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Spawning Distribution and Run Timing of Copper River Sockeye Salmon, 2007 Final Report

Final Report for Study 05-501

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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 2007 field season and synthesizes results from the 2005-2007 studies. 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 profiles of sockeye salmon in the Copper River at the point of capture in Baird Canyon. In 2007 the largest proportion of spawners returned to the Klutina River drainage (0.54), followed by the Tazlina (0.10), Gulkana (0.09), Lower Copper (0.09), Upper Copper (0.07), Chitina (0.05), and Tonsina (0.05) rivers. Run-timing patterns at the capture site varied among stocks in 2007. The mean date of passage at Baird Canyon varied from 5 June for the Tazlina stock to 22 July for the Tonsina stock.

Spawning distributions varied significantly over the three-year study period (χ^2 = 85.6, df = 12, P < 0.001). The largest proportion of spawners returned to the Klutina River in all three years (0.35 in 2005, 0.45 in 2006, and 0.54 in 2007). Contributions by the remaining six spawning tributaries included: Lower Copper (0.06-0.07), Chitina (0.05-0.08), Tonsina (0.05-0.06), Tazlina (0.10-0.12), Gulkana (0.07-0.16), and Upper Copper (0.07-0.28) rivers. Run timing patterns followed similar trends across years; fish returning to rivers in the upper reaches of the Copper River tended to have earlier run timing than those returning to the lower reaches of the Copper River. Mean date of passage at Baird Canyon ranged from 31 May for the Tazlina River (2005) to 22 July for the Tonsina River (2007).

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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), that target a mixture of species and stocks with inter-annual variation in abundance and run timing. Management is further complicated by difficulties in estimating salmon abundance due to the physical characteristics of the drainage, the inability to apportion fish counts to species at the Miles Lake sonar project site, and limited or dated information on stock-specific run-timing. As a result, distribution and abundance of Copper River sockeye salmon were identified as high priority information needs for Federal subsistence management.

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 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 926,438 salmon passed the Miles Lake sonar site between 21 May and 4 August 2007.

Three major stock components of sockeye salmon return to the Copper River each year (Ashe and Taube 2002). The Upper Copper River wild stock is the most abundant component and consists of both early and late runs that 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 enhanced sockeye salmon is the second component and is produced from the Gulkana Hatchery. Run timing of the second component overlaps that of the Upper Copper River components late run. Finally, Lower delta stocks, make up the third component, and 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 gillnet 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 2007, 1,899,635 sockeye salmon were harvested, (ADF&G 2007). This was the third largest harvest in the past 117 years, and was surpassed only by the 1996 and 1997 harvests of 2,356,365 and 2,955,431, respectively.

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 (Appendix A.1). 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 for the Copper River based on mark-recapture experiments done from 1967 to 1972. However, these recoveries were obtained from non-systematic sampling of tributary stocks. Sockeye salmon spawning in areas or at times where they were difficult or impossible to physically recover were not systematically sampled. For example, sockeye salmon 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 sockeye salmon 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, while run timing at Baird Canyon had to be inferred from a limited number of 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. This year (2007) was the conclusion of a three-year study to estimate the spawning distribution and run timing of Copper River sockeye salmon stocks.

Objectives

Objectives for the 2007 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 radiotagged in 2007 at three fishwheels located in Baird Canyon (rkm 69) and tracked throughout the basin using a combination of fixed tracking stations, aerial, and boat-tracking surveys (Figure 1). This project was integrated with two other Monitoring Program projects being conducted by the Native Village of Eyak (NVE): 1) project 04-503 that estimated the annual timing and abundance of Chinook salmon *O. tshawytscha*; and 2) project 06-502 that estimated 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

Adult sockeye salmon were caught for tagging using three live-capture fishwheels that operated on both banks of the mainstem Copper River at Baird Canyon (rkm 69-71) in 2007. 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).

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 (van den Broek et al. 2008). 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 2007. 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 radiotagged 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 radiotagged. 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 radiotagged. 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 radiotagged 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 uniquely numbered pink t-bar tag, printed with the text "radio tag in stomach, pls release fish or return radio tag to NVE PO Box 1388 CDV AK 99574" (Hallprint Pty. Ltd, South Australia, Photo 5).

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 148.003 to 148.385 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

Radiotagged 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 radiotagged 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. The sixth, seventh, eighth, and ninth tracking stations were placed near the mouths of the Tonsina, Klutina, Tazlina, and Gulkana rivers, respectively. 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 radiotagged sockeye salmon entering the Upper Copper River drainage upstream of the Gulkana River.

Aerial-tracking Surveys

The distribution of radiotagged sockeye salmon was further determined by fixed-wing (Piper Cub) aerial-tracking surveys. The purpose of these surveys was to locate tagged sockeye salmon in spawning tributaries other than those monitored with tracking stations, 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 2007, 3 boat-tracking surveys were conducted between the Million Dollar Bridge and approximately 4 km upstream of the Chitina/McCarthy Bridge (Figure 1). Data from these surveys were used to determine whether radiotagged 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; or (3) dead or had 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 radiotagged fish detected, the frequency, code, and GPS location was recorded.

Fate of Radiotagged Fish

To facilitate data analysis, all radiotagged 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. Each fate was assigned a zone number (e.g., zone 10 = Baird tracking station) which Telemetry Manager used for data analysis purposes. (Appendix A.2). In order for a fish to be assigned a final fate as a spawner, it had to be: (1) detected on the upstream antenna of a tracking station located near the mouth of a spawning tributary; (2) detected on one or more mobile-tracking surveys of know spawning grounds; or (3) harvested in a known spawning tributary.

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 radiotagged fish migrating into a specific tributary to the total number of radiotagged fish migrating into all spawning tributaries. The proportion of fish that have fate *j* was estimated as:

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

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 (553 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: Upper 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):

$$f_j(t) = \frac{R_{ij}}{\sum_{i}^{days} R_{ij}}, \text{ where:} \tag{2}$$

$f_j(t)$ = 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 radiotagged 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:

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

and the variance of the run timing distribution estimated as:

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

RESULTS

Capture and Tagging

A total of 553 adult sockeye salmon were radiotagged at three fishwheels located on the mainstem Copper River at Baird Canyon from 22 May to 6 August 2007 (Figures 2 and 3; Table 2). Two hundred and thirty seven fish were radiotagged at fishwheel 2 on the east bank, 2 fish were radiotagged at fishwheel 1 on the west bank, and 314 fish were radiotagged at fishwheel 5 on the west bank. The number of radio tags deployed each day varied from 1 (22-26 May) to 20 (4 June).

From 21 May to 4 August 2007, a total of 926,438 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 0.1 to 46.3 fish per hour on the starboard side of fishwheel 2, and from 0.2 to 34.4 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 4.7-m change in stage height of the Copper River at Baird Canyon from 22 May to 21 June 2007.

Lengths of radiotagged sockeye salmon ranged from 355 to 710 mm FL and averaged 589 mm FL (n = 526; Figure 5). Males averaged 607 mm FL (n = 281) and females averaged 569 mm FL (n = 245).

Tracking Stations and Mobile-Tracking Surveys

The Baird tracking station operated from 21 May to 13 August, and the remaining nine tracking stations operated from about mid-May to mid-late September (Appendix A.5). Of the 514 radiotagged fish detected at one or more tracking stations, 511 fish were first detected at the Baird tracking station, 1 fish was first detected during a boat survey, 1 fish was first detected at the Lower Haley tracking station, and 2 fish were first detected at the Copper tracking station (Table 3). Detection efficiencies at the tracking stations ranged from 71% at the Gulkana station to 100% at the Chitina, Tonsina, and Upper Copper stations.

Three aerial-tracking surveys of the Copper River drainage were conducted from 28 June to 17 September and required a total of 14 d to complete (Table 4). The number of radio tags detected during each survey included 215 (55% of tags released by that date) in late June and early July, 306 (58%) in late July, and 217 (39%) in early to mid September.

Three boat surveys of the lower Copper River mainstem were conducted from 9 July to 14 August and required 6 d to complete. The number of radio tags detected during each survey included 90 in early July, 76 in late July, and 83 in mid-August.

Fate of Radiotagged Fish

Spawning Distribution

Of the 553 radiotagged fish released at Baird Canyon, 11 fish (2.0%) were never detected after release, 17 fish (3%) were last detected downstream of the tagging sites during aerial-tracking surveys, and 525 fish (95.0%) were last detected upstream of the tagging sites (Table 2). Of the 525 radiotagged fish that migrated upstream of the tagging sites, 297 fish (56.6%) were designated as spawners (which included 8 harvested fish), 88 fish (16.8%) were harvested, and 148 fish (28.2%) 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 297 radiotagged fish designated as spawners, the largest proportion returned to the Klutina River (54%), followed by the Tazlina (10%), Gulkana (9%), Lower Copper (9%), Upper Copper (7%), Chitina (5%), and Tonsina (5%) Rivers (Figure 6; Table 5). Specific areas with the most returns included: Klutina Lake (43 fish), the Klutina River upstream of the lake (33 fish), the mainstem of the lower Klutina River (26 fish), the Tiekel River and Swan Lakes area (17 fish), and Mahlo Creek (17 fish; Table 6). The locations where radiotagged fish were last detected on aerial-tracking surveys were plotted on maps of each major drainage area (Figures 7-13). Overall spawning distribution throughout the three years of the study (2005-2007) varied each year with the Klutina and Upper Copper exhibiting the largest difference among years (Figure 14, Table 7).

Thirty-two radiotagged fish were reported harvested in the Chitina Subdistrict, 32 fish in the Glennallen Subdistrict, 6 fish in the sport fishery, and 14 fish in unknown fisheries (i.e., the tags were returned with no information; Appendix A.6). In addition, four radiotagged fish were presumed harvested based on their detection history, including 1 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 15). The mean date of passage at the Baird Canyon fishwheels ranged from 5 June for Tazlina stocks to 22 July for Tonsina stocks (Table 8). Upper Copper stocks passed Baird Canyon from 29 May through 8 July, a period of only 40 d. In contrast, the duration of passage for Tazlina (23 May – 1 August) and Klutina (24 May – 1 August) stocks was considerably more protracted at 70 d and 69 d, respectively. Drainage wide run-timing over the three year study (2005-2007) exhibited similar trends among the years (Figures 16 and 17, Table 9).

Travel times of radiotagged fish from release at Baird Canyon to first detection at the Baird tracking station averaged 34 h for fishwheel 2 (n = 222) and 17 h for fishwheel 5 (n = 305; Figure 18). Two radiotagged fish were released at fishwheel 1, of which only one was detected at the Baird station 6.6 d later. This fish was detected at the Tazlina tracking station 7.6 d after being detected at Baird and averaged 27 km/d. 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-seven percent of fish released at fishwheels 2 and 5 were detected at the Baird station within 1 d of release.

Travel times for radiotagged sockeye salmon to migrate between the Baird and Lower Haley tracking stations ranged from 1.9 to 36.6 d and averaged 11.2 d (Table 10). Over this 89-km distance, these travel times corresponded to migration speeds ranging from 2.4 km/d to 46.2 km/d. Mean travel times from the Baird tracking station to harvest in the Chitina Subdistrict, Glennallen Subdistrict, and Klutina sport fisheries were 16.2, 22.4, and 35.8 d, respectively.

DISCUSSION

Capture and Tagging

Two assumptions must be met in order to obtain unbiased estimates of the spawning distribution: (1) handling and radiotagging sockeye salmon did not affect their natural behavior (i.e., final spawning destination); and (2) sockeye salmon were radiotagged 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 radiotagged in 2005, 2006, and 2007 were not adversely affected by the capture, handling, or tagging process. Of the 1,601 radiotagged fish released over the three years, 96.0% were last detected upstream of the tagging site, 2.1% were last detected downstream of the tagging site, and 2.0% were never detected after release (Table 11). Fish last detected downstream of the tagging site may have regurgitated their radio tags or died after release. Additionally, the majority of radiotagged fish migrated upstream of the tagging site within 1 d of being released (Figure 19). 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 radiotagged 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 radiotagged 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 radiotagged 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 radio tags were deployed in proportion to the magnitude and timing of the run (assumption 2). Due to the late break up of river ice in 2006 and 2007, the fishwheels at Baird Canyon did not begin fishing until 23 May and 18 May, respectively. Despite the late start relative to 2005 (10 May), no sockeye salmon were captured or tagged at Baird Canyon until 24 May 2006 and 21 May 2007, indicating that radiotagging began at the onset of the run (Figures 2, 20, and 21). This was also supported by the fact that very few fish were counted at the Miles Lake sonar during these early periods of 2006 (402 fish) and 2007 (123 fish).

Although tagging began close to the onset of the run in all years, it is possible that some early-run stocks may have been under-tagged (Figures 3, 22 and 23). In 2007, Miles Lake sonar counts in late May and early June were substantially higher than historic counts over the same period. From 29 May to 6 June, 247,940 salmon were counted at the Miles Lake sonar site which represented 27% of the total count for the season. Tagging rates at Baird Canyon were increased (maximum of 20 fish per day) in an attempt to compensate for this unexpectedly large pulse of fish; 25% of all radio tags were deployed from 30 May to 7 June. Despite these efforts, it is possible that the spawning proportions of early-run fish were biased low (i.e., they were under-tagged), which may help to explain the relatively low number of radiotagged fish detected in the Tazlina and Upper Copper rivers in 2007. Similar results were observed in the 2006 study (Wade et al. 2007).

Based on counts at the Miles Lake sonar site at the end of July, and sockeye salmon catches at a fishwheel operated near Canyon Creek from mid-August to late September 2006, late-run fish may have been under-tagged in 2005 and 2006 (Wade et al. 2007; Smith et al. 2006). The tagging period at Baird Canyon was extended for an additional six days in 2007; however, substantial numbers of salmon were still being counted at the Miles Lake sonar site on its last day of operation (6,360 fish on 4 August). Of the seven major spawning tributaries, the Tonsina River had the latest mean run timing for all three years of the study. In 2007, 40% (6) of fish designated as Tonsina River spawners were tagged after 31 July. If a substantial number of fish were migrating past Baird Canyon after tagging was terminated for the season, late-run stocks such as the Tonsina River stock may have been under-tagged and their spawning distributions biased low.

