Fishery Data Series No. 05-38

Estimation of Coho Salmon Abundance and Spawning Distribution in the Unalakleet River 2004

by

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July 2005

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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ABSTRACT

The Unalakleet River supports the largest and arguably the most important coho salmon run in Norton Sound. To monitor salmon escapement in the Unalakleet River drainage, a counting tower has been in operation for several years on the North River (a tributary). Prior to this study it was unknown how the North River coho salmon run related to the drainage as a whole. In 2004, the first year of a 3-year investigation was initiated to describe the extent to which the North River tower counts index escapement of coho salmon into the entire Unalakleet River drainage.

Between July 19 and September 23, 208 coho salmon were captured with beach seines and drift gillnets in the lower portion of the river and fitted with esophageal radio tags. Radio-tagged coho salmon were tracked with a series of four stationary tracking towers and five aerial flights. Coho salmon were also sampled for age, sex, and length data above the North River counting tower and in the Unalakleet River above the North River confluence. Two sample mark-recapture techniques were used to estimate total drainage abundance.

Results indicated that coho salmon migrated into all tributaries of the drainage with the largest concentration of fish migrating to the stretch of the Unalakleet River above the Chiroskey River and below the North Fork Unalakleet River. Earlier running fish dispersed farther into the drainage and later running fish concentrated in the lower section of the Unalakleet River. Estimated proportions of coho salmon migrating to various portions of the drainage were 0.152 (SE=0.028) to the North River, 0.571 (SE=0.044) to the mainstem of the Unalakleet River below the North Fork, and 0.277 (SE=0.036) to the upper Unalakleet and it's tributaries including 0.050 (SE=0.018) to the Chiroskey River, 0.063 (SE=0.019) to the Old Woman River, and 0.023 (SE=0.012) to the North Fork.

Coho salmon sampled in the North River were smaller, on average, than those sampled in the Unalakleet River. However, when stratified into two groups, there were no differences in size distribution in the two rivers for coho salmon ≤ 570 mm MEF or > 570 mm MEF. There was no significant difference in the run timing of North River and Unalakleet River coho salmon for either unadjusted values (D = 0.200, P-value = 0.212) or weighted values (D = 0.215, P-value = 0.219).

A total of 11,187 coho salmon were counted past the North River counting tower over the course of the run. After dividing the run into two size strata, a population estimate of 73,582 coho salmon (SE = 15,570) was generated for the entire Unalakleet River drainage with a 95% credibility interval of 54,040 to 114,600 fish. The majority of coho salmon (98.4%) were determined to be either age-2.1 or -1.1 with more age-2.1 coho salmon appearing later in the run.

Key Words: Unalakleet River, North River, coho salmon *Oncorhynchus kisutch*, radio tag, age, sex, and length, mark-recapture.

INTRODUCTION

The Unalakleet River is a clear, run-off river that drains an area approximately 2,700 square km as it flows southwesterly through the Nulato Hills into Norton Sound (Sloan et al. 1986; Figure 1). The river supports a large run of coho salmon *Oncorhynchus kisutch* as well as runs of Chinook *O. tshawytscha*, chum *O. keta* and pink *O. gorbuscha* salmon. The Unalakleet River also supports resident populations of Dolly Varden *Salvelinus malma* and Arctic grayling *Thymallus arcticus*.

Unalakleet River coho salmon stocks support substantial subsistence and sport fisheries as well as the largest commercial coho salmon fishery in Norton Sound. The Norton Sound District 6 commercial fishery occurs very near the mouth of the Unalakleet River and the majority of fish caught in that fishery are believed to be Unalakleet River stocks. The 2004 District 6 commercial harvest estimate was 29,282 coho salmon with a recent 5 year average (1999-2003) of 17,659 fish (Table 1). The recent 5 year average annual sport coho salmon harvest was 2,820 fish.

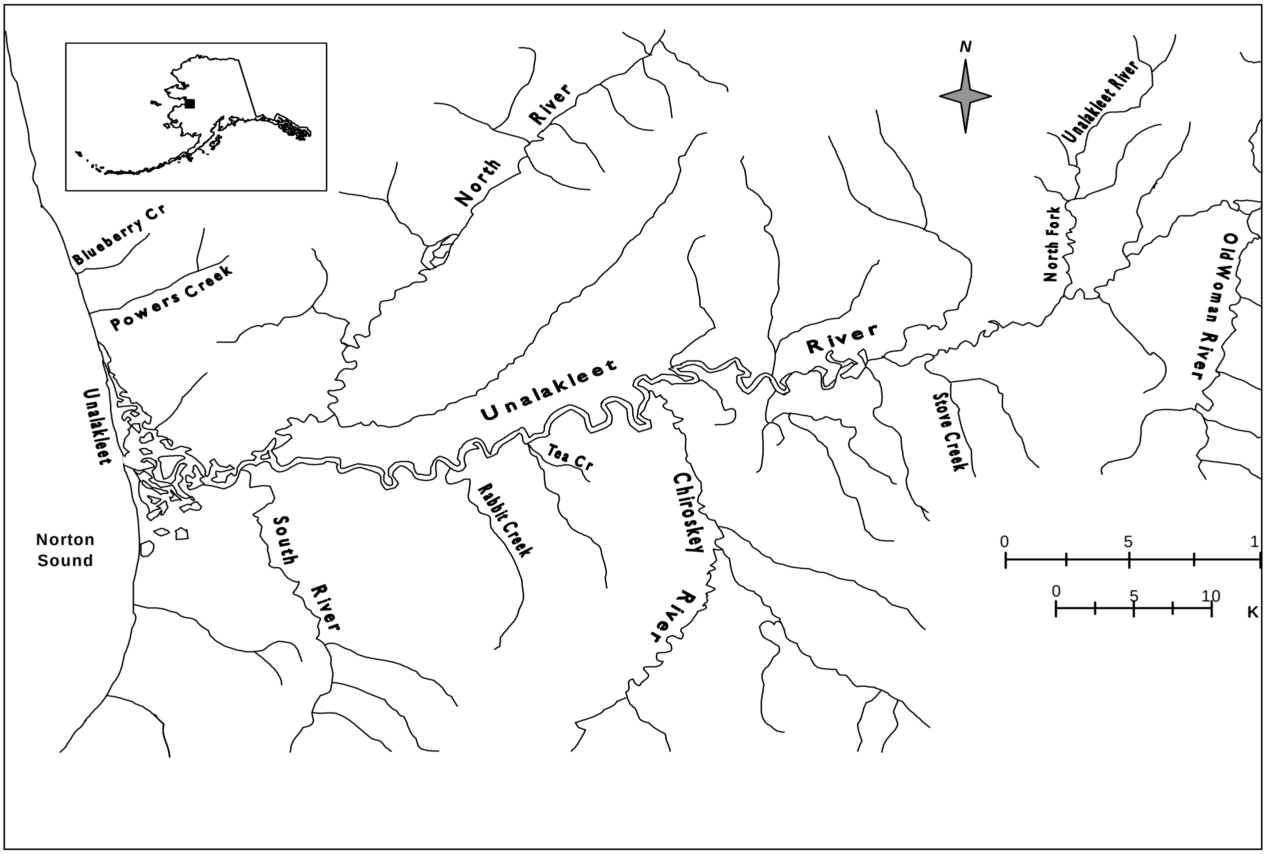

Figure 1.–Map of the Unalakleet River and its tributaries.

In the past 10 years there has been a noticeable increase in the number of sport fishermen participating in the Unalakleet River coho salmon fishery. This increase is of concern to the Unalakleet area residents, who use the coho salmon as their primary subsistence food. In 2003 Unalakleet residents approached the Alaska Department of Fish and Game (ADF&G) and the Federal Bureau of Land Management (BLM) over their concern about the rising amount of sport angling and the lack of reliable escapement estimates for coho salmon.

Escapement of Unalakleet River coho salmon is monitored by a counting tower located on the North River tributary. The tower was operated by Kawerak Inc. from 1996 to 2001. In 2002 the Unalakleet IRA took over operation of the tower with assistance from the Alaska Department of Fish and Game – Commercial Fisheries Division (CFD). The counting tower is typically in operation from June 15 through September 10. In past years tower counts have ceased prior to the end of the coho salmon run due to high water events that created poor viewing conditions (Table 1; Jones *In prep*). Run strength of coho salmon in the Unalakleet River drainage has varied annually as indicated by past tower counts and by commercial and subsistence catches. Total escapement counts past the North River counting tower have varied from 2,966 fish in 2002 to 12,383 fish in 2001. Total subsistence and commercial harvests have also varied substantially over the past 10 years (Table 1).

Little is known about the distribution of coho salmon throughout the Unalakleet River drainage. It is unknown what proportion of the total Unalakleet River drainage coho salmon run spawns in the North River, and without that information the tower counts have very limited utility as an index of drainage-wide abundance. Aerial surveys to enumerate the strength of the coho salmon run in the drainage are ineffective due to poor weather conditions during the peak of spawning.

This project was undertaken to determine the spawning distribution of coho salmon in the Unalakleet River drainage and to determine what proportion of these fish go past the North River counting tower in order to extrapolate these tower counts into an escapement estimate for the entire drainage.

OBJECTIVES

This was intended to be the first year of a 3-year study (2004-2006). The objectives for the first year of this study were to:

1) Estimate the proportions of the coho salmon escapement migrating up the mainstem Unalakleet, North, Chiroskey, and Old Woman rivers, and the North Fork of the Unalakleet River;
2) Estimate the abundance of coho salmon escaping into the Unalakleet River drainage;
3) Estimate the age, sex and length composition of the coho salmon escapement into the Unalakleet River; and,
4) Document the locations of coho salmon spawning areas in the Unalakleet River drainage.

Table 1.–Unalakleet River coho salmon commercial, subsistence and sport harvests, sport catches and the fish counts from the North River tower, 1980-2003.

Brood Year	North River Tower Counts	Last Day of Operation	District 6 Commercial Harvest	District 6 Subsistence Harvest	Unalakleet River Sport Catch	Unalakleet River Sport Harvest
1980			21,512	4,758		
1981			29,845	5,808		
1982			61,343	7,037		
1983			36,098	6,888		
1984			47,904	6,675		
1985			15,421	2,244		
1986			20,580			
1987			15,097			
1988			24,232			
1989			36,025	4,681		
1990			52,015		3,396	1,826
1991			52,033		2,882	2,180
1992			84,449		2,802	1,555
1993			26,290		1,572	643
1994			71,019	16,081	2,488	2,425
1995			31,280	13,110	3,086	2,033
1996	1,229	25-Jul	52,200	15,963	5,863	3,411
1997	5,768	26-Aug	26,079	9,120	4,020	2,784
1998	3,361	12-Aug	24,534	7,303	3,213	2,742
1999	4,792	31-Aug	10,264	8,140	9,593	2,691
2000	6,959	12-Aug	29,803	5,878	9,184	4,103
2001	12,383	15-Sep	15,102	6,270	5,399	2,766
2002	2,966	28-Aug	1,079	4,988	3,691	2,937
2003	5,837	13-Sep	13,027	6,192	2,832	1,604
2004	11,187	14-Sep	29,282	n/a	n/a	n/a
5 yr average 1999-2003 (*2000-2004)			17,049*	6,294	6,140	2,820

Note: Shaded cells indicate an incomplete count of the run.

There was concern that estimating abundance of coho salmon in the Unalakleet River drainage by expansion of the North River tower count (Objective 2) would not be possible (or would be biased) because the run timing of the North River stocks may not be representative of the entire Unalakleet River drainage. Such an occurrence would necessitate additional sampling in the Unalakleet River upstream from the North River and in the North River above the tower site to use as part of the second sample of a mark-recapture study in 2005 and 2006 (study funded by the US Fish and Wildlife Service Office of Subsistence Management) to estimate total drainage abundance. In an attempt to develop an alternative assessment strategy, a project task was to: conduct seining in the Unalakleet River upstream from the North River and in the North River upstream from the tower site; to locate suitable sampling areas to collect ASL samples; and, to assess whether adequate numbers of coho salmon could be captured in upriver sampling areas to serve as a viable second event sample in a mark-recapture experiment to estimate drainage wide abundance in 2005 and 2006.

