Fishery Data Series No. 07-25

Spawning Distribution of Coho Salmon in the Upper Copper River Drainage, 2005

by

James W. Savereide

April 2007

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

Alaska Department of Fish and Game	ADF&G
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

FISHERY DATA SERIES NO. 07–25

SPAWNING DISTRIBUTION OF COHO SALMON IN THE UPPER COPPER RIVER DRAINAGE, 2005

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ABSTRACT

In 2005, radiotelemetry methods were used to determine the majority of spawning locations of coho salmon *Oncorhynchus kisutch* in the Upper Copper River, Alaska. Coho salmon were captured with a fish wheel and dip nets in the mainstem Copper River below Wood Canyon. A total of 1,761 coho salmon were captured from 15 August to 6 October and 122 were fitted with radio tags. Radio-tagged fish were tracked to upriver destinations using a combination of ground-based receiving stations and aerial tracking techniques. Coho salmon in the Upper Copper River spawned in the Chitina, Tonsina, and Klutina rivers. The estimated proportions of fish spawning were 0.67 (SE=0.11) in the Chitina River; 0.22 (SE=0.09) in the Tonsina River; and 0.11 (SE=0.07) in the Klutina River. Run-timing patterns varied only slightly among these spawning stocks. The mean date of passage past the capture site was 19 September for coho salmon bound for the Chitina River, 21 September for coho salmon bound for the Klutina River, and 22 September for coho salmon bound for the Tonsina River.

Key words: Coho salmon, Chitina River, Copper River, Klutina River, radiotelemetry, run-timing patterns, spawning distribution, Tonsina River.

INTRODUCTION

The Copper River is a glacially dominated system located in Southcentral Alaska and is the second largest river in Alaska in terms of average discharge. It flows south from the Alaska Range and Wrangell and Chugach mountains and empties into the Gulf of Alaska, slightly east of Prince William Sound (Figure 1). The Copper River drainage (61,440 km^2) supports spawning populations of coho salmon *Oncorhynchus kisutch*, Chinook salmon *O. tshawytscha*, and sockeye salmon *O. nerka* as well as various resident fish species.

Information on coho salmon in the Copper River drainage (excluding the Copper River delta) is limited to harvest numbers, subsistence uses, and local area knowledge about distribution but no formal research has been conducted. Aerial counts of coho salmon are conducted but this is only for Copper River delta stocks.

Coho salmon returning to the Copper River pass through commercial, subsistence, personal use, and sport fisheries on the way to their spawning grounds. The average annual coho salmon harvest from 1999-2003 was 315,438 fish in the commercial fishery, 3,172 fish in the combined Glennallen subdistrict subsistence (GSS) and Chitina subdistrict dip net (CSDN) personal use fisheries, and 220 fish in the sport fishery (Ashe et al. 2005; Taube 2006). The commercial fishing schedule is established by the department but discussions are held with the Prince William Sound Salmon Harvest Task Force and the public. In 2004, the season began on 9 August with a 24-hour opener. The fishery continued with one 24-hour opener per week until the week of 4 September when two 24-hour periods were fished. During the weeks of 18 and 25 September, the fishery opened for two 36-hour periods because aerial escapement counts were more than anticipated. The remaining two weeks had 156–hour openers because expanded aerial counts showed that delta stocks of coho salmon were near the upper range of the escapement goal and there was little fishing effort due to lack of market. Overall, there was a total of 13 fishing periods from 9 August to 10 October with a total harvest of 467,859 coho salmon.

The GSS fishery is open from 1 June to 30 September from the north side of the Chitina-McCarthy Bridge to the village of Slana. The majority of fishers use fish wheels to harvest salmon, but dip nets and rod and reel are also allowed. Federally qualified subsistence fishers can use fish wheels within the CSDN fishery and the season runs from 15 May to 30 September. However, the state-managed CSDN fishery (which accounts for nearly all of the total harvest in the subdistrict) is strictly a dip net fishery and typically runs from early June to the end of September. The majority of the sport harvest takes place in tributaries of the Tonsina and Chitina rivers, where anglers are limited to rod and reel gear.

The overall goal of the study was to document major spawning locations and characterize their respective run timing to identify potential coho sport fishing opportunities in the Upper Copper River. Documenting spawning areas and the

