U.S. Fish and Wildlife Service
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Fisheries Resource Monitoring Program

Spawning Distribution and Run Timing of Copper River Sockeye Salmon, 2006 Annual Report

Annual Report for Study 05-501

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June 2007

Spawning Distribution and Run Timing of Copper River Sockeye Salmon, 2006 Annual Report

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ABSTRACT

The purpose of this three-year (2005-07) project was to use radiotelemetry techniques to assess the spawning distribution and run timing for adult sockeye salmon *Oncorhynchus nerka* stocks in the Copper River, Alaska. This report summarizes the results from the 2006 field season. Specific objectives were to: (1) estimate the proportions of sockeye salmon returning to major spawning areas of the Copper River (Lower Copper, Chitina, Tonsina, Klutina, Tazlina, Gulkana and Upper Copper rivers) such that the proportions were within 10% of the true proportions 95% of the time; and (2) describe the stock-specific, migratory timing profile of sockeye salmon in the Copper River at the point of capture in Baird Canyon. The largest proportion of spawners returned to the Klutina River drainage (0.45), followed by the Gulkana (0.16), Tazlina (0.11), Upper Copper (0.09), Chitina (0.08), Tonsina (0.06), and Lower Copper (0.06) rivers. Run-timing patterns at the capture site varied among stocks. The mean date of passage at Baird Canyon varied from 7 June for the Upper Copper stock to 17 July for the Tonsina stock.

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INTRODUCTION

Copper River sockeye salmon *Oncorhynchus nerka* support large and important commercial, subsistence, sport, and personal-use fisheries in Southcentral Alaska. Sockeye salmon stocks are widely distributed and known to be present in approximately 125 Copper River tributaries (Roberson 1987; Taube 2002). Harvest is significant in comparison to abundance, and sockeye salmon are the most utilized species for subsistence users. Management of Copper River sockeye salmon has become increasingly complex due to the interplay of federal and state management of a gauntlet of fisheries (commercial, sport, subsistence, and personal use), fisheries that target a mixture of species and stocks, inter-annual variation in the size and timing of stocks, difficulties in estimating abundance due to the physical characteristics of the drainage, and the inability of current management tools such as the Miles Lake sonar to allow species apportionment. To compound these difficulties, stock-specific run-timing and spawning distribution information is either limited or extremely dated. As a result, Copper River sockeye salmon were recently identified as the highest priority for Federal subsistence management information needs.

Management of Copper River salmon is complex in that there is both Federal jurisdiction of subsistence fisheries on Federal public lands; and State jurisdiction of commercial, sport, and subsistence fisheries throughout the drainage (Appendix A.1; Buklis 2002). State fisheries are managed under guidelines established in fishery management plans by the Alaska Board of Fisheries (BOF). Under the Copper River District Salmon Management Plan (5 AAC 24.360), the Alaska Department of Fish and Game (ADF&G) currently manages the Copper River District commercial salmon fishery to achieve a sustainable escapement goal of 300,000 – 500,000 sockeye salmon into the Copper River (AAC 2004). This includes a spawning escapement of 300,000 sockeye, a subsistence component of 160,000 – 225,000 salmon, a sport fishery component of 15,000 salmon, as well as brood and surplus fish to the Gulkana Hatchery that are estimated annually.

ADF&G uses a combination of fishery performance statistics and estimates of sockeye salmon entering the river to make decisions on whether and for how long to open the weekly commercial fishery. Estimates of fish escaping the commercial fishery have been made using sonar counts at a site near the outlet of Miles Lake. An estimated 959,731 salmon passed the Miles Lake sonar site between 13 May and 31 July 2006. In addition, a test fishing project at Flag Point Channel in the lower Copper River has been used to index salmon abundance from 2001-2006 (Link et al. 2001a; Lambert et al. 2003; Degan et al. 2004; Mueller and Degan 2005). The information provided from this project is taken into consideration by fishery managers who make decisions regarding commercial openings.

Three major stock components of sockeye salmon return to the Copper River each year (Ashe and Taube 2002). The Upper Copper River wild stock component is the most abundant component and it consists of both early and late returns, all of which spawn in tributaries above Miles Lake. Major spawning tributaries in the Upper Copper River include the Chitina, Tonsina, Klutina, Tazlina, Gulkana and Slana rivers (Merritt and Roberson 1986). The second component is composed of enhanced sockeye salmon which are produced from the Gulkana Hatchery, and their run timing overlaps with the late-run (upper river) wild stock component. Lower delta stocks, which make up the third component, spawn in systems below the Chugach Mountains between Eyak Lake and the Katalla River. Sockeye salmon stocks begin to enter the Copper River in early to mid May, as rising temperatures and water flush the ice from the river, and nearly all have entered the river by early to mid August.

The majority of Copper River sockeye salmon are harvested in a commercial gill net fishery located in the Copper River District (a designated commercial fishing area in and around the mouth of the Copper River) from mid May through August. An average of 1,540,000 sockeye salmon were harvested annually in the Copper River District from 1994 through 2003 (Ashe et al. 2005). In 2006, 1,462,000sockeye salmon were harvested, the fifth largest harvest in the past 116 years (ADF&G 2006).

Federal subsistence fisheries for sockeye salmon are open from approximately 15 May to 30 September in the Upper Copper River District. This area is comprised of two main subdistricts: 1) the Chitina Subdistrict – waters of the mainstem Copper River from the downstream edge of the Chitina-McCarthy Bridge downstream to an east-west line crossing the Copper River approximately 183 m (200 yards) upstream of Haley Creek; and 2) the Glennallen Subdistrict – waters of the mainstem Copper River from the mouth of the Slana River downstream to the Chitina-McCarthy Bridge. Subsistence fishing also occurs in the Batzulnetas area.

The State subsistence fishery is open from approximately 1 June to 30 September in the Glennallen Subdistrict. Sockeye salmon are also harvested in the personal-use, Chitina Subdistrict dip net (CSDN) fishery which is open from approximately 1 June to 30 September. In 2004, reported harvests of sockeye salmon in the Glennallen and Chitina subdistricts were 52,130 and 93,182 fish, respectively (Ashe et al. 2005).

Sport fishing (rod and reel) for sockeye salmon is open throughout most of the Copper River drainage; however, fishing effort is focused mainly in tributaries of the Upper Copper River such as the Gulkana and Klutina rivers. From 2000 to 2004, sport harvest of Copper River sockeye salmon ranged from 6,464 (2004) to 12,361 (2000) fish and averaged 8,373 fish (Hollowell and Taube 2005).

Early work on characterizing the run timing and distribution of sockeye salmon on the Copper River was limited and has become somewhat out of date. Merritt and Roberson (1986) examined sockeye salmon run-timing patterns on the Copper River. Their analysis was based on tag recoveries obtained during mark-recapture experiments done from 1967 to 1972, however, these recoveries had been obtained from non-systematic sampling of tributary stocks. Fish spawning in areas or at times where they were difficult or impossible to physically recover were not systematically sampled. For example, fish spawning in mainstem locations were not recovered and hence, their run timing was not characterized. Since the early 1970s, the inriver abundance and characteristics of the entire Copper River stock complex have changed. The Gulkana hatchery began producing large numbers of fish in the mid 1980s, different fisheries have expanded or contracted, and environmental and river conditions have varied. Finally, run timing information from Merritt and Roberson (1986) was based on tags applied at Wood Canyon and run timing at the entry to the Copper River had to be inferred from limited tags applied near Miles Lake.

The purpose of this study was to use radiotelemetry techniques to provide accurate and up-to-date information on the run timing and spawning distribution of Copper River sockeye salmon stocks. These data will increase our understanding of the relationship between fish passage at Miles Lake and subsequent weekly abundance through the inriver fisheries, as well as provide fishery managers with additional information that can be used to better manage the fishery and ensure that escapement goals are met.

Objectives

Objectives for the 2006 study were to:

1) Estimate the proportions of sockeye salmon returning to the major spawning tributaries of the Copper River (Lower Copper, Chitina, Tonsina, Klutina, Tazlina, Gulkana and Upper Copper rivers) such that the proportions are within 10% of the true proportions 95% of the time; and

2) Describe the stock-specific, migratory timing profiles of sockeye salmon in the Copper River at the point of capture in Baird Canyon from 2005 through 2007.

To achieve these objectives, approximately 500 adult sockeye salmon were radio-tagged in 2006 at three fishwheels located in Baird Canyon (rkm 69) and tracked throughout the basin using a combination of fixed tracking stations, and aerial and boat-tracking surveys (Figure 1). This project was integrated with two other studies being conducted by the Native Village of Eyak (NVE): 1) an OSM-funded project (FIS04-503) to estimate the annual timing and abundance of Chinook salmon *O. tshawytscha*; and 2) an ADF&G and OSM-funded (FIS06-502) project to estimate the annual abundance of sockeye salmon returning to the Copper River.

Study Area

The Copper River drains an area of more than 62,100 km^2 and flows southward through south-central Alaska before entering the Gulf of Alaska near the town of Cordova (Figure 1). Between the ocean and Miles Lake (rkm 48), the river channel traverses the Copper River Delta which is a large, highly braided, alluvial flood plain. A relatively high proportion of the Copper River's headwaters are glaciated which results in very high unit discharge (volume per square kilometer of drainage area) and sediment loads (Brabets 1997). From 1988 to 1995, the annual mean discharge on the lower Copper River was 1,625 m^3/s (57,400 ft^3/s), with the majority of flow occurring during the summer months from snowmelt, rainfall and glacier melt (Brabets 1997). Peak discharge in June ranged from 3,650 to 4,235 m^3/s while annual peak discharge ranged from 6,681 to 11,750 m^3/s. Water levels in Baird Canyon typically rise sharply from late May through June, level off in July, and then peak in August. Sediment loads cause the water to be unusually turbid and fill the river with numerous ephemeral sandbars and channel braids for most of its length.

METHODS

Capture and Tagging

Fishwheel Design and Operation

The majority of adult sockeye salmon were captured using three live-capture fishwheels that operated on both banks of the mainstem Copper River at Baird Canyon (rkm 69-71) in 2006. Two of the fishwheels (fishwheels 1 and 2) consisted of two, welded-aluminum pontoons (11.6 x 0.9 x 0.5 m), three large baskets (3.0 x 3.0 x 2.1 m) constructed with aluminum tubing (3.8 cm square), and one aluminum live tank (4.3 x 1.5 x 0.6 m) fitted inside each pontoon that held captured fish (Photo 1). The third fishwheel at Baird Canyon (fishwheel 5) was smaller than the other two fishwheels (Photo 2). Fishwheel 5 was constructed from two, welded-aluminum pontoons (10.3 x 0.7 x 0.4 m), four wooden baskets (2.1 x 1.8 x 0.8 m), and two live tanks (4.6 x 0.6 x 0.9 m). The baskets for all three fishwheels were lined with knotless nylon mesh (6.4-cm stretch). On 14 August, two weeks after tagging stopped at Baird Canyon, 13 sockeye salmon were radio-tagged at Canyon Creek (159 rkm) using a fishwheel similar to fishwheels 1 and 2.

The fishwheels were installed and operated similar to the methods used in previous years (Link et al. 2001b; Smith et al. 2003; Smith 2004; Smith et al. 2005; Smith and van den Broek 2005). The fishwheels were operated 24 hours per day, except for stoppages when they were being re-positioned or repaired. Daily water level was measured from a staff gauge secured to a rock wall on the east bank of Baird Canyon.

The Baird Canyon fishwheels were also used to capture adult Chinook salmon for a separate mark-recapture study (Smith and van den Broek 2007). In order to reduce the potential for overcrowding of fish in the live tanks, which may contribute to increased stress on sampled Chinook salmon, escape panels were used in the live tanks of all three fishwheels in 2006. The escape panels consisted of two, adjustable vertical slots in a removable aluminum frame (see Photo 6 on p. 84 in Smith et al. 2003). When installed and opened to the appropriate width (6 to 7.5 cm), the escape panels allow smaller fish such as sockeye salmon and other by-catch species to easily swim out of the live tanks while retaining Chinook salmon. As a result, the escape panels reduce overcrowding and the potential for sampling mortalities during high-catch periods as well as the amount of crew labor for handling fish. However, to ensure that radio-tagged sockeye salmon for this study were not biased by size, only fish captured during periods when the escape panels were closed were sampled. Catch per unit effort (CPUE, fish per hour) was calculated by dividing the total number of sockeye captured while the escape panels were closed by the length of time the escape panels were closed.

Tag Application

A systematic approach was taken to ensure that radio tags were deployed in proportion to the magnitude and timing of the sockeye salmon run (so that fish from all stocks had an equal probability of being tagged). A schedule for deploying the 500 radio tags was drafted prior to the field season using a preseason forecast for Copper River sockeye salmon that was provided by ADF&G fishery managers in Cordova (S. Moffitt, ADF&G, Cordova, pers. comm.). The tagging schedule was adjusted inseason based on daily salmon counts at the Miles Lake sonar site and the number of radio tags remaining.

Only a small portion of the sockeye salmon captured in the fishwheels each day were radio-tagged. Tags were deployed in a manner that would reduce the potential of bias from factors such as day of the week, time of day, bank of deployment, fish size, and gender. For example, the crew alternated daily between banks (east/west) and time of day (morning/evening) when collecting fish for sampling. To obtain fish for tagging each day, a live tank in one of the fishwheels was emptied following either the morning (~0830 hours) or afternoon (~1500 hours) sampling period. The fishwheel was then operated for a specified period, typically until the crew returned to the fishwheel for the next scheduled fishwheel visit, and all fish captured in the live tank were retained. During the next sampling session, sockeye salmon were randomly selected from the live tank and radio-tagged. Once the daily tag quota was met, the remaining sockeye salmon were counted and released. The escape panel in that live tank was then re-opened.

Using a dip net, healthy sockeye salmon were transferred from the live tanks to a water-filled, foam-lined trough for sampling. Radio tags were inserted orally into the upper stomach of the fish using a 20-cm long piece of plastic tubing (Photo 3). The whip antenna of the radio tag was left protruding from the mouth of the fish (Photo 4). All radio-tagged fish were measured for fork length (mm FL) from the tip of the snout to the fork of the tail and sexed from external characteristics. Before release, all fish were given a secondary external mark with a fluorescent pink colored spaghetti tag, printed with the text “radio tag in stomach, pls release fish or return tag.”

Tracking Equipment and Procedures

Tags

Radio tags were Model F1840B pulse-encoded, three-stage transmitters made by Advanced Telemetry Systems, Inc. (ATS; Isanti, MN). Each radio tag was distinguishable by a specific frequency and pulse-encoded pattern. We used twenty frequencies ranging from 148.423 to 148.893 MHz that were spaced approximately 20 kHz apart with 25 encoded pulse patterns per frequency (500 tags total). The tags were 17 x 56 x 15 mm, weighed 20 g each, and contained lithium batteries with a warranted life of 63 d (battery capacity of 127 d). The tags had a pulse rate of 45.8 ppm, a pulse width of 30 ms, and a current drain 0.54 ma. Each tag had NVE’s address printed on the side so that if it was recovered in an inriver fishery it could be returned and potentially re-deployed at Baird Canyon.