METHODS

This experiment was designed to evaluate the feasibility of estimating abundance of coho salmon in the Unalakleet River using either proportional expansion, as described in Wuttig and Evenson (2002), or as a Petersen type two-sample mark-recapture experiment for a closed population (Seber 1982). Therefore the study was designed to meet the requirements of either of those methods. In the case of this study being used as a two-sample mark-recapture experiment, the first event consisted of coho salmon being captured and marked using radio tags in the mainstem Unalakleet River below the confluence with the North River. The second event sample consisted of the total number of coho salmon that were counted past the North River counting tower. The recapture sample was the number of radio-tagged coho salmon that passed the North River tower. In the case of a proportional abundance estimate being developed, the proportion of radio tagged coho salmon that passed the North River tower would have been used as an expansion factor for the remainder of the Unalakleet River drainage.

CAPTURE

Coho salmon were captured primarily by beach seining. Capture for radio-tagging occurred at a single site approximately 5 km upstream from the mouth of the Unalakleet River and 3 km downstream of the mouth of the North River (Figure 2). This tagging location was upstream from the commercial fishery and the majority of the subsistence effort, and downstream from the majority of the sport fishing effort. The beach seine was 100 ft long and 8 ft deep with 2 3/4 in mesh. A drift gillnet was used to capture coho salmon during a high water event from August 13 – 18 when beach seining was not possible. The gillnet was 100 ft long, 33 panels deep (approximately 15 ft) and 5 7/8 in mesh (bar measure).

The seine was operated by a crew of three or four persons utilizing an 18 ft jet-powered skiff. Two people stood and anchored one end of the seine off the bank of the river while the other two crew members in the skiff deployed the seine perpendicular to the bank, looping it downstream and returning back to the bank. The two ends of the seine were then pursed together and brought onshore by pulling in both ends of the seine by hand. During mid to low water levels, all seine hauls were conducted from the south bank and the seine was stretched across virtually the entire

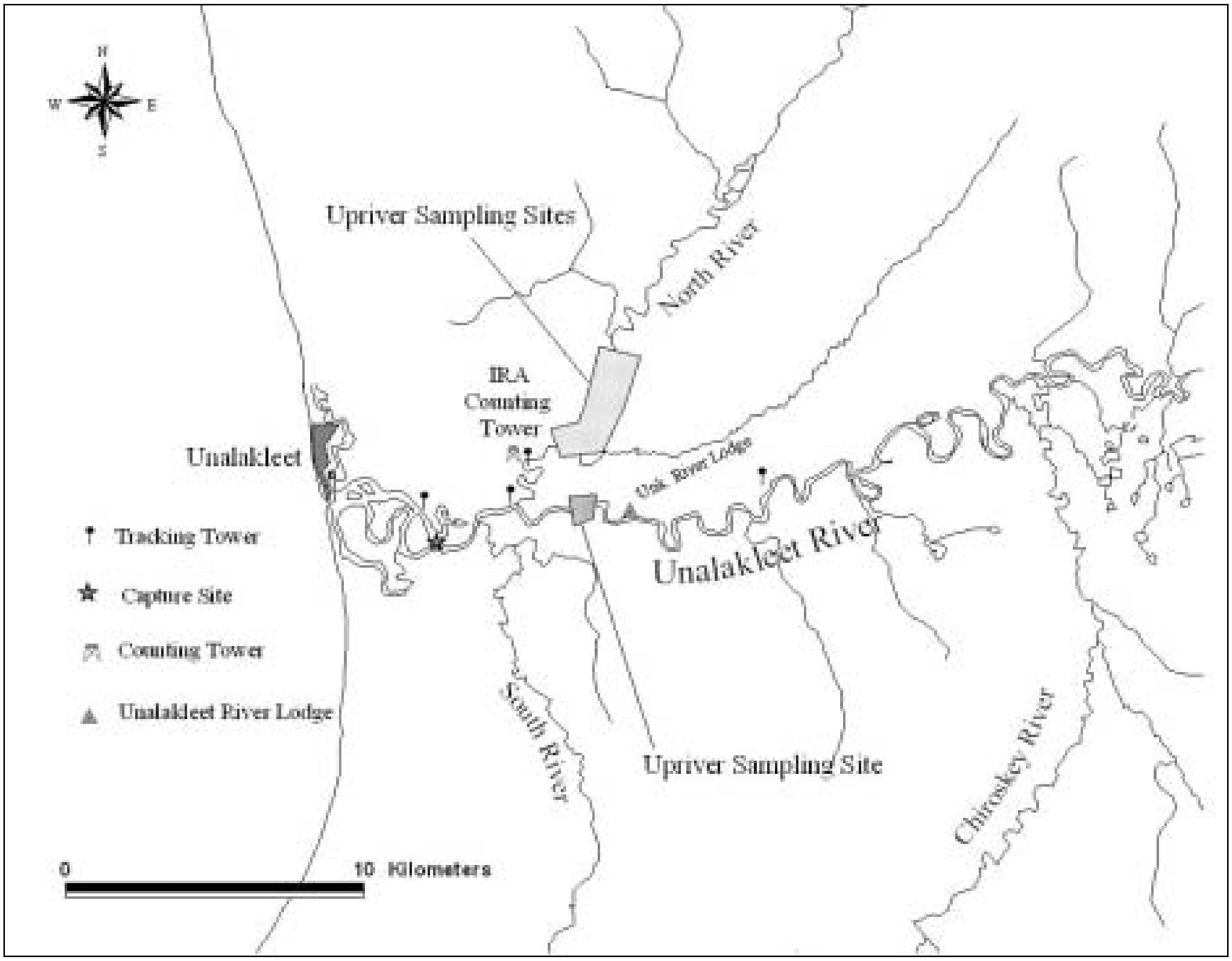

Figure 2.–Coho salmon capture and tracking station locations and North River counting tower site in the Unalakleet River drainage, 2004.

channel. Because of the swift current at mid and low water levels the seine could not be deployed from the north bank. We anticipated little potential for sampling bias using these procedures because the seine reached across at least 80% of the river and unfished waters tended to be shallow and rapid. During high tides, current velocity was much lower and beach seine hauls were performed from both the south and north banks.

Commercial Fisheries Division (CFD) staff notified the Sport Fish Division (SFD) staff on July 17 that they had begun catching coho salmon while they were performing a chum salmon radiotelemetry study (Estensen *In prep*). SFD staff had not planned on deploying radio tags before July 23, therefore CFD began opportunistic radio-tagging of coho salmon on July 19 while they were sampling and tagging chum salmon. Standardized fishing for coho salmon began on July 22. Fishing continued until catches had fallen off to less than two fish per day for several days. The final day of fishing was September 23. Fish capture for radio-tagging occurred four days each week (Monday, Tuesday, Friday and Saturday). Sampling was conducted during a morning shift, approximately 0900-1300 hours, and an evening shift, approximately 1800-2200 hours. Initially, four seine hauls were made during each shift (total of eight per day). When the fishing was slow, an extra seine haul was added on each shift. A 15 minute break was taken between seine hauls in the same stretch of water. If the second haul could be performed 50 to 100 meters below where the first seine haul was performed, then seine hauls were performed without a break.

In August, heavy rainfall in the Norton Sound Area caused an extreme high water event in the Unalakleet River. The ensuing high water and swift current made it unsafe and ineffective to beach seine from August 13 – 18. Drift gillnetting was used during these periods of high flow. Drift gillnetting was performed from 0900 hours through 1930 hours or longer if sample sizes were not being achieved. The net was drifted through a 1,000 m sampling reach that extended from the seining location down past the commercial fishery test net (Figure 2).

TAGGING

After capture, coho salmon were placed in a large holding tub or were left in the beach seine while it was pursed up and acted as a net pen. All captured coho salmon were marked with an opercular punch unique to the periods corresponding to the expected quintiles of the run (Table 2). The sex of each coho salmon was determined by external characteristics and the fish were measured to the nearest 5 mm MEF length.

Table 2.-Unalakleet River coho salmon radio-tagging goals, 2004.

Date	Number of Radio Tags Deployed	Cumulative # of Tags Deployed	Opercula Punch Pattern
7/14-8/7	40	40	Left diamond
8/8-8/13	40	80	Left tear drop
8/14-8/20	40	120	Left heart
8/21-8/28	40	160	Left rectangle
8/29-9/30[a]	40	200	Left circle

[a] Anticipated end date; last day of tagging was 9/23.

A proportion of the coho salmon caught received a Model Five pulse encoded transmitter made by ATS[1]. Each radio-tag was distinguishable by its frequency and encoded pulse pattern. Ten frequencies spaced approximately 10 kHz apart in the 148-149 MHz range with 20 encoded pulse patterns per frequency were used for a total of 200 uniquely identifiable tags. Transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 24 g in air, and had a 30-cm external whip antenna. These radio tags were inserted through the esophagus and into the upper stomach of the fish using a 45-cm polyvinyl chloride (PVC) tube with a diameter equal to that of the radio tags. The end of the PVC tube was slit lengthwise to allow for the antenna end of the radio transmitter to be seated into the tube and held in place by friction. The radio transmitters were pushed through the esophagus and seated using a PVC plunger, slightly smaller than the inside diameter of the first tube, such that the antenna end of the radio tag was 0.5 cm beyond the base of the pectoral fin.

Each radio-tagged coho salmon was also tagged with a uniquely numbered spaghetti tag constructed of a 5-cm section of blue tubing shrunk onto a 38-cm piece of 80-lb monofilament. The monofilament was sewn through the musculature of the fish 1-2 cm ventral to the insertion of the dorsal fin between the third and forth fin rays from the posterior of the dorsal fin. This tag was used to identify spawning fates of those fish that may have lost their radio tag or were later harvested or recovered during upriver seining. After handling, the radio-tagged coho salmon were placed into quiet backwater areas upstream of the capture area for recovery. The entire handling process required approximately 2-3 min per fish.

Both the radio and spaghetti tags were labeled with return information to facilitate identification of the final fates of all fish (i.e., harvested in sport, commercial or subsistence fishery). Flyers describing the project and how to return the tags were posted in public locations throughout Unalakleet and with the local sport fish guiding services. To avoid fishers targeting the tagged fish no lottery or other monetary compensation was awarded for return of the tags.

ADF&G-CFD has operated a set gillnet test fishery in the Unalakleet River since 1981. The historic average run timing of coho salmon through this test fishery was used to develop the tagging schedule for distributing radio tags in proportion to run strength throughout the duration of the run (Figure 3). Tagging goals coincided with twentieth percentile increments of the average run timing pattern to ensure that run size was examined on a fine enough scale to adjust tagging rates if necessary (Table 2). A systematic sampling approach (x number of fish tagged per sampling day) was used to meet the tagging goals. Based on average run timing, the initial tagging schedule was to deploy an average of 3.1 tags/day between 7/14 and 8/7 (14 sampling days), 13 tags per day between 8/8 and 8/13 (3 sampling days), 10 tags per day between 8/14 and 8/20 (4 sampling days), 8 tags per day between 8/21 and 8/28 (5 sampling days) and 2.2 tags per day between 8/29 and 9/30 (18 sampling days). The tagging schedule allowed for deployment of tags throughout the run. The tagging rate was evaluated at the end of every time block of the tagging schedule, and was adjusted to ensure that the overall goal was met.

UPRIVER SAMPLING

Every Wednesday and Thursday from July 21 through September 20, seining was conducted in the Unalakleet River upstream from the North River confluence and in the North River upstream from the counting tower (Figure 2). Both rivers were sampled on each day, one river in the

[1] Advanced Telemetry Systems, Isanti, Minnesota. Use of this company name does not constitute endorsement, but is included for completeness.

