Fishery Data Series No. 08-56

Relative Abundance, Migratory Timing, and Overwintering and Spawning Distribution of Steelhead in the Copper River Drainage

Final Report for Study 05-502
USFWS Office of Subsistence Management
Fisheries Division

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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

FISHERY DATA SERIES NO. 08-56

RELATIVE ABUNDANCE, MIGRATORY TIMING, AND OVERWINTERING AND SPAWNING DISTRIBUTION OF STEELHEAD IN THE COPPER RIVER DRAINAGE

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ABSTRACT

Radiotelemetry methods were used to determine steelhead *Oncorhynchus mykiss* spawning locations, stock-specific run timing profiles, overwintering areas, and the magnitude of the total return to the Upper Copper River (tributaries north of the Chugach Mountains). Steelhead were captured with fish wheels and dip nets in the mainstem Copper River below Wood Canyon. A total of 53 steelhead were fitted with radio tags in the fall of 2005 and 42 were fitted in the fall of 2006. Radio-tagged fish were tracked using a combination of ground-based receiving stations and aerial tracking techniques. Overwintering areas included their natal rivers such as the Gulkana and Hanagita Rivers, the Tazlina Lake outlet, and the turbid mainstems of the Copper, Chitina, and Tazlina rivers. Steelhead in the Upper Copper River spawned in the Gulkana, Tazlina, and Chitina river drainages. The estimated proportion of steelhead spawning in the Dickey and Hanagita lake spawning areas was 0.08 (SE=0.06) in 2006 and 0.22 (0.09) in 2007. Based on stock assessment work in these two areas conducted in previous years, the total run of steelhead in the Upper Copper River drainage is likely within the range of 1,000–45,000. The large range reflects a large annual variation in the proportion spawning in these areas, and poor precision of the annual estimates. The estimated spawning proportions by drainage in 2006 were 0.54 (SE=0.11) for the Tazlina, 0.14 (SE=0.07) for the Chitina, and 0.31 (SE=0.10) for the Gulkana. In 2007, the estimated spawning proportions by drainage were 0.39 (SE=0.10) for the Tazlina, 0.38 (SE=0.11) for the Chitina, and 0.22 (SE=0.09) for the Gulkana. In 2005, the mean date of passage past the capture site was 22 September for steelhead bound for the Tazlina drainage and 24 September for steelhead bound for the Chitina and Gulkana drainages. In 2006, the mean date of passage past the capture site was 25 August, 23 August, and 18 August for steelhead bound for the Tazlina, Chitina, and Gulkana drainages, respectively. Outmigration dates from the Tazlina, Gulkana, and Chitina rivers ranged from 20 May to 24 June in 2006 and 4 May to 20 June in 2007.

Key words: Chitina River, Copper River, dip net, fish wheel, Gulkana River, radiotelemetry, run-timing profiles, steelhead, spawning distribution, Tazlina 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, east of Prince William Sound (Figure 1). The Copper River drainage (61,440 km^2) supports spawning populations of steelhead *Oncorhynchus mykiss,* Chinook salmon *O. tshawytscha*, sockeye salmon *O. nerka*, and coho salmon *O. kisutch* as well as various resident fish species.

Steelhead, an anadromous form of rainbow trout, spawn in tributaries of the Upper Copper River. These fish are thought to be the northernmost stocks of steelhead in North America (Burger et al. 1983). Similar to other salmonid species living on the edges of their distribution, the populations in the Copper River drainage are thought to be relatively sparse and unproductive (Flebbe 1994). There is a lack of comprehensive information for these stocks because population characteristics such as spawning stock size and seasonality coupled with the vastness and remoteness of the Copper River drainage make a thorough scientific study difficult. Adult steelhead pass through commercial, subsistence (Glennallen Subsistence Subdistrict-GSS), personal use (Chitina Subdistrict dip net-CSDN), and sport fisheries on the way to their spawning grounds. No information is available to describe the overall run size or the inriver abundance that enters inriver fisheries. Steelhead harvests reported by subsistence fishers, and catch reports from sport fishers suggest that undocumented spawning stocks exist.

Information on Copper River steelhead has been sporadically collected since the 1960s. Steelhead ascending the Hanagita River were sampled as early as 1963 in the sport fishery located at the outlet of Hanagita Lake (Williams 1964). In the 1980s steelhead were captured from the Copper River near Copperville and fitted with radio transmitters that led researchers to document a few spawning locations within the Tazlina and Gulkana drainages (Burger et al. 1983). Researchers from the University of Alaska-Fairbanks conducted studies along the Middle Fork Gulkana River on steelhead and rainbow trout spawning populations, their habitat,

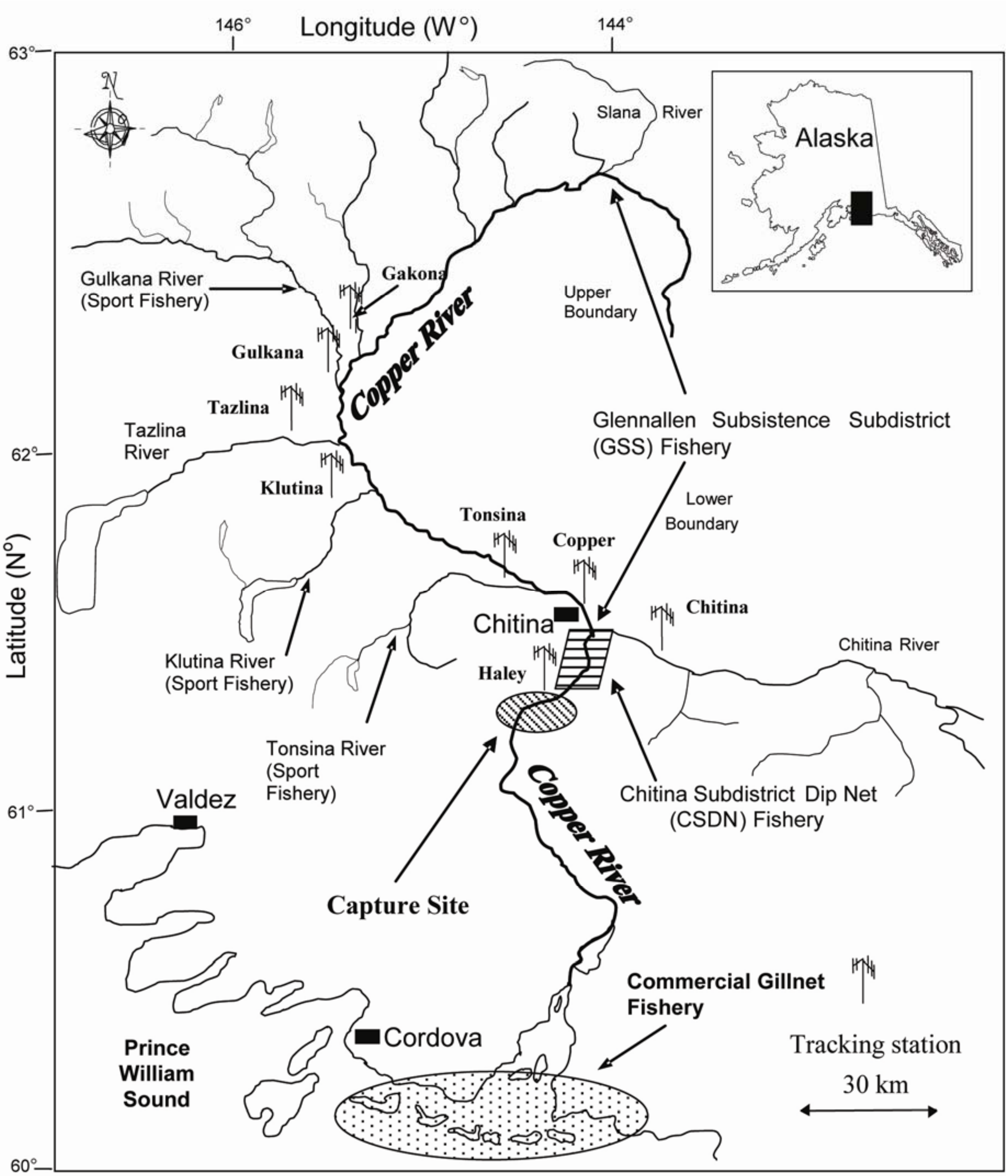

Figure 1.–Map of the Copper River drainage demarcating the capture site, major tributaries, eight radio tower locations, and the commercial, sport, GSS, and CSDN fisheries.

and juvenile feeding ecology (Brink 1995; Stark 1999). From 1998 to 2001, ADF&G Sport Fish Division collected information on what were considered to be two of the most significant steelhead spawning stocks in the Copper River drainage: the Hanagita Lake and Dickey Lake stocks (Fleming 1999, Fleming 2000, Wuttig et al. 2004). The results of the studies demonstrated that these two stocks are genetically distinct and relatively small (< 450 spawning fish combined). Genetic samples were also collected from Hungry Hollow Creek, an adjacent tributary to the Dickey

Lake area, where 63 steelhead were sampled as they passed downstream through a weir after spawning (Wuttig et al. 2004).

Catch information from returned fishing permits from the GSS and CSDN fisheries indicates steelhead have been captured as far upriver as Slana and migrate through the Upper Copper River (tributaries north of the Chugach Mountains) from mid-August to mid-October (Figure 1). Some additional subsistence harvests of steelhead (likely post-spawning fish) have been reported from late May to late June. During late May of 2000–2003, the potential effects (harvests) of an extended subsistence salmon fishing season on out-migrating adult steelhead was examined by fishing two test fish wheels near Tazlina (Eric Veach, Chief of Resources, Wrangell-St. Elias National Park; personal communication). In 2001 and 2003, 181 sockeye salmon and only one steelhead were captured; however, in 2002, only three sockeye salmon were caught (attributed to late run timing), but a total of four steelhead were captured. These observations demonstrate that there is potential for a substantial steelhead harvest if subsistence fishing effort increases early in the season.

