Fishery Data Series No. 07-03

Estimation of Abundance and Distribution of Chum Salmon (*Oncorhynchus keta*) in the Unalakleet River Drainage, 2005

by

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and

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February 2007

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

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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by

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ABSTRACT

This was the second year of a 3 year project using radiotelemetry mark and recapture methods to determine the proportion of chum salmon *Oncorhynchus keta* migrating into North River and above a proposed weir site on Unalakleet River, and to estimate total Unalakleet drainage abundance. Externally mounted radio tags were tracked with stationary sites and aerial tracking flights to monitor upriver movement and distribution of tagged fish. Approximately 10% of radio-tagged chum salmon migrated past the North River Tower and 82% migrated above the proposed mainstem weir site. Drainage wide chum salmon abundance was estimated at 112,358 fish (95% CI 78,474–195,795). Among sampled fish, most were female (55%), and predominant age classes were age 0.3 (81%) and age 0.4 (17%). Radio-tagged chum salmon were located in the South, Chiroskey, and North Fork Rivers. No chum salmon were located in the Old Woman River.

Key words: Norton Sound, Unalakleet River, chum salmon *Oncorhynchus keta*, radiotelemetry, mark and recapture, age, sex, and length composition.

INTRODUCTION

The Unalakleet River drainage is located in Western Alaska on the eastern shore of Norton Sound (Figure 1). Unalakleet River originates in the Nulato Hills and flows southwesterly for approximately 160 km until emptying into Norton Sound at the village of Unalakleet (Figure 2). Unalakleet River and its tributaries drain an area of approximately 5,400 km^2. The upper 130 km of Unalakleet River has been designated a National Wild and Scenic River.

Unalakleet River Chum salmon *Oncorhynchus keta* are harvested by subsistence, commercial, and sport users. Commercial and subsistence harvests of chum salmon occur primarily in management Subdistrict 6 (Figure 2), although some are harvested in Subdistrict 5 (Gaudet and Schaefer 1982). Since 1964, subsistence harvests have ranged from 0 to 16,481 fish, averaging 5,474 fish (Table 1; Kohler et al. 2005). The 2000–2004 average subsistence harvest was 5,603. Because of the declining market value of chum salmon, there has not been a directed chum salmon commercial fishery since 2001, and their commercial harvests have been incidental in the coho salmon *O. kisutch* directed fishery. Since 1961, commercial chum salmon harvests in Subdistrict 6 have ranged from 339 fish to 109,220 fish, averaging 26,119 fish (Table 1; Kohler et al. 2005). The 2001–2005 commercial harvest average was 2,608 fish. Chum salmon sport fish harvests (1990–2004) have ranged from 47 to 714 fish, averaging 335 fish (Table 1; DeCicco 2004). The 2000–2004 average was 392 fish.

Management of Unalakleet River chum salmon is based on information from subsistence harvests, an inriver test fishery (Kohler 2002), aerial surveys, and a counting tower located on the North River (a lower river tributary of Unalakleet River; Kohler and Knuepfer 2002). While the North River counting tower does provide escapement counts for North River, information from harvests and aerial surveys provide only indices of escapement rather than actual escapement counts. Also, index estimates from harvest data may be biased by the presence of stocks outside the Unalakleet River drainage (Gaudet and Schafer 1982). A key information gap for managing Unalakleet River chum salmon is a drainage wide escapement estimate.

Previous attempts to estimate chum salmon escapement in the Unalakleet River have met with only marginal success. Counts based on aerial surveys are equivocal because of poor water clarity, chum salmon coloration that does not contrast against the river bottom, and masking by large pink salmon escapements. Ground based escapement projects such as enumeration weirs, counting towers, and sonar were hindered by high water levels and increased turbidity associated

with seasonal precipitation events (Lean 1985). In the absence of some direct means for enumerating chum salmon escapement in the mainstem Unalakleet River, a method that may have promise is expanding North River tower counts by proportional information obtained from radiotelemetry based mark and recapture (M–R) studies. M–R methodologies have been used throughout Alaska to estimate the proportions of salmon migrating into major tributaries (Der Hovanisian et al. 2005; Joy et al. 2005; Stroka and Reed 2005; Todd et al. 2005; Wuttig 1999).

This was the second year of a proposed 3 year study to determine the proportion of chum salmon migrating up the North River in order to expand North River tower escapement counts into a drainage wide estimate for Unalakleet River. Age, sex, and length (ASL) data were collected from all captured chum salmon. ASL data and drainage wide escapement estimates are crucial for the establishment of a drainage wide Biological Escapement Goal (BEG), allowing for management consistent with the state's Sustainable Salmon Policy (5 AAC 39.222, effective 2000, amended 2001).

The objectives for this project in 2005 were:

1. Estimate the proportion of the chum salmon escapement migrating above the North River counting tower such that, with 95% confidence, the estimate is within ± 5% of the true value.
2. Estimate drainage wide escapement of chum salmon in the Unalakleet River such that, with 95% confidence, the estimate is within ± 40% of the true value.
3. Document tributary distribution and major spawning locations of chum salmon in the Unalakleet River drainage, and determine the proportion that migrates above the proposed weir site.
4. Characterize run timing of Unalakleet River chum salmon stocks and compare to run timing of North River chum salmon stocks.
5. Document ASL composition of chum salmon entering the Unalakleet River drainage and compare to North River chum salmon.

METHODS

RADIOTELEMETRY EQUIPMENT

Advanced Telemetry Systems[1] (*ATS*), *Inc*., *Isanti, MN* manufactured the radiotelemetry equipment used during this study. Model R4500C receiver-data loggers equipped with global positioning systems (GPS) were used at all stationary receiver-tracking sites (SRS) and during aerial tracking flights. Model F2110 pulse-coded radio transmitter tags were externally mounted near the posterior edge of the dorsal fin. Radio tags were equipped with a mortality switch that activated when a fish remained motionless for approximately 4 h. The radio tags weighed approximately 15g and had an expected operational life in excess of 45 d. A total of 16 frequencies in 150 to 151 MHz range with 10 pulse codes each allowed detection of 175 unique tags.

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

STATIONARY RECEIVER SITES

SRS were established at four locations along the Unalakleet River drainage (Figure 3). SRS 1 (N 63º 52.21, W 160º 43.46) was located 1 km upriver from the mouth of the Unalakleet River, and 2 km below the capture and tagging area. SRS 2 (N 63º 52.54, W 160º 39.74) was placed at the confluence of the Unalakleet and North Rivers, approximately 5 km upriver from the mouth and 2 km upriver from the tagging location. SRS 3 (N 63º 53.05, W 160º 39.15) was placed at the North River counting tower approximately 3 km upriver from the confluence with Unalakleet River. SRS 4 (N 64º 53.39, W 160º 29.15) was placed on the Unalakleet River approximately 22 km upriver from the mouth at the location of a proposed enumeration weir. At each SRS a 12-V marine battery and solar panel wired through a solar charge controller provided power for the equipment. A total of two 4-element Yagi antennae were used at all sites except the Unalakleet-North River confluence site (SRS 2), which had 3 antennae. Antennae were positioned to monitor downriver and upriver movement of tagged fish. The third antenna at the confluence site monitored the movement of tagged fish into the North River. At all sites except SRS 3, the antennae (at 6 m) and the solar panel (at 3 m) were mounted to a 6 m high aluminum mast, then bolted to a waterproof equipment box containing the receiver and battery. All cables were run inside the antenna mast to the equipment box to avoid possible damage from animals. At SRS 3, antennae were mounted to the counting tower scaffolding. At all sites an antennae switchbox allowed receivers to scan all antennae simultaneously until a tag was received, at which point the receiver would scan each antenna separately. Direction of tag travel was then determined by the antenna with the strongest signal. Before site deployment, all tag frequencies were entered manually into the receiver and scanning parameters set according to site-specific criteria. Primary parameters were scan time (amount of time receiver remains on each frequency), time out (period of time receiver quits scanning before the scan time is up if there are no incoming signals), and store rate (interval of time between storing same frequency/code when present). Scanning parameters were set to scan a frequency for 6 s with 4 s timeout, and store rates were set at 2 min (the store rate at SRS 2 was set at 5 min).

CAPTURE, TAGGING, AND AGE, SEX, AND LENGTH COLLECTION

The Unalakleet River capture/tagging site was approximately 2 km below the confluence with North River (N 63º 51.61, W 160º 42.38; Figure 3). This location was down river from where the majority of the sport fish harvest occurs and up river from where the majority of the subsistence harvest occurs.

A gravel bar was located along the south bank and water depth gradually increased moving away from the gravel bar with the main channel running along the north bank. River width varied at the capture site depending on tidal stage, ranging from approximately 60 m at low tide to over 100 m at high tide. Attempts were made to seine during the incoming tide when possible. At low tide seine deployments covered the majority of the river width (thus avoiding potential stock bias because of bank orientation). At high tide, approximately 60 m of the river extending from the south bank was not covered to ensure the north side was covered (water depth for the first 60 m extending out from the south bank during high tide was less than 0.5 m and it was assumed no chum salmon were passing in this area during seining events).

Chum salmon were captured using a 30.5 m long by 2.1 m deep, 8.9 cm stretched mesh beach seine. Seining events occurred twice daily, once in the morning and once in the evening. Captured fish were placed in a sampling cradle modified from Larson (1995). The modifications

included a sliding meter stick attached to the outside of the cradle for length measurements, and side notches were deeper to facilitate scale collection and tag mounting. Complete removal of the fish from the water was avoided during tagging or sampling.

