Fishery Data Series No. 02-26

An Investigation of How Catch-and-Release Mortality of Coho Salmon in the Unalakleet River Varies with Distance from Norton Sound

by
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December 2002

Alaska Department of Fish and Game **Division of Sport Fish**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition.

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
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	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. 02-26

AN INVESTIGATION OF HOW CATCH-AND-RELEASE MORTALITY OF COHO SALMON IN THE UNALAKLEET RIVER VARIES WITH DISTANCE FROM NORTON SOUND

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December 2002

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-10-17, Job No. S-3-1(a).

The Fishery Data Series was established in 1987 for the publication of technically-oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

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This document should be cited as:
Stuby, L. 2002. An investigation of how catch-and-release mortality of coho salmon in the Unalakleet River varies with distance from Norton Sound. Alaska Department of Fish and Game, Fishery Data Series No. 02-26, Anchorage.

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ABSTRACT

Catch-and-release mortality was assessed for coho salmon *Oncorhynchus kisutch* on the Unalakleet River using radiotelemetry techniques during August 2001. Logistic regression was used to test the hypothesis that the there was no relationship between the distance upstream from the mouth and the probability of mortality for coho salmon caught-and-released against the alternative hypothesis that the mortality rate decreased with distance from Norton Sound. Sixty-eight coho salmon were captured in the lower river using rod and reel and were radio-tagged at eight sites spaced at least 1.6 km apart. Mortality and survival were assessed by examining fish movements after tagging using a combination of three fixed tracking stations, two aerial surveys of the drainage, and a boat survey of the tagging area. Fates were determined for all but two radio-tagged salmon and ten fish were assumed to have died. There was no significant relationship between the distance upstream from the mouth of the Unalakleet River and the probability of mortality for coho salmon that were captured and then released (χ^2=1.24; P=0.27). This result was in contrast to that of the study by Vincent Lang et al. (1993), which showed that coho salmon caught and released in the estuary of the Little Susitna River, Alaska suffered a significantly higher rate of mortality than did those caught and released upriver in exclusively fresh water. Therefore, the relationship between catch-and-release mortality and upstream distance may be river specific.

Hook placement, sex, and landing and handling times were independent of area of upstream distance (χ^2=0.31; P=0.27, χ^2=0.042; P=0.98, χ^2=7.75; P=0.26, and χ^2=7.85; P=0.25 respectively). All ten fish that died were bleeding and five were hooked in the tongue. Temperature and salinity measurements taken in the lower river indicated marine influence was slight and was limited to the lower 2 km of the river.

Key words: coho salmon, *Oncorhynchus kisutch*, Unalakleet River, North River, tracking stations, aerial survey, boat survey, catch-and-release mortality, radiotelemetry, logistic regression, chi-square tests.

INTRODUCTION

The Unalakleet River is a clear, run-off river in northwestern Alaska that drains approximately 2,700 square kilometers as it flows southwesterly through the Nulato Hills into Norton Sound (Figure 1). The salmon fishery is the most important resource associated with the river and the region (Rob 1998a). The river supports a large run of coho salmon, which are important in commercial, subsistence, and sport fisheries.

The sport fishery is concentrated in the lower reaches of the mainstem river and in the North River, the largest tributary in the system that flows into the mainstem approximately 8.4 km upstream from the mouth. Estimated annual catch by sport anglers from 1990-2000 ranged from 1,572-9,593 coho salmon (Table 1). Estimated annual sport harvest since 1983 ranged from 145-4,103 coho salmon. Thus, substantial numbers of coho salmon are caught-and-released each year. Local residents and patrons of a fishing lodge, located 5 km upstream from the confluence with the North River, fish primarily in the North River and in the mainstem Unalakleet River in close proximity to the lodge. Limited fishing occurs further up in the drainage.

Run strength has varied annually as indicated by past tower counts on the North River and by commercial and subsistence catches (Table 2). Estimates of escapement past the North River counting tower varied from 1,229 in 1996 to 12,383 for 2001. Total combined subsistence and commercial catches have ranged from 15,097-87,100 since 1981.

Prior to 2001, sport fishing regulations allowed for a daily bag and possession limit of 10 coho salmon. The daily bag and possession limit for coho salmon was reduced to five fish for the 2001 season. An additional regulation implemented for the 2001 season required that after taking a bag limit of coho salmon from the Unalakleet River drainage, a person can not sport fish for any fish species downstream from the South River for the remainder of that same day. This

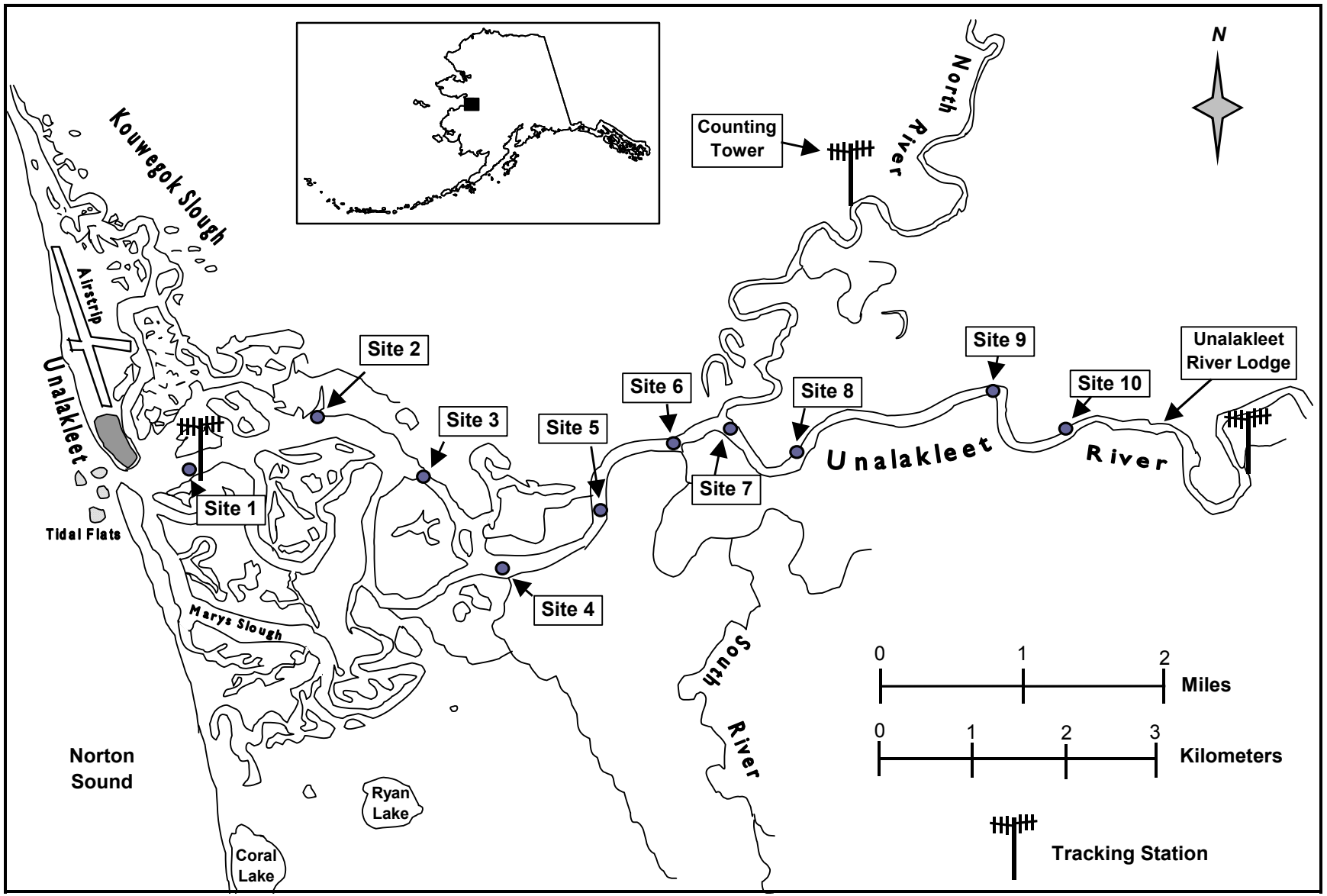


Figure 1.-Map of the Unalakleet River showing tagging sites and placement of tracking stations.

Table 1.-Catch and harvest of coho salmon by sport anglers from the mainstem Unalakleet River and the North River, 1983-2000[a].

	Mainstem		North River		Total	
Year	Catch	Harvest	Catch	Harvest	Catch	Harvest
1983		1,596				1,596
1984		779				779
1985		369				369
1986		1,605				1,605
1987		145				145
1988		182				182
1989		1,185				1,185
1990	3,396	1,826	0	0	3,396	1,826
1991	2,882	2,156	24	24	2,906	2,180
1992	2,802	1,304	292	251	3,094	1,555
1993	1,572	643	0	0	1,572	643
1994	2,488	2,017	408	408	2,896	2,425
1995	3,086	1,816	680	217	3,766	2,033
1996	5,598	3,193	265	218	5,863	3,411
1997	3,876	2,696	144	88	4,020	2,784
1998	3,071	2,613	142	129	3,213	2,742
1999	8,277	2,030	1,316	661	9,593	2,691
2000	8,595	3,914	589	189	9,184	4,103

[a] Data from Mills (1983-1994), Howe et al. (1995-1996, 2001a-d), and Walker et al. (*In prep*).