A primary goal of this study was to gauge the magnitude of the run size of steelhead returning to the Upper Copper River. This was accomplished by estimating the relative contribution of the Dickey and Hanagita lake stocks to the drainage-wide steelhead spawning escapement. Inriver run timing information and documentation of significant spawning and overwintering locations throughout the drainage are also provided.

OBJECTIVES

The objectives of this study in 2005 and 2006 were to:

1. Estimate the proportion of Copper River steelhead that migrate to both the Dickey Lake and Hanagita Lake spawning areas in 2005 and 2006 such that the estimates are within 10 percentage points of the true values 95% of the time; and,
2. Describe the migratory timing profile (upriver and downriver) of the steelhead return in the Copper River at the point of capture (below Wood Canyon) during 2005 and 2006 and investigate potential stock-specific differences in run timing.

A secondary task was to document significant steelhead aggregations in the Copper River drainage during spawning and overwintering periods.

METHODS

CAPTURE AND TAGGING

This study was designed to capture and radio-tag 130 steelhead each year during their migration to their spawning areas in 2005 and 2006. Precision criteria in Objective 1 would be met assuming the radio tags were distributed randomly among returning steelhead and that at least 96 radio-tagged steelhead survived to spawn (Cochran 1977). A standardized method of deployment was going to be used, but low catches led to radio-tagging every steelhead captured.

To provide insight relative to identifying where most (i.e. 90%) of the total steelhead run spawns, Monte Carlo simulations were performed that considered a range of reasonable assumptions about the relative number and use of spawning areas. These simulations demonstrated that 96 radio tags located on spawning areas would represent 90% or more of the spawning population.

This study was designed to capture and radio-tag steelhead using two fish wheels in 2005 and 2006 but extensive damage to one of the fish wheels prior to the 2005 field season forced the sampling crew to supplement the single fish wheel by dipnetting from a river boat. In 2006, the damaged fish wheel was repaired and two fish wheels were used to capture steelhead. Steelhead were captured using aluminum fish wheel(s) located on the west and east banks and dipnetting from a river boat on the east bank of the Copper River below Wood Canyon (Figure 2). The locations were selected based on their effectiveness at capturing Chinook salmon at the same locations (Evenson and Wuttig 2000; Smith et al. 2003). In 2005, the fish wheel (provided by the Native Village of Eyak) was deployed on 15 August and fished until 6 October. In 2006, the wheels were fished on 16 August through 29 September. The fish wheel(s) had one or two large live tanks (4.3 m long x 1.5 m deep x 0.6 m wide) with three to four baskets that fished in a minimum of 2.44 m (8 feet) of water, as described in Smith et al. (2003). The fish wheel(s) were 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(s) to stop fishing. Each 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 steelhead captured and radio-tagged, data collected included:

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

Radio tags were inserted through the esophagus and into the upper stomach of steelhead with an implant device. The device was a 25-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, the distance from the base of the pectoral fin to the tip of the snout was used to determine how far to insert the implant device into the fish.

All radio-tagged steelhead 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.

Ages are shown in European notation (Koo 1962): number of freshwater annuli on the left of the decimal point and number of saltwater annuli are on the right. The total age from the time of egg fertilization is the sum of the fresh and saltwater annuli plus one.

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. Thirteen frequencies spaced approximately 20 kHz apart in the 149–150 MHz range with 10 encoded pulse patterns per frequency were used.

A total of eight stationary radiotracking stations were used to record migrating radio-tagged steelhead (Figure 1). Each station included two deep-cycle batteries, a solar 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 the frequencies at 3-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 were 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 steelhead that successfully migrated out 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 upstream of the Chitina River and the McCarthy Road bridge to identify fish bound for upriver

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

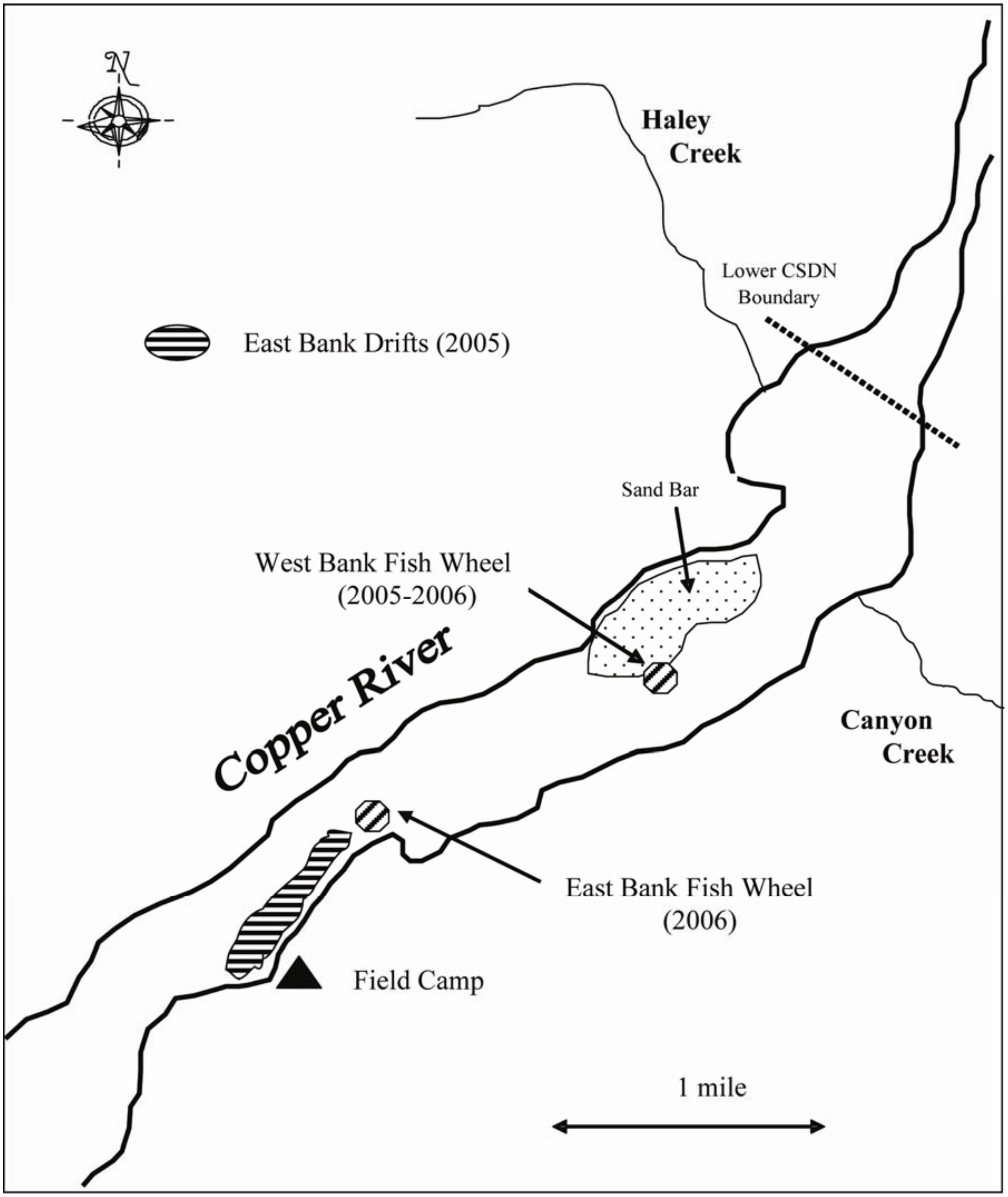

Figure 2.–Map of the Copper River demarcating the fish wheel and dip net capture locations, lower CSDN fishery boundary, and field camp, 2005–2006.

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 upstream of the Gulkana River.

The distribution of radio-tagged steelhead was further determined by aerial tracking from small aircraft. In 2005 and 2006, one aerial-tracking survey (~4 d) of the entire drainage including the mainstem Copper River was conducted after completion of the fall migration. Two more surveys were conducted in March-April, and a minimum of two surveys were done in May-June to determine the overwintering and spawning locations (Table 1). Tracking flights were conducted with one aircraft and one person (in addition to the pilot) utilizing one R4500 receiver. 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, to locate specific spawning areas within a drainage, and to validate that fish recorded on the data loggers did migrate into those streams.

DATA ANALYSIS

Fate Determination

Data from the tracking stations, aerial surveys, and tag return information was used to determine the final fate assigned to each radio-tagged fish (Table 2). Steelhead designated as failures either regurgitated their tag or died from handling. Steelhead designated as spawners were assigned to a particular spawning tributary (Table 2) if its radio tag was located there during an aerial tracking survey or was identified by the spawning tributary's tracking station.

Identification of Spawning Areas

Radio-tagged steelhead assigned a spawner fate were used to identify spawning areas within the major tributaries (Table 2).

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

Distribution of Spawners

The proportion of steelhead returning to the spawning tributaries of the Upper Copper River were estimated as the ratio of numbers of radio-tagged fish migrating into these 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 varied by day. To account for this variation, each radio-tagged fish was assigned a numeric weight w_t corresponding to the effort expended (h_t), number of fish captured (X_t), and the number of fish radio-tagged (x_t) on a given day (t). The adjusted count of fish radiotagged on day t found in spawning tributary j was:

$$R'_{tj} = w_t R_{tj} \tag{1}$$

where:

$$w_t = \left(\frac{\bar{h}}{h_t}\right)\left(\frac{X_t/\bar{X}}{x_t/\bar{x}}\right) \text{ and}$$

R_{tj} = the observed number of fish tagged on day t and found in spawning tributary j. Spawning tributaries included the Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Gakona rivers, which includes all tributaries upstream of the Gulkana River.

Among fish that survived and migrated into the spawning tributaries, the proportion of fish found in tributary j was estimated as:

$$\hat{P}_j = \frac{\sum_{t=1}^{T} R'_{tj}}{\sum_{j}^{\text{tribs}} \sum_{t=1}^{T} R'_{tj}} \tag{2}$$

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'_{tj}). From each bootstrap sample the proportion of spawners in tributary j ($\hat{P}_j^*$) was calculated for a total of 1,000 bootstrap estimates.