Only healthy vibrant chum showing minimal impacts from capture were fitted with a radio tag. Tagging needles were placed over the radio tag cables, and then dipped in a 10% providone iodine solution. Radio tags were mounted on the left side of the fish. The anterior needle was inserted between the pterygiophore bones near the posterior edge of the dorsal fin; the second needle was inserted through musculature posterior of the dorsal fin (Barton 1992). The needles were removed and disk tags and sleeves were placed over the cables extending from the right side of the fish. Tags were held firmly against the fish and sleeves were crimped onto the cable, and excess cable removed. The anterior disk tags were sequentially numbered so if fish were caught and released, they could be identified. Alaska Department of Fish and Game (ADF&G) posted an informational letter at several locations in the village of Unalakleet and at local sport fishing lodges informing the public of the project and providing instructions on what to record if a tagged fish was harvested or released.

During the planning stage, the 10-year average escapement at the North River counting tower was approximately 7,000 chum salmon, which was thought by area biologists to be about 10% of the chum salmon escapement into the Unalakleet River, giving a total estimated drainage wide abundance of 70,000. Based on that assumption, 175 radio tags were deployed to provide binomial proportion estimates within ± 5% of the actual value. The number of deployed tags also provided a Unalakleet River drainage abundance estimate with coefficient of variation (CV) of 50% to the mean estimate.

To distribute radio tags proportional to run strength, tags were deployed following a schedule based on a normal run timing curve derived from historical run timing information at the Unalakleet River test fishery. Tags were deployed in ascending order by pulse code and frequency. This order was chosen to avoid a large number of tags on one frequency being deployed simultaneously, potentially causing data recording problems at SRS locations and during aerial tracking.

ASL information was collected from all 175 tagged chum salmon. In addition, ASL information was collected from an additional 360 chum salmon captured but not tagged. ASL information from chum salmon not tagged was collected in 3 strata (pulses) of 120 fish each, distributed equally over the tag deployment schedule. Each sampled fish was measured for length from the mideye to tail fork (METF) to the nearest 0.5 cm. Sex was determined by examination of external characteristics. One scale was collected from the left side of the fish, approximately two rows above the lateral line in an area crossed by a diagonal from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (INPFC 1963). Scales were arranged on gum cards in the field and sent to the Nome ADF&G office for processing. Impressions from the gum cards were made on cellulose acetate cards with a heated hydraulic press (Clutter and Whitesel 1956). Ages of the salmon were determined by examining the scale impressions (Mosher 1968), and were recorded in European notation (Koo 1962).

AERIAL TRACKING FLIGHTS

Aerial tracking flights were flown in a Cessna 180 aircraft. Tracking flights were flown at altitudes ranging from approximately 230 m (750 ft) to 450 m (1,500 ft) above ground level. Flights were flown at 230 m when numerous tagged fish were present in the area, and flown at

450 m when tagged fish were widely dispersed. Two antennae were used during survey flights; each was mounted side looking with a 30 degree tilt down from horizontal on the aircraft wing lift strut (Gilmer et al. 1981; Kenward 1987). An aircraft switch box inside the fuselage (connected to both antennae) allowed the observer to switch between left, right, or both antennae to better locate the direction of tagged fish (Winter et al. 1978).

A total of seven aerial tracking flights were flown over the mainstem of Unalakleet River and major tributaries between July 5 and August 22. When a tag was pulse coded by the receiver the frequency, pulse code, mortality (if activated), and river location were recorded in a log by the observer, and latitude and longitude were recorded by the receiver. If the receiver was not able to identify the tag, the antenna switchbox was used to determine which antenna had the strongest reception. If the aircraft had already passed the fish, the plane circled back until the tag was identified.

DATA ANALYSIS

Chapman's modification of Petersen's model (Seber 1982) was used to estimate the total Unalakleet River chum salmon population. This model was chosen because this project consists of capturing and tagging chum salmon in the Unalakleet River mainstem and capturing and recapturing tagged and untagged salmon at the North River tower. Since all chum salmon entering the Unalakleet River migrate past the capture site on their way to the spawning grounds, and there is no immigration from other confluences, this M–R study satisfies the closed population assumption. Further, tagged and untagged salmon examined at the North River tower continue migrating to the spawning grounds, satisfying the assumption of recapture without replacement.

ASSIGNMENT OF FATE

The following criteria were used to determine if a tag was used in the proportion and abundance estimate (assigned a fate) or if it was censored:

- tag must have been located on two separate occasions by either/or a combination of the confluence, tower, or proposed weir SRS, or during an aerial tracking flight,
- must have remained at or above confluence site for at least 5 d,
- not recaptured in the inriver test fishery prior to upriver migration (a number of fish were recaptured weeks after migrating upriver and were considered valid tags), also tags harvested in the sport or subsistence fisheries are considered valid tags,
- and do not exhibit nonsensical migration patterns e.g. above the weir site one day and then in the upper North River the next day.

For a radio-tagged fish to be considered a recapture at the North River counting tower, or to have passed the proposed weir site, the fish must have remained above that site for at least 5 days.

Each of the 175 tags was assigned a fate in the following four categories:

	Fate	X:
1	Censored ($M' - M$), including tag loss, down river migrants,	26
2	Assigned below North River tower confluence	12
3	Assigned above Unalakleet River above the proposed weir site	122
4	Assigned above North River tower	15
	Total	175

ASSUMPTIONS

For the estimate $\hat{N}$ to be unbiased, the following conditions must be met (Seber 1982):

1. recruitment and death of chum salmon did not occur between sampling events;
2. tagging did not affect the migration timing and spawning destination of chum salmon;
3. tagged chum salmon did not lose their tags between the tagging site and their spawning destination;

and at least one of the following conditions must be met:

1. every chum salmon had an equal probability of being marked and released alive during the first sampling event (capture and tagging);
2. every chum salmon had an equal probability of being captured during the second sampling event (migrating past the North River counting tower);
3. marked fish will mix completely with unmarked fish between sampling events.

Condition 1 was violated as there were both subsistence and sport harvests of chum salmon above the radio tag deployment area. However, harvests were likely minimal as the majority of the subsistence harvest occurs below the tagging area, and chum salmon are not targeted in the sport fishery. Also, it is assumed the probability of harvest was equal between tagged and untagged fish. Informational flyers were posted throughout the area asking fishers to release radio-tagged chum salmon if captured, and, if harvested, that the radio tag be returned to ADF&G with information on when captured, where, and spawning condition of the fish.

There is no direct test to determine the effects of tagging (condition 2) on the migration and distribution of chum salmon as there was no way to monitor untagged fish. This study was designed to minimize the amount of time spent handling fish during capture and tagging. Also, fish movement was monitored inseason using downloaded tracking data from all SRS. Chum salmon milling in the vicinity of the lower river, dropping below the lower site (SRS 1) after being radio-tagged, or failing to migrate above the confluence SRS (SRS 2) after being radio-tagged, was an indication that handling had an adverse affect. Radio-tagged chum salmon that exhibited these types of behavior were censored. Data from SRS and aerial tracking were used to determine tag loss (condition 3), and fish determined to have lost their radio tags were likewise censored.

To ensure that all chum salmon had an equal probability of being captured and marked (condition 4), a beach seine was used to capture fish for tagging, eliminating any potential size selectivity bias based on gear size. The beach seine was deployed so that the majority of the river was covered to avoid bank bias. Finally, tags were deployed proportional to run strength to avoid temporal bias.

ABUNDANCE ESTIMATE

Peterson's M–R method, as modified by Chapman and reported in Seber (1982) was used to estimate the total Unalakleet River drainage chum salmon population. The North River counting tower chum salmon escapement was expanded by the proportion of marked (radio-tagged) chum salmon that passed the tower site to estimate drainage abundance.

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

where:

$\hat{N}$ = estimated Unalakleet River abundance passing upstream of the tagging site,

M = the number of marked fish that successfully migrated upstream of the tagging site,

C = the number of fish that escaped upstream of the North River, and

R = the number of marked fish recaptured upstream of the North River.

The variance of total abundance was estimated using two-stage parametric bootstrap simulation (Efron and Tibshirani 1993); using 1,000 replicates for the M–R and 1,000 replicates of sampling (by locations in the drainage).

The numbers of fish sharing the same fates arose from the multinomial density function with parameters M', $\pi_1,\ldots\pi_4$ where π_i is the probability that a marked fish would have the *i*th fate. One thousand simulated vectors $\{X_1^*,\ldots X_4^*\}$ were each drawn randomly from the analogous multinomial empirical density function with parameters $M', \hat{\pi}_1,\ldots\hat{\pi}_4$ where $\hat{\pi}_i = X_i / M'$. The number of marked fish in the simulation (M') was treated as fixed at 140 because a finite number of transmitters were available. An estimate of abundance was calculated for each set of replications such that

$$N_{(b)}^* = \frac{(M_{(b)}^* + 1)(C+1)}{R_{(b)}^*} - 1 \qquad (2)$$

where $M_{(b)}^* = M' - X_{1(b)}^*$, $R_{(b)}^* = X_{4(b)}^*$, and b denotes the simulation. Estimated variance and estimated relative statistical bias were approximated as:

$$v(\hat{N}) = \frac{\sum_{(b)} (N_{(b)}^* - \overline{N}^*)^2}{B-1} \qquad (3)$$

$$\text{relative statistical bias} = \frac{\hat{N} - \overline{N}^*}{\overline{N}^*} \times 100 \qquad (4)$$

where B = 1,000 and $\overline{N}^* = (\Sigma N_{(b)}^*) / B$.

RESULTS

Between June 21 and August 9, 175 radio tags were deployed (Table 2). Of those, 149 (85%) were assigned final destinations (Table 3). The remaining 26 radio-tagged fish were censored because of nonsensical or conflicting SRS and/or aerial survey data (7), no SRS or aerial records after tagging (5), recaptured before fish could migrate upriver (3), or backed out of the system immediately after tagging (11).