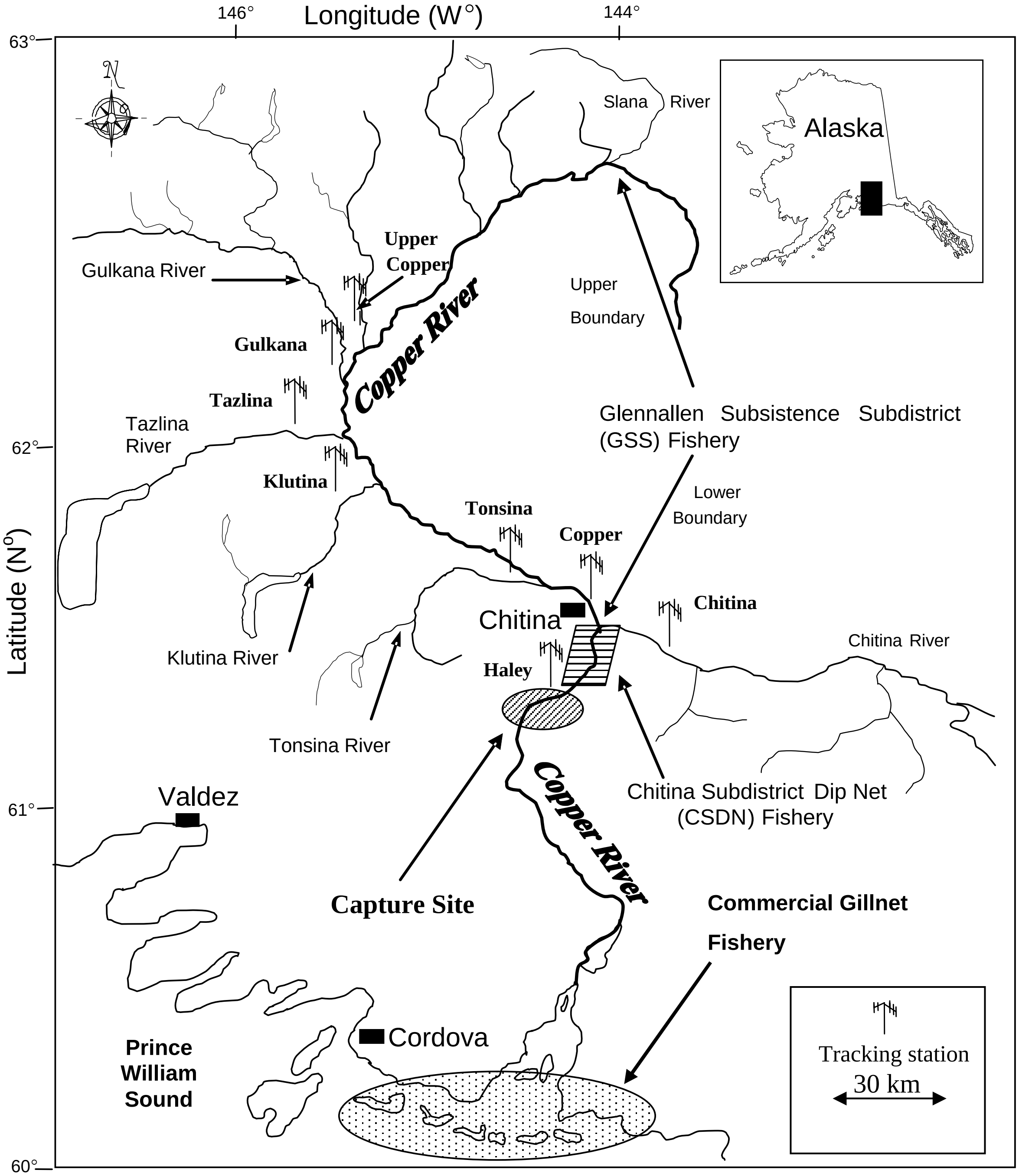

Figure 1.–Map of the Copper River drainage demarcating the capture site, major tributaries, eight radio tower locations, and the commercial, personal use, and subsistence fisheries.

migratory run timing of the coho populations would provide insight into the populations' availability to sport fishing and formalize some of their population dynamics.

OBJECTIVES

The objective of this study in 2005 was to:

1. estimate proportion of spawners using spawning areas accounting for 90% of the spawning population of coho salmon in the Upper Copper River drainage with 90% confidence.

METHODS

CAPTURE AND TAGGING

Coho salmon were captured using one aluminum fish wheel located on the west bank and by dipnetting from a river boat on the east bank of the Copper River below Wood Canyon (Figure 2). The study was designed to capture and radio-tag 120 coho salmon using two fish wheels, but extensive damage to one of the fish wheels prior to the field season forced the sampling crew to supplement the single fish wheel by dipnetting from a river boat. Capture locations were selected based on their effectiveness at capturing Chinook salmon at the same locations in previous studies (Evenson and Wuttig 2000; Smith et al. 2003). The fish wheel (provided by the Native Village of Eyak) was deployed on 15 August and fished until 6 October. The fish wheel had one large live tank (4.3 m long x 1.5 m deep x 0.6 m wide) with baskets that fished in a minimum of 2.44 m (8 feet) of water, as described in Smith et al. (2003). The fish wheel was operated 24 hours a day and seven days per week, however there were instances where changes in water level or floating debris caused the wheel to stop fishing. The fish wheel was checked at least three times a day unless large catches of sockeye or coho salmon required more frequent checks to alleviate overcrowding.

For every coho salmon captured and radio-tagged was placed in a sampling cradle with fresh water, data collected included:

1) measurement of fish length to the nearest 5 mm (FL);
2) radio tag frequency and code;
3) Floy™ tag number and color;
4) date and time of release; and,
5) capture location (e.g., east or west bank).

A systematic approach was taken in an attempt to radio-tag coho salmon in proportion to run strength by distributing radio tags based on daily catches. Initially, 1 out of every 10 coho salmon was radio-tagged. To ensure that radio tags were deployed over the entire run, the tagging rate was adjusted periodically to meet temporal tagging goals.

Radio tags were inserted through the esophagus and into the upper stomach of coho salmon with an implant device. The device was a 35-cm piece of polyvinyl chloride (PVC) tubing with a slit on one end to seat the radio transmitter into the end of the tube. Another smaller diameter section of PVC fit through the first tube acted as a plunger to unseat the radio tag. To ensure proper radio tag placement, tags were inserted to a standard depth equal to the distance from the snout to 1 cm posterior of the base of the pectoral fin.

All radio-tagged coho salmon also received a uniquely numbered Floy™ FD-94 internal anchor tag placed near the rear insertion of the dorsal fin. The entire handling process required approximately two to three minutes per fish.

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio tags were Model Five pulse-encoded transmitters manufactured by ATS[1]. Each radio tag was distinguishable by its frequency and encoded pulse pattern. Twelve frequencies spaced approximately 20 kHz apart in the 149-150 MHz range with up to 10 encoded pulse patterns per frequency were used.

A total of eight stationary radio-tracking stations were used to record migrating radio-tagged coho

