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

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ABSTRACT

Radiotelemetry methods are currently being used to determine the majority of steelhead *Oncorhynchus mykiss* spawning locations, the stock-specific run timing profiles, and the magnitude of the total return to the Upper Copper River (tributaries north of the Chugach Mountains). Steelhead were captured with a fish wheel and dip nets in the mainstem Copper River below Wood Canyon. A total of 59 steelhead were captured and 52 were fitted with radio tags from 15 August to 6 October 2005. Radio-tagged fish were tracked in early November 2005 and will be tracked again in April and May 2006 using a combination of ground-based receiving stations and aerial tracking techniques. Initial locations of radio-tagged steelhead in the Upper Copper River were in the mainstem Copper, Chitina, Tazlina, and Gulkana rivers. Final aerial surveys in April and May 2006 will provide the required information to estimate the spawning distribution and run timing of the steelhead stocks in the Upper Copper River.

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, slightly 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, personal use (PU), 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 Alaska-Fairbanks conducted studies along the Middle Fork Gulkana River on steelhead and rainbow trout spawning populations, their habitat, and juvenile feeding ecology (Brink 1995; Stark 1999). From 1998-2001, 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). The results of the studies demonstrated that these two stocks are genetically distinct and relatively small (< 450 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 subsistence and personal use fisheries in the Glennallen and Chitina subdistricts indicates steelhead have been captured as far

