sex j. The estimated total abundance of each age i and sex j was:

$$\hat{N}_{ij} = \hat{p}_{ij}\hat{N}, \tag{7}$$

with variance (Goodman 1960):

$$\text{v}\hat{\text{a}}\text{r}(\hat{N}_{ij}) = \text{v}\hat{\text{a}}\text{r}(\hat{p}_{ij})\hat{N}^2 + \text{v}\hat{\text{a}}\text{r}(\hat{N})\hat{p}_{ij}^{\,2} - \text{v}\hat{\text{a}}\text{r}(\hat{p}_{ij})\text{v}\hat{\text{a}}\text{r}(\hat{N}) \tag{8}$$

RESULTS

TAGGING

2005

A total of 223 coho salmon were captured at the lower Fish River tagging site between July 26 and September 3; 140 of these were fitted with radio transmitters. The average length of tagged coho salmon was 579 mm METF (n=139). Age was determined for 100 of the tagged coho salmon; 66.0% of the fish spent 2 years in freshwater and 1 year in the ocean (Table 1).

At the Niukluk River counting tower 101 coho salmon were sampled from July 27 to August 26. The average length of sampled coho salmon was 583 mm METF. Age was determined for 72 coho salmon; 79.2% of the fish spent 2 years in freshwater and 1 year in the ocean (Table 1).

2006

A total of 501 coho salmon were captured between July 21 and September 1 and 243 were fitted with radio transmitters. The average length of tagged coho salmon was 553 mm METF (n=243).

Age was determined for 150 tagged coho salmon and 82% spent 2 years in freshwater and 1 year in the ocean (Table 2)

At the Niukluk counting tower, 149 coho salmon were sampled from July 20 to August 12. The average length of sampled coho salmon was 558 mm METF. Age was determined for 121 sampled fish; 89.3% of the coho salmon spent 2 years in freshwater and 1 year in the ocean (Table 2)

FATE OF TAGS

2005

Both the confluence and tower receivers were inoperable at the end of the season in 2005 because of flooding and stormy weather. As a consequence, the last stationary receiver data were from September 8, when personnel left the field. After September 8 aerial survey data were used to apportion tagged fish to tributaries and above Niukluk River counting tower.

Of the 140 radio tags released 85 were recovered as valid tags and 55 were censored. Of the 85 valid tags 38.8% (33 tags) were found above the Niukluk River counting tower and 61.2% (52 tags) remained in the Fish River (Table 3; Figure 4). Of the 55 censored tags, 54.5% (30 tags) were located once, 23.6% (13 tags) were not located, 1.3% (7 tags) were harvested (1 in Golovnin Bay, 2 near Nome, 4 unknown locations), and 1.3% (7 tags) left the Fish River drainage (6 in Klokerblok River; 1 Kachavik River; Table 3; Appendix B1).

2006

Due to poor weather, aerial surveys were limited late in the season. As a consequence, the furthest upriver tag locations may not have been detected.

Of the 243 radio tags released 186 were recovered as valid tags and 57 were censored. Of the 186 valid tags, 43.5% (81 tags) were found upriver of the Niukluk River counting tower and 56.4% (105 tags) remained within the Fish River drainage (Table 3; Figure 4). Of the 57 censored tags, 36.8 % (21 tags) were found once, 28.1% (16 tags) were found at the tagging site, 0.04% (2 tags) were harvested (1 at the confluence of the Fox and Fish rivers, and 1 at the confluence of the Fish and Niukluk rivers), and 31.65 % (18 tags) left the Fish River drainage (8 in Klokerblok River; 10 in Golovnin Lagoon or Golovnin Bay; Table 3; Appendix B2).

MIGRATION TIME AND HOLDING DURATIONS

In 2005 and 2006 tagged coho salmon last located in the upper Fish River migrated faster to the FNC than tagged coho salmon last located above the NCT. In 2005 coho salmon last recorded in the upper Fish River had an average migration time from the tagging site to FNC of 154.2 hours Fish last recorded above the Niukluk River counting tower had an average migration time from the tagging site to FNC of 187.8 hours. In 2006, coho salmon last recorded in the upper Fish River had an average migration time from the tagging site to FNC of 167.7 hours while fish last recorded above the Niukluk River counting tower had an average migration time from the tagging site to the FNC of 208.3 hours (Table 4). Migration to the Niukluk River counting tower was shorter in 2005 than in 2006. The average migration time in 2005 was 242.3 hours while it was 265.1 hours in 2006 (Table 5).

In 2005 fish last recorded in the upper Fish River held at the FNC for an average of 8.6 hours while coho salmon last recorded above the Niukluk River counting tower had an average holding time of 21.0 hours. Similarly, in 2006 fish last recorded in the upper Fish River held at the FNC for an average of 24.5 hours holding time versus an average holding time of 43.5 hours of fish last recorded above Niukluk River counting tower (Table 4). The average holding time at NCT was 12.8 h in 2005 while the average holding time at NCT was 21.9 hours in 2006 (Table 5).

Coho salmon diel migration patterns were similar at FNC and NCT in both years. The majority of the coho salmon arrived and left FNC and NCT between 0000–0400 hours. Fish movement was at a minimum between 0800–2000 hours (Figure 5a, 5b). In 2005 over 55% of fish arrived at the LFS during the 0000–0400 h period and 50% of fish left the LFS between 2000–0000 hours. This was greater than in 2006 when only 40% of the fish arrived at LFS between 0000–0400 hours and 40% left LFS between 1600–2000 hours (Figure 5c).

MARK–RECAPTURE EXPERIMENT

Tests of sampling bias

2005

Tests for length biased sampling during the mark–recapture events detected no length selectivity during either the first or second event in 2005 (Appendix A1). The length frequency distribution of fish marked in the first event was not different than that of marked fish that migrated past the Niukluk River counting tower during the second event (D = 0.106, P = 0.903; Figure 6; Table 6). Similarly, the length frequency distribution of coho salmon collected above the Niukluk River counting tower and the tagged fish above the Niukluk River counting tower were not significantly different (D = 0.123, P = 0.747; Table 6) The results of these tests indicated the abundance of coho salmon could be estimated using a Petersen-type model from the entire data set without stratification (case I in Appendix B1).

Temporal violations of equal probability of capture in 2005 were explored using contingency table analysis (Appendix A2). There was an unequal probability of capture during the first event (χ^2 = 34.69, P < 0.001; Table 7) but not during the second event (χ^2 = 5.39, P = 0.249; Table 7). Another test to evaluate equal probability of capture during the first event was conducted because tagging commenced after coho salmon were documented past the Niukluk River counting tower. The test used capture time starting a week after the first fish was tagged; however, given the adjustment there was still an unequal probability of capture in the first event (χ^2 = 29.32, P < 0.001). Since there was equal probability of capture during the second event, a Peterson-type model could be used to estimate abundance.

