Fishery Data Series No. 98-8

Escapement of Chinook Salmon in the Unalakleet River in 1997

by

Klaus G. Wuttig

May 1998

Alaska Department of Fish and Game Division of Sport Fish

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
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

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

Spell out acre and ton.

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s

Spell out year, month, and week.

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
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.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
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
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 98-8

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May 1998

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-13, Job No. S-3-1(b).

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This document should be cited as:
Wuttig, K. G. 1998. Escapement of chinook salmon in the Unalakleet River in 1997. Alaska Department of Fish and Game, Fishery Data Series No. 98-8, Anchorage.

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ABSTRACT

During 1997, radio telemetry in conjunction with a counting tower on the North River was used to estimate escapement of adult chinook salmon *Oncorhynchus tshawytscha* in the Unalakleet River drainage, Alaska. The estimate was attained by expanding the North River counting tower escapement estimate by the proportion of chinook salmon that migrated up the river as determined from a remote tracking station placed at the confluence of the North and Unalakleet rivers which recorded the movements of radio-tagged salmon. A total of 151 chinook salmon were esophageally implanted with pulse-encoded transmitters. Of the 145 (96%) fish which were successfully located, 37.2% (SE = 4.0) and 62.8% (SE = 4.0) swam up the North and Unalakleet rivers, respectively. Estimated escapements for the North River and the entire Unalakleet River drainage were 7,002 (SE = 471) and 18,802 (SE = 2,215) chinook salmon, respectively. Chinook salmon carcasses were collected in the Unalakleet River drainage to estimate age-sex-length compositions. Females comprised 0.25 (SE = 0.03) of the sample. Age class 1.4 comprised the largest proportion of the females sampled, while age class 1.2 comprised the largest proportion of the males sampled.

Key words: chinook salmon, *Oncorhynchus tshawytscha,* Unalakleet River, North River, radio telemetry, counting tower, abundance, escapement, carcass survey, age-sex-length compositions

INTRODUCTION

The Unalakleet River is located north of the mouth of the Yukon River in Norton Sound (Figure 1). The Unalakleet River and its tributaries drain an area approximately 2,700 square km as it flows southwesterly through the Nulato Hills (Sloan et al. 1986). The Unalakleet River supports an important chinook salmon *Oncorhynchus tshawytscha* run which sustains the largest subsistence, commercial, and sport harvests in Norton Sound.

Since 1989, annual chinook salmon sport harvests have averaged around 250 chinook salmon, while annual catches have averaged about 460 fish (Table 1). Angler effort on the Unalakleet River has been estimated to range from 1,700 to 5,500 angler days annually since 1989, however, only a part of this is directed toward chinook salmon (Mills 1986-1994, Howe et al. 1995-1997). Other sport caught species in the drainage include pink salmon *O. gorbuscha*, chum salmon *O. keta*, coho salmon *O. kisutch*, Dolly Varden *Salvelinus malma*, and Arctic grayling *Thymallus arcticus signifier*. Commercial harvests of chinook salmon have ranged from 2,218 to 12,621 since 1982. Commercial catches have averaged around 5,450 fish (Table 1), and the 1995 harvest of 7,617 was the second highest on record (Bue et al. 1996). Despite the important sport and commercial fisheries, no escapement goals for chinook salmon have been established in the Unalakleet River and there are no harvest guidelines. The lack of escapement goals and harvest guidelines is largely due to unsuccessful attempts at estimating the chinook salmon escapement.

Historically, the Commercial Fisheries Management and Development Division (CFMD) has assessed the Unalakleet River chinook salmon escapement, in part, through aerial surveys (Table 2). However, problems with water clarity and channel morphometry have limited the ability of CFMD to adequately assess salmon spawning escapements in the Unalakleet River using aerial survey techniques. This is in contrast to the North and Old Woman rivers which are smaller and tend to run more clear (Figure 1). Existing aerial survey data suggested that about half of the escapement of chinook salmon spawn in the North River, but this is thought to be biased high because of higher detectability in the North River's clear water (Table 2).

In addition to aerial surveys, CFMD uses a standardized (since 1981) test net (5.875 in stretch measure gillnet) project as an escapement index, and data from commercial catches to manage

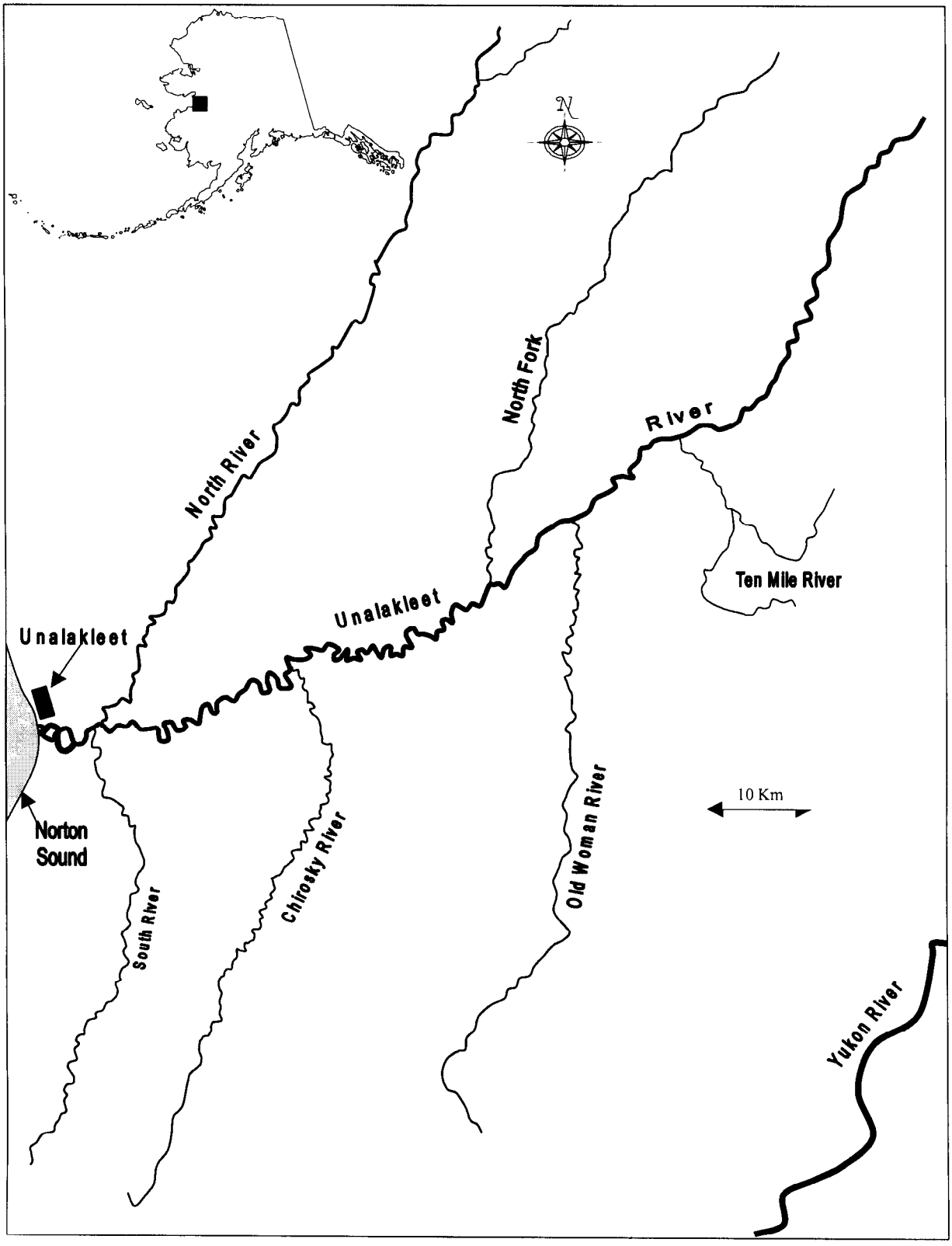

Figure 1. -Unalakleet River drainage.

Table 1.-Unalakleet River chinook salmon commercial harvests, sport harvests and catches, test net catches, and North River tower counts.

Year	North River Tower Count[a]	Sport Catch[b]	Sport Harvest[b]	Commercial Harvest[c]	Commercial Catch CPUE[c]	Test Net Catches[c]	Test net CPUE[c]
1982				3,768	1.65	22	2.74
1983				7,022	2.65	18	2.55
1984	2,844	---	39	6,804	4.44	41	3.63
1985	1,426	---	179	12,621	4.75	171	9.93
1986	1,613	---	850	4,494	1.98	49	2.19
1987		---	---	3,246	2.77	42	2.23
1988		---	---	2,218	1.64	13	0.67
1989		---	49	4,402	2.74	45	2.03
1990		361	276	5,998	3.64	41	1.82
1991		375	296	4,534	2.63	33	1.71
1992		476	117	3,402	1.72	23	1.18
1993		2,340	382	5,944	4.08	91	4.61
1994		517	379	4,400	5.07	35	1.53
1995		588	259	7,617	2.15	85	4.79
1996	1,197	431	176	3,644	2.84	139	6.53

[a] North River tower counts from Rob 1997a.

[b] Sport fish catch and harvest from Mills 1983-1994; Howe et al. 1995-1997.

[c] Commercial harvest and CPUE, and test net catch and CPUE from Rob 1997b.

Table 2.-Summary of aerial survey counts for the Unalakleet River drainage, 1980-1997.

	North River		Old Woman River		Unalakleet River	
Year	Count	Remarks	Count	Remarks	Count	Remarks
1980	61	a	25		-	
1981	31	a	26		3	
1982	4	a	-		-	
1983	347	a	-		-	
1984	51	a	-		-	
1985	873	b	202	f	400	?
1986	-		-		367	?
1987	432	b	130		341	j
1988	202	c	311	g	923	k
1989	-				-	
1990	231	d	211	h	484	k
1991	656	c	389	i	1244	k
1992	329	c	-			
1993	900	e	387	i	253	k
1994			-		-	
1995	622	c	424	i	532	k
1996	106	c	55	i		
1997	1585	c	246	i	984	k

Data from C. Lean, ADF&G, Nome, personal communication, 1997.

Remarks

a Area surveyed not known.
b Mouth to headwaters.
c Mouth to river mi 40 (Sunquist).
d Mouth to river mi 50.
e Mouth to river mi 30.
f Mouth to river mi 15.
g Mouth to river mi 40.
h Mouth to river mi 30.
i Mouth to river mi 25 (Chirosky pass).
j River mi 37 (mink farm) to above Old Woman.
k River mi 45 (Auley's cabin) to Ten Mile River.
? River section unknown.

the chinook salmon fishery (Rob 1997b). Although commercial catches suggest that escapement has remained constant, the ranges of catch per unit effort (CPUE) for the commercial harvest (1.64 to 5.07) and test net catch (0.67 to 9.93) show that the chinook salmon escapements are variable (Table 1). Furthermore, commercial harvests may include fish from other stocks such as the Yukon or Shaktoolik rivers and may not provide dependable indices of run strength to the Unalakleet River.

Other methods implemented to assess salmon escapement have included sonar, inseason subsistence surveys, and counting towers (Rob 1997b). Hydroacoustic counting techniques were unsuccessful in three prior years (Rob 1997b). Estimates of subsistence harvests are limited and were 3,026 and 2,894 for 1995 and 1996, respectively (Bue et al. 1996 and 1997). Chinook salmon have been successfully counted on the North River during 1984 - 1986, and 1996 (Table 1).

Given the relative success of the North River Tower project in past years, this project was initiated as an attempt to describe the chinook escapement into the Unalakleet River in 1997 through the use of radio transmitters implanted in migrating chinook salmon. The specific objectives of the Unalakleet River chinook salmon project in 1997 were to: estimate the proportions of the chinook salmon escapement migrating up the North River, the main stem of the Unalakleet River, the Chirosky River, the North Fork of the Unalakleet River, the Old Woman River, and the Unalakleet River upstream of its confluence with the Old Woman River through the use of radio telemetry; estimate the abundance of chinook salmon escaping into the Unalakleet River drainage by proportional expansion of the North River tower count estimate, or, in the event of failure of the tower to enumerate the run into the North River, estimate abundance with mark-recapture techniques; and estimate the age, size, and sex composition of the chinook salmon escapement into the Unalakleet River drainage.

METHODS

To estimate the proportions of the chinook salmon escapement migrating up the North River and the Unalakleet River and it's tributaries, radio-tags were implanted in chinook salmon downstream from the mouth of the North River. A remote data logger and receiver placed at the mouth of the North River recorded the passage of radio-tagged salmon as they migrated either up the North River or up the main stem of the Unalakleet River. Salmon distributions were further determined using aerial and boat tracking. A counting tower was established on the North River by the Kawarek Corporation Fisheries Group to estimate the number of chinook salmon migrating up the river. The entire Unalakleet River chinook salmon escapement was then estimated by expanding the North River tower count by the inverse proportion of chinook salmon swimming up the North River. Chinook salmon carcasses were collected to determine age-sex-length compositions and to look for marked fish for determining the feasibility of a future mark-recapture experiment should the counting tower be unsuccessful.