Table 2.-Commercial and subsistence harvest, test-net catch, North River tower counts, and aerial survey counts for the Unalakleet River, 1981-2001.[a]

	Harvest			Test Net Catch	North River	
Year	Commercial	Subsistence	Combined		Tower Count	Aerial Survey
1981	29,845	5,808	35,653	301		263
1982	61,343	7,037	68,380	235		4,145
1983	36,098	6,888	42,986	184		
1984	47,904	6,675	54,579	259		152
1985	15,421	2,244	17,665	172	2,045	
1986	20,580		20,580	134		
1987	15,097		15,097	128		680
1988	24,265		24,232	172		
1989	36,025	4,681	40,706	181		
1990	52,015		52,015	254		
1991	52,033		52,033	152		2,510
1992	84,449		84,449	421		398
1993	26,290		26,290	138		1,397
1994	71,019	16,081	87,100	276		
1995	31,280	14,450	45,730	188		
1996	52,027	15,856	67,883	609	1,229	1,834
1997	26,079	9,120	35,199	168	5,768	
1998	24,534	7,303	31,837	186	3,361	
1999	10,264	8,140	18,404	187	4,792	
2000	29,803	5,878	35,681	258	6,961	
2001	15,102[b]	N/A	N/A	200	12,383[c]	
Average	36,261	8,471	42,825	229	5,220	1,422

[a] Data from: Rob (1998a and 1998b); F. Bue, Alaska Department of Fish and Game, Fairbanks, personal communication, and W. Jones, Alaska Department of Fish and Game, Nome, personal communication.

[b] Data preliminary and subject to change.

[c] Counting tower was operated later than in previous years.

restriction was implemented because of the potential for high catch-and-release mortality of coho salmon and because catch and harvest of coho salmon have increased during the recent years. The South River (Figure 1) was selected as the demarcation point for the restriction because it was an easily identifiable reference point and it was assumed to be far enough upstream of the estuarine zone to not be influenced by tidal influxes (C. O. Swanton, Alaska Department of Fish and Game, Fairbanks, personal communication). It has been speculated that the physiological changes that occur in the fish while traveling through estuarine zones increases mortality rates associated with being caught-and-released compared to fresh water. However, no studies have been conducted that specifically address this question.

The objective of this study was to test the hypothesis that there was no relationship between the distance upstream from the mouth of the Unalakleet River and the probability of mortality for coho salmon caught-and-released against the alternative hypothesis that the mortality rate would decrease with distance.

BACKGROUND

Studies in Alaska and elsewhere have shown relatively high mortality rates for coho salmon captured and handled in or near estuarine environments. Booth (1990) and Hammarstrom (*Unpublished*) found that approximately 40% of the coho salmon captured with fish wheels and radio-tagged on the Kenai River in 1998 and 1999 at 30.7 rkm, which was fresh water, died or could not be located after release. In 2000, the fish wheels were relocated further upstream to 43.4 and 44.2 rkm under the assumption that coho salmon captured in the fish wheels were more physiologically adjusted to living in fresh water and more tolerant to the stress of capture and handling. The mortality rate of 204 fish tagged at this upriver location was 17% (J. Carlon, personal communication, Alaska Department of Fish and Game, Soldotna, Alaska). In another Kenai River study, Bendock and Vaught (1994) noted that 47% of coho salmon captured (gill nets, angling, fishwheels) radiotagged and released near the river mouth were subsequently not relocated. Jones et al. (1999) observed that 24% of the coho salmon tagged (gill nets) with radio transmitters at the mouth of the Taku River were never relocated. It was assumed these fish backed-down into salt water and were considered mortalities. In a study that examined the utility of using radio transmitters for coho salmon in the Taku River, Eiler (1990) indicated that 125 of 186 (67%) coho salmon sustained upriver movement after being captured (fishwheels) and marked with radio transmitters in an estuarine environment.

Numerous catch-and-release mortality studies have been conducted on coho salmon and other salmon species, but few have looked specifically at the adverse affects of being caught-and-released during the transition phase from marine to fresh water. Vincent-Lang et al. (1993) compared mortality rates for coho salmon captured and released using sport tackle in the Little Susitna River estuary and 32 river kilometers (rkm) upstream in exclusively fresh water. Coho salmon caught and released in the estuary suffered a significantly higher rate of disappearance (presumed to be mortality equal to 69%) than those captured and released upriver (12%). Vincent-Lang et al. (1993) noted that a higher percentage of coho salmon were hooked in the gill and gullet in the estuary (48%) compared with fish sampled upriver (20%). Identical gear was used to catch fish in both areas, which suggested that coho salmon were more likely to become hooked in a lethal location in the estuary than in freshwater. In another study, short-term (24-hour) catch-and-release mortality was determined for coho salmon sampled by recreational anglers on the mainstem of the Fraser River in southern British Columbia (Fisheries and Oceans

Canada 2000). The study took place at the Brownsville Bar (intertidal transition zone) and Duncan Bar (freshwater zone). Preliminary results suggested that there was no significant difference in mortality between the two zones.

Studies of hooking mortality in recreational fisheries have shown that fish captured and released by anglers usually die from two major causes: injuries from bleeding and physiological stress associated with being played, landed, and handled (Muoneke and Childress 1994). Bleeding severity is related to hook placement, and fish hooked in critical locations such as gill arches, heart, throat/gullet, and tongue tend to bleed the most and suffer the highest rates of mortality (Bendock and Alexandersdottir 1990; Falk et al. 1974; Muoneke and Childress 1994; Wertheimer 1988; Cox-Rogers et al. 1999; Hooton 2001). Hook size, the presence of barbs, and number of hooks can also contribute to mortality. Hooks with large gaps tend to cause deeper wounds but smaller hooks are more easily ingested (Wertheimer et al. 1989; Gjernes et al. 1993). Single hooks are usually more easily swallowed than treble hooks, and removal of deeply ingested hooks often increases mortality (Muoneke and Childress 1994).

Past hooking mortality studies have shown that exhaustive exercise by fish such as that associated with angling, may lead to pronounced physiological disturbances that could contribute to delayed mortality of fish (Graham et al. 1982; Wood et al. 1983; and Holk and Lykkeboe 1998). Also, the brief exposure to air during which the hook is removed and pictures taken is a significant additional stress that may ultimately influence whether a released fish will survive (Ferguson and Tufts 1992).

METHODS

Angling for coho salmon was conducted from 13 to 31 August at ten sites spaced approximately 1.6 km (1.0 mi) apart from the mouth of the Unalakleet River upstream to just below the Unalakleet River Lodge (Figure 1). Locations where fish would shoal during their upstream migration figured into the selection of sites. Site 6 was at the mouth of the South River and was selected because it is the demarcation point for the catch-and-release regulation. The study was designed to dispense 10-13 radio tags into coho salmon at each of the ten sites. One hundred twenty-five radio tags were available for deployment. A hand-held GPS was used to identify exact tagging locations. Three persons conducted the sampling.

Coho salmon were captured using standard catch-and-release techniques as outlined by ADF&G (Appendix A). Monofilament line (9 kg test) was used along with a heavy spinning rod and reel to land the catch quickly. Terminal tackle consisted of single-hooked, 2/0 pixie lures with crimped barbs. Only coho salmon larger than 500 mm FL were selected for tagging in order to ensure transmitters weighed no more than 2% of the body weight of a fish in air or 1.25% of the weight in water (Winter 1983).

All captured fish over 500 mm FL were tagged unless they were hooked in a critical area that caused severe bleeding and immediate death. Captured salmon were placed into a tagging cradle inside of a holding tub containing fresh water. Radio tags were implanted through the esophagus and into the upper stomach using a 45-cm plastic tube with an inside diameter equal to that of the radio-tags. The radio tag was pushed through the esophagus and into the stomach such that the antenna end was seated 0.5 cm anterior to the base of the pectoral fin. The coho salmon were released in quiet water out of the main current.

To simulate proper catch-and-release practices, handling was kept to a minimum. Sex was determined from external characteristics. Salmon were measured for fork length while in the holding tub. For each fish given a radio tag, location, landing time, handling time, fork length, and tag frequency and code were recorded. In addition, hook placement, degree of bleeding, swimming away characteristics, and overall external appearance were recorded and assigned an identification number (Table 3).

To encourage returns of radio tags from coho salmon captured in the subsistence and sport fisheries, the public was made aware of the study through personal contacts and by posting fliers in public places. Additionally, people employed at the fishing/hunting lodges, sport shops, and the fish processing plant were made aware of the study and were asked to save any tags they encountered and to note location and time of capture. Each radio tag had imprinted: "Please return to the nearest Alaska Department of Fish and Game Office, Lisa Stuby 459-7202".

RADIOTELEMETRY SPECIFICS

Radio tags were Model Five pulse-encoded transmitters made by ATS[1]. Tags were 5.5-cm long, 1.6 cm in diameter, weighed 18 g in air, and had a 30-cm external whip antenna. Sixteen frequencies were spaced 10-20 kHz apart in the 149 MHz range with eight encoded pulse patterns per frequency for a total of 125 uniquely identifiable tags.