Radio tag deployment tracked chum salmon run timing at the inriver test fishery (Figure 4). The last radio tag was deployed on August 8 when the inriver test fishery cumulative catch was 97%.

Of the 149 tags assigned spawning destinations, 15 (10%) were recaptured at the North River counting tower (Table 3) giving a proportion of 0.10. Based on this proportion, and Using

Equation (1), the estimated Unalakleet drainage chum salmon abundance was 112,358 fish with 95% CI 78,474–195,795.

Among 504 chum salmon (including radio-tagged fish) sampled for ASL determination, 55% were female with 81% age 0.3 and 17% age 0.4 (Table 4). The mean length of age-0.3 and age-0.4 fish was 581 mm and 598 mm.

Radio-tagged fish migrating into the North River (n = 17) were predominately male (53%), with 88% age-0.3 and 12% age-0.4 fish (Table 5). Mean lengths of age-0.3 and age-0.4 fish was 583 mm and 570 mm.

Radio-tagged chum salmon migrating into the Unalakleet River (n = 144) were predominately female (51%) with 74% age 0.3 and 24% age 0.4 (Table 6). The mean lengths of age-0.3 and age-0.4 fish were 586 mm and 602 mm.

There were slight differences in the proportion of age-0.3 fish (75%) and age-0.4 fish (22%) sampled in the test fishery (Table 7) compared to our ASL sample (including all tagged fish). However, the percentage of males (78%) was substantially higher in fish sampled from the test fishery. On average, fish sampled in the test fishery were larger compared to fish sampled from the tagging project.

Tracking data obtained from SRS and aerial tacking flights were used to assign spawning locations to radio-tagged chum salmon. Of the 149 radio-tagged fish assigned final destinations (Table 3), 15 (10%) were assigned locations above the North River counting tower, 132 (89%) were assigned locations in Unalakleet River and tributaries, and 122 (82%) were located above the proposed weir location. The distribution of the remaining tagged fish is presented in Table 3. Final assigned locations (furthest upriver point a radio-tagged fish was located during any aerial tracking flight) of radio-tagged fish is shown in Figure 5. Of the 122 radio-tagged fish assigned locations above the proposed weir site, 26 (17%) were not located during aerial tracking flights and final spawning.

The relationship between the date of tag deployment and assigned location was examined to observe any temporal or spatial patterns between distribution and run timing (Figure 6). The percentage of tagged fish bound for the North River ranged from 6.5% during the fourth quartile of tag deployment (July 20 through August 9) to 14% during the second quartile (July 1 through July 10). The percentage of tagged fish migrating above the proposed weir site ranged from 56% during the first quartile (June 20 through June 30) to 79% in the second quartile. Temporal and spatial patterns were observed between the dates fish were tagged and their distribution. The percentage of tagged fish migrating into the North River was highest during the second quartile; nearly doubled that of the other three quartiles. A similar pattern was observed for tagged fish migrating above the proposed weir site.

Radio-tagged fish assigned spawning destinations above the proposed weir site took on average 73.9 h (n = 108, σ = 45.4) to reach the site after tagging while traveling an average speed of 0.3 km/h (Table 8; Figure 7). Radio-tagged fish assigned spawning destinations in the North River took on average 148.3 h (n = 14, σ = 130.9) to reach the site after tagging while traveling an average speed of 0.03 km/h (Table 8; Figure 8).

Diel timing of tagged chum salmon migration passed the proposed weir site and North River counting tower were similar (Figure 9). The majority of tagged chum salmon passed between 2000 and 2400 hours (40% and 36%, North River counting tower and proposed weir site), with a

large percentage passing between 1200 and 2000 hours. Fish passage at both sites was the lowest between 0001 and 1200 hours.

DISCUSSION

This was the second year of a proposed 3 year project designed to estimate the proportion of chum salmon migrating into the North River. Proportions attained in 2004 (0.13) and 2005 (0.10) were very similar, suggesting proportion may be relatively consistent (Estensen et al. 2005).

Distribution data provides baseline information on habitat utilized for spawning, which may vary in response to changes in abundance, harvest level, and environmental conditions. Spawning distribution is also important in this study to evaluate the location of a proposed weir site. There were marked differences in the distribution of chum salmon between 2004 and 2005. A greater percentage (82%) of radio-tagged chum salmon migrated above the proposed weir site in 2005 site compared to 62% in 2004. Also, a greater percentage of tagged chum salmon (28%) were assigned locations between the Unalakleet-North Rivers confluence and the proposed weir in 2004 compared to 2005 (5%). The difference in the percentages of tagged chum salmon spawning between the North River confluence and proposed weir site between years (23%) is comparable to the difference in percentages of tagged fish spawning above the proposed weir site (20%). Radio-tagged chum salmon were not located in major tributaries other than the North River in 2004. However, in 2005, radio-tagged chum salmon were located in the South, Chiroskey, and North Fork Rivers. None were located in the Old Woman River in either year despite being a known chum salmon producer and an index area for chum salmon aerial surveys. Further distribution data will help determine the utility of the Old Woman as an index area.

Long term accurate and unbiased ASL information is critical to building brood tables needed to develop biological escapement goals. Historically, ASL information for Unalakleet River chum salmon has been collected from the Subdistrict 6 commercial harvest and from the inriver test fishery. It is thought this information is biased because of size selectivity inherent to the gear used in capturing the fish, and not representative of chum salmon escapement into the Unalakleet River drainage. Age and sex information for chum salmon sampled from the test fishery and Subdistrict 6 commercial harvest were compared to that collected from the telemetry project. Age class compositions were comparable (within ± 8%, each age class) between the test fishery, commercial harvests, and those captured during this project. There were, however, a greater percentage of males (78% male) for fish sampled at the test fishery compared to fish captured for the telemetry project (45%) and sampled from the commercial fishery (52%). This is likely because of pronounced lower mandible teeth males during spawning phase increasing their catchability in the test fishery.

Run timing and ASL data from North and Unalakleet River chum salmon were compared to see if there was evidence of stock separation between the two. Chum salmon run timing at the North River counting tower had a 5–10 d lag time behind that of the test fishery and capture site due to the distance between the sites. The relationship of spawning destination by tagging date (Figure 6) showed the greatest percentage of tagged fish bound for Unalakleet and North Rivers migrated during the 2nd quartile of the run. However, there were no patterns suggesting fish bound for the other tributaries enter the drainage during a specific portion of the run. Age-0.3 fish dominated both groups, although a higher percentage was found in Unalakleet River chum. Caution is needed in interpreting age class composition data from North River chum salmon as

the sample size was small (n = 17). The available information does not provide evidence that North River and Unalakleet River chum salmon are separate stocks. Tissue samples for genetic stock identification (GSI) were collected from chum salmon at the capture site in 2004, and results from this analysis should elucidate whether North River chum salmon are a separate sub-stock.

It is important to note that proportion and distribution data are not robust to criteria used in validating tags. In this study it was assumed the duration of salmon redd life (time from reaching spawning ground to leaving spawning ground, or death) was at least 5 d, based on the investigator's knowledge and experience of Unalakleet River chum salmon spawning behavior, and available literature. Previous studies examining the duration of salmon redd life generally found wide variation between sexes, within gender, between populations, and associated with density and environment (Crone and Bond 1976; Killick 1955; Van Den Berghe and Gross 1986; Willis 1954). In those studies average redd lives ranged from about 9 d to 15 d, with typical ranges around the mean of 3 d to 41 d. There is little information on redd life in Norton Sound salmon populations and spawning characteristics may vary between species, populations, and regions. While selection of specific criteria for determining tag fate was necessary, arbitrary limits on redd life had important impacts. For example, changing the minimum time tagged fish had to remain above either site from 5 d to 7 d reduced the number of tagged fish assigned as spawners above the counting tower from 15 (0.10) to 7 (0.05), and above the proposed weir site from 122 (0.82) to 78 (0.52). It is clear that proportional data is highly sensitive to tag fate criteria and can change markedly in response to initial assumptions.

No major deviations from the study plan are anticipated for 2006. The number of tags deployed will increase to 250 to decrease the CV around the proportional estimate to 4%, and decrease the CV around the abundance estimate to ± 35%. More tags could improve assessment of tributary distribution. Also, attempts will be made to increase the frequency and duration of aerial tracking flights over the Old Woman River to ascertain if radio-tagged fish are migrating into that tributary.

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TABLES AND FIGURES

Table 1.–Historical chum salmon escapement at the North River counting tower, and subsistence, sport, and Norton Sound Subdistricts 5 and 6 commercial chum salmon harvests, 1961–2005.