CHINOOK SALMON CAPTURE, HANDLING, AND TELEMETRY

Chinook salmon were captured 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 from 16 June to 14 July (Figure 2). This tagging location was upstream from the majority of the subsistence effort, and downstream from the majority of the sport fishing effort. Fish were captured by setting a gillnet (20.3 cm stretch mesh, 52 m long, and 4.5 m deep) across a shallow channel (approximately 75 m wide and ≤ 2 m deep) utilized by migrating salmon. The net was set

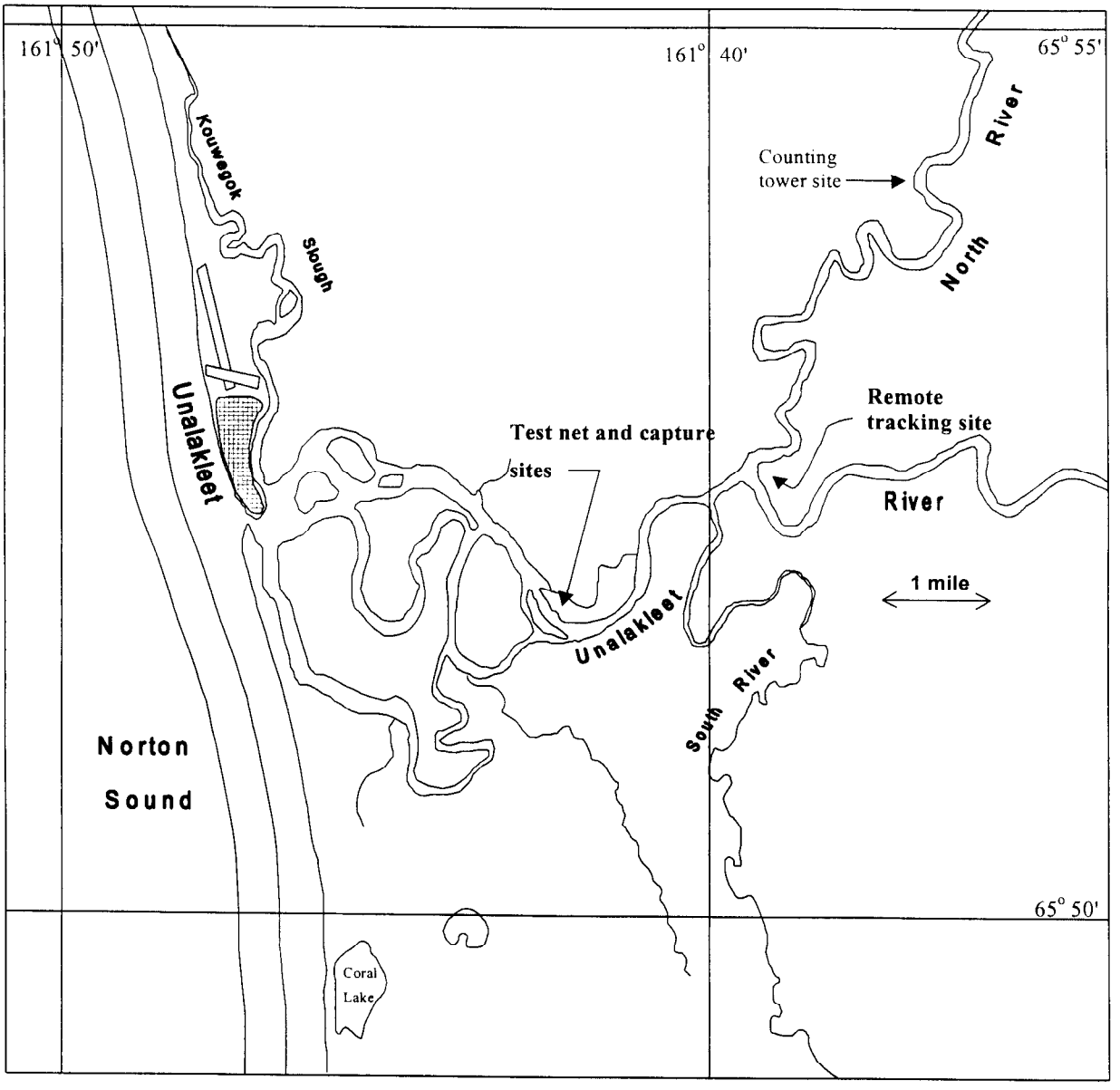

Figure 2.-Unalakleet River capture, test net, remote tracking station, and North River counting tower sites, 1997.

perpendicular to shore with one end secured to shore and the other end (lead-line and float-line) fixed to the stream bottom using 25 lb boat anchors. The net blocked approximately 2/3 of the channel, allowing for boat passage past the site. The net was set so that it angled downstream (lead-line upstream of the float-line) such that a fish would swim under and then into the net. The gillnet was fished for five hours a day, four hours prior to and one hour after high tide, when catch rates tended to be greater. During this time the incoming tide slowed the water velocity enough so that the net would not be washed downstream. Tidal fluctuation ranged from 2 to 4 feet at the capture site. After some experimentation, the method (duration, location, and timing) used for capturing chinook salmon was standardized on 17 July. A two-man crew in a 18' boat waited at the off-shore end of the net to deter fish from migrating around the end of the net and to watch for entangled fish. Once a chinook salmon was entangled, the boat was positioned downstream of the fish, the net was pulled over the bow, and the salmon was placed into a holding tub and removed from the net.

Initially drift netting was attempted to capture chinook salmon. Two-men crews drifted gillnets of varying length (50, 80, 100, and 150 m) downstream through the deepest parts of the river channel within a 3 km section of river below the mouth of the North River. However, numerous snags (rocks and woody debris) on the channel bottom prohibited the use of this capture method. Only five chinook were captured by drift netting.

Once captured, the chinook salmon were placed into a tagging cradle submerged in a trough of water. Radio-tags were inserted through the esophagus and into the upper stomach (esophageal implants) using a 45 cm plastic tube with a diameter equal to that of the radio-tags. The end of the plastic tube was slit lengthwise allowing for the antenna end of the transmitter to be seated into the tube and held in place by friction. The transmitter was pushed through the esophagus such that the antenna end was seated 0.5 cm beyond the base of the pectoral fin. A second tube was slid down the inside of the first tube to unseat the radio transmitter. A total of 151 transmitters were implanted and an attempt was made to distribute the tags proportional to run strength by standardizing fishing effort. Initially, every fish captured during a standardized fishing day was implanted. As run intensity increased, every other, or every third fish captured was not tagged to ensure that tags were distributed over the entire run. For days when not all chinook salmon captured were radio-tagged, a weighting factor was applied to the number of tags that migrated up either the mainstem Unalakleet River or the North River. A weighted proportion of fish migrating up the North River was calculated and compared to the actual proportion migrating up the North River. Dissimilar estimates would imply that run timing varied and tags were not distributed proportional to run strength. The sample size was determined based on objective criteria for estimating proportions of chinook salmon spawning in the various tributaries such that the estimated proportions were within 10% of the true value 95% of the time according to Thompson (1987). This sample size was then adjusted upward by 15% to account for mortality and tag failure. All chinook salmon captured were measured to the nearest 5 mm (mid-eye to fork of tail) and data were recorded on mark-sense forms. Three scales were removed from each fish and placed on gum cards for age determination. Sex determination from external characteristics was not reliable. All chinook salmon captured received an individually numbered jaw tag. The entire handling process required 1 - 2 min per fish and was done without the use of anesthesia. After handling, chinook salmon were taken upstream and placed into quiet backwater areas for recovery.

All fish received a model five pulse encoded transmitter made by ATS (Advanced Telemetry Systems, Isanti, Mn). The transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 18 g, and had a 30.0 cm external whip antenna. Maximum battery life was about four months. Each radio-tag was distinguished by its frequency and encoded pulse pattern. Fifteen frequencies spaced approximately 20 kHz apart in the 150-151 MHz range with 10 encoded pulse patterns per frequency were used for a total of 150 uniquely identifiable tags. One radio-tag was recovered from a subsistence gillnet and was reimplanted for a total of 151 transmitters deployed.

Migrating radio-tagged fish were tracked and recorded as going up either the North River or the mainstem of the Unalakleet River using a remote tracking station. The station was comprised of integrated components; a marine deep cycle battery, an ATS model 5041 Data Collection Computer (DCC II); an ATS model 4000 receiver, and two Yagi antennas. The receiver and DCC were used to detect, identify, and record the radio-tags. The station was placed at the confluence of the North and the Unalakleet rivers with an elevated (3 m) Yagi antenna aimed up each river. The receiver and DCC were programmed to scan through the 15 frequencies at 3 s intervals on each antenna. If no fish were detected, the DCC and receiver were able to cycle through all 150 tags in a period of 1.5 min (15 frequencies x 3 s per frequency x two antennas). This relatively short cycle period minimized the chance that a radio-tagged fish could swim past the receiver site without being detected. If a tag was detected the program would pause for six seconds to record the tag identity, time, signal strength, and antenna number (corresponding to the river). It was also possible that 10 coded tags of a single frequency could pass the receiver at the same time, and that some transmitters could be missed. To minimize the chance of this occurring, the order of the tag frequencies implanted in the fish were rotated through the frequency sequence and repeated until all tags were used.

The distribution of radio-tagged chinook salmon throughout the Unalakleet drainage was further determined by aerial tracking from small aircraft after all fish had moved to spawning areas. One radio tracking flight was conducted on 28 July. The North River, the main stem of the Unalakleet River, the Chirosky River, the North Fork of the Unalakleet River, and the Old Woman River were all surveyed. Total flight time was approximately 5 h.

TOWER COUNTS

Chinook salmon and the other species of salmon returning to the North River were estimated by counting fish as they passed beneath an elevated counting site. The counting tower was operated by the Kawarek Corporation fisheries group under the advice of CFMD. A counting tower, diversion weir, flash panel, and campsite were constructed on the north side of the North River approximately three river miles upstream from it's confluence with the Unalakleet River (Figure 2). Counting was conducted from 16 June through 23 August. Water clarity remained good during the chinook salmon run and visibility was sufficient to accurately count all passing fish.

Three persons were assigned to conduct counts. The sampling schedule was set up such that each sampling day was divided into three 8-h shifts to cover the 24-hour day. Counts were conducted for the first 1/2 h of each hour during each 8-h shift. Shifts I, II, and III started at and ended at 00:00 - 7:59, 08:00 - 15:59, and 16:00 - 23:29, respectively (Appendix A). Shifts not counted were staggered so that a minimum of two shifts were counted each day. Scheduling conflicts with the tower personnel resulted in some deviation from the desired sampling schedule.

ABUNDANCE ESTIMATOR: NORTH RIVER

Estimates of abundance were stratified by day. Abundance estimates were considered a two-stage direct expansion where the first stage is a shift within an eight-hour day and the second stage is 30 min counting periods within a shift. Both stages were considered systematic sampling because neither the shift nor the 30 min counting period were chosen randomly.

The number of salmon to pass by the tower per day was estimated:

$$\hat{N}_d = \overline{Y}_d H_d \tag{1}$$

$$\hat{V}\left[\hat{N}_d\right] = \left(1 - f_{1d}\right) H_d^2 \frac{s_{1d}^2}{h_d} + f_{1d}^{-1} \sum_{i=1}^{h_d} \left[M_{di}^2 \left(1 - f_{2di}\right) \frac{s_{2di}^2}{m_{di}} \right] \tag{2}$$

where:

$$\overline{Y}_d = \frac{1}{h_d} \sum_{i=1}^{h_d} \frac{\sum_{j=1}^{m_{di}} Y_{dij}}{m_{di}} \tag{3}$$

$$s_{1d}^2 = \frac{\sum_{i=1}^{hd} \left(Y_{di} - \overline{Y}_d\right)^2}{h_d - 1} \tag{4}$$

$$s_{2hi}^2 = \frac{\sum_{j=2}^{m_h} \left(y_{hij} - y_{hij-1}\right)^2}{2\left(m_{hi-1}\right)} \tag{5}$$

$$f_{1d} = \frac{h_d}{H_d} \tag{6}$$

$$f_{2di} = \frac{m_{di}}{M_{di}} \tag{7}$$

d	=	day;
i	=	8 h shift;
j	=	30 min counting period;
Y	=	number of chinook salmon counted;
m	=	number of 30 min counting periods sampled in a shift;
M	=	total number of possible 30 min counting periods;
h	=	number of 8 h shifts sampled;
H	=	total number of possible 8 h shifts;
D	=	total number of possible days;
f_1	=	fraction of 8 h shifts sampled;
f_2	=	fraction of 30 min counting periods sampled;

s_2^2 = estimated variance of total across counting periods; and,

s_1^2 = estimated variance of total across shifts.

The abundance of chinook salmon passing the counting tower was then estimated using:

$$\hat{N} = \sum_{d=1}^{D} \hat{N}_d \tag{8}$$

$$\hat{V}\left(\hat{N}\right) = \sum_{d=1}^{D} \hat{V}\left(\hat{N}_d\right) \tag{9}$$

When k consecutive days were not sampled, the moving average estimate for the missing day i was calculated as:

$$\hat{N}_i = \frac{\sum_{j=i-k}^{i+k} I(day\ j\ was\ sampled)\hat{N}_j}{\sum_{j=i+k}^{i+k} I(day\ j\ was\ sampled)} \tag{10}$$

where:

$$I(\cdot) = \begin{cases} 1 & when\ the\ condition\ is\ true \\ 0 & otherwise \end{cases} \tag{11}$$

is an indicator function.

The estimate of the daily variation for missed days was the maximum variance of the k days before and the k days after the missed day i.

ABUNDANCE ESTIMATOR: UNALAKLEET RIVER

The number of chinook salmon escaping into the Unalakleet River was estimated by expanding the North River tower count by the proportion of chinook salmon carrying radio transmitters which migrated up the North River:

$$\hat{N}_{total} = \frac{\hat{N}_{NR}}{\hat{P}} \tag{12}$$

where:

$\hat{N}_{NR}$ = The number of chinook salmon estimated past the North River tower, and

$\hat{P}$ = The estimated proportion of radio-tagged chinook salmon which moved up the North River.

The variance of the total abundance was estimated using Goodman's (1960) formula for an exact variance of a product:

$$V\left[\hat{N}_T\right] = \left(\frac{1}{\hat{P}}\right)^2 \left(V\left[\hat{N}_{NR}\right]\right) + \left(\hat{N}_{NR}\right)^2 \left(V\left[\frac{1}{\hat{P}}\right]\right) - \left(V\left[\frac{1}{\hat{P}}\right]\right)\left(V\left[\hat{N}_{NR}\right]\right) \tag{13}$$

where:

$V\left[\hat{N}_{NR}\right]$ = variance of the estimate

of chinook passage past the North River tower,

$$V\left(\frac{1}{\hat{P}}\right) = \frac{1}{\hat{P}^4} V(\hat{P}) \quad \text{by the delta method.} \tag{14}$$

AGE-SEX-LENGTH COMPOSITIONS

Chinook salmon carcasses were collected from a drifting river boat using long-handled spears. Carcasses were collected from the mainstem of the Unalakleet River 85 to 105 km (5 km upstream of the Old Woman confluence) from it's mouth. In the North River, carcasses were collected 22 to 35 km upstream from it's confluence with the Unalakleet River. The upper limit of the sample areas in both rivers was the furthest point which the river boat (18 ft with a 40 hp jet motor) could navigate. Carcass samples were taken from the Unalakleet and North rivers from 30-31 July, and 3-4 August, respectively.