Two remote tracking stations were located upstream of the tagging area and one station was set up near the mouth of the river. Stations were similar to those described in Eiler (1995). One station was placed at the North River counting tower and a second on the Unalakleet River approximately 2.4 km upriver from the Unalakleet River Lodge (Figure 2). The third station was located in the lower Unalakleet River near the first tagging site. The site for the lower station was selected to detect radio-tagged coho salmon that "backed-out" or left the system after tagging. This station was placed just above the river mouth because salinity concentration at the mouth was greater than 35 ppt, which would have caused attenuation of the radio signal. Stations were placed on high banks with an unobstructed line of sight in all directions in order to ensure good signal reception.

Each tracking station included two deep cycle batteries, a solar array, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, steel housing box, and two Yagi antennas. The receiver and DCC were programmed to scan through the 16 frequencies at 2 s intervals each and received from both antennas simultaneously. When a signal of sufficient strength was encountered, the receiver paused for 5 s on each antenna. Tag frequency, code, signal strength, date, time, and antenna number were then recorded on the data logger for each tag detected. The relatively short cycle period minimized the chance that a radio-tagged fish swam past the receiver site without being detected. Data were downloaded into a laptop computer weekly.

[1] Advanced Telemetry Systems, Isanti, Minnesota. Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

Table 3.-Identification numbers and corresponding descriptions of hook placement, bleeding severity, swimming away characteristics, and overall external appearance.

Identification Number	Hook Placement	Bleeding Severity	Swimming Away Characteristics	Overall External Appearance
0		None-no evidence of external bleeding.	No apparent effects from handling. Fish easily and readily swam away.	No apparent effects from handling. Fish lost little slime and retained all their scales.
1	Upper Jaw	Slight-a small amount of bleeding generally localized near the point of hook entry.	Fish showed some effects from handling, but swam away quickly after release.	Some slime loss, but no scale loss.
2	Roof of Mouth	Moderate-a greater amount of external bleeding generally localized around the point of hook entry.	Fish required a long time to recover and swim away.	Moderate slime loss and some scale loss
3	Esophagus	Severe-copious amounts of blood, staining the water in the holding tub and generally surrounding and obscuring the point of hook entry.	Fish died immediately after release.	Heavy slime and scale loss.
4	Gills			
5	Tongue			
6	Lower Jaw			
7	Snag			
8	Eye			

Adapted from: Stuby and Taube (1998) and Falk and Gillman (1975).

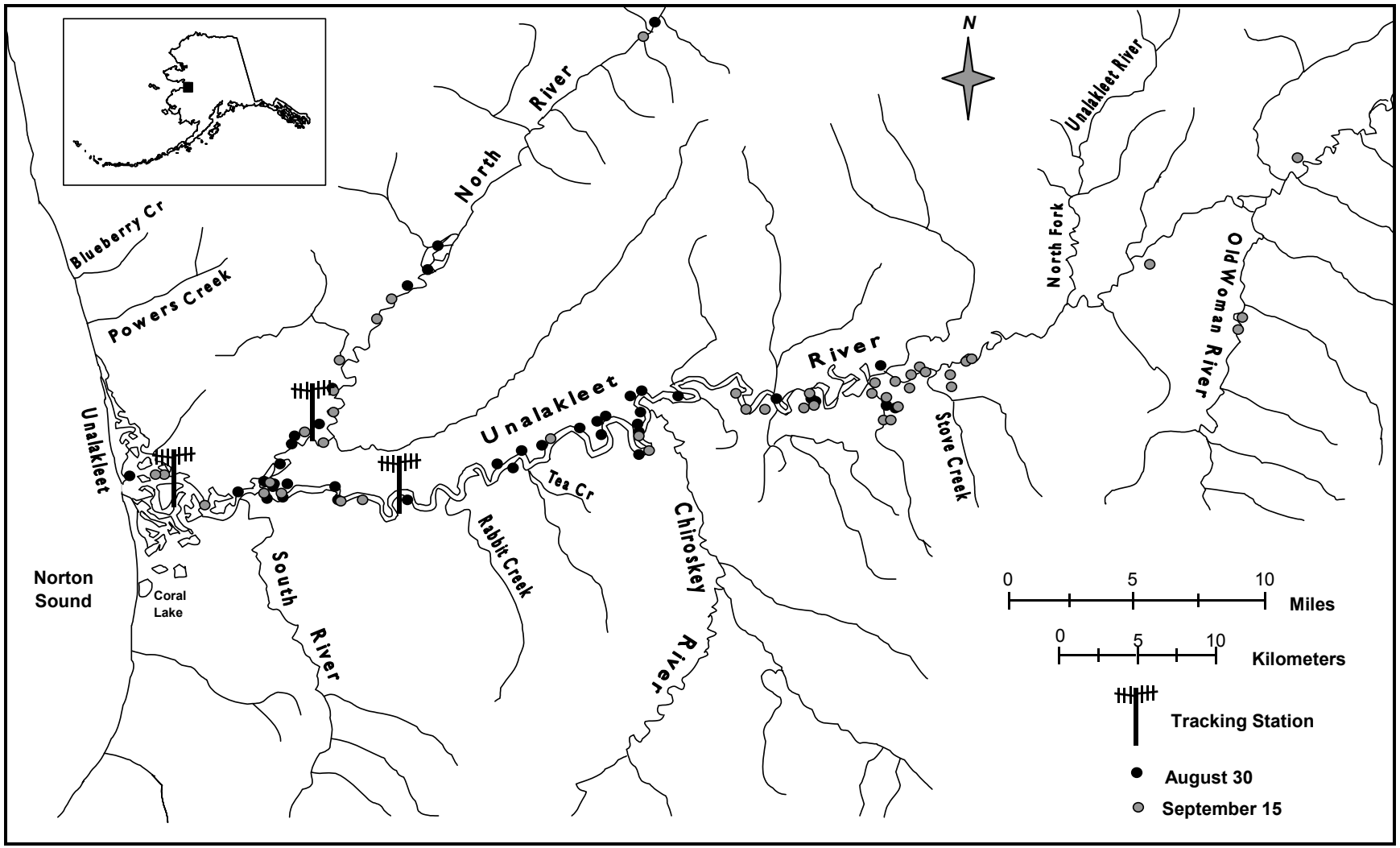


Figure 2.-Map of the Unalakleet River showing locations of radio-tagged coho salmon during two aerial survey flights.

FATES OF RADIO-TAGGED COHO SALMON

All radio-tagged coho salmon were assigned one of four distinct fates (Table 4). These fates defined whether the caught-and–released coho salmon survived and reached spawning areas, or died from injuries associated with capture and handling. The tracking stations assisted in monitoring movements and defining fates of radio-tagged coho salmon. In addition to the tracking stations, the fates and distributions of radio-tagged coho salmon were further examined with aerial tracking from small aircraft on 30 August and 15 September and with a boat survey on 16 September. Aerial flights were conducted up to the headwaters of the mainstem of the Unalakleet River and in the major tributaries (Figure 2). Radio tags were tracked by boat on 16 September from the two upper tracking stations downstream to the mouth of the Unalakleet River. The aerial and boat tracking helped locate tagged fish that the tracking stations failed to record and verified whether a fish recorded by one of the stations migrated past and remained upstream of the station. Radio-tagged fish that did not migrate past the upper stations or that were detected downstream past the lower station were assumed to be hooking mortalities.

HYDROLOGICAL DATA

Salinity and temperature were measured at each of the ten capture sites using a YSI 85[2] probe to investigate any correlation with hooking mortality. More detailed measurements were taken in areas of tidal influence. Vertical transects were taken at five to eight sites within the estuary during one of the highest tides of the month (19 August), a high surge tide (31 August), a low tide (21 August), and an intermediate tide (27 August). Locations of each vertical transect were recorded using a hand-held GPS.

DATA ANALYSIS

The mortality rate at each capture location was calculated as a binomial proportion as:

$$\hat{p}_i = \frac{x_i}{n_i} \tag{1}$$

where:

$\hat{p}_i$ = the mortality rate of fish at site *i*,

x_i = the number of known mortalities that were tagged at site *i*; and,

n_i = the number of fish that were caught at site *i* and assigned a fate of either "hooking survivor" or "hooking mortality" (Table 4).

[2] YSI, Incorporated, Yellow Springs, Ohio. Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

Table 4.-List of fates of radio-tagged coho salmon in the Unalakleet River, 2001.

Fate	Description
Hooking Survivor	Fish that moved upstream past one of the two tracking stations (on the North River or at the Unalakleet River Lodge) or moved into another river system; and, Fish that were observed spawning during a boat survey upstream from their release site, but downstream from the upper tracking stations.
Hooking Mortality	Fish that died immediately after capture (such fish were not radio-tagged); or, fish that were found dead during a boat tracking excursion within 7 days of release downstream from the upper tracking stations that were never previously located upstream; or, fish that moved downstream past the lowermost tracking station and were never located again.
Fishery Mortality	Fish that were harvested in either the sport, commercial, or subsistence fishery. Such fish were not used for estimation of hooking mortality unless the fish remained alive for at least 7 days and moved upstream beyond the study area (e.g. fish was caught in the sport fishery upriver from the Unalakleet River Lodge).
Unknown	Fish that were never located after release. Such fish were not used for estimation of hooking mortality.