In other studies CPUE may be used as an index for tag deployment. As mentioned earlier, CPUE at the fishwheels in this study varied greatly due to changes in stage height. Because of the inconsistent catch rate of fishwheels across time, it is believed that Miles Lake sonar provided the most reliable index for tag deployment.

Fate of Radiotagged Fish

As noted earlier, several modifications of the sampling techniques and protocol were implemented in 2006 and 2007 in order to improve the accuracy of distribution and run timing estimates. These methods included: (1) increasing the number of boat-tracking surveys conducted in the lower Copper River; (2) operating a tracking station on the Copper River near the mouth of O'Brien Creek; (3) applying external secondary tags to radiotagged 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 2005, several fish were last detected in known sockeye spawning habitat of the lower Copper River (Johnson and Weiss 2007). Due to insufficient survey coverage of this area, there was too little data available to justify designating many of these fish as spawners. In 2006 one boat-tracking survey was added to supplement the aerial surveys. Based on the results of the added survey effort in 2006, the effort was continued and increased to a total of 3 boat-tracking surveys in 2007. In addition to the boat-tracking surveys, the new sampling techniques and protocols implemented in 2006 were continued through 2007 (Wade et al. 2006). These were developed to increase the proportion of radiotagged fish designated as spawners or harvested; and thereby decrease the proportion of fish designated as upstream migrants.

The proportion of radiotagged sockeye salmon designated as upstream migrants was greater in 2005 (30%) than in either 2006 (22%) or 2007 (28%; Table 11). The proportion of fish designated as spawners was similar for all three years (57% in 2005, 58% in 2006, and 54% in 2007); while the proportion of fish reported as harvested was less in 2005 (10%) than in either 2006 (18%) or 2007 (17%). These data suggest that adding a tracking station at O'Brien Creek and applying a secondary mark to radiotagged fish helped to increase the number of fish known to be harvested. Although the increase in fish reported harvested was substantial for 2006 and 2007, it is possible that some fish were being harvested but not reported. For example, of the 148 fish designated as upstream migrants in 2007, 43 (29%) were last seen in the personal use CSDN fishery and had tower detections that were characteristic of harvested fish. One of these

fish was detected over 13,000 times at the O'Brien Creek tower from 5 July to 14 September. It is possible that fish such as this one were cleaned and the carcass discarded with the tag still in it. If these 43 fish were considered harvested, then the total number of radiotagged fish harvested would increase to 130, or 24% of the fish radiotagged

Fish returning to the Lower Copper spawning areas are available to be counted at the Miles Lake sonar site but are unavailable to inriver fisheries. Lower Copper spawners may account for a portion of the fish that are believed to go "missing" between the Miles Lake sonar site and the inriver fisheries and upper river spawning escapement. Twenty-two fish (7.4%) were designated as Lower Copper spawners in 2005; all but 3 of these fish were either assigned to the Tasnuna or Bremner rivers. Although more than these 3 fish were detected during aerial surveys on known spawning grounds in the Tiekel River/Swan Lakes region, not enough data was available to designate these other fish as spawners. Lower Copper spawners in 2006 (5.8%) and 2007 (9.0%) included many fish on spawning grounds other than the Tasnuna and Bremner rivers. In addition to the aerial-tracking surveys, boat surveys and stronger tags used in 2006 and 2007 helped to identify fish as spawners in the Tiekel and Uranatina rivers and the Swan Lakes area. It is recommended that boat surveys be conducted in these regions in future studies.

Spawning Distribution

As mentioned earlier, past studies to assess the distribution and run timing of Copper River sockeye salmon have been limited and 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. For all three years of the current study, the largest proportion of spawners returned to the Klutina River (0.35-0.54; Table 7, Figure 14). In 2005, the Upper Copper component made up the second largest proportion of spawners (0.28); however, in 2006 and 2007, this proportion decreased to 0.09 and 0.07, respectively. The remaining spawners were distributed amongst five other tributaries, including the Lower Copper (0.06-0.09), Chitina (0.05-0.08), Tonsina (0.05-0.06), Tazlina (0.10-0.12), and Gulkana (0.07-0.16) rivers.

The spawning distribution for all stocks varied significantly between all three years, ($\chi^2 = 85.6$, df = 12, $P < 0.001$; Table 12). As stated earlier, the Klutina and Upper Copper exhibited the most pronounced variation in distribution. With the Klutina being the largest spawning component of the drainage, increases of 10% per year is a substantial number with respect to the total number of designated spawners. In contrast, the proportion of Upper Copper spawners decreased each year. To date, little data in the form of stream surveys or weir counts is available for the Upper Slana and Mentasta Lake regions. The National Park Service operates a fish weir on Tanada Creek each summer and the number of sockeye salmon counted at the weir has increased each year since 2005. According to the Wrangell-St. Elias National Park and Preserve, the sockeye salmon counts at the weir were 733 in 2005, 7,400 in 2006, and 11,029 in 2007 (M. McCormick, National Park Service, personal communication.).

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 for 2005 through 2007 showed a similar trend (Figures 15, 16 and 17, Table 9). 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. 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 in 2005, 2006 and 2007 than did the Klutina, Tazlina or Upper Copper. 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.

The mean run timing of the Lower Copper was earlier in both 2006 and 2007 then in 2005 by 8 and 12 d, respectively. The Lower Copper component is the only spawning area where the survey methods were significantly modified. With the boat surveys in this region started in 2006 and increased in 2007, more fish located up stream of the Bremner and Tasnuna Rivers were designated as spawners. Based on these two later years, it appears that the upriver components of the Lower Copper tend to have earlier run timing than the fish entering the Bremner and Tasnuna to spawn. The run timing estimates for 2006 and 2007 may be a more accurate representation of the true Lower Copper run timing.

Migration rates (km/d) of radiotagged sockeye salmon showed some variability among stocks and across years (Table 13). These differences may have been caused by the variable and often dramatic changes in stage height observed annually on the Copper River. In addition, in all three years, the three stocks that returned the earliest (Tazlina, Upper Copper and Klutina) exhibited faster migration rates than fish that returned later. This type of upriver migration pattern has also been noted in other studies. For example, Killick (1955) studied sockeye salmon on the Fraser River, BC, and noted variation in migration rates of different spawning stocks in the same drainage and that earlier runs had faster migration rates.

RECOMMENDATIONS FOR FUTURE STUDIES

The following are recommended for future studies:

1) Ensure that early and late-run fish are radiotagged in proportion to the timing and magnitude of the run (i.e., start tagging immediately following ice break-up and continue until all or most fish have passed Baird Canyon);
2) Test all radio tags on the day they are deployed to ensure they are functioning properly;
3) Conduct at least three boat-tracking surveys between Chitina and Miles Lake to 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 radiotagged 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

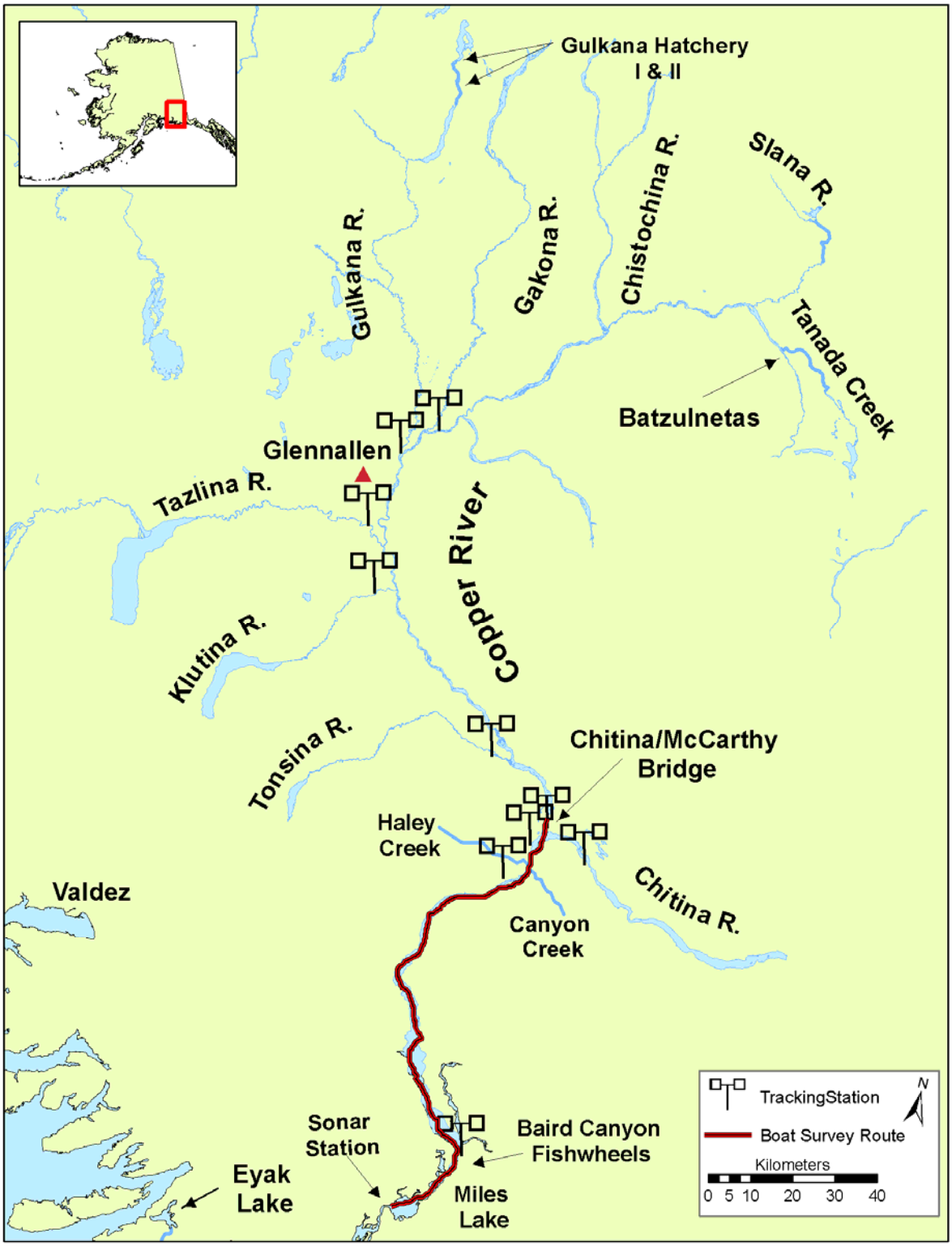


Figure 1. Map of the Copper River watershed in Southcentral Alaska showing the location of the fishwheels used to capture sockeye salmon and ten tracking stations used for tracking radiotagged fish, 2007.

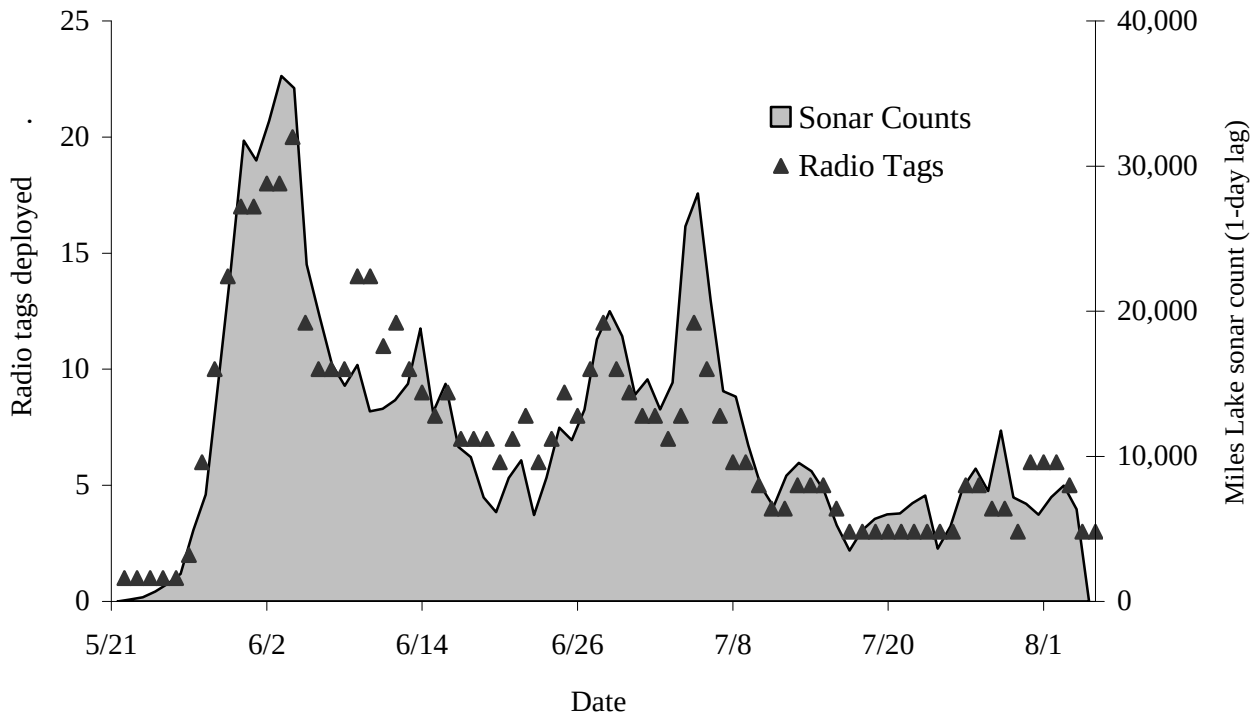


Figure 2. Daily number of sockeye salmon radiotagged at the Baird Canyon fishwheels and the daily number of salmon counted at Miles Lake sonar, 2007.

