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**U.S. DEPARTMENT OF COMMERCE**
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by
J. H. Eiler[1], T. R. Spencer[2], J. J. Pella[1], and M. M. Masuda[1]

[1]Auke Bay Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
11305 Glacier Highway
Juneau, AK 99801
*www.afsc.noaa.gov*

[2]Alaska Department of Fish and Game
333 Raspberry Road,
Anchorage, AK 99518

**U.S. DEPARTMENT OF COMMERCE**
Carlos M. Gutierrez, Secretary
**National Oceanic and Atmospheric Administration**
Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (ret.), Under Secretary and Administrator
**National Marine Fisheries Service**
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## ABSTRACT

A radio telemetry study was conducted on Yukon River Chinook salmon (*Oncorhynchus tshawytscha*) during 2003 to provide information on stock composition and run timing, migration patterns, and locations of important spawning areas. A total of 1,097 fish were radio tagged in the lower Yukon River near the village of Russian Mission. After tagging, most (1,081; 98.5%) fish resumed upriver movements, with 271 fish harvested in fisheries and 810 fish tracked to upriver areas using remote tracking stations and aerial surveys. Stock composition estimates were developed for the return based on the distribution of daily releases of radio-tagged fish weighted by daily measures of abundance and adjusted for fish harvested in fisheries. The Chinook salmon run was composed primarily of Tanana River (18.9%) and upper basin (67.2%) stocks. Canadian-origin fish comprised the largest component of the return (55.4%), with most traveling to reaches of the Yukon River (51.5%) and only small numbers to the Porcupine River (3.9%). Yukon River fish in Canada returned to headwater tributaries (42.2%), including the Stewart, Pelly, Big Salmon, and Teslin rivers (32.2%) and reaches associated with the Yukon River main stem (9.3%). Chandalar and Sheenjek River fish (6.5%) were the principle U.S. stocks in the upper basin. Tanana River stocks were predominantly Chena, Salcha, and Goodpaster River fish (15.3%), with small populations located in other tributaries. Middle basin fish traveling to the Koyukuk, Melozitna, Nowitna, and Tozitna rivers were a minor component of the run (4.0%). Stocks returning to lower basin tributaries (4.6%) were primarily Anvik and Nulato River fish (3.9%). The two major stock groups, Canadian Yukon River and Tanana River fish, exhibited similar run timing with most fish passing through the lower river in mid-June, although several

distinct pulses were also observed in early June and late June-early July. In Canada, Chinook salmon returning to the Klondike River were primarily early-run fish, while upper headwater stocks displayed a later and more protracted run timing. Lower basin stocks consisted primarily of late-run fish. Movement rates for radio-tagged fish averaged 50.9 km/day, although regional differences were observed. Middle and upper basin fish traveled an average of 48.0 km/day and 54.7 km/day, respectively. However, these stocks exhibited comparable movement rates in reaches of the Yukon River main stem, while slower swimming speeds were recorded as the fish approached their natal streams. Movement rates for lower basin stocks were substantially less, averaging 31.2 km/day, possibly due to the shorter distances traveled to reach their spawning areas.

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## INTRODUCTION

Large numbers of Chinook salmon (*Oncorhynchus tshawytscha*) return to the Yukon River basin to spawn. These returns support important fisheries in both the United States and Canada, and have been the focus of numerous discussions between the two countries over management and harvest allocations. Ultimately these discussions contributed to the passage of the Yukon River Salmon Agreement, which provides for cooperative management of salmon returns in the basin (Yukon River Salmon Act 2000). However, Yukon River Chinook salmon have exhibited dramatic declines in recent years (Joint Technical Committee of the Yukon River U.S./Canada Panel 2002), a phenomenon observed in other major river systems in western Alaska, and information is needed to better understand and manage these returns and to facilitate conservation efforts.

The Yukon River basin drains a watershed of more than 855,000 km$^2$. The main river alone flows for more than 3,000 km from its headwaters in Canada to the Bering Sea (Fig. 1). Several major tributaries flow into the Yukon River main stem, including the Koyukuk and Tanana rivers in the United States; the Stewart, White, Pelly, and Teslin rivers in Canada; and the Porcupine River, which transects both countries. Most reaches of the drainage consist of a primary river channel with occasional side channels and sloughs, although the Yukon River main stem is extensively braided between the villages of Rampart and Circle--an area commonly referred to as the Yukon Flats. Sections of the Canadian main stem and the White River are also extensively braided. Water visibility in many areas is extremely poor, particularly in the Yukon River main stem, due to turbidity from the upper reaches of the drainage. The basin is remote with limited access to many areas.

Salmon are a major source of food in many remote communities within the basin, and this resource often provides the primary source of income for local residents. Subsistence, commercial, and personal use fisheries occur throughout the drainage with most fishing effort concentrated near villages along the Yukon River main stem. Fish are also harvested in reaches of the Koyukuk, Tanana, Chandalar, Porcupine, Stewart, Pelly, and Teslin rivers. Limited sport fishing takes place in a number of clearwater tributaries within the basin. The fisheries are managed to maintain essential spawning escapements, support adequate subsistence harvests for local residents, and provide commercial and sport fishing opportunities when appropriate. Chinook salmon harvests from 1961 to 2002 averaged 136,700 fish in the United States and 12,300 fish in Canada, with catches ranging from 45,300 fish (2000) to 198,400 fish (1983) in the United States, and 2,600 fish (1969) to 22,800 fish (1980) in Canada (Joint Technical Committee of the Yukon River U.S./Canada Panel 2004). From 1961 to 1999, commercial fishing accounted for more than 76% of the U.S. harvest and 42% of the Canadian harvest. These fisheries have been severely restricted in recent years due to declining returns, resulting in harvests composed primarily of fish caught for subsistence.

A basin-wide radio telemetry study was initiated in 2000 by the Alaska Department of Fish and Game (ADFG) and the National Marine Fisheries Service (NMFS). The primary objective of this cooperative study was to provide information on the run characteristics of Yukon River Chinook salmon returns, including stock composition and run timing, country of origin, migration patterns, and the location of important spawning areas. Information was also collected to evaluate other projects in the basin that assess run abundance. The study faced severe logistical challenges due to the large size and physical characteristics of the Yukon River basin. In addition, the sizeable runs of Chinook salmon returning to the basin to spawn required the tagging of large numbers of fish to obtain meaningful results. Chinook salmon reputedly travel in deep water during their spawning migration, further complicating efforts to monitor their movements. Work in 2000-2001 focused on the development of capture methods, improved telemetry equipment for tracking the fish, and the infrastructure necessary for a study of this size and scope. Distribution and movement data collected during this exploratory phase were used primarily to evaluate the response by Chinook salmon to the capture and handling procedures, and to provide preliminary information on migration patterns. A large-scale tagging and basin-wide monitoring program was conducted in 2002 which provided new information on the stock composition, run timing, and movement patterns of Yukon River Chinook salmon. A second year of the basin-wide study was conducted in 2003 to address questions related to study findings and annual variation, particularly in relation to run characteristics during years with greater run abundance.

## MATERIALS AND METHODS

### Fish Capture and Handling

Adult Chinook salmon returning to spawning areas in the Yukon River basin were captured with drift gill nets near the village of Russian Mission (Fig. 1). This site was selected because it 1) consisted of relatively narrow, unbraided sections of river, increasing the probability of capturing a representative sample; 2) was downriver of most known Chinook salmon spawning areas (i.e., only the Andreafsky River, located approximately 190 km downriver, was not included); and 3) was upriver of significant commercial and subsistence fisheries lower in the basin. Results from feasibility work in 2000-2001 (Spencer et al. 2003) and the 2002 basin-wide study (Eiler et al. 2004) indicated that sufficient numbers of Chinook salmon could be captured at this site. Local fishers were contracted to fish the site from early June to mid-July (Table 1), with project personnel handling the fish and collecting data. Two day shifts (0900-1700) and one night shift (1800-0200) were fished throughout the tagging period; a second night shift was fished from 16 June to 27 June to increase catches. Fishing effort was divided between the lower and upper sections of the tagging area when two crews were fishing to minimize the recapture of tagged individuals by the other crew.

The site was fished with drift gill nets constructed with No. 21 seine twine, 21.5 cm mesh size, 46 m long, 7.6 m deep, and hung at a 2:1 ratio. This configuration was effective in capturing Chinook salmon while minimizing chum salmon (*O. keta*) bycatch. Nets were monitored continually and fish were removed immediately after capture. The netting was cut to facilitate removal and minimize injuries. A dip net, constructed with soft, fine-mesh netting, was used to lift fish into the boat. A maximum of two fish were tagged per drift to minimize both handling time and potential sampling bias if stocks of fish were poorly mixed. Fish selected for tagging were placed in a neoprene-lined tagging cradle submerged in a trough of fresh water. A pump was used to circulate river water into the trough while fish were being processed. Anesthesia was not used during the tagging procedure.