Tracking Stations

Radio-tagged sockeye salmon were tracked throughout the Copper River drainage using a network of ten ground-based tracking stations (Figure 1; Appendices A.2-A.4). Each station consisted of two, deep-cycle batteries (12 V), a solar array, either a ATS Model R4500 receiver (receiver and data collection) or an ATS Model 5041 Data Collection Computer (DCC II) coupled with an ATS Model 4000 receiver, two Yagi antennas, and a steel housing box. The receiver and DCC II were programmed to scan through the frequencies at 3-s intervals and receive signals from both antennas simultaneously. When a signal of sufficient strength is encountered, the receiver pauses for 12 s on each antenna, and then the tag frequency, tag code, signal strength, date, time, and antenna number are recorded on the data logger. The relatively short cycle period minimizes the chance that a radio-tagged fish will swim past the receiver site without being detected. Receiver data was downloaded to a notebook computer approximately every 7-10 d.

The first tracking station (Baird; rkm 72) was located on the west bank of the Copper River approximately 2 km upstream of Baird Canyon. The second station (Lower Haley; rkm 161) was located on the west bank of the Copper River downstream of the CSDN fishery and the confluence with Haley Creek. The third station (O'Brien; rkm 170) was located near the mouth of O'Brien Creek, just downstream of the Chitina/McCarthy Bridge. The fourth station (Chitina; rkm 178) was placed on the north bank of the Chitina River approximately 6 km upstream from the confluence mouth of the Chitina River. The fifth station (Copper; rkm 175) was placed on a west-side bluff of the Copper River immediately upstream from the upper boundary of the CSDN fishery. Tagged fish entering the Tonsina, Klutina, Tazlina, and Gulkana rivers were detected at tracking stations placed near the mouths of these rivers. The tenth station (Upper Copper; rkm 298) was located on the west bank of the mainstem Copper River approximately 2 km downstream from the mouth of the Gakona River. This station was used to enumerate radio-tagged sockeye salmon entering the Upper Copper River drainage upstream of the Gulkana River.

Aerial-tracking Surveys

The distribution of radio-tagged sockeye salmon was further determined by fixed-wing (Piper Cub) aerial-tracking surveys. The purpose of these surveys was to locate tags in spawning tributaries other than those monitored with tracking stations, to locate fish that the tracking stations failed to record, and to validate that fish recorded on one of the tracking stations did migrate into that particular stream. The aerial surveys were conducted by one person (in addition to the pilot) utilizing one R4500 receiver. All radio-tag frequencies were programmed into the receiver prior to each flight. Dwell time on each frequency was 2 s. Flight altitude ranged from 100-300 m above ground. Two antennas, one on each wing strut, were mounted such that the antennas received peak signals perpendicular to the direction of travel. Once a tag was identified during a flight, the frequency, code, and GPS location were recorded. After the information was recorded the plane circled back to the point where the signal was first heard and tracking resumed.

Boat-tracking Surveys

In 2006, boat-tracking surveys were conducted between the Million Dollar Bride and approximately 4 km upstream of the Chitina/McCarthy Bridge. Data from these surveys were used to identify whether radio-tagged fish last detected in this stretch of the lower Copper River were: (1) potential spawners; (2) harvested in the Chitina Subdistrict and the tag not returned to NVE; (3) or fish that died or regurgitated their tags. Boat surveys were conducted by a two-person crew using a R4500C receiver. As with the aerial surveys, radio-tag frequencies were pre-programmed into the receiver and the dwell time was set at 2 s. The average speed of the surveys was 9.3 mph. For each radio-tagged fish detected, the frequency, code, and GPS location was recorded.

Fate of Radio-tagged Fish

To facilitate data analysis, all radio-tagged sockeye salmon were assigned a fate based on information obtained from the tracking stations, mobile surveys, and voluntary tag returns from inriver fisheries (Table 1). Telemetry Manager© software developed by LGL Limited (Sidney, BC) was used to organize and analyze the radiotelemetry data. In order for a fish to be given the final fate of spawner they had to be: (1) detected by the upstream antenna of the tracking station on a spawning tributary: (2) or two or more mobile-tracking surveys on know spawning grounds; (3) or harvested while on spawning grounds.

Spawning Distribution

Radio-tag detections at the tracking stations and during mobile surveys were used to estimate the proportion of fish returning to major spawning tributaries of the Copper River (Lower Copper, Chitina, Tonsina, Klutina, Tazlina, Gulkana and Upper Copper rivers). The Lower Copper included all areas of the mainstem Copper River and its tributaries (e.g., Bremner, Tasnuna, and Tiekel rivers) that were located between the Baird and Lower Haley tracking stations. For the purposes of this study, the Upper Copper area included all waters upstream of the Upper Copper tracking station.

The distribution of sockeye salmon in the seven major spawning areas was estimated as the ratio of radio-tagged fish migrating into a specific tributary to the total number of radio-tagged fish migrating into all spawning tributaries. The proportion of fish that have fate *j* was estimated as:

$$\hat{P}_j = \frac{\sum_{i}^{\text{days}} R_{ij}}{\sum_{j}^{\text{fates}} \sum_{i}^{\text{days}} R_{ij}} \text{, where:} \tag{1}$$

R_{ij} was the number of fish tagged on day i having fate j. Variance was estimated using bootstrap re-sampling techniques (Efron and Tibshirani 1993). Each bootstrap replicate drew a random sample (with replacement) from the total number of possible radio tag fates (527 tagged fish, Table 2). From each replicate the proportion of spawners with fate j ($\hat{P}^{*}{}_{j}$) was calculated for a total of 1,000 bootstrap data sets. The percentile method was used to estimate confidence intervals.

In addition to assigning spawners to one of the seven major spawning areas, aerial-tracking data was used to assign fish to specific spawning sites within these drainages. For example, the Upper Copper was subdivided into six specific spawning areas: Copper River mainstem, Gakona River, Chistochina River, Slana River, Suslota Creek/Lake, Mentasta Lake, and Tanada Creek.

Run Timing

Radio-tag detections at the tracking stations were used to estimate stock-specific run-timing patterns. Only fish tagged at Baird Canyon were used to compute the run-timing statistics. Run-timing patterns were described as time-density functions where the relative abundance of stock *j* that migrated above the tagging site during time interval *t* was described by (Mundy 1979):

$$f_j(t) = \frac{R_{ij}}{\sum_i^{days} R_{ij}} \text{, where:} \qquad (2)$$

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

R_i = the subset of radio-tagged sockeye salmon bound for tributary *j* that were caught and tagged during day *i*.

For this purpose, stocks were defined as all sockeye salmon spawning in the Lower Copper, Chitina, Tonsina, Klutina, Tazlina, Gulkana, and the Upper Copper drainages. Those fish assigned a fate of "spawner" 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:

$$\bar{t}_j = \sum_i i \, f_j(t), \qquad (3)$$

and the variance of the run timing distribution estimated as:

$$Var\left(t_j\right) = \sum_i \left(i - \bar{t}_j\right)^2 f_j(t). \qquad (4)$$

RESULTS

Capture and Tagging

A total of 514 adult sockeye salmon were radio-tagged at three fishwheels located on the mainstem Copper River at Baird Canyon from 24 May to 14 August 2006 (Figs. 2 and 3; Table 2). Two hundred and forty-five fish were radio-tagged at fishwheel 1 on the east bank, 4 fish were radio-tagged at fishwheel 2 on the west bank, and 265 fish were radio-tagged at fishwheel 5 on the west bank. The number of radio tags deployed each day varied from 1 (24-26 May) to 15 (1-4 June). An additional 13 radio tags were deployed on 14 August at Canyon Creek from fishwheels used for a separate mark-recapture study (van den Broek et al. 2007). These fish were not used to compute run-timing statistics but they were included for estimating spawning distribution.

From 13 May to 31 July 2006, a total of 959,731 fish were counted at the Miles Lake sonar site. Radio-tag deployment was adjusted inseason, based on these counts, in order to tag in proportion to the magnitude and timing of the run (Figures 2 and 3).

Catch per unit effort (CPUE; fish per hour) for sockeye salmon varied with time and across fishwheels, and thus did not appear to be a reliable index of sockeye salmon abundance (Figure 4). Catch per unit effort varied from 0.2 to 19.6 fish per hour on the starboard side of fishwheel 1, and 0.8 to 21.5 fish per hour on the starboard side of fishwheel 5. Changes in fishwheel catch efficiency that result from dramatic changes in water levels likely contributed to this variability. For example, there was a 5.8-m change in stage height of the Copper River at Baird Canyon from 24 May to 18 June 2006.

Lengths of radio-tagged sockeye salmon ranged from 420 to 700 mm FL and averaged 576 mm FL (n = 517; Figure 5). Males averaged 595 mm FL (n = 224) and females averaged 561 mm FL (n = 293).

Tracking Stations and Mobile-Tracking Surveys

The Baird tracking station operated from 24 May to 31 July, and the remaining nine tracking stations operated from about mid-May to mid-late September (Appendix A.5). Of the 494 radio-tagged fish detected at one or more tracking stations, 466 fish were first detected at the Baird tracking station, 23 fish were first detected at the Lower Haley tracking station, 3 fish were first detected at the O'Brien tracking station and 2 fish were first detected at the Chitina tracking station (Table 3). Detection efficiencies at the tracking stations ranged from 51% at the Lower Haley station to 100% at the Tonsina, Upper Copper and Chitina stations (Table 3). The Lower Haley tracking station was not operational from 21 June to 26 June (the memory banks were full).

Three aerial-tracking surveys of the Copper River drainage were conducted from 27 June and 28 August 2006 and required a total of 8 d to complete (Table 4). The number of radio tags detected during each survey ranged from 215 (73% of tags released by that date) in June to 279 (57%) in August.

A total of 157 (33%) radio-tagged fish were detected during boat-tracking surveys on 26 and 27 July in the lower Copper River.

Fate of Radio-Tagged Fish

Spawning Distribution

Of the 514 radio-tagged fish released at Baird Canyon, 2 fish (0.4%) were never detected after release, 12 fish (2.3%) were last detected downstream of the tagging sites during aerial-tracking surveys, and 500 fish (97.3%) were last detected upstream of the tagging sites. Of the 13 radio-tagged fish released at Canyon Creek, 2 fish (15.4%) were last detected downstream of the tagging site, and 11 fish (84.6%) were detected upstream of the tagging site. Of the 511 radio-tagged fish that migrated upstream of their respective tagging sites, 308 fish (60.3%) were designated as spawners (which included 5 harvested fish), 96 fish (19.0%) were harvested, and

114 fish (22.3%) were designated as upstream migrants. For the purposes of this report, upstream migrants had an unknown fate and were not used for calculating spawning distribution or run-timing estimates.

Of the 308 radio-tagged fish designated as spawners, the largest proportion returned to the Klutina River (45%), followed by the Gulkana (16%), Tazlina (11%), Upper Copper (9%), Chitina (8%), Tonsina (6%), and Lower Copper (6%) rivers (Figure 6; Table 5). Specific areas with the most returns included Klutina Lake (33 fish), the Klutina River upstream of the lake (29 fish), St. Anne Creek (18 fish), and Upper Gulkana (17 fish; Table 6). The locations where radio-tagged fish were last detected on aerial-tracking surveys were plotted on maps of each major drainage area (Figs. 7-13).

Fifty-one radio-tagged fish were reported harvested in the Chitina Subdistrict, 21 fish in the Glennallen Subdistrict, 7 fish in the sport fishery, and 8 fish in unknown fisheries (i.e., the tags were returned with no information; Appendix A.6). In addition, nine radio-tagged fish were presumed harvested based on their detection history, including 6 fish in the Chitina Subdistrict, 1 fish in the Glennallen Subdistrict, and 2 fish from unknown locations.

Run Timing

Run-timing patterns at the capture sites varied among the individual spawning stocks (Figure 14). The mean date of passage at the Baird Canyon fishwheels ranged from 7 June for Upper Copper River stocks to 17 July for Tonsina River stocks (Table 7). Upper Copper stocks passed Baird Canyon from 28 May through 25 June, a period of only 28 d. In contrast, the duration of passage for Gulkana (26 May – 30 July) and Tazlina (24 May – 27 July) stocks was considerably more protracted at 65 d and 64 d, respectively.

Travel times of radio-tagged fish from release at Baird Canyon to first detection at the Baird tracking station averaged 27 h for fishwheel 1 (n = 228), 61 h for fishwheel 2 (n = 4), and 8 h for fishwheel 5 (n = 238; Figure 15). Fishwheel 5 was located near the Baird tracking station and thus a large proportion of fish were detected immediately following release. Fish released at fishwheels 1 and 2 had to migrate upstream over 1 km before being detected at the Baird station. Seventy six percent of fish released at fishwheels 1, 2, and 3 were detected at the Baird station within 1 d of release. One fish released at fishwheel 1 on 29 June was not detected at the Baird station until 11 July, and it was subsequently harvested in the Glennallen fishery on 19 July.

Travel times for radio-tagged sockeye salmon to migrate between the Baird and Lower Haley tracking stations ranged from 3.5 d to 29.6 d and averaged 9.7 d (Table 8). Over this 89-km distance, these travel times corresponded to migration speeds ranging from 3 km/d to 25 km/d. Mean travel times from the Baird tracking station to harvest in the Chitina Subdistrict, Glennallen Subdistrict, and Klutina sport fisheries were 14 d, 19 d, and 17 d, respectively (Table 9).

DISCUSSION

Capture and Tagging

Two assumptions must be met in order to obtain unbiased estimates of the spawning distribution: (1) handling and radio-tagging sockeye salmon did not affect their natural behavior (i.e., final spawning destination); and (2) sockeye salmon were radio-tagged in proportion to the magnitude and timing of the run. There was no explicit test for the first assumption because the behavior of unhandled fish could not be observed. However, several observations indicated that sockeye salmon radio-tagged in 2006 were not adversely affected by the capture, handling, or tagging process. Of the 527 radio-tagged fish released, 97.0% were last detected upstream of the tagging site and only 2.7% were last detected downstream of the tagging site (the remaining <1.0% were never detected after release; Table 2). Fish last detected downstream of the tagging site may have regurgitated their radio tags or died after release. Additionally, the majority of radio-tagged fish migrated upstream of the tagging site within one day of being released (Figure 15). These findings compare favorably to other sockeye salmon radiotelemetry studies conducted in Alaska. For example, Waltemyer et al. (2005) reported that 16% of sockeye salmon radio-tagged on the East Alsek River in 2004 were last detected in the vicinity of the tagging site, and 4% of the fish were never detected after release. During a 2002 study in the Chignik Lake system, 89% of radio-tagged sockeye salmon resumed their upstream migration after release (Anderson 2003). During a three-year study (1999-2001) on Lake Clark, Ramstad and Woody (2003) found no significant tag loss or increase in mortality rates associated with radio-tagged sockeye salmon.