2006

Tests for length biased sampling during the mark–recapture events detected no length selectivity during either the first or second event in 2006 (Appendix A1). The length frequency distribution of all fish marked in the first event was not different than that of the marked fish that migrated past the Niukluk River counting tower (D = 0.048, P = 0.998; Figure 7; Table 8). Similarly, the length frequency distribution of coho salmon collected above the Niukluk River counting tower and the tagged fish above the Niukluk River counting tower were not significantly different (Table 8). These results indicated the abundance of coho salmon could be estimated using a Petersen-type model from the entire data set without stratification (case I in Appendix A1). Sex bias was detected during the first event (χ^2 = 5.61, P = 0.0.018; Table 9) but not during the second event (χ^2 = 0.411, P = 0.522; Table 9). These results indicated the abundance of coho salmon could be estimated using a Petersen-type model from the entire data set without stratification (case III in Appendix B1).

Temporal violations of equal probability of capture in 2006 were explored using contingency table analysis (Appendix A2). Temporal violations in the first event could not be evaluated because the majority (71 out of 81) of the marked fish passed the Niukluk River counting tower site after the receiver site was removed. There was no significant difference in the probability of capture during the second event (χ^2 = 5.15, P = 0.27; Table 10). Since every fish has an equal probability of being captured during the second event, the assumptions for a Petersen abundance estimator were fulfilled (Appendix A2).

ABUNDANCE ESTIMATES

2005

In 2005, 85 radiotagged coho salmon remained in the Fish River drainage and were recorded at least twice by stationary receivers or aerial surveys. A total of 2,718 coho salmon passed the Niukluk River counting tower through September 5 and served as the second sample. Thirty-three radiotagged coho salmon migrated past the Niukluk River counting tower as recaptures in the second sample. The estimated total Fish River drainage coho salmon abundance was 6,876 (SE = 986).

2006

In 2006, 186 radiotagged coho salmon remained in the Fish River drainage and were recorded at least twice by stationary receivers or aerial surveys. A total of 11,106 coho salmon passed the Niukluk River counting tower through September 5 and served as the second sample. A total of 81 radiotagged coho salmon migrated past the Niukluk River counting tower as recaptures in the second sample. The estimated total Fish River drainage coho salmon abundance was 25,328 (SE = 2,202).

NIUKLUK RIVER CONTRIBUTION TO FISH RIVER DRAINAGE

The 2005 Niukluk River escapement estimate was 39.5% of the total Fish River drainage abundance estimate. The 2006 Niukluk River escapement estimate was 43.9% of the total Fish River drainage abundance estimate. A two-tailed t-test detected no difference between years of the Niukluk River contribution to the Fish River drainage abundance (P = 0.493).

ESTIMATION OF AGE, SEX, LENGTH COMPOSITION AND SPAWNING PROPORTIONS

2005

There was no length or sex selectivity bias during either the first or the second event therefore composition parameters were estimated after pooling age, sex, and length data from both sampling events. Male coho salmon were longer than female coho salmon, and younger salmon were shorter than older salmon, except for age-3.1 female coho salmon, which were as small as age-1.1 female coho salmon. The average lengths of male coho salmon by age class were 583 mm METF (age 1.1), 587 mm METF (age 2.1), and 618 mm METF (age 3.1). The average lengths of female coho salmon by age class were a 557 mm METF (age 1.1), 574 mm METF (age 2.1), and 557 mm METF (age 3.1; Table 1).

The percentage of males (57.1%) was higher than the percentage of females (42.9%) in the combined sampling events. The percentage of male coho salmon by age was 26.4% age-1.1, 71.2% age-2.1, and 2.4% age-3.1. The percentage of female coho salmon by age was 25.0% age-1.1, 72.1% age-2.1, and 2.9% age-3.1 (Table 11).

2006

There was no length or gender selectively bias during the second event but there was gender selectively bias during the first event therefore the composition parameters for males and females was estimated using sampling event 2 only while age composition was estimated using data from both sampling events. Male coho salmon were longer than female coho salmon and younger salmon were shorter than older salmon. The average lengths of male coho salmon by age class were 548 mm METF (age 1.1), 563 mm METF (age 2.1), and 568 mm METF (age 3.1). The average lengths of female coho salmon by age class were 536 mm METF (age 1.1), 552 mm METF (age 2.1), and 551 mm METF (age 3.1; Table 2).

The percentage of males (59.7%) was higher than the percentage of females (40.3%) in the second sampling event. The percentage of male coho salmon by age was 10.1% age-1.1, 87.8% age-2.1, and 2.2% age-3.1. The proportion of female coho salmon by age was 15.2% age-1.1, 80.4% age-2.1, and 4.3% age-3.1 (Table 12).

DISCUSSION

This radiotelemetry project was conceived to assess the appropriateness of using the coho salmon escapement estimate at the Niukluk River counting tower as an index for the entire Fish River drainage coho salmon run. Currently coho salmon are harvested in subsistence and sport fisheries within the Fish River drainage with a small percentage harvested in salt water. Unfortunately assessment of drainagewide escapement has been based on aerial surveys that are often limited in their utility due to infrequency and poor viewing conditions because of bad weather. Providing another option for assessing escapement will allow fishery managers to establish effective harvest rates and protect the run from overfishing. The results of this project support using Niukluk River coho salmon escapement as an index for Fish River drainagewide coho salmon escapement.

This project was conducted over two years yet aspects of this study suggest the results could be expected year after year. The percentages of Niukluk River coho salmon in the Fish River drainagewide escapement, 39.5% in 2005 and 43.5% in 2006 were not significantly different despite a dramatic difference in the final Niukluk River escapement estimates. In 2005, 2,718 coho salmon were enumerated past the Niukluk River counting tower while escapement into the Niukluk River was 11,106 coho salmon in 2006. Neither of these is uncommon; coho salmon escapement into the Niukluk River has been variable among years ranging from a low of 1,282 (in 2003) to a high of 12,781 (in 1996) coho salmon (Appendix C1). Thus 2005 and 2006 may represent typical years for coho salmon escapement and estimates for all these years support the reasonable expectation that intermediate sized coho salmon runs will return in similar percentages.

Observations of coho salmon dispersal and final tag location also supported the idea of utilizing coho escapement at the Niukluk River counting tower as a proxy for Fish River drainage total coho salmon abundance is. One objective of this study was to determine major spawning areas within the Fish River drainage. Weather conditions in 2005 and 2006 limited tracking of tagged coho salmon to their spawning grounds, but patterns of fish dispersal were similar in both years. The majority of tagged coho salmon were last located in the Fish River and its tributaries in both 2005 and 2006. The majority of coho salmon in the Niukluk River in 2005 and 2006 were located in the main stem of the river and were probably still migrating to their spawning grounds. Additionally, in each year the same tributaries of the Fish and Niukluk rivers, Etchepuk River and Bear Creek, had the largest proportions of tagged coho salmon (Appendices B1, B2). The similarities in dispersal and tag locations of coho salmon in 2005 and 2006 suggests similar run timing patterns despite a sizeable difference in escapement between years. Again this supports the reasonable expectation that intermediate sized coho salmon runs will migrate through the Fish River drainage in a similar fashion.