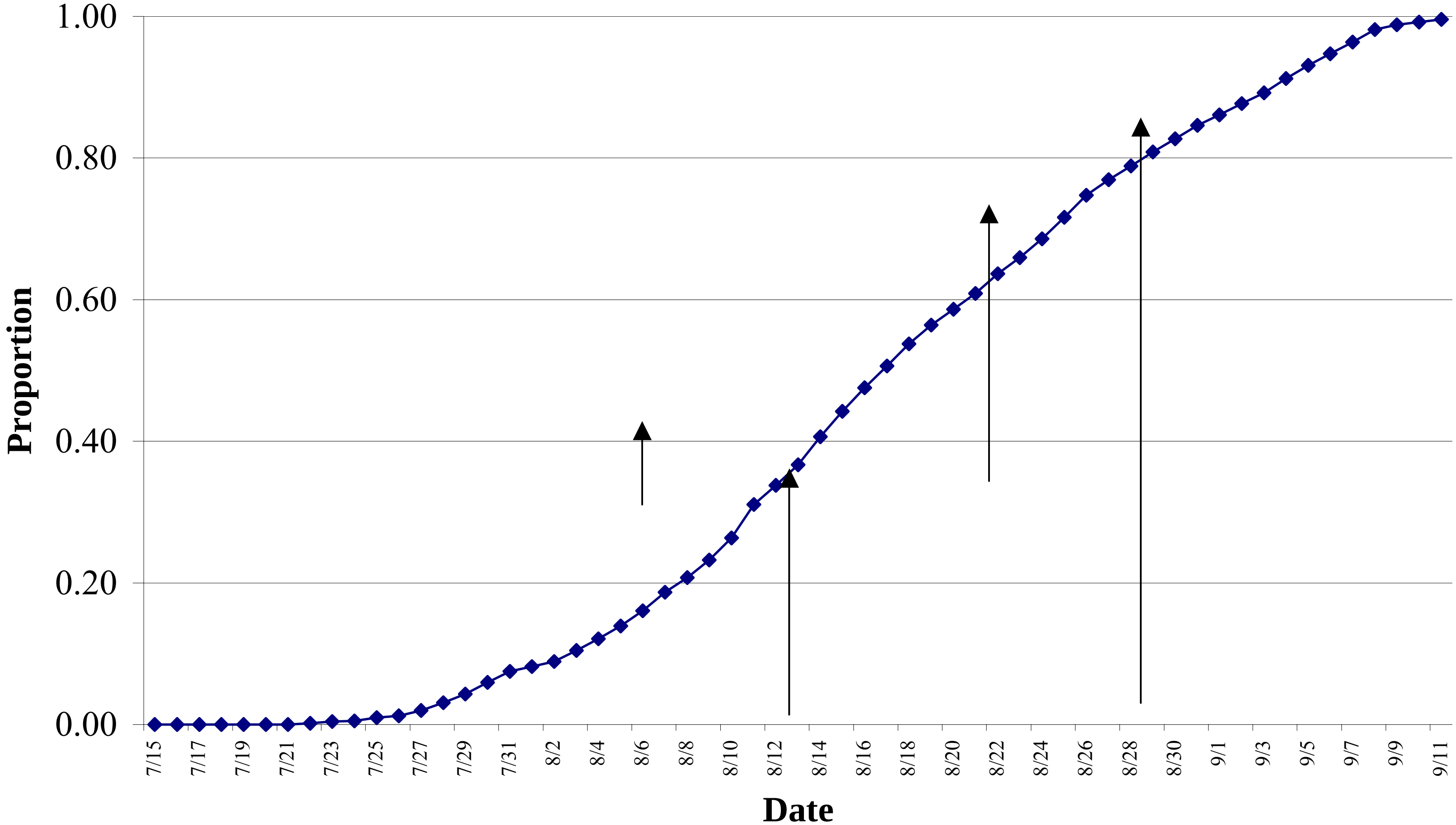

Figure 3.–Average cumulative CPUE of Unalakleet River coho salmon at the ADF&G commercial fish test fishery from 1986 through 2003 with milestone dates of the 2004 tagging schedule demarcated with vertical arrows.

morning and one in the afternoon and then reversing which was sampled first on the following day. Four seine hauls were made in each area on each day. In both areas, the initial objective was to find one or more sites that were suitable for seining. After locating a site the primary objective was to collect a systematic sample of coho salmon throughout the run for ASL composition. Criteria for a "suitable" site included: 1) moderate to slow current velocity; 2) a river width sufficiently narrow so that the seine could cover most of the channel; 3) free of snags and large rocks; 4) an adequate beach to "land" the seine; and, 4) coho salmon were successfully captured at the site. In the Unalakleet River, the section of river that was sampled was approximately 1 km below the Unalakleet River Lodge (Figure 2). In the North River, the section of river that was initially used was 4 km above the counting tower. These sections were chosen for investigation because they met the criteria for a suitable seining area and were located a moderate distance upstream from the marking site which allowed marked fish to recover from any handling effects and allowed marked and unmarked fish to mix between capture events. During the last four weeks of upriver sampling in the North River, fish were no longer holding in this particular section of river. Therefore, new locations were used that were upriver of the initial sampling site where fish were holding and seining was possible.

Upriver seining procedures were similar to those previously described. All coho salmon captured during upriver seining were given an adipose fin clip to uniquely identify them as being captured upriver. All captured fish were inspected for tags and opercular punches and sampled for length, sex, and age. To determine age, three scales were removed from the left side of each fish approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin and placed on gum cards. In the post-season scale impressions were made on acetate cards and viewed at 100X magnification using equipment similar to that described by Ryan and Christie (1976). Ages were determined from scale patterns as described by Mosher (1969).

RADIOTRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio-tagged coho salmon were tracked and spawning destinations were discerned through the use of four stationary radio-tracking towers and several aerial radio-tracking surveys. The first tower was placed below the tagging location (to monitor fish that backed out or left the drainage after spawning), the second was located at the confluence of the North and Unalakleet rivers, the third was at the North River counting tower and the final tower was located at a proposed CFD weir location on the mainstem of the Unalakleet River approximately 14 km above the confluence with the North River (Figure 2).

Each tracking station included one gel-cell, deep-cycle battery, an 80-watt solar array, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, an antenna switching box, a weather-proof metal housing box, and two four-element Yagi antennas (one aimed upstream and the other downstream). The tracking tower at the confluence of the North and Unalakleet rivers had three antennas; one pointing downriver, one pointing up the Unalakleet River and one pointing up the North River. The receiver and DCC II were programmed to scan through the frequencies at three-second intervals receiving with both antennas simultaneously. When a radio signal of sufficient strength was encountered the receiver paused for six seconds, at which time the data logger recorded the frequency, code, signal strength, date, and time for each antenna. Cycling through all frequencies required 2-15 min depending on the number of active tags in reception range. Data were downloaded onto a portable computer every seven to 10 days.

The distribution of radio-tagged salmon throughout the Unalakleet River drainage was further determined by aerial tracking from fixed-wing aircraft to: 1) locate tags in areas other than those monitored with tracking stations; 2) locate fish that the tracking stations failed to record; and, 3) validate that a fish recorded on one of the data loggers did migrate into a particular stream. Aerial surveys were performed on August 23 and 31, September 17, and October 12 and 28. The surveys performed on August 23 and October 12 were limited to the mainstem of the Unalakleet and the lower stretches of the tributaries because of poor weather conditions. The other three surveys were complete in that they included surveys of all tributaries and tertiary streams.

DATA ANALYSIS

Assignment of Fate

For data analysis, each fish was assigned a "final location" based on the furthest upriver location at which it was located by air or tracking station. Each radio-tagged fish was assigned 1 of 6 possible fates based on information collected from aerial tracking surveys and from stationary data logging stations.

Fate 1) In the North River – a fish that was determined to have entered the North River and passed the North River tracking station.

Fate 2) In the Upper Unalakleet River/ Tributaries – a fish that was determined to have migrated into one of the tributaries of the Unalakleet River other than the North River and including the South River, the Chiroskey River, the North Fork, the 10 mile River, and the Old Woman River. Additionally, the section of the Unalakleet River that is above the Old Woman confluence was included in this group based on the GIS analysis and the similarity of these fish to the rest of the tributary destined fish.

Fate 3) In the Mainstem Unalakleet River - a fish that was determined to have migrated into the Unalakleet River and was never detected in any tributary or above the confluence with the Old Woman River.

Fate 4) Dead/Regurgitated – a fish that did not migrate past the confluence of the North and Unalakleet rivers and was assumed to have died and/or regurgitated its radio tag.

Fate 5) Harvested – a fish that was determined to have been harvested by a subsistence or sport fisherman. Fish were assigned this fate when the fisherman returned the tag to the ADF&G or if the tag was continually located in the village of Unalakleet or at the Unalakleet River Lodge. If a tag was recorded repeatedly passing the tracking towers in both directions it was assumed that the fish was harvested and its radio-tag was left in a boat. A harvested fish could be assigned to the North River or the Unalakleet River if it passed a tracking tower before being caught and accurate information regarding its capture location were provided by the fisherman.

Fate 6) Backed Out – a fish that was tagged and then recorded as going downriver past the lower tracking tower and not returning to the river.

Fate 7) Unknown – a fish that was never located during aerial surveys or recorded on a tracking station after tagging.

Conditions for a Consistent Petersen Estimator

For the estimate of abundance from this mark-recapture experiment to be unbiased, certain assumptions needed to have been fulfilled (Seber 1982). The assumptions, expressed in terms of the conditions of this study, respective design considerations, and test procedures are listed below. To produce an unbiased estimate of abundance with the generalized Petersen model, Assumptions I, II and III and one of the conditions of Assumption IV must have been met.

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

This assumption was violated because harvest of some fish occurred between events. However, we assumed that marked and unmarked fish were harvested at the same rate. Thus, provided there was no immigration of fish between events, the estimate was unbiased with respect to the time and area of the first event (estimate of inriver abundance, not escapement). Sampling in both events encompassed the majority of the run. Any immigration of coho salmon past the capture site prior to or after the marking event was assumed to be negligible.

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

There was no explicit test for this assumption because the behavior of unhandled fish could not be observed. However, to minimize any handling effects, the holding and handling time of all captured fish was minimized. Any obviously stressed or injured fish were not radio-tagged. Radio-tagged fish that were not detected past either the North River tracking station or the mainstem Unalakleet River tracking station upstream of the confluence with the North River were removed from the experiment. It was assumed that if a fish was able to migrate this distance, then there were no effects from handling and tagging.

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

A combination of stationary tracking stations and aerial and boat tracking surveys were used to identify radio tags that were expelled. All fish determined to have regurgitated their tags were culled from the analyses.

Assumption IV:

1. **All coho salmon had the same probability of being caught in the first sampling event;**
2. **All coho salmon had the same probability of being captured in the second sampling event; or,**
3. **Marked fish mixed completely with unmarked fish between sampling events.**

It was considered likely that tagging rates would vary and possible that fishing effort would vary. If discrete coho salmon spawning aggregations in the Unalakleet River entered the river with different run timing schedules, varied tagging rates and fishing effort could result in biased estimates of the proportion of the run that migrated past the North River counting tower and proportion estimates for fish spawning in other areas of the drainage.

To evaluate if a Petersen model could be used to estimate abundance rather than proportional expansion, it was necessary to determine if either: A) run-timing at the capture site for fish spawning in the North River was similar to that of fish spawning in all areas of the Unalakleet River drainage; or, B) daily tagging rate and fishing effort did not vary significantly over time during the marking event. If neither of these conditions were met, the use of proportional expansion (Wuttig and Evenson 2002) using weighted observations would be necessary to estimate both the abundance and the proportions of salmon migrating to the North River and other spawning areas.

Weighting

Each radio-tagged fish was assigned a numeric weight w_i corresponding to the number of fish captured, the number of fish tagged, and fishing effort for the day (i) it was captured. Fishing effort was the total number of seine hauls for that day. For the days in which a drift gillnet was deployed, drift time was weighted by dividing the minutes of soak time by 30 in order to standardize the drift gillnet time with the number of seine hauls. Individual weights were calculated:

$$w_i = \left(\frac{\bar{h}}{h_i}\right)\left(\frac{X_i/\bar{X}}{x_i/\bar{x}}\right) \qquad (1)$$

where:

X_i = the number of fish captured on day i;

$\bar{X}$ = the mean daily number of fish captured over all days of fishing;

x_i = the number of fish radio tagged on day i;

$\bar{x}$ = the mean daily number of fish radio tagged over all days of fishing;

h_i = the hours of fishing effort on day i; and,

$\bar{h}$ = the mean hours of fishing effort per day over all days of fishing.