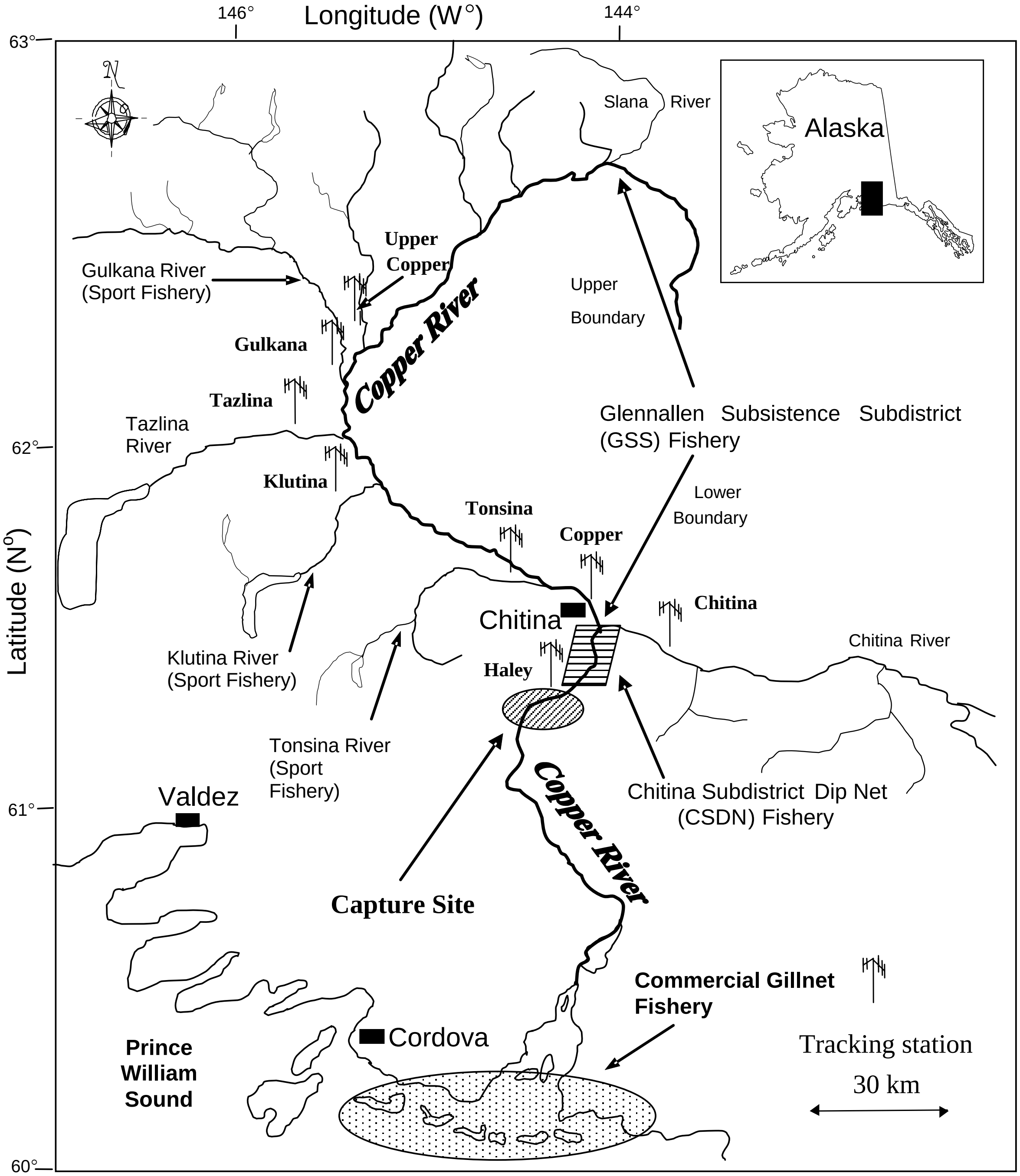

Figure 1.–Map of the Copper River drainage demarcating the capture site, major tributaries, eight radio tower locations, and the commercial, sport, GSS, and CSDN fisheries.

upriver as Slana and migrate through the Upper Copper River 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 impacts (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, Wrangell-St. Elias National Park; personal communication). In 2001 and 2003, 181 sockeye salmon and only 1 steelhead were captured. However, in 2002, only 3 sockeye salmon were caught (attributed to late run timing), but a total of 4 steelhead were captured. These observations demonstrate that there is potential for a substantial steelhead harvest if subsistence fishing effort increases early in the season.

The goal of the steelhead study is to determine if the total return is relatively small (e.g., <1,000 fish) or large (e.g., >5,000 fish). This will be accomplished by estimating the relative contribution of the Dickey and Hanagita lake stocks to the drainage-wide steelhead spawning escapement. The total return will be considered large if the Dickey and Hanagita lake stocks contribute at most 20% (evaluated with point estimate) to the estimated drainage-wide escapement. Inriver run timing information and documentation of significant spawning and overwintering locations throughout the drainage will also be provided. Gaining an understanding of the approximate size of the total return will aid in interpreting the magnitude of exploitation rates in the commercial, personal use, and subsistence fisheries which can be used to evaluate whether current management practices are adequately protecting the stock.

OBJECTIVES

The objectives of this study in 2006 are to:

1. estimate the proportion of the total return that migrates to the Dickey Lake and Hanagita Lake spawning areas such that the estimate is within 10 percentage points of the true value 95% of the time;
2. describe the stock-specific run timing profiles at the point of capture below Wood Canyon and identify potential stock-specific differences in run timing; and,
3. identify spawning areas accounting for 90% of the spawning population of steelhead in the Copper River drainage with 90% confidence.

METHODS

Capture and Tagging

This study was designed to capture and radio-tag 130 steelhead 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. Steelhead were captured using one aluminum fish wheel located on the west bank 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 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 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 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 steelhead captured and radio-tagged, 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. Scale collection for ageing;
5. date and time of release; and,