Data collected from carcasses included the following: date, sex, approximate location, and length (mid-eye to fork-of-tail). Sex was determined from external characteristics and by stripping residual gametes. Three scales were removed from each fish and placed directly on gum cards (ten fish per card) for age determination. Scales were removed from the left side 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 (Welander 1940). Ages were determined from scale patterns as described by Mosher (1969).

Proportions of female and male chinook by ocean-age or 25 mm length category and the associated variances were estimated using:

$$\hat{p}_g = \frac{n_g}{n} \tag{15}$$

$$\hat{V}(\hat{p}_g) = \frac{\hat{p}_g(1-\hat{p}_g)}{n-1} \tag{16}$$

where:

$\hat{p}_g$ = estimated proportion of chinook salmon in age or length class g;

n_g = number of chinook salmon in age or length class g; and,

n = total number of chinook salmon sampled.

MARK-RECAPTURE EXPERIMENT

Favorable environmental conditions at the North River tower permitted successful counting and abundance estimation of chinook salmon. Therefore, the alternative mark-recapture experiment was not necessary. However, the mark recapture data were examined and an abundance estimate was calculated to help assess the feasibility of performing a two sample mark-recapture experiment in 1998 should it prove necessary.

Marking Event

All chinook salmon captured in the gillnet while applying radio-tags were marked with a numbered jaw tag. As noted, length data was recorded and scale samples were taken. No secondary marks were used (e.g. clipping of the adipose fin) due to negligible loss of jaw tags (Evenson, 1996). The target sample size was 300-500 chinook salmon during the marking event.

Recapture Event

Collected chinook salmon carcasses were used for the recapture sample. All chinook salmon collected during the carcass survey were inspected for marks (jaw tags), sex was determined, and length measured to the nearest 5 mm (mid-eye to fork-of-tail). After handling, the adipose fin was removed from each chinook to avoid resampling. The radio receiver was not used as an aid in finding salmon carcasses to prevent biased sampling of the population. Radio transmitters were removed from all carcasses that were carrying one. A similar sample size of 300-500 chinook salmon was anticipated during this event.

Data Analysis

An unbiased estimate of abundance from a two-event mark-recapture experiment (Seber 1982) requires that the following two assumptions must be fulfilled:

1. catching and handling the fish does not affect the probability of recapture; and,
2. marked fish do not lose their mark.

Catching and handling the fish should not affect the probability of recapture because the experiment is designed to mark live fish and later recover carcasses.

Of the following assumptions, at least one must be fulfilled:

1. every fish has an equal probability of being marked and released during gillnetting;
2. every fish has an equal probability of being collected during the carcass survey; or,
3. marked fish mix completely with unmarked fish between events.

The procedures for testing these assumptions and the methods for alleviating bias due to gear selectivity are described by Bernard and Hansen (1992). For the purposes of this study a Chapman (1951) modified estimator was used:

$$\hat{N}^* = \left[\frac{(n_1 + 1)(n_2 + 1)}{(m_2 + 1)} \right] - 1 \tag{17}$$

$$V(\hat{N}^*) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)} \tag{18}$$

where:

$\hat{N}^*$ = the estimated abundance of chinook salmon;
n_1 = the number of fish marked while electrofishing;
n_2 = the number of carcasses collected during the carcass survey; and,
m_2 = the number of marked carcasses collected during the carcass survey.

RESULTS

RADIO TELEMETRY

Two-hundred and seventy-three chinook salmon were captured in the gillnet from 16 June through 16 July. Catches of chinook salmon averaged 10 fish per day with the highest catches occurring on 20 June and 1 July (Figure 3).

A total of 151 radio-tags were implanted into chinook salmon in approximate proportion to run timing and strength (Figure 4). It was assumed that catch rates of the CFMD test net indicated run timing and strength. Of the 151 radio-tagged fish, 145 (96.0%) were detected in either the Unalakleet or the North rivers using the remote tracking station, aerial surveys, or boat surveys. Of the 145 radio-tagged chinook located in the North and Unalakleet rivers, five fish were able to swim past the remote tracking station without being detected, however, they were later detected by the aerial flights or boat surveys. The six remaining undetected chinook salmon either died (due to handling or predation), regurgitated their transmitters, moved downstream, were captured in the commercial, subsistence, or sport fishery, or were never detected upstream. Ninety-one (62.8%; SE = 4.0%) of the radio-tagged chinook salmon swam up the mainstem of the Unalakleet River and 54 (37.2%; SE = 4.0%) swam up the North River. Weighted and unweighted proportions were similar, which implied that tags were distributed proportional to run strength (Table 3). Arrival times to the confluence of the North River were similar throughout the run for both the North Fork and mainstem Unalakleet River stocks (Figure 5).

The radio-tagged chinook salmon required on average 125 h (SE = 19) to recover from handling and migrate to the confluence of the North River. Once detected, the chinook salmon remained at the confluence on average 33 h (SE = 3) before migrating upstream and out of the detection field (Appendix B). Most of the chinook salmon (62%) did not deviate from their intended migration route by falsely swimming up the wrong river (the Unalakleet River or the North River) before migrating upstream to their spawning areas (Figure 6).

The relative proportion of the chinook salmon escapement spawning in each of the major tributaries of the Unalakleet River could not be determined. This was due to the lack of adequate flight time required to locate all the radio-tagged chinook salmon with certainty. A total of 5 h of flight time was used on 28 July to survey both the North and Unalakleet rivers. Of the 91 radio-tagged salmon that swam up the Unalakleet River, 37 were detected by the aerial survey, and of the 54 North River bound fish, 31 were detected by air (Table 4). Although escapement proportions could not be estimated, locations of major spawning congregations were identified (Figure 7).

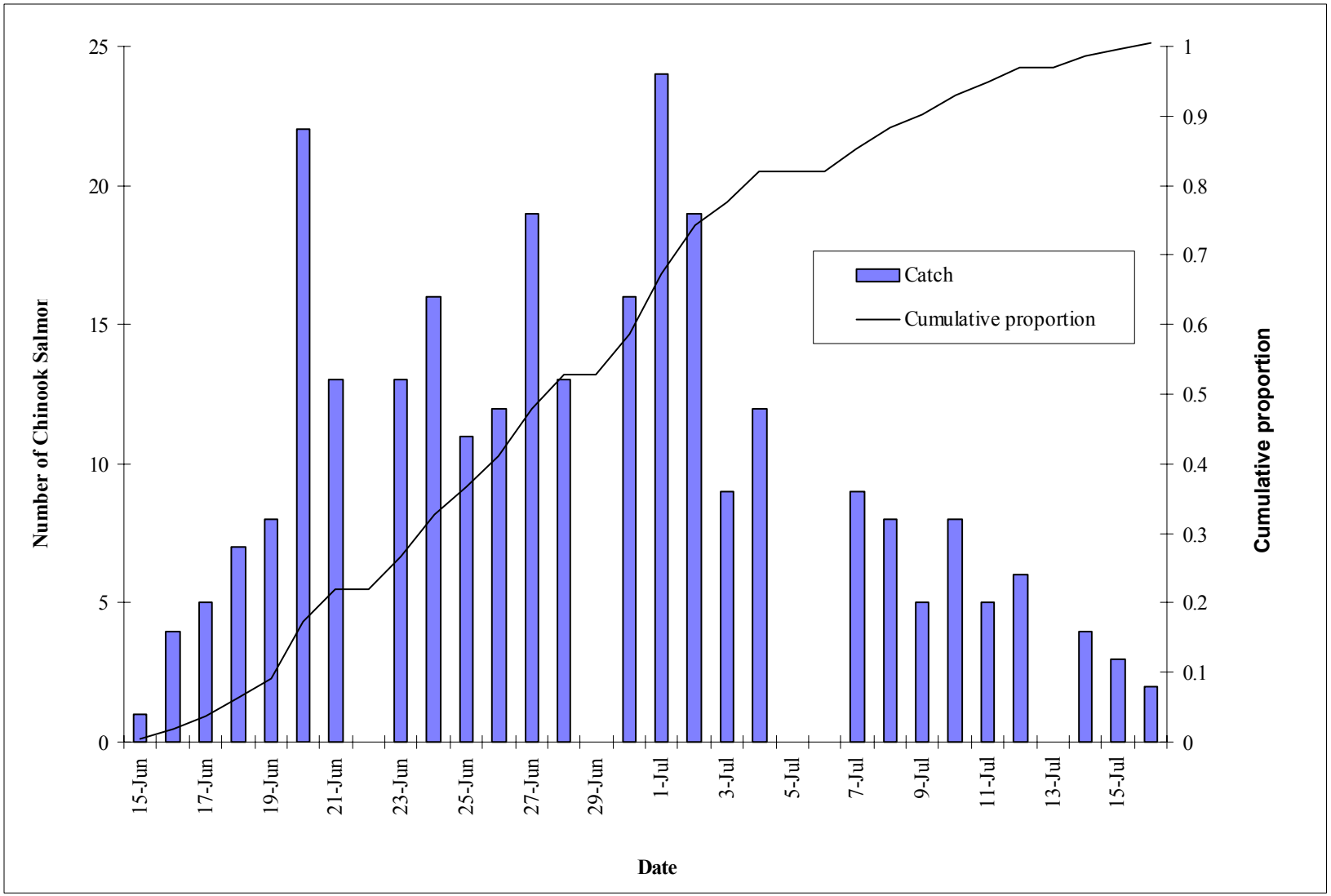

Figure 3.-Daily catches of chinook salmon in gillnet used to mark fish, 1997. Days with no catches shown indicate days when no sampling occurred.

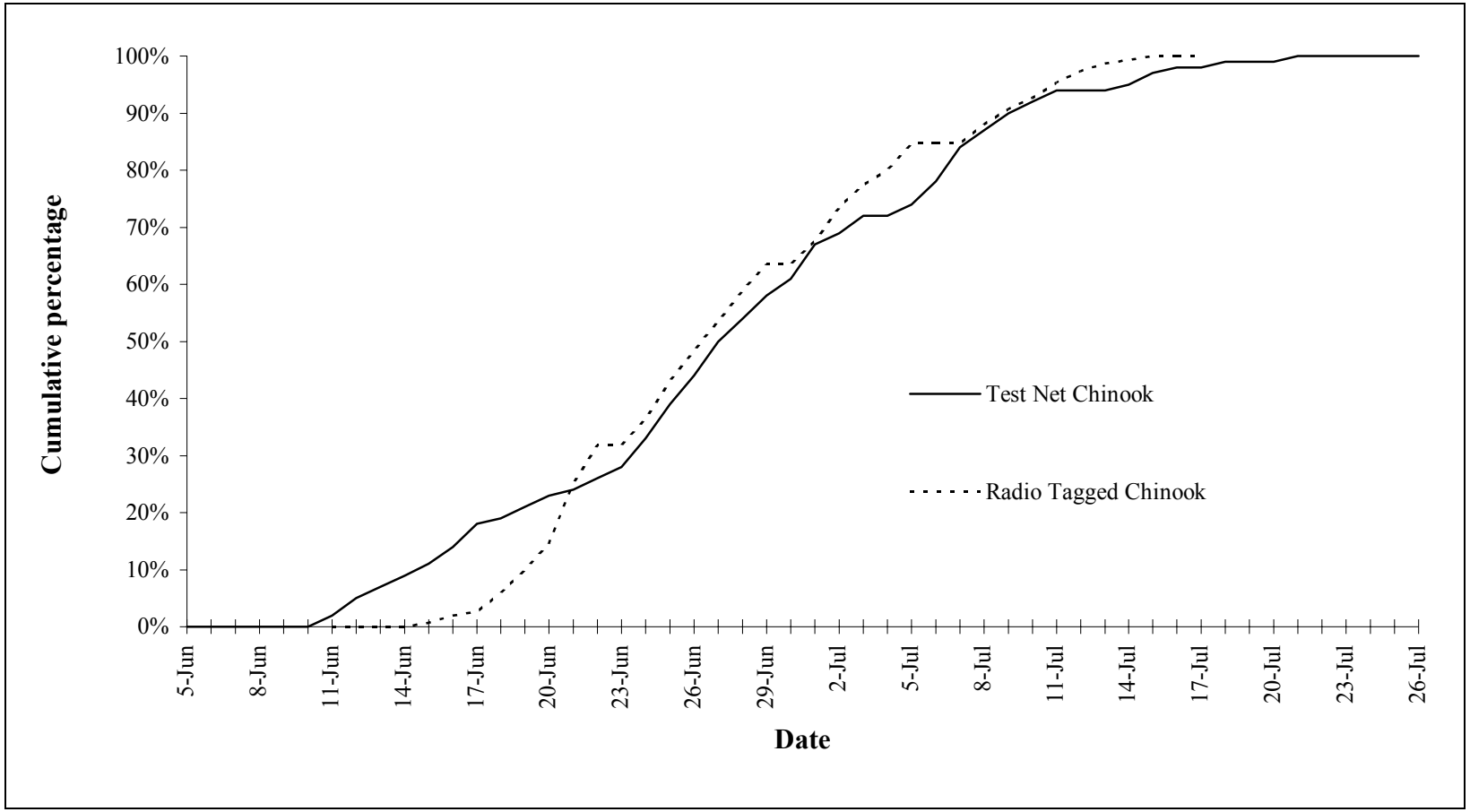

Figure 4.-Cumulative number of radio-tagged chinook salmon released and cumulative catches of chinook salmon in the CFMD test net, 1997.

Table 3.-Total catch, number radio tagged, and number of radio-tagged chinook salmon located in the North and Unalakleet rivers, 1997.