Table 1.–Schedule of aerial flights to locate radio-tagged steelhead, Copper River, fall 2005 to spring 2007.

Dates	Drainage[a]
2005	
1 November - 4 November	Upper Copper
2006	
29 March - 31 March	Upper Copper
11 April - 13 April	Upper Copper
2 May - 4 May	Upper Copper
22-May	Gulkana
29 May - 1 June	Upper Copper
6 October - 7 October	Gulkana, Tazlina
24 October - 25 October	Upper Copper
2007	
9 March - 11 March	Upper Copper
27 March - 29 March	Upper Copper
8-May	Gulkana
17-May	Gulkana, Tazlina
22-May	Chitina, Gakona[b]
30 May - 31 May	Upper Copper
7 June - 8 June	Upper Copper

[a] Upper Copper includes all tributaries north of the Chugach Mountains.
[b] Gakona includes all tributaries north of the Gulkana River.

Table 2.–List of possible fates of radio-tagged steelhead in the Upper Copper River.

Fate	Description
Radio Failure	A fish that was never recorded swimming upstream of the CSDN fishery. This category includes regurgitated tags and mortalities.
Fishery Mortality	A fish harvested in the GSS fishery, in the CSDN fishery, or in the sport fisheries.
Spawner[a]	A fish that entered a spawning tributary of the Upper Copper River. Spawning tributaries included the Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Gakona[b] rivers.
Upstream Migrant	A fish that migrated upstream, was never reported as being harvested, was never recorded on a spawning tributary radio tower, and was located only in the mainstem Copper River.

[a] Only these radio-tagged fish were used to identify spawning tributaries and estimate spawning distribution and stock-specific run-timing. All other fish were culled from the analysis.

[b] Gakona River includes all tributaries north of the Gulkana River.

Stock-Specific Run Timing

Run timing patterns were described as time-density functions (Mundy 1979), where the relative abundance of Upper Copper River steelhead returning to spawning tributary j over the total span of the run was described by:

$$f\left(j_t\right)=\frac{R'_{tj}}{\sum_{t=1}^{T} R'_{tj}} \quad (3)$$

where:

$f\left(j_t\right)$ = the empirical temporal probability distribution over the total span of the run (T) for fish spawning in tributary j (or portion thereof); and,

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

All radio-tagged fish assigned a fate of "spawner" (Table 2) were used to determine time-density functions.

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

$$\bar{t}_j=\sum_t t\, f\left(j_t\right), \quad (4)$$

the variance of the mean date of passage was estimated as:

$$Var\ \bar{t}_j=\frac{\sum_{t=1}^{T}\left(t-\bar{t}_j\right)^2 f\left(t_j\right)}{\sum_{t=1}^{T} R'_{tj}} \quad (5)$$

Certain assumptions must be met to obtain unbiased estimates of the spawning distribution and to describe run timing patterns past the capture site:

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

   Design Considerations: While we did not test this assumption, we have no reason to believe that radio tagging has an affect on a fish's spawning destination.

2. *Captured steelhead were radio-tagged in proportion to the magnitude of the run.*

   Design Considerations: The tagging protocol described was designed in an effort to distribute radio tags proportional to passage of steelhead past the tagging site over the duration of the run.

Previous radiotelemetry research on Chinook salmon has 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. Passage refers to the abundance of fish migrating past the capture site. 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. However, the magnitude of this bias would be small if stock-specific run timing patterns past the capture site are similar.

RESULTS

CAPTURE AND TAGGING

Steelhead were captured from 15 August to 6 October, 2005 and 16 August to 29 September 2006. A total of 59 steelhead, 1,761 coho salmon, and 4,061 sockeye salmon were captured in 2005. In 2006, 46 steelhead, 4,512 coho salmon, and 20,366 sockeye salmon were captured. In 2005, 57 steelhead were captured with the fish wheel and the remaining two were captured by dip net. In 2006, all 46 steelhead were captured with fish wheels. A total of 53 and 42 steelhead were fitted with radio tags and released in 2005 and 2006, respectively. In both years, a number of captured steelhead were determined to be in poor condition because of overcrowding in the live tank and were not radio-tagged.

In 2005, 88% percent of fish recorded between the capture site and the Haley Creek tracking station reached the CSDN fishery in 3 days or less. In 2006, 95% of fish recorded on the tracking stations reached the CSDN fishery in 3 days or less. Transit times through the CSDN fishery were also recorded and the majority of fish migrated through the fishery in less than 5 days.

FATE DETERMINATION

During the study, 100% of the radio tags were located in the Upper Copper River using aerial and stationary radio-tracking techniques. A total of 70 steelhead were located in spawning areas, 18 were located just upstream or downstream of the capture area, 2 were harvested, and 5 were located in the mainstem Copper River between the Tonsina and Klutina rivers (Table 3). No radio tags failed to transmit a signal and no radio-tagged steelhead migrated downstream until after spawning.

Table 3.–Fates of radio-tagged steelhead in the Upper Copper River, spring 2006 and 2007.

Fate	2006	2007
Radio Failure	9	9
Fishery Mortality	1	1
Spawner	38	32
Upstream Migrant	5	0
Total	53	42

AGE DETERMINATION

A total of 52 steelhead were aged: 12 from the 2005 and 40 from the 2006 fall migrations. The small number of scale samples taken in 2005 was due to the loss of the sampling kit when it fell off the fish wheel platform into the river. About 68% of the steelhead sampled were 6 years old (ages 3.2 and 2.3), while 5 (ages 2.2 and 3.1) and 7 (ages 3.3, and 4.2) year olds comprised 20% and 8%, respectively (Table 4).

Table 4.–Number of steelhead in each age class, Copper River, 2005 and 2006.

	Age						
Year	2.2	3.1	2.3	3.2	3.3	4.2	Total
2005	0	2	0	8	2	0	12
2006	3	5	2	27	2	1	40

DISTRIBUTION OF SPAWNERS

The daily radio-tagging rate and hours of fishing effort varied by day (Tables 5-6). Therefore, adjusted counts of radio-tagged fish (equation 1) were used to estimate the proportion of fish in a particular spawning tributary. All spawning steelhead were located in three major drainages, the Chitina, Tazlina, and Gulkana, in both years of the study (Figures 3-8). Kaina Creek, within the Tazlina River drainage, accounted for the greatest proportion of spawners in both 2006 (0.23, SE=0.11) and 2007 (0.23, SE=0.08) (Table 7). Dickey Lake (0.08, SE=0.06 in 2006 and 0.11, SE=0.07 in 2007), within the Gulkana River drainage, and Hanagita Lake (0.00, SE=0.00 in 2006 and 0.12, SE=0.06 in 2007), within the Chitina River drainage, are considered important spawning areas.

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 past the capture site were similar among the individual spawning stocks within a particular year but varied between years (Figure 9). The mean date of passage for all steelhead stocks within a particular year was within 6 days of each other, but the mean date of passage between years was over 30 days apart (Table 8).

Downstream run timing, from spawning streams towards the ocean, was more variable and protracted among the three major spawning stocks than upstream run timing past the capture site to spawning streams (Figures 9 and 10).

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Table 5.–Fish wheel (FW), dip net (DN), and total (h_t) hours fished, steelhead captured (X_t), steelhead radio-tagged (x_t), and tagging rate (x_t/X_t) by day, 2005.

Date	FW Hours	DN Hours	h_t	Steelhead (X_t)	Steelhead Radio (x_t)	Tagging Rate (x_t/X_t)
27-Aug	24.0	0.0	24.0	1.0	0.0	0.0%
28-Aug	0.0	0.0	0.0	0.0	0.0	0.0%
29-Aug	6.5	0.0	6.5	0.0	0.0	0.0%
30-Aug	24.0	0.0	24.0	0.0	0.0	0.0%
31-Aug	24.0	0.0	24.0	1.0	1.0	100.0%
1-Sep	24.0	0.0	24.0	0.0	0.0	0.0%
2-Sep	24.0	0.0	24.0	0.0	0.0	0.0%
3-Sep	23.5	0.0	23.5	0.0	0.0	0.0%
4-Sep	23.8	0.0	23.8	0.0	0.0	0.0%
5-Sep	24.0	2.0	26.0	0.0	0.0	0.0%
6-Sep	24.0	1.8	25.8	0.0	0.0	0.0%
7-Sep	24.0	0.0	24.0	0.0	0.0	0.0%
8-Sep	24.0	2.0	26.0	0.0	0.0	0.0%
9-Sep	24.0	0.0	24.0	0.0	0.0	0.0%
10-Sep	24.0	2.0	26.0	0.0	0.0	0.0%
11-Sep	9.0	0.0	9.0	0.0	0.0	0.0%
12-Sep	24.0	1.8	25.8	0.0	0.0	0.0%
13-Sep	24.0	4.0	28.0	0.0	0.0	0.0%
14-Sep	24.0	2.0	26.0	0.0	0.0	0.0%
15-Sep	24.0	2.5	26.5	1.0	1.0	100.0%
16-Sep	22.0	0.0	22.0	0.0	0.0	0.0%
17-Sep	24.0	1.0	25.0	1.0	1.0	100.0%
18-Sep	23.5	2.0	25.5	0.0	0.0	0.0%
19-Sep	23.3	2.0	25.3	3.0	3.0	100.0%
20-Sep	24.0	0.5	24.5	8.0	8.0	100.0%
21-Sep	23.6	0.0	23.6	8.0	4.0	50.0%
22-Sep	24.0	0.0	24.0	3.0	3.0	100.0%
23-Sep	24.0	0.0	24.0	5.0	5.0	100.0%
24-Sep	24.0	0.0	24.0	8.0	8.0	100.0%
25-Sep	24.0	2.5	26.5	1.0	1.0	100.0%
26-Sep	16.0	1.0	17.0	2.0	2.0	100.0%
27-Sep	24.0	1.3	25.3	1.0	1.0	100.0%
28-Sep	23.4	0.0	23.4	6.0	5.0	83.3%
29-Sep	24.0	0.0	24.0	1.0	1.0	100.0%
30-Sep	24.0	0.0	24.0	1.0	1.0	100.0%
1-Oct	24.0	0.0	24.0	2.0	2.0	100.0%
2-Oct	23.4	0.0	23.4	2.0	2.0	100.0%
3-Oct	24.0	0.0	24.0	1.0	1.0	100.0%
4-Oct	24.0	0.0	24.0	0.0	0.0	0.0%
5-Oct	24.0	0.0	24.0	1.0	1.0	100.0%
6-Oct	13.0	0.0	13.0	2.0	2.0	100.0%

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

Table 6.–Total (h_t) hours fished (fish wheels), steelhead captured (X_t), steelhead radio-tagged (x_t), and tagging rate (x_t/X_t) by day, 2006.