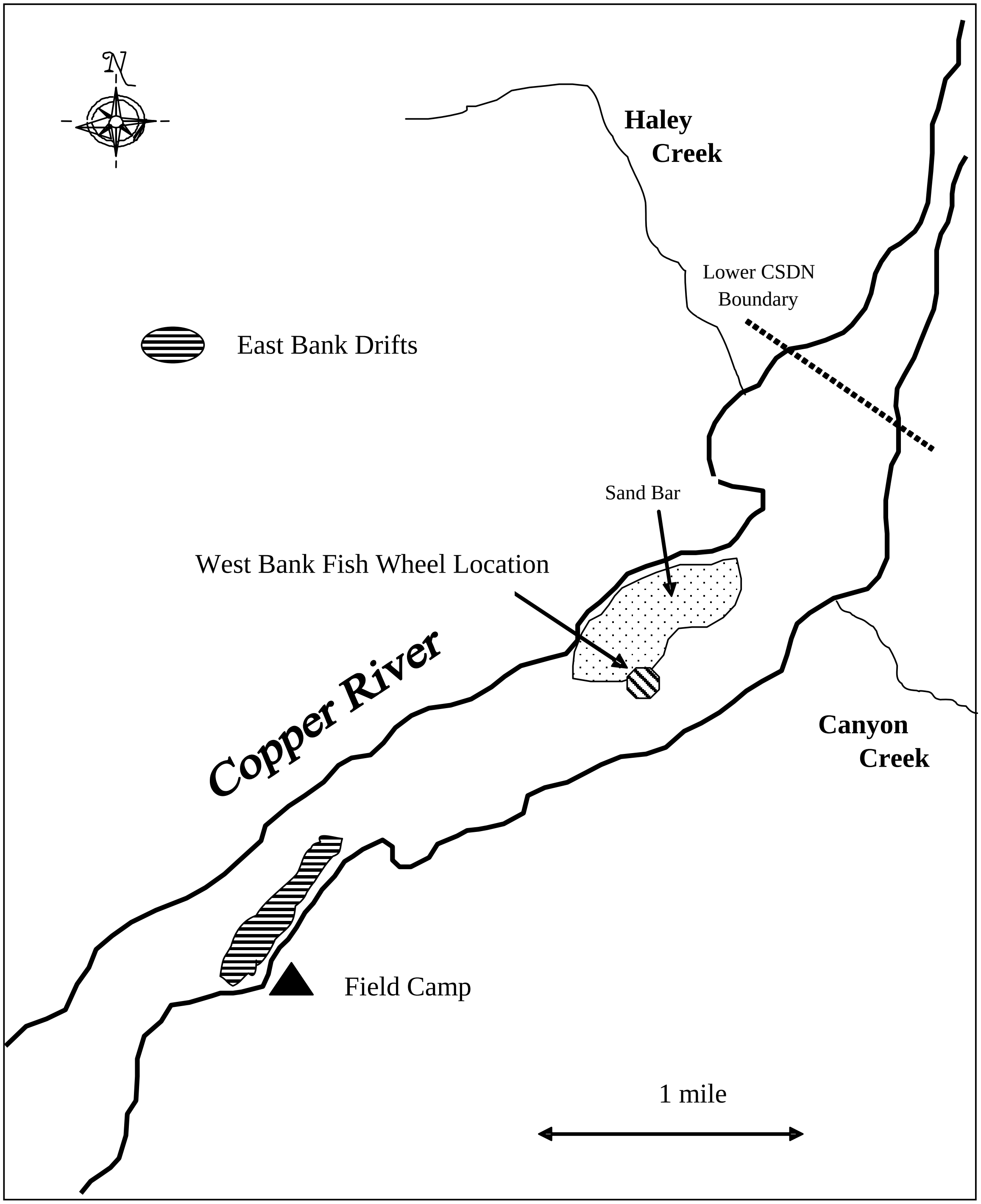

Figure 2.–Map of the Copper River demarcating the fish wheel and dip net capture locations, lower CSDN fishery boundary, and field camp, 2005.

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 between a point one cm posterior 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.

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 radio-tracking 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 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 steelhead that successfully migrate 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 immediately upstream of the Chitina River and the McCarthy Road bridge to identify fish bound for upriver areas. Radio-tagged fish entering the Tazlina, Tonsina, Klutina, 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 entering the tributaries upstream of the Gulkana River.

The distribution of radio-tagged steelhead 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. Two more surveys will be conducted in April and May 2006 to determine the overwintering and spawning locations. 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 receive signals perpendicular to the direction of travel. Once a tag was identified, its frequency, code, and GPS location were recorded by the receiver. The

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

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 one of the data loggers did migrate into that particular stream.

Data Analysis

Fate Determination

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

Identification of Spawning Areas

Radio-tagged steelhead assigned a "spawner" fate will be used to identify spawning areas (Table 1).