Salmon counts at the Miles Lake sonar site provided an independent inseason index of salmon abundance that could be used to evaluate whether our tags were deployed in proportion to the magnitude and timing of the run (assumption 2). Due to the late break up of river ice, all three fishwheels at Baird Canyon did not begin fishing until 23 May. Despite the late start relative to 2005, no sockeye salmon were captured or tagged at Baird Canyon until 24 May, indicating that radio-tagging began at the onset of the run (Figure 2). This was also supported by the fact that only 402 salmon were counted at the Miles Lake sonar site from 13-22 May.

Conversely, salmon counts at the Miles Lake sonar site were still relatively high in late July indicating that radio-tagging at Baird Canyon was stopped prior to the end of the run. The last sockeye salmon was radio-tagged at Baird Canyon on 31 July, yet the day prior there were almost 10,000 salmon counted at the sonar site. Further evidence that the latter portion of the run was not adequately represented came from a separate steelhead and coho salmon study conducted by ADF&G near Canyon Creek (89 rkm upstream of Baird Canyon). From 15 August to 28 September, over 20,000 sockeye salmon were reported captured in two fishwheels (J. Savereide, ADF&G Sport Fish Division, personal communication). Based on this information, a portion of the 2006 sockeye salmon run migrated through Baird Canyon after 31 July with no chance of being radio-tagged. As a result, it is likely that the spawning distribution and run timing estimates are biased by not accounting for these late run fish. Radio-tagging was stopped early in 2006 for budgetary reasons. As such, efforts should be made in 2007 to ensure that at least one fishwheel operates to mid-August.

We also found evidence to suggest that radio tags were not deployed at Baird Canyon in proportion to abundance during the start of the season. Over a 6-day period from 30 May to 4 June, 271,708 salmon were counted at the Miles Lake sonar site, which represented 28% of the count for the season. From 31 May to 5 June (which assumes a 1-d travel time between Miles Lake and Baird Canyon), 84 sockeye salmon were radio-tagged representing 16% of the total number released in 2006 (Figure 3). Despite increasing the tagging rate to 15 fish a day during this period; it appears that this large pulse of early-run fish was not sufficiently tagged. As a result, the distribution estimates for this component of the run may be biased low. Based on the stock-specific run-timing patterns (Figure 14), it is likely that these early-run fish were composed largely of fish bound for the Upper Copper, Tazlina and Klutina rivers. In 2007 a new sockeye salmon mark-recapture study may provide data that could be used to investigate this type of bias.

Fate of Radio-tagged Fish

In 2006, we implemented new sampling techniques and protocols in order to increase the proportion of radio-tagged fish designated as spawners or harvested; and thereby decrease the proportion of fish designated as upstream migrants. These new methods included: (1) conducting boat-tracking surveys between Miles Lake and the Chitina/McCarthy Bridge; (2) operating a tracking station on the Copper River near the mouth of O'Brien Creek; (3) applying external secondary tags to radio-tagged fish to make them more easily recognized if recovered in an inriver fishery; and (4) using 3-stage radio transmitters that emit a stronger signal than the tags used in 2005. In 2006, the proportion of radio-tagged sockeye salmon designated as upstream migrants (22% of 527 released), or fish that moved upstream of the tagging sites but were never detected in known spawning areas, was lower than in 2005 (30%). The proportion of fish designated as spawners was 58% in 2006 and 57% in 2005. Ultimately, by increasing the proportion of fish designated as spawners, we increase our sample sizes and in turn potentially increase the accuracy and/or precision of the parameter estimates.

Eighteen fish (5.8%) were designated as Lower Mainstem spawners in 2006 as compared to 22 (7.4%) fish in 2005. In 2005, all Lower Mainstem spawners were assigned to the Tasnuna and Bremner rivers. In 2006, 9 fish (50% of Lower Mainstem spawners) were assigned to spawning grounds other than the Tasnuna or Bremner rivers. In addition to the aerial-tracking surveys, boat-tracking surveys and tags with stronger signal strength in 2006 helped to identify fish in spawning areas such as the Tiekel and Uranatina rivers and the Swan Lakes area. Fish returning to the Lower Copper drainage are counted at the Miles Lake sonar site but are unavailable to the inriver fisheries. This Lower Copper component of the run may account for at least some of the fish that are believed to go "missing" between the Miles Lake sonar site and the inriver fisheries and upper river spawning escapement. We recommend that boat-tracking surveys be conducted throughout the 2007 season.

Another factor that played a part in designating the final fate of a fish in 2006 was the addition of a highly visable secondary mark on all radio-tagged sockeye salmon. Eighty seven fish (17% of tagged fish) were reported as harvested in 2006 as compared to 52 fish (10%) in 2005. It is believed that a portion of radio-tagged fish harvested in 2005 was not reported because fishermen did not notice the radio tag. Four of the pink spaghetti tags used for the secondary mark were returned with not radio tag. It is possible that the radio tags were regurgitated when the fish was harvested. Sixty four fish were last detected at or between the Lower Haley (rkm 161) and Copper (rkm 175) tracking stations in 2006. Nine of these fish were designated as harvested based on their tracking history despite the fact they were not reported harvested. In addition, a fourth tracking station was added to the Chitina harvest area at the mouth of O'Brien Creek in 2006 to improve tracking coverage in the harvest area. A total of 10 radio tags from harvested fish were returned with no information attached. In 2007, it is recommended that the level of public awareness be raised to include the importance of providing detailed harvest data (i.e., date caught, location caught, and gear type) for recovered fish.

As mentioned earlier, past studies to assess the distribution and run timing of Copper River sockeye salmon have been limited are now somewhat outdated. Based on data collected from 1967 to 1972, Merritt and Roberson (1986) reported that the two stocks with the greatest estimated spawning population size were in the Gulkana (Upper Gulkana) and Chitina (Long Lake) rivers. In 2006, the largest proportion of spawners returned to the Klutina (0.45), Gulkana (0.16), and Tazlina (0.11) drainages (Figure 6; Table 5). Significant spawning areas included the Klutina Lake, mainstem Klutina River, and Upper Gulkana (Figure 7). The largest difference in spawning distribution between the 2005 and 2006 studies occurred for the Upper Copper stocks (Figure 6). In 2005, 85 fish (28%) were last detected in the Upper Copper, whereas in 2006 only 28 fish (9%) were last seen in the Upper Copper and its tributaries. In 2006, these fish had the earliest run timing (7 June) which means that over half of this stock had passed Baird Canyon by that date. As mentioned earlier, the Miles Lake sonar site counted an unusually high number of salmon in late May and early June. It is likely that too few radio tags were deployed on this component of the run and thus the distribution estimates may have been biased low.

Merritt and Roberson (1986) also found that groups of stocks with early mean arrival dates tended to spawn in the uppermost areas of the Copper River drainage. Results from the 2005-06 study showed a similar trend (Table 8). The mean date of passage at Baird Canyon for the Klutina, Tazlina, and Upper Copper stocks was earlier than the mean date of passage for Lower Copper, Chitina, and Tonsina stocks (Table 7). An exception to this trend was the Gulkana River stocks. Although the Gulkana River is located higher in the drainage than the Klutina and Tazlina rivers, Gulkana River fish displayed a later run timing pattern (mean date of passage was 7 July). This may be due to the fact that the majority of the Gulkana River run is made up of hatchery fish whose run timing is typically later in the year.

Stock-specific run-timing patterns in 2006 followed the same general trends as seen in 2005, although there were a couple of differences. The mean date of passage for most stocks was 3 to 13 d later in 2006 than in 2005. Late break up of river ice may have played a role in delaying the run timing. One exception to this trend was the Lower Copper stock which had a mean run timing that was 8 d earlier in 2006 than 2005. Again, this could be explained by the fact that we stopped radio-tagging fish at Baird Canyon when this component of the run was still present in the lower river. One other difference in run timing was the short duration that the Upper Copper stocks exhibited (28 d in 2006, 51 d in 2005). This may be the result of deploying too few tags in late May and early June when Upper Copper stocks were passing Baird Canyon.

CONCLUSIONS

This year (2006) was the second of a three-year study to estimate the spawning distribution and run timing of Copper River sockeye salmon. Despite numerous challenges encountered during the 2006 field season, all project objectives were met or exceeded. Fishery technicians hired by NVE acquired the skills and experience required for this and other fisheries research jobs. Projects such as this help NVE to be an integral part of Copper River salmon research and management. This project promoted interaction between a major subsistence group (NVE) and various management agencies (USFWS, ADF&G Division of Sport Fish, ADF&G Division of Commercial Fisheries). This project also engaged tribal organizations from different regions and promoted interactions amongst subsistence users.

RECOMMENDATIONS FOR 2007

The following are recommended for the 2007 field season:

1) Radio tag sockeye salmon through August to ensure that late-run fish are represented;
2) Test all radio tags on the day they are deployed to ensure they are functioning properly;
3) Conduct regular inseason mobile-tracking surveys by boat between Chitina and Miles Lake to obtain more detailed tracking data and identify potential spawners which would otherwise be classified as upstream migrants;
4) Continue to utilize a brightly colored spaghetti tag as a secondary mark on radio-tagged fish; and
5) Increase public awareness of the study in an effort to increase the proportion of tags reported harvested in inriver fisheries and the amount of harvest information provided (i.e., capture date, location, and gear type).

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FIGURES

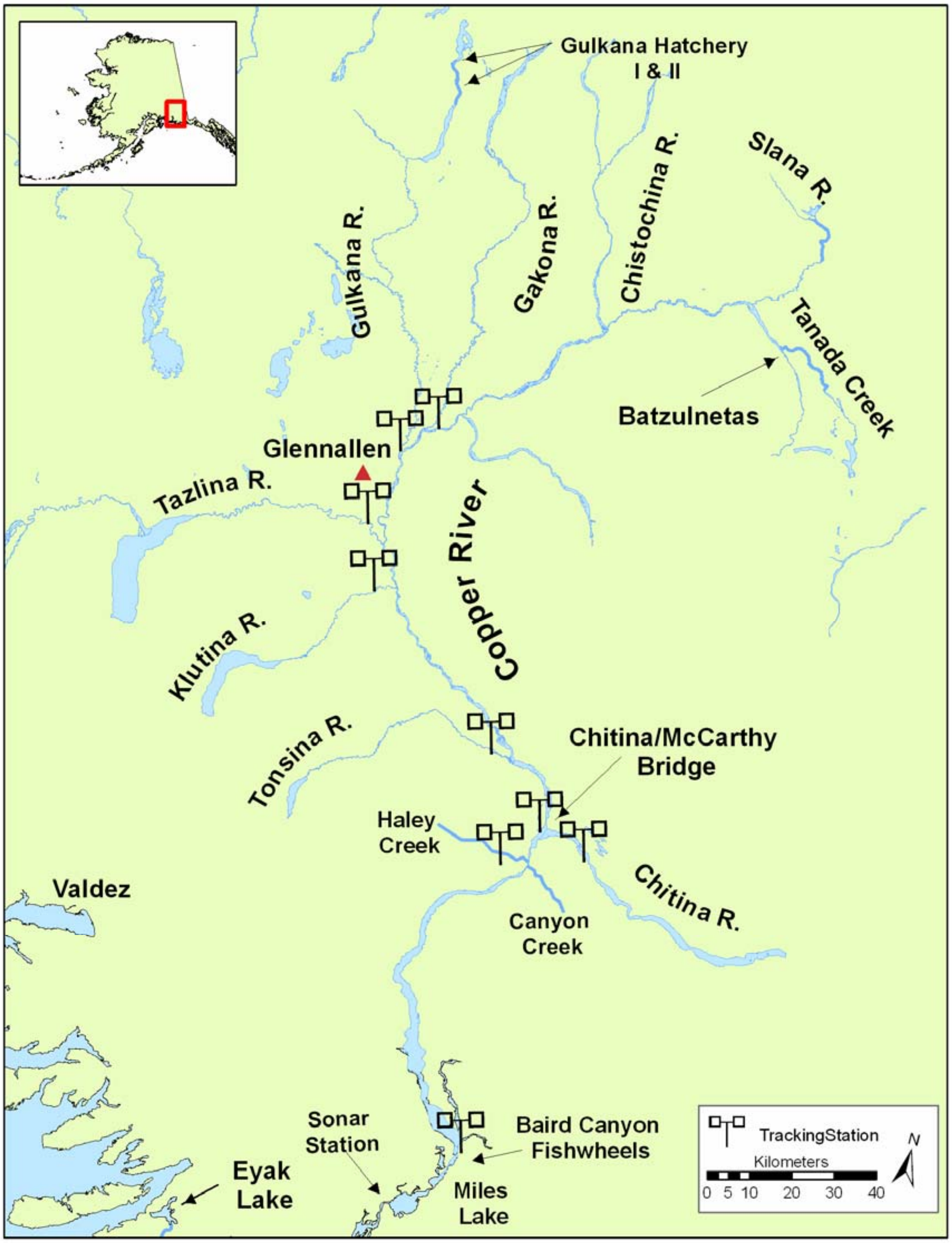


Figure 1. Map of the Copper River watershed in Southcentral Alaska showing the location of the fishwheels used to capture sockeye salmon and ten tracking stations used for tracking radio-tagged fish, 2006.

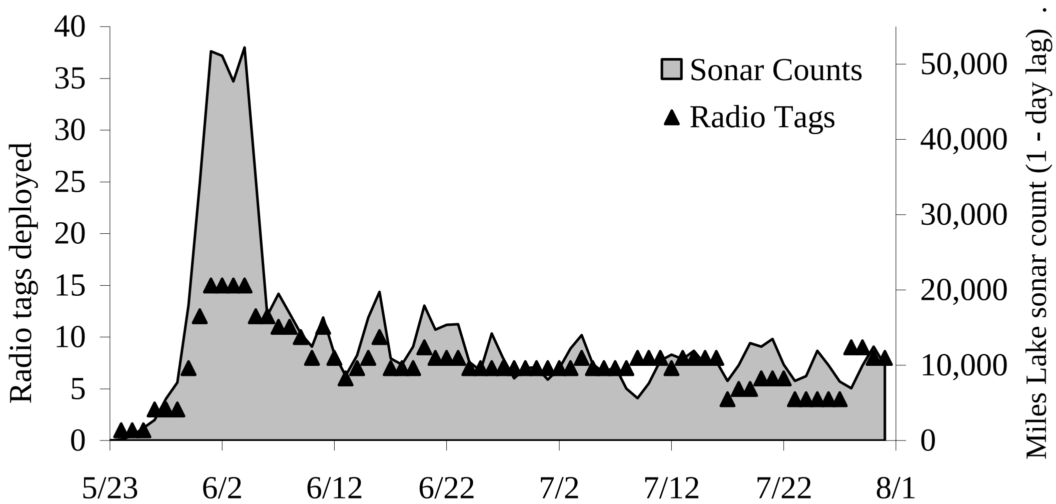


Figure 2. Daily number of sockeye salmon radio-tagged at the Baird Canyon fishwheels and the daily number of salmon counted at the Miles Lake sonar, 2006.