Date	h_t	Steelhead (X_t)	Steelhead Radio (x_t)	Tagging Rate (x_t/X_t)
17-Aug	48.0	1	1	100.0%
18-Aug	48.0	0	0	0.0%
19-Aug	40.5	1	1	100.0%
20-Aug	41.0	0	0	0.0%
21-Aug	48.0	0	0	0.0%
22-Aug	48.0	0	0	0.0%
23-Aug	48.0	0	0	0.0%
24-Aug	48.0	0	0	0.0%
25-Aug	47.0	1	1	100.0%
26-Aug	39.0	0	0	0.0%
27-Aug	42.0	0	0	0.0%
28-Aug	48.0	0	0	0.0%
29-Aug	48.0	1	1	100.0%
30-Aug	46.5	1	1	100.0%
31-Aug	48.0	2	2	100.0%
1-Sep	48.0	1	1	100.0%
2-Sep	48.0	3	3	100.0%
3-Sep	48.0	0	0	0.0%
4-Sep	46.5	1	1	100.0%
5-Sep	40.0	4	4	100.0%
6-Sep	37.5	0	0	0.0%
7-Sep	34.0	0	0	0.0%
8-Sep	38.0	1	1	100.0%
9-Sep	44.0	3	3	100.0%
10-Sep	48.0	5	4	80.0%
11-Sep	48.0	2	2	100.0%
12-Sep	48.0	1	0	0.0%
13-Sep	48.0	3	3	100.0%
14-Sep	48.0	3	2	66.7%
15-Sep	48.0	5	4	80.0%
16-Sep	48.0	4	3	75.0%
17-Sep	48.0	1	1	100.0%
18-Sep	44.0	0	0	0.0%
19-Sep	16.0	0	0	0.0%
20-Sep	24.0	0	0	0.0%
21-Sep	24.0	0	0	0.0%
22-Sep	24.0	0	0	0.0%
23-Sep	24.0	2	2	100.0%

[a] Fishing began on 16 August but no steelhead were captured until 17 August.

Table 7.–Spawning distribution of Upper Copper River steelhead by drainage (bold) and the proportion of all spawners found in the primary spawning areas (not bold) within each drainage in spring 2006 and 2007.

	2006		2007	
Drainage	Proportion	SE	Proportion	SE
Chitina	**0.14**	**0.07**	**0.38**	**0.11**
Hanagita Lake	0.00	0.00	0.12	0.06
Tazlina	**0.54**	**0.11**	**0.39**	**0.10**
Kaina Creek	0.23	0.11	0.23	0.08
Gulkana	**0.31**	**0.10**	**0.22**	**0.09**
Dickey Lake	0.08	0.06	0.11	0.07

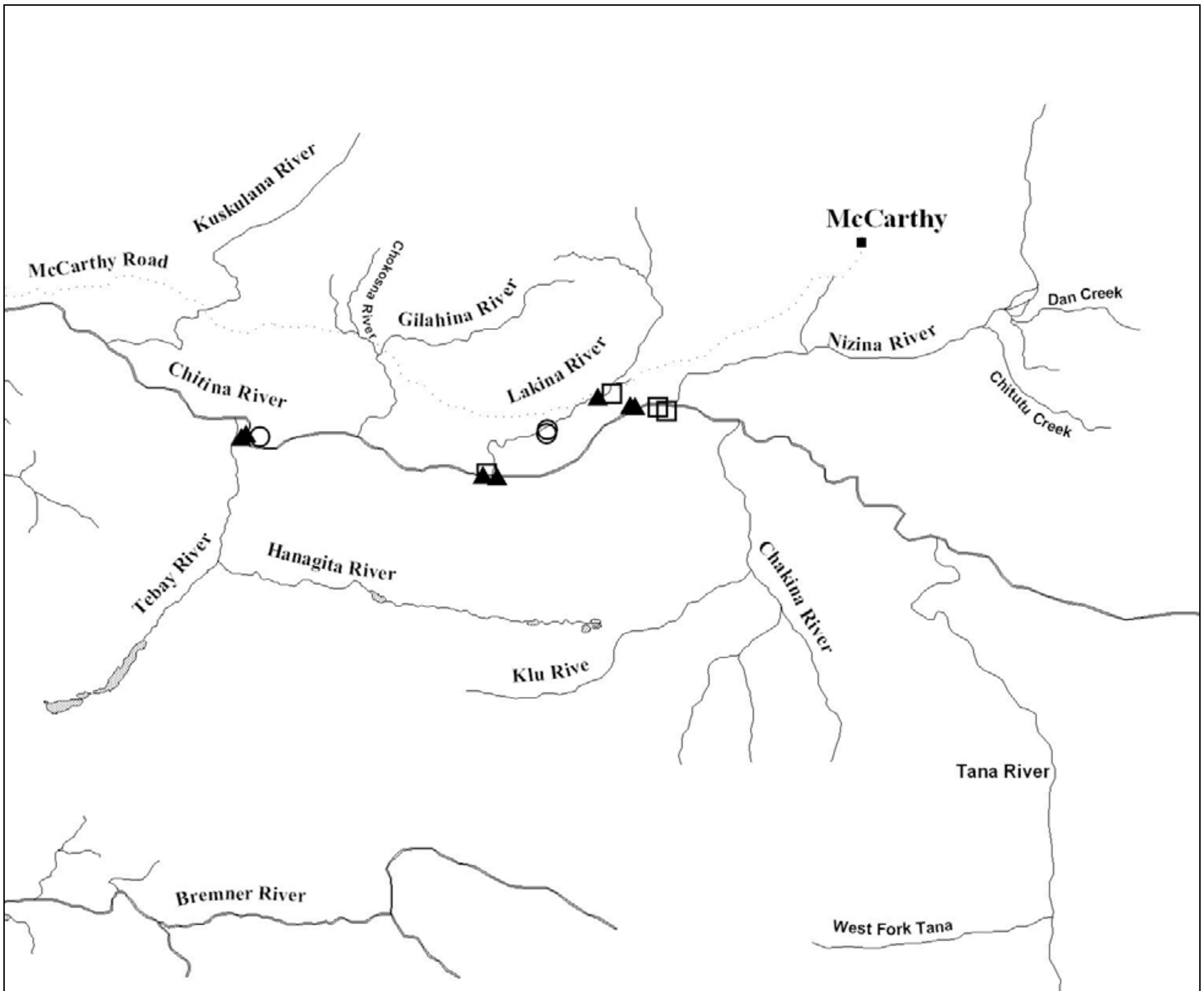


Figure 3.–Map of the Chitina River drainage demarcating the locations of radio-tagged steelhead during fall migration (□), overwintering (▲), and spring spawning (○) from fall 2005 to spring 2006.