Spawning areas of steelhead will be 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 will be 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 (h_i) varied by day. The count of fish tagged on day i having fate j (R_{ij}) will be 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 will be:

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

Among fish that survive and migrate into spawning areas, the proportion of fish that had fate j will be estimated as:

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

where R_{ij} was the number of fish tagged on day i having fate j. Variance will be estimated using bootstrap resampling techniques (Efron and Tibshirani 1993). Each bootstrap sample will comprise 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 ($\hat{P}^*{}_j$) will be calculated for a total of 1,000 bootstrap estimates.

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

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

   Test: 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 tag would change a fish's destination.

2. *Captured steelhead were radio-tagged in proportion to the magnitude of the run or no difference in run timing between stocks.*

   Design Considerations: The tagging protocol described was designed to distribute tags over time proportional to passage of steelhead 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

Table 1.–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 into the CSDN fishery.
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.

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 will not be possible. It is assumed that the magnitude of this bias will be small relative to the estimate.

Stock-Specific Run Timing

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

$$f_j(t) = \frac{R'_{tj}}{\sum_{i}^{days} R'_{ij}} \quad (3)$$

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 steelhead 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* will be estimated as:

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

the variance of the run timing distribution will be estimated as:

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

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

1. *Radio-tagging steelhead did not affect their migratory behavior (final spawning destination).*

   Design Considerations: Handling and tagging have been shown to delay a fish's otherwise natural run timing (Bernard et al. 1999). To account for this potential delay, the beginning of a radio-tagged fish's run was when the fish migrated past a radio tower located approximately 1 km upstream of the capture site. The amount of time between capture and migration past the radio tower will be considered the handling-induced delay.

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

   Design Considerations: The tagging protocol described was designed to distribute radio tags over time proportional to passage of steelhead past the tagging site.

RESULTS

Capture and Tagging

Steelhead were captured from 15 August to 6 October, 2005. A total 59 steelhead, 1,761 coho salmon, and 4,061 sockeye salmon were captured. Fifty-seven steelhead were captured with the fish wheel and the remaining 2 were captured by dip net. Of the 59 steelhead captured, 52 were fitted with radio tags and released. The daily catch of steelhead ranged from 0 to 8 fish and the daily radio-tagging rate varied from 50 to 100% of all captured steelhead (Figure 3).

Eighty-eight percent of fish recorded between the capture site and the Haley Creek tracking station reached the CSDN fishery in 3 days or