The standard error was estimated by (Zar 1984):

$$SE[\hat{p}_i] = \left[\frac{\hat{p}_i(1-\hat{p}_i)}{(n_i - 1)} \right]^{1/2} \quad (2)$$

Logistic regression was used to test the hypothesis that there was no linear relationship between the distance upstream from the mouth of the Unalakleet River and the probability of mortality for coho salmon caught-and-released against the alternative hypothesis that mortality rate decreased with distance. The model used was:

$$\ln\left(\frac{\hat{p}_i}{1-\hat{p}_i} \right) = \alpha + \beta x \quad (3)$$

where:

α = constant, and

βx = the effect of distance x.

Assumptions of the experiment were that all coho salmon were handled in a similar manner and the probability of capture by area was similar with respect to sex and hook placement. The study section was described as lower (sites 1-6), middle (sites 7 and 8), and upper (sites 9 and 10) river areas to facilitate testing. Chi-square analyses were performed comparing capture location with hook placement, sex, and landing and handling times.

RESULTS

Between 15 and 31 August, 68 coho salmon were captured and fitted with radio tags at eight of the ten fishing sites. Ten fish were hooking mortalities and 56 were hooking survivors. Two fish were not logged by the tracking stations and were not detected during the aerial and boat surveys and their fates were deemed unknown.

Sampling objectives were to radio-tag 12-13 fish at each site. For sites 6-10, sampling objectives were met. Only four fish were captured and tagged at sites below the South River (site 6): two at site 1, one at site 3, and one at site 5 (Table 5). Mortality rates varied from 0.00 at sites 1-5 combined to 0.21 (SE=0.11) at site 9. The mortality rate for all sites combined was 0.15 (SE=0.04; Table 5). The logistic regression showed no significant relationship between the distance upstream from the mouth of the Unalakleet River and the probability of mortality for coho salmon that were captured and released (χ^2=1.24; P=0.266; Figure 3). Hook placement (χ^2=0.31; df=4; P=0.99; Table 6) and sex (χ^2=0.042; df=2; P=0.98; Table 7) were independent of the study area.

Of the ten fish assigned hooking mortality fate, five were found in the study section during the boat survey, three dropped out of the river soon after tagging and were logged by the lower station, and two fish moved upstream past one of the upper stations after tagging, but then dropped back into the study area or out of the river (Table 8). Of the 56 fish assigned hooking survivor fate, all were logged by at least one of the two upriver tracking stations. Two of these fish were captured in subsistence nets upstream from the upper Unalakleet River station. Seven

Table 5.-Mortality rates of coho salmon captured and radio-tagged at each site in the Unalakleet River, 2001.

Site	River Kilometer	Number Radio-tagged	Number of Mortalities	Mortality Rate	SE
1	0.7	2	0	0.000	0.000
2	2.3				
3	3.6	1	0	0.000	0.000
4	5.1				
5	6.5	1	0	0.000	0.000
6 (South River)	7.8	13	1	0.077	0.077
7	8.4	12	2	0.167	0.112
8	9.8	12	2	0.167	0.112
9	11.9	14	3	0.214	0.114
10	13.4	11	2	0.182	0.122
All		66	10	0.152	0.044

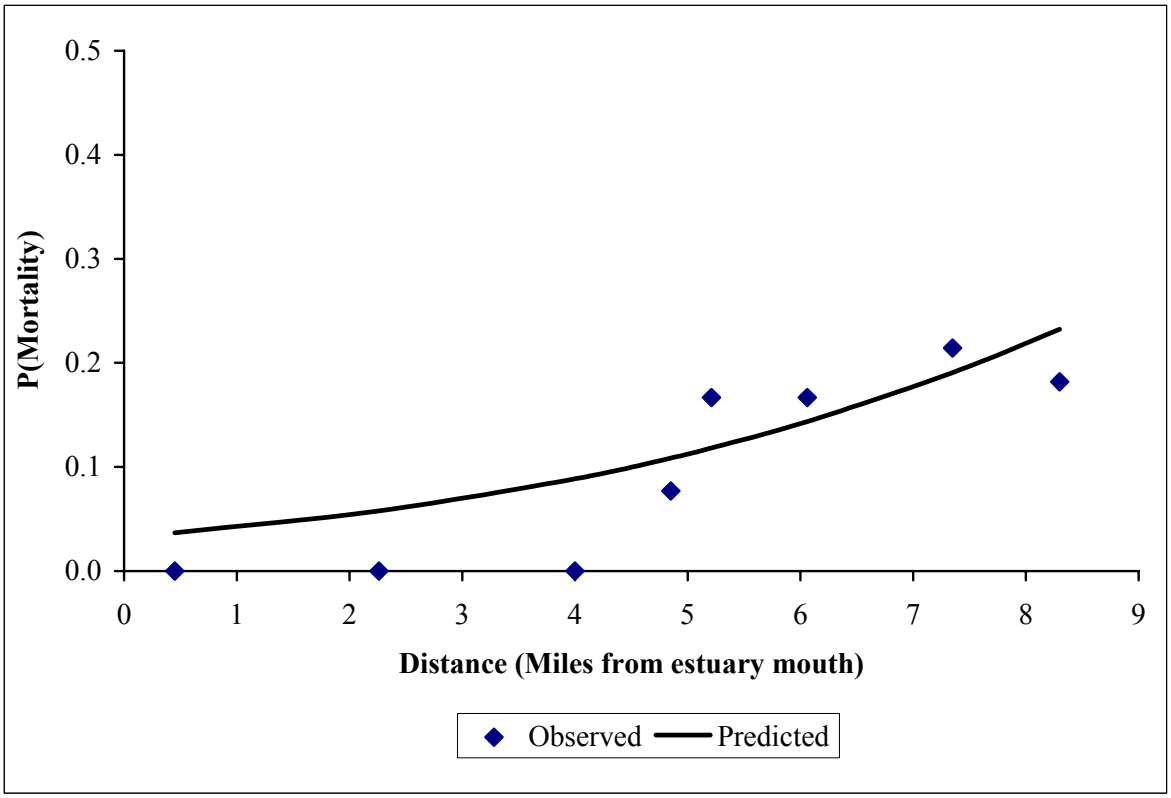


Figure 3.-Observed mortality rates and the associated predicted regression line for coho salmon caught and released from the Unalakleet River, 2001.

Table 6.-Results from a chi-square test that examined hook placement with respect to capture location for coho salmon from the Unalakleet River, 2001.

		Capture Location			
Hook placement	Test Results	Lower	Middle	Upper	Total Fish
Upper and Lower Jaws	Number of Fish	14	19	19	52
	Expected Values	13.39	18.91	19.70	
	Cell χ^2	0.027	0.000	0.025	
	Proportion	0.21	0.28	0.29	
Tongue	Number of Fish	2	3	4	9
	Expected Values	2.32	3.27	3.41	
	Cell χ^2	0.044	0.023	0.102	
	Proportion	0.03	0.05	0.06	
Snag and Eye	Number of Fish	1	2	2	5
	Expected Values	1.29	1.82	1.89	
	Cell χ^2	0.064	0.018	0.006	
	Proportion	0.02	0.03	0.03	
	Total Fish	17	24	25	66
	Total proportion	0.26	0.36	0.38	
	χ^2 results		χ^2=0.310[a]; df=4; P=0.99		

[a] Due to low expected values, the χ^2 may be biased high.

Table 7.-Results from a chi-square test that examined capture proportions of male and female coho salmon with respect to capture location on the Unalakleet River, 2001.

Location	Test Results	Males	Females	Total Fish
Lower	Number of Fish	10	7	17
	Expected Values	9.79	7.21	
	Cell χ^2	0.005	0.006	
	Proportion	0.15	0.11	
Middle	Number of Fish	14	10	24
	Expected Values	13.82	10.18	
	Cell χ^2	0.002	0.003	
	Proportion	0.21	0.15	
Upper	Number of Fish	14	11	25
	Expected Values	14.39	10.61	
	Cell χ^2	0.011	0.015	
	Proportion	0.21	0.17	
	Total Fish	38	28	66
	Total proportion	0.57	0.43	
	χ^2 results	χ^2=0.042; df=2; P=0.98		

Table 8.-Number of hooking survivors and hooking mortalities of radio-tagged coho salmon captured at eight sites in the Unalakleet River, 2001.

Tagging Location	Hooking Survivors Detected by: Up-River Tracking Station	Hooking Survivors Detected by: North River Tracking Station	Hooking Survivors Detected by: Both Stations	Hooking Mortalities Detected by: Estuary Station	Hooking Mortalities Detected by: Both upper Tracking Stations	Hooking Mortalities Detected by: Aerial and Boat Trackings	Not Found	Total Number Radio-Tagged
Site 1	2							2
Site 3			1					1
Site 5	1							1
Site 6	7	2	3	1			1	14
Site 7	3	4	3	1		1		12
Site 8	9	1			1	1		12
Site 9	11			1	1	1		14
Site 10	8	1				2	1	12
Total	41	8	7	3	2	5	2	68

salmon were recorded by both upper tracking stations. For example, one fish was tagged at site 6 on 18 August, was recorded by the North River tracking station on 23 August, was then recorded by the upper Unalakleet River tracking station on 4 September, then finally was recorded again at the North River station on 8 September.

During the first aerial survey on 30 August, 43 of 62 tagged fish were located. During the second aerial survey, 44 of 68 tagged fish were located. Five fish were located during the boat survey of the study area. In combination, the aerial and boat surveys located 81% of the tags.