Fish were tagged with pulse-coded radio transmitters (Fig. 2) manufactured by Advanced Telemetry Systems Inc. (Isanti, Minnesota)[1]. The transmitters, which were 5.4 cm long, 2.0 cm in diameter, had a 30-cm transmitting antenna, and weighed 20 g, were gently inserted through the mouth and into the stomach using a plastic tube 0.7 cm in diameter. Each transmitter emitted a unique signal (i.e., transmitters were placed on 11 discrete frequencies in the 150-151 MHz frequency range spaced a minimum of 20 kHz apart, with up to 100 distinct pulse codes per frequency), making it possible to identify each individual fish. Transmitters were also equipped with a motion sensor and activity monitor. The motion sensor, an integrated tilt switch sensitive to movement, inserted additional signal pulses distinct from the basic signal pattern each time the transmitter moved. The activity monitor altered the signal pattern to an inactive mode (Eiler 1995) if the motion sensor was not triggered for 24 hours; the signal reverted to the original pattern if the motion sensor was activated. Transmitters had a minimum battery life of 90 days. Fish were marked externally with yellow spaghetti tags attached below the dorsal fin (Wydoski and Emery 1983). A subsample of fish was tagged with radio-archival tags that recorded water depth and temperature every 3 minutes as well as transmitting a signal. Fish with radio-archival tags were marked externally with pink spaghetti tags.

Information on length (mid-eye to fork of tail), skin color (bright iridescent silver, dull silver, and blush--silver with reddish tinges), and condition of the fish was also recorded. Discrete data on gender were not collected because of difficulties in distinguishing males from females in the lower river due to the lack of distinct external characteristics (Eiler et al. 2004). A

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tissue sample was taken from an axillary process for separate genetic stock identification studies being conducted by ADFG, and scales were collected to provide age data. Fish were released back into the main river immediately after the tagging procedure was completed. Handling, from retrieval of the net from the water to release, took 6 to 8 minutes depending on the number of fish tagged per drift.

## Tracking Procedures

Radio-tagged fish that moved upriver were tracked by remote tracking stations (Fig. 3) located at 39 sites throughout the Yukon River basin (Table 2; Fig. 4). Sites selected were on important migration corridors and major tributaries of the drainage. When possible, the stations were placed on bluffs overlooking straight, narrow single-channel sections of the river to maximize reception range and increase the probability of detecting fish moving past the site. Stations consisted of several integrated components, including a computer-controlled receiver developed by Advanced Telemetry Systems Inc., and satellite uplink (Campbell Scientific, Logan, Utah). A self-contained power system--consisting of a bank of six 6-volt, sealed lead-acid batteries connected in series and parallel (12 V, 610 Ah) and charged by two 80-W solar panels--supplied power to the stations. Signals from radio-tagged fish within reception range were identified and recorded by the stations. Information collected included the date and time tagged fish were present at the site, signal strength of the transmitter, and the orientation of the fish in relation to the station (i.e., upriver or downriver from the site). Information was recorded at 10-minute intervals. Because of the isolated nature of the sites, the telemetry data collected, including information on station operations (e.g., voltage levels for the station components, and whether the reference transmitter at the site was properly recorded), were transmitted every hour to a geostationary operational environmental satellite (GOES) and relayed to a receiving station operated by NOAA, National Environmental Satellite and Data Information Service (NESDIS) near Washington D.C. (Fig. 3). Information was accessed daily via the Internet and uploaded into a computer database for analysis (Eiler and Masters 2000).

Radio-tagged Chinook salmon that passed the first set of tracking stations (hereafter referred to as Paimiut; Fig. 4), located approximately 62 km upriver from Russian Mission, were considered to have resumed upriver movements. Stations were operated at sites on the Yukon River main stem, including Paimiut, Yukon-Anvik River confluence, Yukon-Yuki River confluence, Rampart Rapids, Circle, U.S.-Canada Border (hereafter referred to as Yukon Border), downriver from the Yukon-White River confluence, upriver from the Yukon-White River confluence, Selkirk, Yukon-Tatchun Creek confluence, Yukon-Teslin River confluence, and Hootalinqua. United States tributaries monitored by tracking stations included the Bonasila, Anvik, Innoko, Nulato, Koyukuk (including sites near the mouth, Gisasa River, Hogatza River and upper section of the main stem), Melozitna, Nowitna, Tozitna, Tanana (including sites near Manley, Nenana, Chena River, Salcha River, and upper section of the main stem), Chandalar, and Porcupine (including sites on the Sheenjek River, Black River, Porcupine-Coleen River confluence, and U.S.-Canada Border hereafter referred to as the Porcupine Border) rivers. Tracking stations were also operated on Canadian tributaries including the Stewart (including sites near the mouth and above Fraser Falls), Pelly, Big Salmon, and Kluane rivers (Yukon River drainage), and Fishing Branch River (Porcupine River drainage). Pairs of stations were operated at locations with special significance, including Paimiut, lower Koyukuk River, lower Tanana River, Rampart Rapids, Yukon Border, and Porcupine Border, to avoid potential unintended loss of data (e.g., technical problems with equipment, damage from bears and other causes). Fish tracked to terminal reaches of the drainage were classified as distinct spawning stocks. The status of fish that remained in non-terminal areas, such as sections of the Yukon River main stem, was less certain because these fish could represent local spawners or fish destined for spawning areas farther upriver. Many non-terminal areas were turbid and hard to access, making verification of spawning activity difficult.

Aerial surveys were conducted in selected reaches of the drainage to locate radio-tagged fish that traveled to areas between station sites and upriver of stations on terminal tributaries. Fish were tracked from fixed-wing aircraft and helicopters equipped with 4-element Yagi receiving antennas mounted on both sides of the aircraft and oriented forward. Tracking receivers contained an integrated global positioning system (GPS) receiver to assist in identifying and recording locations. Areas surveyed in the United States included the Yukon River main stem from 41 km downriver of Russian Mission to the Yukon Border, and reaches of the Anvik, Innoko, Nulato, Koyukuk, Nowitna, Tanana, Chandalar, Sheenjek, Black, Charley, Kandik, Nation, and Tatonduk rivers. In Canada, surveys were flown along reaches of the Yukon River main stem and in numerous mainstem tributaries including Chandindu River, Klondike River, White River, Stewart River, Pelly River, Tatchun Creek, Nordenskiold River, Little Salmon River, Big Salmon River, and Teslin River. Surveys were also flown in Canadian reaches of the Porcupine River, including Old Crow, Whitestone, Miner, and Fishing Branch rivers.

**Stock Composition Estimation**

Returning Chinook salmon passing through the lower Yukon River are composed of a number of distinct stocks. These stocks travel to spawning areas throughout the basin and differ in entry timing and magnitude. A portion of these fish are intercepted in Yukon River fisheries before reaching their spawning areas. Stock composition at the tagging site is assessed by capturing, radio tagging, and tracking individuals to their final destination. The upriver distribution of the fish tagged per day is weighted by daily measures of abundance at the tagging site and adjusted to account for tagged fish removed in upriver fisheries. This approach provides an estimate of the relative abundance of stocks passing through the lower river on both a daily and seasonal basis.

The number of radio-tagged fish released on day *t* at the capture sites in the lower Yukon River are denoted as $R = (R_1, \ldots, R_T)'$. Radio-tagged fish are assumed to represent a random sample from the mixture of Chinook salmon stocks passing the tagging site each day. A total of 46 separate stocks (Fig. 5) are considered in the analysis, and the unknown stock proportions of this mixture on day *t* are denoted by $\theta_t = (\theta_{t,1}, \ldots, \theta_{t,46})'$. Final destinations include 42 terminal spawning areas and four non-terminal areas (i.e., U.S. reaches of the Yukon River main stem potentially used for spawning or as a corridor for fish traveling farther upriver; these areas potentially include main stem tributaries not surveyed during the study). The numbers of radio-tagged fish escaping to spawning areas from releases on day *t* are denoted as $\boldsymbol{r}_t = (r_{t,1}, \ldots, r_{t,46})'$. A total of 15 fisheries that harvest fish upriver from the tagging site were defined during the study (Table 3; Fig. 5); 14 of these fisheries (Fisheries B through O, numerically indexed in the estimation formulas as Fisheries 1 through 14, respectively) presumably alter the initial stock composition because together they disproportionally intercept stocks traveling to upriver spawning areas; that is, stocks traveling farther upriver are exposed to more fisheries than lower river stocks. The first of the 15 fisheries, Fishery A, is lowest in the study area, below all spawning areas, and therefore is assumed to exploit the stocks equally. Hereafter, radio-tagged fish caught in Fishery A are subtracted from the initial releases to provide a corrected set of daily releases, namely, $R = (R_1, \ldots, R_T)'$ ; fish caught in Fishery A are not considered further in this analysis. Tagged fish destined for any spawning stock, such as stock *s*, are exposed to a downriver subset of the 14 fisheries, and the collection of these fishery indices is denoted by $F_s$ . Catches in the 14 fisheries from releases of day *t* are denoted by $C_t = (c_{t,1}, \ldots, c_{t,14})'$ and the corresponding exploitation rates, or fractions of tagged fish entering and removed by each fishery, are denoted by $\phi_t = (\phi_{t,1}, \ldots, \phi_{t,14})'$ . The set of stock indices of upriver stocks passing through fishery *f* will be denoted by $S_f, f = 1, \ldots, 14$ .