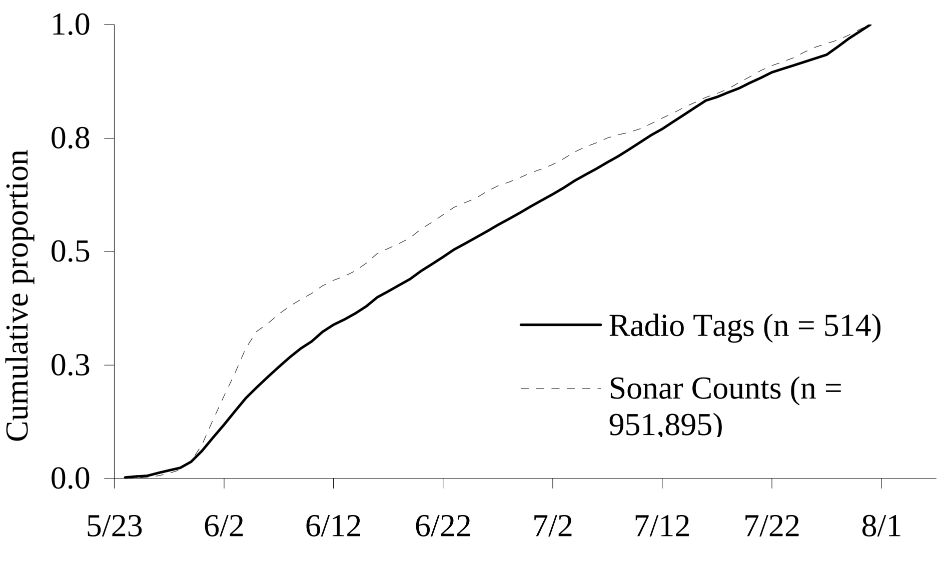


Figure 3. Cumulative proportion of sockeye salmon radio-tagged at the Baird Canyon fishwheels and the cumulative proportion of salmon counted at the Miles Lake sonar, 2006.

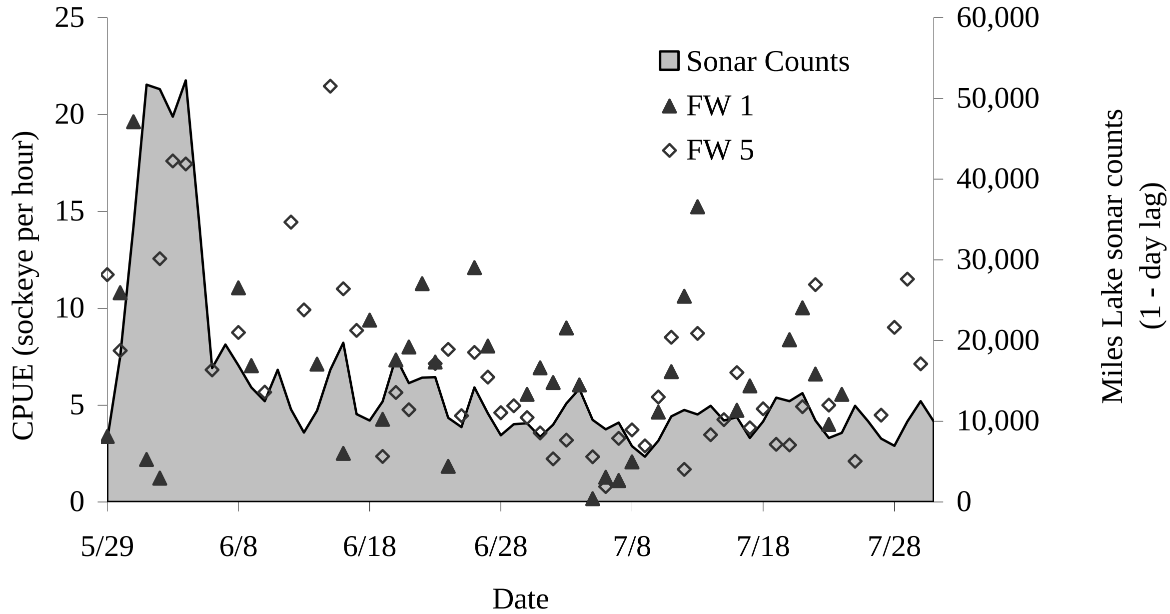


Figure 4. Catch per unit effort (fish per hour) for sockeye salmon captured at the Baird Canyon fishwheels during periods when escape panels were closed, 2006. Daily counts at the Miles Lake sonar site in 2006 are shown for comparison.

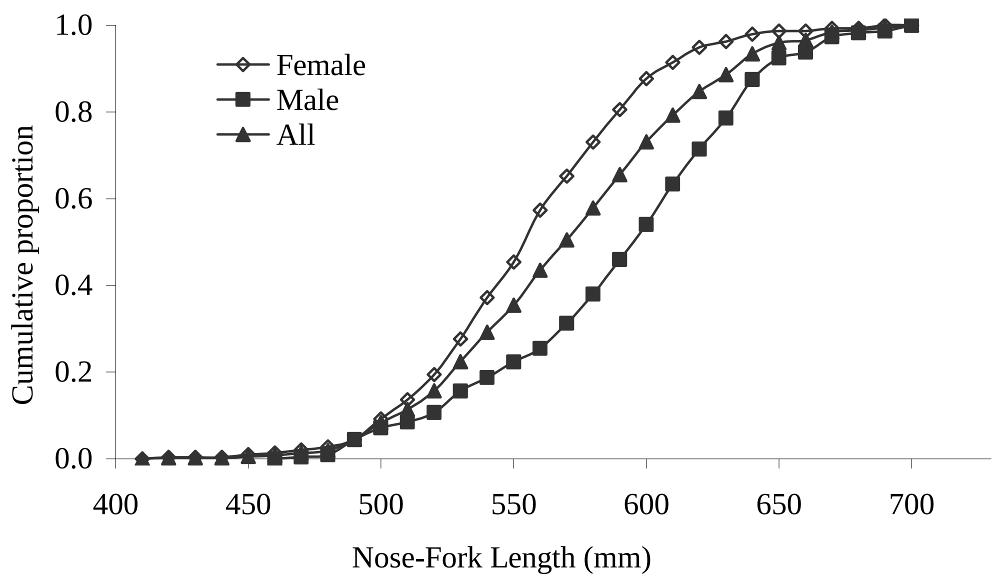


Figure 5. Cumulative length-frequency distributions for sockeye salmon radio-tagged at the Baird Canyon fishwheels on the Copper River, 2006.

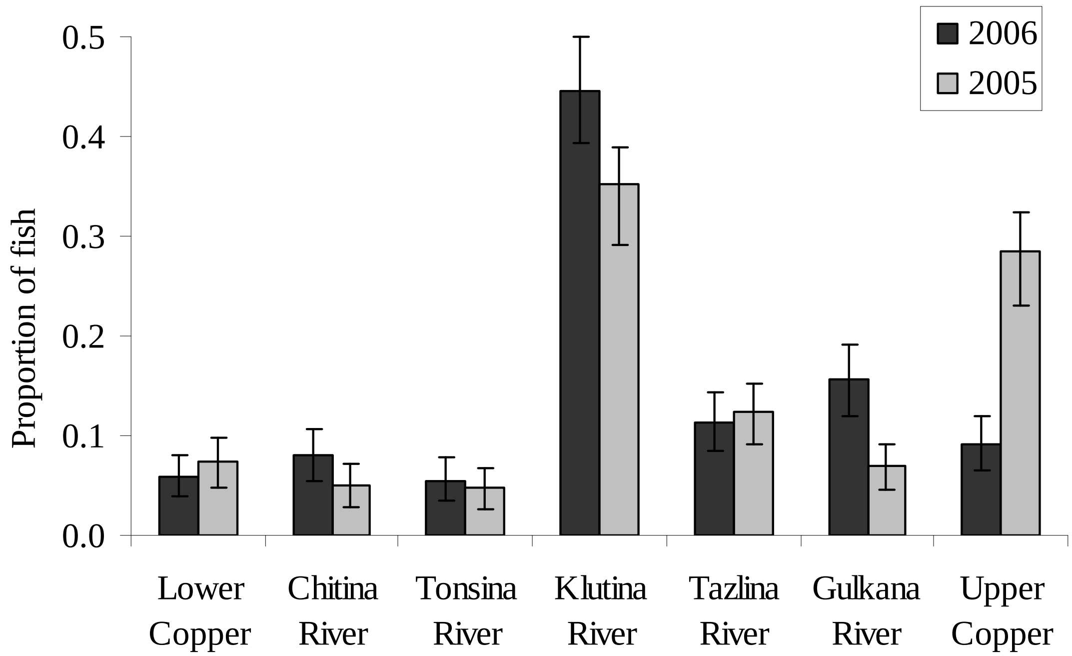


Figure 6. Spawning distribution and 95% confidence intervals of Copper River sockeye salmon by major drainage, 2005-06.

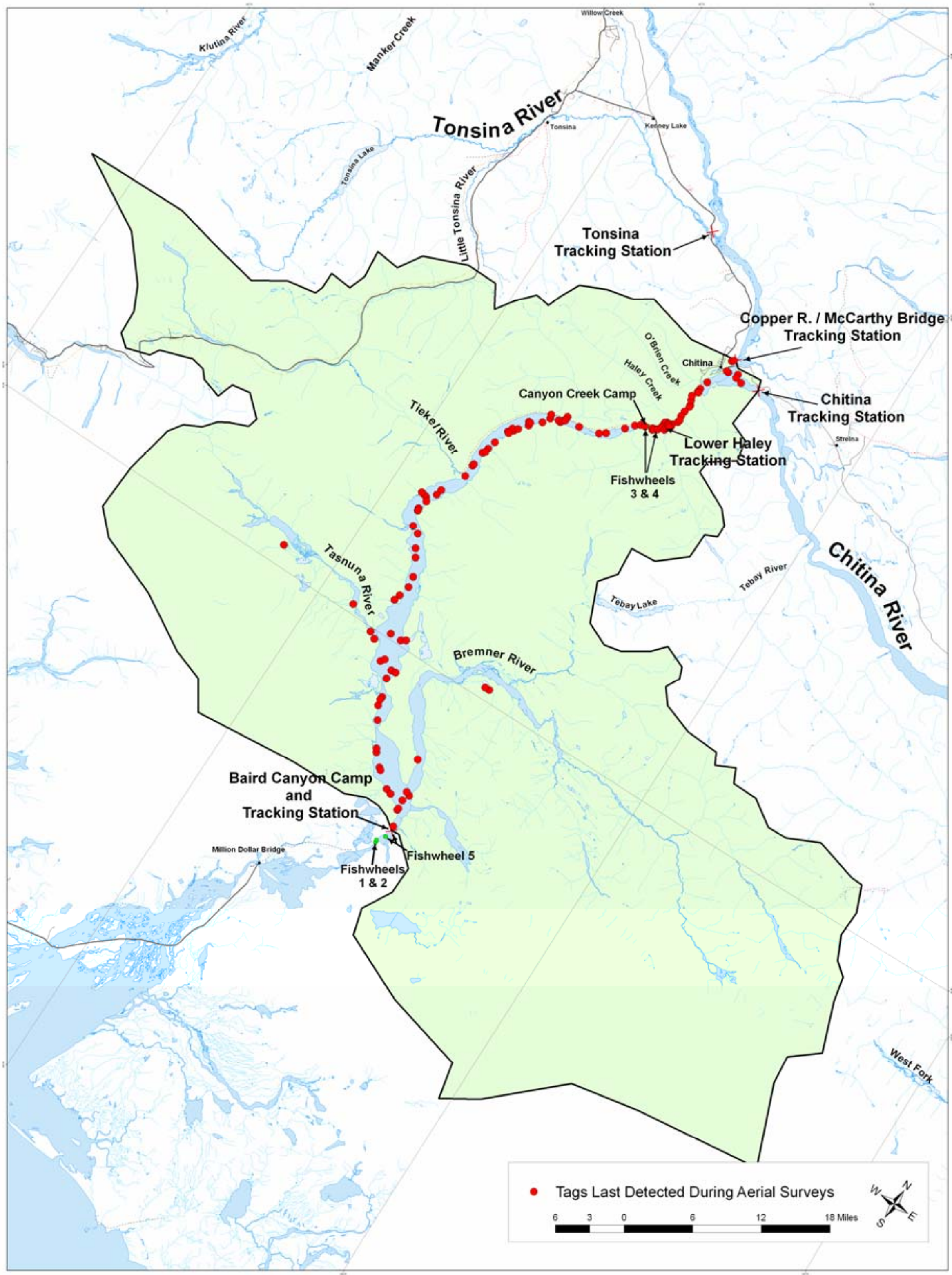


Figure 7. Map of the Lower Copper River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