Of the 66 coho salmon used in the analysis, 38 were males and 28 were females. Five fish of each sex died. All ten fish that died were bleeding when released. Five fish hooked in the tongue and four fish hooked in the lower jaw died. Of the 38 tagged males, 17 (45%) were blush-colored and were assumed completely osmoregulated to fresh water conditions. All of the captured female salmon were silver. Two of 17 blush-colored males died, and three of 21 silver-colored males died (Table 9).

Landing times varied from 15 s to 90 s and handling times varied from 30 s to 180 s (Figure 4). On average, landing time was 38 s and handling time was 85 s. Of the 14 fish handled in 60 s or less, one died and two of three fish handled for more than 120 s did not survive. Landing times were independent of capture location (χ^2=7.753; df=6; P=0.26) as were handling times (χ^2=7.853; df=6; P=0.25; Table 10).

Archived data are listed in Appendix B.

HYDROLOGICAL DATA

Salinity and temperature measurements were collected for potential use in the logistic regression model. However, marine influence on salinity and temperature did not extend past site 2. Therefore, those parameters were not included in the model. Throughout August 2001, fresh water from the Unalakleet River dominated the estuary. The highest tides measured 1.34 m (4.4 ft) and occurred on 18 and 19 August. The estuary remained predominantly fresh except near the mouth and slightly upriver from site 1 (Figure 5). Measurements on 21 August during a low tide of 0.06 m (0.2 ft) showed no inclusion of saline water, including at the mouth (Figure 6). A similar effect was also seen on 27 August during a 0.24 m (0.8 ft) tide (Figure 7). However, on 31 August during a 1.13 m (3.7 ft) tide, a tidal surge brought in saline water from Norton Sound. Salinity was highest at the mouth but virtually nonexistent at site 2 (Figure 8). Temperature increased with increasing salinity. Salinity tended to increase at 1 to 2 meters from the bottom and was highest on the surface.

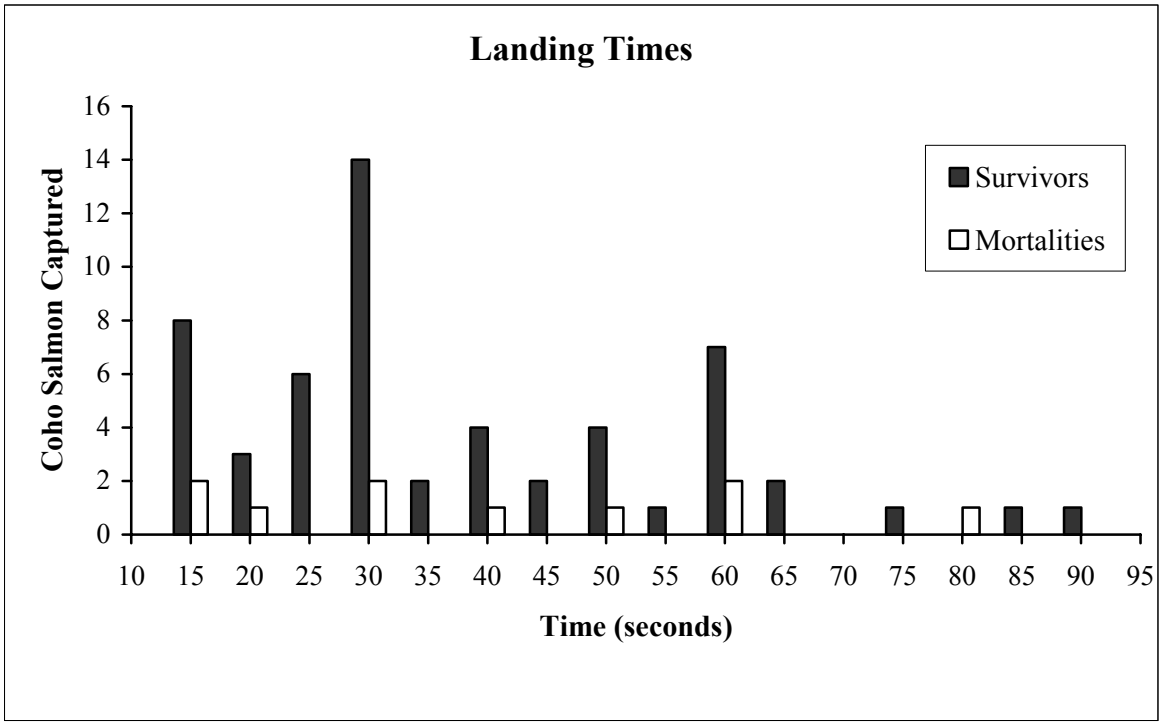
The estuary was generally shallow, deepest by the mouth, and shallowest near the center. During low tides, the shallow areas often became islands. Sites for the salinity and temperature measurements in the estuary varied in depth from 1-10 m depending on tide level and discharge from the Unalakleet River.

Mean daily discharge ranged from 1,380 cfs on 8 August to 3,570 cfs on 21 August (Figure 9). Mean daily discharge for the Unalakleet River was negatively correlated with average daily precipitation recorded for Nome (R=-0.22). Two rainstorms recorded in Nome occurred on the same dates as those in Unalakleet. The first storm did not appear to make an appreciable difference in discharge. However, the Unalakleet River became murky and began to rise shortly after the second storm .

Table 9.-Number of coho salmon survivors and mortalities from the Unalakleet River for various measures of hook placement, bleeding severity, swimming away characteristics, and overall external appearance.

Hooking Parameter/	Male		Female		Total	
Identification No.[a]	Survivor	Mortality	Survivor	Mortality	Survivor	Mortality
Hook placement						
1 (Upper Jaw)	15	0	14	0	29	0
2 (Roof of Mouth)	0	0	0	0	0	0
3 (Esophagus)	0	0	0	0	0	0
4 (Gills)	0	0	0	0	0	0
5 (Tongue)	2	3	2	2	4	5
6 (Lower Jaw)	14	2	5	2	19	4
7 (Snag)	1	0	1	1	2	1
8 (Eye)	1	0	1	0	2	0
Bleeding Severity						
0 (None)	18	0	11	0	29	0
1 (Slight)	13	1	11	3	24	4
2 (Moderate)	2	3	1	1	3	4
3 (Severe)	0	1	0	1	0	2
Swimming Away Characteristics						
0	30	3	20	3	50	6
1	3	1	3	2	6	3
2	0	1	0	0	0	1
3	0	0	0	0	0	0
Overall External Appearance						
0	13	1	3	1	16	2
1	10	4	3	0	13	4
2	10	0	13	4	23	4
3	0	0	4	0	4	0
Skin Color						
Silver	18	3	23	5	41	8
Blush	15	2	0	0	15	2

[a] Identification numbers are explained in Table 3.



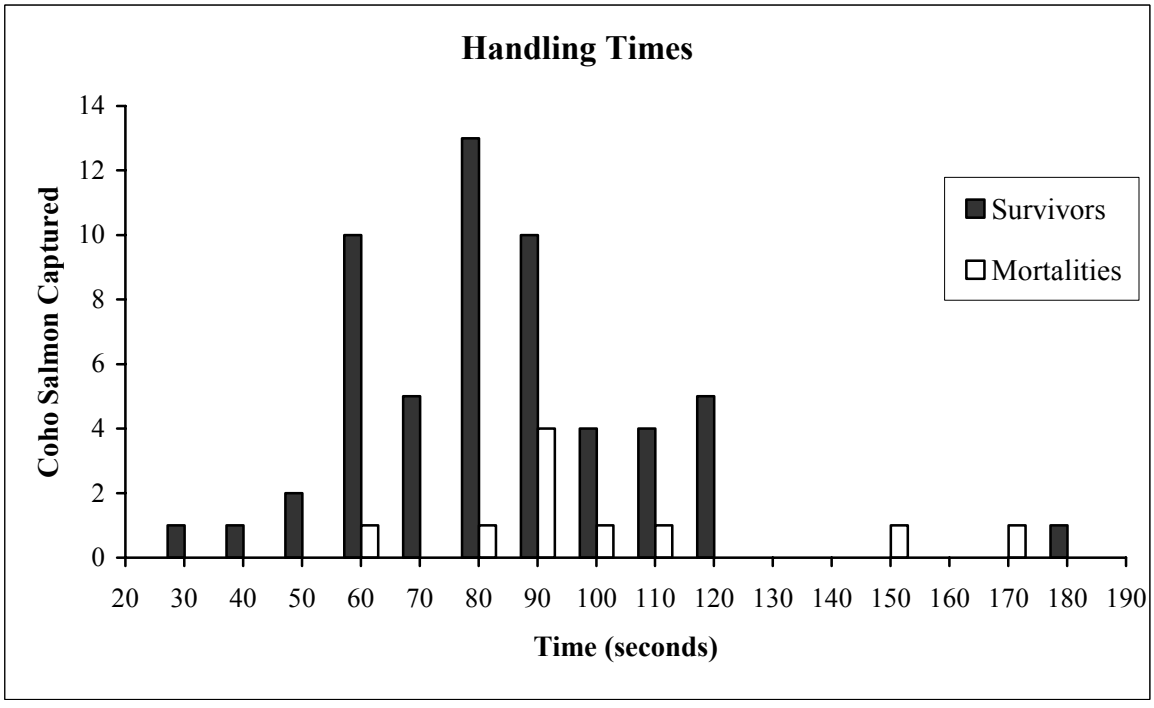


Figure 4.-Landing and handling times of coho salmon caught-and-released in the Unalakleet River, 2001.