Diagnostic Tests

Cumulative run-timing distributions (at the capture site) for salmon spawning in the North River and salmon spawning in the remainder of the Unalakleet River drainage were tested for homogeneity using Kolmogorov-Smirnov (K-S) two-sample tests (Conover 1980). Run-timing curves were constructed using the weighted values described by equation (1) and compared using a randomization test (Manly 1997) for the K-S test statistic, and curves using unweighted values were compared using the conventional K-S test.

Equal probability of capture was evaluated by size and temporally. Coho salmon were captured and tagged over the entire span of the run. Radio tags were implanted into coho salmon of various sizes. Length, date, and time of release were recorded for all tagged fish. The North River tower counts occurred over the span of the run. Age, sex, and length data were collected from the samples of fish past the North River tower and in the mainstem Unalakleet River above the confluence of the North River. The procedures to evaluate equal probability of capture across size categories are described in Appendix A1, as well as corrective measures (stratification), based on diagnostic test results to minimize bias in estimates of abundance and composition. Due to potential errors in correctly identifying the gender of coho salmon at the tagging site, sex ratios of tagged fish and fish spawning in the North River were not compared.

To further evaluate the three conditions of Assumption IV, contingency table analyses recommended by Seber (1982) and described in Appendix A2 were used to detect significant temporal violations of assumptions of equal probability of capture.

ABUNDANCE ESTIMATE

Abundance of coho salmon was estimated after stratification by size to minimize bias. For each stratum, abundance was estimated using the Chapman modification to the Petersen estimator (Chapman 1951) and stratum estimates were summed to estimate total abundance:

$$\hat{N} = \sum_{s=1}^{S} \hat{N}_s \text{, and} \tag{2}$$

$$\hat{N}_s = \frac{(\hat{C}_s + 1)(M_s + 1)}{R_s + 1} - 1; \tag{3}$$

where:

- $\hat{N}_s$ = estimated abundance of coho salmon in the Unalakleet River upstream from tagging site in stratum s, s = 1 to S;
- M_s = the number of radio-tagged coho salmon in stratum s known to survive tagging and handling;
- R_s = the number of radio-tagged coho salmon in stratum s moving past the North River counting tower; and,
- $\hat{C}_s$ = the estimated number of coho salmon in stratum s counted past the North River tower.

The number of coho salmon in stratum s that passed the North River tower was estimated:

$$\hat{C}_s = \hat{p}_s C \tag{4}$$

where the proportion of salmon in stratum s was estimated from length composition data collected inriver above the North River tower:

$$\hat{p}_s = n_{Cs} / n_C \tag{5}$$

and where:

- n_{Cs} = number of coho salmon in size stratum s observed of those sampled for composition above the tower;
- n_C = the total number of coho salmon sampled for composition above the tower; and,
- C = the number of coho salmon counted past North River tower.

Variance and 95% credibility interval for the estimator (equation 2) were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for the $\hat{N}_s$ and $\hat{N}$ were generated by collecting 400,000 simulated values of $\hat{N}_s$ and $\hat{N}$ which were calculated using equations (1-5) from simulated values of equation parameters. Simulated values were modeled from observed data using the following distributions:

observed $n_{C1},\ldots,n_{CS}$ ~multinomial $((p_1,\ldots,p_S), n_C)$;

observed R_s ~binomial (q_s, M_s), s = 1 to S; and,

where q_s is the probability that a radio-tagged salmon from stratum s passed the North River tower and was treated as a recapture.

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

$$\overline{N} = \frac{\sum_{b=1}^{400,000} \hat{N}_{(b)}}{400,000} \text{ and,} \tag{6}$$

$$V\hat{a}r(\hat{N}) = \frac{\sum_{b=1}^{400,000} (\hat{N}_{(b)} - \overline{N})^2}{400,000 - 1} \tag{7}$$

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

AGE, SEX, AND LENGTH COMPOSITION AND SPAWNING PROPORTIONS

The numbers of coho salmon by length, age or sex group *k* were estimated first within size strata and within major spawning destination *d* where *d* indicates either North River or mainstem Unalakleet River stocks and then combined arithmetically. Composition proportions were first estimated using:

$$\hat{p}_{ksd} = \frac{n_{ksd}}{n_{sd}} \tag{8}$$

where:

$\hat{p}_{ksd}$ = estimated proportion of coho salmon in group *k,* within size stratum *s* at destination *d*;

n_{ksd} = number of sampled coho salmon in group *k,* stratum *s,* at destination *d*; and,

n_{sd} = total number of coho salmon sampled at destination *d* in size stratum *s.*

Estimates of total numbers of salmon in group *k* within each combination of *d* and *s* were calculated:

$$\hat{N}_{ksd} = \hat{T}_{sd}\,\hat{p}_{ksd} \tag{9}$$

where $\hat{T}_{sd}$ =:

$\hat{C}_s$ where *d* indicates North River, and,

$\hat{N}_s - \hat{C}_s$ where *d* indicates mainstem Unalakleet River.

These estimates were summed across strata and destination to calculate the estimated number of coho salmon in group *k* in the escapement:

$$\hat{N}_k = \sum_{s=1}^{S}\sum_{d=1}^{2}\hat{N}_{ksd}\ , \tag{10}$$

and the proportion of coho salmon in group *k* was estimated:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N}\ . \tag{11}$$

Variance for the estimates of $\hat{N}_k$ and $\hat{p}_k$ were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for $\hat{N}_k$ and $\hat{p}_k$, which were calculated using equations (2-5) and (8-12) were generated by collecting 400,000 simulated values of $\hat{N}_k$ and $\hat{p}_k$ from simulated values of equation parameters. The simulated values were modeled from observed data using multinomial models within strata and destination, in addition to those distributions described above. Formulae similar to equations (6) and (7) were used to estimate variance.

Estimates of proportions of coho salmon migrating to different spawning destinations were estimated by size strata and then combined, using procedures similar to those described above for composition groups, with samples based on radio-tagged coho salmon.

Mean length at age within sex and/or spawning destination categories and its sampling variance were estimated using standard sample summary statistics (Cochran 1977).

Data from capture, tagging, and radiotelemetry used to estimate parameters of the coho salmon abundance and length, age, and sex compositions in this study were entered into Excel spreadsheets for analysis and archival (Appendix B).

RESULTS

TAGGING AND FATES OF RADIO-TAGGED SALMON

Between July 19 and September 23 a total of 529 coho salmon were captured at the lower river tagging site and 208 radio transmitters were deployed. The fish ranged in length from 345 to 700 mm MEF (Figure 4; Table 3). The length distribution of radio-tagged fish was not significantly different from those not radio-tagged (D=0.111, P-value=0.079).

Of the 208 salmon that were radio-tagged, 190 continued upstream migration past the tracking towers on the Unalakleet and North rivers. Two fish backed out of the Unalakleet River after tagging and did not migrate back into the river. Four fish either regurgitated their radio tags or died near the tagging site. Fifteen coho salmon were known to have been harvested, although several of those migrated past the upriver tracking stations before being harvested (Table 4).

Distribution of Radio-Tagged Coho Salmon

Radio-tagged coho salmon were detected in all portions of the Unalakleet River drainage including the South, North, Chiroskey, 10 Mile, North Fork Unalakleet, and Old Woman rivers (Figure 5; Table 5). The area with the highest concentration of coho salmon as determined by aerial radio-tracking surveys was the section of the Unalakleet River that lies above the Chiroskey River and below the North Fork.

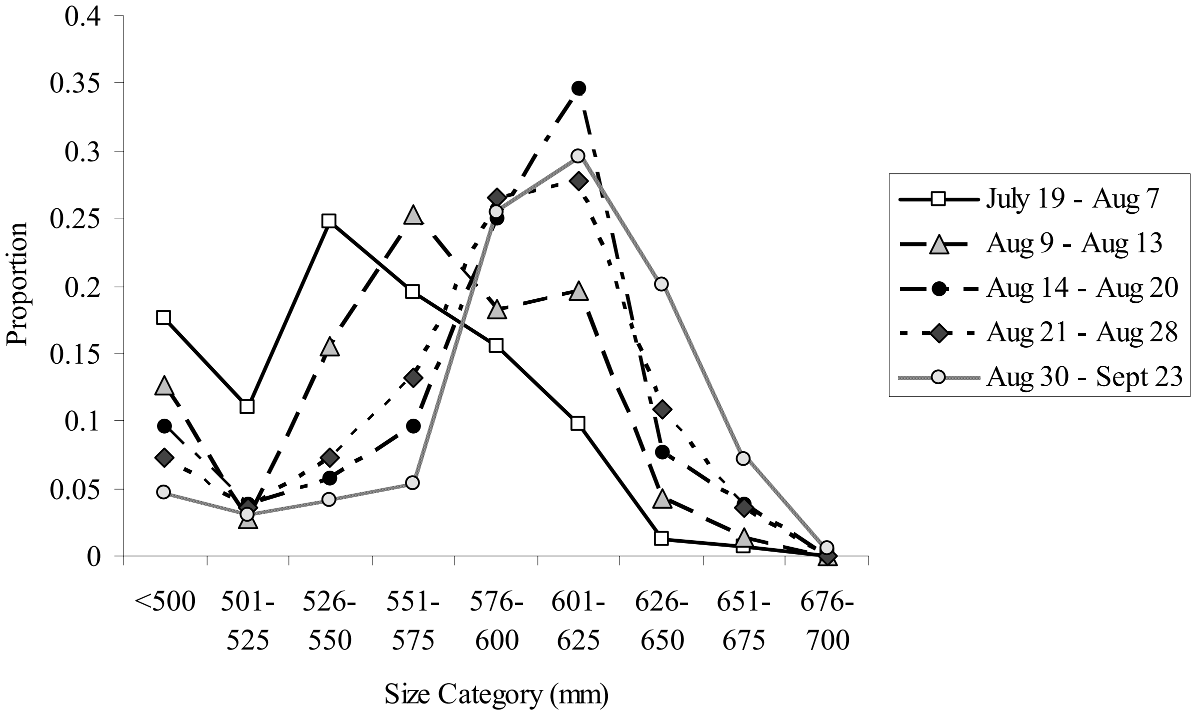

Figure 4.–The length distribution of Unalakleet coho salmon captured at the tagging site for each of the five run quintiles, 2004.

Table 3.–Catch, length and sex ratio statistics of coho salmon sampled in the North and mainstem Unalakleet rivers, 2004.

Statistic	Downriver Tagging Location		Upriver Sampling	
	All Fish	Tagged Fish	Unalakleet River	North River
Number caught				
All	529	208	325	482
Male	270	104	187	264
Female	259	104	137	215
Mean Length (mm)				
All (SD)	576 (53)	582 (46)	580 (56)	569 (54)
Male (SD)	574 (61)	586 (52)	579 (63)	571 (58)
Age 1.1	-	-	583 (59)	561 (52)
Age 2.1	-	-	593 (54)	575 (40)
Female (SD)	577 (45)	577 (45)	583 (41)	569 (44)
Age 1.1	-	-	575 (45)	564 (34)
Age 2.1	-	-	587 (36)	561 (40)
Length Range				
All	345-700	430-660	380-675	320-675
Male	345-700	430-660	380-675	320-675
Female	385-660	475-660	465-655	400-650
% Male ≤570 mm	51%	43%	59%	53%
% Male >570 mm	50%	54%	57%	57%

Table 4.–Fates of radio-tagged coho salmon in the Unalakleet River drainage, 2004.