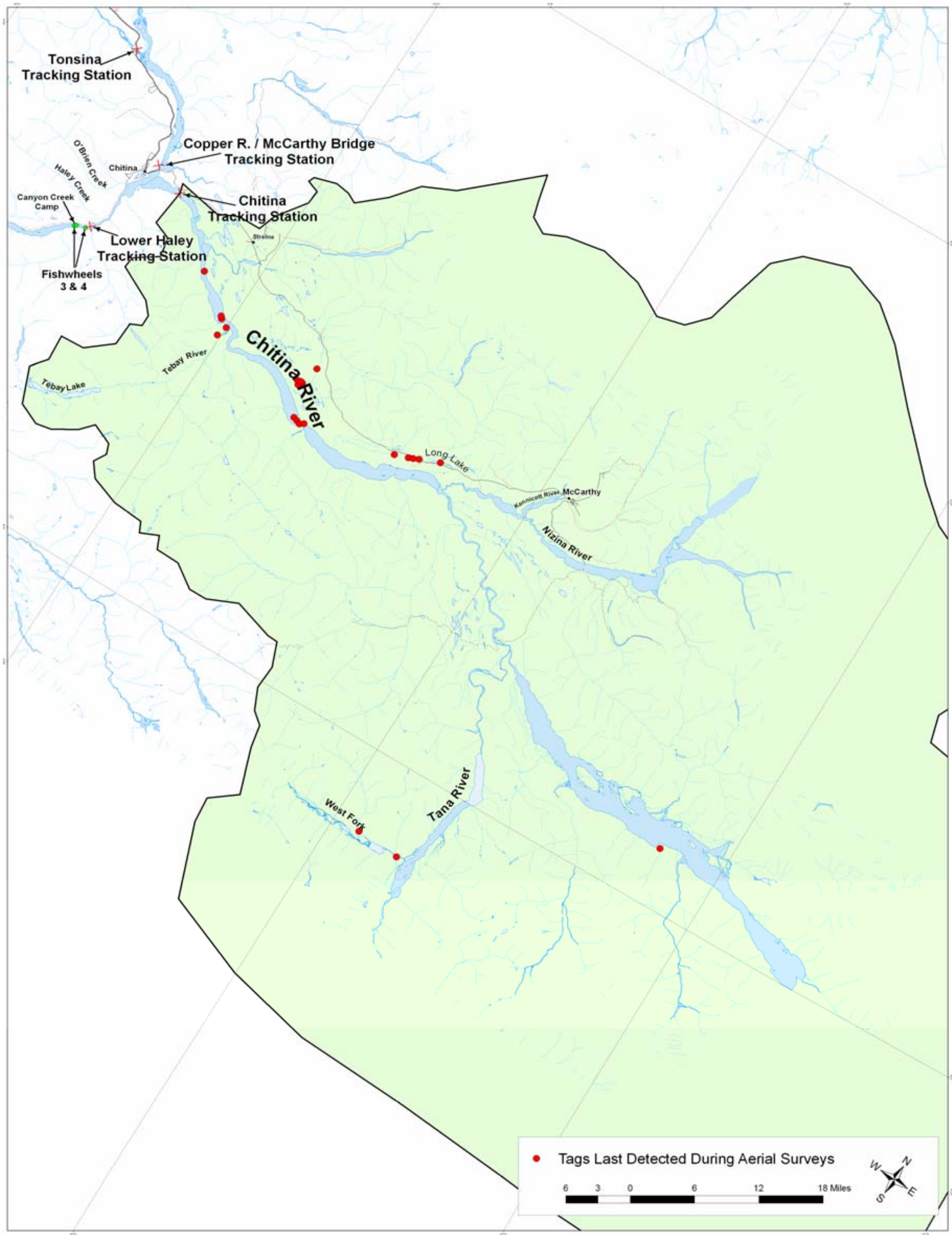


Figure 8. Map of the Chitina River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

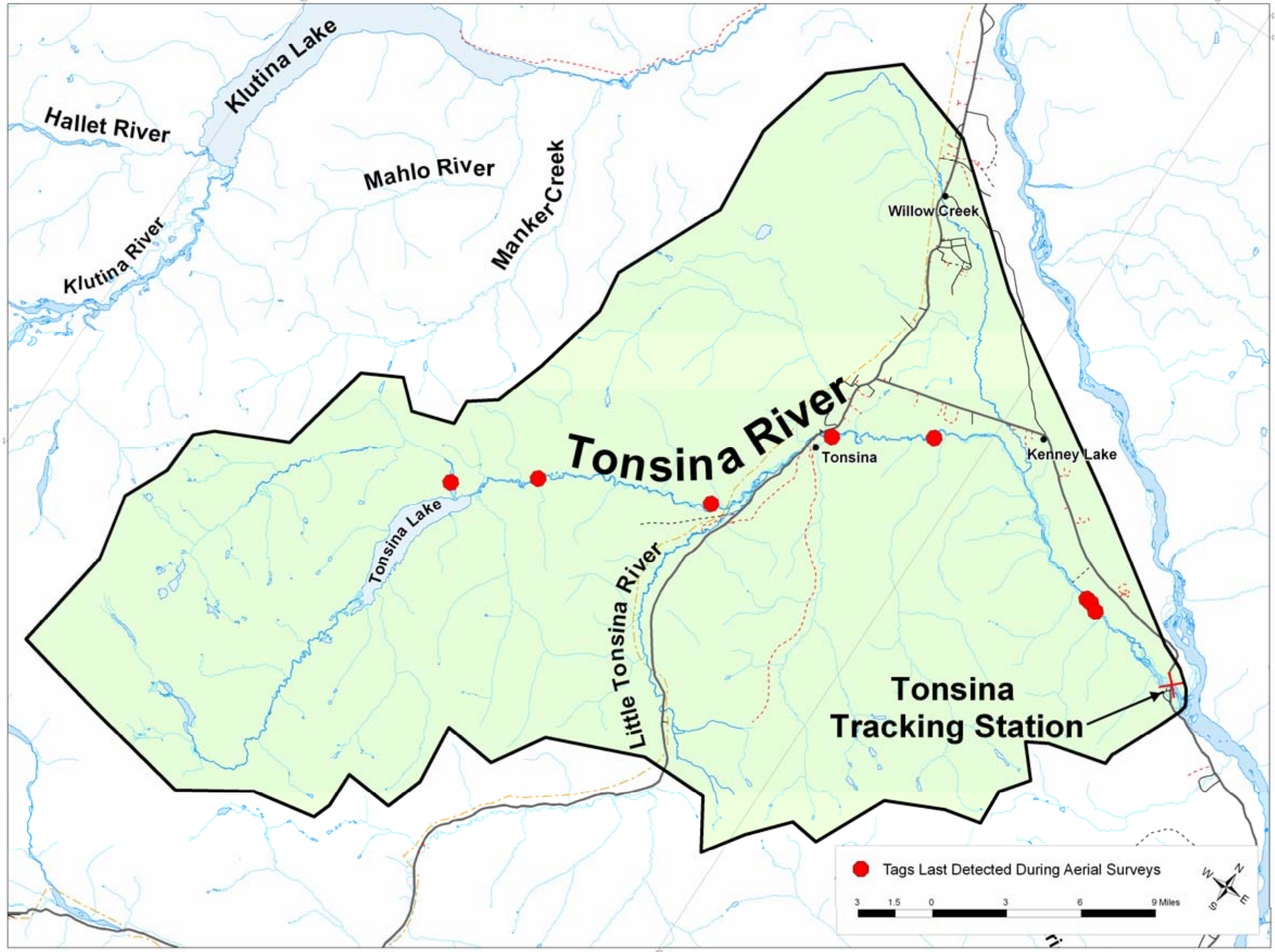


Figure 9. Map of the Tonsina River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

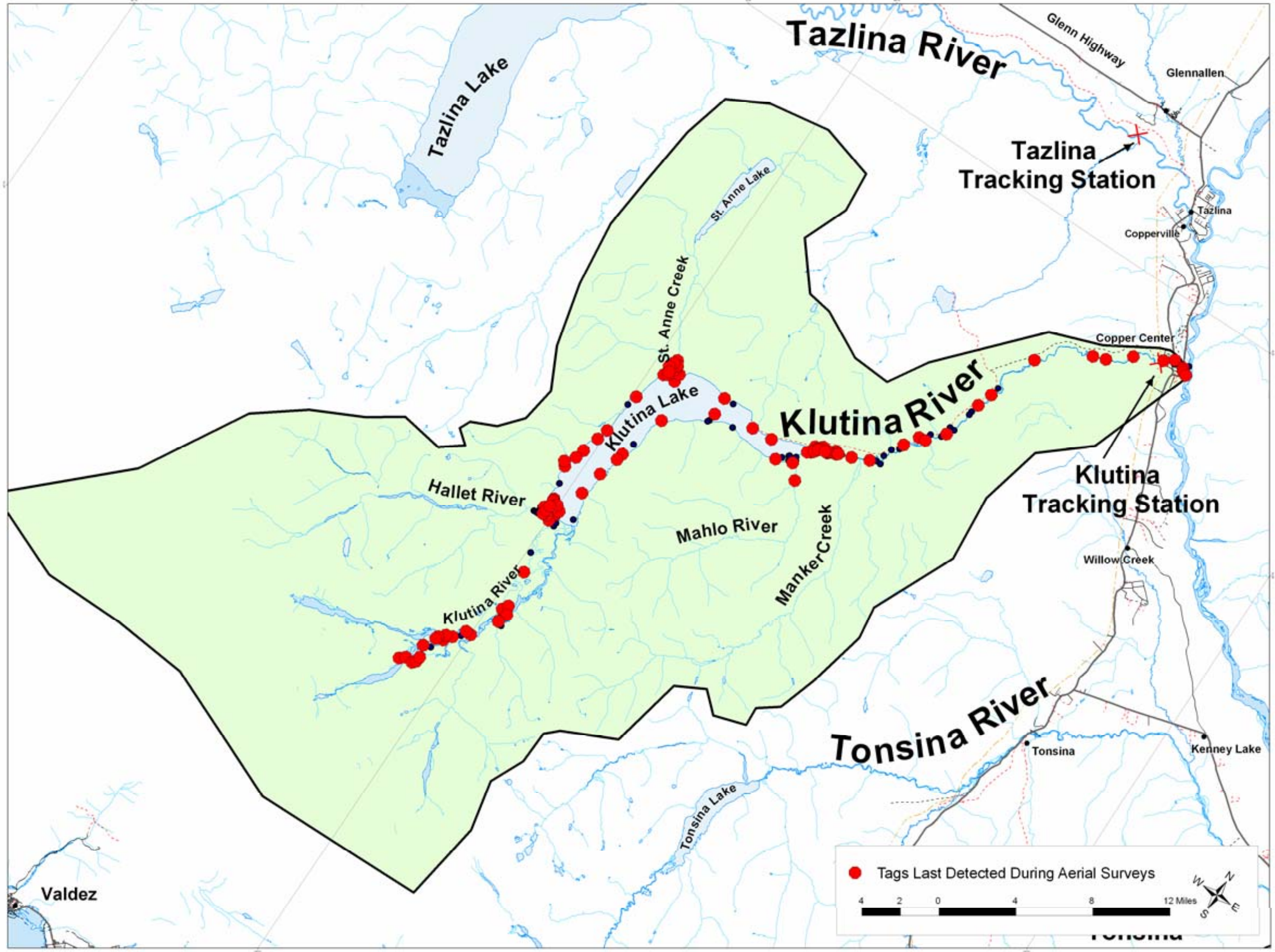


Figure10. Map of the Klutina River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

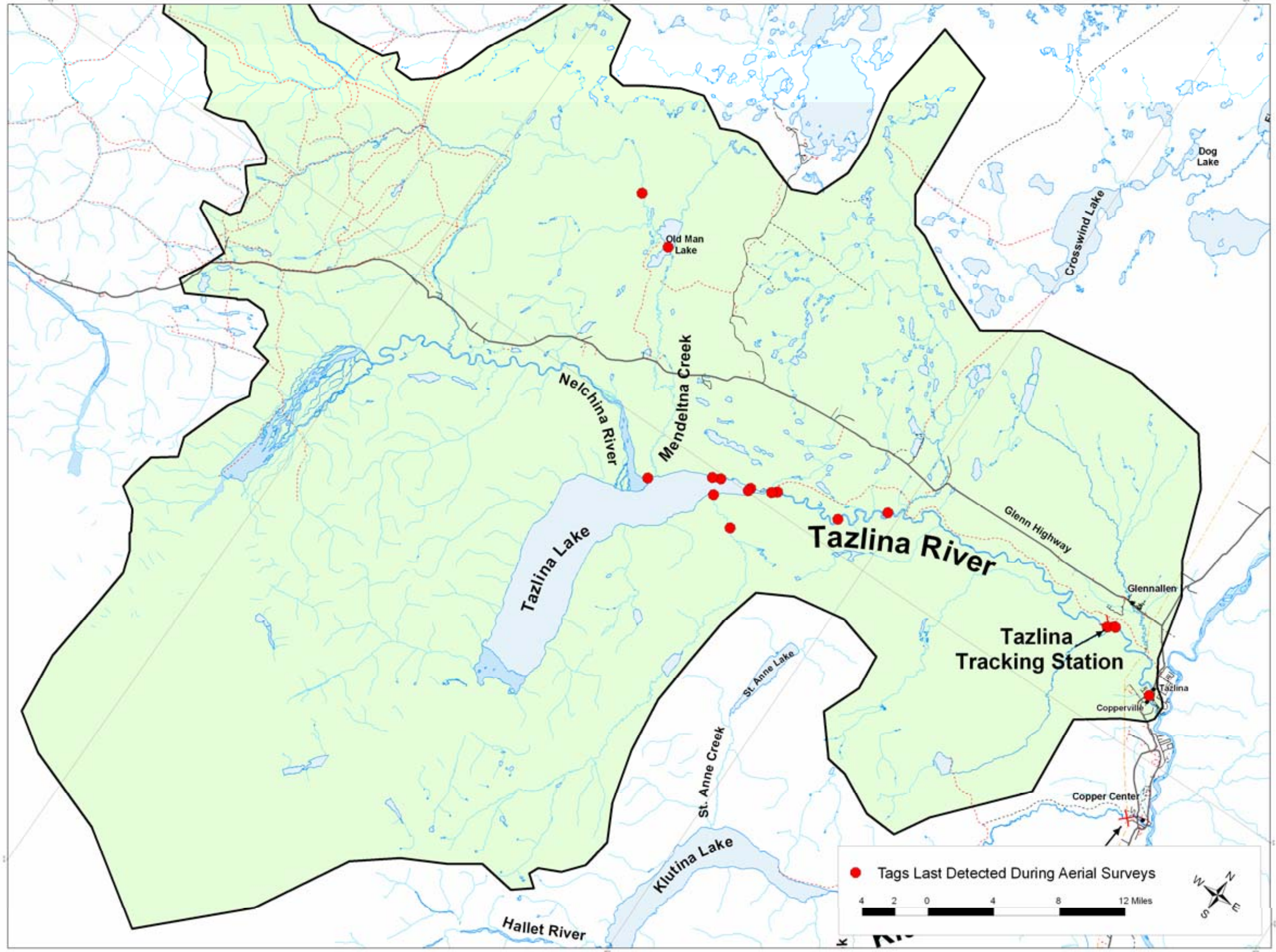


Figure11. Map of the Tazlina River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