Studies are inconclusive about the effects of different types of radio tags on recovery time, potential mortality, regurgitation, and migration (e.g., Wuttig and Evenson 2002, Brown and Eiler 2000; Joy and Reed 2007). Tag type was changed over the course of the study; external tags were used in 2005 and esophageal tags in 2006. The use of esophageal tags made the tagging process more efficient and may have resulted in fewer censored tags. The proportion of censored tags located only once or not at all after tagging dropped from 26.4% in 2005 to 15.2% 2006. This proportion may have also declined because of improved tagging efficiency on the part of the field crew in 2006; the number of tags incorrectly placed decreased. Conversely, external tags appeared to be a better choice for maximizing migration rates and minimizing holding time. Generally, coho salmon migrated faster and held less in 2005 when external tags were used than in 2006 when esophageal tags were used. However, these results should be viewed with caution. Since this study was not designed to measure migration rates and holding time by tag type additional variables affecting salmon movement, such as water height and water speed, were not measured. In the absence of this additional supporting data, only broad generalities can be drawn.

The proportion of coho salmon that migrate passed the Niukluk River counting tower allows for a reasonable estimate of escapement into the entire Fish River drainage. However, it is important to remember this project only encompassed part of the coho salmon brood year-to-return cycle. A complete mark–recapture study should be conducted over 5 years to ensure all age classes from a given brood year are represented. Consistency across all five years would indicate that age composition of a given year's return does not unduly influence the proportion migrating past the Niukluk River counting tower.

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TABLES AND FIGURES

Table 1.–Summary of coho salmon sampled at the capture site and above the Niukluk River counting tower, 2005.

	Sampling event 1[a]						Sampling event 2[b]			Combined		
	Sampled			Tagged								
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
Male[c]	86	586	46.8	55	588	44.3	38	583	42.6	124	587	42
Age 1.1	24	584	42.3	14	580	48.9	9	578	39.1	33	583	40.9
Age 2.1	59	586	49.4	38	589	43.7	29	585	44.1	88	587	47.4
Age 3.1	3	618	15.3	3	618	15.3	0	-	-	3	618	15.3
Female[c]	70	564	37.9	45	565	40.5	34	581	30.2	104	571	36.6
Age 1.1	22	561	37.5	16	552	42.4	4	567	29.6	26	557	44.4
Age 2.1	47	560	44	28	574	37.1	28	583	30.8	75	574	40.8
Age 3.1	1	510	-	1	510	-	2	581	29.7	3	557	46.1
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
All[d]	220	579	42.0	139	579	40.0	101	583	36.8	321	580	40.4
Male	127	589	41.9	77	586	39.8	56	583	42.3	183	587	42.0
Female	93	566	31.9	63	570	38.8	45	583	29.1	138	571	36.6

[a] Includes coho salmon captured in the lower Fish River as part of the first sampling event.
[b] Includes coho salmon collected for ASL above the Niukluk River counting tower in the second sampling event.
[c] Does not include sampled fish with regenerated scales.
[d] Includes sampled fish with regenerated scales.

Table 2.–Summary of coho salmon sampled at the capture site and above the Niukluk River counting tower, 2006.

	Sampling event 1[a]			Sampling event 2[b]			Combined		
	n	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
Male[c]	104	557	35.5	75	567	39.8	179	561	37.5
Age 1.1	13	551	38.8	5	540	51.8	18	548	41.2
Age 2.1	90	558	35.3	67	569	38.5	157	563	37.1
Age 3.1	1	550	-	3	573	35.1	4	568	31.0
Female[c]	46	551	34.2	46	547	26.4	92	549	30.5
Age 1.1	11	539	44.4	3	527	68.2	14	536	47.5
Age 2.1	33	555	30.8	41	549	22.0	74	552	26.3
Age 3.1	2	563	3.5	2	540	35.4	4	551	24.3

	N	Mean Length	SD	n	Mean Length	SD	n	Mean Length	SD
All[d]	243	553	34.1	149	558	36.7	392	555	35.2
Male	161	555	34.5	89	566	39.8	250	559	36.7
Female	82	550	33.8	60	547	28.3	142	549	31.5

[a] Includes coho salmon captured in the lower Fish River as part of the first sampling event.

[b] Includes coho salmon collected for ASL above the Niukluk River counting tower in the second sampling event.

[c] Does not include sampled fish with regenerated scales.

[d] Includes sampled fish with regenerated scales.

Table 3.–Summary of tag fates in 2005 and 2006.

	2005		2006	
Fate	Tags	Percent	Tags	Percent
Fish River	52	37.1%	105	43.2%
Niukluk River above counting tower	33	23.6%	81	33.3%
Censored	55	39.3%	57	23.5%
Total tags deployed	140		243	

Table 4.–Migration time to and holding time at the confluence of the Fish and Niukluk rivers (FNC) of tagged coho salmon last located in the upper Fish River (FR) and above the Niukluk River counting tower (NCT), 2005 and 2006; *N*-number of tagged fish, mean number of hours, SD-standard deviation (SD), and median, minimum and maximum migration and holding times.

	Tagging site to FNC (h)				Holding time at FNC (h)			
	2005		2006		2005		2006	
	FR	NCT	FR	NCT	FR	NCT	FR	NCT
N	38	32	91	82	38	30	91	82
Mean	154.2	187.8	167.7	208.3	8.6	21	24.5	43.3
SD	129.6	159.5	117.3	124.7	11.1	31.7	47.5	60.4
Median	113.7	157.2	126.1	182	2.9	8.2	9.8	17.4
Minimum	26.7	15.4	25.4	21.7	0.2	0.9	0.7	0.7
Maximum	606.4	743.9	606.2	660.7	40.8	136.1	290.9	277.9

Table 5.–Migration time to and holding time at Niukluk River counting tower (NCT) of tagged coho salmon last located above the Niukluk River counting tower (NCT), 2005 and 2006; N-number of tagged fish, mean number of hours, SD-standard deviation, and median, minimum, and maximum migration and holding times.

	Tagging site to NCT (h)		Holding time at NCT (h)	
	2005	2006	2005	2006
N	32	82	32	82
Mean	242.3	265.1	12.8	21.9
SD	161.3	124.9	24.1	58.5
Median	215.7	251.2	1.1	3.9
Minimum	22.3	27.7	0.3	0.4
Maximum	757.1	686.8	90	342.2

Table 6.–Summary of Kolmogorov-Smirnov two sample tests of length selective sampling in the first or second events, 2005.