		Harvest				
	North River	Subsistence	Sport	Commercial		
Year	Escapement	(Unalakleet River)	(Unalakleet River)	Subdistrict 6	Subdistrict 5	5/6 Combined [a]
1961	n/a	n/a	n/a	23,586	24,746	48,332
1962	n/a	n/a	n/a	30,283	8,718	39,001
1963	n/a	n/a	n/a	27,003	19,153	46,156
1964	n/a	6,726	n/a	19,611	35,272	54,883
1965	n/a	8,791	n/a	26,498	8,356	34,854
1966	n/a	3,387	n/a	16,840	8,292	25,132
1967	n/a	n/a	n/a	8,502	1,655	10,157
1968	n/a	2,982	n/a	14,865	2,504	17,369
1969	n/a	4,196	n/a	22,032	8,645	30,677
1970	n/a	7,214	n/a	40,029	15,753	55,782
1971	n/a	7,073	n/a	37,543	13,399	50,942
1972	2,332	4,132	n/a	20,440	12,022	32,462
1973	4,334	3,426	n/a	25,716	14,500	40,216
1974	826	588	n/a	36,170	26,391	62,561
1975	n/a	2,038	n/a	48,740	49,536	98,276
1976	n/a	2,832	n/a	24,268	15,798	40,066
1977	n/a	6,085	n/a	32,936	36,591	69,527
1978	n/a	3,442	n/a	37,079	35,388	72,467
1979	n/a	1,597	n/a	30,445	22,030	52,475
1980	n/a	5,230	n/a	64,198	27,453	91,651
1981	n/a	4,235	n/a	39,186	21,097	60,283
1982	n/a	4,694	n/a	44,520	26,240	70,760
1983	n/a	4,401	n/a	109,220	67,310	176,530
1984	2,915	3,348	n/a	43,317	32,309	75,626
1985	4,567	1,968	n/a	25,111	13,403	38,514
1986	3,738	0	n/a	30,239	16,126	46,365
1987	n/a	n/a	n/a	17,525	14,088	31,613
1988	n/a	n/a	n/a	25,363	21,521	46,884
1989	n/a	1,388	n/a	20,825	19,641	40,466
1990	n/a	n/a	298	23,659	21,748	45,407
1991	n/a	n/a	497	39,609	31,619	71,228
1992	n/a	n/a	379	52,547	27,867	80,414
1993	n/a	n/a	116	28,156	20,864	49,020
1994	n/a	12,732	220	12,288	5,411	17,699
1995	n/a	13,460	207	24,843	14,775	39,618
1996	9,789	16,481	463	7,369	3,237	10,606
1997	6,904	7,649	228	17,139	5,747	22,886
1998	1,526	7,962	447	6,210	7,080	13,290
1999	5,600	10,040	211	5,700	2,181	7,881
2000	4,971	7,294	403	2,700	2,751	5,451
2001	6,515	9,163	714	1,512	1,819	3,331
2002	5,918	8,599	607	339	261	600
2003	9,859	1,785	191	3,075	485	3,560
2004	9,624	1,174	47	4,924	1,372	6,296
2005	11,984	n/a	n/a	3,192	791	3,983
Historic Avg. 1961–2005	5,713	5,474 [b]	335 [b]	26,119	17,021	43,140
5-year Avg 2001–2005	8,780	5,603 [c]	392 [c]	2,608	946	3,554

Note: n/a = information not available. Subsistence and commercial harvest data from Kohler et al. 2005. Sport Fish harvest data from DeCicco 2004.

[a] Harvested chum salmon in both subdistricts originate from the Unalakleet and Shaktoolik River (see Gaudet and Schaefer 1982).

[b] Averages calculated for years 1964–2004.

[c] Averages calculated for years 2000–2004.

Table 2.–Tag deployment schedule, and assigned locations of chum salmon tagged on that date, Unalakleet River, 2005.

Date	Number Captured	Number Radiotagged	Assigned North River	Assigned Below Weir	Assigned Above Weir	Censored
20-Jun	0	0	0	0	0	0
21-Jun	6	3	0	0	2	1
22-Jun	3	1	0	0	0	1
23-Jun	11	1	0	0	1	0
24-Jun	28	4	1	0	3	0
25-Jun	21	0	0	0	0	0
26-Jun	0	0	0	0	0	0
27-Jun	25	6	0	0	4	2
28-Jun	16	0	0	0	0	0
29-Jun	39	7	1	1	2	3
30-Jun	17	3	0	0	2	1
1-Jul	56	8	4	0	3	1
2-Jul	48	8	0	0	8	0
3-Jul	0	0	0	0	0	0
4-Jul	0	0	0	0	0	0
5-Jul	6	6	1	0	5	0
6-Jul	6	6	0	0	5	1
7-Jul	6	6	3	0	3	0
8-Jul	17	12	0	1	10	1
9-Jul	48	12	0	0	12	0
10-Jul	0	0	0	0	0	0
11-Jul	7	7	1	0	6	0
12-Jul	49	12	1[a]	1	10	0
13-Jul	38	8	0	2	5	1
14-Jul	44	9	0	2	5	2
15-Jul	37	6	1	0	3	2
16-Jul	0	0	0	0	0	0
17-Jul	0	0	0	0	0	0
18-Jul	19	4	1	0	3	0
19-Jul	0	0	0	0	0	0
20-Jul	88	11	1[a]	1	8	1
21-Jul	0	0	0	0	0	0
22-Jul	82	8	0	0	7	1
23-Jul	15	0	0	0	0	0
24-Jul	0	0	0	0	0	0
25-Jul	50	8	0	2	5	1
26-Jul	58	7	0	0	5	2
27-Jul	0	0	0	0	0	0
28-Jul	32	4	1	0	2	1
29-Jul	44	1	1	0	0	0
30-Jul	0	0	0	0	0	0
31-Jul	0	0	0	0	0	0
1-Aug	48	2	0	0	0	2
2-Aug	32	1	0	0	1	0
3-Aug	0	0	0	0	0	0
4-Aug	15	1	0	0	1	0
5-Aug	9	1	0	0	0	1
6-Aug	0	0	0	0	0	0
7-Aug	0	0	0	0	0	0
8-Aug	32	2	0	0	1	1
9-Aug	16	0	0	0	0	0
Totals	1,068	175	17[b]	10	122	26

[a] Located in North River below the counting tower.

[b] Includes two radio-tagged fish assigned to a location below the counting tower.

Table 3.–Assigned locations of radio-tagged chum salmon in the Unalakleet River drainage determined from aerial tracking and stationary receiver data, 2005.

	No. Tags Assigned	% of Assigned Tags[a]
Unalakleet River		
between confluence and proposed weir site	8	5.4
above the proposed weir site	122	81.9
above weir but not located during aerial tracking flights	26	17.4
between proposed weir site and Chiroskey River	36 [b]	24.2
at or in Chiroskey River	8 [b]	5.4
between Chiroskey and North Fork Rivers	43 [b]	28.9
at or in North Fork River	6 [b]	4.0
between North Fork and Old Woman Rivers	3 [b]	2.0
at or above 10-Mile River	0 [b]	0.0
in South River	2 [b]	1.3
Total Unalakleet River and tributaries	**132**	**88.6**
North River		
between the confluence and counting tower	2	1.3
above the tower	15	10.1
Total North River	**17**	**11.4**
Total Assigned Tags	**149**	**100.0**
Censored		
nonsensical SRS and aerial tracking data	7	
no SRS or aerial record after tagging	5	
tagged fish recaptured before spawning	3	
fish left system within 5 days after tagging	11	
Total censored tags	**26**	

[a] Calculated as percentage of 149 total tags.
[b] Final destinations determined by aerial tracking.

Table 4.–Age and sex composition, and mean lengths by sex and age class of Unalakleet River drainage chum salmon (including radio-tagged fish) sampled at the capture/tagging site, 2005.

		Sample		Length (mm)			
	Age	**Size**	**Percentage[a]**	**Mean**	**SD**	**Min**	**Max**
Male	0.2	1	0.00	495	N/A	N/A	N/A
	0.3	184	0.37	603	34.9	520	700
	0.4	38	0.08	622	27.0	570	670
	0.5	3	0.01	612	35.5	580	650
	total	226	0.45	606	30.4	520	670
Female	0.2	3	0.01	578	66.6	505	635
	0.3	225	0.45	563	29.5	460	670
	0.4	47	0.09	578	29.2	505	620
	0.5	3	0.01	575	36.1	545	615
	total	278	0.55	566	30.4	460	670
Total	0.2	4	0.01	558	68.5	495	635
	0.3	409	0.81	581	37.9	460	700
	0.4	85	0.17	598	35.7	505	670
	0.5	6	0.01	593	37.8	545	650

[a] Calculated from total number of sampled fish that were aged, n = 504.

Table 5.–Age, sex composition, and mean lengths by sex and age class of radio-tagged chum salmon assigned locations in the North River, 2005.

	Age	Sample Size	Percentage[a]	Length (mm) Mean	SD	Min	Max
Male	0.3	8	0.47	596	38.3	540	650
	0.4	1	0.06	630	N/A	N/A	N/A
	total	9	0.53	599	37.6	540	650
Female	0.3	7	0.41	569	32.0	515	620
	0.4	1	0.06	510	N/A	N/A	N/A
	total	8	0.47	561	36.0	510	620
Total	0.3	15	0.88	583	515	650	37
	0.4	2	0.12	570	85	510	630

[a] Calculated from total number of sampled fish that were aged, n = 17. Includes two radio-tagged fish assigned to the North River but did not migrate above counting tower.

Table 6.–Age and sex composition, and mean lengths by sex and age class of radio-tagged chum salmon assigned locations in the Unalakleet River and its tributaries (excluding North River), 2005.

		Sample		Length (mm)			
	Age	**Size**	**Percentage[a]**	**Mean**	**SD**	**Min**	**Max**
Male	0.3	54	0.38	601	33.6	540	690
	0.4	14	0.10	625	29.4	580	670
	0.5	2	0.01	592	17.7	580	605
	total	70	0.49	606	33.6	540	690
Female	0.3	53	0.37	571	25.2	510	635
	0.4	21	0.15	587	25.8	505	620
	0.5	0	0.00	N/A	N/A	N/A	N/A
	total	74	0.51	576	26.2	505	635
Total	0.3	107	0.74	586	33.2	510	690
	0.4	35	0.24	602	32.7	505	670
	0.5	2	0.01	592	17.7	580	605

[a] Calculated from total number of sampled fish that were aged, n=144.

Table 7.–Age, sex composition, and mean lengths by sex and age class of chum salmon sampled at the Unalakleet River test fishery, 2005.