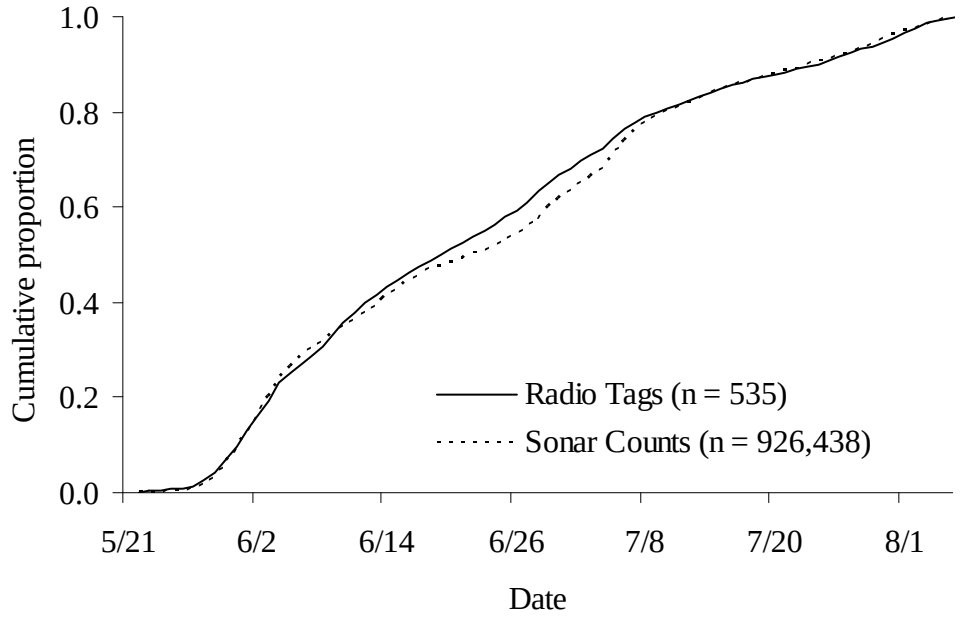


Figure 3. Cumulative proportion of sockeye salmon radiotagged at the Baird Canyon fishwheels and the cumulative proportion of salmon counted at the Miles Lake sonar, 2007.

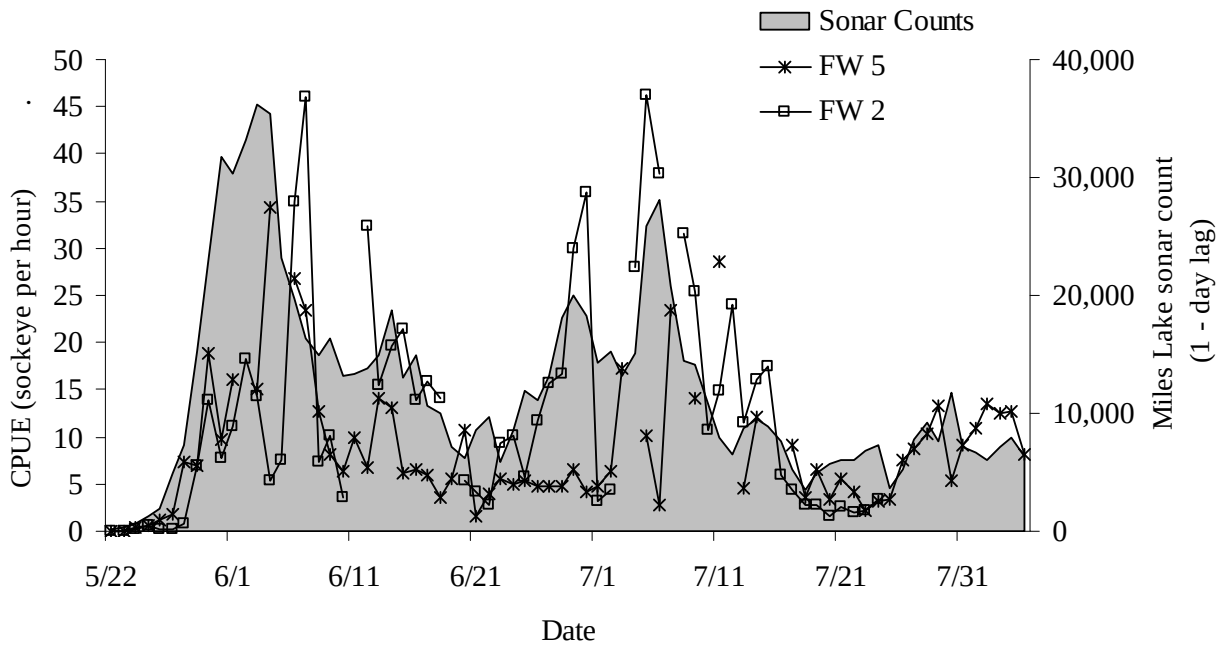


Figure 4. Catch per unit effort (fish per hour) for sockeye salmon captured in the starboard live tanks of fishwheels 2 and 5 at Baird Canyon during periods when escape panels were closed, 2007. Daily counts at the Miles Lake sonar site in 2007 are shown for comparison.

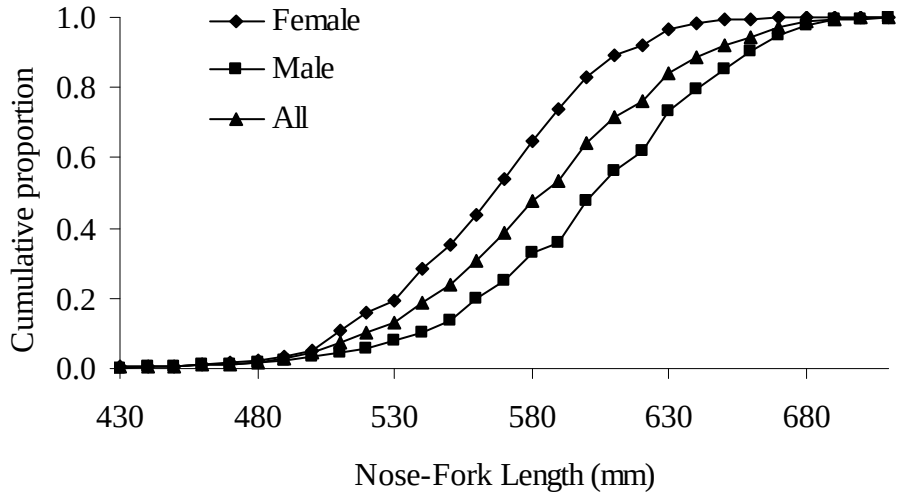


Figure 5. Cumulative length-frequency distributions for sockeye salmon radiotagged at the Baird Canyon fishwheels on the Copper River, 2007.

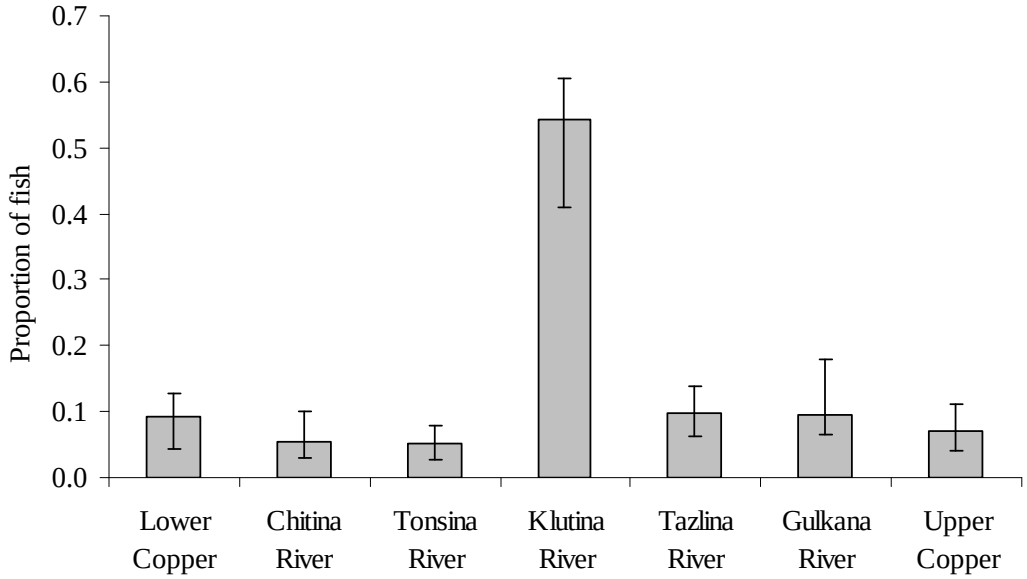


Figure 6. Spawning distribution and 95% confidence intervals of Copper River sockeye salmon by major drainage, 2007.

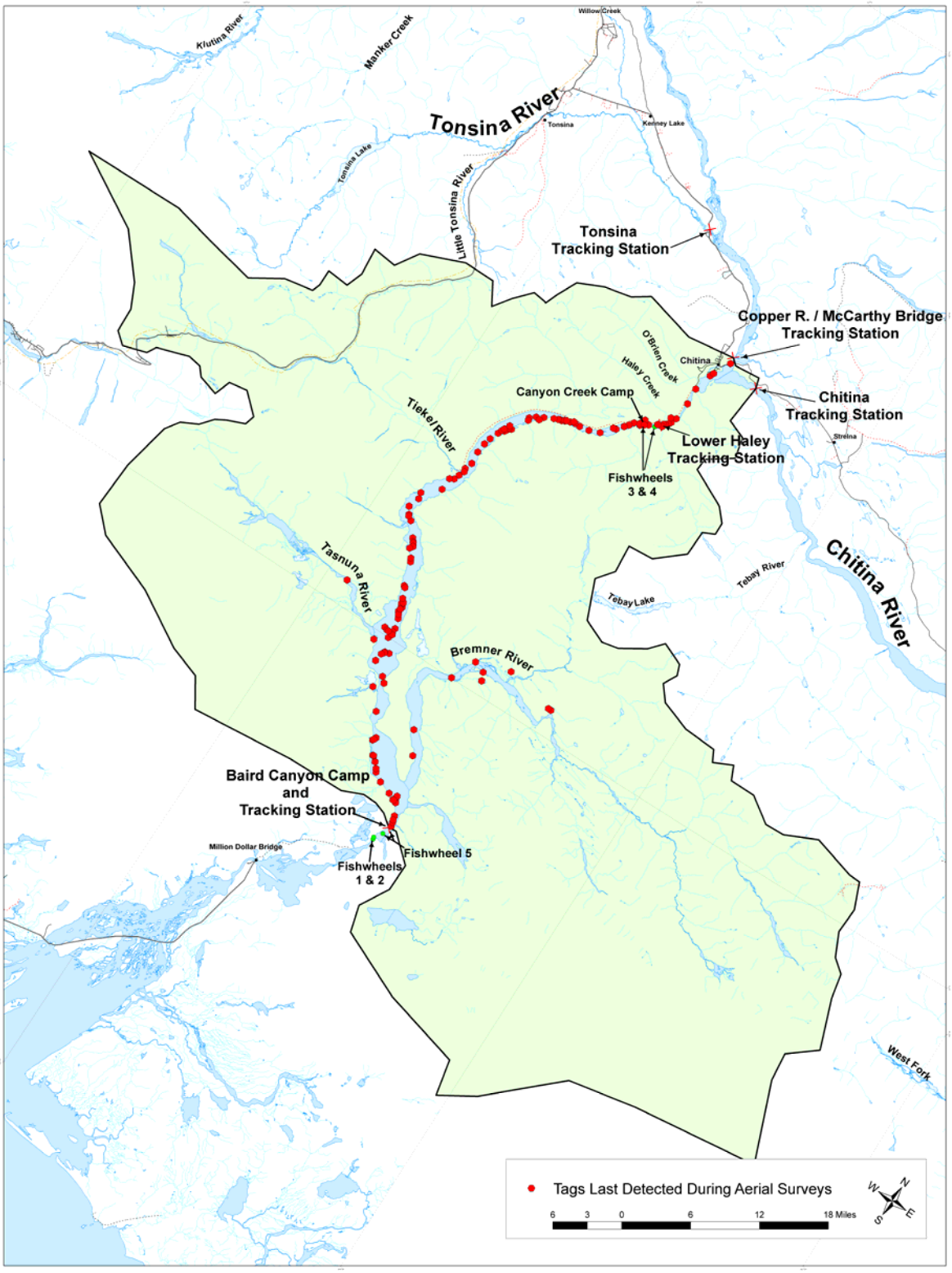


Figure 7. Map of the Lower Copper River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

Figure 8. Map of the Chitina River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

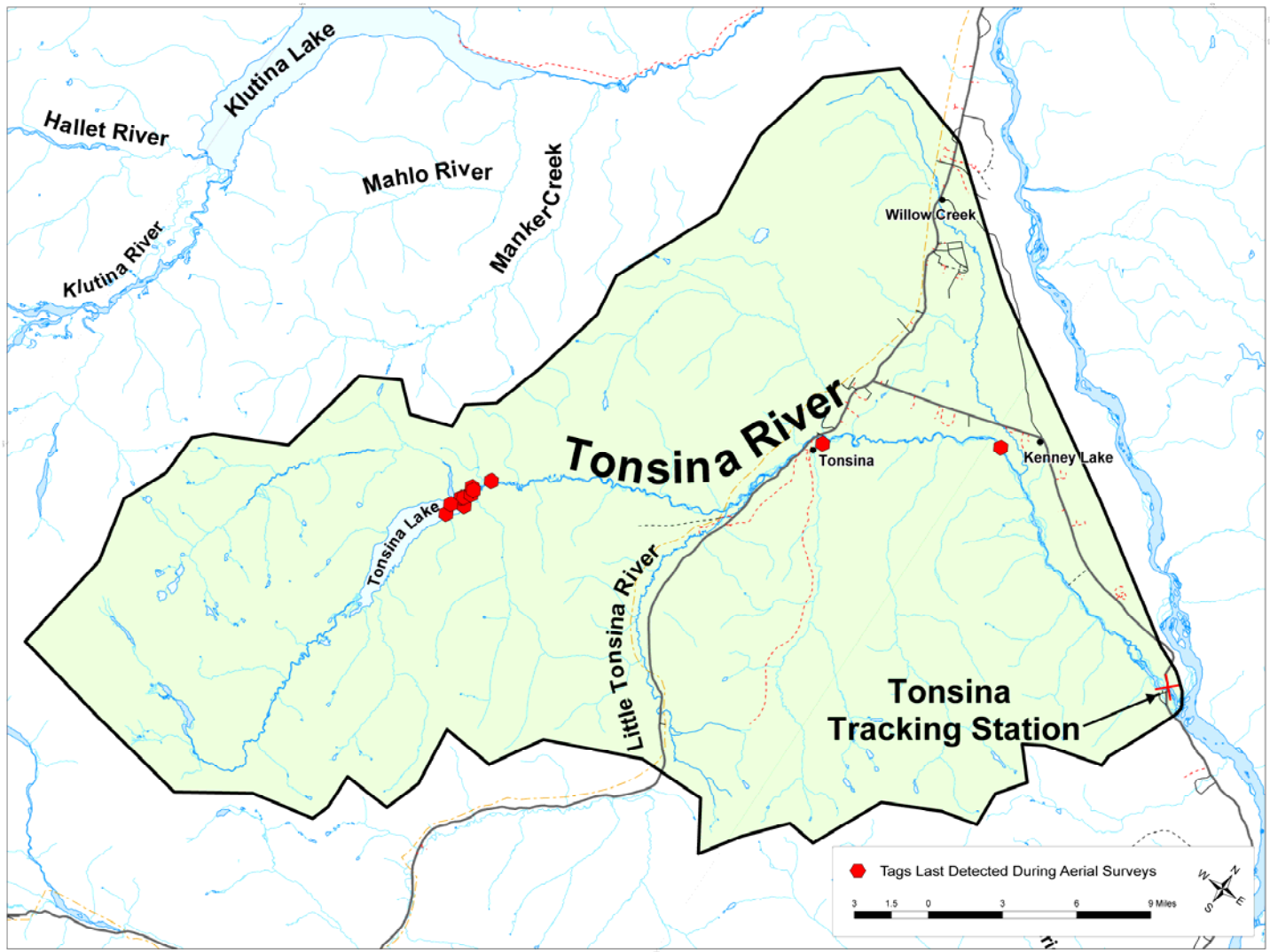


Figure 9. Map of the Tonsina River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