Date	Total Catch	Number Radio-Tagged	Number Tracked Tags	Tags Found in North River	Tags Found in Unalakleet River
15-June	1	1	1	1	0
16-June	4	3	3	2	1
17-June	5	5	5	2	3
18-June	7	6	6	1	5
19-June	8	7	7	3	4
20-June	22	16	15	10	5
21-June	13	10	10	1	9
22-June					
23-June	13	7	7	2	5
24-June	16	10	10	5	5
25-June	11	8	7	0	7
26-June	12	8	8	2	6
27-June	19	8	7	2	5
28-June	13	7	5	3	2
29-June					
30-June	16	6	6	3	3
1-July	24	9	9	4	5
2-July	19	6	6	1	5
3-July	9	4	4	1	3
4-July	12	7	7	1	6
5-July					
6-July					
7-July	9	5	5	1	4
8-July	8	4	4	3	1
9-July	5	3	3	1	2
10-July	8	4	3	3	0
11-July	5	3	3	0	3
12-July	6	2	2	1	1
13-July	1	1	1	0	1
14-July	4	1	1	1	0
15-July	3	0	0		0
Totals	273	151	145	54	91

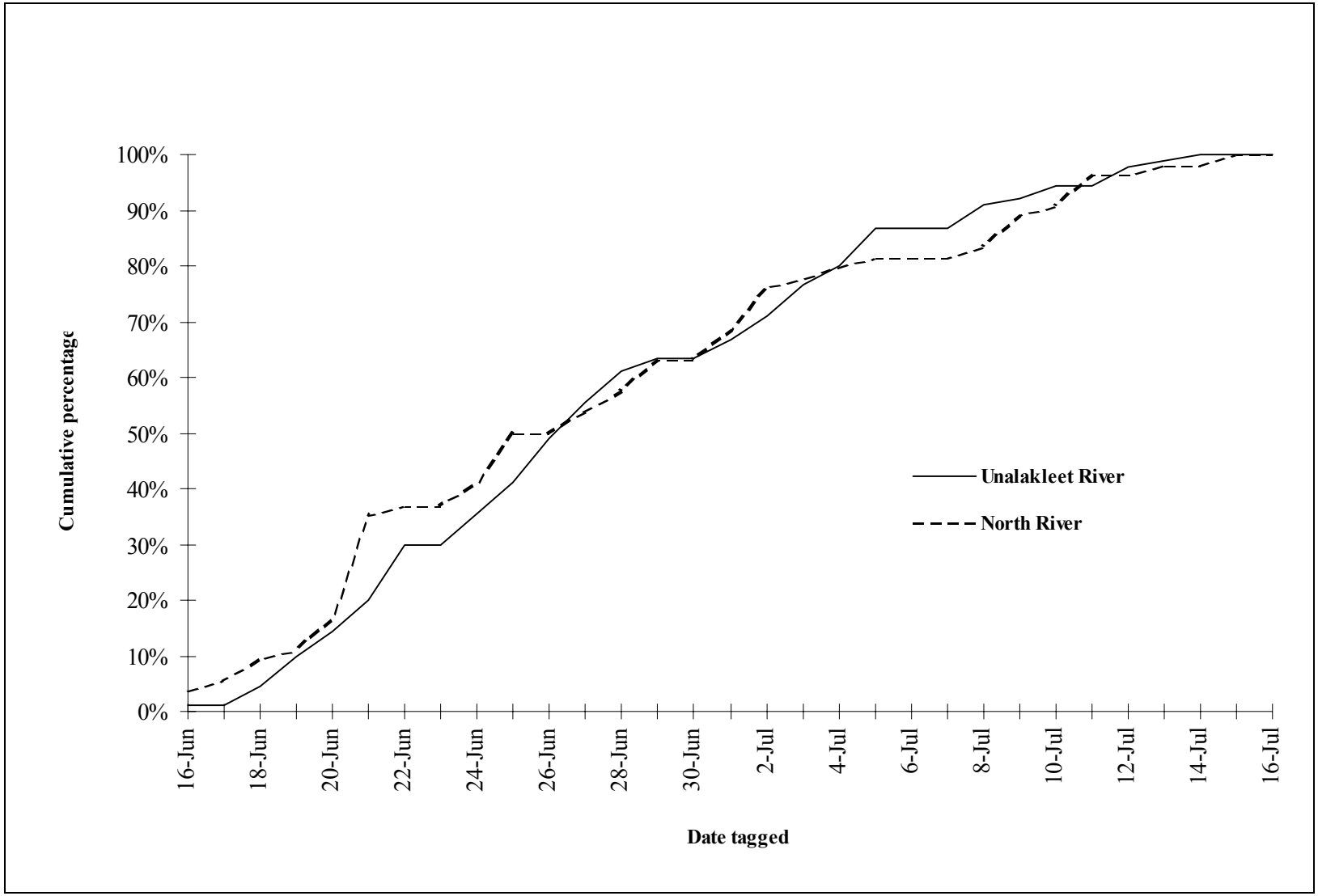

Figure 5.-Cumulative proportion of radio-tagged chinook salmon that migrated up either the North or Unalakleet rivers, 1997. The date indicates the day the Chinook salmon was radio-tagged.

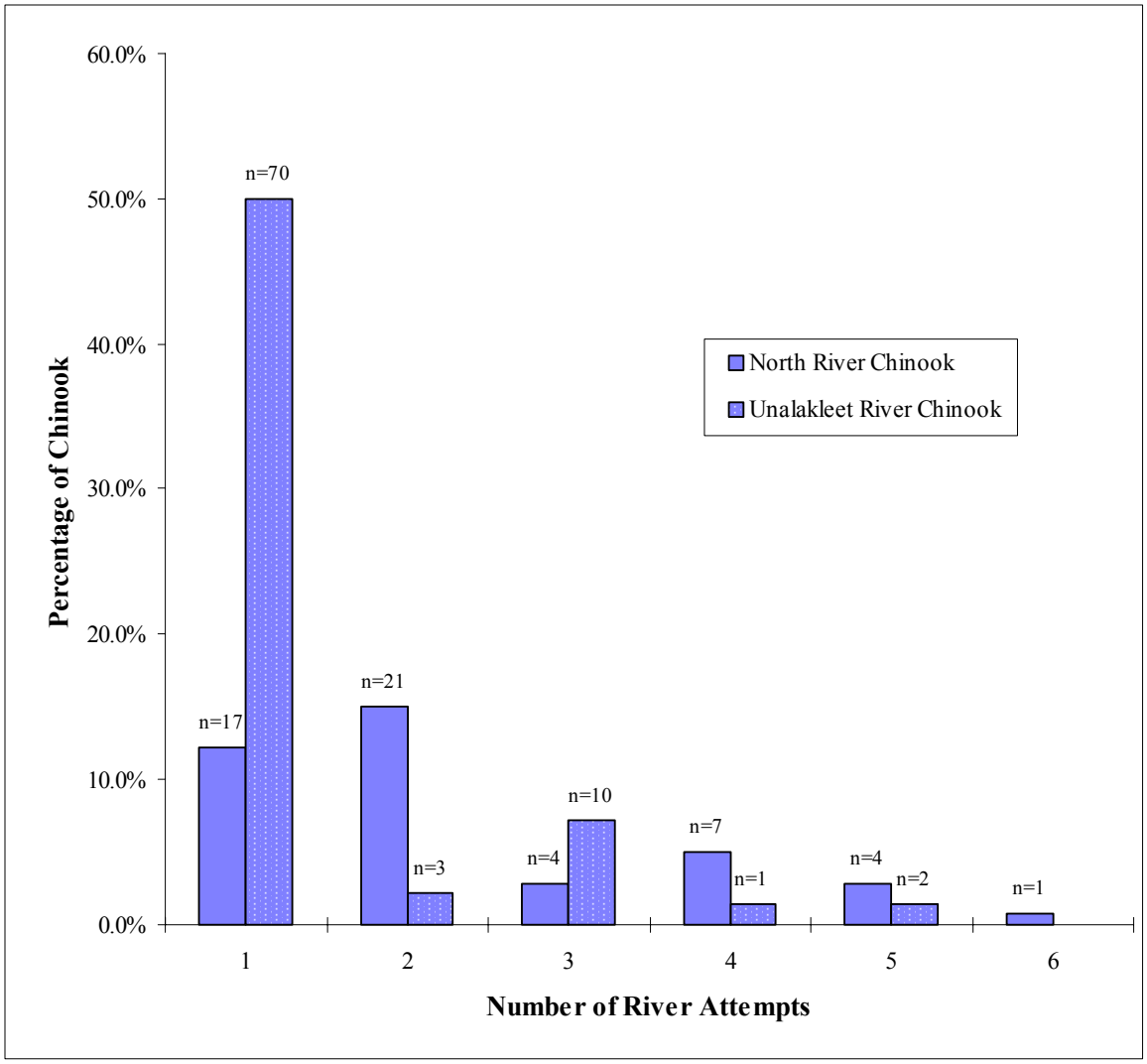

Figure 6.-Uncertainty in selection of a migration route for chinook salmon at the confluence of the Unalakleet and North rivers. The y-axis represents the percentage of radio-tagged fish that migrated up either the North or Unalakleet rivers to spawn. The x-axis is the number of times a chinook salmon swam into the North or Unalakleet rivers until it "decided" which of the two rivers to migrate up (e.g. a "3" North River fish indicates a North River bound Chinook salmon that first swam into the North River, then into the Unalakleet River then finally migrated up the North River, whereas a "2" North River fish is one which initially swam up the Unalakleet River, swam downstream, then migrated up the North River).

Table 4.-Number of radio transmitters (n = 58) found by aerial surveys in portions of the Unalakleet River and it's tributaries.

River	River Section[a]	Number of tags located
Unalakleet (main stem)		
	Above Ten Mile River	1
	Ten Mile River to Old Woman	12
	Old Woman to the North Fork	7
	North Fork to Chirosky	7
	Chiroskey to mouth of river	2
North		27
Chirosky		0
North Fork		2
Old woman		6
Ten Mile		0

[a] see Figure 3 for relative locations of river sections.

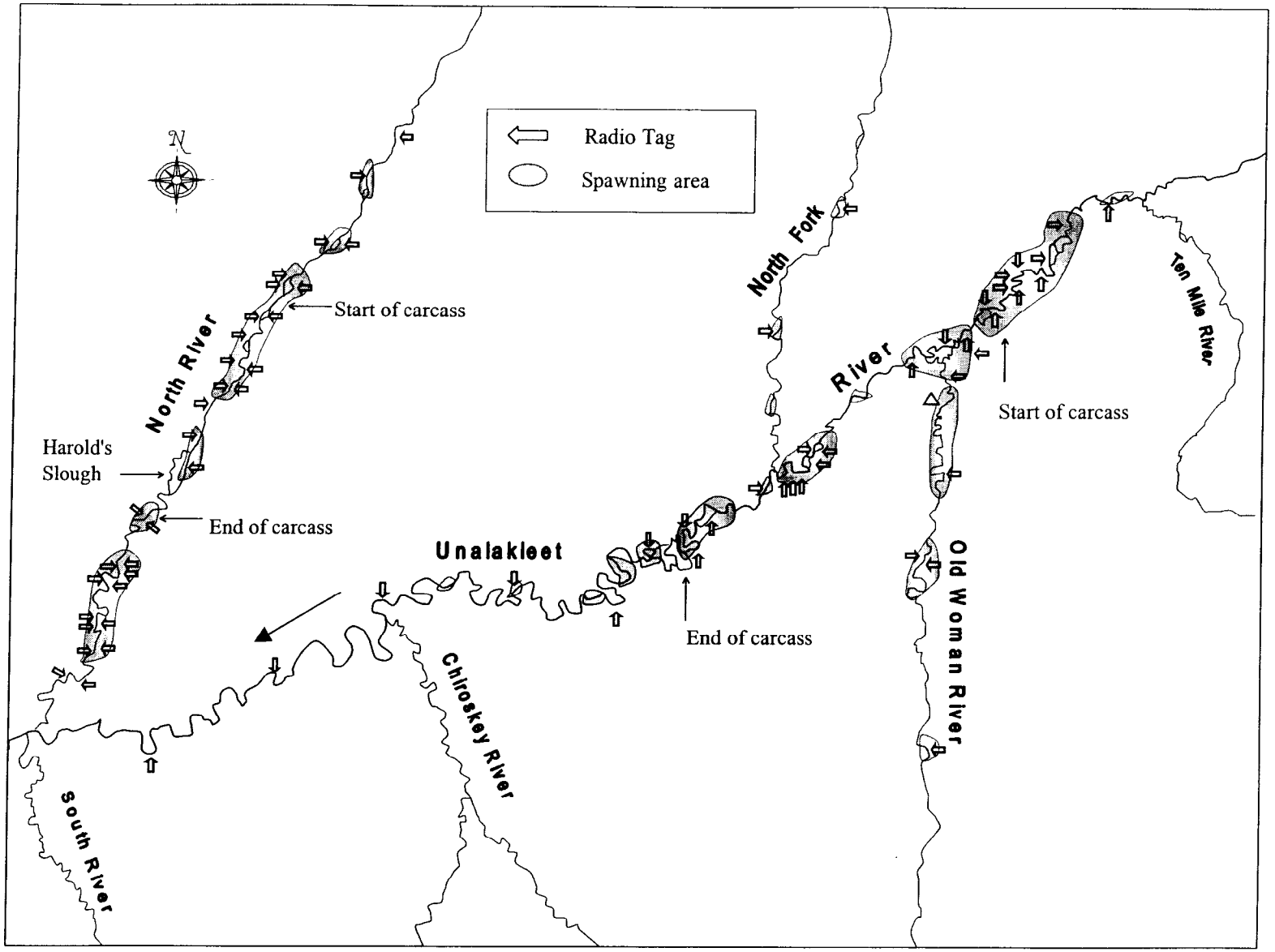

Figure 7.-Location of radio-tagged chinook salmon and spawning areas on the Unalakleet River drainage, 1997.