Kolmogorov-Smirnov test of length frequencies	D	P-value	N	$D_{0.05}$	Conclusion
M (marked in first event) vs. R (tags above tower)	0.106	0.903	85	0.234	Fail to reject H_0
C (all above tower) vs. R (tags above tower)	0.123	0.747	135	0.234	Fail to reject H_0
M (marked in first event) vs. C (all above tower)	0.080	0.868	187	0.160	Fail to reject H_0

Table 7.–Data used to test the assumptions of equal probability of capture by time during the first (test II) and second (test III) events, 2005.

Test II			Test III		
Date	Marked	Not marked	Date	Recaptured	Not recaptured
7/18–8/11	1	620	7/26–8/9	7	10
8/12–8/17	1	586	8/10–8/16	4	11
8/18–8/23	5	478	8/17–8/21	7	15
8/24–8/28	8	520	8/22–8/26	10	6
8/29–9/9	18	490	8/27–9/7	5	10

Table 8.–Summary of Kolmogorov-Smirnov two sample tests of length selective sampling in the first or second events, 2006.

Kolmogorov-Smirnov test of length frequencies	D	*P*-value	N	$D_{0.05}$	Conclusion
M (marked in first event) vs. R (tags above tower)	0.048	0.998	186	0.144	Fail to reject H_0
C (all above tower) vs. R (tags above tower)	0.096	0.649	230	0.144	Fail to reject H_0
M (marked in first event) vs. C (all above tower)	0.082	0.578	335	0.124	Fail to reject H_0

Table 9.–Summary of contingency table analysis to detect sex bias in the first and second sampling events, 2006.

	χ^2	*P*-value	N	Conclusion
M (marked in first event) vs. R (tags above tower)	0.411	0.522	186	Fail to reject H_0
C (all above tower) vs. R (tags above tower)	5.612	0.018	230	Reject H_0
M (marked in first event) vs. C (all above tower)	5.130	0.024	335	Reject H_0

Table 10.–Data used to test the assumptions of equal probability of capture by time during the second event, 2006.

Date	Recaptured	Not recaptured
7/21-8/9	18	18
8/10-8/14	11	24
8/15-8/18	23	20
8/19-8/23	16	27
8/24-9/1	13	16

Table 11.–Estimated age and sex composition of the Fish River coho salmon escapement, 2005.

Sex / Age Category	$\hat{p}_{ij}$	$SE(\hat{p}_{ij})$	$\hat{N}_{ij}$	$SE(\hat{N}_{ij})$
Male	0.570	0.028	3,920	593
1.1	0.264	0.040	1,035	219
2.1	0.712	0.041	2,791	451
3.1	0.024	0.014	94	55
Female	0.429	0.028	2,956	464
1.1	0.250	0.043	739	170
2.1	0.721	0.044	2,132	358
3.1	0.029	0.016	85	50

Table 12.–Estimated age and sex composition of the Fish River coho salmon escapement, 2006.

Sex / Age Category	$\hat{p}_{ij}$	$SE(\hat{p}_{ij})$	$\hat{N}_{ij}$	$SE(\hat{N}_{ij})$
Male	0.597	0.040	15,129	1,663
1.1	0.101	0.023	1,521	378
2.1	0.878	0.025	13,270	1,504
3.1	0.022	0.011	338	171
Female	0.403	0.040	10,199	1,349
1.1	0.152	0.038	1,552	433
2.1	0.804	0.042	8,204	1,164
3.1	0.043	0.021	443	224

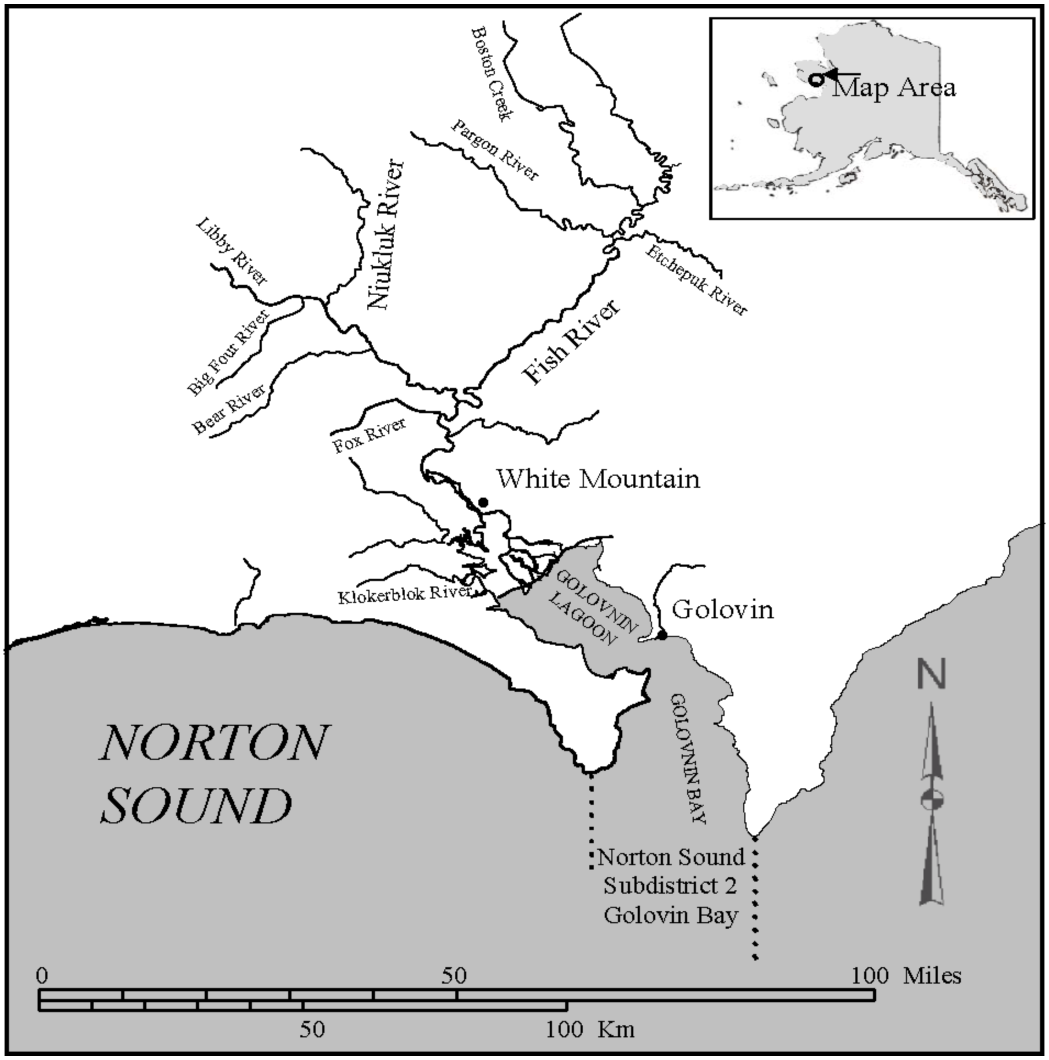


Figure 1.–Fish River drainage, southern Seward Peninsula.