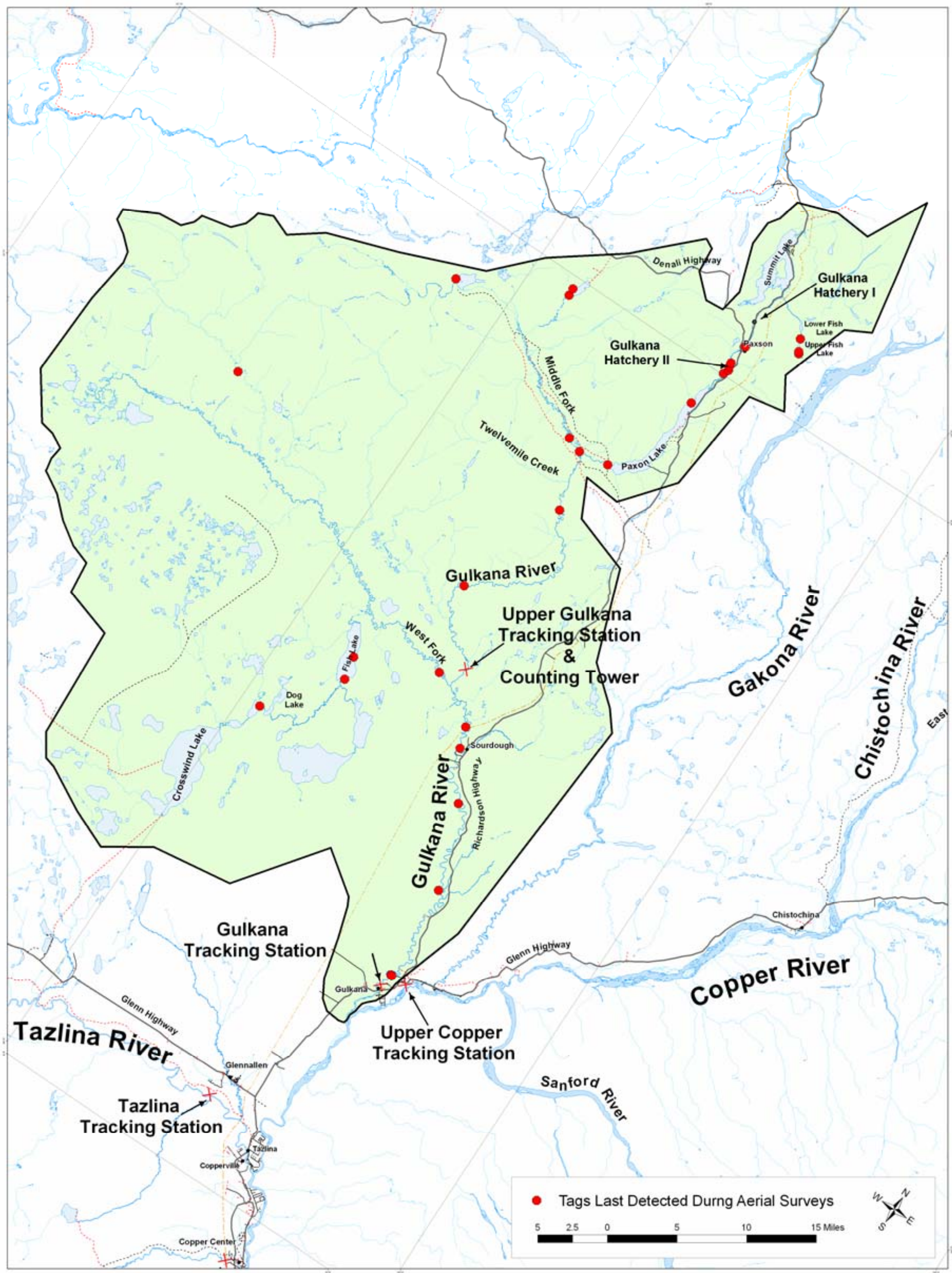


Figure12. Map of the Gulkana River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

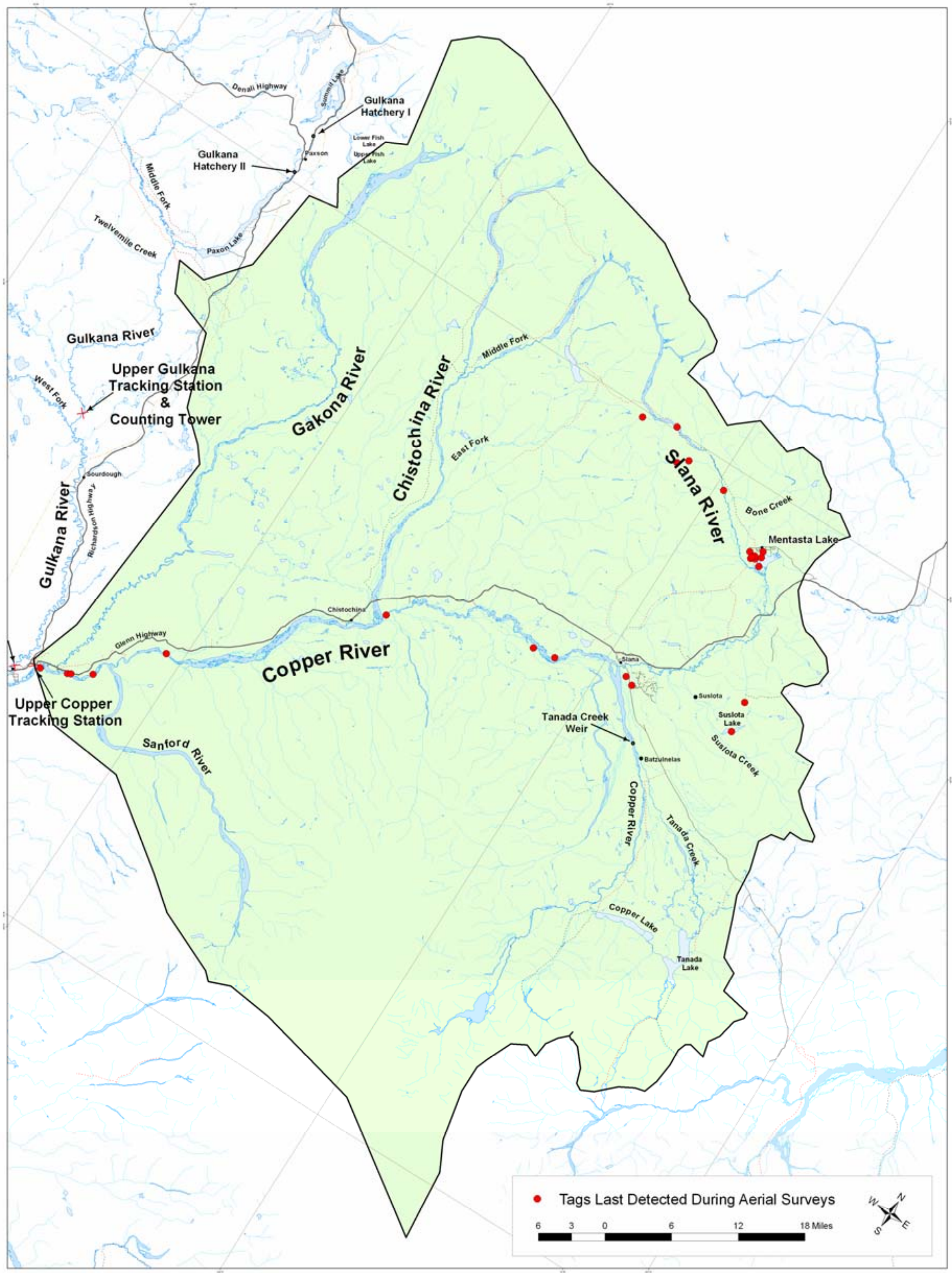


Figure13. Map of the Upper Copper River drainage showing the location where radio-tagged sockeye salmon were last detected on aerial-tracking surveys, 2006.

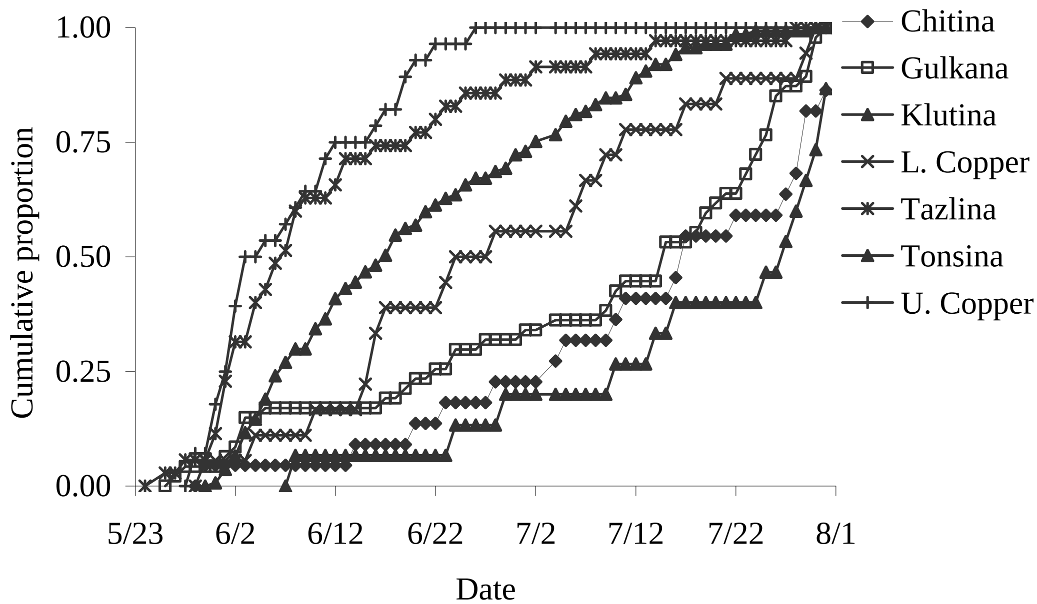


Figure 14. Run-timing patterns of sockeye salmon at the capture site for the major stocks in the Copper River, 2006.

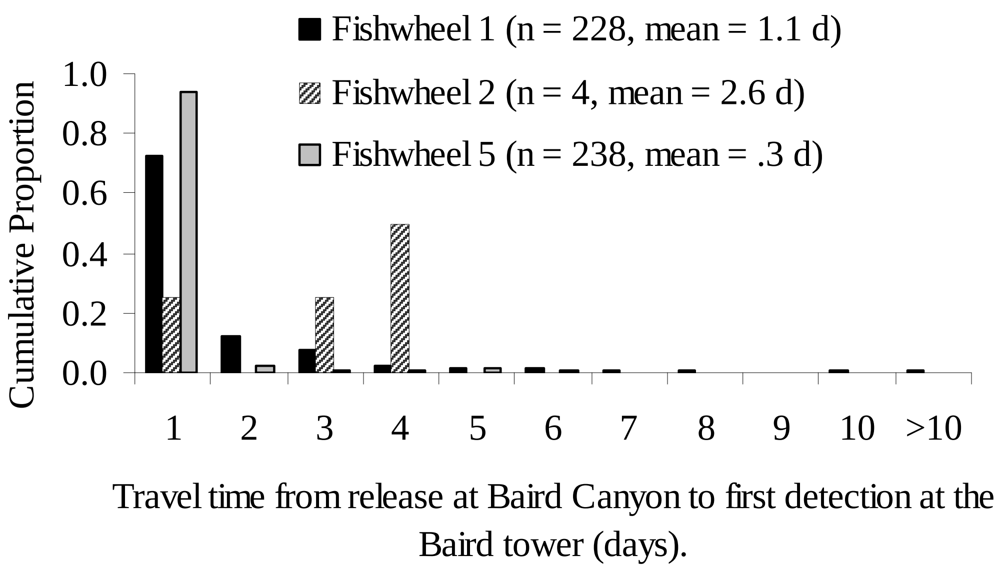


Figure 15. Travel time (d) for radio-tagged sockeye salmon from release at the Baird Canyon fishwheels to first detection at the Baird tower, 2006.

TABLES

Table 1. List of possible fates for radio-tagged sockeye salmon on the Copper River, 2006.

Fate	Description
Radio Failure	Never recorded swimming upstream of the Baird tracking station.
Chitina Subdistrict Fishery Mortality	Harvested in the Chitina Subdistrict.
Glennallen Subdistrict Fishery Mortality	Harvested in the Glennallen Subdistrict.
Sport Fishery Mortality	Harvested in one of the sport fisheries.
Unknown Fishery Mortality	Harvested, but the specific location of harvest was unknown.
Spawner [a]	Entered a spawning tributary of the Copper River or was detected on two or more aerial-tracking surveys in the vicinity of a known spawning area close to the mainstem in the lower Copper River (e.g., Tiekel River or Swan Lakes).
Upstream migrant	Migrated upstream of the Baird station, but was never reported as harvested, and was either never detected after passing the Baird station, or was only detected in the mainstem Copper River between the Baird and Upper Copper stations but not near a known spawning area.

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

Table 2. Fates of sockeye salmon that were radio-tagged at the Baird Canyon fishwheels on the Copper River, 2006.

Fate[a]	Fishwheel 1	Fishwheel 2	Fishwheel 3	Fishwheel 5	Total
Deployed at Baird Canyon	245	4	0	265	514
Deployed at Canyon Creek			13		13
Radio Failure[b]	7		2	5	14
Chitina Subdistrict	23			30	57
Glennallen Subdistrict	12			10	22
Sport fishery	4			3	7
Unknown fishery	5			5	10
Upstream migrant[c]	49	1	5	63	114
Spawner[d]	148	3	6	151	308

[a] Refer to Table 1 for a description of fates.

[b] Includes 2 radio tags never detected after release and 8 radio tags that were last detected downstream of the tagging site.

[c] Migrated upstream of the Baird station, but was never reported as harvested, and was either never detected after passing the Baird station, or was only detected in the mainstem Copper River between the Baird and Upper Copper stations but not near a known spawning area.

[d] Includes 5 fish harvested in the Klutina sport fishery(1 @ FW1, 2 @ FW 5).

Table 3. Number of radio-tagged sockeye salmon detected at the tracking stations in the Copper River basin, 2006.

		Number of Fish			Detection
		First	Total	Total	Efficiency
Zone #	Location	Detection	Detected	Passed	%
-1	Baird				
10	Baird fishwheels	466	466	500	93.2
20	Lower Haley	23	234	456	51.3
30	O'Brien	3	389	439	88.6
40	Chitina	2	25	25	100.0
50	Copper		380	400	95.0
60	Tonsina		17	17	100.0
70	Klutina		130	137	94.9
80	Tazlina		34	35	97.1
90	Gulkana		44	48	91.7
110	Upper Copper		28	28	100.0
Total		494			

Table 4. Number of radio-tagged fish detected, by area and date, during aerial surveys in the Copper River drainage, 2006.