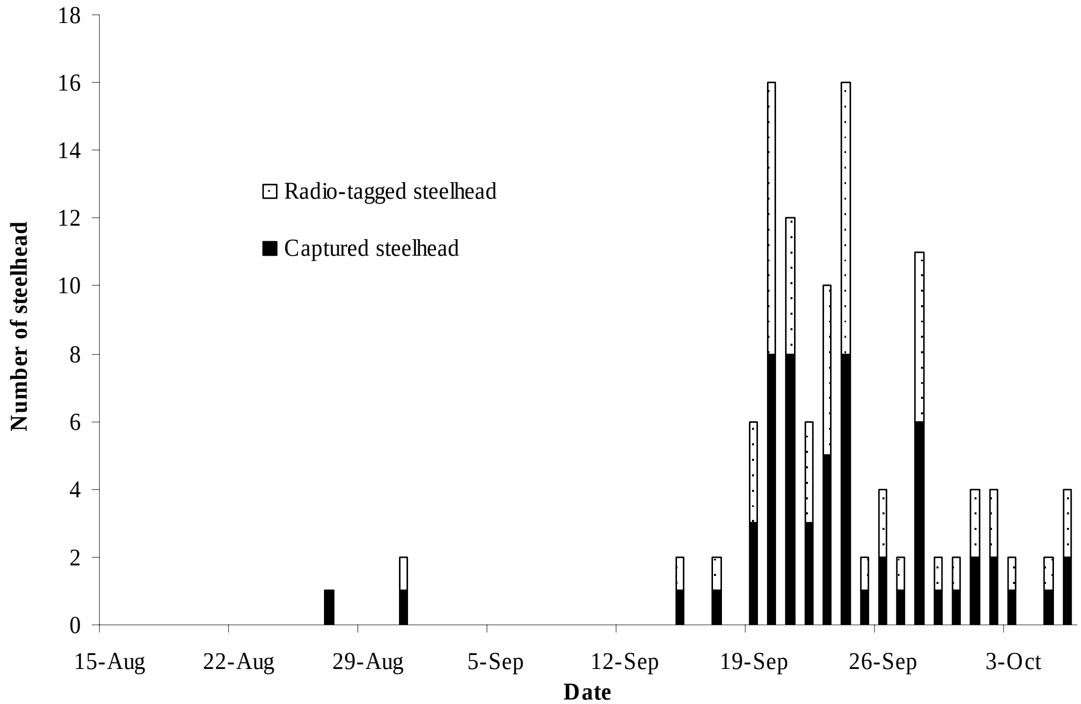

Figure 3.–Total number of steelhead captured and radio-tagged by day, 2005.