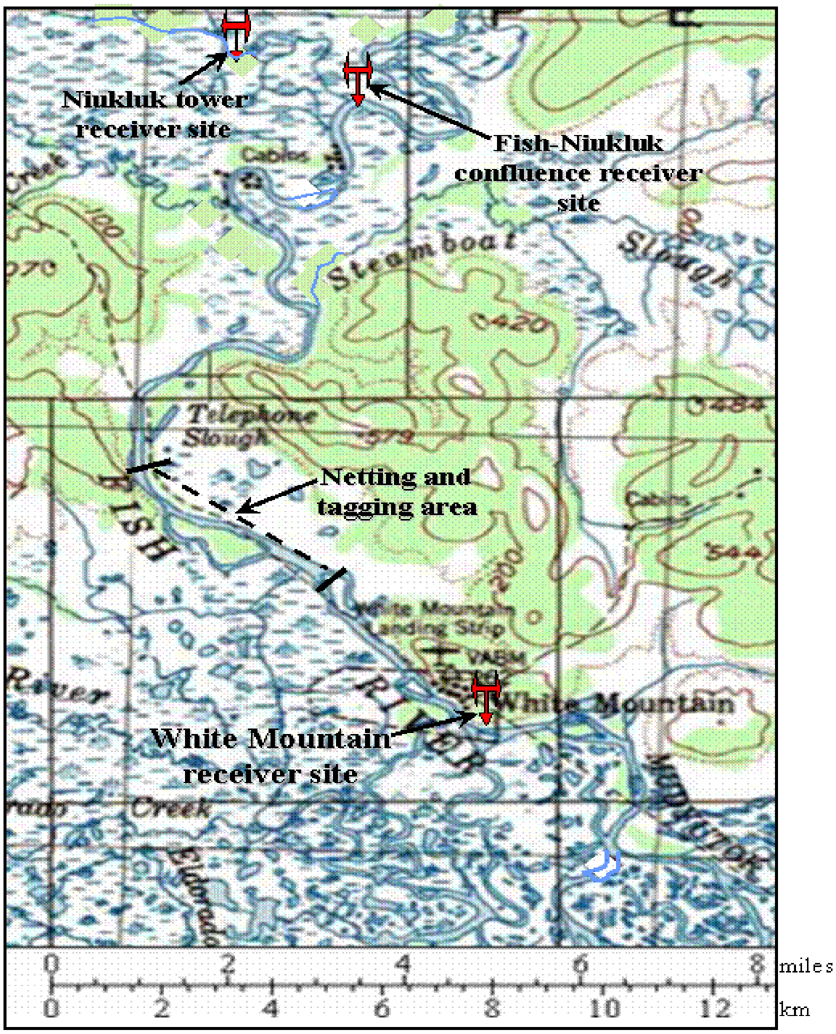


Figure 2.–Capture locations from the Fish River and receiver sites indicated with red triangles.

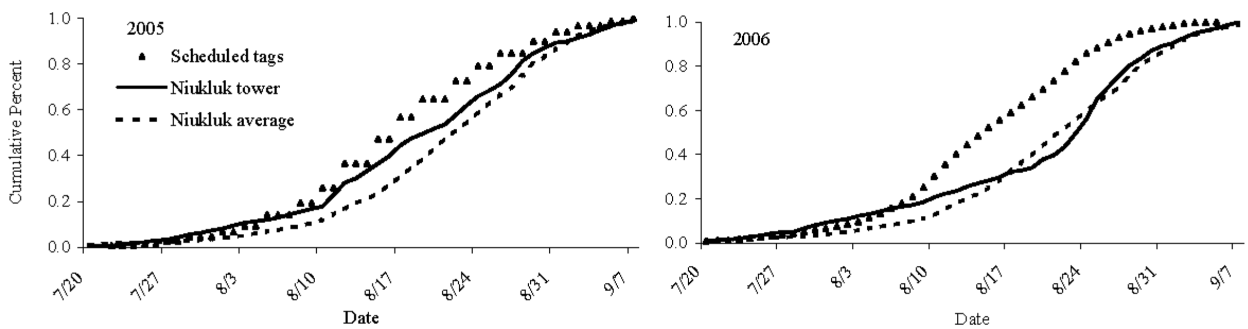


Figure 3.–Cumulative percent coho salmon passage at the Niukluk River counting tower in 2005 and 2006 and cumulative percent scheduled tag deployment in 2005 and 2006, compared with the average cumulative percent coho salmon passage at the tower (1995–2006).