Zone	Survey Location	27-Jun	28-Jun	25-Jul	27-Jul	30-Jul	23-Aug	27-Aug	28-Aug	Total
5	Copper mainstem - mouth to Baird	7				8		7		22
6	Bremner River	2				3		2		7
7	Tasnuna River	2				1		3		6
15	Copper mainstem - Baird to Lower Haley	68				74		35		177
25	Copper mainstem - Lower Haley to Copper	28				21		18		67
451	Chitina River mainstem	1				8		14		23
452	Lakina River/Long Lake							5		5
453	Tana River	1				2		2		5
55	Copper mainstem - Copper to Upper Copper	60	1	4		37		38		140
65	Tonsina River								8	8
751	Lower Klutina mainstem		12	10		5		4	27	58
752	Klutina Lake		9	32					21	62
753	Mahlo Creek			2					2	4
754	St. Anne Creek			9					14	23
755	Upper Klutina mainstem		2	19					25	46
851	Tazlina mainstem/Lake		6		6				8	20
852	Mendeltna Creek				1				2	3
951	Lower Gulkana		2		2		6			10
952	Upper Gulkana		4		9		15			28
97	West Fork Gulkana River				1		5			6
115	Copper mainstem - u/s Upper Copper station		2	8			5			15
116	Gakona River									
1181	Slana River		8	7			7			22
1182	Suslota Creek/Lake			1			1			2
1183	Mentasta Lake			8			5			13
119	Tanada Creek									
Total		169	46	100	19	159	44	128	107	772

Table 5. Distribution of sockeye salmon in major spawning drainages in the Copper River, 2006.

Spawning Tributary	Number of Tags	Proportion	SE	95% Confidence Limits Lower	Upper
Lower Copper	18	0.058	0.01	0.04	0.08
Chitina River	25	0.081	0.02	0.06	0.11
Tonsina River	17	0.055	0.01	0.04	0.08
Klutina River	137	0.445	0.03	0.39	0.50
Tazlina River	35	0.114	0.02	0.08	0.14
Gulkana River	48	0.156	0.02	0.12	0.19
Upper Copper	28	0.091	0.02	0.06	0.12
Total	308	1.000			

Table 6. Distribution of radio-tagged sockeye salmon (spawners only) in the Copper River drainage, 2006.

Drainage	Zone	Tributary	Number of fish	Proportion of total
Lower Copper	6	Bremner River	5	0.016
	7	Tasnuna River	4	0.013
	151	Tiekel River/Swan Lakes	9	0.029
		Subtotal	18	0.058
Chitina	40	Chitina tracking station	2	0.006
	451	Chitina River mainstem	16	0.052
	452	Lakina River/Long Lake	5	0.016
	453	Tana River	2	0.006
		Subtotal	25	0.081
Tonsina	60	Tonsina tracking station	9	0.029
	65	Tonsina River	8	0.026
		Subtotal	17	0.055
Klutina	70	Klutina tracking station	20	0.065
	751	Lower Klutina mainstem	29	0.094
	752	Klutina Lake	33	0.107
	753	Mahlo Creek	3	0.010
	754	St. Anne Creek	18	0.058
	755	Upper Klutina mainstem	29	0.094
	159	Klutina sport fishery	5	0.016
		Subtotal	137	0.445
Tazlina	80	Tazlina tracking station	21	0.068
	851	Tazlina mainstem/Lake	12	0.039
	852	Mendeltna Creek	2	0.006
		Subtotal	35	0.114
Gulkana	90	Gulkana tracking station	19	0.062
	951	Lower Gulkana	4	0.013
	952	Upper Gulkana	17	0.055
	97	West Fork Gulkana River	8	0.026
		Subtotal	48	0.156
Upper Copper	110	Upper Copper tracking station	5	0.016
	115	Copper River mainstem	6	0.019
	116	Gakona River	0	0.000
	1181	Slana River	8	0.026
	1182	Suslota Creek/Lake	1	0.003
	1183	Mentasta Lake	8	0.026
	119	Tanada Creek	0	0.000
		Subtotal	28	0.091

Table 7. Run-timing statistics past the capture site at Baird Canyon of the major sockeye salmon spawning stocks in the Copper River, 2006.

	Duration			Date of Passage	
Spawning Stock	Start	End	Total (d)	Mean	SE
Lower Mainstem	29-May	29-Jul	61	28-Jun	17.7
Chitina	29-May	31-Jul	63	13-Jul	17.6
Tonsina	7-Jun	31-Jul	54	17-Jul	16.0
Klutina	30-May	29-Jul	60	20-Jun	15.2
Tazlina	24-May	27-Jul	64	11-Jun	14.1
Gulkana	26-May	30-Jul	65	7-Jul	20.5
Upper Copper	28-May	25-Jun	28	7-Jun	8.0

Table 8. Mean date of passage and duration of run past the tagging site at Baird Canyon for major sockeye salmon spawning stocks in the Copper River, 2005-06.

	Duration (d)		Mean Date of Passage	
Spawning Stock	2005	2006	2005	2006
Lower Mainstem	46	61	6-Jul	28-Jun
Chitina	68	63	30-Jun	13-Jul
Tonsina	56	54	13-Jul	17-Jul
Klutina	75	60	13-Jun	20-Jun
Tazlina	52	64	31-May	11-Jun
Gulkana	73	65	4-Jul	7-Jul
Upper Copper	51	28	2-Jun	7-Jun

Table 9. Travel time (d) and migration speed (km/d) of radio-tagged sockeye salmon detected at fixed-station receivers of reported harvested on the Copper River, 2006.

Tracking Stations	Dist.	Travel Time (d)[a]			Migration Speed (km/d)			Sample
From - to	(rkm)	Min	Max	Mean	Min	Max	Mean	size(n)[b]
From Baird to -								
Lower Haley	89	3.5	29.6	9.7	3.0	25.3	9.2	204
Chitina	106	4.3	31.0	13.4	3.4	24.5	7.9	309
Copper	104	4.7	31.6	13.7	3.3	22.3	7.6	305
Tonsina	125	5.5	36.1	15.7	3.5	22.8	7.9	276
Klutina	181	9.7	34.3	19.8	5.3	18.7	9.1	129
Tazlina	206	8.3	50.4	18.0	4.1	24.9	11.5	43
Gulkana	225	9.9	43.3	23.1	5.2	22.8	9.7	76
Upper Copper	226	9.9	42.2	17.1	5.4	22.9	13.2	33
Chitina Harvest		4.5	32.5	14.2				49
Glennallen Harvest		6.7	51.8	18.8				20
Sport Fishery Harvest		7.4	25.5	16.5				6
From Lower Haley to -								
Chititna	17	0.6	23.6	3.9	0.7	30.1	4.3	164
Copper	15	0.7	24.6	4.3	0.6	20.7	3.5	170
Tonsina	37	1.5	20.7	6.0	1.8	24.5	6.2	157
Klutina	92	5.1	25.6	11.1	3.6	17.9	8.3	72
Tazlina	117	4.7	22.0	9.1	5.3	24.8	12.8	29
Gulkana	136	4.8	19.5	10.5	7.0	28.1	12.9	35
Upper Copper	137	4.8	18.2	9.3	7.5	28.3	14.8	21
Chitina Harvest		0.1	21.7	5.2				28
Glennallen Harvest		3.5	32.7	9.6				9
Sport Fishery Harvest		4.5	10.2	7.4				2

[a] Travel time is measured from the last detection at the first site to the first detection at the second site.
[b] Sample sizes exclude fish that were missing an arrival time at any particular site.

APPENDICES

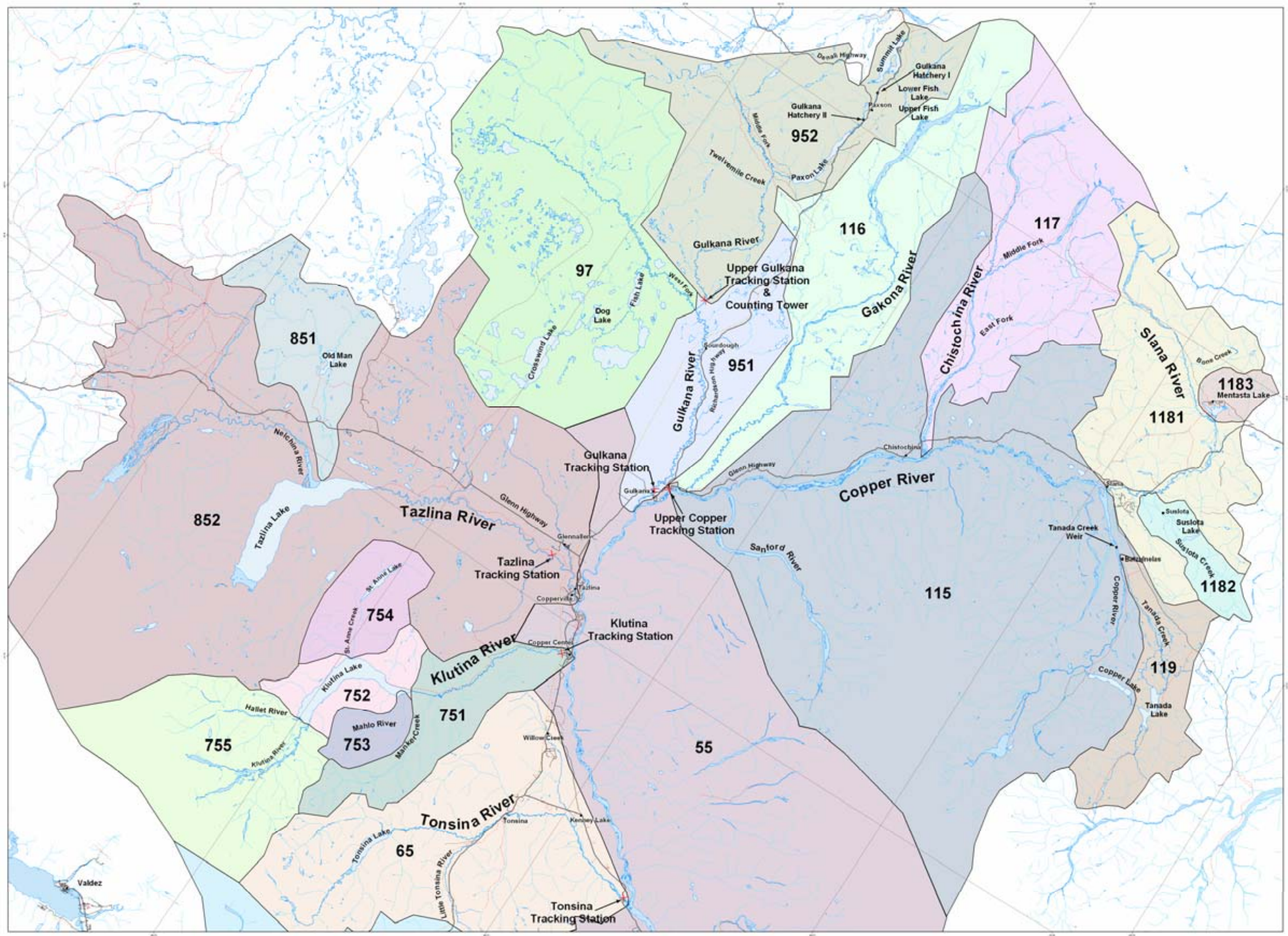
Appendix A.1. Map of the Copper River watershed in Southcentral Alaska showing the location of the Copper River District and the Chitina and Glennallen subdistricts.

Appendix A.2. Location of fishwheels (tag sites), tracking stations, and mobile-tracking zones used in the Copper River sockeye radiotelemetry study, 2006.

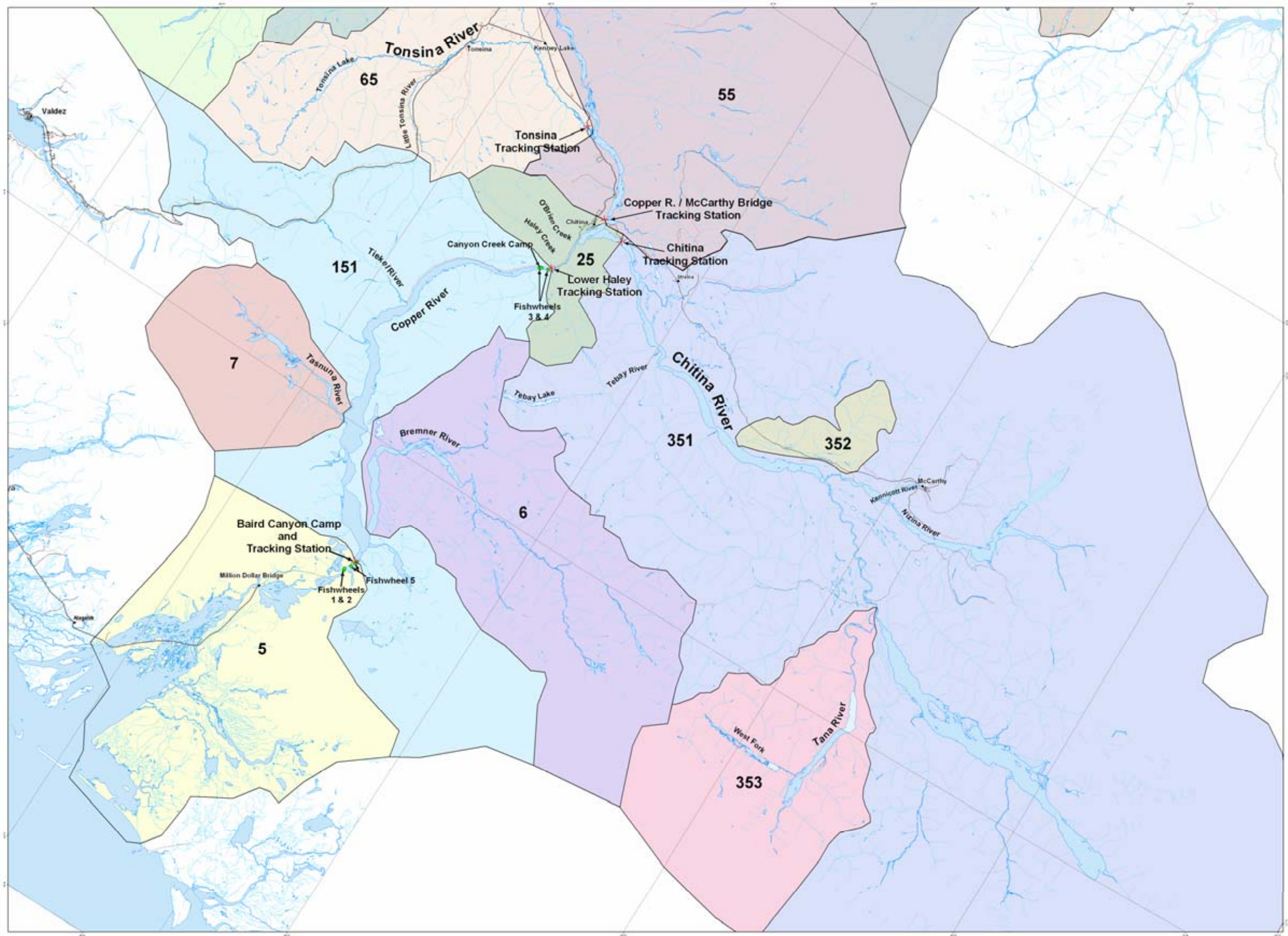
Zone	Sub-zone	Site Name	Description	Lat	Long	rkm
Tag Sites						
-1		Fishwheel 1	East bank of Baird Canyon	60.776	144.521	69
-2		Fishwheel 2	West bank of Baird Canyon	60.778	144.522	69
-5		Fishwheel 5-1	West bank 1.5 km u/s of Baird Canyon	60.788	144.508	71
-5		Fishwheel 5-2	West bank 1 km u/s of Baird Canyon	60.797	144.501	71
Tracking Stations						
10		Baird	West bank 2 km u/s Baird Canyon	60.799	144.504	72
20		Lower Haley	West bank d/s of Haley Creek	61.412	144.479	161
30		O'Brien	West bank near O'Brien Creek mouth	61.481	144.452	170
40		Chitina	North bank Chitina River near mouth	61.516	144.320	178
50		Copper	Copper River u/s McCarthy Bridge	61.533	144.414	175
60		Tonsina	Tonsina River near the mouth	61.654	144.650	197
70		Klutina	Klutina River near the mouth	61.949	145.332	253
80		Tazlina	Tazlina River near the mouth	62.083	145.564	278
90		Gulkana	Gulkana River near the mouth	62.276	145.383	296
110		Upper Copper	Copper River d/s Gakona River mouth	62.290	145.336	298
Mobile Zones						
5		Copper mainstem - mouth to Baird				
6		Bremner River				
7		Tasnuna River				
15		Copper mainstem - Baird to Lower Haley				
	151	Copper mainstem spawning areas (Tiekel R/Swan Lk)				
25		Copper mainstem - Lower Haley to Copper				
35		Chitina River				
	351	Chitina River mainstem				
	352	Lakina River/Long Lake				
	353	Tana River				
55		Copper mainstem - Copper to Upper Copper				
65		Tonsina River				
75		Klutina River				
	751	Lower Klutina mainstem				
	752	Klutina Lake				
	753	Mahlo Creek				
	754	St. Anne Creek				
	755	Upper Klutina mainstem				
85		Tazlina River				

Appendix A.2. Location of fishwheels (tag sites), tracking stations, and mobile-tracking zones used in the Copper River sockeye radiotelemetry study, 2006.