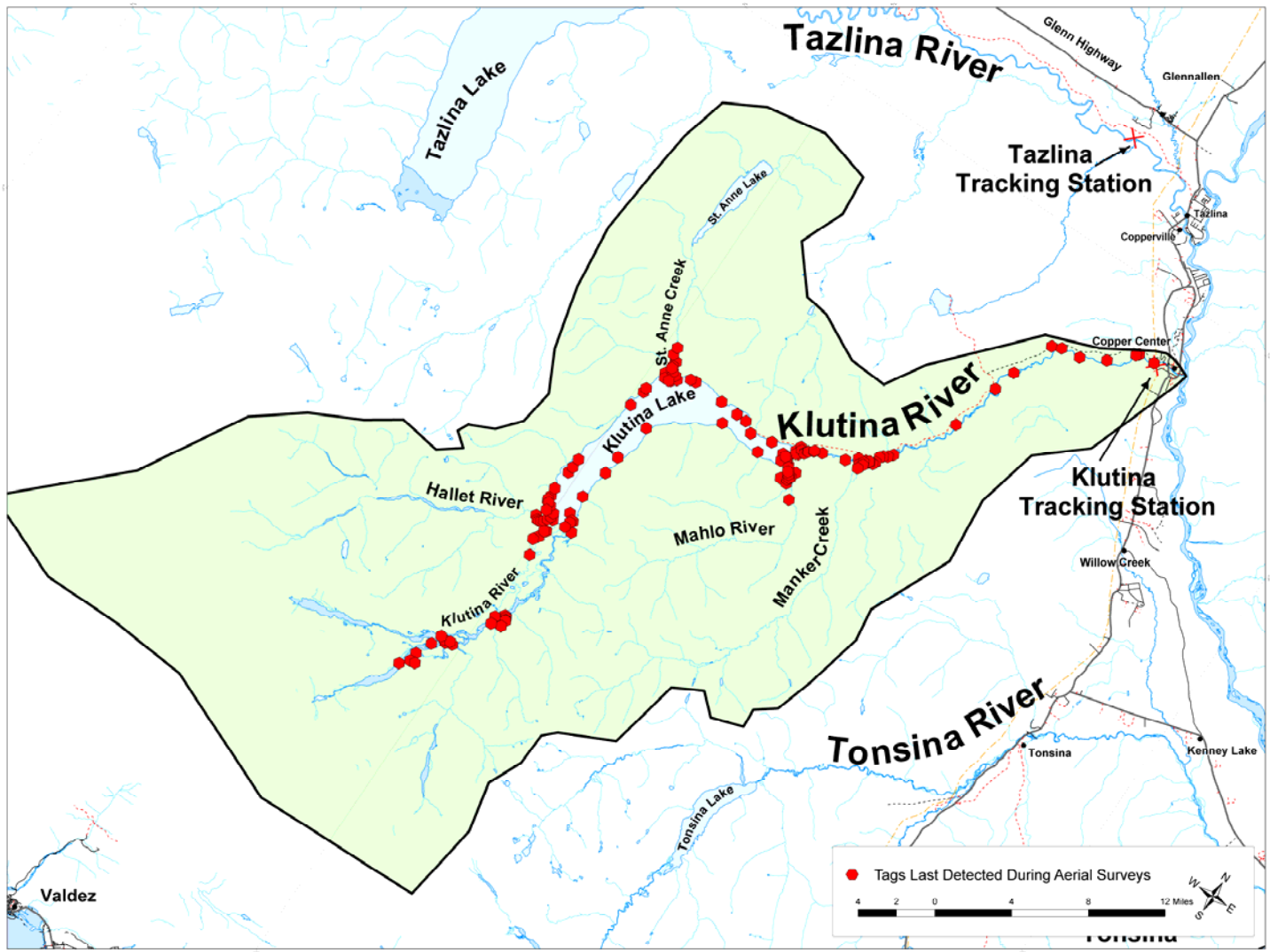


Figure 10. Map of the Klutina River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

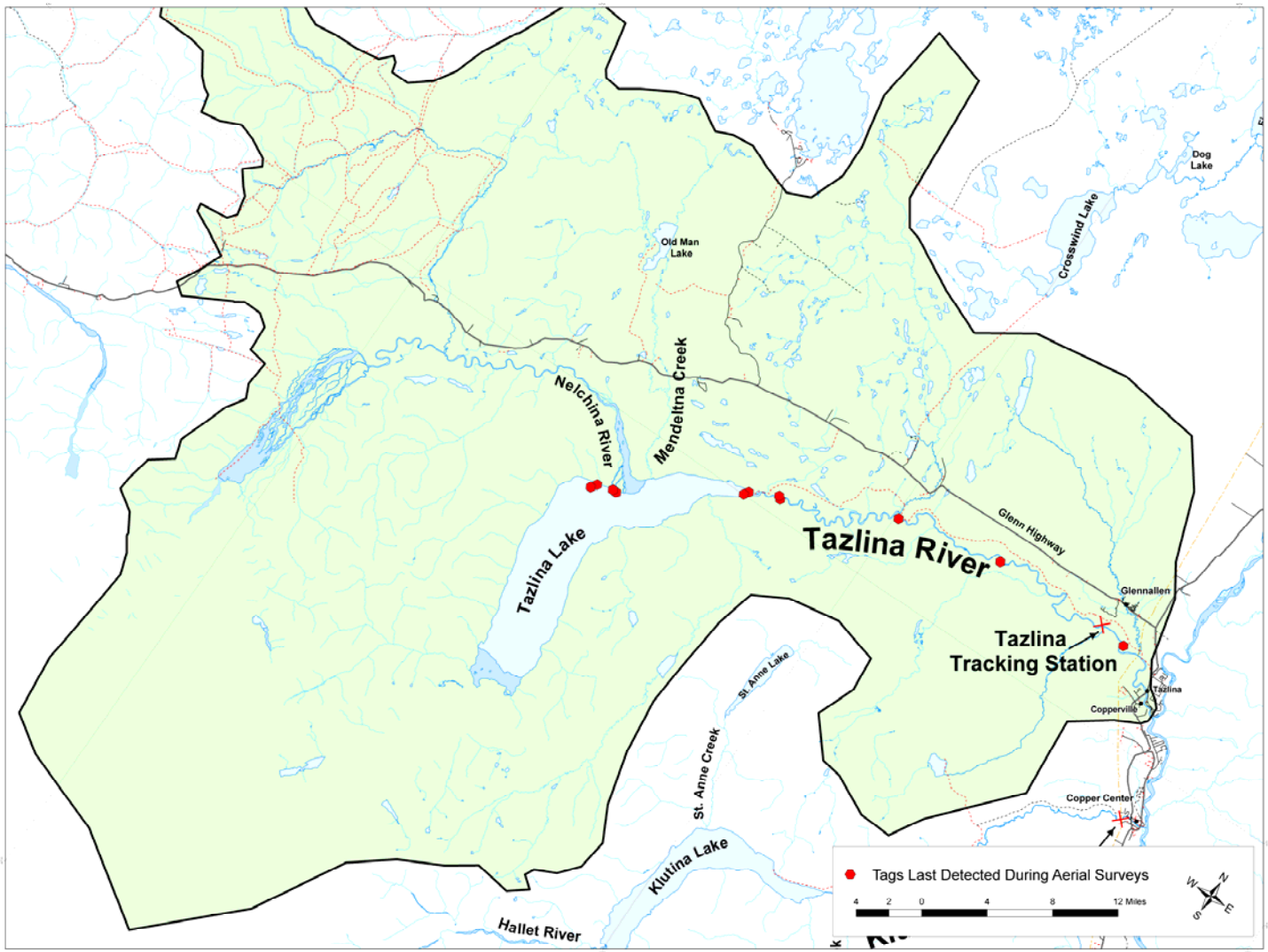


Figure 11. Map of the Tazlina River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

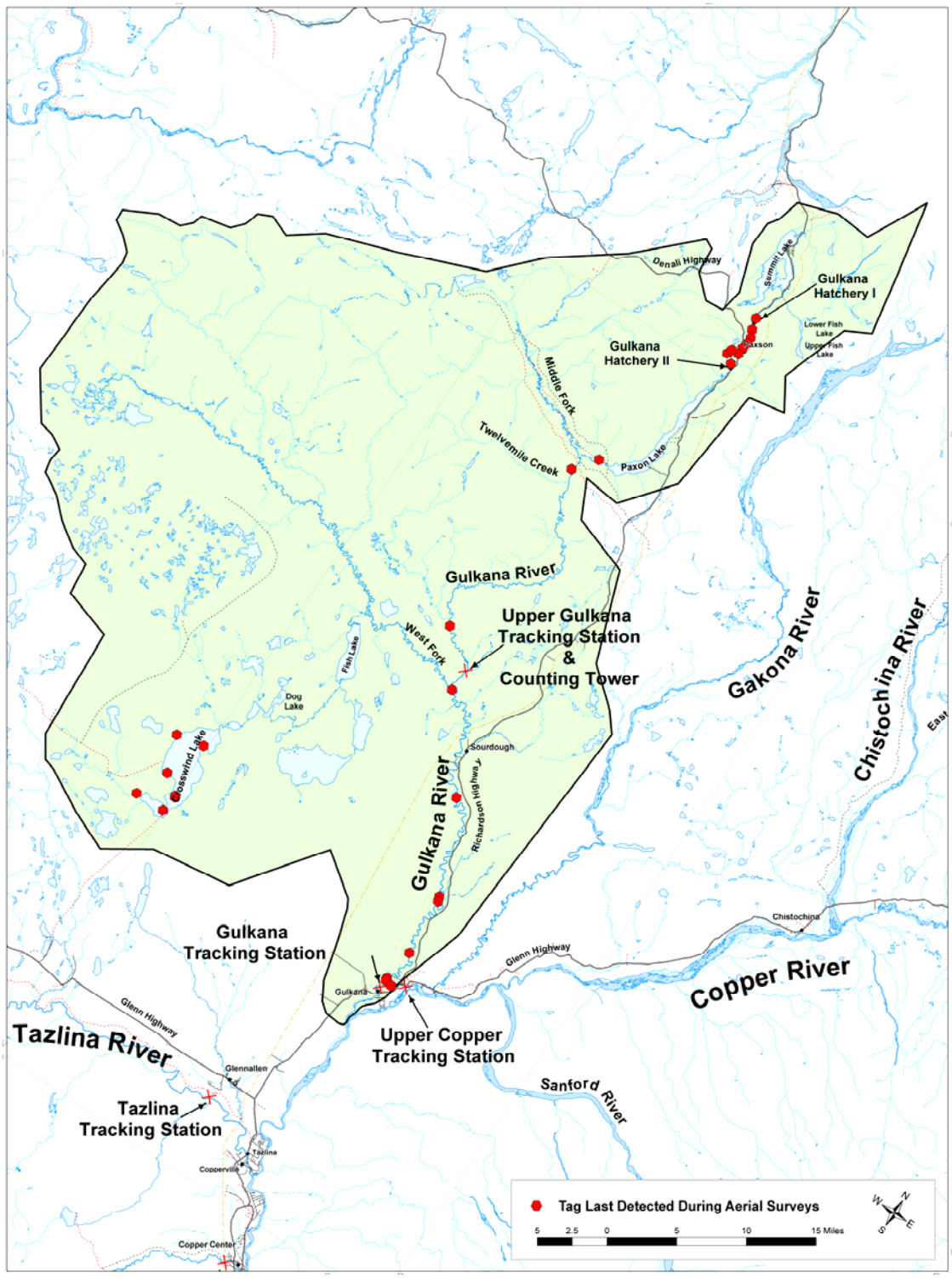


Figure 12. Map of the Gulkana River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