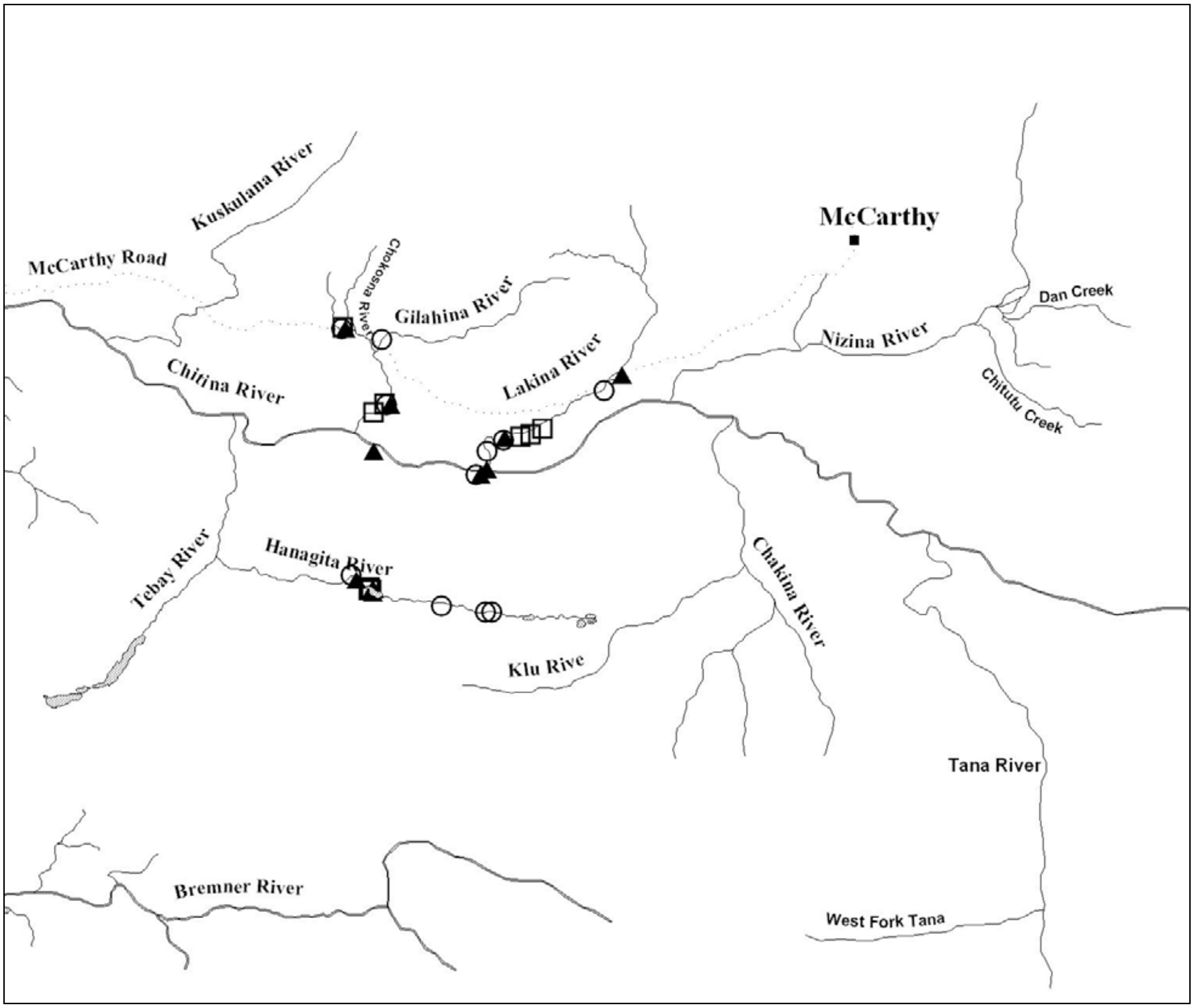


Figure 4.–Map of the Chitina River drainage demarcating the locations of radio-tagged steelhead during fall migration (□), overwintering (▲), and spring spawning (○) from fall 2006 to spring 2007.

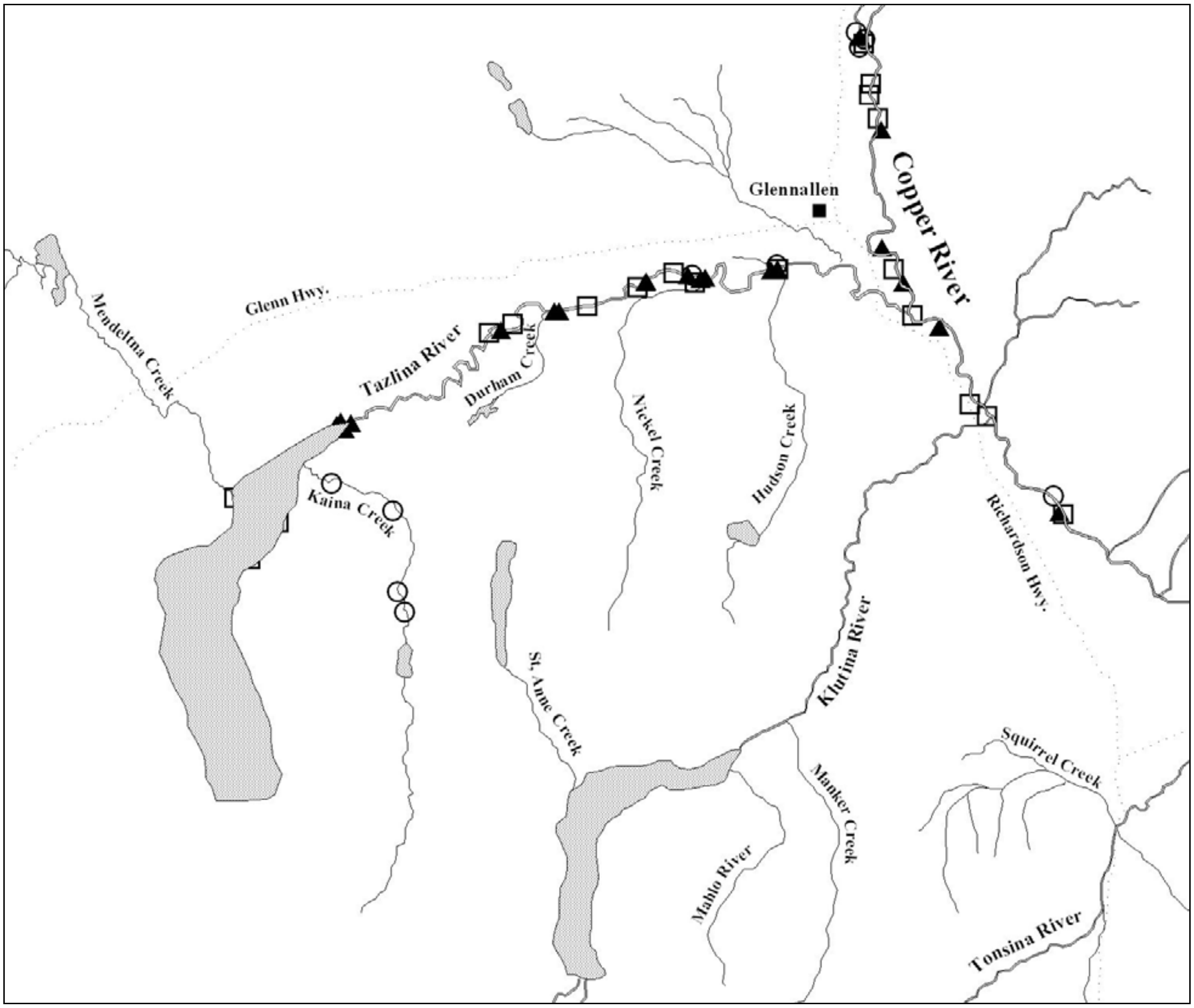


Figure 5.–Map of the Tazlina River drainage demarcating the locations of radio-tagged steelhead during fall migration (□), overwintering (▲), and spring spawning (○) from fall 2005 to spring 2006.

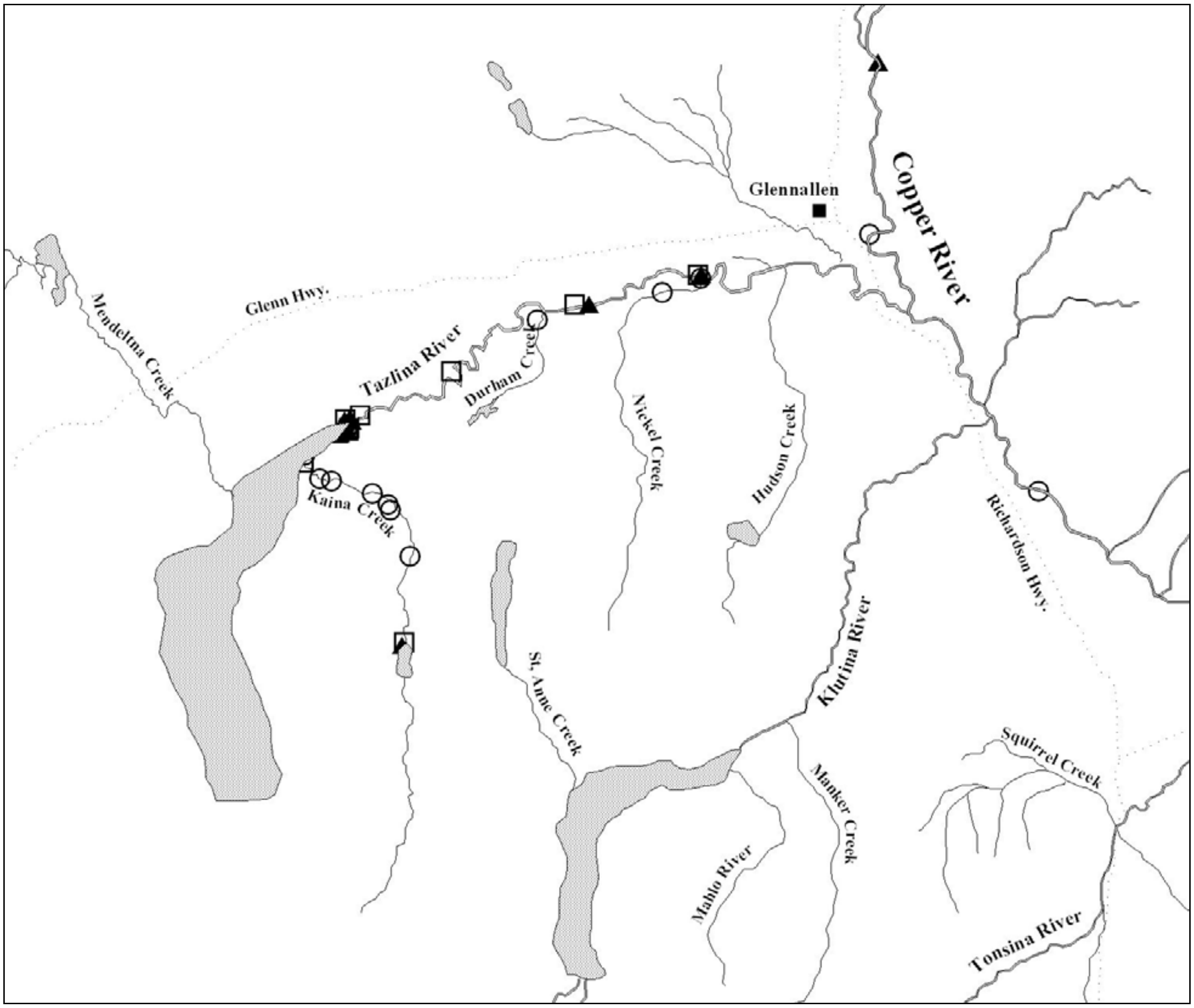


Figure 6.–Map of the Tazlina River drainage demarcating the locations of radio-tagged steelhead during fall migration (□), overwintering (▲), and spring spawning (○) from fall 2006 to spring 2007.