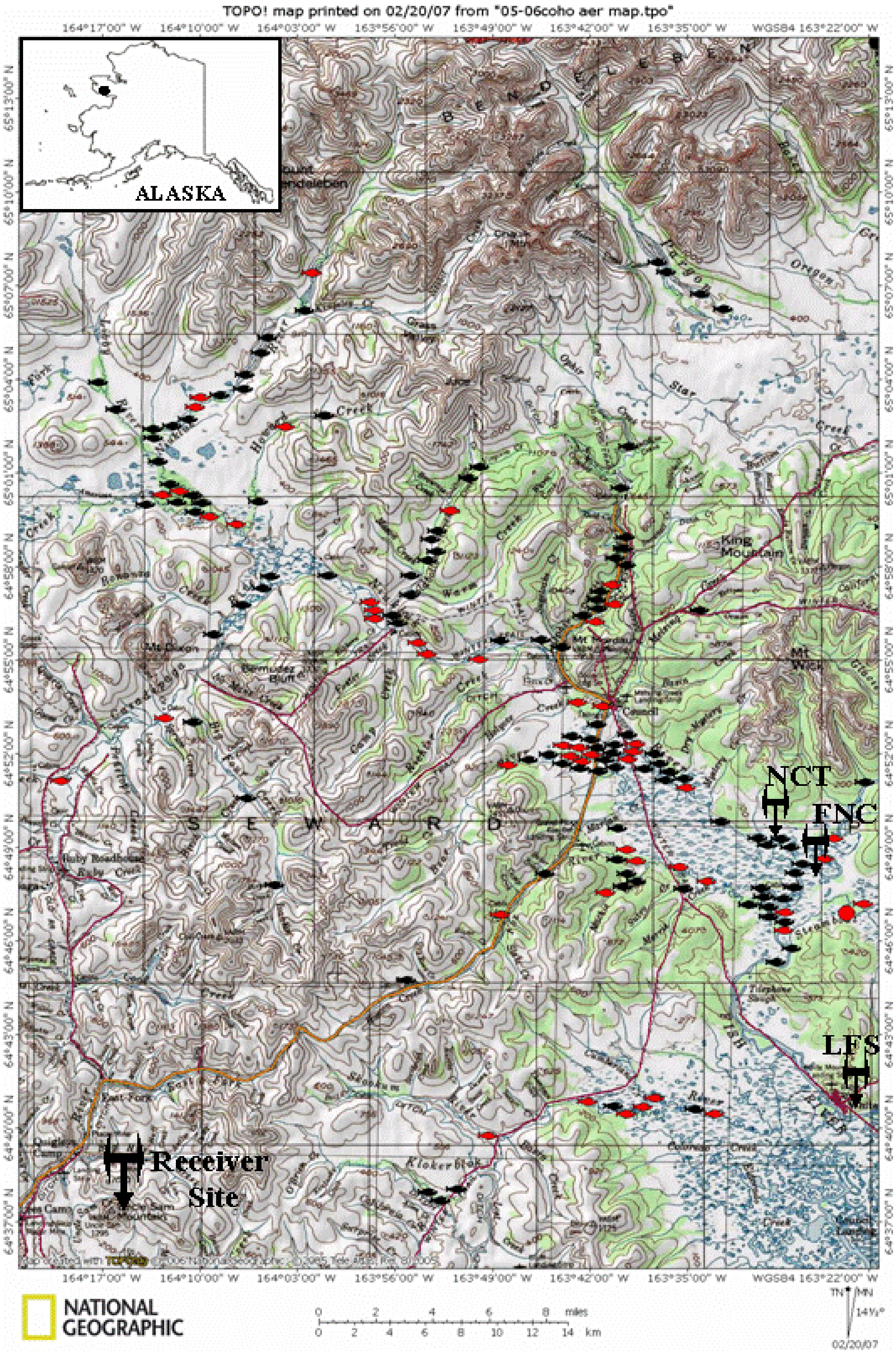


Figure 4.–Fish River and Niukluk River watersheds showing radiotelemetry receiver sites and final locations for radiotagged coho salmon, 2005 data are in red or gray and 2006 data are in black; page 1 of 2.

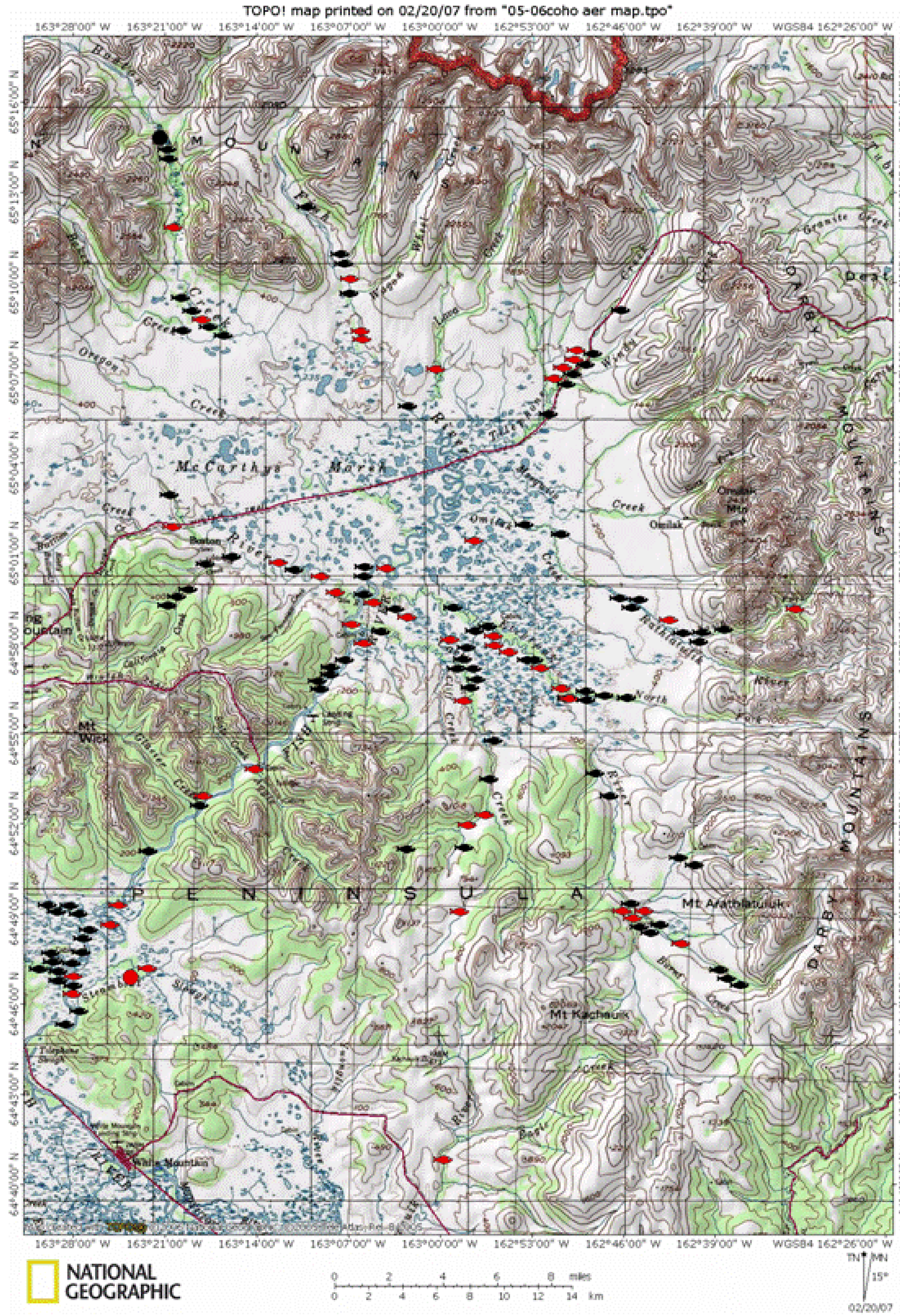
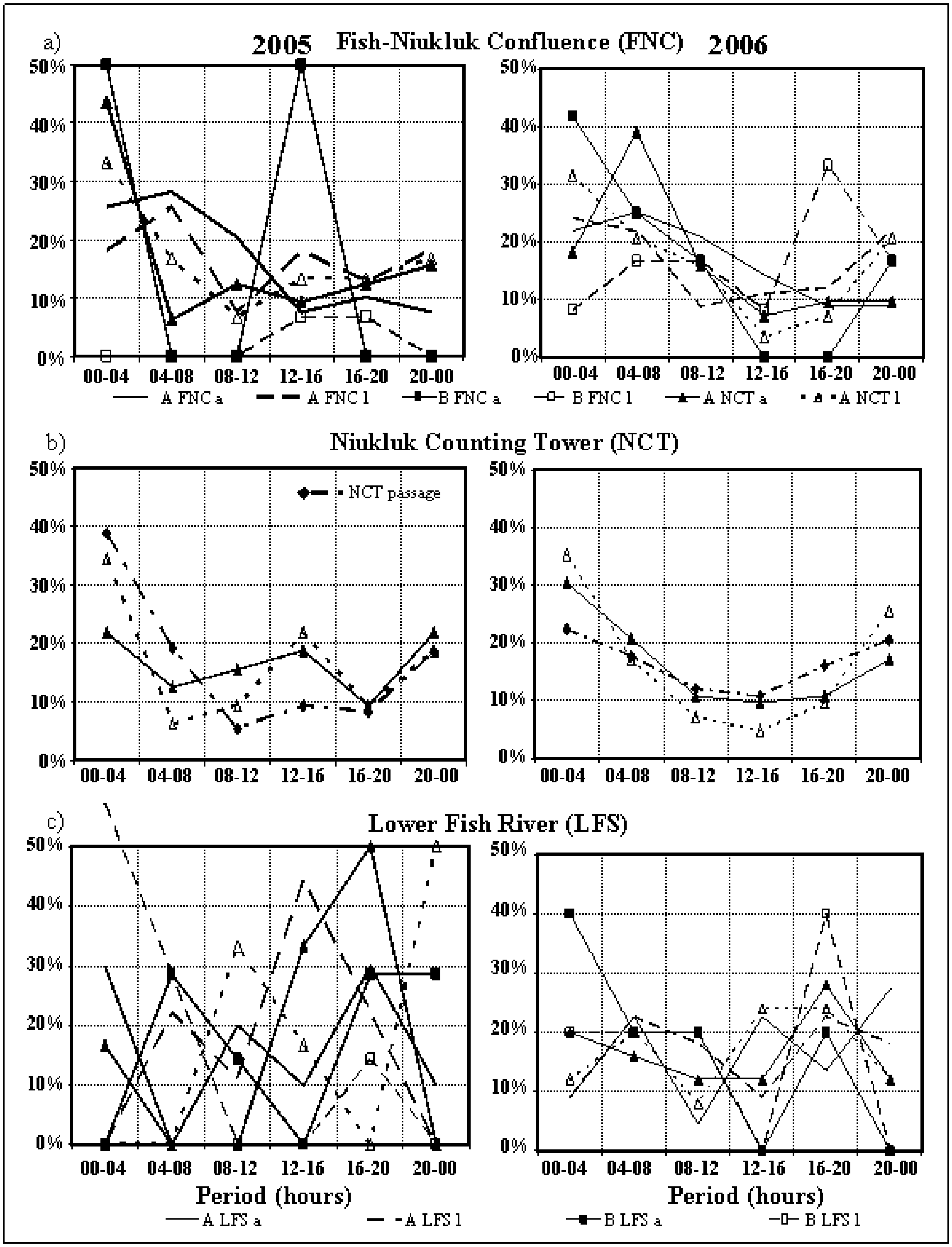