Observed counts of radio-tagged fish among spawning areas and catches were modeled so the effects of unequal harvests among the stocks would not bias estimates of the stock composition at the tagging site. The naive estimate of stock composition, equal to the observed distribution of radio-tagged fish escaping to spawning areas, was rejected out-of-hand because of its inherent bias. A probability model was developed using the schematic for the migration routes, fisheries, and spawning areas in the Yukon River basin (Fig. 5). Counts of fish in the escapements and catches from a daily release are assumed to have the multinomial distribution,

$$p(r_{t,1},\ldots,r_{t,46},c_{t,1},\ldots,c_{t,14})=\left(\frac{R_t!}{\prod_{s=1}^{46} r_{t,s}!\prod_{f=1}^{14} c_{t,f}!}\right)\prod_{s=1}^{46}\left(\theta_{t,s}\cdot\psi_{t,s}\right)^{r_{t,s}}\prod_{f=1}^{14}\left(\mu_{t,f}\right)^{c_{t,f}}$$
$$\sum_{s=1}^{46}\theta_{t,s}\psi_{t,s}+\sum_{f=1}^{14}\mu_{t,f}=1,\quad t=1,\ldots,T, \tag{1}$$

where $\psi_{t,s}=\prod_{j\in F_s}(1-\phi_{t,j})$ is the probability that a fish destined for stock *s* escapes downriver fisheries, $\mu_{t,f}=\prod_{j\in H_f}(1-\phi_{t,j})\cdot\phi_{t,f}\cdot\sum_{s\in S_f}\theta_{t,s}$ is the probability that a tagged fish released on day *t* is caught in fishery *f*, and $H_f$ is the set of indices for fisheries downstream from fishery *f*. The Lagrange function for the unknowns given the recoveries and catches from day *t*, which is the likelihood function with an added term to constrain the daily probabilities to equal 1, is

$$\log L(r,c;\theta_t,\phi_t)=\kappa+\sum_{s=1}^{46} r_{t,s}\log\left(\theta_{t,s}\cdot\psi_{t,s}\right)+\sum_{f=1}^{14} c_{t,f}\log\left(\mu_{t,f}\right)+$$
$$\gamma\left(\sum_{s=1}^{46}\theta_{t,s}\psi_{t,s}+\sum_{f=1}^{14}\mu_{t,f}-1\right), \tag{2}$$

where $\kappa$ is a constant and $\gamma$ is a constant called the Lagrange multiplier. The Lagrange function is maximized by values of $\theta_{t,s}$ given in Table 4 with known values of $\phi_{t,f}$ given by

$$\phi_{t,f} = c_{t,f} \Bigg/ \left( R_t - \sum_{s\in G_f} r_{t,s} - \sum_{j\in H_f} c_{t,j} \right), f = 1,\ldots,14, \qquad (3)$$

where $G_f$ is the set of indices for stocks downstream from fishery $f$.

The numbers of radio-tagged fish released on any particular day, however, are quite limited for the estimation of the unknown daily fractions destined for the various stocks. Therefore, releases over longer periods than a single day are considered. The daily fractions destined for the various stocks are expected to be more similar on days nearby than they are on days distant. Therefore, this estimation for the days of release, $t$ = 1, 2, …, $T$, is accomplished by use of a moving window of width equal to $2d + 1$ days ($d$ = 0, 1, …, $d_{max}$) centered on the day $t$, namely, $[t - d, t + d]$. The moving-window estimate on day $t$, $\hat{\theta}_{t,s}^{(d)}$, is computed from the equations of Table 4, substituting $R_t^{(d)}$ for $R_t$, $r_{t,s}^{(d)}$ for $r_{t,s}$ and $c_{t,f}^{(d)}$ for $c_{t,f}$. Here $R_t^{(d)} = \sum_{j=t-d}^{t+d} R_j$ is the total number of radio-tagged fish released during days included in the window about $t$, $r_{t,s}^{(d)} = \sum_{i=t-d}^{t+d} r_{i,s}$ is the total number of radio-tagged fish migrating to stock $s$ from releases of days included in the window about $t$, and $c_{t,f}^{(d)} = \sum_{j=t-d}^{t+d} c_{j,f}$ .

The estimated fractions at day $t$ destined for the stocks are the fractions of total releases during the window centered on day $t$ that would have ultimately tracked to the various stocks had the fisheries not intercepted them. At the beginning and the end of the tagging interval, $[1, T]$, the window includes days for which no releases were made. These days represent periods of few migrants and have little effect on estimates. The recoveries from these days are set to zero in the moving-window estimator. For example, if window width is $2d + 1 = 3$, the moving-window estimator of migration composition at day 1 includes no recoveries of day 0, and $r_{0,s}$ is set to zero for $s = 1, 2, \ldots, S$. At day $T$, the window includes no recoveries of day $T + 1$ so $r_{T+1,s}$ is set to zero for $s = 1, 2, \ldots, S$. In effect, the window width is reduced at the beginning and end of the tagging interval during which minimal numbers of migrants passed the tagging site. We chose $d = 3$, or a window width of one week, as reasonable.

Although the estimates of daily stock composition are of interest, they do not reflect the changes in magnitude of daily returns to the Yukon River. The unknown daily numbers of fish passing the capture site are denoted as $E_1, E_2, \ldots, E_T$, and their season total is $E_. = \sum_{i=1}^{T} E_i$ .

The daily fractions of the total return passing the capture site are denoted as

$$\pi_i = E_i / E_., \quad i = 1, \ldots, T \ . \tag{4}$$

Daily fractions of the total season return of Chinook salmon to the Yukon River that pass the capture site are estimated from the catch rates of gill nets used to capture fish for tagging. Gill nets are expected to capture fish in proportion to daily effort. Daily catches, $X_1, \ldots, X_T$ , are assumed to be Poisson random variables with expected values,

$$\lambda_t = \lambda h_t E_t = (\lambda E_.) h_t \frac{E_t}{E_.} = \lambda_0 h_t \pi_t, \quad t = 1, \ldots, T \ , \tag{5}$$

where $\lambda_0 = \lambda E_.$ is a constant proportional to the total return, and $h_t$ is the number of units of effort fished on day *t*. Maximum likelihood estimates of the daily migration fractions, $\pi = (\pi_1, \ldots, \pi_T)'$, can be shown to be the time series of normalized catch per effort,

$$\hat{\pi}_t = Y_t \Big/ \sum_{j=1}^{T} Y_j = \left( X_t / h_t \right) \Big/ \left( \sum_{t'=1}^{T} X_{t'} / h_{t'} \right), \quad t = 1, \ldots, T \;. \tag{6}$$

The maximum likelihood estimate of $\lambda_0$ is $\hat{\lambda}_0 = \sum_{t=1}^{T} X_t / h_t$ .

Daily fractions of the total season return to the Yukon River basin that are destined for any particular stock equal the products of the stock's daily proportions, $\theta_{t,s}$, and the corresponding daily fractions of the total season return passing the tagging site, namely, $\omega_{t,s} = \pi_t \theta_{t,s}$. These stock-specific daily fractions of the total return are estimated by the daily products of the estimates of stock composition (Table 4) and the daily migration fractions, $\hat{\pi}_t$, $t = 1, \ldots, T$, from Equation 6,

$$\hat{\omega}_{t,s} = \hat{\pi}_t \hat{\theta}_{t,s}, \quad s = 1, \ldots, 46;\; t = 1, \ldots, T \;. \tag{7}$$

Finally, the estimated fraction of the total season return to the Yukon River basin that belonged to any stock *s* equals the sum,

$$\hat{\alpha}_s = \sum_{t=1}^{T} \hat{\omega}_{t,s}, \quad s = 1,\ldots,46 \tag{8}$$

To evaluate the sampling variation in estimates, a parametric bootstrap was performed. First, random bootstrap samples of daily gillnet catches, $X_1^*, X_2^*,\ldots, X_T^*$, were drawn from Poisson distributions with expected values of the $X_t^*$ determined from the maximum likelihood estimates and equal to $\hat{X}_t = \hat{\lambda}_0 h_t \hat{\pi}_t,\ t = 1,2,\ldots,T$. These random catches were used to compute corresponding bootstrap catch rates $Y_1^*, Y_2^*,\ldots, Y_T^*$, and daily migration fractions, $\pi_t^*,\ t = 1,\ldots,T$. Next, independent daily multinomial samples of radio-tagged fish, either migrating to the possible stocks, $r_{t,1}^*, r_{t,2}^*,\ldots, r_{t,S}^*$, or caught in the various fisheries, $c_{t,1}^*,\ldots, c_{t,14}^*$, from the daily known numbers released, $R_t$, were drawn with probabilities equal to the original maximum likelihood estimates,

$$p(r_{t,1}^*,\ldots, r_{t,S}^*, c_{t,1}^*,\ldots, c_{t,14}^*) = \left( \frac{R_t\,!}{\prod_{s=1}^{S} r_{t,s}^*\,! \prod_{f=1}^{14} c_{t,f}^*\,!} \right) \prod_{s=1}^{S} \left( \hat{\theta}_{t,s}^{(d)} \cdot \psi_{t.s}^{(d)} \right)^{r_{t,s}^*} \prod_{f=1}^{14} \left( \hat{\mu}_{t,f}^{(d)} \right)^{c_{t,f}^*} . \tag{9}$$

Bootstrap samples of tagged fish in catches and escapements were used to compute the corresponding bootstrap estimates for stock proportions, such as $\hat{\theta}_t^{(d)*}$, just as with the original counts of tagged fish. Finally, bootstrap estimates for stock proportions were weighted by the bootstrap daily migration fractions. The next bootstrap sampling began with another draw of the daily gillnet catches and tagged numbers migrating to the possible stocks or caught in the fisheries, followed by computation of the bootstrap estimates of daily catch rates, daily migration fractions, daily stock compositions, and weighted stock compositions.