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

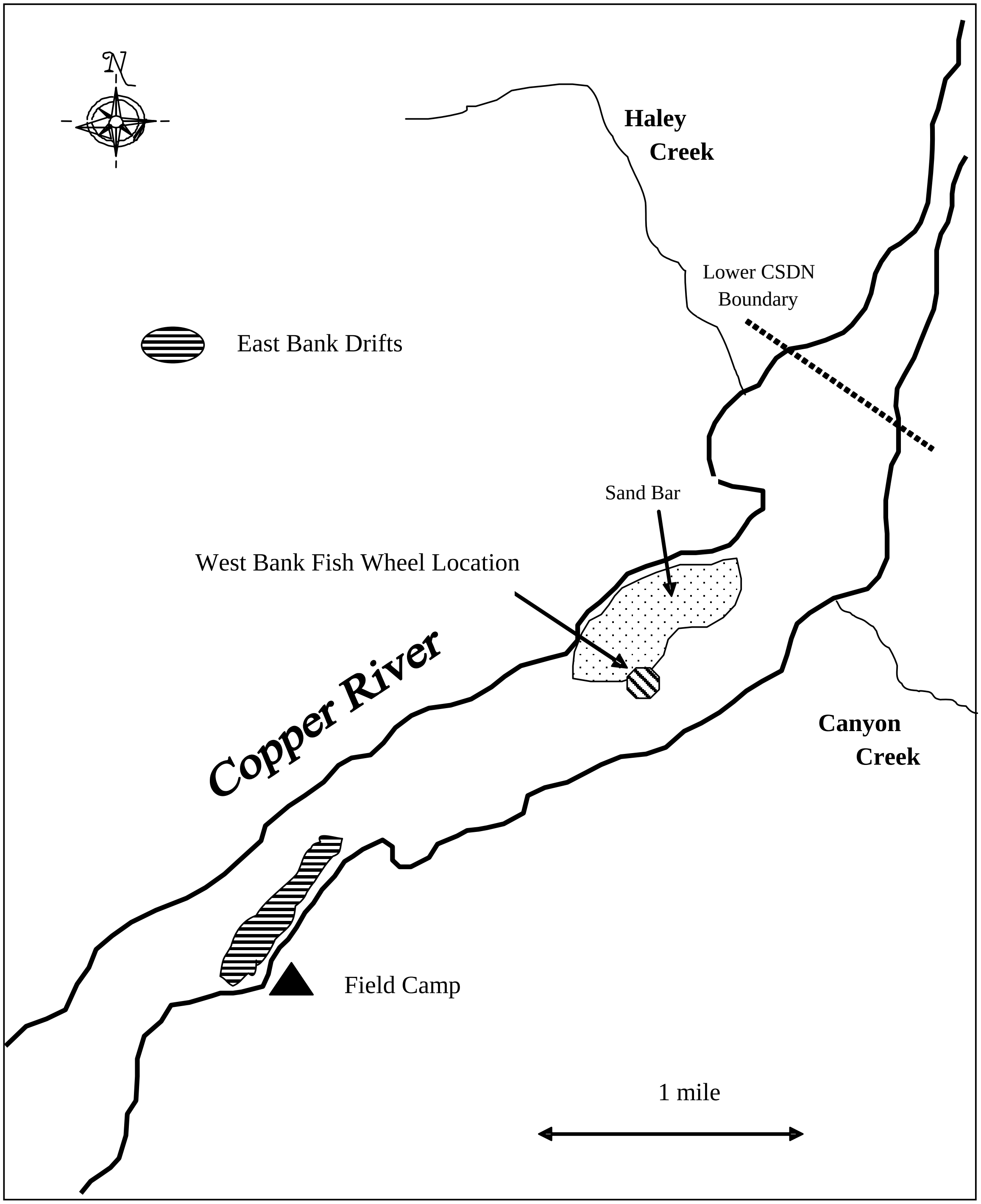

Figure 2.–Map of the Copper River demarcating the fish wheel and dip net capture locations, lower CSDN fishery boundary, and field camp, 2005.

salmon (Figure 1). Each station included two deep-cycle batteries, a solar battery charging array, an antenna switch box, a steel housing box, two Yagi antennas, and either an ATS Model 5041 Data Collection Computer (DCC II) coupled with an ATS Model 4000 receiver or an ATS Model R4500 (DCC and receiver combined). The units were programmed to scan through 10 frequencies at 2-s intervals, and receive from both antennas simultaneously. When a signal of sufficient strength was encountered, the receiver paused for 12 s on each antenna, and then tag frequency, tag code, signal strength, date, time, and antenna number were recorded on the data logger. The relatively short cycle period minimized the chance that a radio-tagged fish would swim past the receiver site without being detected. Cycling through all frequencies required up to 1 min depending on the number of active tags in the reception range and level of background noise. Recorded data was downloaded to a laptop computer every 7-10 days.

The first station was placed on the west bank at the lower boundary of the CSDN fishery (below Haley Creek; Figure 1) to determine the total number of radio-tagged coho salmon that successfully migrated upstream of the capture area. A second station was placed on the north bank of the Chitina River approximately 6 km upstream from its confluence with the Copper River to identify fish bound for the Chitina River drainage. The third station was placed on a west-side bluff of the Copper River immediately upstream of the Chitina River and the McCarthy Road bridge to identify fish bound for upriver areas. Radio-tagged fish entering the Tonsina, Klutina, Tazlina, and Gulkana rivers were recorded from stations placed near the mouths of these rivers. The last station was placed on the mainstem Copper River approximately 2 km downstream from the mouth of the Gakona River. This station was used to enumerate all radio-tagged fish migrating to areas upstream of the Gulkana River.

The distribution of radio-tagged coho salmon was further determined by aerial tracking from small aircraft. One aerial-tracking survey (4 days) of the entire drainage including the mainstem Copper River was conducted after completion of the fall migration. Tracking flights were conducted with one aircraft and one person (in addition to the pilot) utilizing one R4500 receiver. All frequencies were loaded into the receiver prior to each flight. Dwell time on each frequency was 2 s. Flight altitude ranged from 100 to 300 m above ground. Two antennas, one on each wing strut, were mounted such that the antennas received signals perpendicular to the direction of travel. Once a tag was identified, its frequency, code, and GPS location were recorded by the receiver. The purpose of the aerial tracking was to locate tags in tributaries other than those monitored by remote tracking stations, to locate fish that the tracking stations failed to record, locate specific spawning areas within a drainage, and to validate that fish recorded on each data logger did migrate into that particular stream.

DATA ANALYSIS

Fate Determination

Data from the tracking stations, aerial survey, and tag return information were used to determine the final fate assigned to each radio-tagged fish (Table 1). A coho salmon was assigned to a particular tributary if it was located there during the aerial tracking survey and/or was identified by the tributary's tracking station.

Identification of Spawning Areas

Radio-tagged coho salmon assigned a "spawner" fate were used to identify spawning areas (Table 1). Spawning areas of coho salmon were determined during one aerial survey conducted in early November. Because only one survey was conducted, locations of radio-tagged fish may not have corresponded to exact spawning sites (i.e., fish may still have been in transit to spawning site). Therefore, spawning areas were described as being within a particular stream as opposed to a particular stretch within a stream. It was anticipated that some coho salmon would spawn in portions of the mainstem Copper River and in sections of glacial tributaries (e.g., Chitina River). For these fish, it was difficult to differentiate between fish that were in a spawning area and fish that were still transiting to a spawning area (i.e., to a clear-water tributary).

Table 1.–List of possible fates of radio-tagged coho salmon in the Upper Copper River.