Table 10.-Results from chi-square tests that examined landing and handling times with respect to capture location for coho salmon from the Unalakleet River, 2001.

Time (seconds)	Capture Location			Total Fish
	Lower	Middle	Upper	
		Landing		
10 to 25	7	4	9	20
26 to 30	3	7	6	16
35 to 50	4	8	2	14
55 to 95	3	5	8	16
Total	17	24	25	66
χ^2 results		χ^2=7.753[a]; df=6; P=0.26		
		Handling		
20 to 60	5	7	4	16
70 to 90	2	8	11	21
95 to 130	3	3	6	12
140 to 190	7	6	4	17
Total	17	24	25	66
χ^2 results		χ^2=7.853[b]; df=6; P=0.25		

[a] Twenty-five percent of expected values under 5.

[b] Thirty-three percent of expected values under 5.

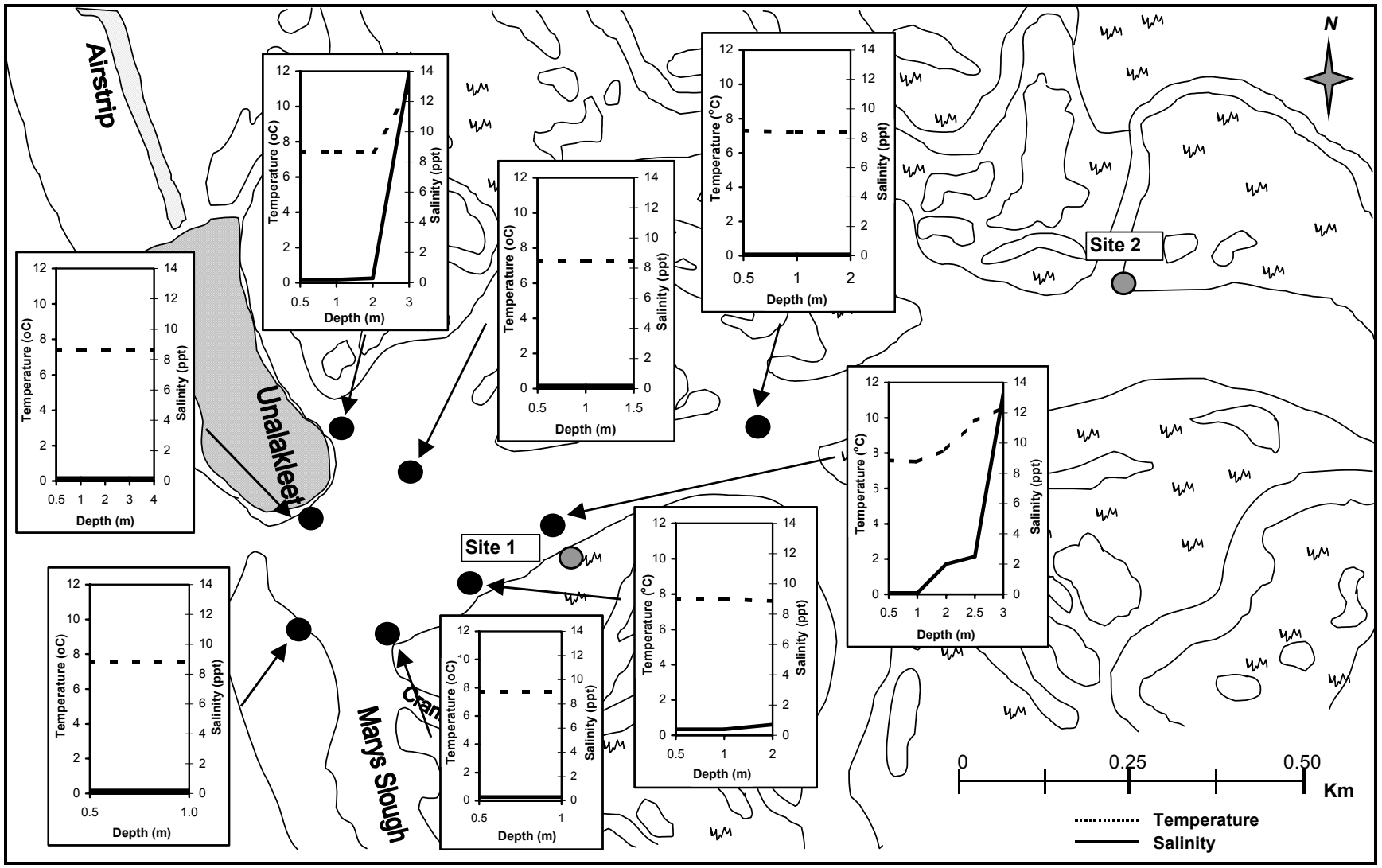


Figure 5.-Temperature and salinity by depth for eight sites within the estuary of the Unalakleet River, 2001. Measurements were taken during a 4.4 ft high tide on 19 August 2001.

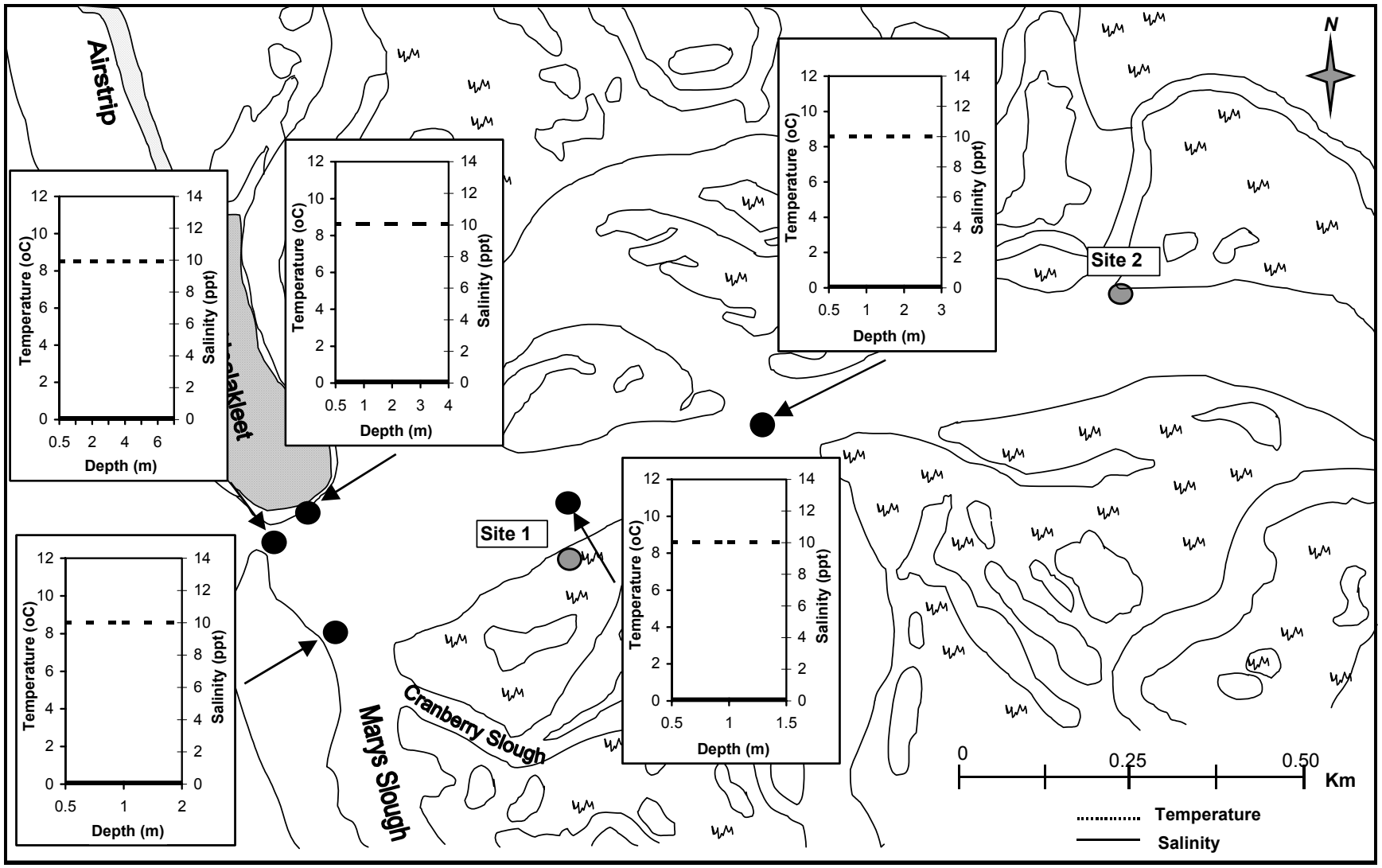


Figure 6.-Temperature and salinity by depth for five sites within the estuary of the Unalakleet River, 2001. Measurements were taken during a 0.2 ft low tide on 21 August 2001.