General Fate	Number of Radio tags	Specific Fate	Number of Radio Tags
		North River	26
North River	29	Little North River	2
		Harvested in North River	1
		Upper Mainstem	17
		South River	5
Upper Unalakleet/		Chiroskey River	9
Tributaries	48	North Fork Unalakleet	4
		Old Woman River	11
		10 Mile River	2
Mainstem Unalakleet	95		95
Unalakleet-Unknown	13		13
Harvested above tracking tower on Unalakleet	5		5
Total past tracking towers	**190**		**190**
Dead or Regurgitated Tags	4		4
		Sport fishery	6
Harvested below	9	Subsistence fishery	1
tracking towers		Unknown	2
Backed-out after tagging	2		2
Unknown	3		3
Total that never passed tracking towers	**18**		**18**

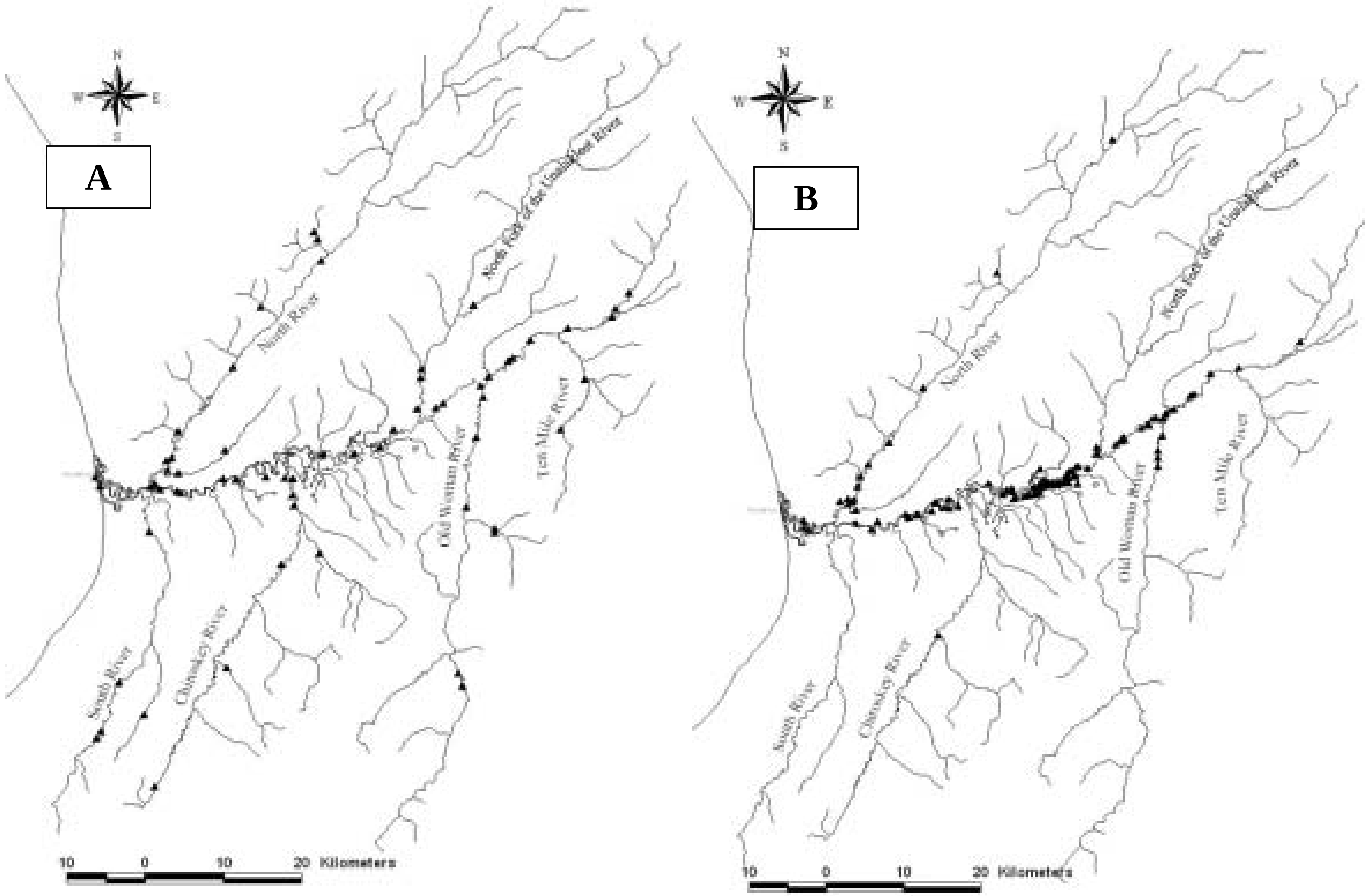

Figure 5.–Maps showing the furthest detected migration of all radio-tagged coho in the Unalakleet drainage, 2004. A shows the distribution of coho salmon that were radio-tagged on or before August 13 and B shows the distribution of coho salmon that were radio-tagged after August 13.

Table 5.–Estimated proportions of coho salmon entering the North River, the mainstem Unalakleet, the Upper Unalakleet/ tributaries, the Chiroskey River, the Old Woman River, the North Fork Unalakleet River, and the entire Unalakleet drainage (excluding the North River), 2004. Standard errors for estimates are in parentheses.

	Estimated Proportion		
Area	≤570 mm MEF	>570 mm MEF	All
North River	0.266	0.109	0.152
	(0.054)	(0.027)	(0.028)
Mainstem Unalakleet	0.357	0.651	0.571
	(0.064)	(0.043)	(0.044)
Upper	0.377	0.240	0.277
Unalakleet/Tributaries	(0.064)	(0.039)	(0.036)
Chiroskey River	0.113	0.026	0.050
	(0.043)	(0.015)	(0.018)
Old Woman River	0.094	0.051	0.063
	(0.039)	(0.020)	(0.019)
North Fork	0.038	0.017	0.023
	(0.026)	(0.012)	(0.012)
Entire Unalakleet	0.734	0.891	0.848
	(0.054)	(0.027)	(0.028)

Of the 190 radio-tagged coho salmon that passed the tracking stations and were located upriver, 29 coho migrated past the North River counting tower (hereafter referred to as *North River coho salmon*), 45 coho salmon migrated into other tributaries or migrated up the mainstem of the Unalakleet River above the Old Woman River (hereafter referred to as *upper Unalakleet/tributary coho*) and 116 coho salmon migrated up the mainstem of the Unalakleet River and remained in the section between the North River and the Old Woman River (hereafter referred to as *mainstem coho salmon*). When referring to *upper Unalakleet/tributary coho* and *mainstem coho* collectively they will be referred to as *Unalakleet coho salmon*. Estimated proportions of coho salmon migrating to these various portions of the drainage were 0.152 (SE=0.028) to the North River, 0.571 (SE=0.044) to the mainstem of the Unalakleet River below the North Fork, and 0.277 (SE=0.036) to the upper Unalakleet and it's tributaries including 0.050 (SE=0.018) to the Chiroskey River, 0.063 (SE=0.019) to the Old Woman River, and 0.023 (SE=0.012) to the North Fork (Table 5). Of the tributary streams, the North River accounted for the largest proportion of radio-tagged fish that migrated upstream after capture (Figure 6).

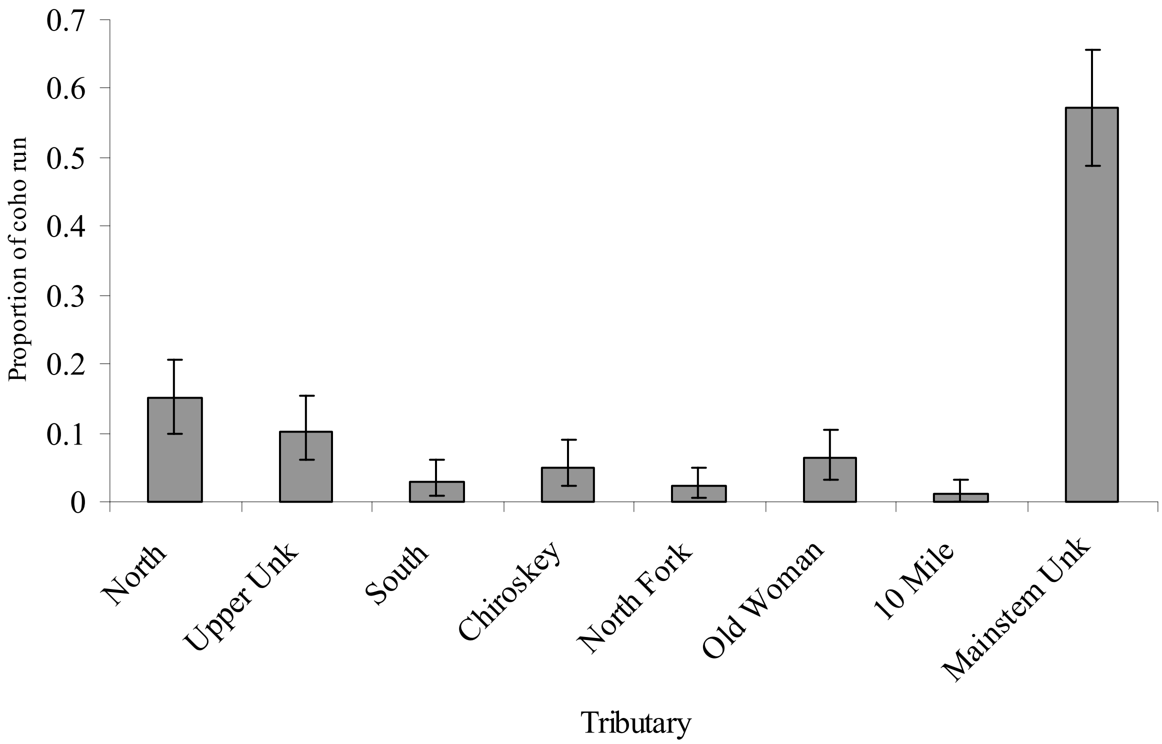

Figure 6.–The estimated proportional distribution of coho salmon in the Unalakleet River tributaries in 2004. The Upper Unalakleet is defined in this report as the section of the Unalakleet River located above its confluence with the Old Woman River. The mainstem Unalakleet River is defined in this report as the section of the Unalakleet River located below its confluence with the Old Woman River. Error bars represent 95% confidence intervals.

ABUNDANCE ESTIMATION

Diagnostics

Diagnostic tests indicated that there were no significant differences between the run timing of North River and Unalakleet coho salmon (Figure 7). There were no significant differences in run timing when unweighted values were used (D = 0.200, p-value = 0.212) nor when the weighted values of the radio-tagged fish were used (D = 0.215, P-value = 0.219). Based on these results, it was determined that a Petersen type model could be used to estimate abundance.

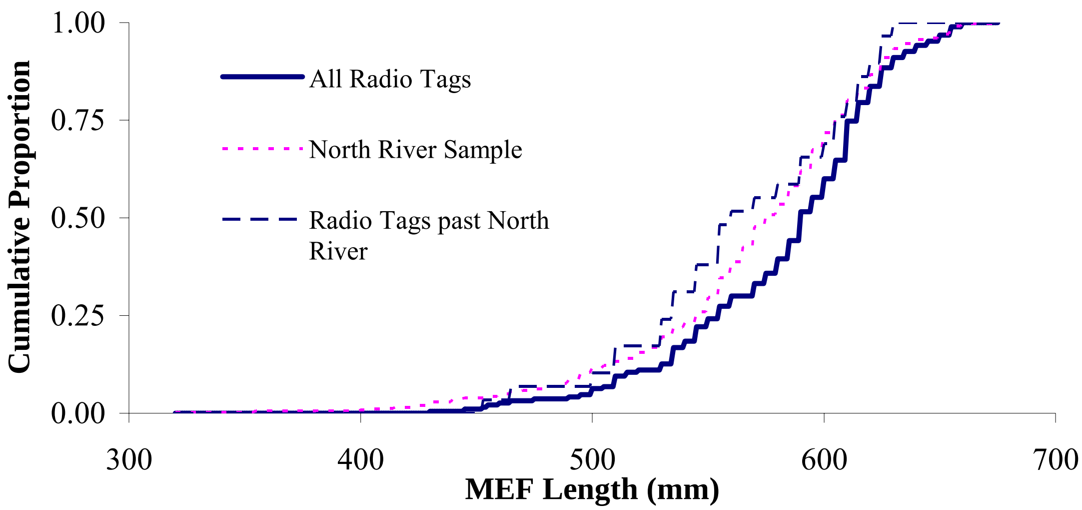

Figure 7.–Cumulative length frequency distributions of all radio-tagged fish, all fish sampled above the North River counting tower, and all radio-tagged fish migrating above the North River counting tower, 2004.