## Migration Rates

Migration rates for radio-tagged Chinook salmon were calculated by comparing the date and time that the fish moved upriver past the Paimiut tracking stations with information (i.e., date and time of passage, and the distance traveled upriver from Paimiut) from the station farthest upriver that last recorded the fish. Movements by the fish between the tagging site and Paimiut were not included in these calculations to avoid incorporating tagging-induced behavior that would bias the results, although these data were used as a relative measure to evaluate how the fish responded to the capture and tagging procedures. Migrations rates between tracking stations were also calculated to determine movement patterns within different reaches of the basin.

# RESULTS

## Fish Capture and Tagging

Drift gill nets were an effective method for capturing large numbers of adult Chinook salmon in suitable condition for tagging. Fishing commenced early in the run and continued until the end of the run when catch rates were low. A total of 490 hours were fished at Russian Mission from 3 June to 14 July, and 2,312 Chinook salmon were captured (Table 1). Catch per unit effort (CPUE) data from the site suggest that the entire Chinook salmon return exhibited a relatively normal distribution, although the latter portion of the return was more protracted than the early run (Fig. 6). Although several distinct pulses of fish moved through the lower river, the peak of the run was pronounced and passed Russian Mission between 15 June and 21 June (Week 25).

Of the 2,312 Chinook salmon captured, 1,097 fish were radio tagged, ranging from 390 fish in Week 25 (15-21 June) to 5 fish in Week 29 (13-14 July)(Table 1). Six-year-old fish were the dominant age group in the tagged sample (69.3%). The remaining fish were primarily 5-year-olds (22.1%), with smaller percentages of 7-year-olds (8.1%), 4-year-olds (0.4%), and 8-year-olds (0.1%). Radio-tagged fish averaged 849 mm in length, ranging from 530 mm to 1,075 mm. Fish were primarily bright, iridescent silver in color during the first 4 weeks of tagging, ranging from the entire sample in Week 23 to 68.2% of the sample in Week 26 (Table 5). This color phase was less prominent near the end of the run, ranging from 52.7% of the sample in Week 27 to 36.4% of the sample in Weeks 28-29. Increasing numbers of fish exhibited a dull silver coloration later in the run, with 50.6% of the sample displaying this color phase in Weeks 28-29.

Fish with pre-spawning colors, ranging from blush (silver with reddish tinges) to a pronounced reddish coloration, were first observed in Week 25 (0.8% of the sample) and became more prevalent later in the run (7.4% of the sample in Week 27 and 13.0% of the sample in Weeks 28-29)(Table 5). Fish color in the lower river was also influenced by the final destination of the fish. Most Chinook salmon traveling to Canadian reaches of the basin were iridescent silver when passing the Russian Mission tagging site (92.0% of the Yukon River fish and 93.3% of the Porcupine River fish). Only a small percentage were dull silver, and no Canadian fish displayed pre-spawning coloration (Fig. 7). Iridescent silver color was also prominent for U.S. stocks traveling to middle and upper reaches of the basin, ranging from 48.3% of the Koyukuk River fish to 69.6% of the Porcupine River fish. These stocks also exhibited the dull silver color (ranging from 26.1% of the Porcupine River fish to 41.4% of the Koyukuk River fish), and fish destined for the Koyukuk (10.3%), Tanana (1.1%), upper Yukon (2.2%), and Porcupine (4.3%) rivers also displayed pre-spawning coloration. Most fish (75.9%) returning to lower basin tributaries were dull silver in color, with smaller percentages exhibiting iridescent silver (11.1%) and pre-spawning (13.0%) coloration (Fig. 7).

## Fish Response to Tagging

Chinook salmon responded well to the capture and tagging procedures, with most fish resuming upriver movements after release (Table 6; Fig 7). A total of 1,081 (98.5%) radio-tagged fish passed Paimiut and traveled to upriver reaches (810, 73.8%) or were caught in upriver fisheries (271, 24.7%). Sixteen (1.5%) fish did not resume upriver movements, and either regurgitated their tags or died due to handling, predation, or undocumented encounters with fisheries. Radio-tagged fish averaged 1.8 days after release to pass Paimiut, traveling an average of 32.9 km/day (Table 7). Comparable rates (i.e., weekly averages) were observed throughout the tagging period, ranging from 27.2 km/day (Week 27) to 37.9 km/day (Week 23). Movement rates between the tagging area and Paimiut did not vary substantially by fish age or length, although average rates were faster for fish released in the lower section of the tagging area and that had farther to travel prior to reaching Paimiut (Table 8).

## Fishery Recoveries

A total of 271 radio-tagged fish were harvested in fisheries throughout the Yukon River basin (Table 6). Most (226, 83.4%) of these fish were caught in U.S. fisheries (Table 9; Fig. 8). Harvest rates differed between regions, with 27 (10.0%) fish caught from Russian Mission to Holy Cross, 56 (20.6%) fish caught from Anvik to Ruby, and 114 (42.1%) fish caught in the upper Yukon River from the Yukon-Tanana River confluence to Eagle (Table 9; Appendix A). With the exception of the fishery near Eagle, these fish were likely comprised of both U.S. and Canadian stocks. Fish caught near Eagle were assumed to be destined for spawning areas in Canada. Twenty-five (9.2%) fish were harvested in the Tanana River, with most (22, 8.1%) caught near Nenana and Fairbanks (Appendix A). Four (1.5%) fish were caught near villages on the Koyukuk River. Aerial surveys, flown over villages along the Tanana River and Yukon River main stem, documented that 67 of the 226 (29.7%) fish harvested were not reported by fishers.

Forty-five (16.6%) fish were harvested in Canadian reaches of the basin (Table 9). Forty-two (15.5%) of these fish were destined for Yukon River spawning areas, with most of the recoveries from Dawson, Carmacks, Stewart River, Pelly River, and the Teslin River (Appendix A). Three (1.1%) fish were caught in the Porcupine River fishery near the village of Old Crow.

## Distribution of Radio-Tagged Fish

Radio-tagged Chinook salmon traveled to areas throughout the Yukon River basin (Fig. 9). A total of 884 fish were tracked to upriver areas or recovered in terminal fisheries. Fish traveling upstream of the Yukon-Tanana River confluence (hereafter referred to as the upper basin) comprised the largest component of the sample, with 541 (61.2%) fish returning to the upper Yukon and Porcupine rivers (Table 10, Fig. 10). A substantial number of these fish traveled to Canadian reaches, including 413 (46.8%) Yukon River fish and 30 (3.3%) Porcupine River fish (Fig. 10). Most (318, 36.0%) Canadian fish were tracked to tributaries of the Yukon River main stem (Table 10), including the Stewart (31, 3.6%), Pelly (79, 8.9%), Big Salmon (59, 6.7%), and Teslin (71, 8.0%) rivers (Appendices B, C). Small numbers of fish were also located in the Chandindu River (5, 0.6%), Klondike River (19, 2.1%), White River (12, 1.4%), Big Creek (1, 0.1%), Tatchun Creek (3, 0.3%), Nordenskiold River (8, 0.9%), Little Salmon River (17, 1.9%), and headwater areas upriver of the Yukon-Teslin River confluence (13, 1.5%) including 6 (0.7%) fish in the Takhini River (Appendix B). Seventy-four (8.4%) fish remained in reaches of the Yukon River main stem or traveled to associated tributaries not monitored by tracking stations or surveyed by aircraft (Table 10); most (61, 6.9%) of these fish were located upriver of Selkirk (Appendix B). Canadian fish in the Porcupine River were tracked to headwater tributaries including the Miner (13, 1.5%), Whitestone (1, 0.1%) and Fishing Branch (1, 0.1%) rivers (Appendices B, D). Radio-tagged fish were also located in upper reaches of the Old Crow River (2, 0.2%). Ten (1.1%) fish that passed the Porcupine Border, and were not harvested in the Old Crow fishery, were not located during survey flights, suggesting that Chinook salmon may utilize other spawning areas in the Porcupine River drainage.

Ninety-eight (11.1%) fish were tracked to the U.S. portion of the upper basin, including 76 (8.6%) Yukon River fish and 22 (2.5%) Porcupine River fish (Table 10). Forty-five (5.1%) fish in the upper Yukon River were tracked to tributaries (Fig. 10; Appendix E). Most of these fish returned to the Chandalar River (36, 4.1%), although small numbers were located in Beaver Creek (3, 0.3%) and the Charley (3, 0.3%), Kandik (1, 0.1%) and Nation (2, 0.2%) rivers (Appendix B). Thirty-one (3.5%) fish remained in reaches of the Yukon River main stem or traveled to associated tributaries not monitored by tracking stations or surveyed by aircraft (Fig. 10), including 21 (2.4%) fish downriver from Circle and 10 (1.1%) fish upriver from Circle. Most Porcupine River fish returned to the Sheenjek River (20, 2.3%), while two (0.2%) fish were tracked to the upper reaches of the Black River (Appendices B, E).