NORTH RIVER TOWER COUNTS AND ESTIMATES OF ABUNDANCE

Water quality factors did not interfere with the counting of chinook salmon from the North River counting tower. A total of 2,940 chinook salmon were observed passing the North River counting tower from 16 June to 1 August. Peak daily escapement occurred on 30 June with 1,293 (SE = 120) chinook passing by the tower (Figure 8; Table 5). Daily passage tended to be greatest during early morning (00:00-02:00) and late afternoon (14:00-15:00; Figure 9).

Escapement for the North River was estimated at 7,002 (SE = 471) chinook salmon. Escapement for the entire Unalakleet River drainage was estimated at 18,802 (SE = 2,215).

AGE-SEX-LENGTH COMPOSITIONS

A total of 375 carcasses were collected from the North and mainstem Unalakleet rivers combined. Sex ratios were 0.75 (SE = 0.02) males and 0.25 (SE = 0.02) females, and were found to be similar among the two drainages (X^2 = 0.07, *df* = 1; *P* = 0.78). Comparison of the North River and Unalakleet River samples showed that the length compositions differed slightly (*DN* = 0.15; *P* = 0.02; Figure 10). Ages were determined for 329 (0.88) chinook salmon (Table 6). Proportions of aged males and females were found to be similar to those not-aged (X^2 = 1.67; *df* = 1; *P* = 0.20). Male chinook were composed mostly of age 1.2 fish (59%) and females were most frequently age 1.4 fish (21%).

North River

Two-hundred twelve chinook salmon carcasses were collected from the North River. Ages were determined for 198 fish (0.93 of the sample). The proportion of male and female chinook salmon were 0.78 (SE = 0.03) and 0.22 (SE = 0.03), respectively. Proportions of aged males and females were found to be similar to those not-aged (X^2 = 1.67; *df* = 1; *P* = 0.20), and length distributions were also found to be similar (*DN = 0.30*; *P* = 0.30). Male chinook salmon were Most frequently represented by age 1.2 (62%) fish, whereas females were most represented by age 1.4 (15%) fish (Table 7). Lengths were obtained from all 212 carcasses. Male and female chinook salmon averaged 636 and 801 mm, respectively (Figure 11).

Unalakleet River

One hundred sixty-three carcasses were collected from the Unalakleet River. Ages were determined for 131 fish (0.80 of the sample). The proportion of male and female chinook salmon were 0.72 (SE = 0.04) and 0.28 (SE = 0.04), respectively. Proportions of aged males and females were found to be similar to those not-aged (X^2 = 0.98; *df* = 1; *P* = 0.32), and length distributions were also found to be similar (*DN* = 0.30; *P* = 0.30). Male chinook were most frequently represented by age 1.2 fish, whereas females were ost represented by age 1.4 chinook (Table 8). Lengths were obtained from all carcasses. Male and female chinook salmon averaged 640 and 870 mm, respectively (Figure 11).

CFMD Test Net

A total of 119 chinook salmon were captured in the CFMD test net. Average lengths of males and females were 701 (SE = 115) and 830 (SE = 105) mm, respectively (Table 9). The proportions of male and female chinook salmon were 0.50 (SE = 0.05) and 0.50 (SE = 0.05), respectively. Ages were determined for 113 (95%) of the chinook salmon.

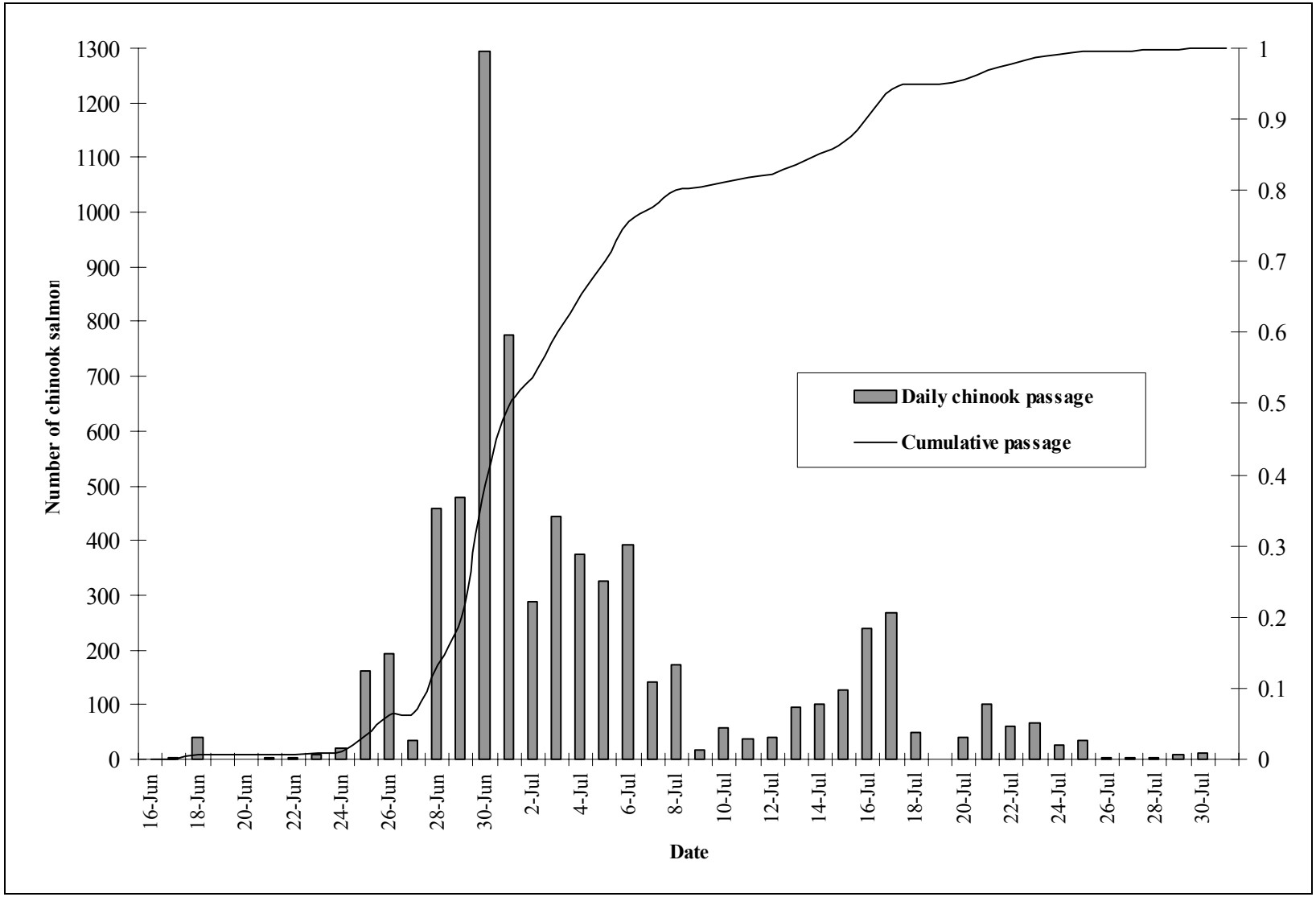

Figure 8.-Daily estimates (expanded counts) of passage for chinook salmon past the North River counting tower, 1997.

Table 5.-Daily counts and estimates of the number of chinook salmon passing by the North River counting tower, 1997.

Date	Count Periods	Count	Expanded Count	SE	Date	Count Periods	Count	Expanded Count	SE
17-June	20	2	4	3	11-Jul	22	18	37	10
18-June	24	20	40	27	12-Jul	15	20	42	10
19-June	24	0	0	0	13-Jul	23	44	94	15
20-June	24	0	0	4	14-Jul	22	44	100	20
21-June	15	2	4	4	15-Jul	16	64	128	42
22-June	15	2	4	4	16-Jul	16	66	240	67
23-June	16	4	8	5	17-Jul	16	134	268	25
24-June	19	8	20	24	18-Jul	13	24	48	10
25-June	24	80	160	38	19-Jul	0	0	0	36
26-June	20	88	192	65	20-Jul	4	10	40	50
27-June	14	16	35	12	21-Jul	24	50	100	12
28-June	15	218	458	138	22-Jul	24	30	60	12
29-June	15	230	477	128	23-Jul	18	32	67	29
30-June	22	612	1293	120	24-Jul	23	12	25	13
1-July	24	388	776	121	25-Jul	23	16	34	10
2-July	21	128	289	48	26-Jul	12	2	4	7
3-July	15	202	445	89	27-Jul	7	-4	4	7
4-July	0	0	375	64	28-Jul	16	2	4	10
5-July	0	0	326	58	29-Jul	15	4	9	8
6-July	22	178	392	45	30-Jul	24	6	12	8
7-July	24	70	140	15	31-Jul	24	0	0	4
8-July	22	84	174	27	1-Aug	24	0	0	4
9-July	15	8	18	15	2-Aug	12	0	0	0
10-July	14	24	59	23					

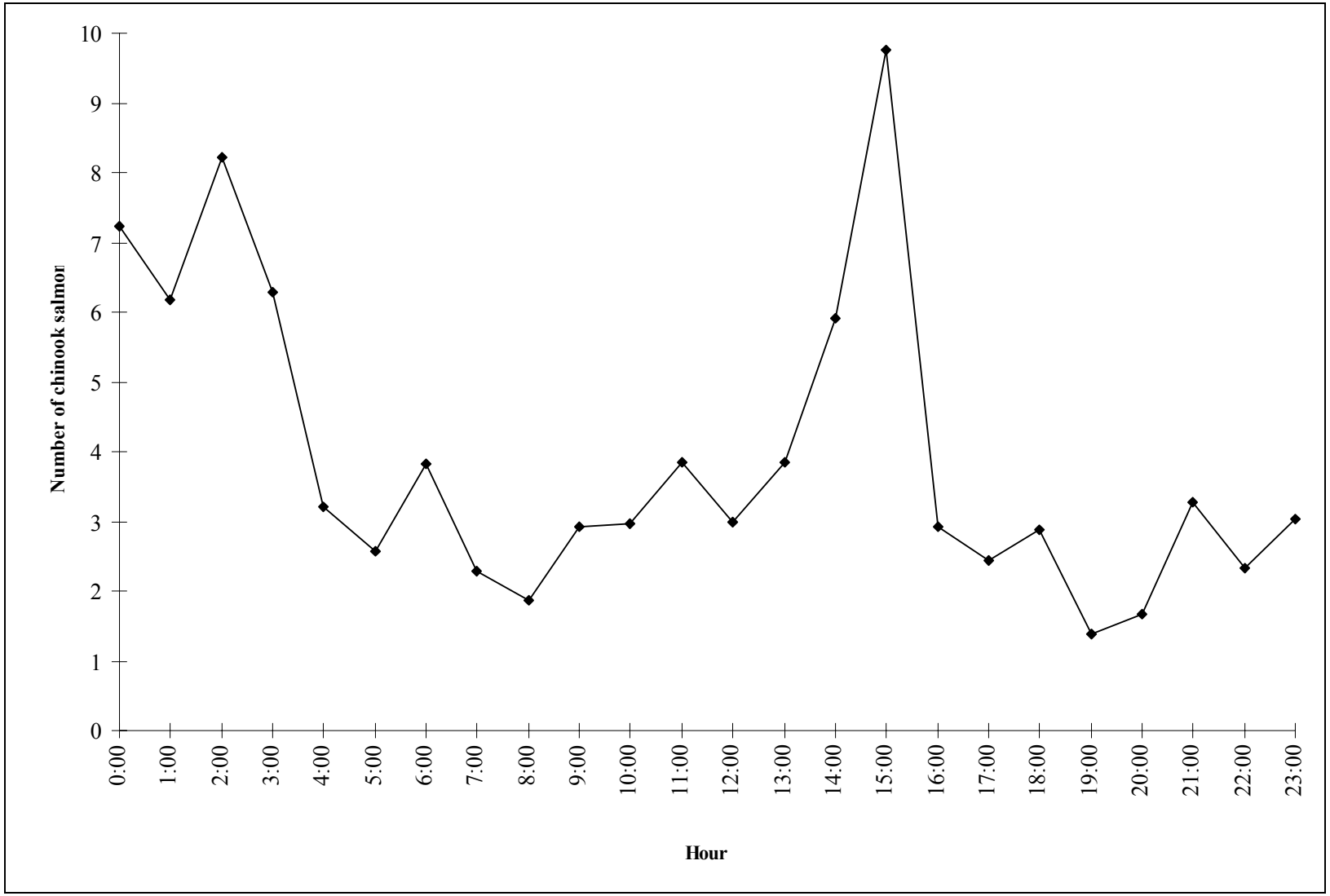

Figure 9.-Average hourly (unexpanded) passage of chinook salmon past the North River counting tower, 1997.