Tests for size biased sampling (Appendix A1) indicated that there was a significant difference in the length distribution of all radio-tagged coho salmon and the length distribution of those fish sampled above the North River counting tower (D = 0.150, P-value = 0.004). However, there was no difference in length distribution of radio-tagged coho that migrated past the North River counting tower and those salmon sampled in the North River (D = 0.136, p-value = 0.664), nor in the length distribution of those radio-tagged coho salmon that migrated past the North River tower and the length distribution of all radio-tagged coho salmon (D = 0.220, p-value = 0.129: Figure 8). The results of these tests indicated a Case II type experiment precluding the need to stratify by size to estimate abundance and composition proportions. However, there was a significant difference in the size distribution of North River and Unalakleet coho salmon (D = 0.136, P-value = 0.001) with North River fish being, on average, smaller than those that migrated up the mainstem of the Unalakleet (Figure 9). This additional test result combined with a marginal P-value (P-value = 0.129) when comparing all marked fish to recaptured marked fish led to the conclusion that stratification by size, though conservative, would be prudent for this experiment.

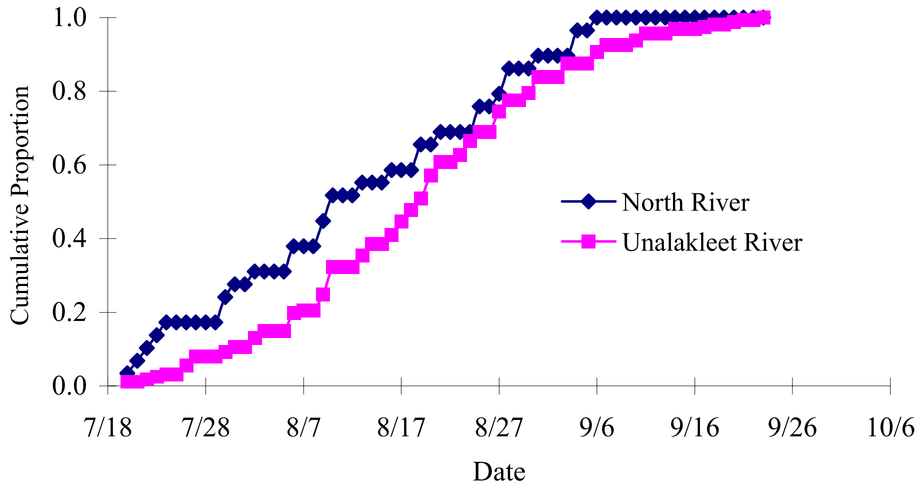

Figure 8.–Cumulative run timing past the capture site for radio-tagged coho salmon that migrated up the North River and up the Unalakleet River, 2004.

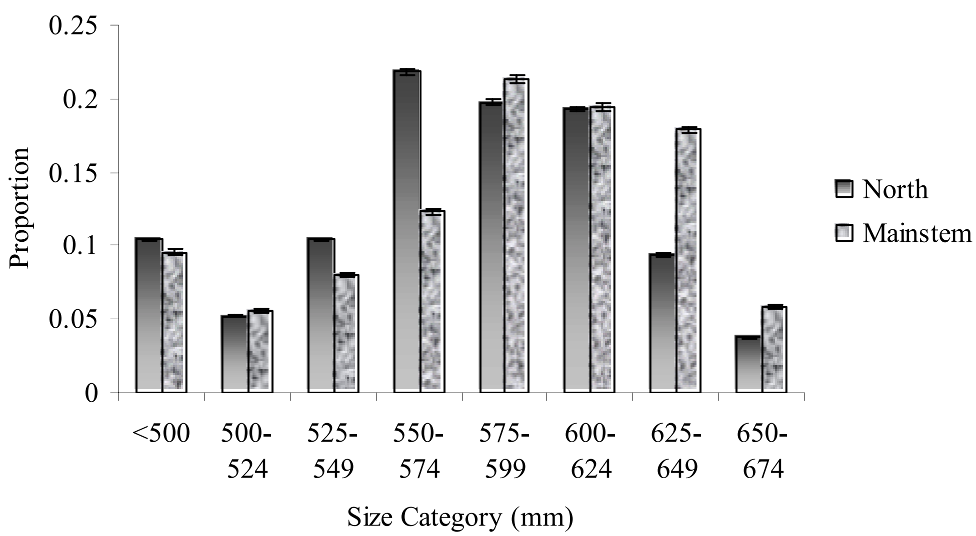

Figure 9.–Size distribution of coho salmon sampled in the Unalakleet and North rivers, 2004. Error bars represent 95% confidence intervals.

The data were split into two size strata: ≤570 mm MEF and >570 mm MEF. For fish ≤570 mm MEF, there were no significant differences between length distributions of all radio-tagged coho salmon and coho salmon sampled above the North River tower (D = 0.118, P-value = 0.292), between radio-tagged coho salmon that migrated up the North River and those sampled above the North River tower (D = 0.149, P-value = 0.881), or between all radio-tagged coho salmon and those radio-tagged coho salmon that migrated up the North River (D = 0.072, P-value = 1.000). Similarly, for fish >570 mm MEF, there were no significant differences between length distributions of radio-tagged coho salmon and coho salmon sampled above the North River tower (D = 0.077, P-value = 0.619), between radio-tagged coho salmon that migrated up the North River and coho salmon sampled above the North River tower (D = 0.153, P-value = 0.930), or between all radio-tagged coho salmon and radio-tagged coho salmon that migrated up the North River (D = 0.116, P-value = 0.997). These results indicated no evidence of size biased sampling within the two size strata, and further stratification was unnecessary.

Following size stratification, the initial test of run timing of North River and Unalakleet River coho salmon was repeated for each size strata , and there was no significant difference in run timing of fish ≤ 570 mm MEF (D = 0.201, P-value = 0.553) or, of fish > 570 mm MEF (D = 0.226, P-value = 0.500) using the weighted tag values.

Temporal violations of equal probability of capture during the second event (upriver sampling) were explored using contingency table analyses (Appendix A2; Table 6). No significant difference was detected in the probability that a marked fish was recaptured during the second event between the five quintiles of the run when examining all radio-tagged salmon (χ^2 = 5.765, P-value = 0.217). For fish ≤ 570 mm MEF there was no significant difference (χ^2 = 1.211, P-value = 0.876) nor was there a significant difference for fish > 570 mm MEF (χ^2 = 2.585, P-value = 0.629). These results were sufficient to conclude that a temporally stratified model was not necessary to estimate abundance.

Table 6.–Data used to test the assumption of equal probability of capture by time during the second event for all fish, fish ≤570 mm, and fish >570 mm.

	All Fish		≤570 mm		>570 mm	
Quintile Dates	Recaptured	Not Recaptured	Recaptured	Not Recaptured	Recaptured	Not Recaptured
7/19-8/7	11	33	9	19	2	14
8/8-8/13	5	24	2	8	3	16
8/14-8/20	3	35	2	8	1	27
8/21-8/28	6	33	2	8	4	25
8/29-9/23	4	36	1	4	3	32

The run-timing of mainstem coho salmon and upper Unalakleet/tributary coho salmon were also compared (Figure 10). There was a significant difference in run-timing of these two groups of fish (D = 0.397, P-value <0.001) with the upper Unalakleet/tributary coho salmon entering the system significantly earlier than mainstem coho salmon.

There were also significant differences in run timing for coho salmon ≤570 mm MEF (D = 0.488, P-value < 0.01) and for coho salmon >570 mm MEF (D = 0.609, P-value < 0.01). When both size strata were pooled, there remained significant differences in run timing (D = 0.585, P-value < 0.01).

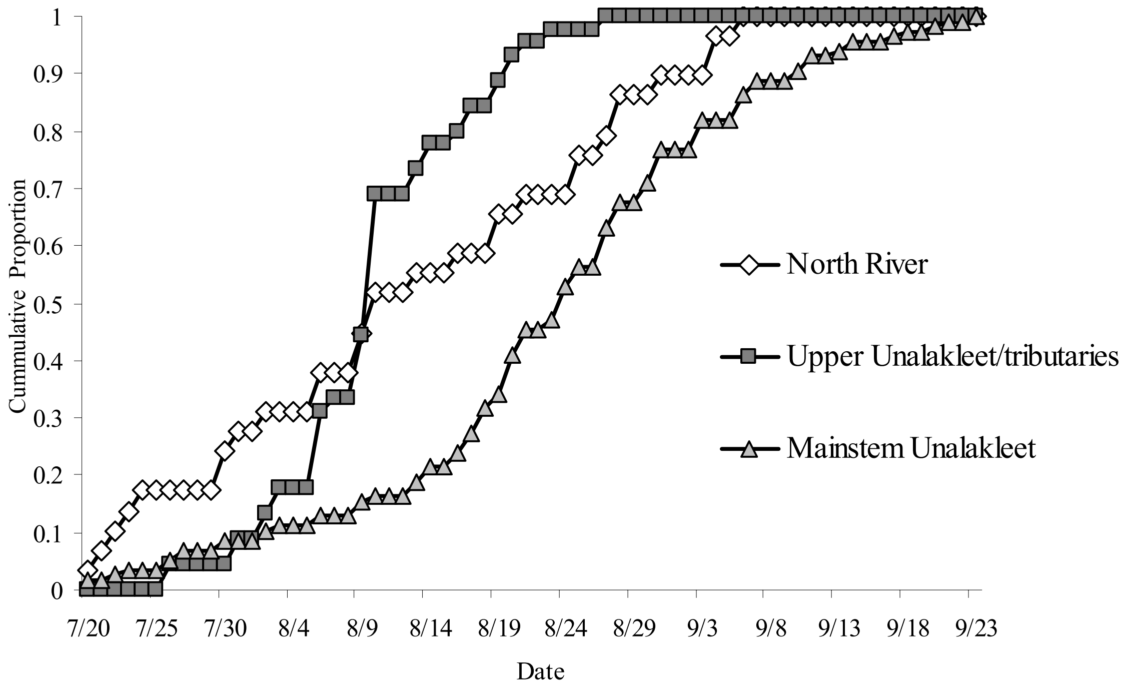

Figure 10.–Cumulative run timing past the capture site for three groups of coho salmon in the Unalakleet River drainage, 2004. North River coho salmon are those fish that migrated up the North River; Upper Unalakleet/Tributary coho salmon are those that migrated into tributaries other than the North River or migrated up the Unalakleet River past the Old Woman River confluence. Mainstem Unalakleet refers to those coho salmon that migrated up the Unalakleet River but never entered a tributary nor passed the confluence with the Old Woman River.

It was unnecessary to test for bank orientation because most seining (≅ 90%) occurred such that the net was stretched across most (≅ 80%) of the river channel. Additionally, during north bank seine hauls only 12 coho salmon were captured and 7 radio-tagged (2% and 3% of respective totals at tagging location).

Abundance Estimate

One hundred ninety radio-tagged coho salmon continued upstream migration past the tracking towers on the Unalakleet and North rivers and served as the marked sample (M). A total of 11,187 coho salmon were counted past the North River counting tower (C) in 2004 (Jones *In prep*). Of these an estimated 20,099 (SE=4,054) were ≤570 mm and 53,483 (SE=13,017) were >570 mm. Twenty-nine radio-tagged coho salmon migrated past the North River counting tower and served as the recapture sample (R). Of these, 16 were ≤570 mm and 13 were >570 mm.

The estimated abundance of coho salmon that entered into the Unalakleet River drainage above the capture site was 20,099 fish ≤570 mm MEF (SE = 4,054) and 53,483 fish >570 mm MEF (SE = 13,017). The estimated abundance of all coho salmon entering into the Unalakleet River drainage above the capture site was 73,582 fish (SE = 15,570) with a 95% credibility interval of 54,040 to 114,600 fish.