Fate	Description
Radio Failure	A fish that was never recorded swimming upstream into the CSDN fishery. Causes for radio failure include tag regurgitation, failure to transmit, and handling effects.
Subsistence Fishery Mortality	A fish harvested in the GSS fishery upstream of the McCarthy Road bridge.
Personal Use Fishery Mortality	A fish harvested in the CSDN fishery downstream of the McCarthy Road bridge.
Sport Fishery Mortality	A fish harvested in one of the sport fisheries.
Spawner[a]	A fish that entered a spawning tributary of the Upper Copper River.
Upstream migrant	A fish that migrated upstream, was never reported as being harvested, and was either located only in the mainstem Copper River, or was never located anywhere after migrating upstream of Wood Canyon.

[a] These radio-tagged fish were used to identify spawning tributaries and estimate spawning distribution and stock-specific run-timing.

Spawning areas of coho salmon were tabulated by tributary and plotted on maps using GIS software.

Distribution of Spawners

The proportion of coho salmon returning to the spawning tributaries of the Upper Copper River were estimated as the ratio of numbers of radio-tagged fish migrating into a specific spawning tributaries to the total number of radio-tagged fish surviving and migrating into all spawning tributaries.

The daily radio-tagging rate and hours of fishing effort (h_i) varied by day. The count of fish tagged on day i having fate j (R_{ij}) was adjusted by dividing by fishing effort (h_i) and the tagging rate (x_i/X_i) where x_i was the number of fish radio tagged and X_i was the total number of fish caught on day i. The adjusted count was:

$$R'_{ij} = \left(\frac{X_i}{h_i x_i}\right) R_{ij} . \tag{1}$$

Among fish that survived and migrated into spawning areas, the proportion of fish that had fate j was estimated as:

$$\hat{P}_j = \frac{\sum_i^{\text{days}} R'_{ij}}{\sum_j^{\text{fates}} \sum_i^{\text{days}} R'_{ij}} \tag{2}$$

where R_{ij} was the number of fish tagged on day i having fate j. Variance was estimated using bootstrap resampling techniques (Efron and Tibshirani 1993). Each bootstrap sample comprised a simple random sample taken with replacement from the total number of adjusted counts ($R_{ij}^{'}$). From each bootstrap sample the proportion of spawners with spawning fate j ($\hat{P}^*{}_j$) was calculated for a total of 1,000 bootstrap estimates.

Certain assumptions must have been met to obtain unbiased estimates of the spawning distribution:

1. *Radio-tagging coho salmon did not affect their final spawning destination.*

There was no explicit test for this assumption because we cannot observe the behavior of unhandled fish. However, there were no plausible reasons why a radio tagging would affect a final spawning destination.

2. *Captured coho salmon were radio-tagged in proportion to the magnitude of the run or there were no difference in run timing among stocks.*

The tagging protocol described was designed to distribute tags over time proportional to passage of coho salmon past the tagging site.

Previous radiotelemetry studies on Chinook salmon have shown that stock-specific differences in run timing can lead to biased estimates of spawning distribution because the probability of capturing fish often varies over time (Savereide 2004). This bias can be corrected with adjustments to the distribution estimates based on estimated total passage. Using passage, rather than CPUE, is preferred because CPUE may not vary in proportion to passage due to fluctuations in gear efficiency resulting from changes in river water levels and fish wheel placement. In this study no information on total passage was available therefore the ability to detect and describe any bias in the estimates of spawning distribution was not possible. It was assumed that the magnitude of this bias was small relative to the estimate.

Stock-Specific Run Timing

Run timing patterns were described as time-density functions, where the relative abundance of stock j (where stock was defined as all coho salmon returning to either the Chitina, Tonsina, Klutina, Tazlina, Gulkana, or Upper Copper drainages, which includes all rivers upstream of the Gulkana River) located upstream of Haley Creek during time interval t were described by (Mundy 1979):

$$f_j(t) = \frac{R'_{tj}}{\sum_i^{days} R'_{ij}} \tag{3}$$

where:

$f_j\ (t)$ = the empirical temporal probability distribution over the total span of the run for fish spawning in a tributary (or portion thereof) j; and,

R'_{tj} = the subset of radio-tagged coho salmon bound for tributary j that were caught and tagged during day t.

Those fish assigned a fate of "spawner" (Table 1) were used to determine the time-density functions.

The mean date of passage ($\bar{t}_j$) past the capture site for fish spawning in tributary j was estimated as:

$$\bar{t}_j = \sum_t t\ f_j(t), \tag{4}$$

the variance of the run timing distribution was estimated as:

$$Var\ (t_j) = \sum_t (t - \bar{t}_j)^2\ f_j(t). \tag{5}$$

Certain assumptions must be met to obtain unbiased estimates of stock-specific run timing:

1. *Captured coho salmon were radio-tagged in proportion to the magnitude of the run.*

The tagging protocol described was designed to distribute radio tags over time proportional to passage of coho salmon past the tagging site.

RESULTS

CAPTURE AND TAGGING

Coho salmon were captured from 15 August to 6 October, 2005. A total 1,761 coho salmon, 4,061 sockeye salmon, and 53 steelhead were captured. Of the 1,761 coho salmon captured, 122 were fitted with radio tags and released. The daily catch of coho salmon ranged from zero fish to 447 fish and the daily radio-tagging rate varied from 2.0 to 100% of all captured coho salmon (Figure 3).

FATE DETERMINATION

The combination of stationary and aerial tracking techniques accounted for 100% of the radio tags deployed. Detection rates of the tracking stations in the spawning tributaries ranged from 93-100% (Table 2).

Table 2.–Number and percent of radio tags detected by radio tracking stations and aerial surveys for each tributary with radio-tagged coho salmon.

	Chitina	Tonsina	Klutina
Total Tags	73	27	8
Stations	71 (97%)	25 (93%)	8 (100%)
Aerial Survey	52 (71%)	25 (93%)	7 (88%)

Of the 122 radio-tagged coho salmon, 113 fish (93%) entered the CSDN fishery and 111 (91%) exited the fishery. Two-radio tagged fish were harvested in the CSDN fishery and returned to ADF&G. Three radio-tagged fish were never reported as harvested or located in a spawning tributary (upstream migrant fate), zero fish were known to be harvested in subsistence fish wheels, zero fish were known to be harvested in sport fisheries, and 108 (89%) fish were located in spawning areas (Table 3).

Table 3.–Fates of radio-tagged coho salmon in the Upper Copper River, 2005.

Fate	Radio Tags
Radio Failure	9
CSDN Fishery Mortality	2
GSS Fishery Mortality	0
Sport Fishery Mortality	0
Spawner	108
Upstream Migrant	3
Total	122

DISTRIBUTION OF SPAWNERS

Ninety-eight percent of fish recorded between the capture site and the Haley Creek tracking station reached the CSDN fishery in 3 days or less and 90% migrated through the CSDN fishery in 5 days or less (Figure 4).