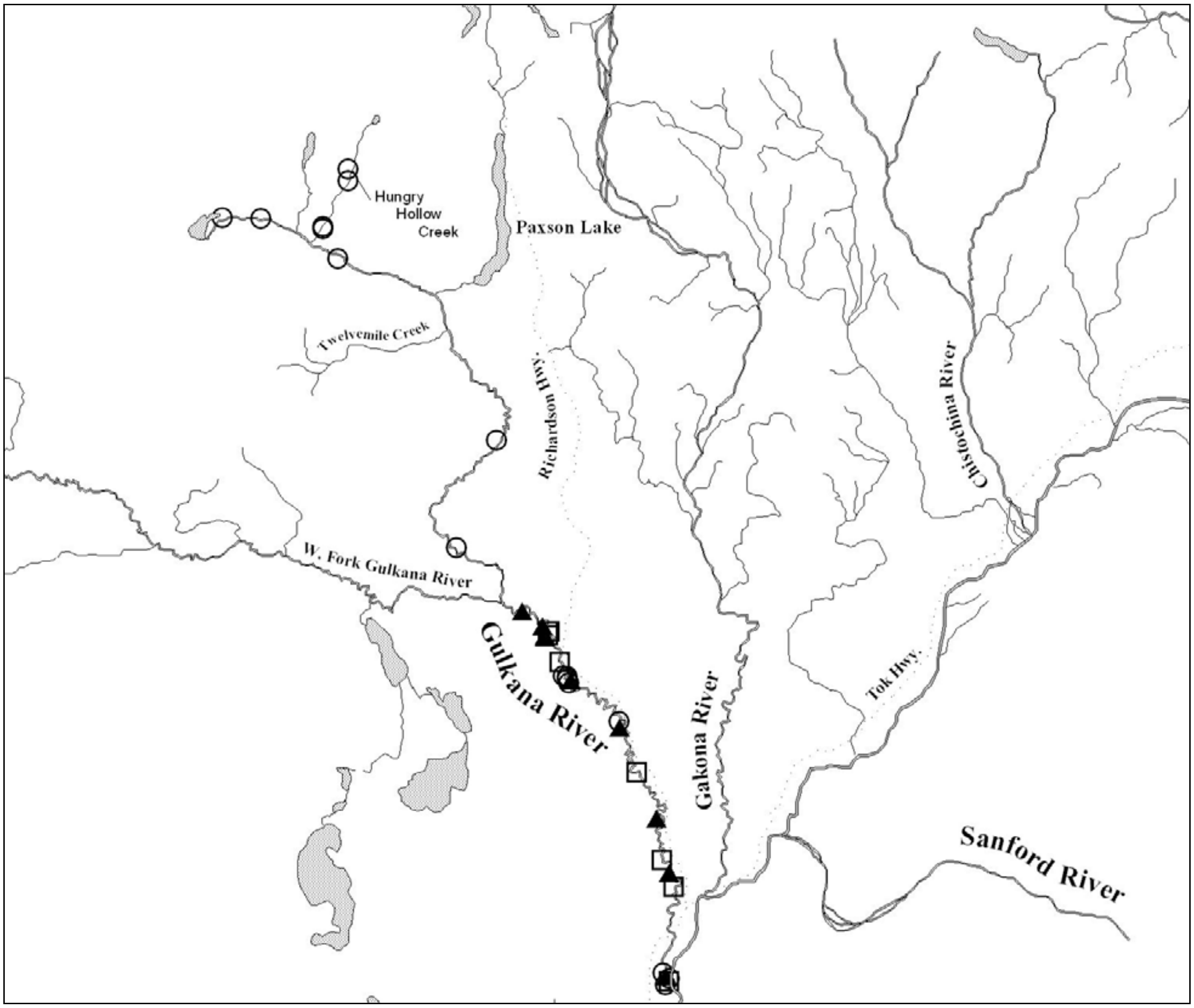


Figure 7.–Map of the Gulkana River drainage demarcating the locations of radio-tagged steelhead during fall migration (□), overwintering (▲), and spring spawning (○) from fall 2005 to spring 2006.

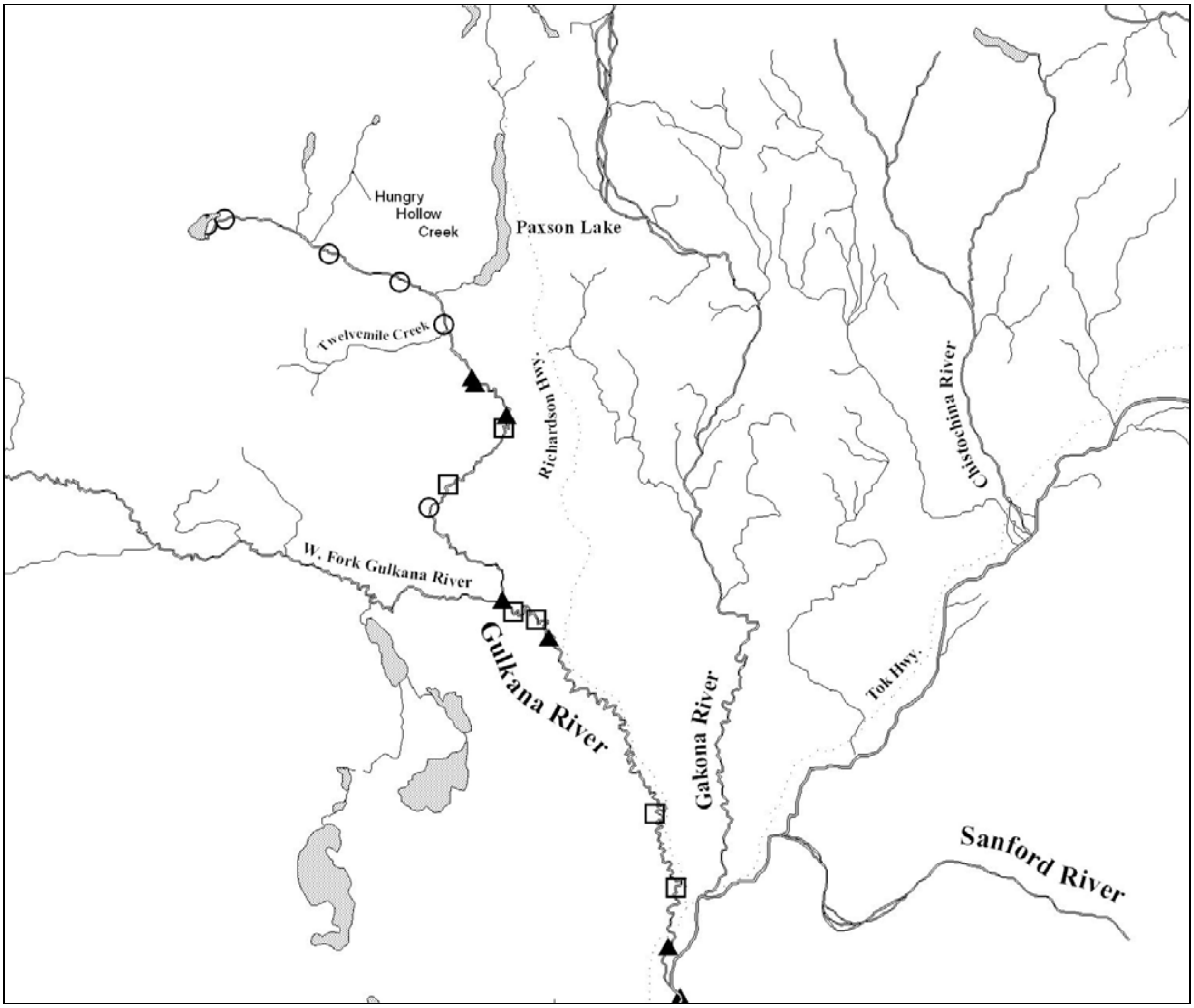
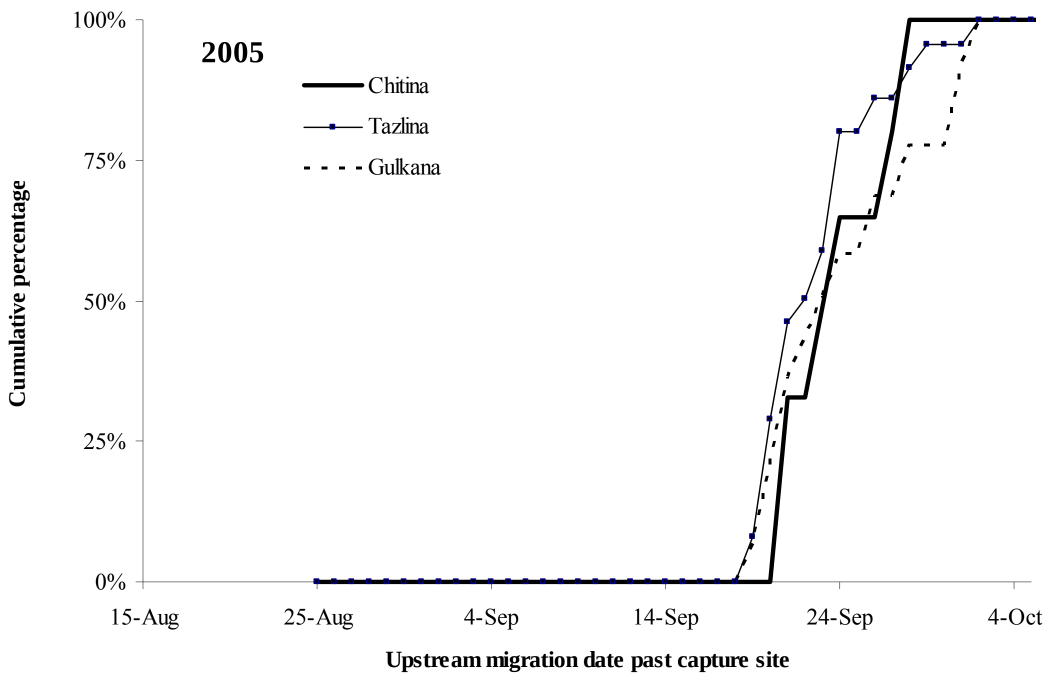


Figure 8.–Map of the Gulkana River drainage demarcating the locations of radio-tagged steelhead during fall migration (□), overwintering (▲), and spring spawning (○) from fall 2006 to spring 2007.