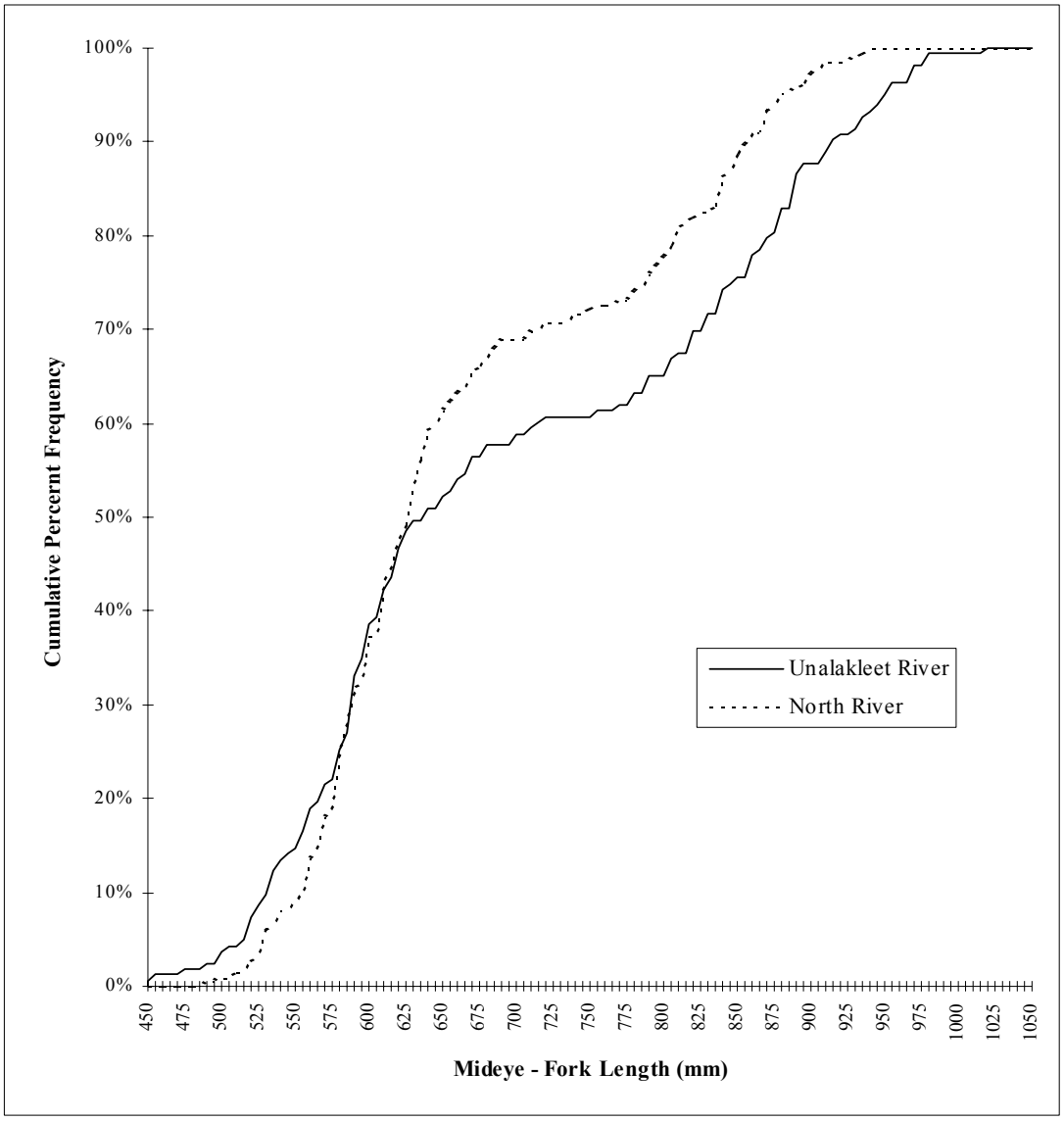

Figure 10.- Cumulative frequency distributions of chinook salmon lengths from the Unalakleet and North rivers, 1997.

Table 6.-Estimated proportions and mean lengths by age class of male and female chinook salmon in the mainstem Unalakleet River and North River combined during 1997.

		Sample			Length (mm)			
	Age	Size	Proportion	SE	Mean	SE	Min	Max
Male	1.2	188	0.59	0.04	590	50	440	710
	1.3	22	0.07	0.06	700	75	565	845
	1.4	34	0.08	0.05	847	85	610	980
	1.5	1	0.00		1020			
	2.2	2	0.01	0.08	570	70	520	620
	2.3	1	0.00		665			
	All	283	0.75	0.03	636	109	440	1020
Female	1.2	7	0.02	0.06	600	30	570	650
	1.3	5	0.02	0.06	735	110	610	910
	1.4	67	0.21	0.05	850	50	750	970
	1.5	1	0.00		970			
	2.4	1	0.00		880			
	All	92	0.25	0.03	832	89	570	970

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

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Table 7.-Estimated proportions and mean lengths by age class of male and female chinook salmon in the North River during 1997.

Sex	Age	Sample Size	Proportion	SE	Length (mm) Mean	SE	Min	Max
Male	1.2	123	0.62	0.04	600	40	490	710
	1.3	12	0.06	0.07	725	50	640	815
	1.4	19	0.10	0.07	825	80	610	940
	2.2	2	0.01	0.10	570	70	520	620
	2.3	1	0.01		665			
	All	212	0.78	0.03	635	95	490	940
Female	1.2	7	0.04	0.08	600	30	570	650
	1.3	3	0.02	0.09	770	150	610	910
	1.4	30	0.15	0.07	845	50	750	935
	2.4	1	0.01		880			
	All	46	0.22	0.03	800	100	570	935

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

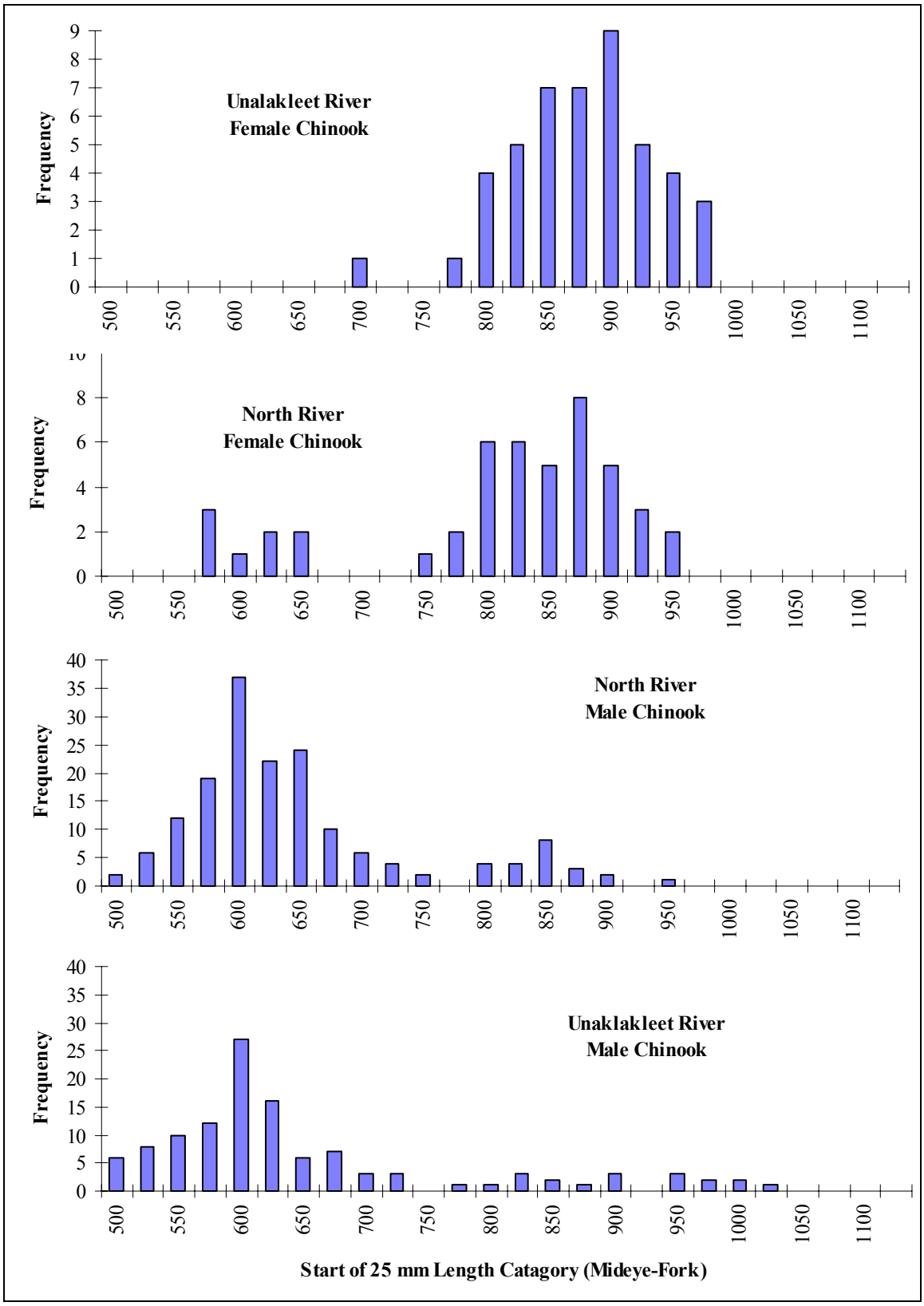

Figure 11.- Length frequency distributions of male and female chinook salmon carcasses collected from the North and Unalakleet rivers, 1997.

Table 8.-Estimated proportions and mean lengths by age class of male and female chinook salmon in the mainstem of the Unalakleet River during 1997.

	Age	Sample Size	Proportion	SE	Length (mm) Mean	SE	Min	Max
Male	1.2	65	0.50	0.06	575	55	450	680
	1.3	10	0.08	0.09	665	85	565	845
	1.4	15	0.11	0.09	870	90	700	980
	1.5	1	0.01		1020			
	All	117	0.72	0.04	640	130	450	1050
Female	1.3	2	0.02	0.12	730	40	700	755
	1.4	37	0.28	0.08	865	50	780	970
	1.5	1	0.01		970			
	All	46	0.28	0.04	865	60	700	970

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

Table 9.- Estimated proportions and mean lengths by age class of male and female chinook salmon from the CFMD Unalakleet River test net during 1997.

	Age	Sample Size	Proportion	SE	Length Mean	Length SE	Length Min	Length Max
Male	1.2	31	0.27	0.08	620	40	555	695
	1.3	8	0.07	0.10	755	80	670	890
	1.4	16	0.14	0.09	830	100	605	1070
	all	59	0.50	0.05	700	115	555	1070
Female	1.2	8	0.07	0.10	605	30	560	640
	1.3	10	0.09	0.09	825	70	750	995
	1.4	39	0.35	0.08	870	55	755	1010
	1.5	1	0.02		895		895	895
	all	59	0.50	0.05	830	105	560	1010

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 1.4 represents one annuli formed during freshwater residences and four years of ocean residence). One annulus is formed each year.

MARK-RECAPTURE EXPERIMENT

A total of 237 fish were captured, tagged, and released during the marking event. During the recapture event (carcass survey), a total of 375 chinook were collected and examined for jaw tags. Six of the carcasses (four males and two females) were marked. All fish were examined for potential tag loss and no tag loss was noted (radio-tags served as a secondary mark for part of the sample).

Due the small number of recaptures, tests for equal probability of capture by sex and river area were not performed.

No significant differences were found between the length distributions of all marked releases and the recaptured fish obtained from the carcass survey (DN = 0.21; P = 0.96). A significant difference was found between all marked fish and all fish examined during the carcass survey (DN = 0.48; P < 0.001; Figure 12). This difference is likely due to the gear selectivity during the marking event. Size selectivity during the recapture event is unknown. The mesh of the gillnet used selected for larger sized fish. Without corrections for possible size or sex selective sampling, the Unalakleet River basin escapement was estimated at 14,716 (SE = 5,088) chinook salmon.

DISCUSSION

The use of a gillnet to capture chinook salmon and esophageal implants did not appear to affect the migration pattern (behavior) of the chinook salmon. Of the chinook salmon captured and tagged with radio-tags, 96% were tracked upstream to spawning areas. In the Taku River, Eiler (1990) found that 89% of the chinook salmon implanted with radio-tags were tracked upstream of the tagging site. Within one week of tagging, 80% of the Unalakleet River fish had swam 3 km to the mouth of the North River. This is comparable to the Kenai River where 79% of the radio-tagged chinook salmon were found upstream of the tagging site within 1 week after tagging (Burger et al. 1985).

Despite the relative success of the remote tracking station, five radio-tagged salmon were able to migrate past without being detected. It is possible that these fish swam by too deeply to emit a strong enough signal strength in order for the DCC to decode the signal, or the fish may have passed the station before the receiver could cycle through to the radio-tag frequencies. A reconfiguration of the remote tracking station would lessen the chance that a radio-tag could swim past undetected. Software available from ATS that allows all the antennas to listen simultaneously would halve the time required to cycle through all the frequencies. A third listening antenna is also recommended. It was assumed that an increasing then decreasing signal strength pattern recorded by an antenna represented a fish migrating upstream past the receiver. However, it is possible that a radio-tagged chinook salmon that swam into the detection field, perhaps through, and then migrated back downstream would have a similar pattern. A third antenna would be able to better discern migration patterns and detect a fish migrating back downstream.

Estimates of the proportions of the chinook salmon escapement in the remainder of the Unalakleet River drainages through radio telemetry were not attained because of the lack of sufficient aerial survey time needed to detect all the radio-tagged chinook salmon. During the sole aerial flight, only 41% of the Unalakleet River bound radio-tags that migrated past the remote tracking station were detected. In the Taku River, radio-tagged chinook salmon were