Figure 4.–Page 2 of 2.



Note: First (arrive, a) and last (leave, l) receiver records for radiotagged fish by site and final destination.

Figure 5.–Fish River radiotagged coho salmon diel migratory timing at the confluence of the Fish and Niukluk rivers (a), Niukluk River counting tower, and Niukluk River counting tower coho salmon passage (b), and lower Fish River (c) sites for fish spawning above (A) or below (B) the site, 2005 and 2006.

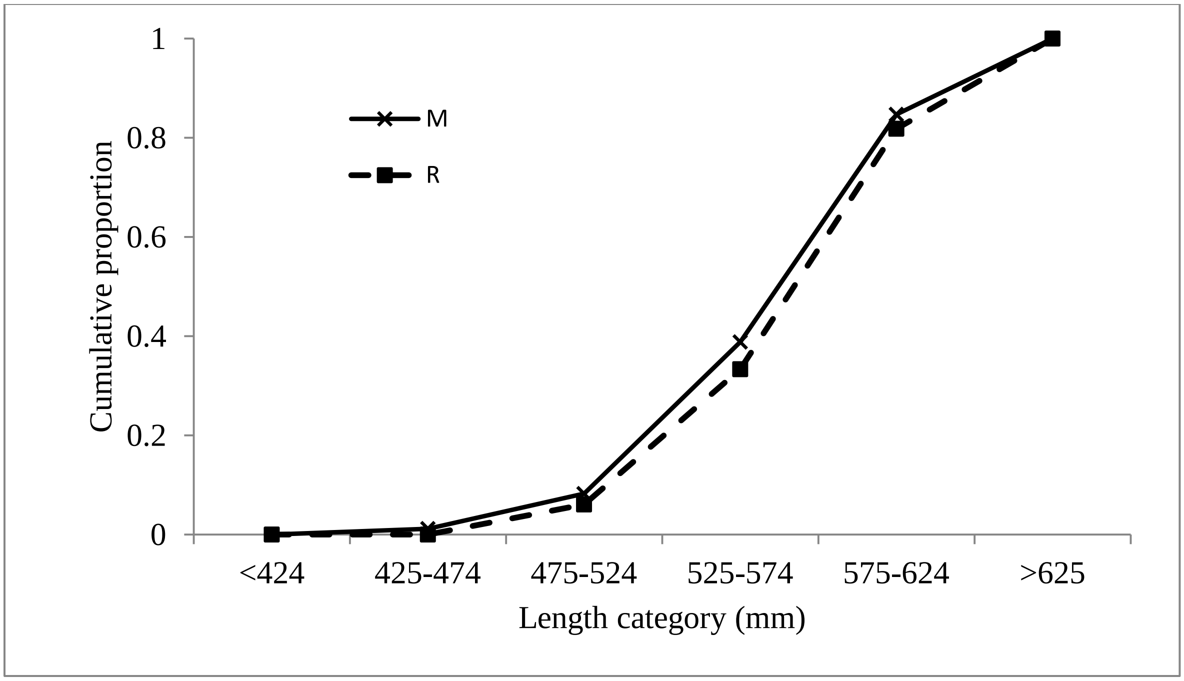


Figure 6.–Cumulative length frequency distribution of coho salmon marked in the first event (M) and marked coho salmon recaptured in the second event (R), 2005.