Zone	Sub-zone	Site Name	Description	Lat	Long	rkm
	851	Mendeltna Creek				
	852	Tazlina mainstem/Lake				
97		West Fork Gulkana River				
95		Gulkana River - mainstem and Middle Fork				
	951	Lower Gulkana				
	952	Upper Gulkana				
115		Copper mainstem - u/s Upper Copper station				
116		Gakona River				
117		Chistochina River				
118		Slana River				
	1181	Slana River				
	1182	Suslota Creek/Lake				
	1183	Mentasta Lake				
119		Tanada Creek				
Recovery Zones						
150		Unknown	Harvested, but location was unknown			
153		CSS	Harvested in the Chitina Subdistrict			
156		GSS	Harvested in the Glennallen Subdistrict			
159		Sport	Harvested in an in-river sport fishery			



Appendix A.3. Map of the upper portion of the Copper River drainage showing the location of the zones and sub-zones used to determine the final fate of radio-tagged sockeye salmon, 2006.



Appendix A.3. Map of the lower portion of the Copper River drainage showing the location of the zones and sub-zones used to determine the final fate of radio-tagged sockeye salmon, 2006.

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River drainage, 2006.

Date	Baird	L.Haley	O'Brien	Chitina	Copper	Tonsina	Klutina	Tazlina	Gulkana	U. Copper	Comment
10-May		A	A	A	A	A	A	A	A	A	
11-May											
12-May											
13-May											
14-May											
15-May											
16-May											
17-May											
18-May											
19-May											
20-May											
21-May											
22-May											
23-May	A/FD										
24-May											
25-May											
26-May											
27-May											
28-May											
29-May											
30-May											
31-May											
1-Jun		FD									
2-Jun			FD	FD	FD						
3-Jun						FD					
4-Jun											
5-Jun											
6-Jun								FD			
7-Jun											
8-Jun										FD	
9-Jun									FD		
10-Jun											
11-Jun											
12-Jun							FD				

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River drainage, 2006.

Date	Baird	L.Haley	O'Brien	Chitina	Copper	Tonsina	Klutina	Tazlina	Gulkana	U. Copper	Comment
13-Jun											
14-Jun											
15-Jun			D			D	D	D	D	D	
16-Jun	D	D		D	D						
17-Jun											
18-Jun											
19-Jun											
20-Jun											
21-Jun		NO									
22-Jun		NO									
23-Jun		NO									
24-Jun		NO									
25-Jun		NO									
26-Jun	D	D	D	D	D						LH memory full on 21-June
27-Jun						D	D	D			
28-Jun											
29-Jun											
30-Jun											
1-Jul											
2-Jul											
3-Jul	D										
4-Jul											
5-Jul											
6-Jul		D	D		D	D	D		D	D	
7-Jul											
8-Jul											
9-Jul											
10-Jul								D			
11-Jul											
12-Jul											
13-Jul											
14-Jul		D									

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River Drainage, 2006.

Date	Baird	L.Haley	O'Brien	Chitina	Copper	Tonsina	Klutina	Tazlina	Gulkana	U. Copper	Comment
15-Jul	D										
16-Jul									D		Lots of noise on freq 683
17-Jul											
18-Jul											
19-Jul											
20-Jul			D			D	D	D	D	D	
21-Jul	D	D		D	D						
22-Jul											
23-Jul	D										
24-Jul											
25-Jul											
26-Jul											
27-Jul											
28-Jul											
29-Jul											
30-Jul											
31-Jul											
1-Aug	D										
2-Aug											
3-Aug		D									
4-Aug											
5-Aug											
6-Aug											
7-Aug			D	D	D	D	D				
8-Aug								D	D	D	
9-Aug											
10-Aug											
11-Aug											
12-Aug	D/S										
13-Aug											
14-Aug											
15-Aug											

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River Drainage, 2006.

Date	Baird	L.Haley	O'Brien	Chitina	Copper	Tonsina	Klutina	Tazlina	Gulkana	U. Copper	Comment
16-Aug											
17-Aug											
18-Aug											
19-Aug											
20-Aug											
21-Aug										D	
22-Aug				D	D		D	D			
23-Aug											
24-Aug											
25-Aug											
26-Aug											
27-Aug											
28-Aug											
29-Aug											
30-Aug											
31-Aug											
1-Sep											
2-Sep											
3-Sep											
4-Sep											
5-Sep			D			D		D	D	D	
6-Sep											
7-Sep											
8-Sep											
9-Sep											
10-Sep											
11-Sep											
12-Sep											
13-Sep											
14-Sep											
15-Sep	D		D			D	D	D	D	D	

A = Activate; D = Download; FD = First Detection; NO = Not Operational; S = Shutdown

Appendix A.6. List of radio tags recovered in inriver fisheries in the Copper River basin, 2006.

Freq.	Code	Recovery Date	Capture Method	Recovery	Location
148.423	4		Fishwheel	Glennallen	
148.423	8		Fishwheel	Glennallen	
148.423	23				
148.445	6		Sport	Klutina River	
148.445	13	30-Jul	Dipnet	Chitina	
148.445	14	29-Jun	Dipnet	Chitina	
148.445	20	23-Jun	Dipnet	Chitina	
148.463	12	8-Aug	Dipnet	Chitina	
148.463	13	28-Jul	Dipnet	Chitina	
148.463	21	14-Sep	Found	Tasnuna	
148.483	4	19-Jul	Dipnet	Chitina	
148.483	16	22-Jun	Dipnet	Chitina	
148.483	20	21-Jun	Dipnet	Chitina	
148.483	24				
148.483	26	10-Jun	Fishwheel	Glennallen	Downstream of Klutina R. Mouth
148.505	2	4-Jul	Fishwheel	Glennallen	Wolf Point
148.505	21	21-Jul	Dipnet	Chitina	
148.524	1	26-Jun	Dipnet	Glennallen	3/4 mile below Klutina R. mouth
148.524	14	19-Jun	Dipnet	Chitina	Below Wood Canyon
148.524	18	2-Aug			
148.545	11	14-Aug	Dipnet	Chitina	
148.545	13	30-Jul	Dipnet	Chitina	1/4 mile upstream of Haley Creek
148.545	14	22-Jun	Dipnet	Chitina	
148.545	15	29-Jun	Fishwheel	Glennallen	400 yards above Klutina R. mouth
148.545	18				
148.545	24	20-Jul	Fishwheel	Glennallen	
148.564	0	10-Jun	Dipnet	Chitina	
148.564	2		Fishwheel	Glennallen	
148.564	4	29-Jun	Dipnet	Chitina	
148.564	15	20-Jun	Sport	Copper Rivere	
148.564	21	27-Jul	Dipnet	Chitina	
148.586	2	24-Jun	Dipnet	Chitina	
148.586	4	7-Jul	Dipnet	Chitina	
148.586	18				Mile 6 Copper R. railroad bed
148.586	23				
148.586	24	19-Jul	Dipnet	Chitina	
148.605	1		Dipnet	Chitina	
148.605	5	21-Jul	Fishwheel	Glennallen	
148.605	8	6-Aug			Found in bushes
148.605	12	1-Aug	Fishwheel	Glennallen	
148.605	16	19-Jun	Dipnet	Chitina	

Appendix A.6. List of radio tags recovered in inriver fisheries in the Copper River basin, 2006.

Freq.	Code	Recovery Date	Capture Method	Recovery	Location
148.605	18	1-Aug	Sport	Klutina River	
148.605	75	12-Jun	Sport	Glennallen	Bridge above Chitina
148.625	3				
148.625	16	3-Jul	Sport	Klutina River	
148.625	18				
148.625	20	16-Jun	Dipnet	Chitina	
148.654	6	22-Jun	Dipnet	Chitina	
148.654	12	4-Aug	Dipnet	Chitina	
148.654	13	28-Jul	Dipnet	Chitina	
148.654	14	18-Jun	Dipnet	Chitina	
148.654	17	28-Jun	Fishwheel	Glennallen	Copper Center
148.654	20	18-Jun	Dipnet	Chitina	4 mile below Chitina
148.654	22	27-Jul	Dipnet	Chitina	
148.683	8	4-Aug	Fishwheel	Glennallen	
148.683	11	18-Aug	Dipnet	Chitina	
148.683	12	26-Jul	Dipnet	Chitina	Canyon below Chitina
148.683	18	28-Jul	Dipnet	Chitina	
148.714	5	14-Jul	Dipnet	Chitina	
148.743	1	18-Jul	Found	Glennallen	1/2 mile down stream of Klutina R
148.743	3	12-Jul	Fishwheel	Glennallen	
148.743	17	24-Jun	Dipnet	Chitina	Neat O'Brien Creek
148.773	2	1-Jul	Fishwheel	Glennallen	
148.773	3	29-Jun	Dipnet	Chitina	
148.773	13	22-Jul	Dipnet	Chitina	
148.773	17	25-Jun	Dipnet	Chitina	
148.773	19	26-Jul	Dipnet	Chitina	
148.773	22	19-Jul	Fishwheel	Glennallen	
148.773	24	18-Jul	Fishwheel	Glennallen	
148.773	75		Dipnet	Chitina	
148.804	14				
148.804	21	3-Aug	Dipnet	Chitina	
148.833	0	11-Jun	Fishwheel	Glennallen	
148.833	6	2-Jul	Sport	Klutina River	
148.833	12	31-Jul	Dipnet	Chitina	Near Haley Creek
148.833	17	30-Jun	Sport	Klutina River	Lower Klutina
148.833	24	29-Jul	Fishwheel	Glennallen	
148.864	15	2-Jul	Dipnet	Chitina	
148.864	16	17-Jun			
148.864	17	23-Jun	Dipnet	Chitina	By Haley Creek

Freq.	Code	Recovery Date	Capture Method	Recovery	Location
148.864	17	23-Jun	Dipnet	Chitina	By Haley Creek
148.864	24	24-Jul	Dipnet	Chitina	
148.893	0	10-Jun	Dipnet	Chitina	
148.893	3	20-Jul	Dipnet	Chitina	
148.893	6	12-Jul	Fishwheel	Glennallen	
148.893	9	2-Aug			
148.893	13	27-Jul	Dipnet	Chitina	
148.893	20	14-Jun	Dipnet	Chitina	
148.893	24	8-Aug	Fishwheel	Glennallen	

PHOTO PLATES

Photo 1. Fishwheel 2 operating on the west bank of the Copper River at Baird Canyon (rkm 69), 2006.

Photo 2. Fishwheel 5 operating on the west bank of the Copper River approximately 1.5 km upstream of Baird Canyon (rkm 71), 2006.

Photo 3. Inserting a Model F1840 ATS radio transmitter into an adult sockeye salmon, 2006.

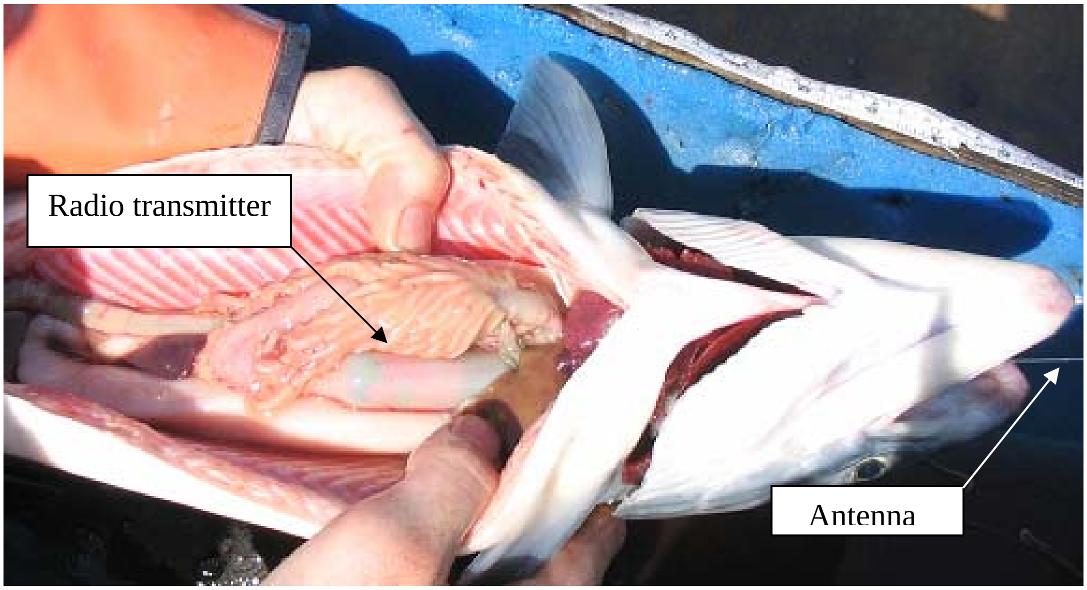


Photo 4. The transmitter is located in the stomach and the whip antenna is shown protruding from the mouth, 2006.

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