Tanana River fish comprised a major component of the sample, with 190 (21.5%) fish returning to areas within the Tanana River drainage (Table 10; Fig. 10). Most (136, 15.4%) Tanana River fish traveled to tributaries in the upper reaches of the drainage, including the Chena (40, 4.5%), Salcha (58, 6.5%), and Goodpaster (36, 4.1%) rivers (Appendices B, F). Fish were also located in reaches of the Kantishna (15, 1.7%) Tolovana (5, 0.6%), and Nenana

(3, 0.3%) rivers. Twelve (1.4%) fish remained in reaches of the Tanana River main stem or traveled to associated tributaries not surveyed. Nineteen (2.1%) fish were harvested in fisheries in the Tanana River main stem, with most (18, 2.0%) caught near Nenana and Fairbanks (Appendix B).

Fifty-four (6.1%) fish traveled to tributaries in the lower basin (Table 10; Fig. 10). Anvik River (31, 3.5%) and Nulato River (15, 1.7%) fish were most prevalent, with smaller numbers of fish traveling to the Innoko (2, 0.2%) and Bonasila (6, 0.7%) rivers (Appendices B, G). Thirteen (1.5%) fish returned to tributaries associated with the middle Yukon River (Table 10; Fig. 10), including the Melozitna (1, 0.1%), Nowitna (2, 0.2%), and Tozitna (10, 1.1%) rivers (Appendices B, H). Twenty-nine (3.3%) fish returned to the Koyukuk River (Table 10; Fig. 10), including 11 (1.2%) Gisasa River fish and two (0.2%) fish that traveled to middle drainage tributaries. Twelve (1.4%) Koyukuk River fish traveled to upper reaches of the drainage, including the Hogatza (1, 0.1%), Henshaw (1, 0.1%), South Fork (3, 0.3%), and Middle Fork (2, 0.2%) rivers. The five (0.6%) remaining fish were not located during aerial surveys of the upper headwaters. Fifty-seven (6.4%) fish were last recorded in non-terminal reaches of the Yukon River main stem, including 49 (5.5%) fish in the lower basin and 8 (0.9%) fish in the middle Yukon River (Table 10). Some of these non-terminal fish may have traveled to mainstem tributaries not surveyed during the study.

## Stock Composition

Stock composition estimates were derived for the Chinook salmon return based on the distribution of radio-tagged fish, adjusted to account for both the harvest of tagged individuals in upriver fisheries and changes in run abundance at the Russian Mission tagging site. The Chinook run was composed primarily of Tanana River (18.9%) and upper basin (67.2%) stocks (Table 11). Canadian fish comprised a substantial proportion of the return (55.4%), with the majority (51.5%) traveling to reaches of the Yukon River and only a small percentage (3.9%) traveling to the Porcupine River (Table 11, Fig. 11). Most Canadian fish (42.2%) returned to tributaries of the Yukon River main stem, primarily the Stewart (4.2%), Pelly (10.6%), Big Salmon (8.0%), and Teslin (9.4%) rivers (Fig. 12). Smaller stocks included the Chandindu (0.4%), Klondike (2.8%), White (1.7%), Tatchun (0.3%), Nordenskiold (1.2%), and Little Salmon (2.1%) rivers and reaches upriver of the Yukon-Teslin River confluence (1.5%) (Appendix I). Canadian fish also remained in reaches of the Yukon River main stem and small associated tributaries (9.3%), including 0.5% downriver from Dawson (i.e., the lower Canadian Yukon River), 4.4% between Dawson and the Yukon-Tatchun Creek confluence (i.e., the mid-Canadian Yukon River), and 4.4% upriver of the Yukon-Tatchun Creek confluence (i.e., the upper Canadian Yukon River). Most (2.1%) Porcupine River fish traveled to the Miner River, although small numbers also returned to the Old Crow, Whitestone, and Fishing Branch rivers.

Chinook salmon stocks returning to U.S. reaches comprised a substantial proportion (44.6%) of the run, including 18.9% Tanana River fish and 7.9% upper basin fish (Table 11, Fig. 13). Fish returning to the Chena (4.6%), Salcha (6.5%), and Goodpaster (4.2%)

rivers were the dominant Tanana River stocks (Fig. 13). Tanana River fish also returned to the Kantishna River (1.4%), Tolovana River (0.5%), and other small tributaries (Appendix I). A small proportion of the return (1.8%) remained in reaches of the Tanana River main stem or traveled to associated tributaries not surveyed during the study, including fish in the lower (0.2%), middle (0.7%), and upper (0.9%) drainage. Upper basin fish traveled to reaches in both the Yukon (5.2%) and Porcupine (2.7%) rivers (Fig. 11). Spawning populations were documented in Yukon River tributaries including Beaver Creek (0.4%), and the Chandalar (4.1%), Charley (0.4%) and Kandik/Nation (0.4%) rivers (Fig. 13). Fish also remained in reaches of the Yukon River main stem or small associated tributaries not surveyed during the study (3.9%), including 2.6% downriver from Circle and 1.3% between Circle and Eagle. Fish returning to U.S. reaches of the Porcupine River traveled to spawning areas in the Sheenjek (2.4%) and Black (0.3%) rivers (Fig. 13). Although no tracking surveys were conducted, local residents observed untagged Chinook salmon spawning in the Coleen River, a tributary of the Porcupine River located downriver from the Porcupine border.

Chinook salmon also spawned in reaches of the lower basin and middle Yukon River. A total of 4.6% of the run returned to tributaries in the lower basin (Fig. 11), including the Innoko (0.2%), Bonasila (0.5%), Anvik (2.6%), and Nulato (1.3%) rivers (Fig. 13). Middle Yukon River tributaries comprised 1.3% of the return, with most fish traveling to the Tozitna River (1.0%), and smaller numbers spawning in the Melozitna (0.1%) and Nowitna (0.2%) rivers. Fish also remained in reaches of the Yukon River main stem downstream of the Yukon-Tanana River confluence or traveled to small associated tributaries not surveyed during the study (5.3%), with most of these in the lower basin (4.6%). Relatively small numbers of Chinook salmon returned to the Koyukuk River (2.7%), with fish traveling to the Gisasa River (1.0%) and upper reaches of the drainage (1.7%) (Fig. 11, Appendix I).

Most Chinook salmon stocks passing through the lower Yukon River exhibited similar run timing patterns, although some regional differences were observed. Tanana River and Canadian Yukon River stocks were present throughout the return, but were most abundant in mid-June during the peak of the run (Fig. 14). Several distinct pulses were also observed during early June and late June-early July. A similar pattern was observed for Porcupine River fish and stocks returning to tributaries in U.S. reaches of the upper Yukon River. Koyukuk and middle Yukon River tributary fish were present in small numbers throughout the return, although these stocks were primarily middle and late run fish. Fish traveling to lower basin tributaries were also present throughout the run, although these stocks were more abundant during late June and July (Fig. 14).

Run timing differences were also observed within regions of the basin. Chinook salmon returning to the Klondike River were primarily early run fish compared to fish returning to the Stewart, White, Pelly, Little Salmon, and Big Salmon rivers (Fig. 15). Fish traveling to the Teslin River and headwater areas upriver of Hootalinqua exhibited a more protracted run timing that extended later into the run. A similar pattern was observed for fish returning to middle and upper reaches of the Canadian main stem and associated tributaries. Canadian stocks returning to the Porcupine River were generally early and middle run fish (Fig. 15), particularly those returning to the Miner River in the upper headwaters. Fish traveling to the Old Crow River and other areas not identified during aerial surveys exhibited a more protracted and later run timing. Chinook salmon returning to U.S. reaches of the Porcupine River were comprised primarily of

Sheenjek River fish which passed through the lower river from mid-June to early July, while small numbers of Black River fish moved through this area in mid-June. Although Sheenjek River and Chandalar River fish exhibited similar run timing, the Chandalar River return was more protracted, extending from early June to mid-July (Fig. 16). In the Tanana River drainage, Chena, Salcha, and Goodpaster River fish were primarily early and middle run stocks, while Kantishna River fish were observed during the middle run. Koyukuk River fish were present throughout the run; however, the run timing of upper headwater stocks was somewhat earlier, with fish passing through the lower river from early June to early July, compared to Gisasa River fish which were observed from mid-June to mid-July. The run timing for Anvik and Nulato River fish, the dominant stocks in the lower basin, was later than that exhibited by middle and upper basin fish (Fig. 16). Similar run timing was observed for Bonasila River fish.