		Sample		Length (mm)			
	Age	**Size**	**Percentage[a]**	**Mean**	**SD**	**Min**	**Max**
Male	0.2	5	0.00	601	28.8	570	638
	0.3	635	0.59	594	26.5	525	677
	0.4	177	0.17	609	28.7	496	694
	0.5	16	0.01	614	22.3	570	660
	0.6	1	0.00	574	N/A	N/A	N/A
	total	834	0.78	597	27.6	496	694
Female	0.2	0	0.00	N/A	N/A	N/A	N/A
	0.3	167	0.16	581	32.9	287	648
	0.4	60	0.06	598	22.5	533	643
	0.5	8	0.01	608	19.9	570	637
	total	235	0.22	586	31.3	287	648
Total	0.2	5	0.00	601	28.8	570	638
	0.3	802	0.75	591	28.4	287	677
	0.4	237	0.22	606	27.5	496	694
	0.5	24	0.02	612	21.3	571	660
	0.6	1	0.00	574	N/A	N/A	N/A

[a] Calculated from total number of sampled fish that were aged, n = 1,069.

Table 8.–Timing of migration (time tagged to first arrival at receiver sites) and travel speed of radio-tagged chum salmon assigned locations in the Unalakleet River above the North River confluence, and in North River, 2005.

						Travel Speed (km/h)	
	n	Mean (h)	Minimum (h)	Maximum (h)	SD	Average	Range
Chum salmon located in Unalakleet River above proposed weir site							
Travel time to confluence after tagging (2 km)	108	19.9	1.5	105.0	50.5	0.10	0.02–1.33
Holding time at confluence	108	19.6	0.1	134.2	31.6	N/A	N/A
Travel time to weir after tagging (22 km)	108	73.9	4.6	230.1	45.4	0.30	0.09–4.78
Travel time to weir after confluence (20 km)	108	52.1	13.3	120.2	26.7	0.38	0.17–1.50
Chum salmon located in North River							
Travel time to confluence after tagging (2 km)	14	43.6	3.4	130.0	46.1	0.04	0.01–0.59
Holding time at confluence	14	36.2	0.1	144.6	46.8	N/A	N/A
Travel time to tower after tagging (5 km)	14	148.3	9.9	503.4	130.9	0.03	0.01–0.50
Travel time to tower after confluence (3 km)	14	64.7	4.7	340.0	98.7	0.05	0.01–0.64

Note: N/A denotes information not applicable.

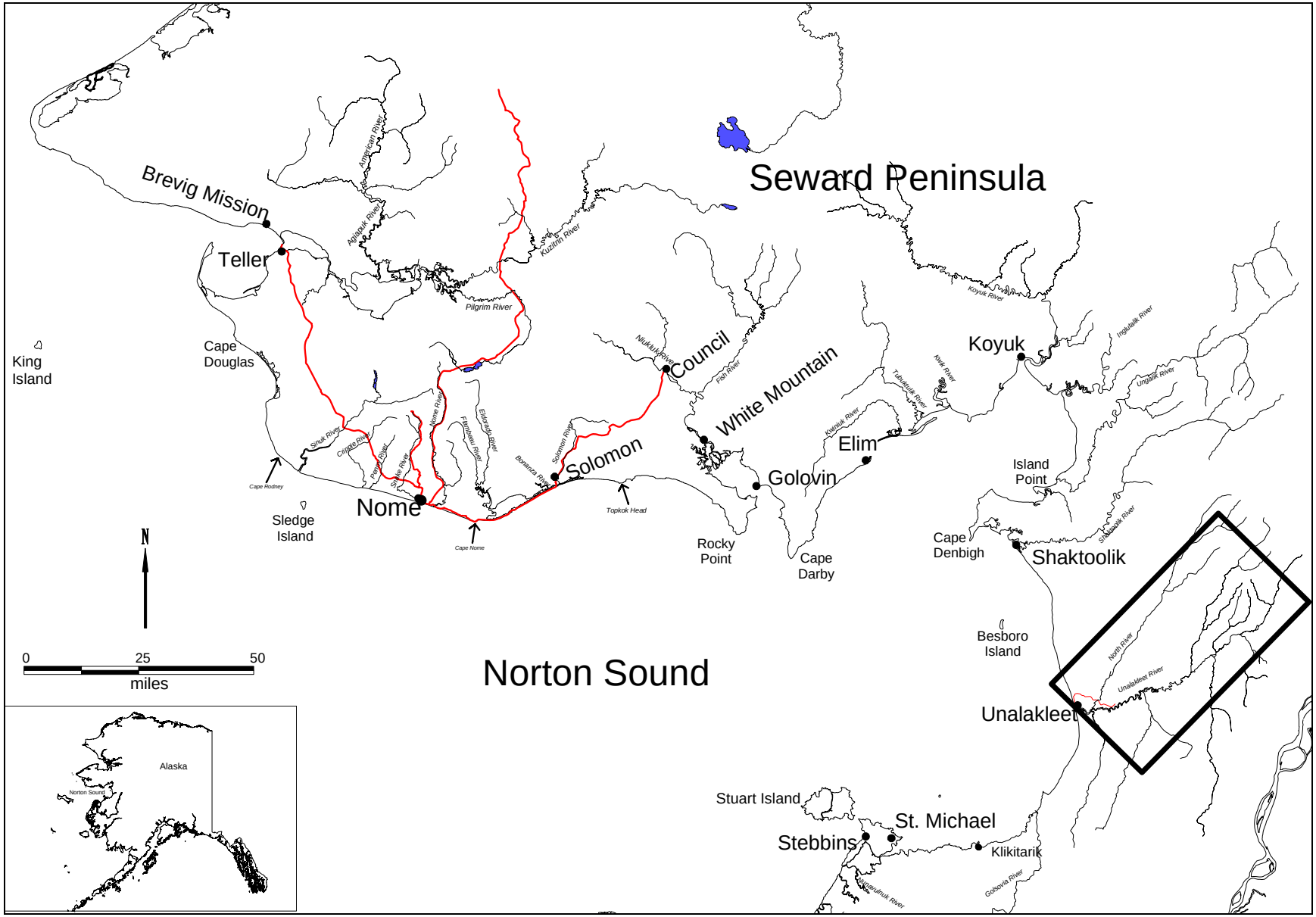


Figure 1.–Norton Sound area showing the location of the Unalakleet River drainage.