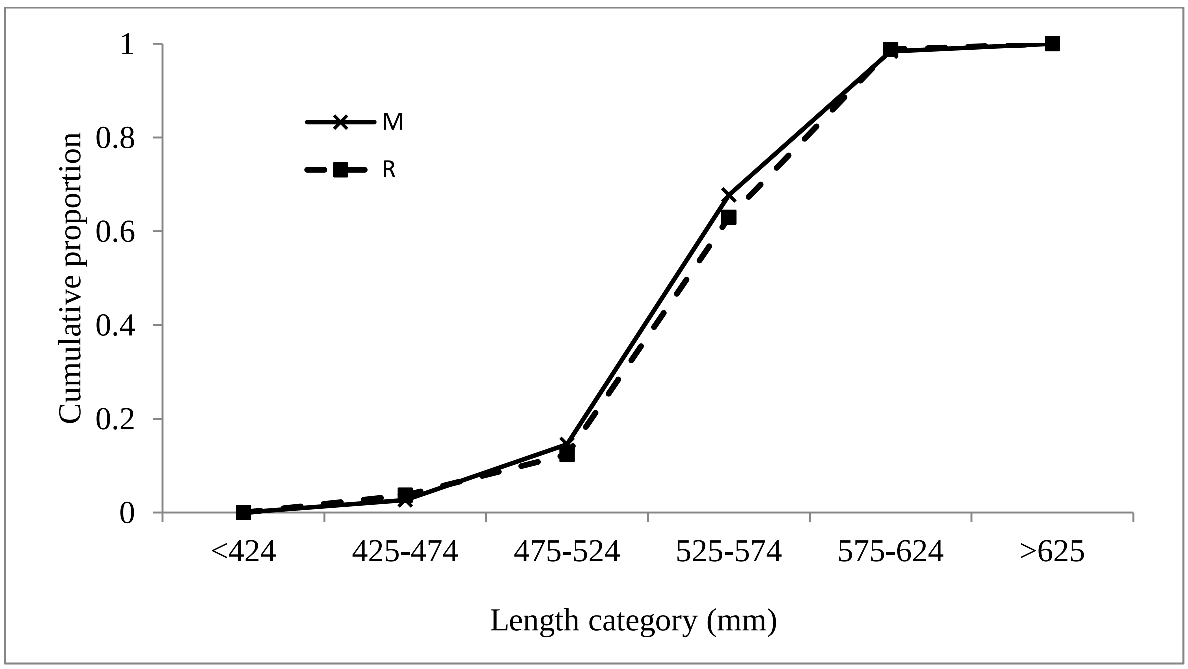


Figure 7.–Cumulative length frequency distribution of coho salmon captured in the first event (M) and marked coho salmon captured in the second event (R), 2006.

APPENDIX A

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

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

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

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

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

Case II:		
Reject H_o	Fail to reject H_o	Reject H_o

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

Case III:		
Fail to reject H_o	Reject H_o	Reject H_o

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

Case IV:		
Reject H_o	Reject H_o	Either result possible

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

Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

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

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

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

-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, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

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

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

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; and,

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

Appendix A2.–Tests of consistency for the Petersen estimator (from Seber (1982), page 438).

Tests of consistency for the Petersen estimator

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

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

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

I.-Test For Complete Mixing[a]

Area/Time	Area/Time Where Recaptured				Not Recaptured
Where Marked	**1**	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

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

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked $(n_2\text{-}m_2)$				

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

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured $(n_1\text{-}m_2)$				

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

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

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

APPENDIX B

Appendix B1.–Fate of tagged coho salmon by tributary, 2005.

Tags	Percent	Tributary or Location
8	9.4%	Lava,Telephone, Windy, Fish above any tributaries
2	2.4%	Omilak, Mosquito, Rathlatulik
3	3.5%	Boston Creek
13	15.3%	Etchepuk River
6	7.1%	Cache Creek
4	4.7%	Pargon River
6	7.1%	Fox River
2	2.4%	Fish-Niukluk confluence & below
7	8.2%	Fish Flats (not assigned to tributary)
1	1.2%	Niukluk River below counting tower
52	61.2%	*Total Fish River and tributaries*
2	2.4%	Goldbottom Creek
0	0.0%	Howard Creek
8	9.4%	Bear Ceek
2	2.4%	Casadepaga River
4	4.7%	Ophir Creek
0	0.0%	American Creek
1	1.2%	Niukluk River at Village of Council
16	18.8%	Niukluk River
0	0.0%	Libby River
33	38.8%	*Total Niukluk River above counting tower*
85	60.7%	Total valid tags
13	9.3%	Golovnin Bay, Klokerblok River, other drainages
5	3.6%	Harvested tags
37	26.4%	Tags located once or not at all
55	39.3%	Total censored tags
140	100.0%	Total tags

Appendix B1.–Fate of tagged coho salmon by tributary, 2006.

Tags	Percent	Tributary or Location
5	2.7%	Lava,Telephone, Windy, Fish above any tributaries
9	4.8%	Omilak, Mosquito, Rathlatulik
7	3.8%	Boston Creek
22	11.8%	Etchepuk River
12	6.5%	Cache Creek
12	6.5%	Pargon River
8	4.3%	Fox River
9	4.8%	Fish-Niukluk confluence & below
12	6.5%	Fish Flats (not assigned to tributary)
9	4.8%	Niukluk River below counting tower
105	56.5%	*Total Fish River and tributaries*
11	5.9%	Goldbottom Creek
1	0.5%	Howard Creek
17	9.1%	Bear Ceek
7	3.8%	Casadepaga River
11	5.9%	Ophir Creek
4	2.2%	American Creek
1	0.5%	Niukluk River at Village of Council
27	14.5%	Niukluk River
2	1.1%	Libby River
81	43.5%	*Total Niukluk River above counting tower*
186	76.5%	Total valid tags
18	7.4%	Golovnin Bay, Klokerblok River, other drainages
2	0.8%	Harvested tags
37	15.2%	Tags located once or not at all
57	23.5%	Total censored tags
243	100.0%	Total tags

APPENDIX C

Appendix C1.–Historical salmon escapements at the Niukluk River counting tower, 1995–2006.

Year	Operating Period	Chum salmon	Pink salmon	Chinook Salmon	Coho salmon
1995	June 29–Sept 12	86,332	17,088	123	4,713
1996	June 23–Sept 12	80,178	1,154,922	243	12,781
1997	June 28–Sept 09	57,305	10,468	259	3,994
1998	July 04–Aug 09	45,588	1,624,438	260	840
1999	July 04–Sept 04	35,239	20,351	40	4,260
2000	July 04–Aug 27	29,573	961,603	48	11,382
2001	July 10–Sept 08	30,662	41,625	30	3,468
2002	June 25–Sept 10	35,307	645,141	621	7,391
2003	June 25–Sept 10	20,018	75,855	179	1,282
2004	June 25–Sept 08	10,770	975,895	141	2,064
2005	June 28–Sept 09	25,598	270,424	41	2,727
2006	June 28–Sept 08	29,199	1,371,919	39	11,169
Average		40,481	597,471	169	5,930[a]
Odd-year Pink salmon average (1995-2005)			72,635		
Even-year Pink salmon average (1996-2006)			1,122,320		

Note: all escapements were determined using the pre-2009 interpolation methods described in this report.

[a] Average does not include 1998 because the majority of the coho salmon run was not enumerated.