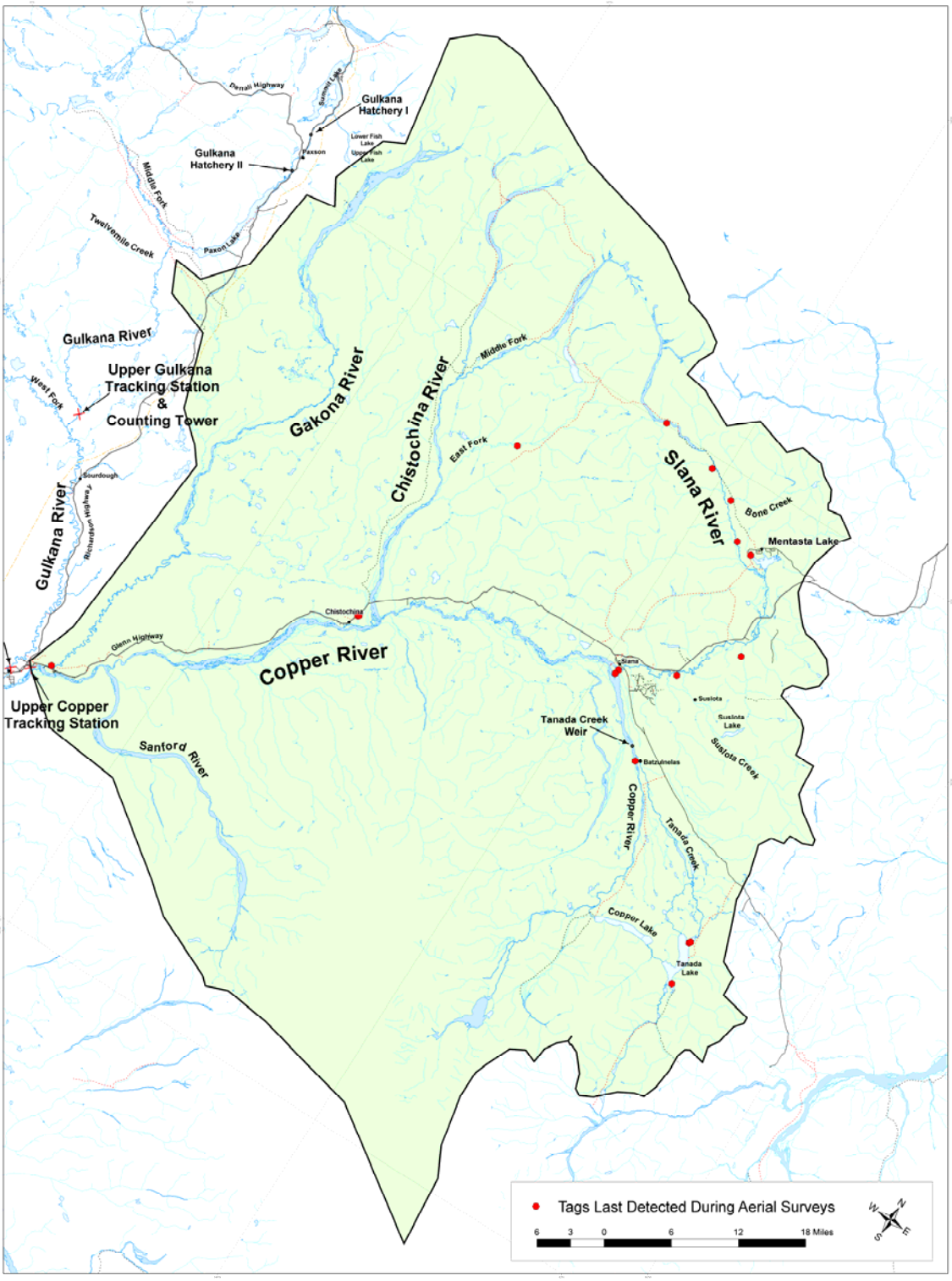


Figure 13. Map of the Upper Copper River drainage showing the last location at which each radiotagged sockeye salmon was detected during aerial-tracking surveys, 2007.

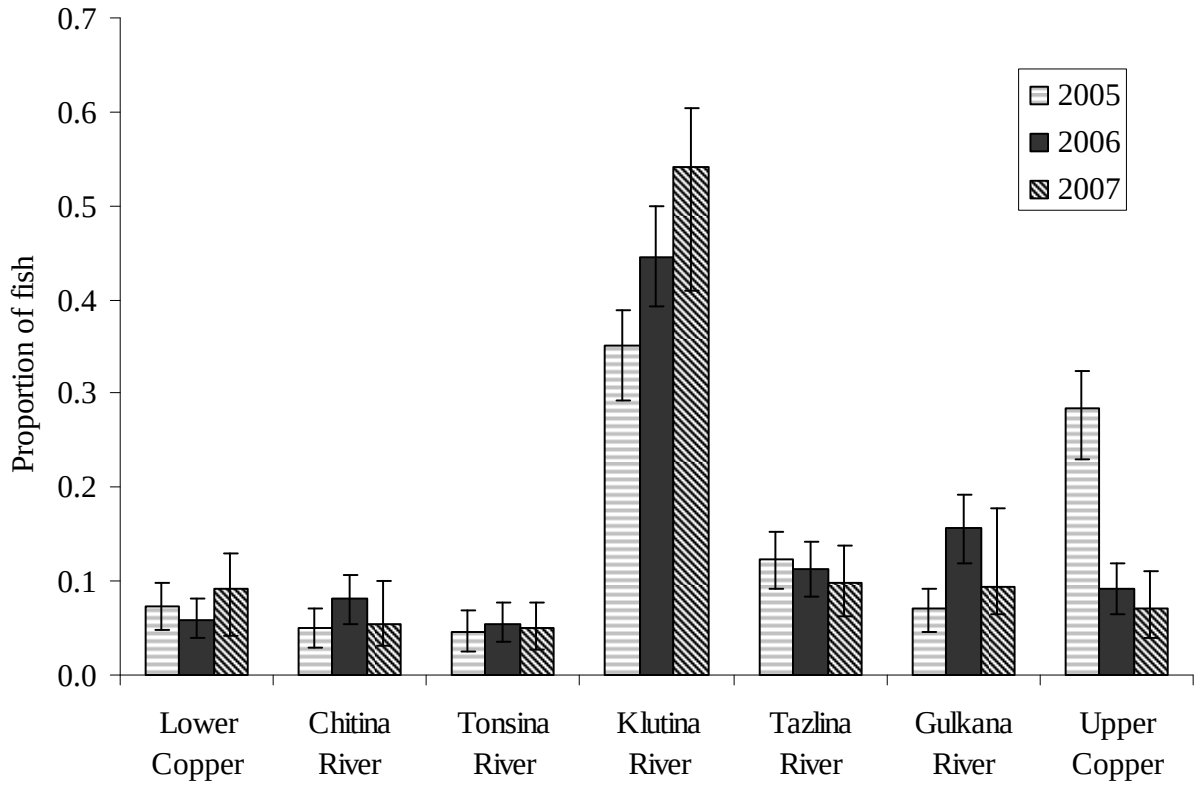


Figure 14. Spawning distribution and 95% confidence intervals of Copper River sockeye salmon by major drainage, 2005-2007.

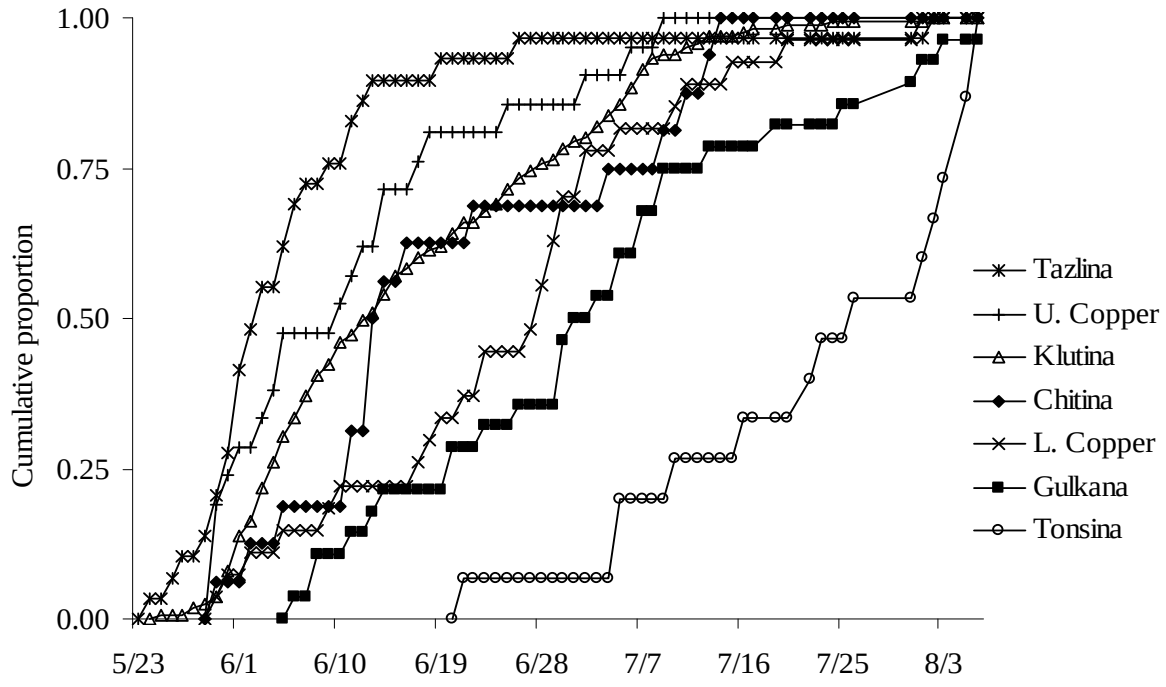


Figure 15. Run-timing patterns of sockeye salmon at the capture site for the major stocks in the Copper River, 2007.

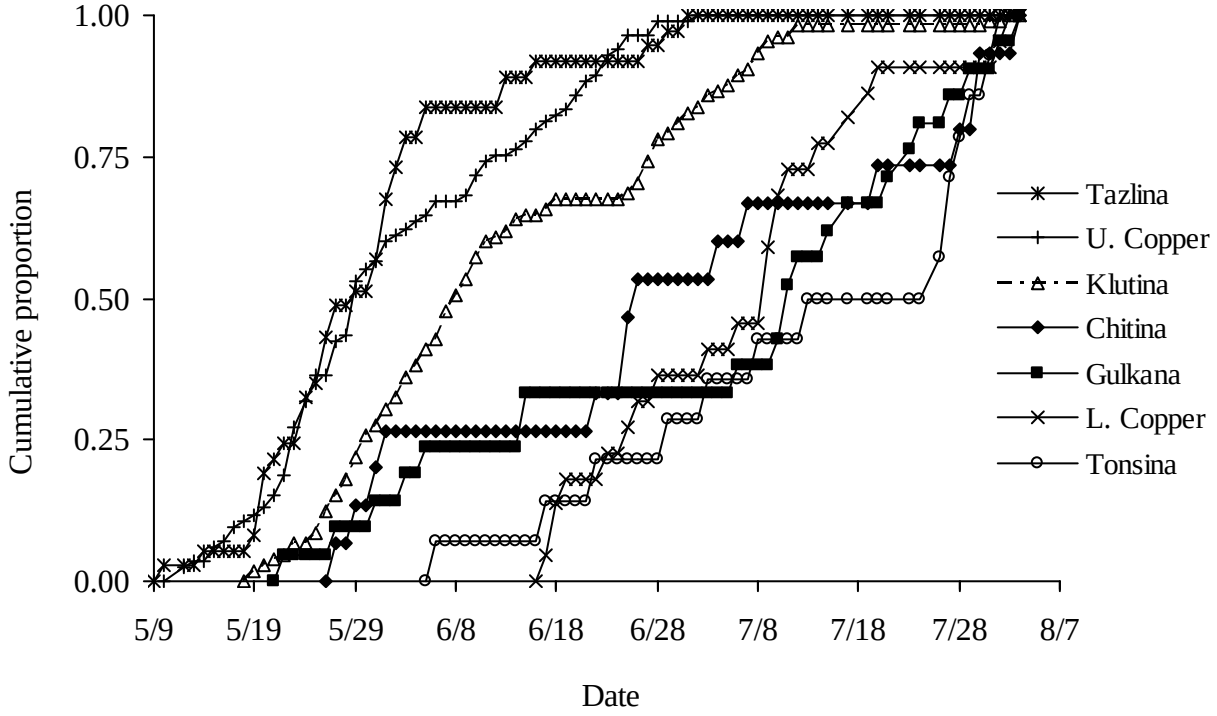


Figure 16. Run-timing patterns of sockeye salmon at the capture site for the major stocks in the Copper River, 2005.

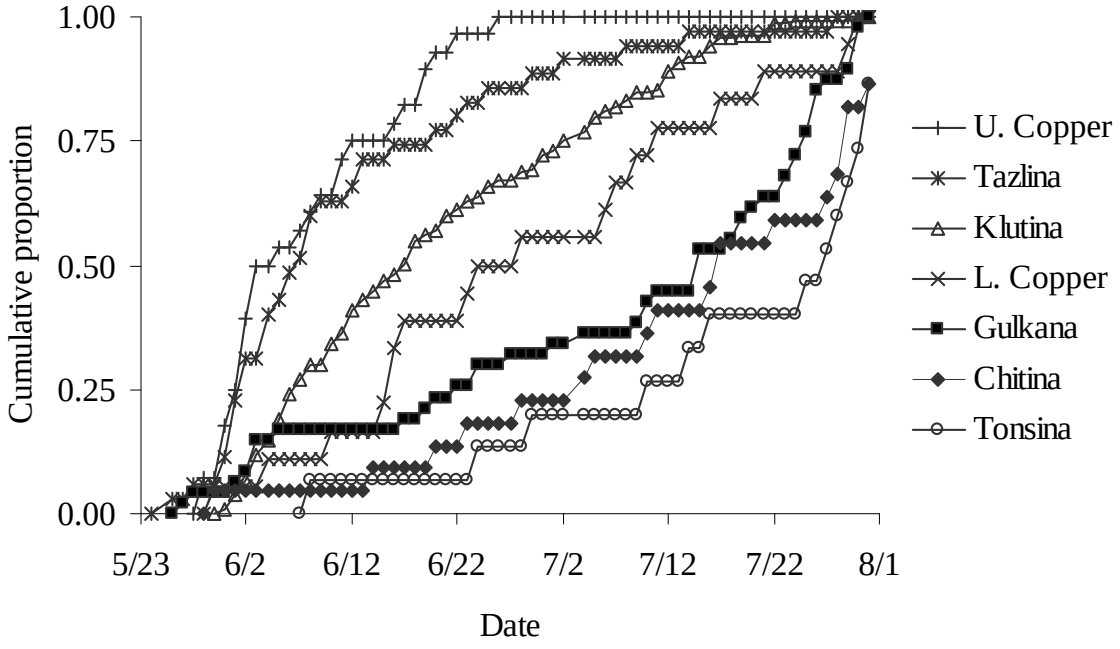


Figure 17. Run-timing patterns of sockeye salmon at the capture site for the major stocks in the Copper River, 2006.