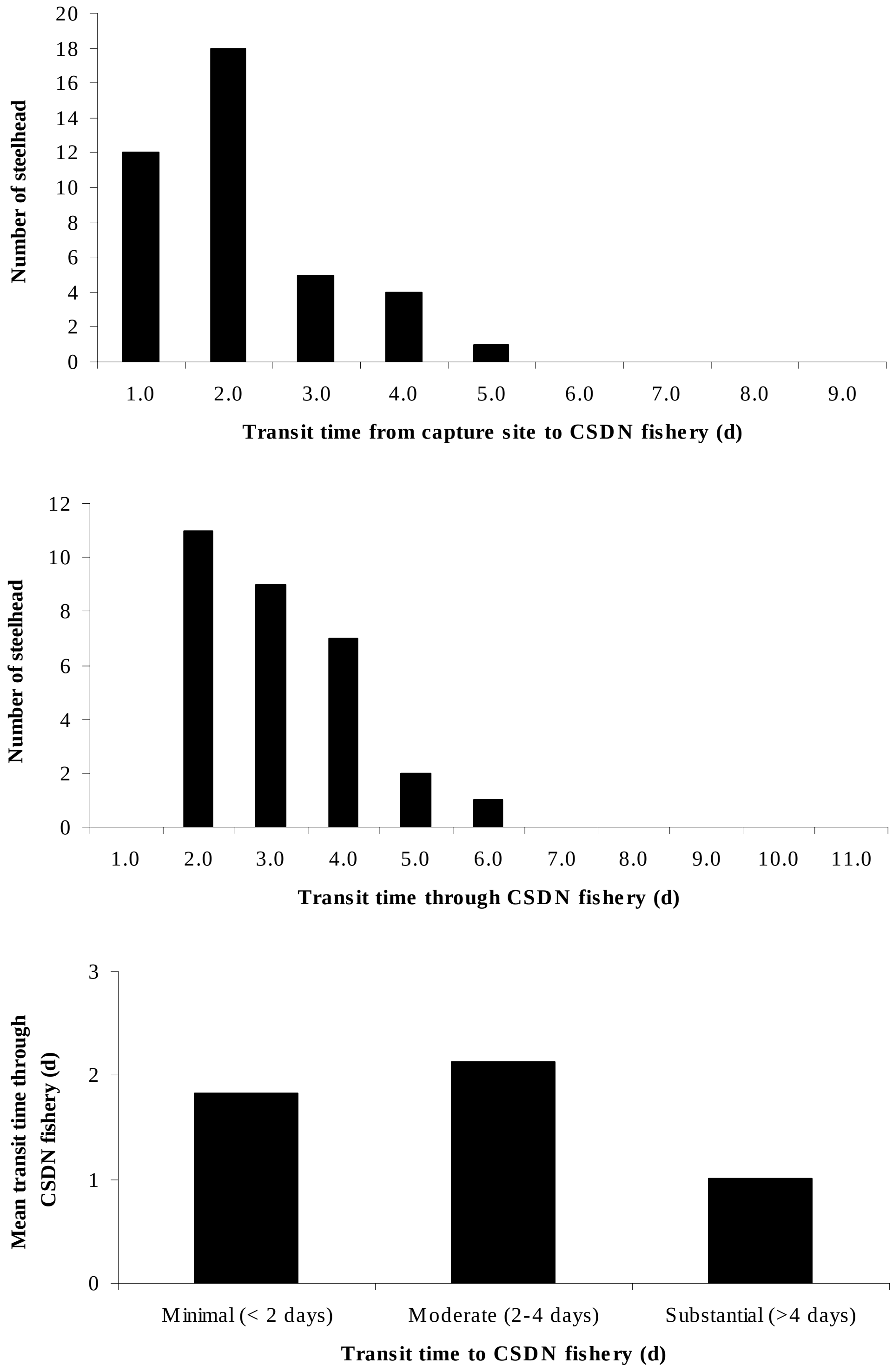

Figure 4.–Transit times from capture site to the CSDN fishery (top panel), transit times through the CSDN fishery (middle panel), and a comparison of mean transit times through the CSDN fishery of fish that exhibited minimal, moderate, and substantial transit times (bottom panel) for radio-tagged steelhead in the Upper Copper River, 2005.

less and 97% migrated through the CSDN fishery in 5 days or less (Figure 4). In addition, transit times through the CSDN fishery appeared to correlate with transit times to the CSDN fishery (Figure 4).

Fate Determination

The combination of stationary and aerial tracking techniques has accounted for 100% of the radio tags deployed; however, at this time, the final locations of steelhead are not known because the aerial surveys are not completed (Figure 5). The next aerial survey, in mid-April 2006, will be used to determine the overwintering locations of steelhead. Flights conducted in late May 2006 will be used to designate spawning locations.

Distribution of Spawners

The daily radio tagging rate (x_i/X_i) and hours of fishing effort (h_i) varied by day (Table 2). Therefore, after the final fates are determined, equation 1 will be used to calculate weights for radio-tagged fish on day *i* and equation 2 will be used to estimate the proportion of fish with fate *j*.

Stock-Specific Run Timing

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

DISCUSSION

Final estimates of spawning distribution and run timing are not completed. Once the final fates are determined the final estimates will be calculated; however, the objective criteria will not be met because the sample size of 130 radio-tagged steelhead was not achieved.

Other than a few occasions where the water dropped substantially overnight, the fish wheel fished almost continuously from 15 August to 6 October (Table 4). The ability to capture steelhead was hindered by the damaged fish wheel. The damaged fish wheel was removed from the capture site and repaired. With both fish wheels functioning, one on each bank, virtually all day every day our ability to capture and radio tag the desired sample size (130) in the fall of 2006 will be greatly increased.

Transit times from the capture site to the CSDN fishery and through the CSDN fishery suggest that radio-tagging steelhead had little or no effect on its upstream migration. Previous studies have provided varying theories on the effects of tagging on salmonid 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, Bromaghin et al. (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 steelhead and fish wheels were checked regularly to minimize the amount of time spent in the live- tank and over-crowding. The proportion of radio tags that failed to migrate upstream was 6% (n=3). Comparable studies on steelhead in the Columbia, Snake, and Vedder-Chilliwack rivers have observed similar failure, regurgitation, or retreat rates (Keefer et al. 2005; Nelson et al. 2005). Even though the failure rates observed in this study are not uncommon, the central question of whether handling affects migratory behavior still remains. Handling effect was examined in this study by comparing transit times through the CSDN fishery for radio-tagged fish that exhibited varying migration times from the tagging site to the fishery. The assumption was that transit time was a relative measure of stress. Comparable transit times through the CSDN fishery for radio-tagged steelhead already located in the Chitina, Tazlina, and Gulkana rivers suggested that any handling-induced changes in migratory behavior did not affect their final destination.