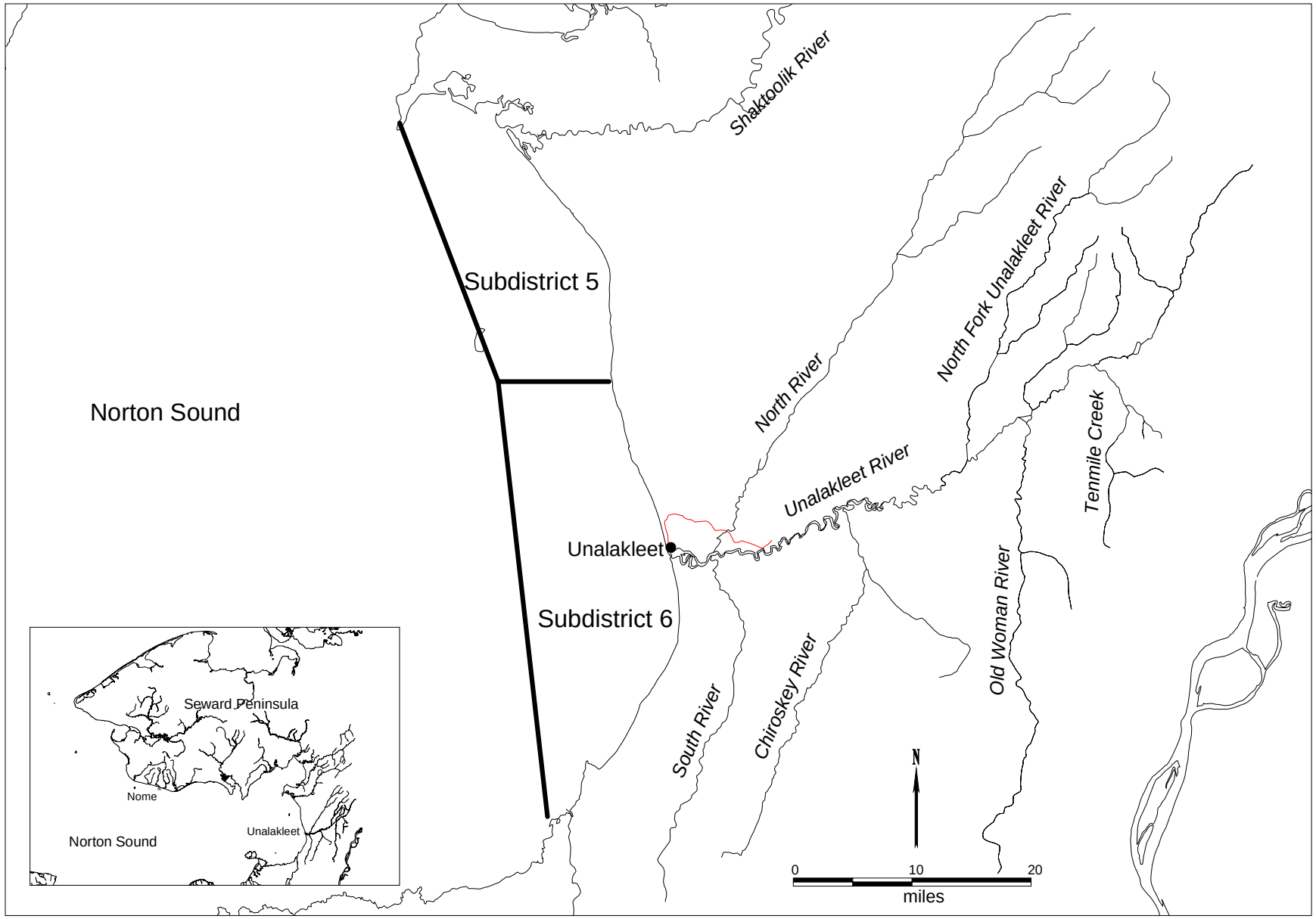
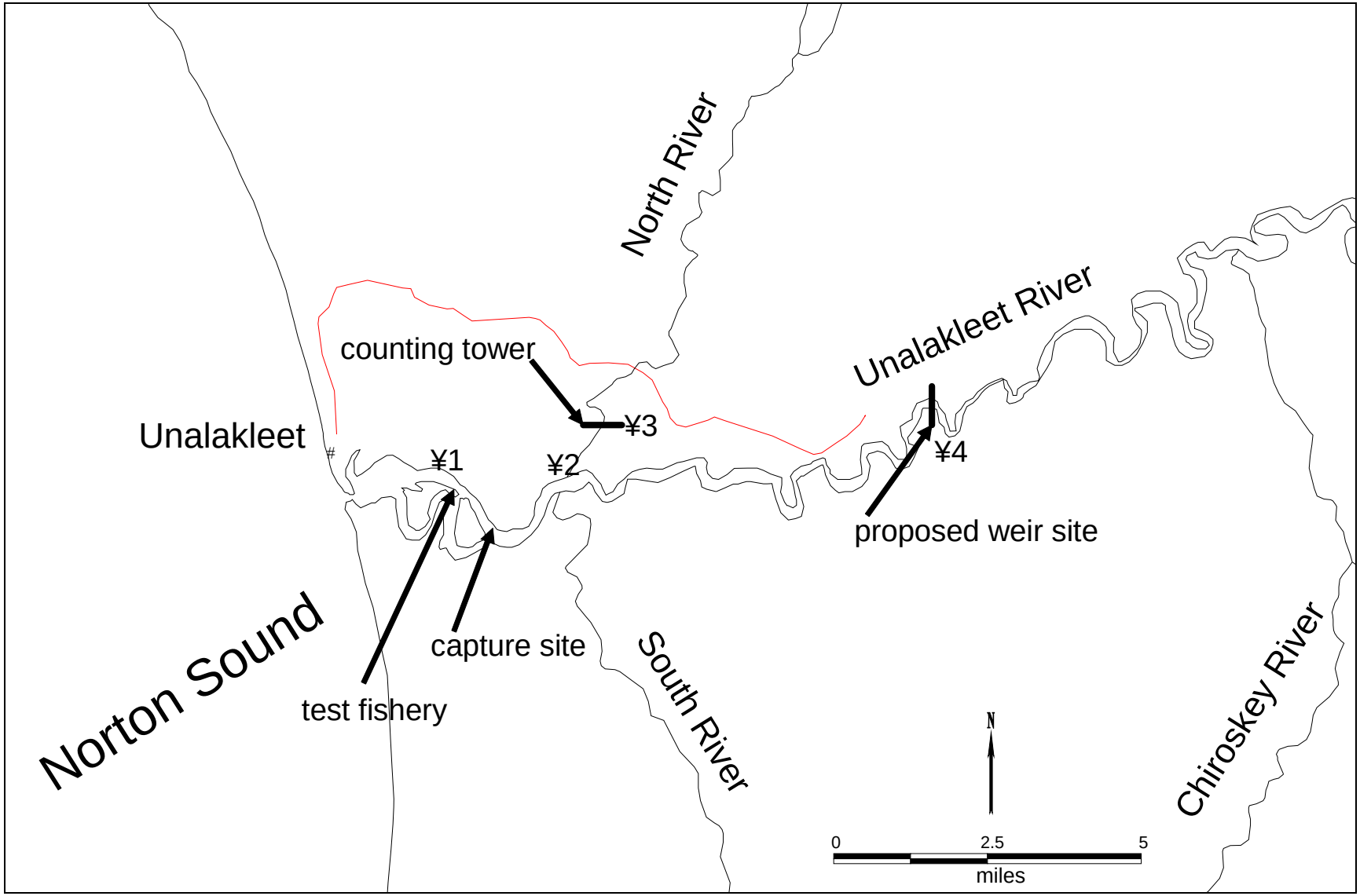


Figure 2.–Location of Unalakleet River drainage and major tributaries including management Subdistricts 5 and 6.



Note: ¥ 1= Lower site SRS; ¥ 2= North and Unalakleet Rivers confluence SRS; ¥ 3= North River counting tower SRS; ¥ 4= proposed weir site SRS.

Figure 3.–Unalakleet River drainage showing the capture/tagging site and stationary receiver sites (SRS).

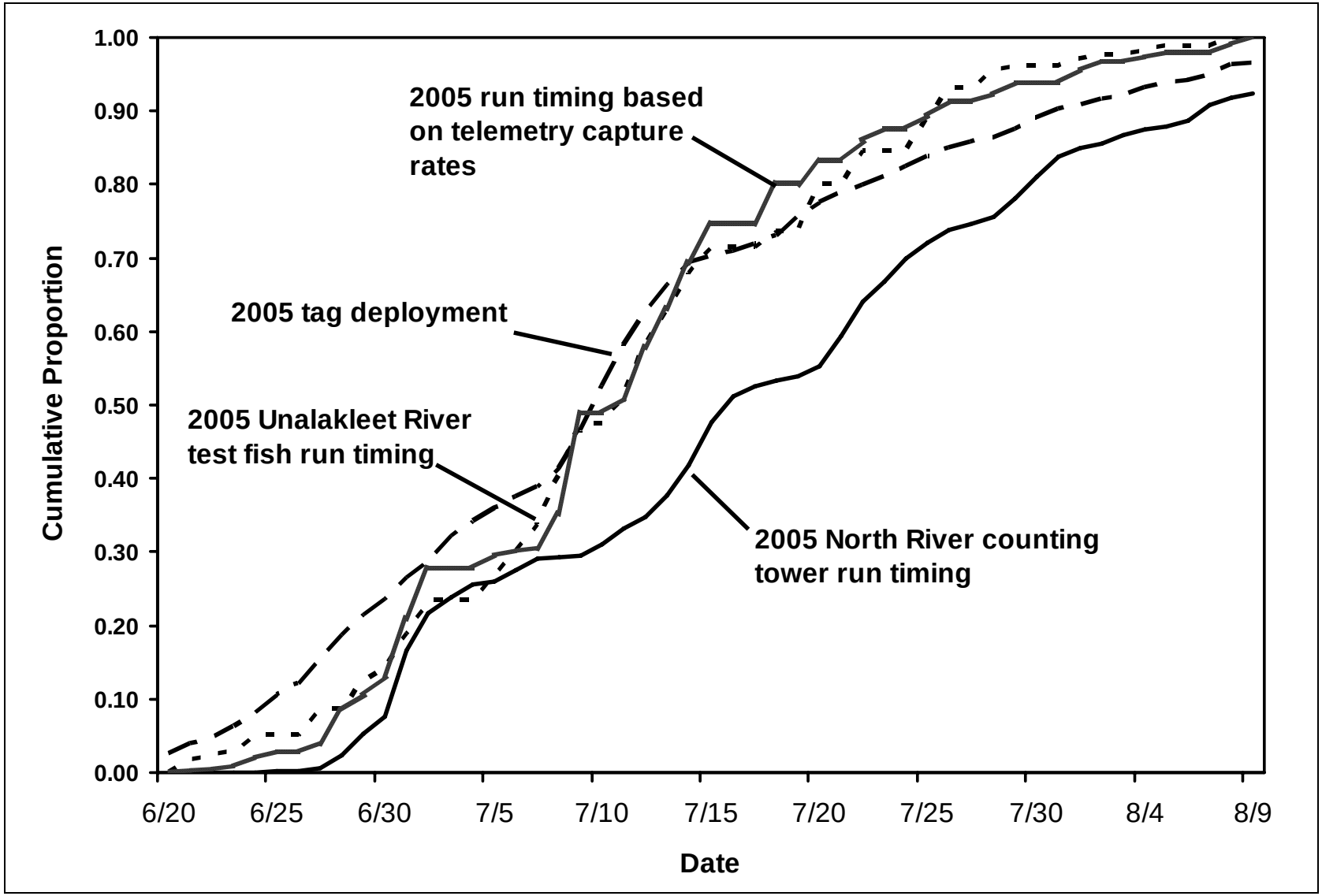


Figure 4.–Comparison of chum salmon run timing, inriver test fishery, North River counting tower, capture/tagging site, and radio tag deployment, 2005.