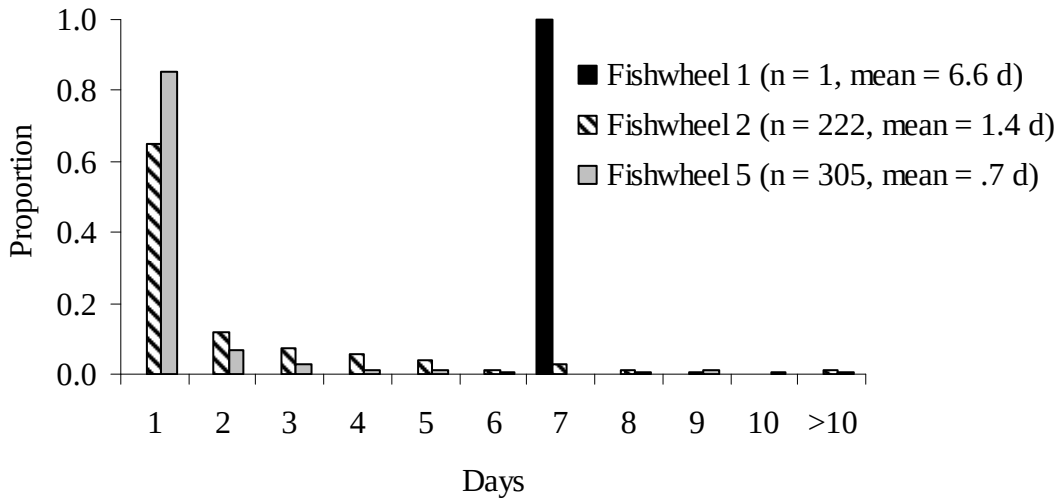


Figure 18. Travel time (d) for radiotagged sockeye salmon from release at the Baird Canyon fishwheels to first detection at the Baird tower, 2007.

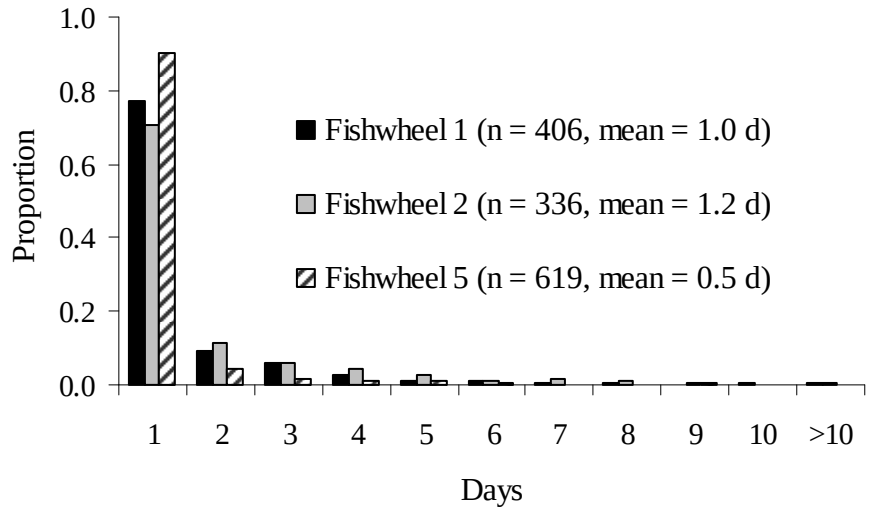


Figure 19. Travel time (d) for radiotagged sockeye salmon from release at the Baird Canyon fishwheels to first detection at the Baird tower, 2005-2007.

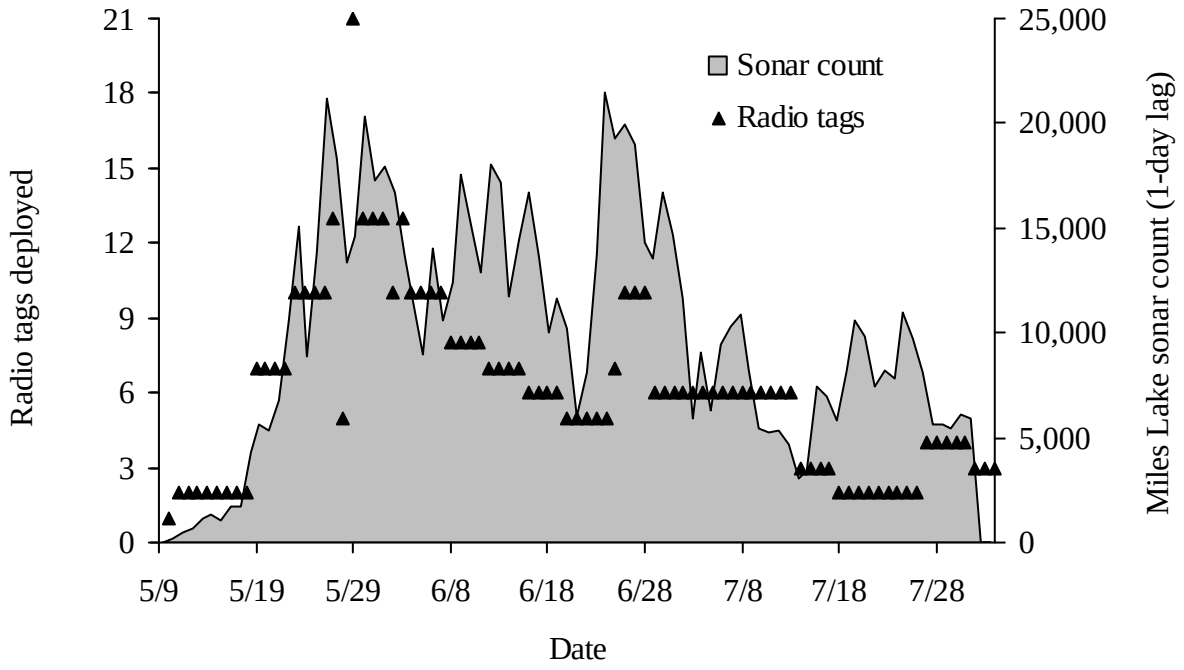


Figure 20. Daily number of sockeye salmon radiotagged at the Baird Canyon fishwheels and the daily number of salmon counted at the Miles Lake sonar, 2005.

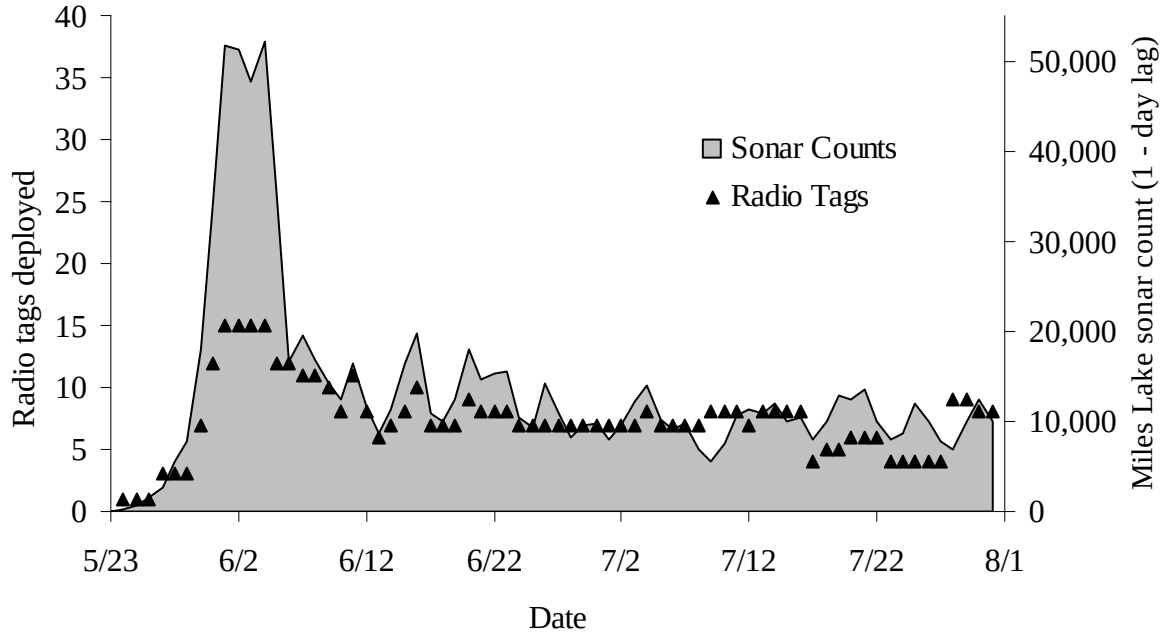


Figure 21. Daily number of sockeye salmon radiotagged at the Baird Canyon fishwheels and the daily number of salmon counted at the Miles Lake sonar, 2006.

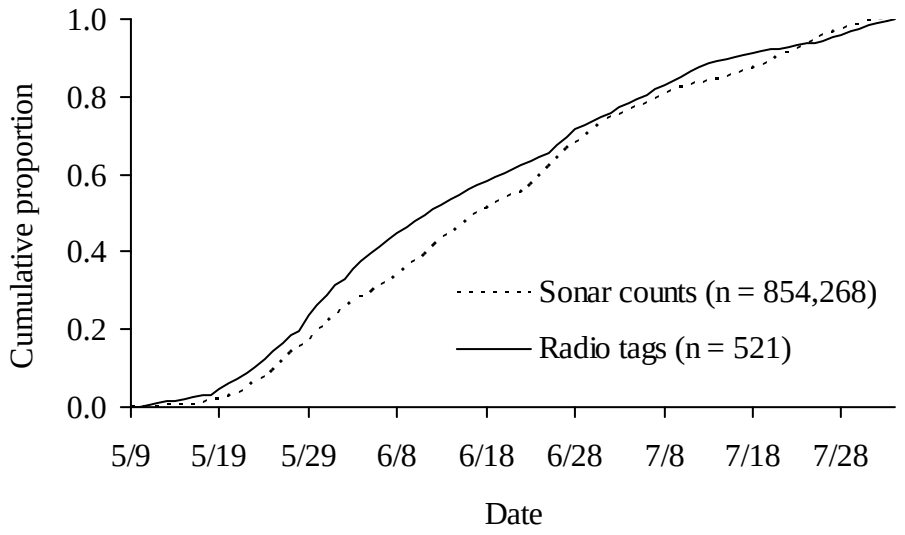


Figure 22. Cumulative proportion of sockeye salmon radiotagged at the Baird Canyon fishwheels and the cumulative proportion of salmon counted at the Miles Lake sonar, 2005.

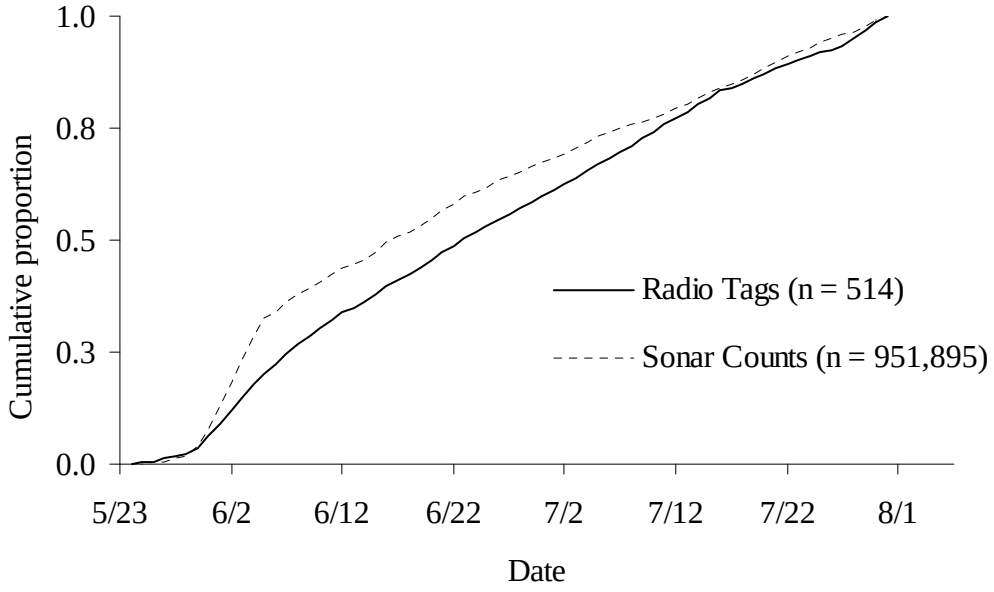


Figure 23. Cumulative proportion of sockeye salmon radiotagged at the Baird Canyon fishwheels and the cumulative proportion of salmon counted at the Miles Lake sonar, 2006.

TABLES

Table 1. List of possible fates for radio-tagged sockeye salmon on the Copper River, 2007.

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 radiotagged at the Baird Canyon fishwheels on the Copper River, 2007.

Fate[a]	Fishwheel 1	Fishwheel 2	Fishwheel 5	Total
Deployed at Baird Canyon	2	237	314	553
Radio Failure[b]	0	12	16	28
Chitina Subdistrict	0	14	18	32
Glennallen Subdistrict	0	13	18	32
Sport fishery	0	1	4	6
Unknown fishery	0	8	10	18
Upstream migrant[c]	1	45	102	148
Spawner[d]	1	145	151	297

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

[b] Includes 11 radio tags never detected after release and 17 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(2 @ FW2, 3 @ FW 5), 1 fish harvested in the Chitina sport fishery(1 @ FW 5) and 2 fish harvested in the state subsistence fishery (2 @ FW5).

Table 3. Number of radiotagged sockeye salmon detected at the tracking stations in the Copper River basin, 2007.

		Number of Fish			
Zone	Location	First Detection	Total Detected	Total Passed	Detection Efficiency
-1	Baird				
10	Baird fishwheels	511	511	525	97.3%
20	Lower Haley	1	404	416	97.1%
30	O'Brien		379	398	95.2%
40	Chitina		16	16	100.0%
50	Copper	2	312	338	92.3%
60	Tonsina		15	15	100.0%
70	Klutina		158	163	96.9%
80	Tazlina		26	28	92.9%
90	Gulkana		20	28	71.4%
110	Upper Copper		20	20	100.0%
Total		514			

Table 4. Number of radiotagged fish detected, by area and date, during aerial surveys in the Copper River drainage, 2007.