The daily radio tagging rate (x_i/X_i) and hours of fishing effort (h_i) varied by day (Table 4). Therefore, equation 1 was used to calculate weights for radio-tagged fish on day i and

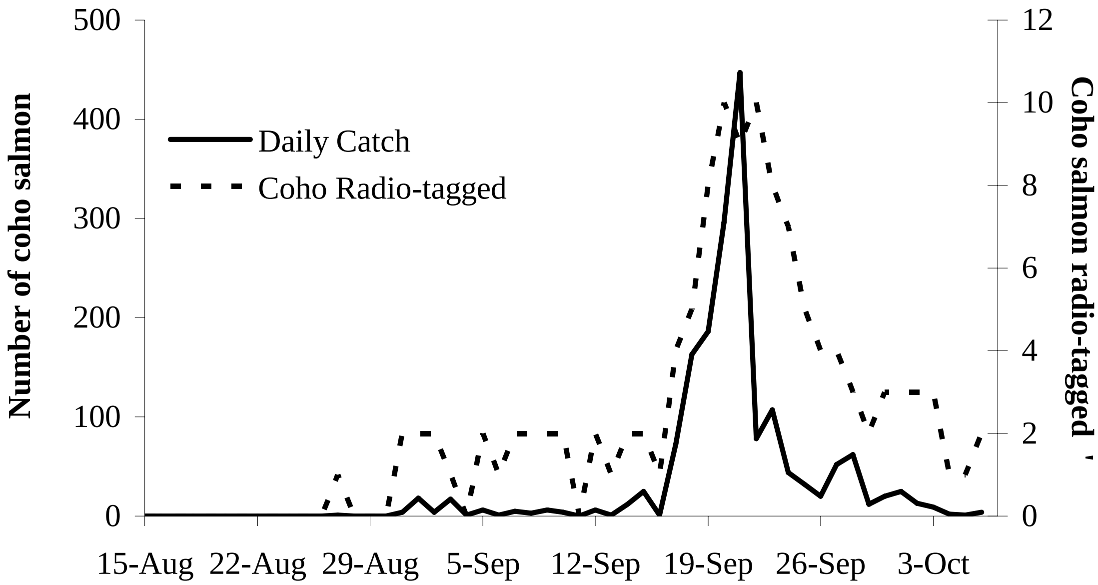

Figure 3.–Total number of coho salmon captured and radio-tagged by day, 2005.

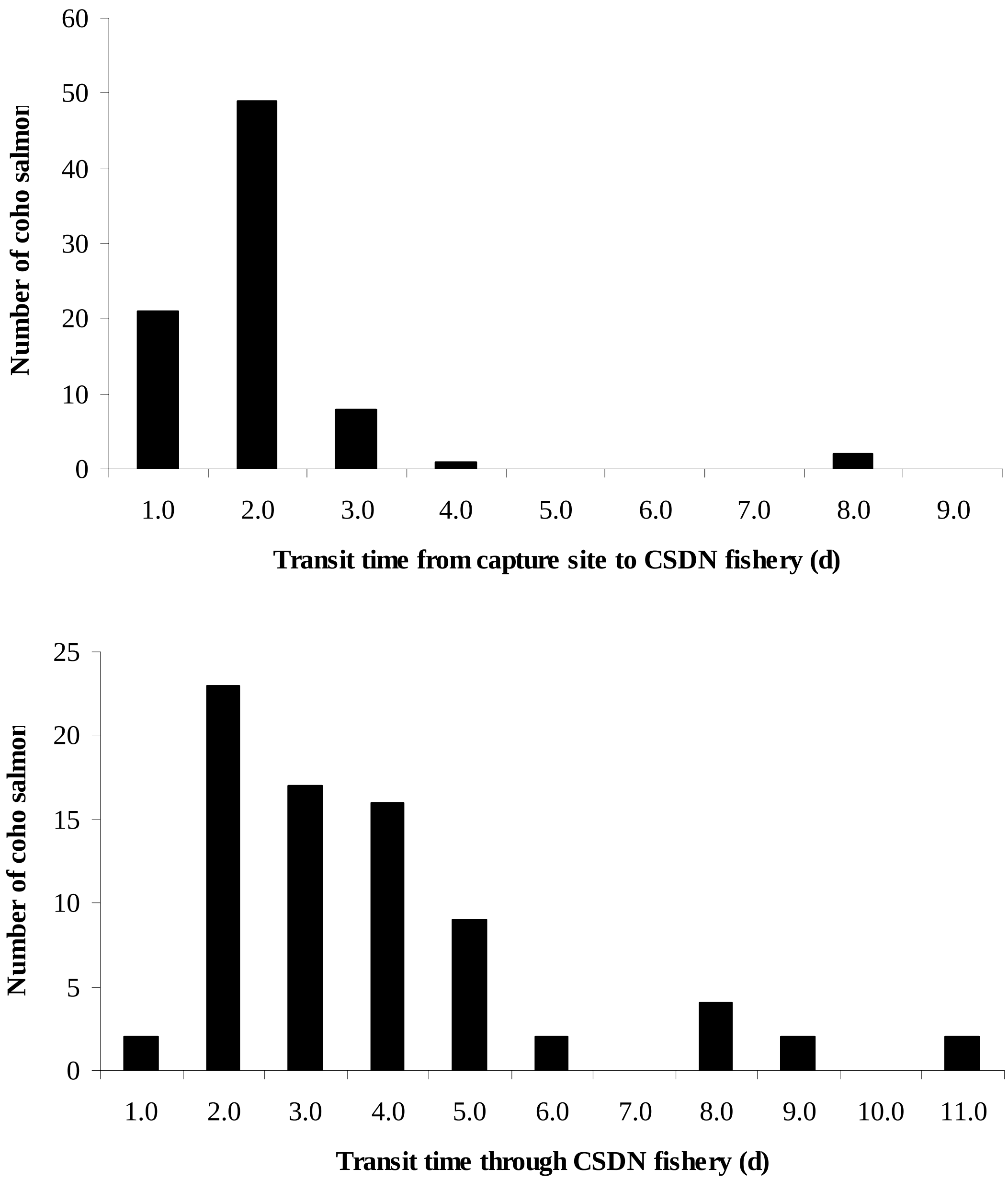

Figure 4.–Transit times from capture site to the CSDN fishery (top panel) and transit times through the CSDN fishery (bottom panel) for radio-tagged coho salmon in the Upper Copper River, 2005.