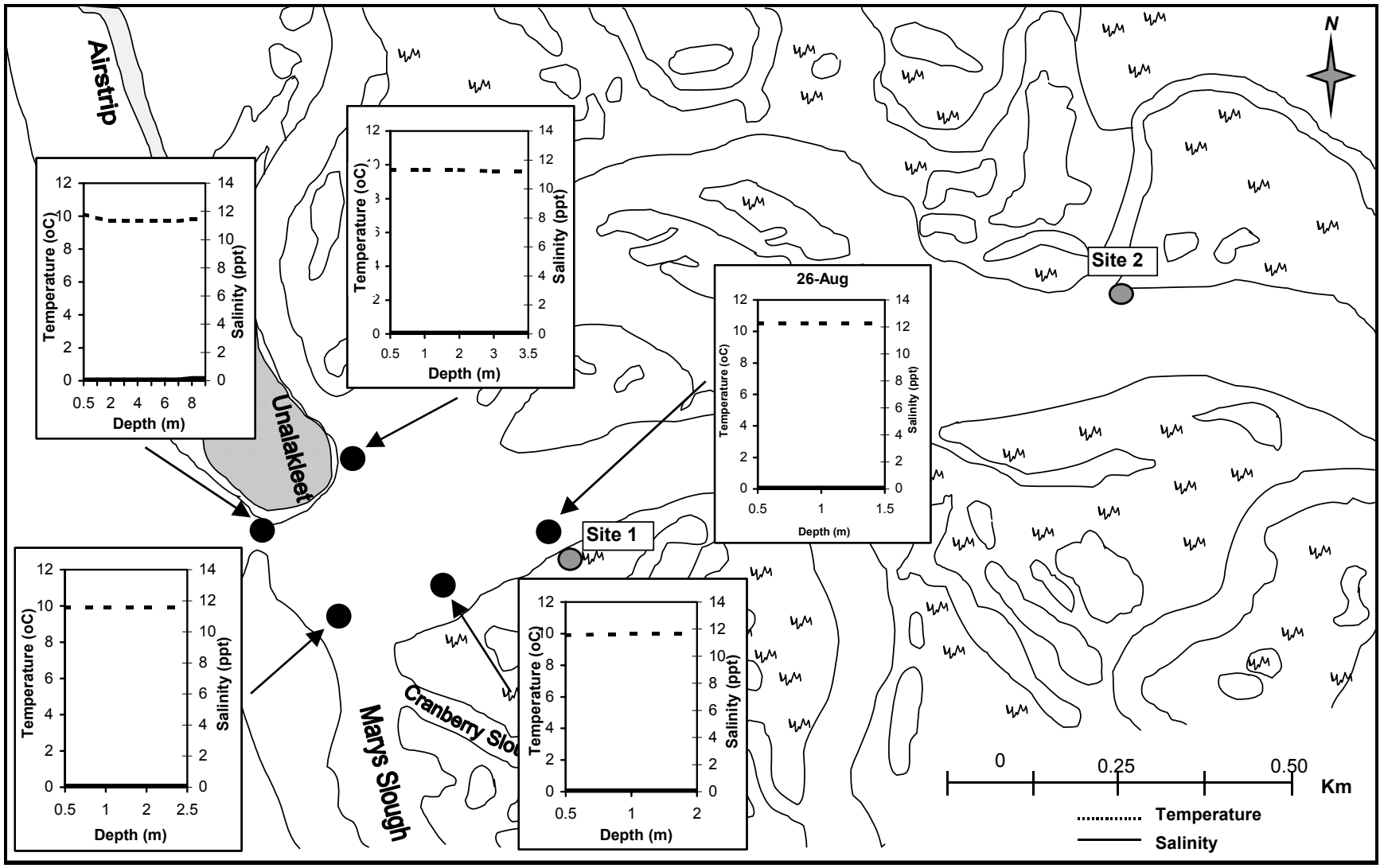


Figure 7.-Temperature and salinity by depth for five sites within the estuary of the Unalakleet River, 2001. Measurements were taken during a 0.8 ft intermediate tide on 26 and 27 August 2001.

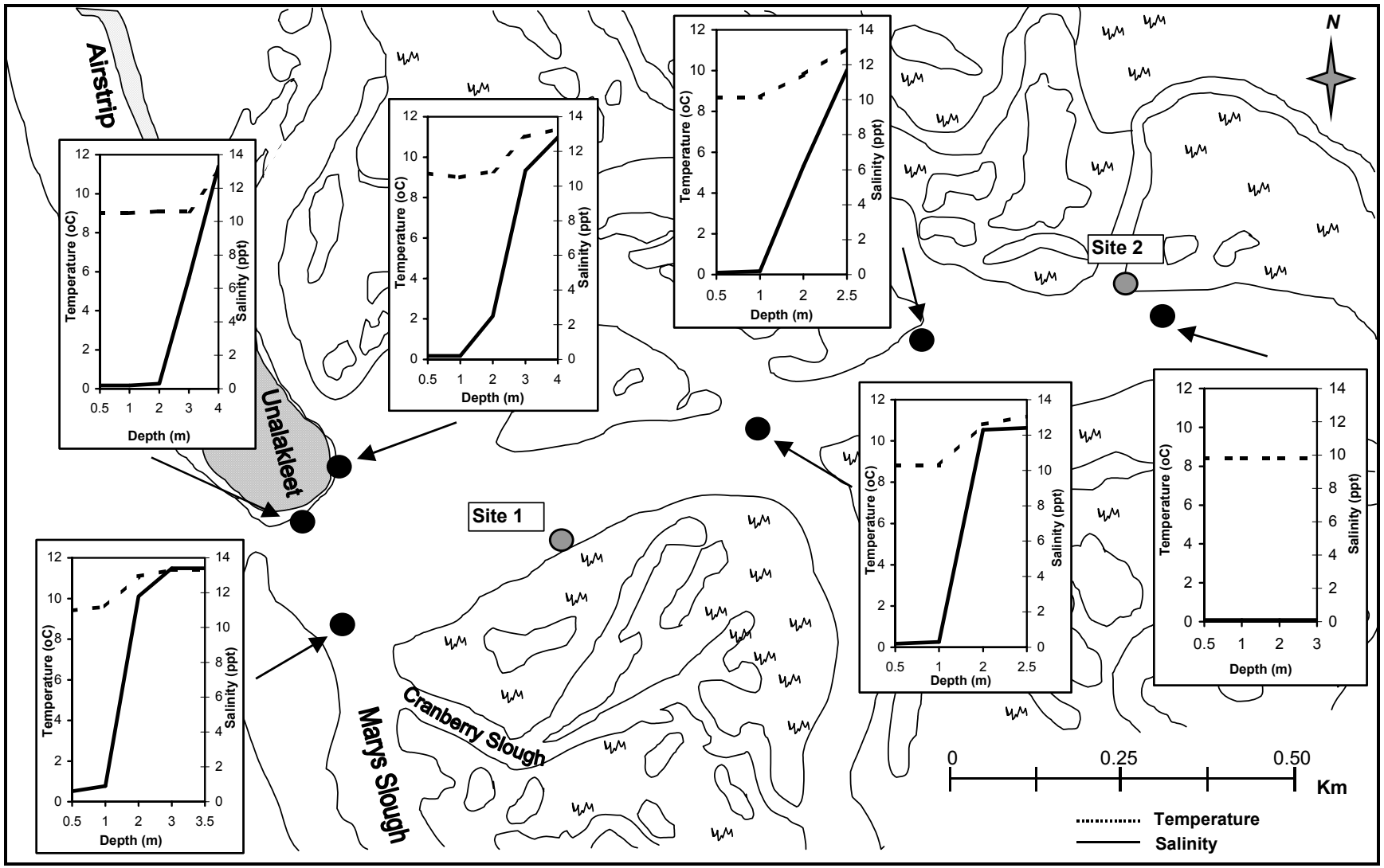


Figure 8.-Temperature and salinity by depth for six sites within the estuary of the Unalakleet River, 2001. Measurements were taken during a 3.7 ft surge tide on 31 August 2001.