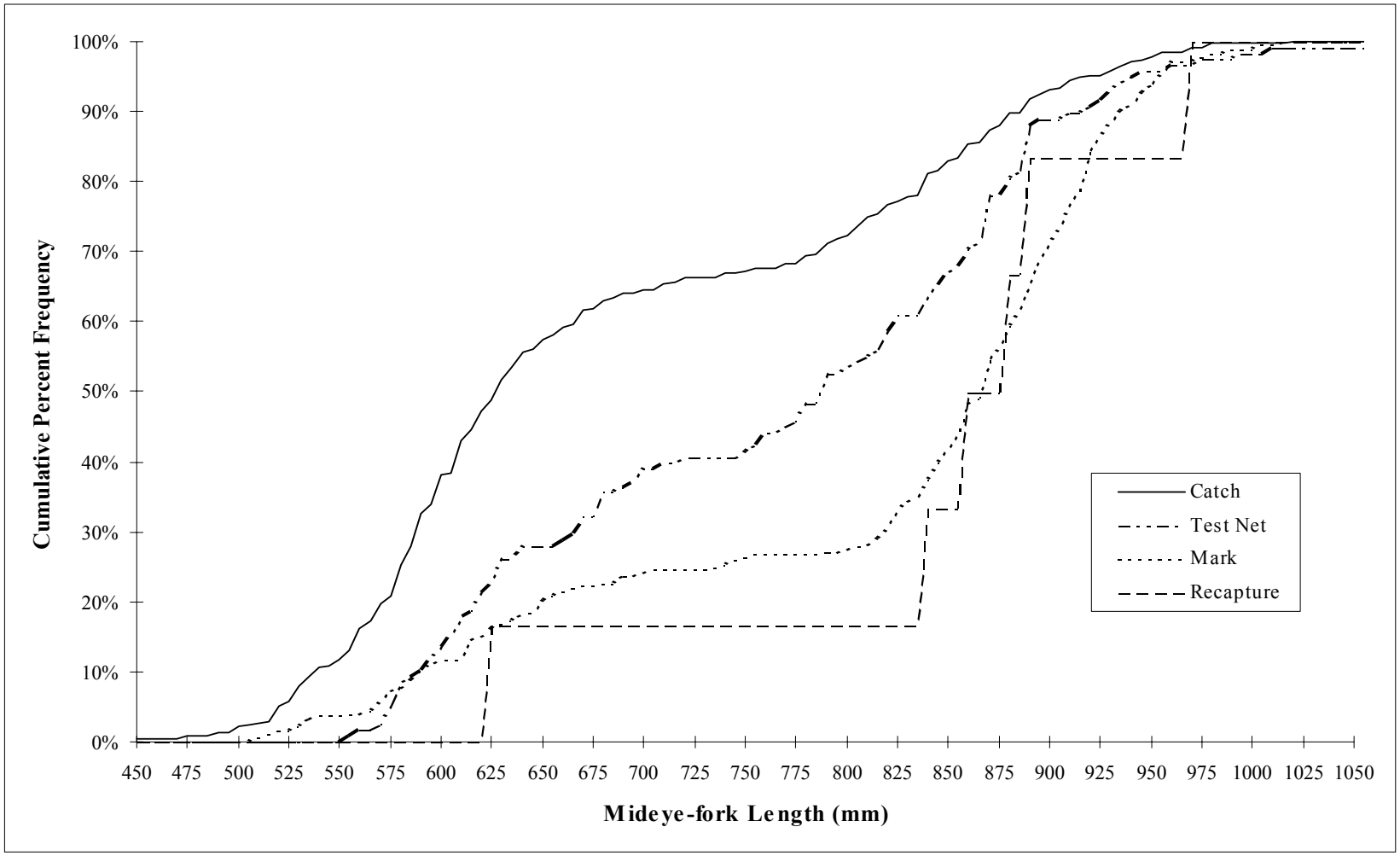

Figure 12.-Cumulative length frequency distributions of chinook caught during the marking (gillnetting), and capture (carcassing) events, the recaptured fish and test net fish from the Unalakleet River drainage, 1997.

tracked weekly for up to 16 weeks using an aircraft equipped with multiple receivers and three observers in order to successfully relocate and track 92.5% of the fish that migrated upstream to spawning areas throughout the drainage (Eiler 1990). Burger et al. (1985) utilized boats and/or aircraft every 2 d to locate radio-tagged chinook salmon in the Kenai River drainage.

On the Unalakleet River, the radio-tags were distributed over a 4-week period and it is unlikely that all the chinook salmon had finished their migrations and were alive and spawning on the day the aerial survey was conducted. During the carcass survey, radio-tags were found in a variety of situations. Carcasses were found lying in deep pools (>2 m) emitting weak signals due to the increased water depth, some fish were found actively spawning in shallow riffles emitting stronger signals, and some radio-tags were found out of the fish lying near a beached carcass, that had been fed on by a bear, emitting a very strong signal. Recommended measures which would to minimize the uncertainties of detection include the use of additional aerial flights and a second remote tracking station located at the confluence of the Old Woman and Unalakleet rivers. Additional aerial flights would minimize the chance that a radio tag would go undetected, allow for the determination of whether a fish has reached its spawning grounds, and determine if a dead or dying radio-tagged chinook salmon has drifted downstream into another river. Burger et al. (1985) found that the length of residence at the spawning area averaged 13 d for the early run of chinook salmon on the Kenai River. Use of a second tracking station would provide an accurate estimate of the proportion of chinook salmon spawning in the Unalakleet River above, below, and within the Old Woman River. This information would be valuable because over 50% of the aerial tracked Unalakleet River fish were found upstream of the Old Woman River confluence.

Age-sex-length compositions of chinook salmon for the Unalakleet and North rivers are suspect due to possible gear selectivity, timing of the carcass survey, and the area sampled. Gear selectivity with carcass sampling may occur due to a person preferentially spearing a chinook salmon carcass based on the visibility, catchability, and attractability (a large fish) of the fish. Timing of the carcass survey is important because it is assumed the salmon carcasses available at the time of sampling are representative of the population (e.g. male and female chinook salmon may have differing longevity on the spawning grounds). Evenson (1996) found significantly different sex ratios but similar length compositions between two carcass samples collected on the Salcha River. Efforts were made to minimize selectivity on the Unalakleet and North rivers, however, the timing of the carcass survey as well as the area surveyed may have introduced bias because only a small segment of the population was sampled. During the Unalakleet River carcass survey a majority of the chinook were still actively spawning, thereby limiting the number of carcasses available for sampling. The number of carcasses was further limited because the major spawning congregations could not be reached by boat and only the lower spawning areas of the Unalakleet River could be sampled. However, on the North River, access to the major spawning congregations was not limited, and the carcass survey was conducted later so that more carcasses were available for sampling. A more representative sex-age-length composition for the Unalakleet River drainage could be attained by collecting carcasses on two or more occasions, and by collecting carcasses from throughout the main spawning areas. A second sampling occasion is feasible and is recommended, however sampling the main spawning areas on the Unalakleet River (Ten Mile River to the Old Woman) could not be reached by boat. The major spawning grounds could be sampled by flying a canoe or raft to Ten Mile River and floating downstream.

Favorable environmental conditions at the North River tower permitted the successful counting of chinook salmon. The North River counting tower has been operated for 8 years (1972-74, 84-86, and 96-97), and of these years water clarity has not interfered with the counting and identification of chinook salmon (C. Lean, Alaska Department of Fish and Game, Nome, personal communication). Although water clarity remained good in 1997, adherence to the sampling schedule was not maintained and two consecutive days (4-5 July) of counts were missed during a period when relatively large daily escapements were occurring. Average peak escapement during the 1980's and 1990's has occurred on 1-2 July. Better precision and less uncertainty of escapement estimates could be attained through stricter adherence to the counting schedule and increased counting periods scheduled during periods of peak escapement (i.e. 29 June - 5 July).

The methods used for the expansion of tower counts warrants investigation. The estimate of the North River chinook salmon escapement (7,002) differs markedly from the CFMD estimate of 8,370 fish. The methods of estimation differ by the way in which a missed counting period (a 1 h block of time; e.g. 1:00 - 2:00 am) is accounted. For a missed period, the CFMD method takes the average of the period counts from the pervious day and following day for which there is a count, as opposed to this method which uses the average of all the counted periods for that particular day. If there is a diurnal migration pattern and counts are missed during peak migration the current method may result in an underestimated escapement count for that day. Had the CFMD expansion been used, the Unalakleet River chinook salmon estimate would have been 22,475, however the precision of this estimate cannot be estimated.

The precision of the tower count expansion using radio telemetry was substantially better than the precision of the mark-recapture experiment. This result was expected because the success of the counting tower and the radio telemetry negated the need for additional effort to capture a large number of chinook salmon during the recapture event. However, sufficient data was collected to asses the feasibility of a future mark-recapture experiment if a back-up means of estimating total escapement is desired.

If a mark-recapture experiment is needed for an estimating abundance, experimental design changes are required for an equivalent level of precision attained from the proportional expansion of the tower count. Foremost, the number of fish marked and captured would have to increase substantially. If future Unalakleet River chinook salmon escapements are comparable to 1997 levels, which was above normal, approximately 1,000 fish would have to be both marked and captured for an estimate that is within 25 percentage points of the true proportions 90% of the time (Robson and Regier 1964). Considerable additional hours of sampling effort during the mark and recapture (carcass survey) events would be required too if 2,000 fish are to be handled. Furthermore, use of a smaller, 17.8 cm (7 in), stretch mesh gillnet is recommended. A smaller mesh size would still capture the larger fish as well as selecting for more smaller fish which tend to dominate the run. Using an even smaller mesh size, such as the 5.875 in stretch mesh used for the test net, could catch greater numbers of smaller sized chinook salmon, however too many chum and pink salmon would be captured resulting in an unmanageable situation. Given the unlikelihood of a failed tower count, the considerable amount of additional effort required, and the associated costs, an attempt to conduct a mark-recapture experiment is neither very feasible nor recommended.

Although a mark-recapture is not recommended, changes in the mesh size of the gillnet are still recommended. The mesh sized used in 1997 tended to select for larger fish which resulted in a

disproportionate number of larger chinook salmon receiving radio-tags. This could result in a biased estimates of the proportion of chinook salmon migrating up the tributaries of the Unalakleet River. Bias resulting from a disproportionate number of chinook based on size spawning in a particular Unalakleet River tributary did not seem likely in this years study given that the length compositions of the North and Unalakleet rivers differed only slightly.

As is often the case with studies designed to estimate fish abundance, biological as well as numerical information is acquired. Data recorded by the remote tracking station revealed interesting migrational behavior patterns, and the chinook salmon carcasses sampled contained a notable proportion of apparent (visual determination only) chinook-chum salmon hybrids and jacks. During carcass sampling 1.3% of the carcasses collected were chinook-chum hybrids. Chinook-chum hybrids are known to occur (W. Smoker, University of Alaska SE, personal communication, 1997), however the frequency of such occurrence has been studied little. Examination of the telemetry data shows that the chinook salmon paused for 33 h on average at the mouth of the North River before continuing their migration. While at the river confluence a majority of the North River bound fish were observed initially swimming up, or nosing into the Unalakleet River before finally "homing in" or deciding to swim up the North River (Figure 6). In some instances several false attempts were made before the natal stream was selected. This navigational or homing behavior was less pronounced for the Unalakleet River bound fish. Although it is common knowledge among anglers that migrating chinook salmon will congregate at a river confluence, the telemetry data elucidates some additional interesting salmon behavior relating to homing and navigational behavior. Lastly, a high proportion of small chinook salmon could result from a number of theoretical causes: The commercial fishery gear could simply be selecting for the larger sized fish, genetic factors may be regulating fish size, or the rearing Unalakleet River chinook may experience fast growth rates thereby triggering early maturation of the fish (W. Smoker, University of Alaska SE, personal communication, 1997).

ACKNOWLEDGMENTS

Bryant Ryan, Michael (Wolf) Cartusciello, and Peggy Merritt assisted with field work and data collection. Tracy Lignau aged the samples. Matt Evenson and Fred DeCicco developed the operational plan, assisted in the field, and reviewed the report. Mike Wallendorf assisted with data analysis and sampling design and also reviewed the report. Sara Case prepared the final report. John Eiler and Advanced Telemetry Systems provided technical expertise. The Unalakleet River Lodge, the Ryan family, and the friendly people of Unalakleet provided exceptional hospitality and assistance. Francis Degnan granted permission to use her land allotment. The Kawarek Corporation provided the tower count data. The U.S. Bureau of Land Management provided field logistical support and funding for the aerial surveys. The Commercial Fisheries Management and Development Division provided logistical support and technical advise.

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Appendix A

Appendix A.-North River counting schedule and counts of chinook salmon during 1997. Numbers indicate a count of salmon during a 30 min period, negative counts indicated movement of fish downstream, and blanks indicate hours not counted.

Date	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
7/16											**Start of count →**				0	0	0	0	0	0	0	0	0	0
6/17	0	2	0	0	0	0	0	0	0	0	0					0	0	0	0	0	0	0	0	0
6/18	0	0	0	18	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
6/19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/20	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	-2	0	0	0	0	0	0	0
6/21									0	0	0	2	0	0	0	0		0	0	0	0	0	0	0
6/22	0	0	0	2	0	0	0	0									0	0	0	0	0	0	0	
6/23	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0								
6/24	0	0	2	0	0	0	0	0	0	0	0		0	8	-2					0	0	0	0	0
6/25	0	0	6	0	2	0	0	0	0	0	0	14	26	6	0	0	20	0	0	0	0	0	4	2
6/26	2	34	8	-2	6	0	0	10					0	0	4	4	0	0	0	0	0	22	0	0
6/27									2	0	4	6	0	0	0	0			0	0	0	0	2	2
6/28	88	26	10	8	6	0	4	0									0	4	0	0	6	54	12	
6/29		4	30	6	0	12	8	0	6	2	0	10	6	30	20	96								
6/30	18	24	44	48	24	18	22	18	8	42	46	20	12	8	44	112			28	6	0	18	18	34
7/1	32	36	24	26	2	0	28	20	12	24	20	0	0	16	78	0	28	22	4	2	8	0	2	4
7/2	12	8	10	10	0	4	16	2	0	0	2	6	2	20	0				6	4	2	4	10	10
7/3	6	8	10	10	10	6	6	4									16	18	40	18	38	0		12
7/4																								
7/5																								
7/6	10	6	10	28	22	18	10	6			8	24	12	6	4	0	0	2	0	0	0	0	6	6
7/7	18	12	12	4	0	0	0	0	6	0	0	0	4	0	0	0	0	2	0	0	0	2	4	6
7/8	14	8	14	4	0	4	12	6	12	2	0	6	0	0	0			0	0	0	0	0	0	2
7/9	0	0	2	0	0	0	0	0									0	0	0	6	0	0	0	
7/10	0	2	14	6	0	2	0	0	0	0													0	0
7/11	0	2	6	2	0	0	0	0			0	2	0	0	0	0	0	0	4	2	0	0	0	0
7/12									4	2	2	4	0	0	0	2	2	4	0	0	0	0	0	

-continued-

Appendix A.-Page 2 of 2.