Differences were also observed in the daily composition of stocks moving through the lower river (Appendix J). Canadian stocks were predominant throughout most of the run (Fig. 17), comprising an average of 52.1% of the fish passing the Russian Mission tagging site per day. These stocks were somewhat more prevalent during early and mid-June, with daily composition averaging 61.6% and 42.1% during the first and last half of the run, respectively. Although less abundant than Canadian stocks, Tanana River fish (16.6% daily average) exhibited a similar pattern with daily averages of 20.2% and 12.9% during the first and last half of the run, respectively. In contrast, fish returning to tributaries in the lower and middle basin were more prevalent later in the run. Although relatively minor in terms of overall abundance (Fig. 11, Table 11), these stocks comprised a substantial portion of the late run with daily composition averaging 22.3% compared to an average of 4.3% during early and mid-June. A similar pattern was observed for fish returning to tributaries in U.S. reaches of the upper basin. Daily averages of non-terminal fish remaining in upper reaches of the basin were consistent throughout the return, ranging from 3.4% during the first half and 4.1% during the last half of the run. In the lower basin, fish remaining in non-terminal areas were more prevalent later in the run, with daily average of 9.9% compared with 4.5% during early and mid-June.

Stock composition estimates were based on the assumption that fish allocated to designated stock groups, including those in non-terminal areas, represented spawning populations. Non-terminal stock groups that included fish in-transit to areas farther upriver (i.e., fish that were harvested in fisheries but not reported, or died due to disease, injuries, or predation prior to reaching their final destination) would bias composition estimates and underestimate the contribution of upriver stocks. To address this concern, stock composition estimates were recalculated with fish remaining in non-terminal areas categorized as in-transit and treated as fishery recoveries. Composition estimates for most stocks were similar using the two approaches (Fig. 18). The greatest difference was observed for Yukon River fish in Canada, with estimates ranging from 51.5% of the return when non-terminal fish were categorized as spawning populations to 58.1% of the return when these fish were considered in-transit to spawning areas farther upriver.

## Movement Patterns

Radio-tagged fish traveled an average of 50.9 km/day, although regional and stock differences were observed. Upper basin fish traveled an average of 54.7 km/day. Fish returning to the Yukon River in Canada averaged 53.6 km/day, ranging from 48.7 km/day for fish traveling to reaches of the Yukon River main stem to 60.1 km/day for Klondike River fish (Table 12). Similar rates were observed for stocks traveling to U.S. reaches in the upper Yukon River, with averages of 58.7 km/day for tributary fish and 55.4 km/day for fish remaining in non-terminal areas (i.e., reaches of the main stem or associated tributaries not monitored during the study). Porcupine River fish typically traveled faster than upper Yukon River fish, averaging 61.3 km/day for U.S. stocks and 58.6 km/day for Canadian stocks (Table 12). Tanana River fish exhibited slower migration rates (47.6 km/day average), with rates for Chena River, Salcha River, and Goodpaster River fish ranging from averages of 44.8 km/day to 47.0 km/day. Tributary fish returning to the middle Yukon River averaged 47.2 km/day; a similar rate (49.6 km/day) was observed for non-terminal fish within this section of the basin. In the Koyukuk River drainage, Gisasa River fish averaged 42.9 km/day, compared to 63.1 km/day for fish traveling to the upper headwaters of the drainage. Chinook salmon returning to reaches in the lower basin moved substantially slower than middle and upper basin stocks. Fish located in lower river tributaries averaged 31.2 km/day, ranging from 24.2 km/day for Anvik River fish to 45.6 km/day for Bonasila River fish (Table 12; Appendix K).

Migration rates recorded for Chena, Salcha, and Goodpaster River fish were substantially slower than most middle and upper basin stocks. However, the tracking stations used to monitor these tributaries were located relatively close to spawning areas, and the lower rates likely reflect slower swimming speeds as the fish approached their natal streams. When comparing swimming rates based on movements from Paimiut to the lower Tanana River, these stocks averaged between 54.4 km/day and 60.0 km/day (Table 13), movement rates comparable to upper basin fish (Fig. 19). A similar phenomenon was observed for other stocks, including fish traveling to the Gisasa and Nulato rivers. In contrast, tracking stations on tributaries associated directly with the Yukon River main stem, such as the Chandalar, Sheenjek, Stewart, and Pelly rivers, were typically placed near the confluence and were often located a substantial distance from spawning areas. The average movement rates for fish passing these stations were comparable to rates observed lower in the basin (Table 13, Fig. 19). For example, Stewart River fish averaged 55.9 km/day between tracking stations at Paimiut and the Stewart River (located approximately 20 km from the Yukon-Stewart River confluence), compared to 56.8 km/day for these fish between Paimiut and the Yukon border. Similarly, Chandalar River fish averaged 58.3 km/day between Paimiut and the Chandalar tracking station (located approximately 10 km from the Yukon-Chandalar River confluence), compared to 60.4 km/day between Paimiut and the Rampart Rapids tracking station.

## DISCUSSION

Management of Yukon River Chinook salmon has become complicated by recent declines in abundance and the international nature of the drainage, which makes it necessary to address harvest allocation issues in both the United States and Canada. Radio telemetry has been used effectively to provide information on Pacific salmon (Burger et al. 1985, Eiler et al. 1992, Bendock and Alexandersdottir 1993); however, the logistical problems associated with capturing, tagging, and tracking large numbers of highly mobile fish in the Yukon River basin are unique and severe. Preliminary work in 2000-2001 and a large-scale study in 2002 (Eiler et al. 2004) demonstrated that basin-wide radio-tagging programs on Yukon River Chinook salmon are feasible and provide useful information on run characteristics and fish movements. The 2003 basin-wide study was conducted to collect additional information on Chinook salmon run characteristics and movements, and to address annual variation.

Drift gill nets were effective in capturing adequate numbers of fish in the lower Yukon River in suitable condition for tagging, with 1,097 fish tagged and released in 2003. Satellite-linked tracking stations, combined with aerial surveys in selected reaches of the basin, and an integrated database and GIS mapping program were used to collect and summarize telemetry data in-season, making it possible to effectively monitor fish movements and prioritize field activities. A primary assumption in tagging studies is that capture and tagging procedures do not adversely affect the fish (i.e., tagged fish behave the same as untagged fish), or that any effect is limited in severity and duration, and ultimately has a negligible impact. Chinook salmon tagged in 2003 appeared to recover promptly from the handling methods with most (98.5%) resuming upriver movements after release. Similar results were observed during the 2002 basin-wide study when more than 97% of the tagged Chinook salmon traveled to upriver areas or were recovered in upriver fisheries (Eiler et al. 2004). The percentages of fish not moving upriver after release during both 2002 (2.2%) and 2003 (1.5%) are lower than reported for other tagging studies (Burger et al. 1985, Milligan et al. 1985, Johnson et al. 1992).

Fish adversely affected by tagging would likely show reduced vitality as they moved upriver, particularly those individuals traveling long distances. However, the movement rates observed during the 2003 study did not exhibit this pattern, with upper basin fish traveling an average of 55 km/day. A similar pattern was observed during the 2002 study, with upper basin fish averaging 54 km/day (Eiler et al. 2004). Pulses of untagged Chinook salmon in the Yukon River are thought to travel between 48 km/day and 56 km/day based on estimated arrival times at village fisheries along the drainage (T. Vania, Fishery Management Biologist, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518. Pers. commun., February 2001) . These estimates are comparable to migration rates observed for radio-tagged fish during the 2002 and 2003 studies. Information from previous tagging studies also suggests that handling did not adversely affect migration rates. Chinook salmon radio tagged at Rampart Rapids in 1998 traveled an average of 53 km/day (Joint Technical Committee of the Yukon River U.S./Canada Panel 1998), movement rates comparable to those for upper basin fish tagged during the 2003 study, even though these individuals traveled substantially greater distances. By comparison, radio-tagged Chinook salmon in the Columbia River traveled between 43 km/day and 77 km/day through dam reservoirs (i.e., slow-moving water with minimal current) and about half that rate in riverine sections of the basin (Bjornn et al. 2000, Keefer et al. 2004).

The initial response exhibited by fish tagged at Russian Mission (i.e., the movement rate between the tagging site and the Paimiut tracking stations) indicates that the fish exhibited a delay in upriver movements or slower swimming speeds initially after release. However, the movement rates observed after passing Paimiut were substantially greater and were comparable to the rates observed for pulses of untagged fish caught in village fisheries, suggesting that any adverse effect from tagging was limited or short-term. Migration rates calculated for Chinook salmon (Tables 12, 13) were based on the movements of radio-tagged fish upriver from Paimiut to exclude tagging-induced behavior that would bias the results and not reflect typical movements of untagged fish.