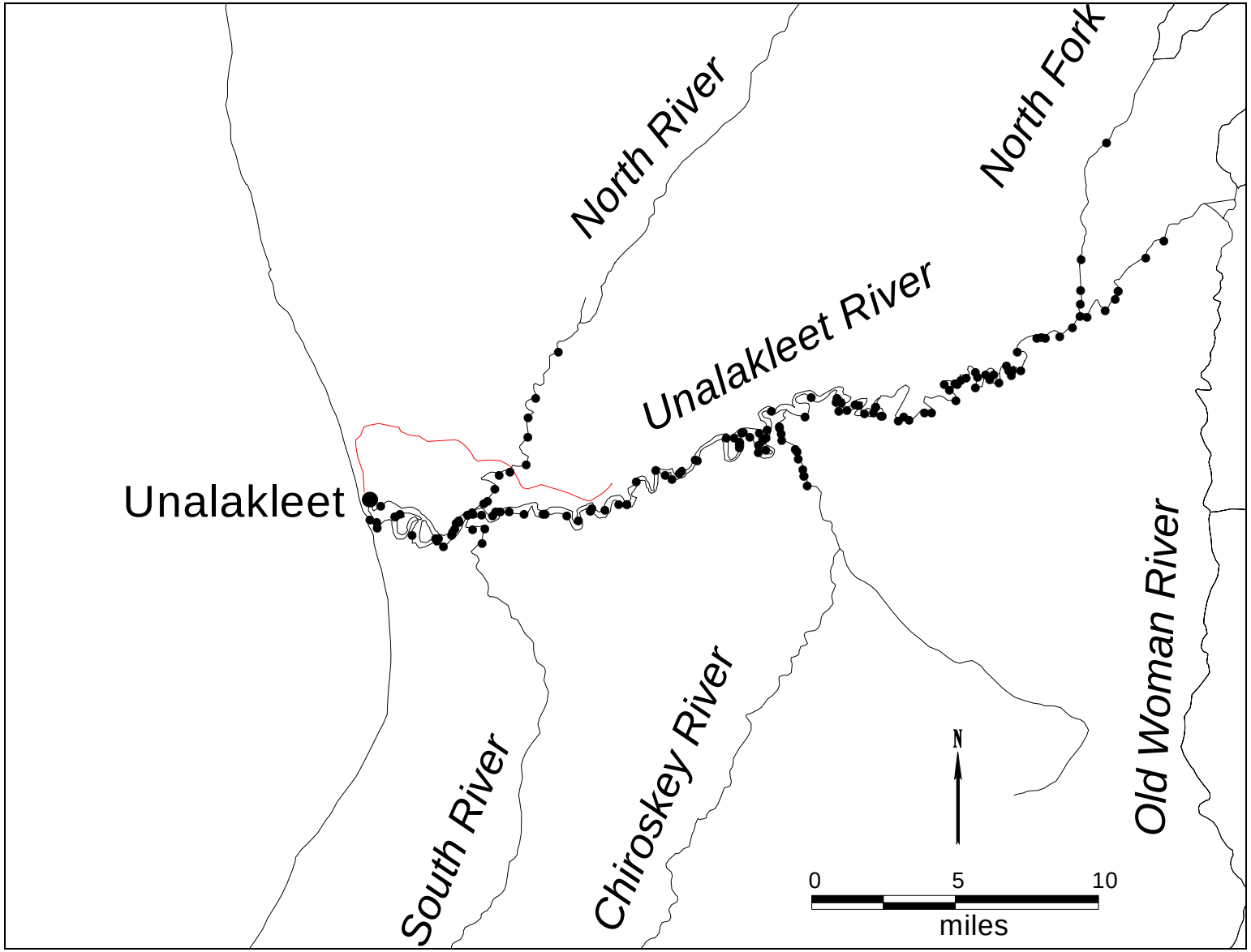
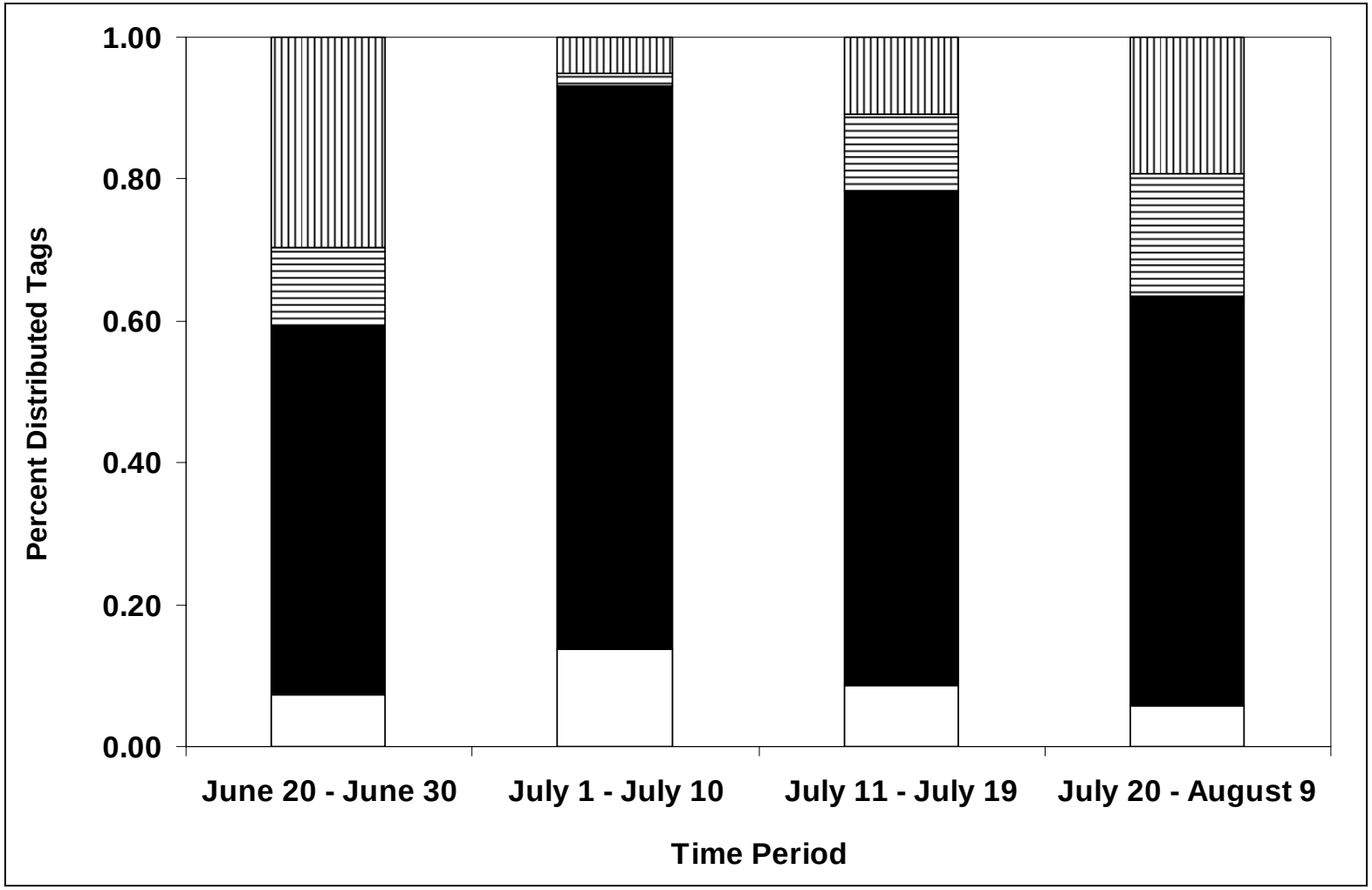
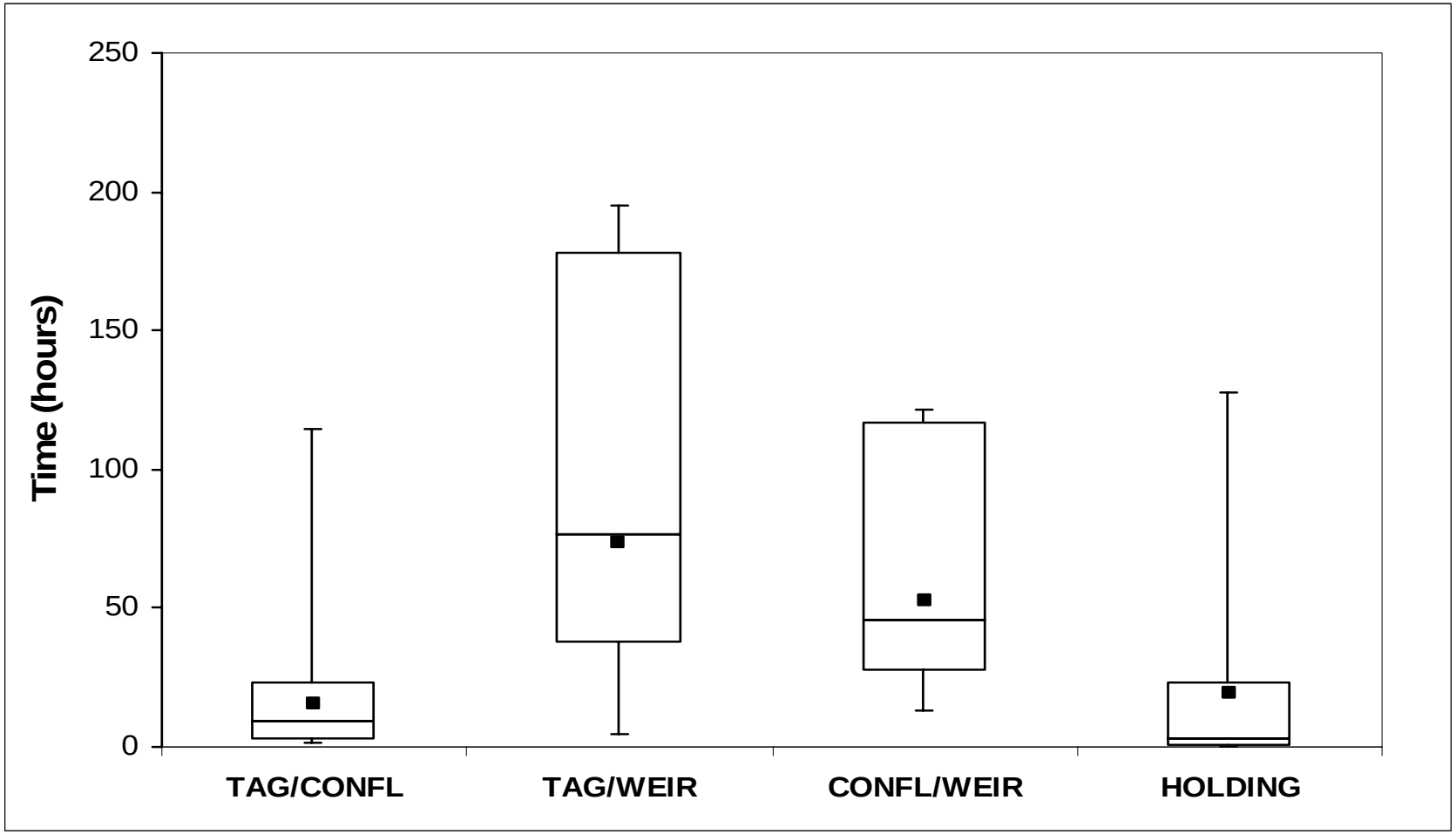


Figure 5.–Final locations of radio-tagged chum salmon during aerial tracking flights, 2005.