Table 4.–Fish wheel (FW), dip net (DN), and total (h_i) hours fished, coho salmon captured (X_i), coho salmon radio-tagged (x_i), and tagging rate (x_i/X_i) by day, 2005.

Date[a]	FW Hours	DN Hours	h_i	Captured (X_i)	Radio-tagged (x_i)	Tagging Rate (x_i/X_i)
27-Aug	24.0	0.0	24.0	1	1	100.0%
28-Aug	0.0	0.0	0.0	0	0	0.0%
29-Aug	6.5	0.0	6.5	0	0	0.0%
30-Aug	24.0	0.0	24.0	0	0	0.0%
31-Aug	24.0	0.0	24.0	4	2	50.0%
1-Sep	24.0	0.0	24.0	18	2	11.1%
2-Sep	24.0	0.0	24.0	4	2	50.0%
3-Sep	23.5	0.0	23.5	17	1	5.9%
4-Sep	23.8	0.0	23.8	1	0	0.0%
5-Sep	24.0	2.0	26.0	6	2	33.3%
6-Sep	24.0	1.8	25.8	1	1	100.0%
7-Sep	24.0	0.0	24.0	5	2	40.0%
8-Sep	24.0	2.0	26.0	3	2	66.7%
9-Sep	24.0	0.0	24.0	6	2	33.3%
10-Sep	24.0	2.0	26.0	4	2	50.0%
11-Sep	9.0	0.0	9.0	0	0	0.0%
12-Sep	24.0	1.8	25.8	6	2	33.3%
13-Sep	24.0	4.0	28.0	1	1	100.0%
14-Sep	24.0	2.0	26.0	12	2	16.7%
15-Sep	24.0	2.5	26.5	25	2	8.0%
16-Sep	22.0	0.0	22.0	1	1	100.0%
17-Sep	24.0	1.0	25.0	73	4	5.5%
18-Sep	23.5	2.0	25.5	163	5	3.1%
19-Sep	23.3	2.0	25.3	186	8	4.3%
20-Sep	24.0	0.5	24.5	296	10	3.4%
21-Sep	23.6	0.0	23.6	447	9	2.0%
22-Sep	24.0	0.0	24.0	78	10	12.8%
23-Sep	24.0	0.0	24.0	107	8	7.5%
24-Sep	24.0	0.0	24.0	44	7	15.9%
25-Sep	24.0	2.5	26.5	32	5	15.6%
26-Sep	16.0	1.0	17.0	20	4	20.0%
27-Sep	24.0	1.3	25.3	52	4	7.7%
28-Sep	23.4	0.0	23.4	62	3	4.8%
29-Sep	24.0	0.0	24.0	12	2	16.7%
30-Sep	24.0	0.0	24.0	20	3	15.0%
1-Oct	24.0	0.0	24.0	25	3	12.0%
2-Oct	23.4	0.0	23.4	13	3	23.1%
3-Oct	24.0	0.0	24.0	9	3	33.3%
4-Oct	24.0	0.0	24.0	2	1	50.0%
5-Oct	24.0	0.0	24.0	1	1	100.0%
6-Oct	13.0	0.0	13.0	4	2	50.0%

[a] Fishing began on 15 August but no coho salmon were captured until 27 August.

equation 2 was used to estimate the proportion of fish with fate *j*.

In 2005, radio-tagged coho salmon were located in 17 separate streams within the Chitina, Tonsina, and Klutina tributaries of the Upper Copper River (Figures 5-6). The smallest proportion of spawners returned to the Klutina River (0.11) and the largest proportion returned to the Chitina River (0.67; Table 5).

Table 5.–Spawning distribution of Upper Copper River coho salmon by major drainage, 2005.

	Chitina	Tonsina	Klutina
Number Radio-tagged	73	27	8
Proportion	0.67	0.22	0.11
SE	0.06	0.05	0.04

STOCK-SPECIFIC RUN TIMING

As with estimates of spawning distribution, weighted observations for individual radio-tagged fish (equation 1) were used to describe run timing because the daily radio tagging rate and hours of fishing effort varied by day.

Run-timing patterns at the capture site varied slightly among the individual spawning stocks (Figure 7). The mean date of passage at the capture site varied from 19 September for coho salmon bound for the Chitina River to 22 September for coho salmon bound for the Tonsina River (Table 6).

Table 6.–Statistics regarding the run timing past the capture site of the major Upper coho salmon spawning stocks in the Copper River, 2005.

	Chitina	Tonsina	Klutina
First Fish	27-Aug	7-Sept	19-Sept
Last Fish	5-Oct	2-Oct	26-Sept
Duration (d)	39	25	7
Mean Date	19-Sept	22-Sept	21-Sept
SE	5.41	4.04	1.49

DISCUSSION

Other than a few occasions where the water dropped substantially overnight, the fish wheel operated almost continuously from 15 August to 6 October (Table 4). The ability to fish throughout the day coupled with daily dipnetting allowed us to achieve our sampling goal and to sample fish migrating past the capture site at different times of the day. Even though one fish wheel provided ample coho salmon for tagging, a second fish wheel on the opposite bank would ensure an equal amount of tags could be deployed from each side of the river. The unused damaged fish wheel was removed from the water in late September and shipped to Cordova for repairs in preparation for next season.

Information from the aerial tracking survey and tracking stations was used to determine the fate of all radio-tagged fish and a spawning fate was assigned to 89% of the tagged fish. However, because only one survey was conducted, locations of radio-tagged fish may not have corresponded to exact spawning sites. Thus, spawning distribution was described by major river drainage with the assumption that the radio-tagged fish located there spawned somewhere within the drainage. Within all three major spawning drainages, some radio-tagged fish were located in the glacially-occluded stretches of the mainstem river, however for the same reason we were unable to ascribe these as spawning areas. In 2006, to improve the accuracy of describing spawning distribution within a drainage, an additional aerial survey (4 days) will be conducted.