Regional differences were observed in migration rates of Chinook salmon stocks in 2003. Upper basin fish generally exhibited faster upriver movements, traveling an average of 55 km/day. These movements are noteworthy considering the long distances traveled by the fish, with stocks returning to the uppermost Canadian headwaters traveling more than 2,300 km prior to reaching spawning areas. On average, lower basin tributary fish exhibited substantially lower rates (31.2 km/day) than middle and upper basin fish. The slower movements may be associated with the shorter distances these fish are traveling and may reflect reduced swimming speeds as the fish approach their natal streams. This phenomenon was documented for fish leaving the Yukon River main stem and traveling up the Tanana River, with movement rates dropping substantially as the fish approached their spawning tributaries. Migration rates exhibited by Chinook salmon stocks were remarkedly similar while moving through reaches of the Yukon River main stem, even for fish returning to reaches of the lower basin. Although Nulato River fish traveled an average of 39.2 km/day between Paimiut and the Nulato River, migration rates between Paimiut and the Yukon-Anvik River confluence averaged 55.2 km/day (Table 13), a rate comparable to the rate for upper basin fish. Milligan et al. (1985) reported a migration rate of 36 km/day for Chinook salmon radio-tagged above the Yukon Border in 1982-1983 compared to 53 km/day observed for Canadian stocks during this study. The slower speed reported in the 1985 report may relate to a variety of factors including differences in water levels, handling and tagging procedures, tracking methods, and sample composition.

Chinook salmon returning to the Yukon River basin in 2003 were primarily Tanana River (18.9%) and upper basin stocks (67.2%), comprising approximately 86% of the return. A similar pattern was observed during the 2002 study, in which these two stock groups comprised

87% of the return (Eiler et al. 2004). Canadian fish were the dominant component of the run in 2003 (55.4%), with most (42.2%) traveling to headwater tributaries of the Yukon River. Stewart, Pelly, Big Salmon, and Teslin River fish were the primary Canadian stocks. Smaller tributaries also supported spawning populations, and appreciable numbers of fish remained in Canadian reaches of the Yukon River main stem, although turbid conditions made it impossible to verify spawning activity. Chinook salmon spawning has been previously reported in these areas (Milligan et al. 1985), suggesting that these fish may represent spawning populations. Small numbers (3.9%) of fish also returned to Canadian reaches in the Porcupine River.

United States stocks were also an important component of the 2003 return. Similar to the Canadian component, these fish included a combination of major and minor stocks. Chinook salmon returning to the Tanana River (18.9%) were predominantly Chena, Salcha, and Goodpaster River fish (15.3%), although minor spawning populations were also documented in the Kantishna, Tolovana, and Nenana rivers as well as in reaches of the Tanana River main stem and small associated tributaries. Although spawning has been reported for Chinook salmon in U.S. reaches of the upper basin, it was generally thought to be minor. However, this stock group comprised about 7.6% of the return, with Chandalar and Sheenjek River fish as the primary components (6.5%). Radio-tagged fish were located in small mainstem tributaries, and fish also remained in non-terminal areas or traveled to associated tributaries not surveyed during the study.

Relatively few radio-tagged fish returned to the middle Yukon River compared to other regions of the basin. The small middle river tributaries (i.e., Melozitna, Nowitna, and Tozitna rivers) comprised only 1.3% of the sample combined. Although the Koyukuk River drains a large watershed, the percentage of fish tracked to this tributary was also relatively low (2.7%).

Chinook salmon traveled to lower basin tributaries, comprising 4.6% of the return. Chinook salmon in this region were predominantly Anvik and Nulato River fish (3.9%), with small numbers of fish traveling to other areas.

Chinook salmon returns passing through the lower Yukon River are composed of a number of distinct stocks. These stocks travel to spawning areas throughout the basin, and differ in run timing and magnitude. The two major stock groups, Canadian Yukon River and Tanana River fish, exhibited similar run timing patterns, with most fish passing through the lower river during the peak of the run in mid-June with several distinct pulses during the early and late run, while lower basin stocks were comprised primarily of late-run fish (Fig. 14). Differences in run timing were also observed within regions. For example, Canadian fish returning to the Teslin River and middle-upper Yukon River main stem displayed a more protracted run timing that extended later into the run than other Canadian stocks (Fig. 15). In the Porcupine River, fish traveling to U.S. reaches exhibited a later run timing than Canadian stocks, which were primarily early run fish (Figs. 15, 16). However, in general, stocks within the Yukon River basin were not temporally distinct, making it difficult to separate stocks based on run timing.

Daily stock composition estimates for Chinook salmon further illustrated the predominance of Canadian Yukon River and Tanana River stocks. When compared on a daily basis, Canadian fish were the most abundant stock group moving through the lower river during the early and middle run (Fig. 17). Although less abundant, Tanana River fish displayed a similar pattern during this period. Fish destined for the Porcupine River and U.S. tributaries in the upper basin were present from early June to mid-July, although these stocks were a minor component throughout the run. Lower basin fish were prevalent later in the run, although the Canadian contribution was comparable during this period.

Country of origin estimates for 2003 indicate that Canadian stocks comprised approximately 55% of the Yukon River Chinook salmon return, with most of these fish traveling to the Canadian portion of the Yukon River (51.5%) and a relatively minor component to the Porcupine River (3.9%). Comparable estimates (53%) were obtained during the 2002 basin-wide study (Eiler et al. 2004). Country of origin estimates based on telemetry information during 2002-2003 are also consistent with other estimates reported for the drainage. Scale pattern analysis from the early 1980s suggested that Canadian-origin fish comprised between 42% and 54% of the return (Anon 1985). Milligan et al. (1985) estimated that approximately 50% of the Chinook salmon return was made up of Canadian stocks, based on catch and escapement information, ranging from 44% to 51% in years with low returns and 48% to 57% during years of greater abundance. Genetic stock identification estimates of the Canadian contribution from 1987 to 1990 averaged 53% of the return, ranging from 42% to 61% (Wilmot et al. 1992). However, not all stocks were included in the genetic baseline used for this analysis, including U.S. stocks in the upper basin, notably fish returning to the Chandalar and Sheenjek rivers, which could bias the results. Similarities were also observed between the run timing of the significant stock groups reported by Wilmot et al. (1992) and those observed during the 2003 study. Although differences existed, particularly when comparing results from the different years of genetic sampling, the general agreement between the two methods suggests that the estimates derived from the 2003 telemetry study are credible.

Questions exist about the status of fish remaining in non-terminal areas (i.e., U.S. reaches of the Yukon River main stem). Non-terminal areas not only serve as migration corridors for fish traveling farther upriver, but potentially support spawning populations. However, many non-terminal areas are turbid and hard to access, making verification of spawning activity difficult. Anadromous stream catalogs for the lower and upper basin indicate that Chinook salmon spawners have been observed in tributary streams not surveyed during the study, although these populations are thought to be minor. It is not known if radio-tagged fish last located in non-terminal reaches of the Yukon River main stem ultimately traveled to these tributaries. Mainstem spawning has been reported for Chinook salmon in the Canadian portion of the Yukon River (Milligan et al. 1985), although the extent has not been determined due to turbid conditions. It is not known if suitable salmon spawning habitat exists in U.S. reaches, although evidence of non-salmonid spawning has been reported (Brown 2000).

An alternative explanation is that non-terminal fish represent tagged individuals that died while in-transit to upriver spawning areas due to handling, predation, disease, or injuries from encounters with fishing gear. These fish may also have been harvested in fisheries but not reported. Reluctance by fishers to provide information on tag recoveries is often a problem as demonstrated by the substantial number (29.7%) of unreported recoveries in 2003. Similar problems were encountered during the 2002 basin-wide study (Eiler et al. 2004). There is also anecdotal information that tags were periodically thrown back into the river or left on the shore, further limiting our ability to determine fish status. Incidents of radio-tagged fish regurgitating their tags when captured and removed from fishing gear have also been reported by fishers within the basin. Although it is difficult to substantiate or to rule out these factors, tracking data collected during the study does provide some insights. The distribution pattern of non-terminal fish was clumped in the lower basin between Holy Cross and Nulato, and in the upper Yukon River between Tanana and Fort Yukon--both areas with intensive fishing--while relatively few non-terminal fish were observed in the middle Yukon River between Galena and Tanana, or in the upper Yukon River between Circle and the Yukon Border. Many non-terminal fish were last located in outlying areas near villages or in the general vicinity of fish camps (i.e., areas where their status could not be readily verified), suggesting some interaction with local fisheries may have occurred.

Adverse impacts from handling are always a concern in tagging studies. Numerous studies have been conducted to assess tagging effects on fish, and anomalous behavior has periodically been reported (McCleave and Stred 1975, Mellas and Haynes 1985, Brown and Eiler 2000). However, the large percentage of fish that moved upriver (Table 6), the relatively rapid, sustained movement rates observed (Table 12), and the presence of non-terminal fish in the upper basin, suggests that adverse impacts from tagging were minimal.

Since the late 1990s, the fish parasite *Ichthyophonus* has been reported in Yukon River Chinook salmon (Kocan and Hershberger 1999). Recent sampling studies in the basin have suggested that infected fish destined for the Tanana River and the upper basin may succumb to the parasite while in-transit to upriver spawning areas. Although some of the non-terminal fish may be infected individuals that died prior to reaching spawning areas farther upriver, the distribution pattern observed during the study does not fully fit this explanation. Although *Ichthyophonus*-related mortality would potentially explain the presence of non-terminal fish between Rampart and Fort Yukon, it does not address the concentration of non-terminal fish in the lower basin or the general absence of non-terminal fish in the middle basin; however, it has been shown that the severity of the infection increases as the fish move farther upriver (Kocan and Hershberger 1999). Another explanation is that non-terminal fish represent a combination of factors, including fish that spawned in associated areas not monitored during the study, or that died while in-transit to spawning areas farther upriver because of undocumented encounters with fisheries, disease, or handling mortality.