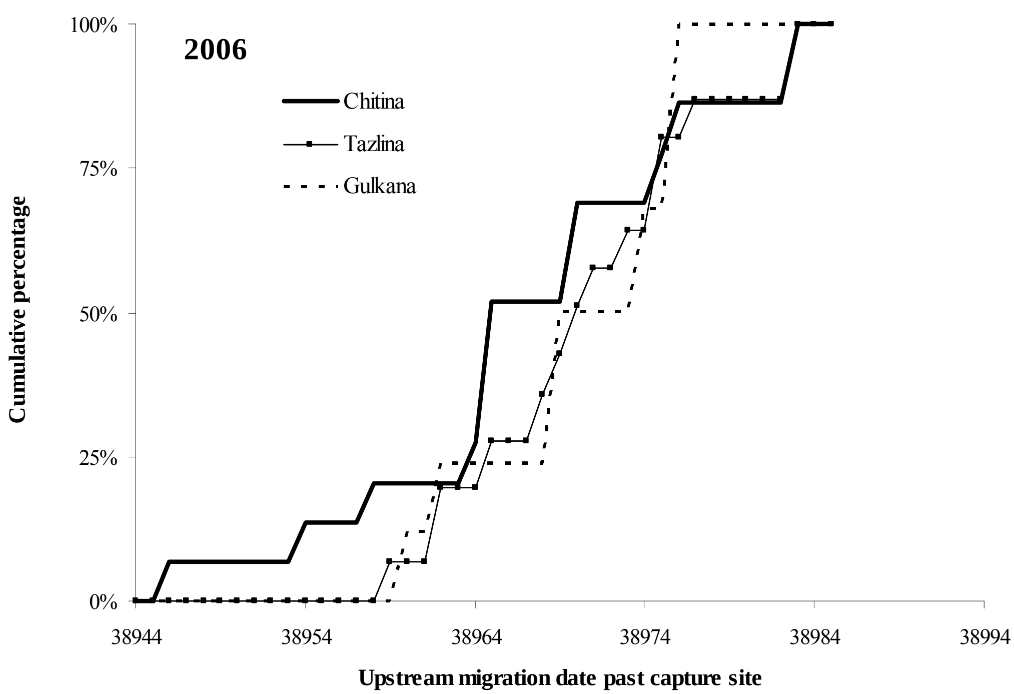


Figure 9.–Upstream migratory run-timing of steelhead at the capture site for the three major stocks in the Upper Copper River, 2005 and 2006.

Table 8.–Migratory timing statistics past the capture site of the three major steelhead spawning stocks, 2005 and 2006.

	2005			2006		
	Chitina	Tazlina	Gulkana	Chitina	Tazlina	Gulkana
First Fish	21-Sep	19-Sep	19-Sep	17-Aug	30-Aug	31-Aug
Last Fish	28-Sep	29-Sep	1-Oct	23-Sep	15-Sep	16-Sep
Duration (days)	7	10	12	37	16	16
Mean Date Passage	24-Sep	22-Sep	24-Sep	7-Sep	10-Sep	10-Sep
SE (d)	1.2	0.7	1.3	2.9	2.0	2.3

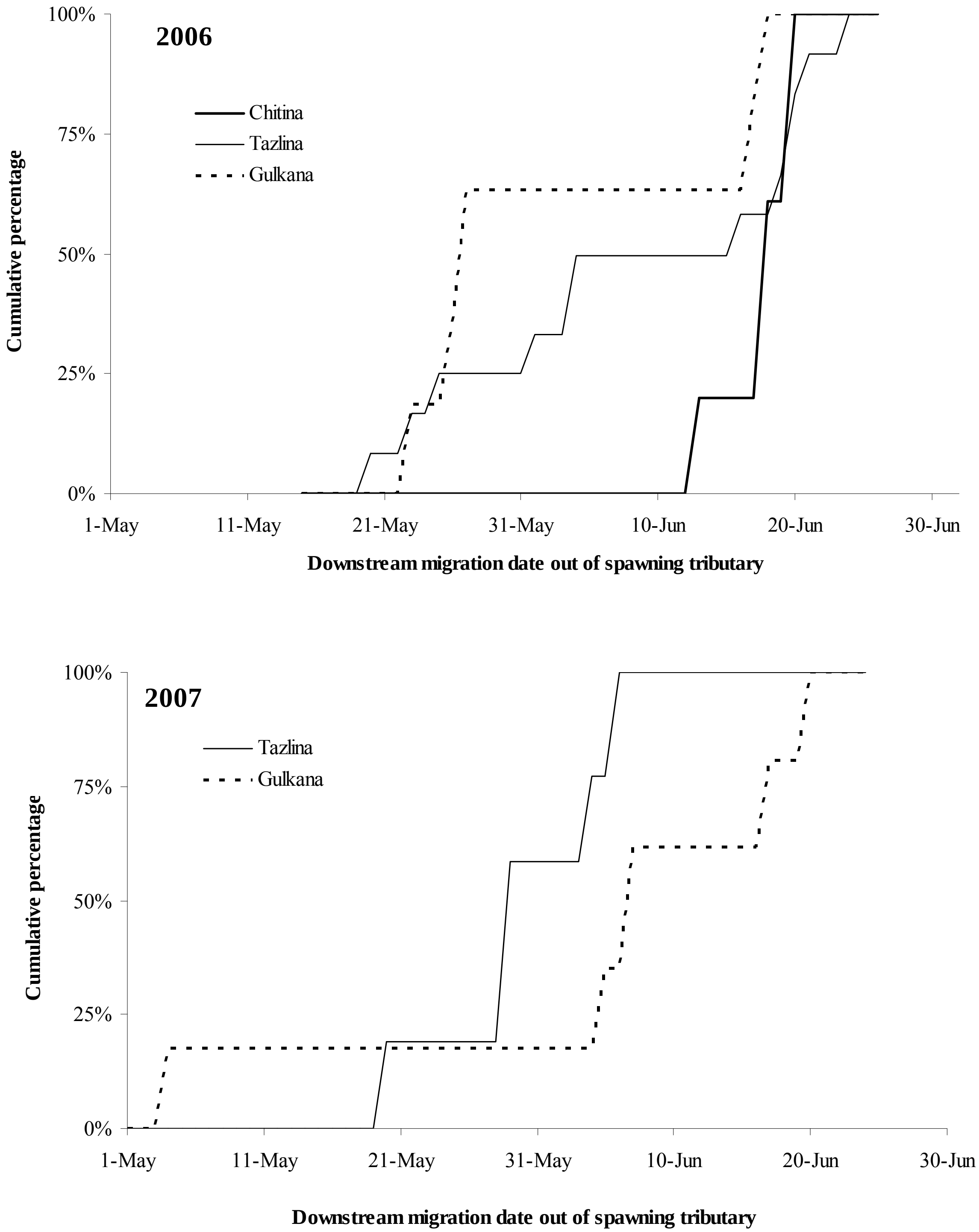


Figure 10.–Downstream migratory run timing of steelhead past the tributary tracking stations for the three major stocks in the Upper Copper River, 2006 and 2007 (data not available for the Chitina stock in 2007 due to tracking station malfunction).

DISCUSSION

The precision of distribution and run timing estimates was limited by our ability to capture and successfully radio-tag steelhead. The amount of fishing effort expended was not great enough to radio-tag the desired number of steelhead, and an unexpectedly high number of tag failures decreased the sample size even further. We suspect the bottle-nosed type radio tag (tapered at the antenna end) used were more easily regurgitated than the more commonly used non-tapered tags.

The interpretation of study objectives was constrained by the lack of desired precision around estimates of distribution and run timing. The large standard errors associated with estimated proportions of steelhead returning to the spawning areas resulted in a proportionate amount of uncertainty in determining the magnitude of the run. In past years, the estimated average annual abundance of steelhead in Dickey and Hanagita lakes was 450 steelhead (Fleming 1999 and 2000, Wuttig et al. 2004). During our study, these two spawning areas accounted for 0.08 (SE=0.06) and 0.22(SE=0.09) of the steelhead spawning stocks in 2005 and 2006, respectively. Assuming the spawning abundance of steelhead in Dickey and Hanagita lakes is known without error (450 steelhead) and incorporating the standard errors around spawning distribution estimates, the magnitude of the run ranges from ~1,000 to 45,000 steelhead between 2005 and 2006

The tails of the estimated run timing curve are also sensitive to small sample sizes. For example, in 2005, the first radio-tagged fish failed to migrate upstream to a spawning tributary. If this fish was subsequently located in a spawning tributary, it could have greatly changed the run-timing estimate for that stock.

The small sample size also limited our ability to locate spawning areas. For example, none of the radio-tagged steelhead migrated to tributaries of the Copper River upstream of the Gulkana River or to the Klutina River, where anglers have reported catching steelhead. More importantly, no radio-tagged steelhead were located in Twelvemile Creek, which is a documented spawning area. However, over the course of the study, five undocumented spawning areas were located, which included one in the Tazlina drainage (Nickel Creek) and four in the Chitina drainage (Chokosna River, Gilahina River, Chakina River, and the Nizina River). The fact that five new areas were documented with a limited number of radio tags suggests that more spawning areas are left to be identified.

CONCLUSIONS

Even though the relatively small number of steelhead that were radio-tagged and subsequently located limited study results, several significant and interesting findings were made. There are numerous spawning areas throughout the Gulkana, Tazlina, and Chitina drainages, and a number of them were undocumented. The distribution of steelhead in the Tazlina and Gulkana River drainages was consistent with the distribution study done by Burger et al. (1983). Dickey and Hanagita lakes are likely important spawning areas, and account for 0.22 of the total spawning population in 2007.

The Tazlina River drainage appears to support the largest spawning aggregation within the Upper Copper River, and within this drainage Kaina Creek may support the largest steelhead spawning population within the Upper Copper River. In both years of the study, Kaina Creek accounted for 0.23 of the total spawning population.