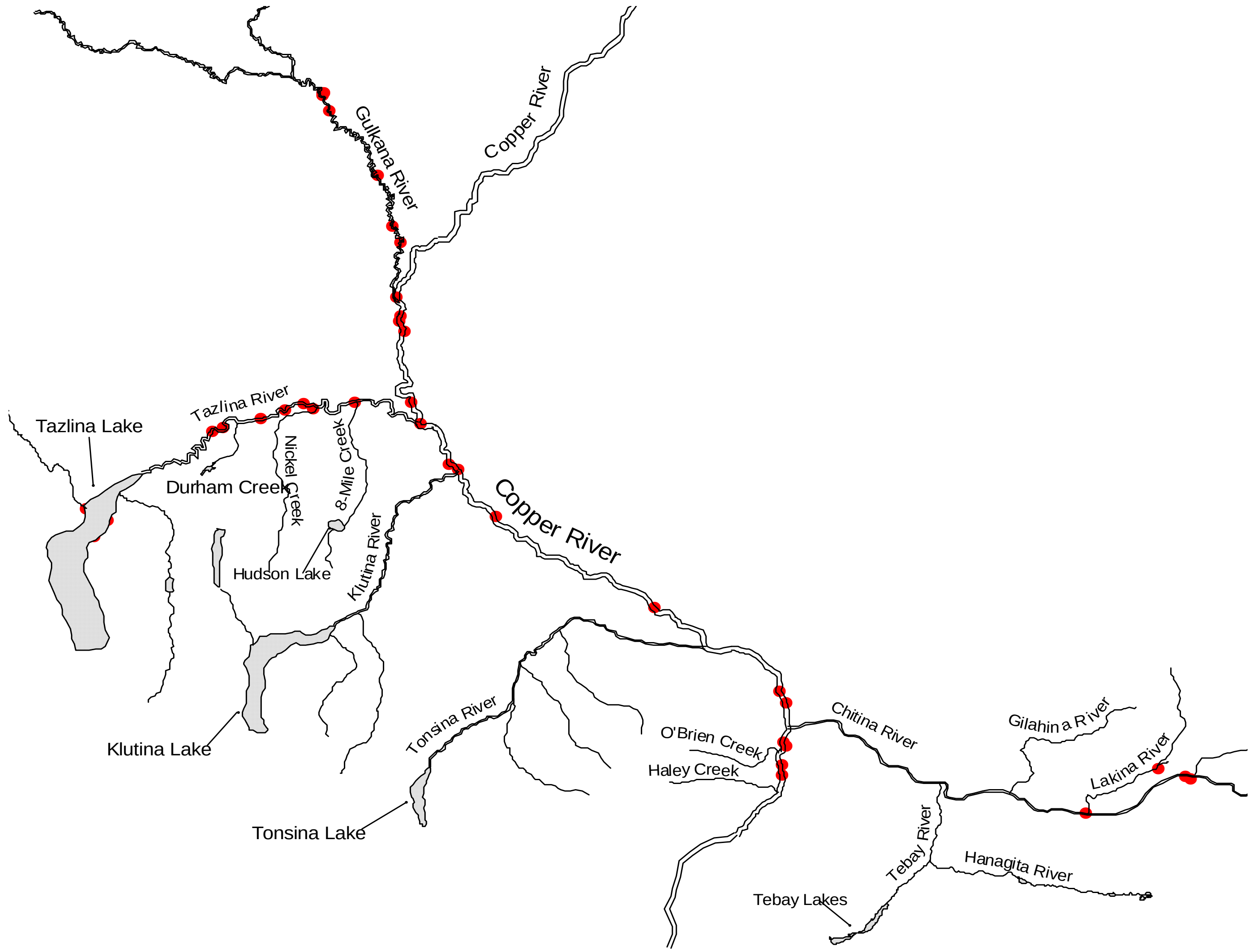

Figure 5.-Map of the Copper River demarcating the locations of radio-tagged steelhead in November, 2005

Table 2.–Fish wheel (FW), dip net (DN), and total (*h_i*) hours fished, steelhead captured (*X_i*), steelhead radio-tagged (*x_i*), and tagging rate (*x_i/X_i*) by day, 2005.

Date	FW Hours	DN Hours	h_i	Steelhead (X_i)	Steelhead Radio (x_i)	Tagging Rate (x_i/X_i)
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.

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