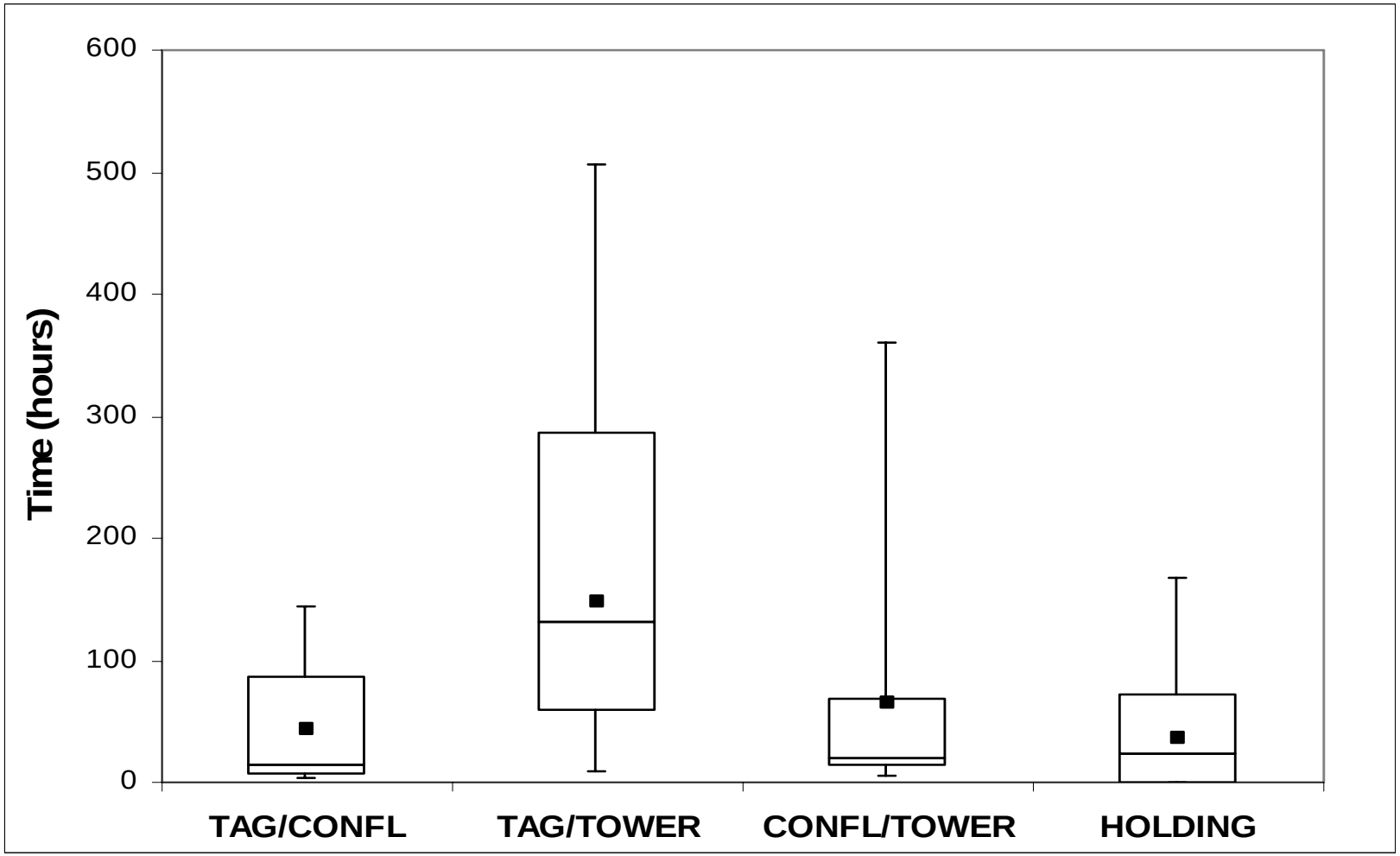
Note: Percentages are of the total number of tags deployed during each interval. White bars = tagged fish assigned locations in North River; black bars = tagged fish assigned locations above the proposed weir site; horizontal stripped bars = tagged fish assigned locations below the proposed weir site; and vertical striped bars = censored tags.

Figure 6.–Distribution of radio-tagged chum salmon by tagging date intervals.



Note: The box identifies 50% of the data (25th to 75th percentile), median in the line across each box, vertical lines represent the data range, and the square represents the average. Timing was recorded between the tagging site and confluence (TAG/CONFL), tagging site and proposed weir site (TAG/WEIR), North River confluence and proposed weir site (CONFL/WEIR), and holding time (HOLDING) at the North River confluence.

Figure 7.–Box plots showing variation in the timing of chum salmon migration above the proposed weir site.



Note: The box identifies 50% of the data (25th to 75th percentile), median in the line across each box, vertical lines represent the data range, and the square represents the average. Timing was recorded between the tagging site and the North River confluence (TAG/CONFL), tagging site and the counting tower (TAG/TOWER), North River confluence and the counting tower (CONFL/TOWER), and holding time (HOLDING) at the North River confluence.

Figure 8.–Box plots showing variation in the timing of chum salmon migration above the North River counting tower.

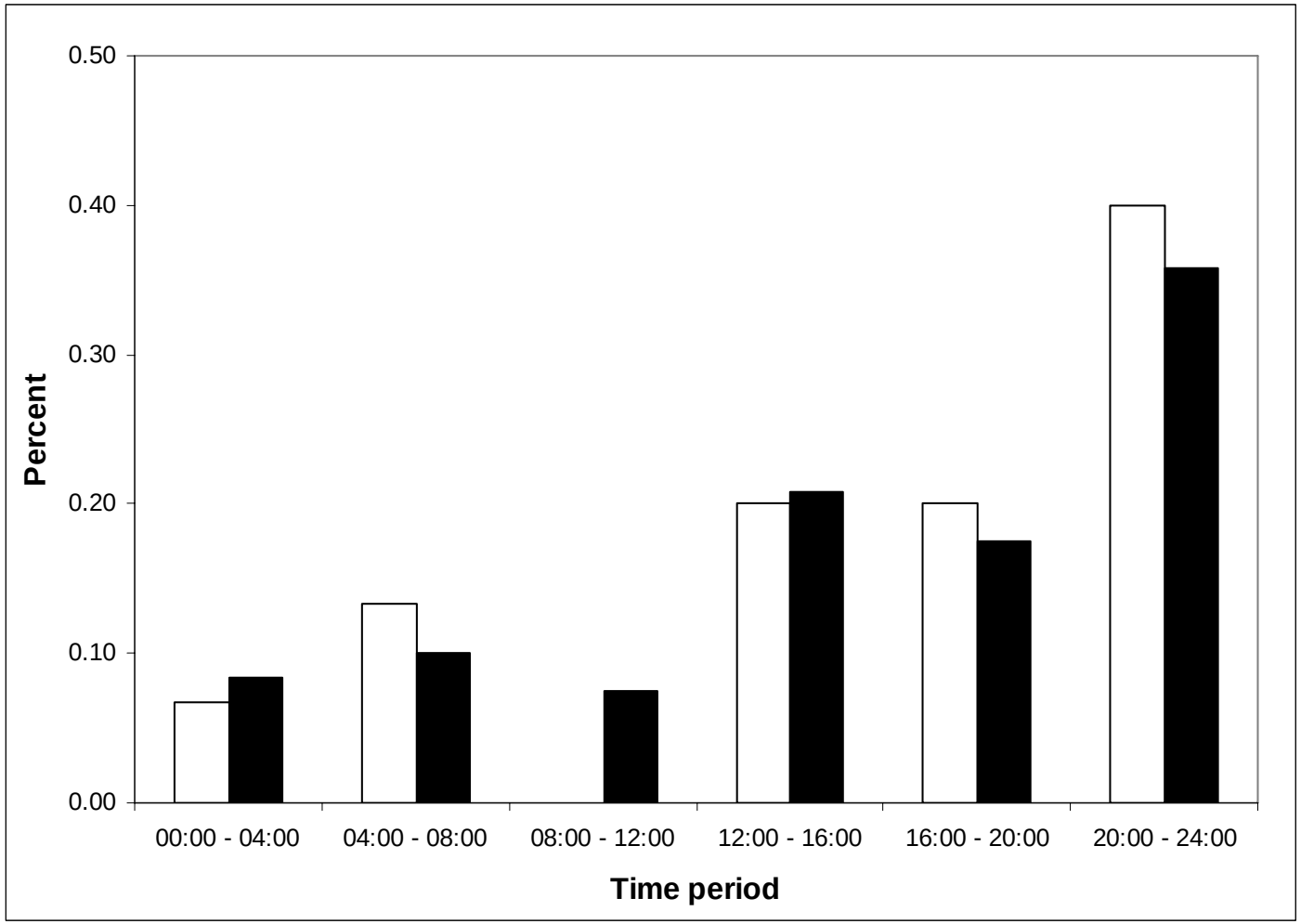


Figure 9.–Diel timing of radio-tagged chum salmon passing the North River counting tower (white bars) and proposed weir site (black bars), 2005.