The spawning distribution and run-timing estimates in this study were determined with the assumptions that the population was radio-tagged in a representative manner and that tagging did not alter the fish's behavior. The effects of inserting radio tags into coho salmon on survival, migratory behavior, and catchability are not fully understood. The proportion of radio-tagged coho salmon that failed to migrate upstream was 7% (n=9). Although radio-tagged fish that failed to migrate upstream were removed from estimation of spawning distribution and run timing, a large incidence of failure may be indicative of chronic handling-induced effects in those salmon that did migrate upstream. Comparable studies on Chinook salmon in the Copper, Stikine and Taku rivers have observed similar failure or retreat rates (Savereide 2003; Savereide 2004; Pahlke and

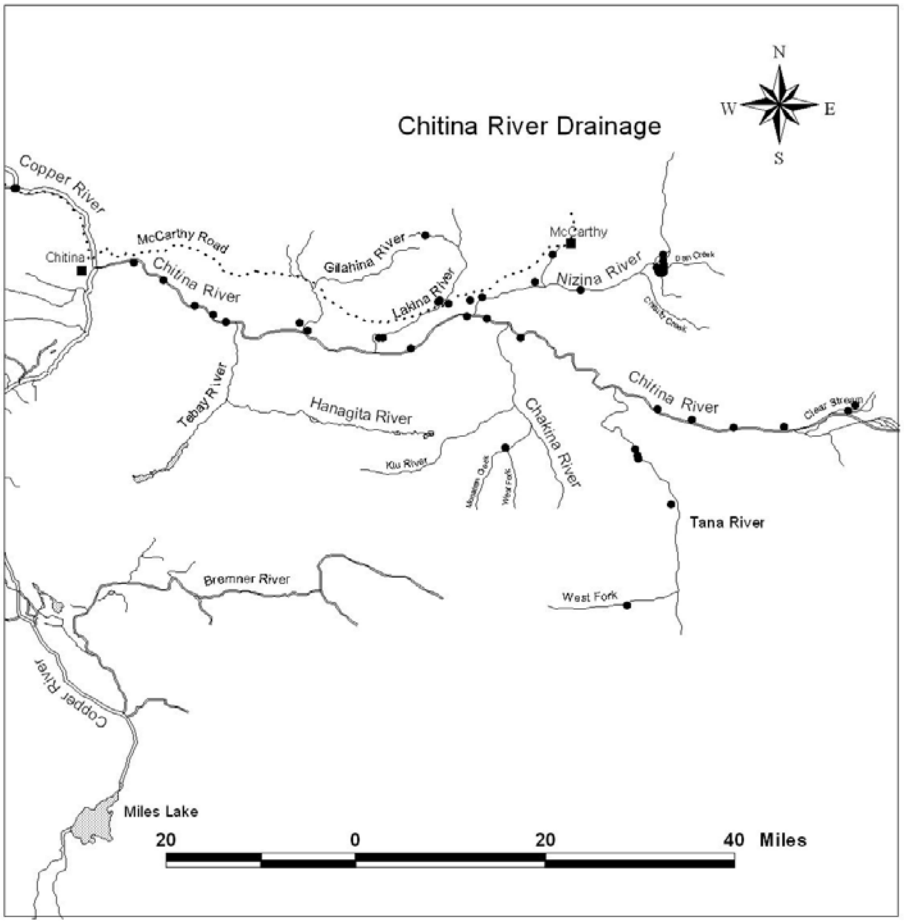

Figure 5.–Locations of radio-tagged coho salmon detected from the aerial survey in the Chitina River (● = radio-tagged coho salmon).

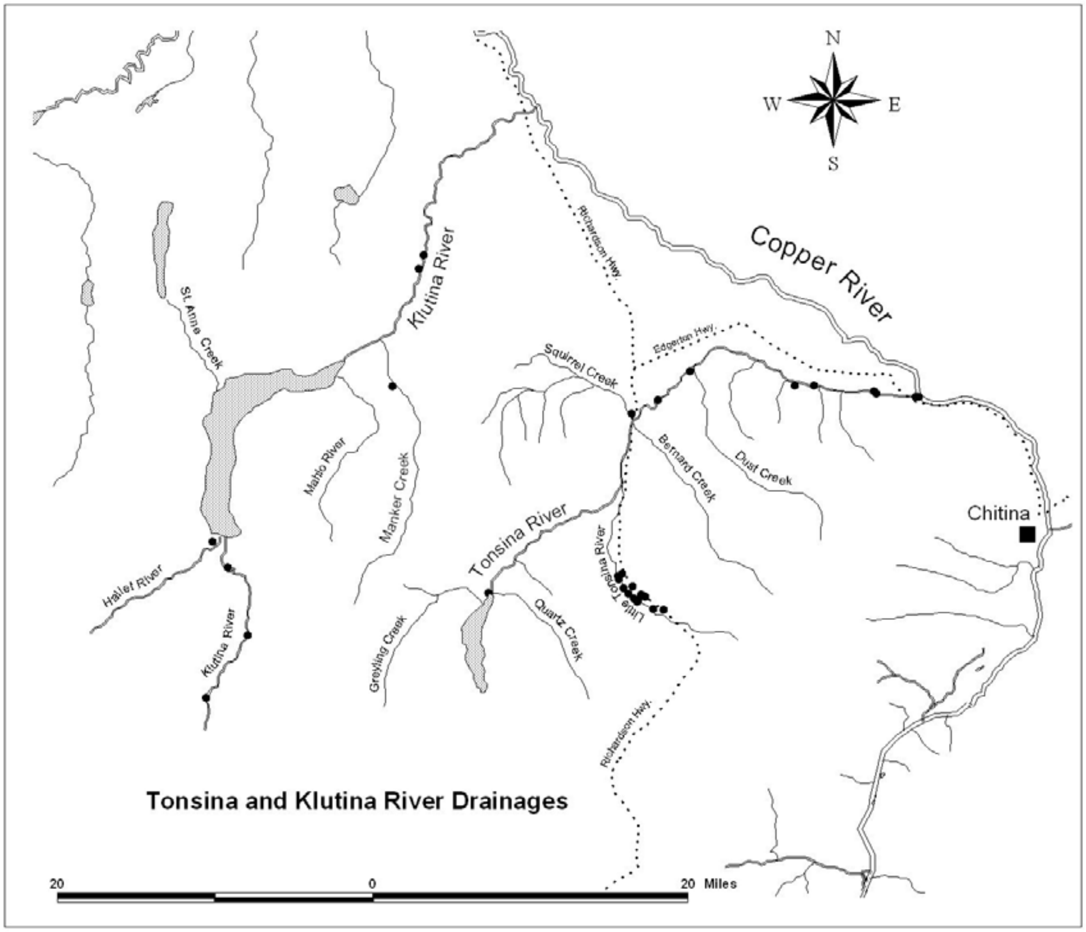

Figure 6.–Locations of radio-tagged coho salmon detected from the aerial survey in the Tonsina and Klutina rivers (● = radio-tagged coho salmon).