Zone	Survey Location	28-Jun	29-Jun	30-Jun	2-Jul	3-Jul	23-Jul	24-Jul	27-Jul	28-Jul	31-Jul	8-Sep	11-Sep	16-Sep	17-Sep	Total
5	Copper mainstem - mouth to Baird				12						24		7			43
6	Bremner River				4			7					7			18
7	Tasnuna River							2					1			3
15	Copper mainstem - Baird to Lower Haley				94			6			70		46			216
25	Copper mainstem - Lower Haley to Copper				10	6					12		4			32
451	Chitina River mainstem					3		4					2			9
452	Lakina River/Long Lake												3			3
453	Tana River					2		6					7			15
55	Copper mainstem - Copper to Upper Copper				8				33		13	3	21			78
65	Tonsina River													11		11
751	Lower Klutina mainstem			15					11					21		47
752	Klutina Lake			29					36					18		83
753	Mahlo Creek			3					16					9		28
754	St. Anne Creek			5					9					4		18
755	Upper Klutina mainstem			7					30					15		52
851	Tazlina mainstem/Lake			5						2		6				13
852	Mendeltna Creek															0
951	Lower Gulkana	1					6					7				14
952	Upper Gulkana	1					4					1			9	15
97	West Fork Gulkana River											7				7
115	Copper mainstem - u/s Upper Copper station		2				3			3		1			1	10
116	Gakona River															0
117	Chistochina River		1							1					1	3
1181	Slana River		3				5								2	10
1182	Suslota Creek/Lake						1									1
1183	Mentasta Lake		4				1								1	6
119	Tanada Creek						1								2	3
Total		2	10	64	128	11	21	25	135	6	119	25	98	78	16	738

Table 5. Distribution of sockeye salmon in major spawning drainages in the Copper River, 2007.

Spawning Tributary	Number of Tags	Proportion	SE	95% Confidence Limits Lower	95% Confidence Limits Upper
Lower Copper	27	0.091	0.02	0.04	0.13
Chitina River	16	0.054	0.02	0.03	0.10
Tonsina River	15	0.051	0.01	0.03	0.08
Klutina River	161	0.542	0.05	0.41	0.60
Tazlina River	29	0.098	0.02	0.06	0.14
Gulkana River	28	0.094	0.03	0.06	0.18
Upper Copper	21	0.071	0.02	0.04	0.11
Total	297	1.000			

Table 6. Distribution of radiotagged sockeye salmon (spawners only) in the Copper River drainage, 2007.

Drainage	Zone	Tributary	Number of fish	Proportion of total
Lower Copper	6	Bremner River	8	0.027
	7	Tasnuna River	2	0.007
	151	Tiekel River/Swan Lakes	17	0.057
		Subtotal	27	0.091
Chitina	40	Chitina tracking station	3	0.010
	451	Chitina River mainstem	4	0.013
	452	Lakina River/Long Lake	3	0.010
	453	Tana River	6	0.020
		Subtotal	16	0.054
Tonsina	60	Tonsina tracking station	3	0.010
	65	Tonsina River	12	0.040
		Subtotal	15	0.051
Klutina	70	Klutina tracking station	25	0.084
	751	Lower Klutina mainstem	26	0.088
	752	Klutina Lake	43	0.145
	753	Mahlo Creek	17	0.057
	754	St. Anne Creek	16	0.054
	755	Upper Klutina mainstem	33	0.111
	159	Klutina sport fishery	3	0.010
		Subtotal	163	0.549
Tazlina	80	Tazlina tracking station	18	0.061
	851	Tazlina mainstem/Lake	10	0.034
	852	Mendeltna Creek	0	0.000
		Subtotal	28	0.094
Gulkana	90	Gulkana tracking station	6	0.020
	951	Lower Gulkana	5	0.017
	952	Upper Gulkana	12	0.040
	97	West Fork Gulkana River	5	0.017
		Subtotal	28	0.094
Upper Copper	110	Upper Copper tracking station	3	0.010
	115	Copper River mainstem	4	0.013
	116	Gakona River	0	0.000
	1181	Slana River	6	0.020
	1182	Suslota Creek/Lake	1	0.003
	1183	Mentasta Lake	2	0.007
	119	Tanada Creek	4	0.013
		Subtotal	20	0.067
Total			297	1.000

Table 7. Distribution of sockeye salmon in major spawning drainages in the Copper River, 2005-2007.

	Number of Tags			Proportion			SE		
	2005	2006	2007	2005	2006	2007	2005	2006	2007
Lower Copper	22	18	27	0.074	0.058	0.091	0.02	0.01	0.02
Chitina River	15	25	16	0.050	0.081	0.054	0.01	0.02	0.02
Tonsina River	14	17	15	0.047	0.055	0.051	0.01	0.01	0.01
Klutina River	105	137	161	0.351	0.445	0.542	0.03	0.03	0.05
Tazlina River	37	35	29	0.124	0.114	0.098	0.02	0.02	0.02
Gulkana River	21	48	28	0.070	0.156	0.094	0.01	0.02	0.03
Upper Copper	85	28	21	0.284	0.091	0.071	0.03	0.02	0.02
Total	299	308	297	1.000	1.000	1.000			

Table 8. Run-timing statistics past the capture site at Baird Canyon of the major sockeye salmon spawning stocks in the Copper River, 2007.

	Duration			Date of Passage	
Spawning Stock	Start	End	Total (d)	Mean	SE
Lower Copper	29-May	31-Jul	63	24-Jun	15.0
Chitina	29-May	13-Jul	45	19-Jun	14.7
Tonsina	20-Jun	5-Aug	46	22-Jul	13.9
Klutina	24-May	1-Aug	69	16-Jun	14.5
Tazlina	23-May	1-Aug	70	5-Jun	12.8
Gulkana	5-Jun	6-Aug	62	2-Jul	17.2
Upper Copper	29-May	8-Jul	40	11-Jun	12.2

Table 9. Mean date of passage and duration of migration past the tagging site at Baird Canyon for major sockeye salmon spawning stocks in the Copper River, 2005-2007.

2005-2007 Run Timing						
	Duration (d)			Mean Date of Passage		
Spawning Stock	2005	2006	2007	2005	2006	2007
Lower Copper	46	61	63	6-Jul	28-Jun	24-Jun
Chitina	68	63	45	30-Jun	13-Jul	19-Jun
Tonsina	56	54	46	13-Jul	17-Jul	22-Jul
Klutina	75	60	69	13-Jun	20-Jun	16-Jun
Tazlina	52	64	70	31-May	11-Jun	5-Jun
Gulkana	73	65	62	4-Jul	7-Jul	2-Jul
Upper Copper	51	28	40	2-Jun	7-Jun	11-Jun

Table 10. Travel time (d) and migration speed (km/d) of radiotagged sockeye salmon detected at fixed-station receivers or reported harvested on the Copper River, 2007.

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	1.9	36.6	11.2	2.4	46.2	8.0	404
Chitina	106	2.5	40.2	13.9	2.6	42.5	7.6	346
Copper	104	3.4	40.6	14.5	2.6	30.3	7.2	310
Tonsina	125	3.7	48.8	16.0	2.6	33.9	7.8	308
Klutina	181	9.4	48.8	21.5	3.7	19.3	8.4	188
Tazlina	206	7.6	28.8	16.1	7.2	26.9	12.8	31
Gulkana	225	9.2	45.6	25.5	4.9	24.4	8.8	38
Upper Copper	226	9.3	47.3	19.9	4.8	24.4	11.4	27
Chitina Harvest		6.4	37.6	16.2				26
Glennallen Harvest		8.3	66.3	22.4				31
Sport Fishery Harvest		11.6	58.7	35.8				4
From Lower Haley to -								
Chititna	17	0.3	15.3	3.0	1.1	54.3	5.7	333
Copper	15	0.3	24.8	3.9	0.6	54.3	3.9	281
Tonsina	37	0.8	42.7	5.3	0.9	43.9	7.0	293
Klutina	92	4.6	42.7	11.3	2.2	20.2	8.1	178
Tazlina	117	5.5	14.7	8.4	8.0	21.2	14.0	31
Gulkana	136	3.4	37.1	15.9	3.7	39.8	8.6	37
Upper Copper	137	4.7	26.4	11.9	5.2	28.8	11.5	22
Chitina Harvest		0.0	27.5	4.5				23
Glennallen Harvest		1.7	45.8	10.5				29
Sport Fishery Harvest		4.5	42.6	22.2				4

[a] Travel time was 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.

Table 11. Fates of sockeye salmon that were radiotagged at the Baird Canyon and Canyon Creek fishwheels on the Copper River, 2005-2007.

Fate[a]	2005	2006	2007	Total
Deployed at Baird Canyon	521	514	553	1588
Deployed at Canyon Creek	0	13	0	13
Radio Failure[b]	25	14	28	67
Chitina Subdistrict	22	57	32	111
Glennallen Subdistrict	21	22	32	75
Sport Fishery	5	7	6	18
Unknown Fishery	6	10	18	34
Upstream migrant[c]	155	114	148	417
Spawner[d]	299	308	297	904

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

[b] Includes 30 radio tags never detected after release and 33 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 12 fish harvested in 2005, 5 in 2006 and 8 in 2007

Table 12. Chi-square tests showing significant variation in spawning distribution for all years 2005-2007.

Tributary	2005	2006	2007
Lower Copper	22	18	27
Chitina	15	25	16
Tonsina	14	17	15
Klutina	105	137	161
Tazlina	37	35	29
Gulkana	21	48	28
Upper Copper	85	28	21
Total	299	308	297

($x^2 = 85.56$, df = 12, $P < 0.001$)

Table 13. Travel time (d) and migration speed (km/d) of radiotagged sockeye salmon detected at fixed-station receivers of reported harvested on the Copper River, 2005-2007.

		Mean Travel Time (d)[a]			Mean Migration Speed (km/d)			Sample size (n) [b]		
From Baird to-	Dist. (rkm)	2005	2006	2007	2005	2006	2007	2005	2006	2007
Lower Haley	89	8.4	9.7	11.2	10.5	9.2	8.0	324	204	404
Chitina	106	11.1	13.4	13.9	9.5	7.9	7.6	23	309	346
Copper	104	13.0	13.7	14.5	7.9	7.6	7.2	199	305	310
Tonsina	125	19.9	15.7	16.0	6.3	7.9	7.8	14	276	308
Klutina	181	25.4	19.8	21.5	7.1	9.1	8.4	89	129	188
Tazlina	206	14.7	18.0	16.1	14.1	11.5	12.8	25	43	31
Gulkana	225	27.1	23.1	25.5	8.3	9.7	8.8	12	76	38
Upper Gulkana[c]	294	32.9			8.9			4		
Upper Copper	226	17.6	17.1	19.9	12.8	13.2	11.4	60	33	27
Chitina harvest		10.8	14.2	16.2				19	49	26
Glennallen harvest		21.5	18.8	22.4				20	20	31
Sport Fishery harvest		23.3	16.5	35.8				4	6	4
From Lower Haley to-										
Chitina	17	3.1	3.9	3.0	5.5	4.3	5.7	34	164	333
Copper	15	2.6	4.3	3.9	5.7	3.5	3.9	256	170	281
Tonsina	37	5.3	6.0	5.3	7.0	6.2	7.0	21	157	293
Klutina	92	11.2	11.1	11.3	8.2	8.3	8.1	100	72	178
Tazlina	117	7.7	9.1	8.4	15.2	12.8	14.0	33	29	31
Gulkana	136	14.8	10.5	15.9	9.2	12.9	8.6	22	35	37
Upper Gulkana	205	21.7			9.5			5		
Upper Copper	137	9.0	9.3	11.9	15.3	14.8	11.5	77	21	22
Chitina harvest		1.3	5.2	4.5				17	28	23
Glennallen harvest		11.9	9.6	10.5				19	9	29
Sport Fishery harvest		15.9	7.4	22.2				5	2	4

[a] Travel time was 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.
[C] The Upper Gulkana tracking station was removed after 2005.

APPENDICES

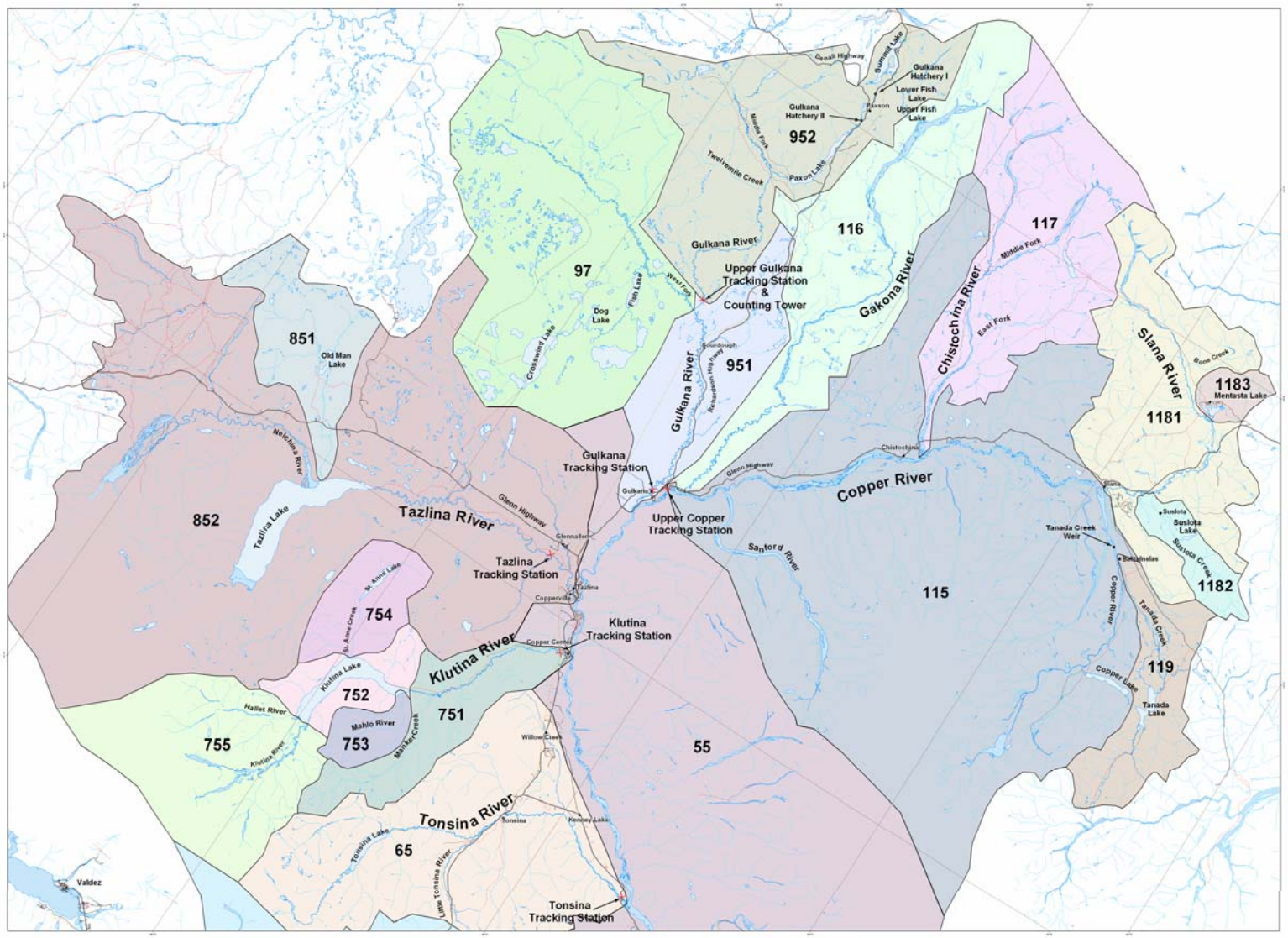
Appendix A.1. Map of the Copper River watershed in Southcentral Alaska showing the location of the Copper River District and the Chitina and Glennallen subdistricts.