Date	0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
7/13		8	10	4	2	0	0	-4	0	2	0	0	2	2	0	4	0	4	0	0	2	0	4	4
7/14	0	0	10	4	0	0	0	0	0	4	2	2	4	0	0	0			6	0	2	4	2	4
7/15	4	0	10	14	-2	0	18	6									0	4	0	0	4	0	6	0
7/16	6	18	18	4					4	2	0	0	0	0	0	6					0	4	2	2
7/17	12	18	22	16	20	10	4	2									4	8	2	4	0	2	4	6
7/18	2	4	8	4	2	2	0	2	0	0	0	0	0											
7/19																								
7/20																					0	4	6	0
7/21	6	10	8	6	4	8	2	2	0	2	-2	0	0	0	0	0	2	0	0	2	0	0	0	0
7/22	2	0	2	0	0	6	2	2	0	0	2	0	4	2	2	4	0	4	0	0	0	-2	0	0
7/23	10	-2	2	6	8	0	0	0	0	0	2	0	4	4							-2	2	-2	0
7/24	0	-2	2	-2	2	0	0	2	0	0	0	2		2	0	0	0	0	2	-2	0	4	0	2
7/25	0	0	2	0	4	0	0	2	0	0	0	0		0	2	4	0	-2	2	2	0	0	0	0
7/26	2	0	0	-2	0	0	2	0	0	0	0	0												
7/27																		-2	0	0	0	0	0	-2
7/28	2	-2	-2	-2	0	0	0	0	0								0	0	-2	0	2	2	0	4
7/29	2	0	0	2	0	-2	0	0										0	0	0	0	0	2	0
7/30	-2	0	0	2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	2	-2	0	0	2
7/31	0	-2	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
8/1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0
8/2	0	0	0	0	0	0	0	0	0	0	0	0												

Appendix B

Appendix B.-Timing and movement patterns of radio-tagged chinook salmon on the Unalakleet River, 1997.

Jaw Tag Number	Date Radio-tagged (m/d/yr h:min)	Length (mm)	River[a]	Time Until Detected[b] (d h:min)	Time at Confluence[c] (d h:min)	Pattern[d]
1	6/14/97 23:50	815	N	17 16:02	0 1:04	U.N
2	6/15/97 9:00	820	U	14 15:03	0 0:05	U
4	6/15/97 11:00	920	N	5 20:40	8 15:22	U.N.U.N
3	6/16/97 10:00	590	N	13 13:36	0 1:10	N
5	6/17/97 2:30	738	N	9 10:35	0 0:11	N
6	6/17/97 3:30	926	U			
7	6/17/97 7:00	830	U			
8	6/17/97 10:30	651	U	8 5:06	2 6:26	U
9	6/17/97 10:30	944	N	5 0:07	6 11:43	U.N
10	6/18/97 5:30	859	U	7 7:15	0 0:07	U
11	6/18/97 8:15	1005	N	2 7:20	10 13:33	U.N.U.N.U
12	6/18/97 8:25	825	U	2 12:48	3 10:09	U
13	6/18/97 9:00	877	U	11 12:38	0 0:03	U
14	6/18/97 10:00	662	U	11 18:57	0 0:09	U
15	6/18/97 10:25	928	U	3 19:32	0 11:17	U
17	6/19/97 5:40	615	N	13 17:54	3 17:26	U.N.U.N
18	6/19/97 6:40	600	U	10 6:48	0 0:08	U
19	6/19/97 7:00	885	U	2 1:43	2 10:43	U
20	6/19/97 7:20	920	U	11 5:20	3 20:17	U
21	6/19/97 7:40	895	N	10 19:43	0 0:26	N
22	6/19/97 8:00	821	U	10 1:37	0 19:34	U
23	6/19/97 8:30	945	N	16 1:22	2 19:54	N.U.N.U.N
24	6/20/97 6:30	895	U	10 22:56	0 0:02	U
27	6/20/97 6:30	585	N	7 8:27	3 20:02	U.N
28	6/20/97 7:00	615	N	9 17:59	0 4:23	N
29	6/20/97 7:20	870				
30	6/20/97 7:40	895	U	4 23:55	0 0:06	U
31	6/20/97 8:00	855	N	10 14:15	0 8:58	N.U.N.U.N
33	6/20/97 8:30	820	N	9 15:19	0 10:30	N

-continued-

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Jaw Tag Number	Date Radio-tagged (m/d/yr h:min)	Length (mm)	River[a]	Time Until Detected[b] (d h:min)	Time at Confluence[c] (d h:min)	Pattern[d]
35	6/20/97 9:00	615	N	10 20:43	1 20:13	N
36	6/20/97 9:15	865	U	2 1:31	2 12:12	N.U
37	6/20/97 9:30	565	N	9 14:50	0 5:08	U.N
38	6/20/97 9:45	870	N	9 14:53	0 4:38	U.N
39	6/20/97 10:00	887	N	11 3:28	1 19:33	N.U.N.U.N
26	6/20/97 10:15	577	N	5 7:33	2 22:08	U.N
40	6/20/97 10:15	910	U	6 2:34	2 10:22	U
41	6/20/97 10:30	955	N	6 18:51	0 18:42	N.U.N
32	6/20/97 11:00	960	U	1 22:44	3 12:29	U
25	6/21/97 7:25	588	U	9 5:14	0 0:09	U
42	6/21/97 7:40	842	U			
34	6/21/97 8:45	858	U	4 9:00	0 0:35	U
43	6/21/97 9:00	855	N	5 7:54	0 0:25	N
44	6/21/97 9:05	613	U	5 19:18	1 0:53	U
45	6/21/97 9:10	950	U	8 4:36	0 5:10	U.N.U
46	6/21/97 9:45	595	U	5 12:35	2 3:26	U
47	6/21/97 10:43	900	U	8 18:47	0 13:45	N.U
48	6/21/97 11:05	845	U	5 1:27	3 18:32	U.N.U
49	6/21/97 11:25	870	U	4 23:59	2 20:58	U.N.U
50	6/23/97 8:30	890	U	6 23:15	0 16:58	U
51	6/23/97 9:06	670	U	2 5:48	0 0:35	U
52	6/23/97 10:30	880	U	2 1:51	0 0:02	U
53	6/23/97 11:06	860	U	4 20:10	0 0:05	U
54	6/23/97 11:34	890	N	3 7:28	3 4:24	U.N
55	6/23/97 12:10	920	U	3 14:57	0 0:04	U
56	6/23/97 13:03	935	N	3 16:31	1 10:18	U.N
57	6/24/97 9:53	585	N	3 17:37	2 18:12	N
58	6/24/97 10:37	910	U	5 12:15	0 3:26	U.N.U
59	6/24/97 10:52	920	U	1 17:57	0 19:11	U
60	6/24/97 11:31	880	N	5 18:49	0 0:07	N

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Jaw Tag Number	Date Radio-tagged (m/d/yr h:min)	Length (mm)	River[a]	Time Until Detected[b] (d h:min)	Time at Confluence[c] (d h:min)	Pattern[d]
62	6/24/97 11:40	870	N	1 11:53	1 22:34	N.U.N
61	6/24/97 11:58	615	U	1 8:48	0 0:09	U
63	6/24/97 13:10	895	N	4 1:53	0 0:56	N
64	6/24/97 13:52	840	U	7 23:17	0 0:04	U
71	6/24/97 14:08	830	N	2 21:27	0 0:04	U.N
72	6/24/97 14:25	900	U			
65	6/25/97 10:09	745	U	1 18:13	1 20:31	U
66	6/25/97 10:32	690	U	1 10:10	0 11:09	U
67	6/25/97 12:12	570	U	8 1:21	0 0:07	U
68	6/25/97 12:48	930	U	0 23:28	1 4:21	U
69	6/25/97 14:01	825	U	1 12:41	0 0:15	U
70	6/25/97 14:05	900	U	4 10:00	0 0:06	U
73	6/25/97 14:44	650				
74	6/25/97 15:10	840	U			
75	6/26/97 10:46	925	U	3 20:22	2 20:14	U.N.U
76	6/26/97 10:47	870	N	3 18:36	3 14:16	U.N.U.N.U.N
78	6/26/97 11:20	660	U	3 22:18	0 0:11	U
77	6/26/97 11:34	856	U	1 4:59	0 14:49	U
79	6/26/97 12:38	920	N	3 7:12	0 14:15	N
80	6/26/97 13:26	860	U	3 15:53	0 10:01	U
81	6/26/97 13:38	910	U	3 15:41	0 0:05	U
82	6/26/97 14:28	860	U	2 23:10	0 0:02	U
83	6/27/97 11:20	870	U	2 13:18	0 0:00	U
84	6/27/97 11:34	845	U	3 3:44	0 11:18	U
85	6/27/97 11:45	885	U	5 11:41	0 0:03	U
86	6/27/97 12:00	745	N	5 12:00	2 16:07	U.N
89	6/27/97 12:57	680				
90	6/27/97 13:19	835	N	1 10:04	0 0:28	U.N
91	6/27/97 13:30	910	U	3 6:09	0 0:00	U
92	6/27/97 14:14	955	U	2 15:09	0 13:10	U

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Jaw Tag Number	Date Radio-tagged (m/d/yr h:min)	Length (mm)	River[a]	Time Until Detected[b] (d h:min)	Time at Confluence[c] (d h:min)	Pattern[d]
93	6/28/97 5:36	615				
94	6/28/97 6:11	630	N	1 23:39	1 11:25	N.U.N
95	6/28/97 6:21	880	N	1 23:44	1 0:42	N
96	6/28/97 7:02	925	N	1 22:27	7 3:26	U.N.U
98	6/28/97 7:47	900				
97	6/28/97 8:08	790	U	2 0:01	1 21:58	U
99	6/28/97 9:21	910	U	1 17:16	0 0:08	U
100	6/30/97 5:15	860	U	2 3:20	2 18:28	U
101	6/30/97 5:20	885	N	5 15:35	0 4:22	U.N
102	6/30/97 5:40	855	N	3 21:20	0 2:33	N.U.N
103	6/30/97 5:57	840	U	1 20:03	0 0:21	U
104	6/30/97 6:30	830	N	4 5:17	0 9:38	N
105	6/30/97 8:03	650	U	4 5:32	0 0:11	U
107	7/1/97 5:49	895	N	3 22:01	0 1:28	N
108	7/1/97 6:15	945	U	5 2:01	0 16:48	U
109	7/1/97 6:43	890	U	0 20:47	1 14:07	U
110	7/1/97 6:55	880	U	16 4:54	2 16:53	U.N.U
111	7/1/97 7:09	955	N	2 22:05	0 0:29	N
112	7/1/97 7:15	890	U	3 15:50	4 4:31	U.N.U
106	7/1/97 8:32	875	U	3 1:35	4 23:46	U.N.U
87	7/1/97 12:15	870	N	2 19:42	0 21:22	N.U
88	7/1/97 12:31	925	N	1 11:57	2 20:45	U.N
113	7/2/97 5:40	825	U	0 19:19	0 0:08	U
114	7/2/97 6:32	920	U	3 5:28	8 17:29	U.N.U
115	7/2/97 7:24	890	N	3 2:01	2 1:59	U.N.U.N
116	7/2/97 7:45	860	U	2 19:48	0 0:13	N.U
117	7/2/97 7:58	935	U	2 17:39	0 1:20	U
118	7/2/97 8:22	875	U	3 3:35	0 0:25	U
119	7/3/97 8:08	889	U	1 5:09	0 0:05	U

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Jaw Tag Number	Date Radio-tagged (m/d/yr h:min)	Length (mm)	River[a]	Time Until Detected[b] (d h:min)	Time at Confluence[c] (d h:min)	Pattern[d]
120	7/3/97 10:52	650	U	2 15:27	0 0:08	U
121	7/3/97 11:19	945	U	4 18:09	2 13:44	U
122	7/3/97 12:45	910	N	1 16:33	1 3:59	U.N
123	7/4/97 8:04	890	U	5 10:05	2 3:45	U
124	7/4/97 8:14	920	U	2 17:34	0 13:04	U
125	7/4/97 8:14	735	U	1 7:25	1 23:52	U
126	7/4/97 8:56	925	U	0 19:40	10 1:18	U.N.U.N.U
127	7/4/97 9:05	885	U	0 21:33	0 0:02	U
129	7/4/97 9:42	870	U	3 1:16	0 2:02	U.N.U
128	7/4/97 10:01	920	N	2 10:45	5 3:29	U.N.U.N
130	7/7/97 8:15	840	N	14 7:14	0 18:52	N
131	7/7/97 8:35	845	U			
132	7/7/97 9:21	825	U	3 6:11	2 15:10	N.U.N.U
133	7/7/97 9:37	940	U	2 14:31	0 5:04	U
134	7/7/97 10:10	935	U	2 7:03	3 12:19	U
135	7/8/97 1:01	850	N	11 12:47	3 14:57	U.N.U.N.U.N .U.N
137	7/8/97 9:45	890	N	10 23:26	0 0:04	N.U.N
136	7/8/97 9:47	885	U	2 20:15	0 0:01	U
138	7/8/97 10:38	915	N	10 6:14	1 16:19	U.N.U.N
139	7/9/97 8:35	895	U	3 21:40	1 13:55	U
140	7/9/97 10:30	845	N	4 19:05	4 4:40	U.N
141	7/9/97 12:47	895	U	5 23:26	1 16:23	U
142	7/10/97 9:32	840	N	9 2:00	0 13:06	U.N
143	7/10/97 9:36	905	N	3 19:49	1 22:12	U.N
144	7/10/97 10:20	855				
145	7/10/97 12:27	860	N	6 17:15	0 20:17	U.N
146	7/11/97 9:53	890	U			
147	7/11/97 10:38	860	U	4 13:38	0 0:12	U

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Jaw Tag Number	Date Radio-tagged (m/d/yr h:min)	Length (mm)	River[a]	Time Until Detected[b] (d h:min)	Time at Confluence[c] (d h:min)	Pattern[d]
148	7/11/97 12:50	870	U	8 17:15	1 5:55	U.N.U.N.U
149	7/12/97 7:45	920	N	1 21:57	8 3:28	U.N.U.N
150	7/12/97 9:22	895	U	4 19:08	5 0:00	U
151	7/13/97 7:10	875	U	2 19:43	2 1:56	U

[a] U indicates a fish that migrated up the Unalakleet River and N indicates a North River fish.

[b] This the time elapsed from when a radio-tagged salmon was released until it was fist detected at the remote tracking station.

[c] This is the time elapsed from when a radio-tagged salmon was first detected until last detected.

[d] This is the movement pattern of a salmon at the confluence of the North and Unalakleet rivers. (e.g. a N.U.N pattern indicates a North River bound fish that first swam up the North River, then into the Unalakleet River, before finally migrating up the North river to spawn.

[e] shaded areas indicate no available data.