ESTIMATION OF AGE, SEX, AND LENGTH COMPOSITION

Age, sex, and length compositions of the escapement were estimated from coho salmon sampled at the upriver sites on the North River and Unalakleet River. The size distribution of coho salmon sampled at each site was considered unbiased because a beach seine was used that caught coho as small as 345 mm MEF. However, the length distribution of coho salmon sampled at the upper site in the Unalakleet River was significantly different than the length distribution of those fish sampled above the North River counting tower (D = 0.136, P-value = 0.001; Figure 9). Therefore, composition estimates were calculated by summing weighted (by relative abundance) estimates from each area (see Equations 10, 11). Sex composition of the escapement was 0.57 males (SE=0.025) and 0.43 females (SE=0.025). Estimated abundance of males was 42,007 fish (SE=9,102), and estimated abundance of females was 31,576 (SE=6,974: Table 7). The majority (98.4%) of the 371 coho salmon that were successfully aged were either age-2.1 or age-1.1 (Table 7). Of the six fish that were aged otherwise, four were age-1.2, one was age-2.2, and one was age-3.1. For both male and female coho salmon, age-1.1 dominated the sample, and there were a higher proportion of age-2.1 fish in the Unalakleet River than in the North River (Table 8).

Estimates of mean length of male and female coho salmon in the North River and Unalakleet River also substantiated size differences between the two drainages. The average size of male coho salmon in the North River was 571 mm MEF (SD = 58) and the average size of female coho salmon was 569 mm MEF (SD=44). The average size of male coho salmon sampled in the Unalakleet River was 579 mm MEF (SD = 63) and the average size of female coho salmon was 584 mm MEF (SD=41). The proportion of male coho salmon in the North River sample was 0.55 (SE = 0.023) and the proportion of male coho salmon in the Unalakleet River was 0.58 (SE = 0.027; Table 7).

There was also evidence of temporal differences in size and age compositions. The size distribution of coho salmon handled at the capture location during the first two quintiles of the run (between July 19 and August 13) was significantly smaller than the coho salmon handled during the last three quintiles of the run (between August 14 and September 23; D-statistic = 0.451, P-value < 0.01; Figure 4). This difference was also significant when males and females were examined separately (D = 0.447, P-value < 0.01 for males: D = 0.501, P-value < 0.01 for females). Coho salmon captured by gillnetting were excluded from this analysis. In addition, coho salmon captured during the first two quintiles of the run had a much higher proportion of age-1.1 and a smaller proportion of age-2.1 than did the coho salmon sampled during the last three quintiles of the run (between August 14 and September 23; Figure 11). The difference was significant for the North River (χ^2 = 14.59, P-value < 0.01) and the Unalakleet River (χ^2 = 6.23, P-value = 0.01). Additionally, for male coho salmon, the difference was significant in the North River (χ^2 = 6.11, P-value = 0.01) and was significant at the 91% confidence level in the Unalakleet River (χ^2 = 2.92, P-value = 0.09). For female coho salmon, the difference was also significant in the North River (χ^2 = 7.42, P-value = 0.01) and was significant at the 91% confidence level in the Unalakleet River (χ^2=2.86, P-value=0.09).

Table 7.–Estimated age, sex, and length composition of the coho salmon escapement in the Unalakleet River drainage, 2004.

Category	$\hat{p}_k$	SE($\hat{p}_k$)	$\hat{N}_k$	SE($\hat{N}_k$)
MEF Length (mm)				
≤570	0.273	0.066	20,099	4,054
>570	0.727	0.066	53,483	13,017
Sex/Age				
Male (total)	0.571	0.025	42,007	9,102
1.1	0.668	0.039	28,066	6,209
1.2	0.010	0.008	418	408
2.1	0.317	0.039	13,298	3,515
2.2	0	0.02	0	0
3.1	0	0.02	0	0
Female (total)	0.429	0.025	31,576	6,974
1.1	0.552	0.055	17,429	4,152
1.2	0.013	0.010	401	328
2.1	0.427	0.056	13,494	3,762
2.2	0.002	0.002	51	51
3.1	0.006	0.007	200	226

Table 8.–The proportion of male and female coho salmon that migrated up the North and Unalakleet rivers that were age-1.1 and -2.1 in 2004. Standard errors for estimates are in parentheses.

Sex	River	Age 1.1	Age 2.1
Males	North River	0.769 (0.042)	0.219 (0.041)
	Unalakleet River	0.651 (0.010)	0.333 (0.045)
	Entire Drainage	0.668 (0.039)	0.317 (0.039)
Females	North River	0.645 (0.053)	0.345 (0.053)
	Unalakleet River	0.534 (0.015)	0.443 (0.008)
	Entire Drainage	0.552 (0.055)	0.427 (0.056)

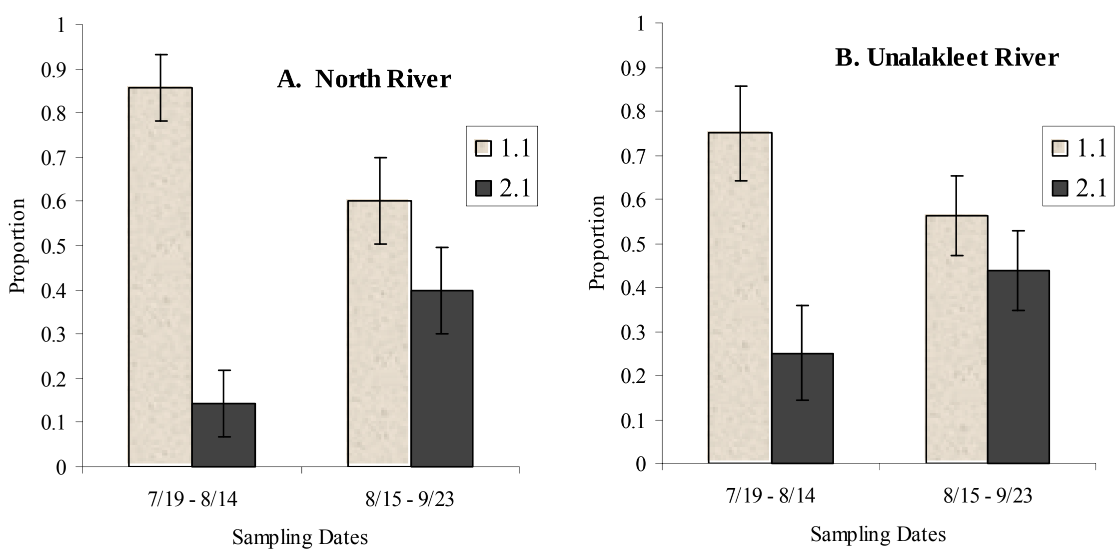

Figure 11**.–**The proportion of fish age-1.1 and -2.1 in the North (A) and Unalakleet rivers (B) during the first two run quintiles (coho sampled between 7/19 and 8/14/04) and the last three run quintiles (coho sampled between 8/15 and 9/23/04). Error bars represent 95% confidence intervals.

Age-2.1 coho salmon were, on average, larger than fish age-1.1 with the exception of females in the North River where there was no statistical difference between the size of fish age-1.1 and -2.1 (Figure 12).

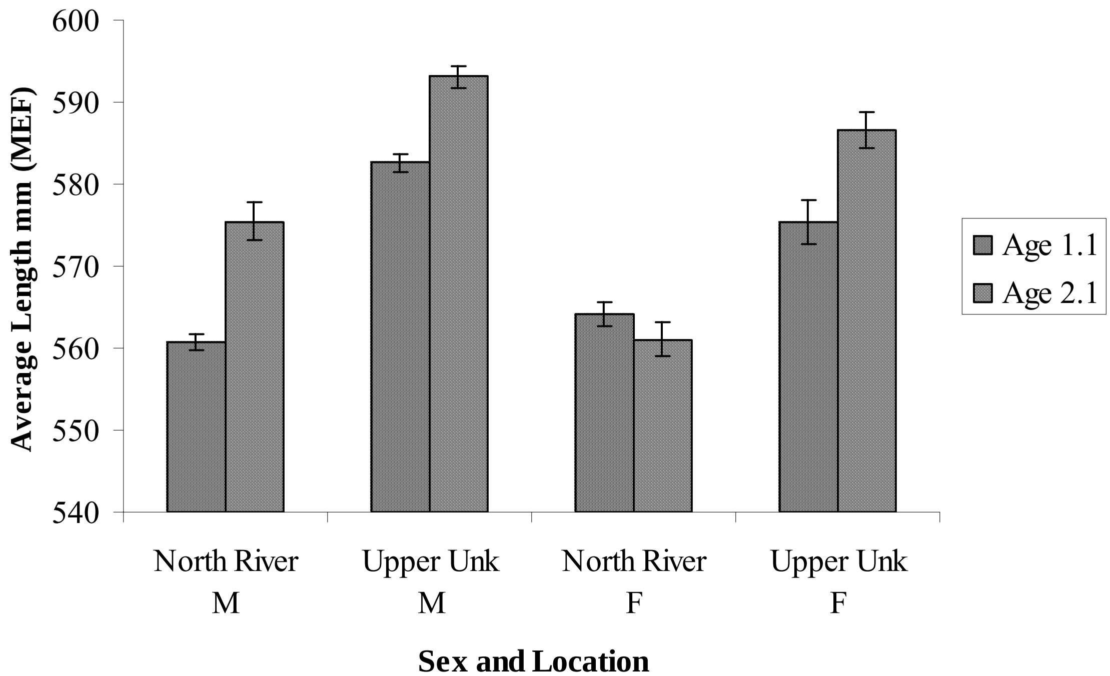

Figure 12.–Average length of male and female coho in the North and Unalakleet rivers that were age-1.1 and -2.1, 2004. Error bars represent 95% confidence intervals.

MARK-RECAPTURE EVALUATION EFFORTS

The feasibility of performing a conventional tagging mark-recapture study on Unalakleet River coho salmon was evaluated in conjunction with the upriver collection of ASL samples. Several suitable beach seining sites were located in the North and Unalakleet rivers. In the North River, the initial seining sites provided adequate numbers of fish during the first half of the run; however, after August 25 it became necessary to move progressively upriver to capture coho salmon. In the Unalakleet River, the upriver sampling location was adequate for capturing large numbers of coho until mid September after which several sites farther upriver had to be used. Upriver sampling was not possible during the August high water event because the current was too swift to effectively and/or safely seine.

After a total of 14 sampling days (4 seine hauls per river/per day), 324 coho salmon were sampled in the Unalakleet River upper location and 481 coho salmon were sampled in the North River. Three radio-tagged and/or opercular-punched coho salmon were recaptured in the Unalakleet River and two were recaptured in the North River. These small numbers were inadequate for making a meaningful estimate of coho escapement.

DISCUSSION

Spawning Distribution

Radio-tagged coho salmon were detected in every major tributary and in many tertiary streams over the course of the five aerial survey flights. The most coho salmon were detected in the section of the Unalakleet River above the Chiroskey River and below the North Fork. Only coho salmon from the last three quintiles of the run were detected in this section of the river (Figure 5). It is unclear why coho salmon would be clustered in this location. No ground-truthing was performed in this area to determine whether the coho salmon were holding, spawning, or dead. If this same clustered pattern is seen in future years of this study, on-the-ground observations will be attempted in order to ascertain fish status and habitat characteristics.

While Figure 5 represents the farthest upriver locations at which each radio-tagged coho salmon was detected, it may not necessarily represent the actual spawning destination of each radio-tagged fish. Of the 190 coho salmon that migrated past tracking stations, 83 moved downstream from their farthest detected upstream location based on tracking stations and aerial surveys. Thirty-three of these fish were recorded passing the lower tracking station and entering into the estuary. Nine of the coho salmon in the first quintile of the run were recorded as having backed out of the drainage before the first complete aerial survey on August 30.

Eighty-six of the radio-tagged coho salmon were detected in the same location during each of the aerial surveys. However, it is not known whether these fish were at their final spawning location, were still migrating, or had migrated downriver some distance from their actual spawning destination. It is likely that many of the coho salmon locations indicated in Figure 5 lie below the actual spawning location of the individual fish.

Despite the shortcomings of the telemetry data, the distributions of upper Unalakleet and mainstem coho salmon that appear in Figure 5 may nevertheless be indicative of a true biological pattern present in the population. While it is likely that some of the mainstem coho salmon that were not detected above the North Fork of the Unalakleet did migrate upstream of this point, it is also unlikely that all of these mainstem fish migrated past the North Fork, spawned, and then drifted down and settled in this portion of the river.