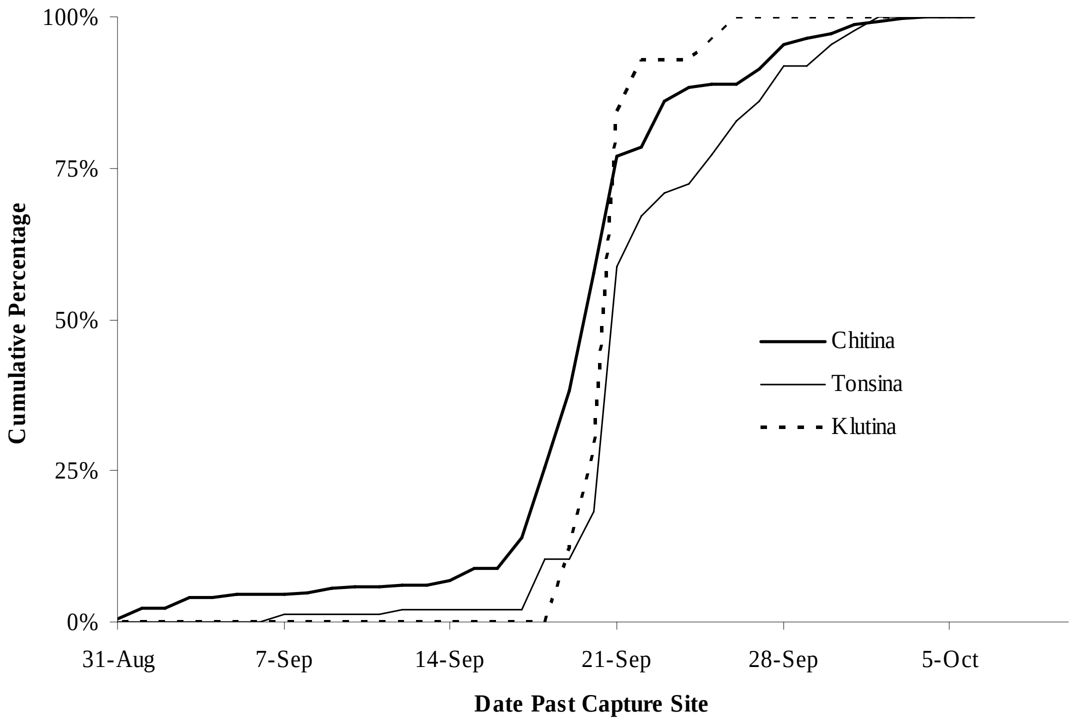

Figure 7.–Run-timing patterns of coho salmon at the capture site for the major stocks in the Upper Copper River, 2005.

Bernard 1996; Bernard et al. 1999). Even though the failure rate observed in this study was low and comparable to other studies, the central question of whether handling affects migratory behavior still remains.

Previous studies have provided varying theories on the effects of radio tags on salmon migration. Monan and Liscom (1975) suggested that spring and fall run Chinook salmon can successfully migrate to their spawning grounds when fitted with internal radio tags. In contrast, Gray and Haynes (1979) found that the proportion of Chinook salmon fitted with internal radio tags that returned to their spawning grounds was significantly less than fish tagged with only spaghetti tags. The latter study concluded that the majority of unsuccessful migrations were caused by placing the radio tag into the posterior stomach instead of just behind the esophageal sphincter in the anterior stomach. In addition, Bromaghin and Underwood (2004) revealed a positive relationship between the amount of time a tagged chum *O. keta* salmon spent in a fish wheel's live-tank and their probability of recapture. In other words, tagged chum salmon had a higher probability of being recaptured the longer they spent in a live-tank before being tagged and released. In this study radio tags were placed in the anterior stomach of coho salmon and fish wheels were checked regularly to minimize the amount of time spent in the live-tank and over-crowding. Only 2.7% (3 out of 122) of the radio-tagged fish that migrated through the CSDN fishery that were not known to be harvested were never located in a spawning tributary. These results imply that correctly placed internal radio tags and proper handling techniques do not negatively affect migratory behavior of coho salmon. Because only fish that successfully migrated into spawning streams were used to estimate spawning distribution and run timing, it was assumed that the probability that a radio-tagged fish successfully migrated to a spawning stream did not vary by spawning stock.

To locate 90% of the coho salmon spawning locations with 90% confidence a total of 96 radio-tagged coho salmon (established from Monte Carlo simulations) needed to successfully migrate to their spawning grounds. In 2005, a total of 108 radio-tagged coho salmon were located on 17 separate streams within three major Upper Copper River spawning tributaries. Based on the results, at least 90% of the coho salmon spawning occurs in the Chitina, Tonsina, and Klutina rivers. Estimates of the spawning proportion in each tributary revealed the Chitina River supports the largest percentage (66%) of the total escapement whereas the Klutina River supports the smallest (11%). This information supports the local resident's and area manger's previous knowledge and the but it has never been officially documented until now.

The Statewide Sport Fish Harvest Survey indicates the majority of the coho sport fishing occurs in the Tonsina drainage. This is because nearly all of the spawners in the Tonsina drainage are located in the Little Tonsina River which is easily accessible from the Richardson Highway. In contrast, the majority of coho spawning in the Upper Copper River takes place in the Chitina drainage and even though there is a road to McCarthy nearly all of the coho spawning streams are not easily accessible by foot.

Harvest reports from the CSDN fishery suggested that coho salmon would be migrating past the capture site in early August (Figure 3); however, coho salmon weren't captured until 27 August and substantial numbers didn't appear until mid-September. This delay in typical migration was likely an artifact of the high-water observed in August. As the river began to drop toward the end of August, coho salmon holding in the lower river started to appear in the fish wheel and dip nets.

The migratory run timing patterns of coho salmon past the capture site were very similar for the three major tributaries with coho salmon bound for the Chitina and Klutina tributaries passing slightly earlier than those bound for the Tonsina River. This is in contrast to the run timing patterns exhibited by Upper Copper River Chinook salmon which exhibited distinct run-timing patterns among stocks, where upriver salmon stocks migrated into the river before downriver stocks (Savereide 2004).

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