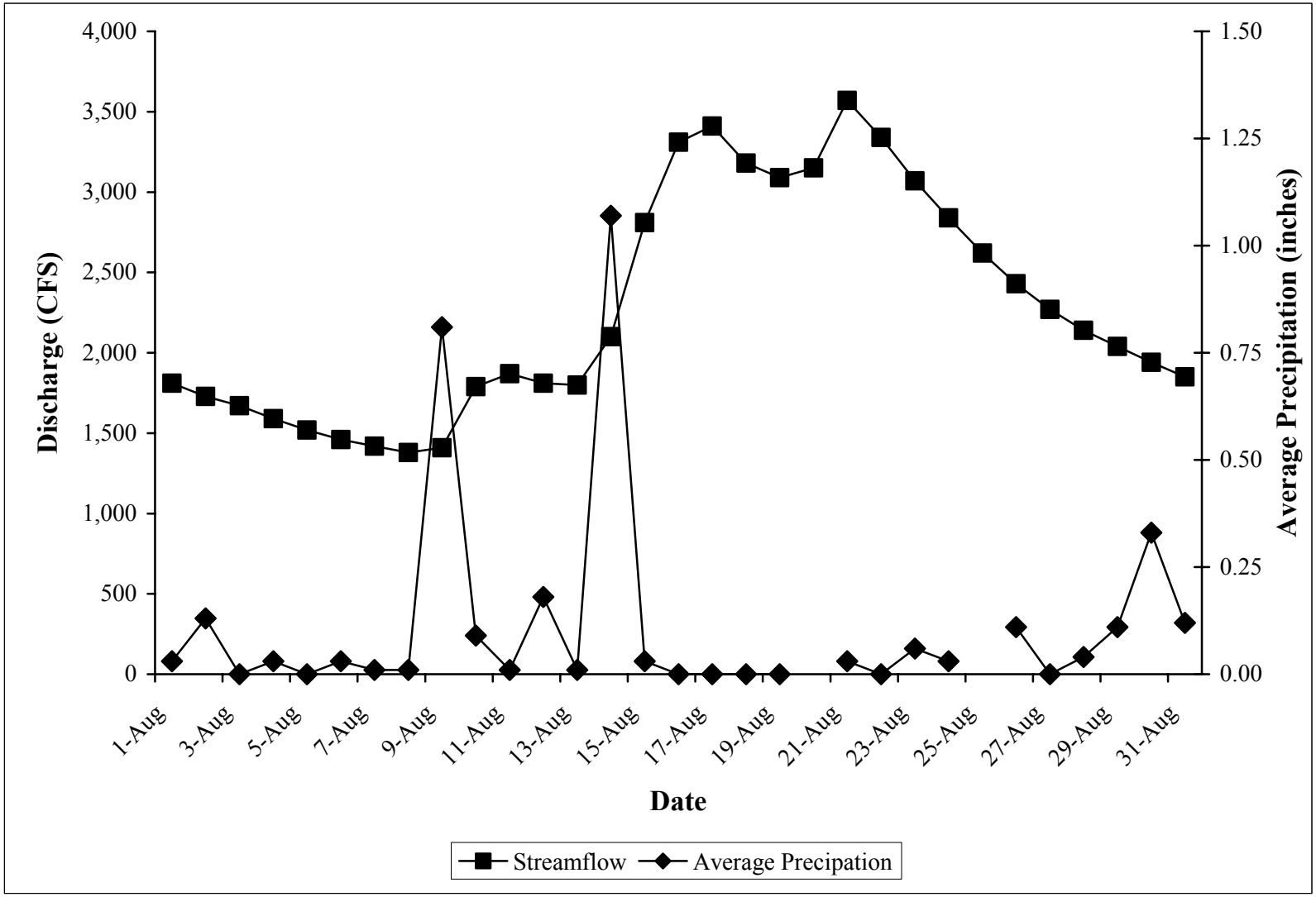


Figure 9.-Mean daily discharge from the Unalakleet River and daily precipitation at the Nome Airport for 01-31 August 2001. Gauging station located near Chirosky River confluence. Hydrological data from United States Geological Survey (USGS 2001), and climatic data from National Oceanic and Atmospheric Administration (NOAA 2001).

DISCUSSION

In this study, catch-and-release mortality for coho salmon did not significantly decrease with distance upriver from the estuary. Rather, there was a slight increase in mortality with distance upriver, which was the opposite effect of the hypothesis. Although the study suffered from tagging only four fish in the lower river, all four fish survived, which indicates that mortality was likely not higher than in upriver areas.

This conclusion was in contrast to that of Vincent-Lang et al. (1993), which found a significantly higher mortality for coho salmon captured and released in the Little Susitna River estuary compared to those captured and released 32 rkm upriver in exclusively fresh water. Concerns over probable catch and release mortality for the Unalakleet River stemmed from the conclusions of the Little Susitna River coho salmon study. The conclusions from these two studies show that each river system in Alaska may be different with regards to catch and release mortality for coho salmon with respect to distance from the ocean.

In this study, temperature and salinity measurements were taken over a range of tides to define the extent of marine influence in the lower river. The influence of marine water extended no more than 1.9 km upriver from the mouth of the river. There were no observations of coho salmon milling or holding in specific areas within the estuary. From observations of this study and discussions with local fishers, site 5 and the South River are usually the first locations where any substantial numbers of coho salmon congregate.

Of the 38 males sampled, 45% had blush-colored skin. These fish were captured in all sections of the river, including one in the estuary. Coho captured at sea or shortly after entry into fresh water are mostly silver-colored on their sides and ventral surfaces (Sandercock 1991). Blush-colored fish could be considered osmoregulated to freshwater. Vincent-Lang et al. (1993) also observed that a large number of coho salmon handled in the estuary easily lost their scales, while those 32 km upriver did not lose their scales as readily when handled. Black (1957, 1958) reported that scale-loss and abrasion of the mucus coat were major factors contributing to mortality rates in coho salmon that were captured and released.

A great deal of effort was expended trying to catch coho salmon downstream from the South River with limited success. Discussions with local fishers and sport fishing guides indicated few people attempt to fish downstream from the South River, and rarely in the estuary. Popular fishing areas are in the North River and in the Unalakleet River at and upstream from the South River. Poor catch rates in the lower river may also have been due to a small run size. The 2001 commercial coho harvest was one of the lowest on record. During the sampling period, the commercial fishery CPUE was below average, despite the low fishing effort that resulted from fishery restrictions (Menard 2001).

In this study, hook size, line strength, and lure type were standardized to remove the effects of gear on estimates of mortality for the different river areas. The gear was selected to mimic what is commonly used by anglers. Because only ten fish died in this study, there was little power to test for differences in mortality rates for various parameters such as sex, hook placement, bleeding severity, skin color, swimming away characteristics, and external appearance. However, it was evident that the most probable cause of mortality was from bleeding.

A constant challenge for fishery managers when faced with an issue like catch-and-release mortality is how to best prevent unnecessary mortality, yet preserve angling opportunity. The lack of information on catch-and-release mortality below the South River should not affect management decisions regarding current catch-and-release practices in the Unalakleet River. It is apparent that little sport fishing is conducted downstream from the South River. Therefore, if catch-and-release mortality is greater than what was estimated in this study, the current regulation that prohibits catch-and-release fishing downstream from the South River after a daily bag limit is taken should protect this stock from excessive harvest.

ACKNOWLEDGEMENTS

Ryan Sipary, Tim Stadtmiller, and Nathan Suel assisted with collecting data. Ryan Sipary also assisted in setting up and dismantling the tracking stations. Pat Hansen assisted with data analysis and project design. Matt Evenson assisted with project planning, logistics, and edited this report. Sara Case reviewed the final report. Jim Menard and Wes Jones of the Alaska Department of Fish and Game, Commercial Fisheries Division, Nome, provided housing at the Unalakleet bunkhouse and a boat and motor to access the sampling sites. Personnel from the Anchorage Bureau of Land Management assisted with the capture and tagging of coho salmon. Art Ivanoff of the Native Village of Unalakleet, Jerry Ivanoff of the Norton Sound Economic Development Corporation, and Paul Johnson of Unalakleet Native Corporation provided valuable information about the coho salmon fishery. Don Stiles of Kawerak Inc. granted permission for one of the tracking stations to be set up at the North River counting tower site. The Unalakleet Native Corporation and Larry Ivanoff granted permission to use their land for placement of two radio tracking stations. Jim Tweto of Hageland Aviation Services expertly flew the Unalakleet River and its associated drainages in search of radio tags. The residents of Unalakleet returned radio tags and provided friendly and invaluable information about the river, its history, and the subsistence, commercial, and sport fisheries.

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APPENDIX A

CATCH AND RELEASE GUIDELINES

Appendix A.-Standard ADF&G catch-and-release guidelines.

Tackle

- Use strong line to bring catch in quickly.
- Fish caught with flies or lures survive at a higher rate than fish caught with bait.
- Hooks appropriate to the size of the fish should be used. Overly large hooks can damage mouth parts or eyes and small hooks can be taken deeply.
- Barbs should be pinched down.

Landing the catch

- Fish should be landed as carefully and quickly as possible.
- Fish should not be removed from the water.
- Fish should not be allowed to flop in shallow water, over rocks, or on dry land.
- Landing nets made with soft or knotless mesh should be used.

Handling the catch

- Fish should be kept in the water
- Fish should be cradled gently with both hands: one under its belly and one near its tail.
- Fingers should be kept out of and away from the gills.
- When handling the fish, use wet cloth gloves or wet hands.
- Fish should never be squeezed.
- Fish should be supported in the water prior to picture taking.

Removing the hook

- Long-nosed pliers should be used to back the hook out.
- Hook should be removed quickly and gently while fish is held underwater.
- If a fish is hooked deeply, then line near hook should be cut.
- Avoid stainless steel hooks. If a hook has to be left in the fish, it should be able to quickly rust out.

Reviving the catch

- Fish should be pointed into a slow current or gently moved back and forth until gills are working properly and balance is maintained.
- Let fish go after it recovers and attempts to swim away.
- Large fish may take longer to revive.

APPENDIX B

ARCHIVED DATA FILES

Appendix B.-Data files used to describe and estimate parameters of coho salmon in the Unalakleet River, 2001.

Data Files[a]	Description
Aerial Tracking83001.xls	Data file of tag locations from the 30 August and 15 September aerial surveys and the 16 September boat survey on the Unalakleet River, 2001.
Hydrology Data.xls	Data file of salinity and temperature with depth characteristics at different locations within the estuary during high and low tides.
Tag Data.xls	Data file of tagging information for each fish captured, including: landing time, time in boat, fork length, hook placement, bleeding severity, ability to swim away after being handled, and overall external appearance. In addition, file contains movement of each tag detected and percent mortality.
Results.xls	Results from logistic regression relating distance between tagging locations and the proportion of mortalities at each location.

[a] Data files are available from the author. bilingual