Overwintering steelhead were located in a wide range of habitats. Some steelhead overwintered in their spawning area, while others overwinted in the glacially occluded waters of mainstem Chitina and Copper rivers. The outlet of Tazlina Lake was an important overwintering area for the Tazlina population.

Stock-specific upriver run-timing past the capture site indicated that among-year variability for all stocks was greater than within-year variability. If all stocks have similar within year run timing patterns, then all stocks may be equally vulnerable to the commercial and subsistence fisheries. During years when steelhead run timing is early, steelhead could be particularly vulnerable to harvest during the coho salmon fishery.

While the uncertainty in our estimates did not allow us to determine the magnitude of the steelhead run, arguments can be made to suggest the run is greater than 1,000 fish. While other spawning populations are known to occur within the Upper Copper River, the small number of steelhead that were radio-tagged probably resulted in some spawning areas not being represented. Even though the Dickey and Hanagita lake areas are significant, there were numerous other areas within each drainage, and the Tazlina stocks were larger than the Dickey and Hanagita stocks combined. Reported annual subsistence harvests have ranged up to 114 steelhead, annual sport harvests have generally been less than 10 steelhead, and annual commercial harvests are not reported. Numerous spawning areas, annual subsistence harvests, and the apparent, although unsubstantiated, harvests in the commercial fishery support the argument that the annual run size to the Upper Copper River is certainly greater than 1,000 fish.

RECOMMENDATIONS

To provide more insight about the relative abundance of Upper Copper River steelhead, continued work needs to be done to locate all of the spawning areas. Because annual run timing is similar for all stocks, periodic monitoring of the most significant stocks could provide an indication of overall population status. For this reason, periodically monitoring Kaina Creek, Dickey Lake, and Hanagita Lake could provide useful information on the general status the Copper River steelhead run..

Given our experiences during this study, a large increase in fishing effort would be needed to capture and radio-tag sufficient numbers of steelhead to estimate the magnitude of the total run. This would again require the use of both fish wheels and dip nets. Fish wheels allow continuous fishing, but they are limited in their ability to adapt to river flow and stage height. Dipnetting on the other hand, allows fishermen to place their gear and drift their boat through multiple areas (near shore, low-flow, etc.) in attempts to find where the fish are migrating and/or holding.

The proportion of radio-tagged steelhead that failed to migrate upstream, regurgitated their tag, or died from handling was 16% (n=9) in 2005 and 21% (n=9) in 2006. Studies on steelhead in the Columbia, Snake, and Vedder-Chilliwack rivers have observed failure, regurgitation, or retreat rates ranging from 3% to 10% (Keefer et al. 2004; Nelson et al. 2005). We feel the high failure rates in our study can be largely attributed to the tapered radio tags we used. For this reason, future work should be done with a larger, non-tapered radio tag. Additionally, wrapping radio tags with either a rubber band or piece of Velcro, has been shown to reduce the regurgitation rate by approximately 5% (Keefer et al. 2004).

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APPENDIX A

Appendix A1.–Date tagged, final fate, and date past the tracking stations for every radio-tagged steelhead, 2005.

Date Tagged	Frequency	Code	Drainage	Final Fate[a]	Haley	Chitina	Tazlina[b]	Gulkana
15-Sep	355	15	-	Harvested	16-Sep	-	-	-
19-Sep	337	15	Tazlina	near Nickel Creek	23-Sep	-	-	-
19-Sep	456	15	Tazlina	Kaina Creek	20-Sep	6-Oct	-	-
19-Sep	477	15	Gulkana	mainstem	20-Sep	-	-	2-Oct
20-Sep	316	15	Tazlina	near Hudson Creek	23-Sep	-	-	-
20-Sep	416	15	Tazlina	Hudson Creek	21-Sep	-	-	-
20-Sep	496	15	Gulkana	Hungry Hollow Creek	21-Sep	-	-	6-Oct
20-Sep	516	15	Gulkana	Hungry Hollow Creek	23-Sep	-	-	5-Oct
20-Sep	516	16	Tazlina	Kaina Creek	21-Sep	-	-	-
20-Sep	537	15	Tazlina	near Durham Creek	20-Sep	-	-	-
20-Sep	556	15	Tazlina	Nickel Creek	21-Sep	-	-	-
21-Sep	416	16	Tazlina	Kaina Creek	21-Sep	-	-	-
21-Sep	437	16	Chitina	mainstem	22-Sep	24-Sep	-	-
21-Sep	477	16	Gulkana	Dickey Lake	21-Sep	-	-	4-Oct
21-Sep	496	16	Tazlina	Kaina Creek	21-Sep	-	-	-
22-Sep	337	16	Gulkana	mainstem	24-Sep	-	-	-
22-Sep	395	16	Tazlina	Kaina Creek	23-Sep	-	-	-
23-Sep	355	16	Gulkana	mainstem	24-Sep	-	-	8-Oct
23-Sep	375	16	Tazlina	mainstem	24-Sep	3-Oct	-	-
23-Sep	537	16	Tazlina	near Hudson Creek	23-Sep	-	-	-
23-Sep	556	16	Chitina	Nizina River	24-Sep	27-Sep	-	-
24-Sep	337	17	Tazlina	Kaina Creek	25-Sep	-	-	-
24-Sep	395	17	Tazlina	Nickel Creek	27-Sep	-	-	-
24-Sep	416	17	Tazlina	Kaina Creek	24-Sep	-	-	-
24-Sep	496	17	Chitina	Nizina River	25-Sep	29-Sep	-	-
24-Sep	516	17	Tazlina	near Durham Creek	24-Sep	-	-	-
24-Sep	537	17	Gulkana	Middle Fork	25-Sep	-	-	7-Oct
24-Sep	556	17	Tazlina	Kaina Creek	25-Sep	-	-	-
26-Sep	375	17	Tazlina	mainstem	28-Sep	-	-	-
26-Sep	477	17	Gulkana	mainstem	27-Sep	-	-	-
27-Sep	437	17	Chitina	Chakina River	-	1-Oct	-	-
28-Sep	355	18	Tazlina	Nickel Creek	28-Sep	-	-	-
28-Sep	375	18	Gulkana	Dickey Lake	28-Sep	-	-	-
28-Sep	556	18	Chitina	Lakina River	29-Sep	30-Sep	-	-
29-Sep	516	18	Tazlina	Nickel Creek	-	-	-	-
1-Oct	355	17	Gulkana	mainstem	-	-	-	-
1-Oct	496	18	Gulkana	Hungry Hollow Creek	-	-	-	20-Oct
2-Oct	337	18	Tazlina	Kaina Creek	-	-	-	-
2-Oct	477	18	Gulkana	mainstem	-	-	-	-

[a] The final fate was the fish's furthest upstream point and not necessarily its spawning area.

[b] No data exists for the Tazlina tracking station in 2005 due to a software malfunction.

Appendix A2.-Date tagged, final fate, and date past the tracking stations for every radio-tagged steelhead, 2006.

Date Tagged	Frequency	Code	Drainage	Final Fate[a]	Haley	Chitina	Tazlina	Gulkana
17-Aug	375	23	Chitina	Hanagita Lake	27-Aug	2-Sep	-	-
25-Aug	477	23	Chitina	Hanagita Lake	26-Aug	28-Aug	-	-
29-Aug	496	23	Chitina	Gilahina River	29-Aug	2-Sep	-	-
30-Aug	375	22	Tazlina	Kaina Creek	30-Aug	-	7-Sep	-
31-Aug	437	22	Gulkana	mainstem	1-Sep	-	-	19-Sep
2-Sep	355	23	Tazlina	Kaina Creek	2-Sep	-	18-Sep	-
2-Sep	437	23	Gulkana	mainstem	2-Sep	-	-	19-Sep
2-Sep	456	23	Tazlina	lake outlet	2-Sep	-	14-Sep	-
4-Sep	316	23	Chitina	Lakina River	4-Sep	9-Sep	17-Sep	-
5-Sep	395	23	Tazlina	Nickel Creek	7-Sep	-	17-Sep	-
5-Sep	477	22	Chitina	Chokosna River	5-Sep	10-Sep	-	-
5-Sep	516	22	Chitina	Gilahina River	7-Sep	11-Sep	-	-
5-Sep	537	23	Chitina	Hanagita Lake	6-Sep	8-Sep	-	-
8-Sep	496	22	Tazlina	Kaina Creek	8-Sep	-	18-Sep	-
9-Sep	337	23	Tazlina	Kaina Creek	9-Sep	-	-	-
9-Sep	416	22	Gulkana	Middle Fork	-	-	-	18-Sep
9-Sep	556	23	Gulkana	Middle Fork	9-Sep	-	-	18-Sep
10-Sep	316	22	Chitina	Hanagita Lake	11-Sep	13-Sep	23-Sep	-
10-Sep	395	22	Chitina	Lakina River	10-Sep	11-Sep	-	-
10-Sep	516	23	Tazlina	Nickel Creek	10-Sep	-	24-Sep	-
11-Sep	477	19	Tazlina	Durham Creek	11-Sep	-	19-Sep	-
11-Sep	537	19	-	Harvested	-	-	-	-
13-Sep	496	19	Tazlina	Kaina Creek	-	-	22-Sep	-
14-Sep	516	19	Gulkana	Dickey Lake	-	-	-	23-Sep
15-Sep	337	22	Tazlina	lake outlet	-	-	-	-
15-Sep	395	19	Tazlina	Kaina Creek	-	-	6-Oct	-
15-Sep	416	19	Chitina	Lakina River	-	20-Sep	-	-
16-Sep	375	19	Gulkana	Dickey Lake	-	-	-	4-Oct
16-Sep	496	24	Chitina	Lakina River	-	20-Sep	-	-
16-Sep	556	24	Gulkana	Dickey Lake	-	-	-	25-Sep
17-Sep	375	24	Tazlina	lake outlet	-	-	29-Sep	-
23-Sep	316	24	Chitina	Gilahina River	-	-	-	-
23-Sep	477	24	Tazlina	Kaina Creek	-	-	7-Oct	-

[a] The final fate was the fish’s furthest upstream point and not necessarily its spawning area.