Appendix A.2. Location of fishwheels (tag sites), tracking stations, and mobile-tracking zones used in the Copper River sockeye radiotelemetry study, 2007.

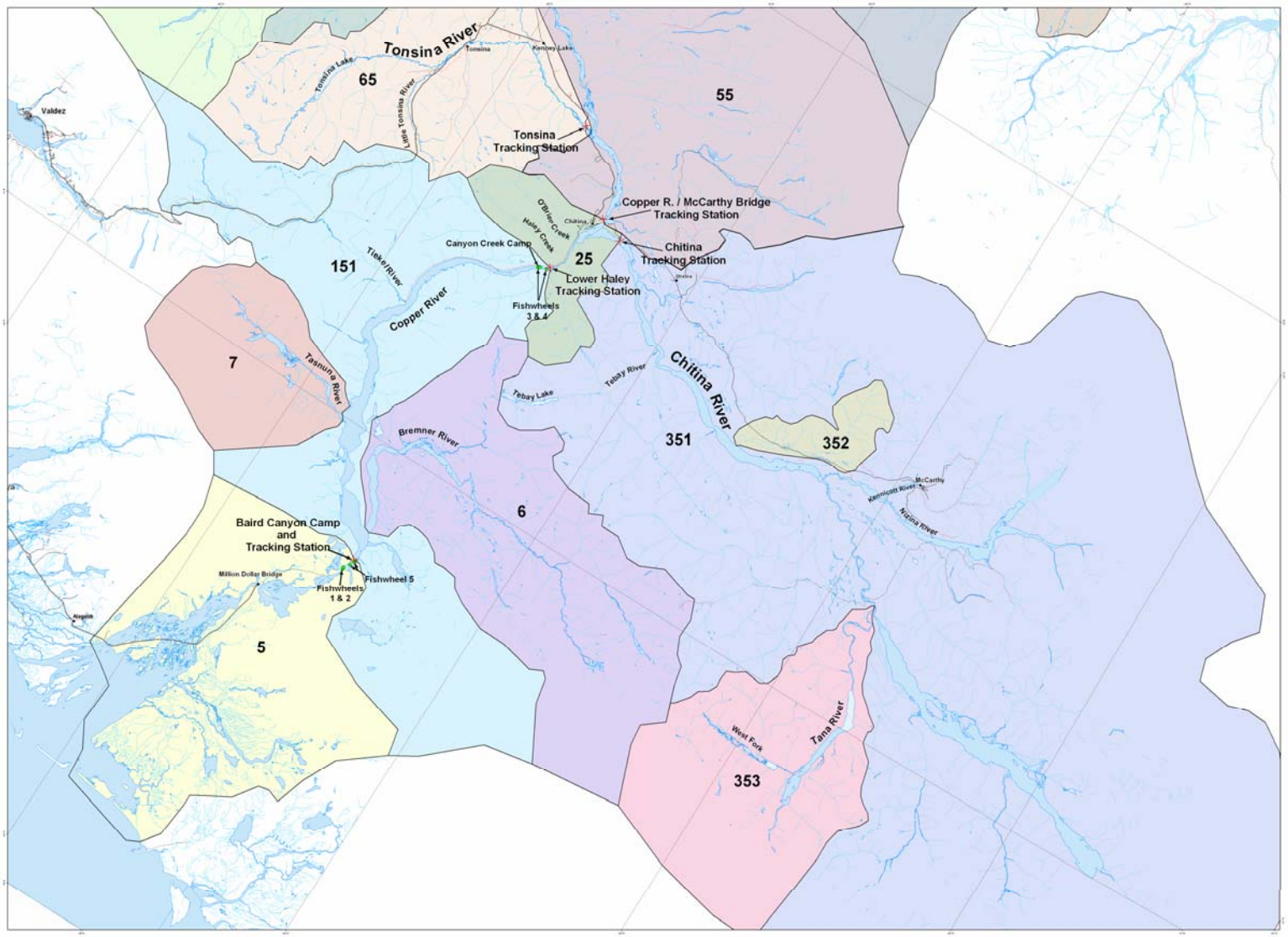
Zone	Sub-zone	Site Name	Description	Lat	Long	rkm
Tag Sites						
-1		Fishwheel 1	East bank of Baird Canyon	60.776	144.521	69
-2		Fishwheel 2	West bank of Baird Canyon	60.778	144.522	69
-5		Fishwheel 5	West bank 1.5 km u/s of Baird Canyo	60.788	144.508	71
Fixed Stations						
10		Baird	West bank 2 km 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 moutl	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, 2007.

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 radiotagged sockeye salmon, 2007.



Appendix A.4. 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 radiotagged sockeye salmon, 2007.

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River drainage, 2007.

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

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River drainage, 2007.

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

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River Drainage, 2007.

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

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River Drainage, 2007.

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

Appendix A.5. Schedule of operations for the ten tracking stations operated in the Copper River Drainage, 2007.

Date	Baird	L.Haley	O'Brien	Chitina	Copper	Tonsina	Klutina	Tazlina	Gulkana	U. Copper	Comment
19-Sep											
20-Sep											
21-Sep											
22-Sep											
23-Sep											
24-Sep											
25-Sep											
26-Sep											
27-Sep											
28-Sep											
29-Sep											
30-Sep											
1-Oct											
2-Oct			D	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.

Frequency	Code	Recovery Date	Capture Method	Recovery	Location
149.003	2	14-Jun	Dipnet	Chitina	West bank
149.003	3	15-Jul	Dipnet	Chitina	
149.003	8	27-Jun	Dipnet	Chitina	
149.003	12	21-Jul	Fishwheel	Glennallen	
149.003	13	12-Jul	Dipnet	Chitina	O'Brien Creek
149.024	8				
149.024	9	14-Jul	Fishwheel	Glennallen	Copper Center
149.024	14	1-Aug	Fishwheel	Glennallen	Silver Springs
149.024	15	27-Jul	Fishwheel	Glennallen	
149.024	22	12-Aug			Near O'Brien Creek
149.024	24	25-Jul		Chitina	
149.045	2	19-Jun	Dipnet	Chitina	
149.045	6	11-Jul	Dipnet	Chitina	
149.045	24	30-Jul	Fishwheel	Glennallen	
149.064	1	4-Jul		Chitina	
149.064	14	15-Jul	Fishwheel	Glennallen	
149.064	22	25-Aug	Fishwheel	Chitina	Above bridge
149.086	0				
149.086	6	2-Jul	Dipnet	Chitina	
149.086	9	13-Jul	Fishwheel	Glennallen	1/4 mile d/s of Klutina
149.086	26	14-Jun	Fishwheel	Glennallen	
149.106	2				
149.106	5	21-Jun	Dipnet	Chitina	Mile 6.11 O'Brien Creek
149.106	9	9-Jul	Fishwheel	Glennallen	
149.106	21	12-Jun	Dipnet	Chitina	West bank
149.106	21	10-Aug	Fishwheel	Glennallen	
149.123	14	14-Jul	Dipnet	Chitina	
149.123	18	20-Jun	Fishwheel	Glennallen	Above bridge
149.123	21	14-Jun	Dipnet	Chitina	
149.123	21	7-Jul	Dipnet	Chitina	Wood Canyon
149.123	26	27-Jun			
149.123	75	17-Jul	Fishwheel	Glennallen	
149.144	2	26-Jun	Fishwheel	Glennallen	
149.144	9	25-Jul	Fishwheel	Glennallen	
149.144	9	4-Jul	Fishwheel	Glennallen	
149.144	11	22-Aug	Fishwheel	Chistochina	
149.144	12	25-Jul	Fishwheel	Glennallen	

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

Frequency	Code	Recovery Date	Capture Method	Recovery	Location
149.144	15	27-Jul	Fishwheel	Glennallen	
149.144	21	23-Jun		Glennallen	
149.144	55	14-Aug	Fishwheel	Glennallen	Above bridge
149.165	0	13-Jun	Fishwheel	Chitina	Above bridge
149.165	3	1-Jul	Dipnet	Chitina	
149.165	8	20-Jul	Sport	Klutina River	St. Anne Creek
149.165	12	13-Jul	Fishwheel	Glennallen	
149.184	4	9-Jul	Fishwheel	Glennallen	
149.184	13	2-Aug	Fishwheel	Glennallen	Mouth of Tazlina
149.184	18	28-Jul	Sport	Klutina River	
149.204	0	6-Jul	Dipnet	Chitina	Below Wood Canyon
149.204	3	19-Jun	Dipnet	Chitina	
149.204	3	2-Aug	Fishwheel	Glennallen	
149.204	4	1-Aug			
149.224	4	2-Jul	Fishwheel	Glennallen	
149.224	8	3-Jul		Chitina	Haley Creek
149.224	17	16-Aug	Dipnet	Chitina	Above bridge
149.245	-6	30-Jun	Fishwheel	Glennallen	
149.245	3	14-Jul	Dipnet	Chitina	
149.245	6	12-Jul	Fishwheel	Glennallen	
149.245	13	5-Jul	Dipnet	Chitina	
149.245	15	11-Aug	Fishwheel	Glennallen	
149.245	16	1-Aug	Dipnet	Chitina	
149.265	12	2-Jul	Dipnet	Chitina	
149.265	14	30-Aug	Sport	Chokosna River	
149.265	21	14-Jun	Sport	Klutina River	
149.265	22	15-Aug	Fishwheel	Glennallen	
149.265	75				
149.285	8	2-Jul	Dipnet	Chitina	
149.285	13	18-Jul			West bank
149.285	24	21-Jul	Sport	Klutina River	
149.304	8	8-Jul	Fishwheel	Glennallen	
149.304	11	29-Jun	Dipnet	Chitina	
149.304	24	17-Jul	Dipnet	Chitina	South of Obrien Creek
149.325	13	9-Jul	Dipnet	Chitina	
149.325	20	15-Jun	Fishwheel	Glennallen	Silver Springs
149.343	2	29-Jul	Dipnet	Chitina	Above bridge

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

Frequency	Code	Recovery Date	Capture Method	Recovery	Location
149.343	4	25-Jun	Dipnet	Chitina	
149.343	4	2-Aug	Dipnet	Chitina	
149.343	20	9-Jun	Fishwheel	Glennallen	Above bridge
149.343	23	12-Jul	Dipnet	Chitina	10 miles d/s Copper Center
149.343	26	22-Jun	Fishwheel	Glennallen	Mile 8 Tok road
149.365	6	25-Jun	Dipnet	Chitina	
149.365	9	Mid-Summer	Fishwheel	Glennallen	Slana River
149.365	11	16-Jul		Chitina	1/4 mile north of bridge
149.385	11	30-Jun	Dipnet	Chitina	West bank
149.385	11	5-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, 2007.

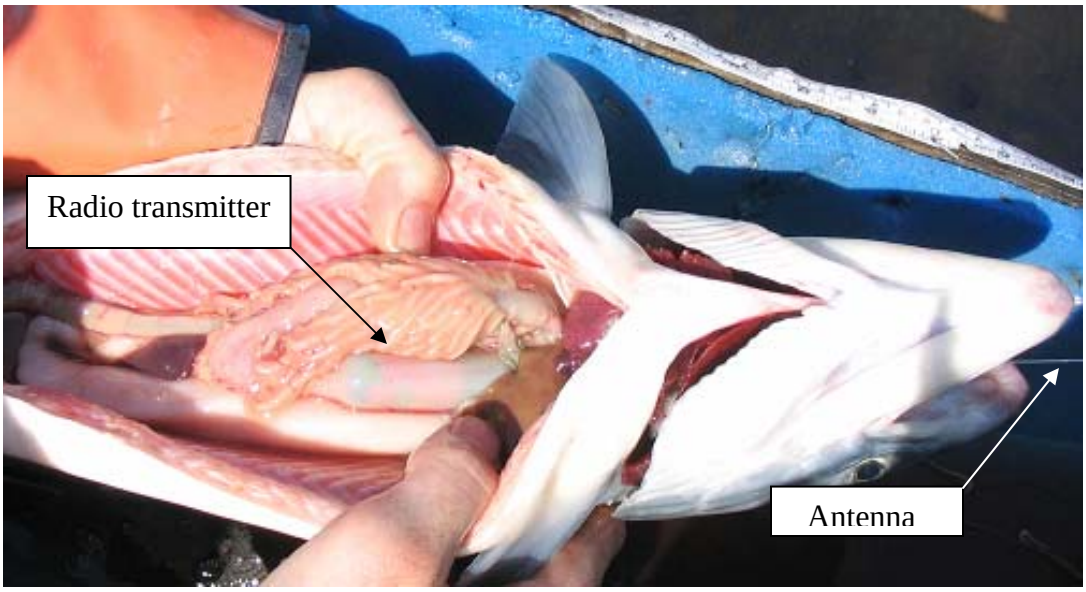


Photo 4. The transmitter is located in the stomach and the whip antenna is shown protruding from the mouth, 2007.

Photo 5. Example of the external t-bar tag used to notify fisherman of the radio tag, 2007.

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