Although this was only the first year of a 3 year study and the actual proportions presented may be biased in favor of mainstem coho, the significant differences observed in the run timing, length distribution, age distribution and spawning locations suggest that there may be two relatively distinct groups of coho salmon migrating into the Unalakleet River drainage with overlapping run timing. Coho salmon migrating into the drainage between July 19 and August 13 were on average smaller, mostly age-1.1 and were destined for tributaries and the upper portion of the Unalakleet drainage. Coho salmon migrating into the drainage after August 14 were on average, larger, had an even proportion of age-1.1 and -2.1 fish and were mostly limited to the portion of the Unalakleet River below the North Fork. These differences were significant for both males and females and were not likely to be related to the earlier run timing of male coho.

North River and Unalakleet River Comparisons

Coho salmon sampled in the North River had a smaller mean length than those sampled in the Unalakleet River and had a significantly smaller length distribution (Figure 9). This is unlikely to have resulted from biased sampling as the same beach seine was used for sampling in both rivers, and sampling occurred in both rivers on sampling days. While North River coho salmon were smaller than their counterparts in the Unalakleet River, their run-timing (Figure 10) and age distribution (Figures 11 and 12) patterns were similar to coho salmon in the Unalakleet River. The run timing of North River coho salmon appeared to overlap the run timing of both *upper Unalakleet/tributary* coho and *mainstem coho* (Figure 10). Additionally, the pattern of more age-2.1 coho moving into the drainage later in the run was observed both in the North and Unalakleet rivers (Figure 11). Similarly age-2.1 coho salmon were larger than age-1.1 coho in both rivers. These patterns suggest that both the North River and Unalakleet River coho salmon stocks are composed of two runs of fish with an early run of smaller fish mostly age-1.1 and a later run of larger coho salmon age-2.1. There were no obvious distinctions in spawning distribution in the North River, but this may be due to the downriver migration of North River coho after spawning. More detailed telemetry data will be needed to discern if there are distinct spawning distributions within the North River.

The primary purpose of this study was to determine if the estimates/counts of coho salmon from the North River counting tower could be expanded to provide a reliable estimate of coho salmon escapement into the entire Unalakleet River drainage. Results from this year suggest that the North River coho salmon tower count may be an appropriate index for the entire Unalakleet River drainage. Diagnostic tests indicated that there were no significant differences between the Unalakleet River and North River with regards to run timing, size distribution and age distribution when the coho were stratified into two different size categories (≤ 570 mm and > 570 mm MEF). Data from the coming years will help determine whether these patterns remain consistent over time.

AGE COMPOSITION

The relative abundance of age-1.1 and -2.1 coho salmon spawning in the North and Unalakleet rivers in 2004 appeared to vary temporally and geographically. Whether this pattern is consistent from year to year or highly variable between years, or alternatively, was an artifact of sampling during 2004, will only be determined after examining data collected in subsequent years of this experiment. The mixture of coho age-1.1 and -2.1 is not unusual for coho stocks and the ratios observed in this study are comparable to other studied coho runs at this latitude (Sandercock 1991). The age ratio within a stock may vary between years (Sandercock 1991) and data from future seasons will allow the comparison of interannual variation in age ratios. While there were apparent age structure patterns with a higher proportion of age-2.1 coho salmon being detected later in the run and in both the North and Unalakleet rivers, the patterns are ambiguous.

If this relationship is more than coincidental, one may hypothesize that tributary spawners (and tertiary spawners in the North River) tend to be earlier running coho salmon that are age-1.1, while fish spawning in the lower Unalakleet and the mainstem of the North tend to be later running and age-2.1. This may indicate that the upper reaches of the drainage, and tertiary streams in particular, offer favorable habitat to coho salmon fry allowing them to progress to smolt stage in 1 year. The lower reaches of the drainage may offer the later running coho salmon less favorable rearing habitat thus necessitating 2 years in fresh water before they reach smolt stage. Taking scale samples from all radio-tagged coho salmon, performing more aerial surveys and setting up more tracking stations may help to elucidate these differences.

SUGGESTIONS FOR YEARS 2 AND 3

One of the goals of this first year was to assess the logistics and sampling techniques for the following 2 years of the study. In 2004 beach seining was found to be a highly efficient and effective method for capturing coho salmon, and it resulted in a sample with an unbiased size distribution. However, 2004 was an unusually warm and dry year and the resulting low water levels were particularly conducive to seining. Drift gillnetting was only necessary during a five day high water event in August when seining was impossible. This high water event was extreme and exceeded by an order of magnitude the highest recorded stream flows during all coho seasons since 1997 (USGS Real-Time Water Data for Alaska http://waterdata.usgs.gov/ak/nwis/uv). If future years produce more average weather patterns (higher mean water levels and no extreme high water events) it is unclear if seining will be successful. If seining is not possible it will be important to keep a gillnetting sampling protocol in place.

In 2004 several shortcomings were noted in the tracking and locating of coho salmon. The proportion of the run that migrated to the Upper Unalakleet and tributaries was probably underestimated because many of the early running coho salmon were not tracked to spawning locations and many fish migrated downriver after spawning. In the future, earlier and more frequent aerial survey flights will help to better understand this issue. Additionally, more tracking towers will be needed to provide further detail on the movement of tagged coho salmon. The South River enters the Unalakleet River below the North River and therefore it was possible for coho salmon to spawn in the South River and exit the system without passing any tracking stations other than the one below the tagging location. A tracking tower on another tributary such as the Chiroskey River will allow for an estimation of how many coho are entering and exiting that particular tributary before being recorded by an aerial survey. An additional tower at the confluence of the North Fork of the Unalakleet will help to elucidate the importance of the section of the Unalakleet River that lies below the North Fork and above the Chiroskey River.

The upriver fishing effort applied in 2004 did not provide enough recaptures for a meaningful mark-recapture estimate of coho escapement and we do not consider upriver sampling with seines to be a logistically feasible alternative to employ as a second event sampling effort. Using the North River tower counts as a second event with radio-tagged fish serving as marks is logistically feasible; however, a larger sample of radio-tags will need to be deployed in order to provide a reasonable expectation of realizing our precision criteria for estimating abundance.

In future seasons, on-the-ground observations should be attempted in the section of the Unalakleet River that is above the Chiroskey River and below the North Fork in an attempt to identify why coho salmon would be clustered in this section of river. Surveys should include habitat descriptions, and observations of coho salmon status (live, dead, holding, etc.).

The 2004 season provided initial evidence for the existence of two overlapping coho runs in the Unalakleet River drainage as shown by run-timing, spawning distribution, size distribution patterns and age patterns. More detailed data should be collected to further examine the system. In future year's scales will be taken from all radio-tagged coho to determine if different aged fish are spatially segregated in spawning distribution. Furthermore, a simple index indicating the spawning condition of the coho upon capture (e.g., chrome, blush, rosy, and red) may further help to determine the nature and timing of the coho run.

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REFERENCES CITED

Bailey, N. J. T. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38: 293-306.

Bailey, N. J. T. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21: 120-127.

Carlin, B. P., T. A. Louis. 2000. Bayes and empirical bayes methods for data analysis, 2nd ed. Chapman & Hall/CRC. New York. 419pp.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. No. 1: 131-160.

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

Conover, W. J. 1980. Practical nonparametric statistics 2nd ed. John Wiley & Sons, New York. 493pp.

Darroch, J. N. 1961. The two sample capture-recapture census when tagging and sampling are stratified. Biometrika 48:241-260.

Estensen, J. L. *In prep*. Abundance estimation and distribution of chum salmon in the Unalakleet River drainage using radio telemetry and mark and recapture techniques. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Jones, W. W. *In prep*. North River salmon counting tower project, 2002-2004. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Manly, B. F. J. 1997. Randomization, bootstrap and Monte Carlo methods in biology 2nd ed. Chapman & Hall / CRC. Boca Raton, FL. 399pp.

Mosher, K. H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. United States Department of the Interior, U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Washington, D.C., Circular 317.

Ryan, P, and M. Christie. 1976. Scale reading equipment. Fisheries and Marine Service, Canada, Technical Report PAC/T-75-8, Vancouver.

Sandercock, F. K. 1991. Life history of coho salmon (Oncorhynchus kisutch). *In* C. Groot and L. Margolis, editors. Pacific Salmon Life Histories. UBC Press, Vancouver, British Columbia.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffen and Company, Limited, London.

Sloan, C. E., D. R. Fernodle, and R. Huntsinger. 1986. Hydrologic reconnaissance of the Unalakleet River Basin, Alaska, 1982-83. U.S. Geological Survey Water Resources Investigations Report 86-4089. 18p.

Wuttig, K. G. and M. J. Evenson. 2002. Assessment of Chinook, chum, and coho salmon escapements in the Holitna River drainage using radiotelemetry, 2001. Alaska Department of Fish and Game, Fishery Data Series No. 02-05, Anchorage.

APPENDIX A

Appendix A1.–Statistical tests for evaluating sex and size bias and the assumptions of a two-event mark-recapture experiment conducted on Chinook salmon in the Kuskokwim River, 2005.

The following statistical tests will be used to analyze the data for significant bias due to gear selectivity by sex and length.

A test for significant gear bias by sex will be based on a contingency table of the number of males and females that were recaptured and were not recaptured. The chi-square statistic will be used to evaluate the bias. If this test indicates a significant bias, then the following tests will be conducted for males and females separately. If this test does not indicate a bias, then males and females will be pooled and the following tests will be performed on the pooled data.

Tests for significant gear bias by size are based on Kolmogorov-Smirnov two sample tests that compare cumulative length frequency distributions of: A) all Chinook salmon marked in the first event and marked fish that pass through the weirs in the second event; and, (B) all Chinook salmon marked in the first event and those Chinook salmon sampled for age, sex, and length at the four weirs (subsample of the total second event sample). The null hypothesis assumes no difference between the distributions of length for Test A or for Test B. For these two tests there will be four possible outcomes.

Case I. Accept both A and B.

There is no size-selectivity during either sampling event.

Case II. Accept A and Reject B.

There is no size-selectivity during the second sampling event but there is size-selectivity during the first.

Case III. Reject A and Accept B.

There is size-selectivity during both sampling events.

Case IV. Reject both A and B.

There is size-selectivity during the second sampling event but the status of size-selectivity during the first is unknown.

Depending on the outcome of the tests, the following procedures will be used to estimate the abundance of the population:

Case I. One unstratified abundance estimate will be calculated and the length, sex, and age data from both sampling events will be pooled in order to improve precision of the proportions in estimating the age, sex and length composition that represents the estimated population.

Case II. One unstratified abundance estimate will be calculated and the length, sex, and age data will be taken from the second sampling event.

Case III. Both sampling events will be completely stratified and abundance will be estimated for each stratum. Abundance estimates will get summed across strata in order to get a single estimate for the population. Length, age, and sex data from both sampling events will be pooled in order to improve precision of composition proportions and a formula will be applied to correct for the size bias in the pooled data.

Case IV. Both sampling events will be completely stratified and abundance will be estimated for each stratum. Abundance estimates will get added across strata in order to get a single estimate for the population. Also, one unstratified estimate will be calculated for the population. Length, age, and sex data from the second sampling event will be used to estimate the age, sex, and length composition for the estimated population and formulae will be applied to correct for size bias to the data from the second event.

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

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

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

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

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

I.-Test For Complete Mixing[a]

Area/Time Where Marked	Area/Time Where Recaptured				Not Recaptured
	1	**2**	**…**	**t**	(n_1-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-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-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.-Data files used to estimate parameters of the coho salmon abundance and length, age and sex distributions in the Unalakleet River drainage, 2004.

Data File	Description
04UnakPopEst.xls[a]	Excel spreadsheet with finalized population parameters and estimates.
Chapman Estimates – Unk Coho 2004.xls[a]	Excel spreadsheet with finalized Chapman calculations and estimates for coho abundance.
Tagged Coho Log – Final.xls [a]	Excel spreadsheet with consolidated data on all radio-tagged coho including calculations used in Chapman estimates.
Unk Coho Master Data – Final.xls[a]	Excel spreadsheet with raw data on all captured and sampled coho in the Unalakleet River drainage in 2004 including data from upriver sampling occasions.

[a] Data files have been archived at the Alaska Department of Fish and Game, Research and Technical Services, Anchorage, Alaska 99518; and are available from the authors, Division of Sport Fish, 1300 College Road, Fairbanks, AK 99701.