Stock composition estimates for the 2003 Chinook salmon return were based on the assumption that fish in designated stock groups, including those in non-terminal areas, represent spawning populations. Stock groups that include fish that died while in-transit to spawning areas would bias these estimates and under-represent the contribution of fish traveling farther upriver, particularly for upper basin stocks, and to a lesser extent, Tanana River fish. Conversely, estimates derived under the assumption that all non-terminal fish were in-transit would potentially overestimate upper river stocks. Composition estimates derived for 2003 based on both assumptions were similar, suggesting minimal bias related to the treatment of non-terminal fish. In regard to country of origin, the estimates suggest that Canadian Yukon River stocks comprised from 51.5% to 58.1% of the Yukon River return; these proportions are consistent with other estimates reported for the basin.

The basin-wide telemetry study in 2003 was successful in obtaining additional information on the stock composition, run timing, spawning distribution, and movement patterns of Yukon River Chinook salmon. Adequate numbers of fish were captured, tagged, and tracked upriver, making it possible to identify and compare the principal components of the return. The system of satellite-linked tracking stations, combined with aerial surveys in selected reaches of the basin, and the integrated database and GIS mapping program were used effectively to collect and summarize telemetry data in-season, making it possible to prioritize field activities and to address management issues within the basin. Stock composition and run timing estimates derived from these data provide a detailed look at the temporal and spatial dynamics of the 2003 return, information needed to better address conservation and harvest allocation issues within the basin. The data collected will also be useful in addressing other research needs, such as expanding the genetic stock identification baseline by identifying spawning populations not currently included, evaluating abundance estimates from other assessment projects, and providing movement and behavioral data to address other concerns, such as the impacts of *Ichthyophonus* on Chinook salmon returns. Results from this study, combined with telemetry data from 2002, will also be useful in addressing questions related to annual variation, particularly in relation to run characteristics during years with greater abundance.

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Table 1. -- Weekly and total numbers of Chinook salmon captured with drift gill nets and radio tagged in the lower Yukon River near the village of Russian Mission during 2003.

| Capture week | Dates | Fish captured | Fish tagged |
|---|---|---|---|
| 23 | 3-7 June | 144 | 78 |
| 24 | 8-14 June | 378 | 168 |
| 25 | 15-21 June | 949 | 390 |
| 26 | 22-28 June | 423 | 236 |
| 27 | 29 June - 5 July | 274 | 148 |
| 28 | 6-12 July | 135 | 72 |
| 29 | 13-14 July | 9 | 5 |
| Total | 3 June - 19 July | 2,312 | 1,097 |

Table 2. -- Location of remote tracking stations used to monitor the movements of radio-tagged Chinook salmon in the Yukon River during 2003. Distances from Paimiut, located 62 km upriver from the village of Russian Mission, and the previous downriver station are indicated.

| | | Distance traveled (km) | |
|---|---|---|---|
| Region | Tracking station | From Paimiut | From previous station[1] |
| Lower Yukon River basin[2] | Paimiut[3] | -- | -- |
| | Bonasila | 112 | 112 |
| | Anvik | 142 | 142 |
| | Innoko | 261 | 261 |
| | Yukon-Anvik[4] | 134 | 134 |
| | Nulato | 396 | 262 |
| Koyukuk River | Lower Koyukuk[3,4] | 448 | 314 |
| | Gisasa | 522 | 74 |
| | Hogatza | 895 | 447 |
| | Upper Koyukuk | 934 | 486 |
| Mid-Yukon River basin[5] | Yukon-Yuki[4] | 519 | 385 |
| | Melozitna | 566 | 47 |
| | Nowitna | 709 | 190 |
| | Tozitna | 732 | 213 |
| Tanana River | Lower Tanana[3,4] | 835 | 316 |
| | Nenana[4] | 1,012 | 177 |
| | Chena | 1,150 | 138 |
| | Salcha | 1,158 | 146 |
| | Upper Tanana | 1,204 | 192 |

Table 2. -- Continued.

| Region | Tracking station | Distance traveled (km) | |
|---|---|---|---|
| | | From Paimiut | From previous station[1] |
| Upper Yukon River (U.S.)[6] | Rampart Rapids[3,4] | 811 | 292 |
| | Chandalar | 1,231 | 420 |
| | Circle[4] | 1,401 | 590 |
| Upper Yukon River (Can) | Yukon Border[3,4] | 1,704 | 303 |
| | Stewart | 1,901 | 197 |
| | Fraser Falls | 2,207 | 306 |
| | Below Yukon-White[4] | 1,898 | 197 |
| | Above Yukon-White[4] | 1,904 | 6 |
| | Kluane | 2,216 | 312 |
| | Selkirk[4] | 2,028 | 124 |
| | Pelly | 2,065 | 37 |
| | Tatchun[4] | 2,136 | 108 |
| | Big Salmon | 2,320 | 184 |
| | Yukon-Teslin[4] | 2,335 | 199 |
| | Hootalinqua | 2,354 | 19 |
| Porcupine River (U.S.) | Black | 1,405 | 594 |
| | Sheenjek | 1,313 | 502 |
| | Lower Porcupine[4] | 1,450 | 137 |

Table 2. -- Continued.

| Region | Tracking station | Distance traveled (km) | |
|---|---|---|---|
| | | From Paimiut | From previous station[1] |
| Porcupine River (Can) | Porcupine Border[3,4] | 1,573 | 123 |
| Porcupine River (Can) | Fishing Branch | 2,062 | 489 |

[1] Station located immediately downriver on migration route traveled by fish.
[2] Section of the Yukon River from Russian Mission to the Yukon-Koyukuk River confluence.
[3] Two tracking stations located at site.
[4] Located on primary migration route and used to calculate rates of fish traveling farther upriver.
[5] Section of the Yukon River from Galena to the Yukon-Tanana River confluence.
[6] Section of the Yukon River from Yukon-Tanana River confluence to Eagle.

Table 3. -- Fishery designations used to model stock composition estimates of Yukon River Chinook salmon. The corresponding fishing districts managed by the Alaska Department of Fish and Game (ADFG) and Department of Fisheries and Oceans Canada (DFO) are noted.

| Fishery | Area covered by fishery | Fishing district |
|---|---|---|
| A | Yukon River from Marshall to Holy Cross | ADFG District 3 |
| B | Yukon River from Anvik to Nulato | ADFG District 4a |
| C | Yukon River from Nulato to Ruby | ADFG District 4b, 4c |
| D | Yukon River from Ruby to below Tanana | ADFG District 4b, 4c |
| E | Lower Tanana River | ADFG District 6a |
| F | Tanana River near Nenana | ADFG District 6b |
| G | Tanana River near Fairbanks | ADFG District 6c |
| H | Yukon River from Tanana to Beaver | ADFG District 5a, 5b, 5c, 5d |
| I | Yukon River near Fort Yukon | ADFG District 5d |
| J | Lower Porcupine River | ADFG District 5d |
| K | Porcupine River near Old Crow | DFO Porcupine River Fishery |
| L | Yukon River near Circle | ADFG District 5d |
| M | Yukon River near Eagle | ADFG District 5d |
| M | Yukon River from the Border to Dawson | DFO Yukon River Fishery |
| N | Yukon River from Dawson to Carmacks | DFO Yukon River Fishery |
| O | Yukon River from Carmacks to Whitehorse | DFO Yukon River Fishery |

Table 4. -- Yukon River Chinook salmon stocks and the maximum likelihood estimates of their proportions among fish passing the Russian Mission tagging site.

| Stock name | Stock index | Estimates of stock proportions |
|---|---|---|
| Innoko | 1 | $\hat{\theta}_{t,1} = r_{t,1} / R_t = r_{t,1} / D_{t,1}$ |
| Bonasila | 2 | $\hat{\theta}_{t,2} = r_{t,2} / R_t = r_{t,2} / D_{t,1}$ |
| Anvik | 3 | $\hat{\theta}_{t,3} = r_{t,3} / R_t = r_{t,3} / D_{t,1}$ |
| Lower Yukon | 4 | $\hat{\theta}_{t,4} = r_{t,4} \Bigg/ \left[ R_t - \dfrac{C_{t,1}}{1 - \sum_{s=1}^{3} \hat{\theta}_{t,s}} \right] = r_{t,4} / D_{t,2}$ |
| Nulato | 5 | $\hat{\theta}_{t,5} = r_{t,5} / D_{t,2}$ |
| Lower Koyukuk | 6 | $\hat{\theta}_{t,6} = r_{t,6} / D_{t,2}$ |
| Gisasa | 7 | $\hat{\theta}_{t,7} = r_{t,7} / D_{t,2}$ |
| Kateel | 8 | $\hat{\theta}_{t,8} = r_{t,8} / D_{t,2}$ |
| Hogatza | 9 | $\hat{\theta}_{t,9} = r_{t,9} / D_{t,2}$ |

Table 4. -- Continued.

| Stock name | Stock index | Estimates of stock proportions |
|---|---|---|
| Upper Koyukuk | 10 | $\hat{\theta}_{t,10} = r_{t,10} / D_{t,2}$ |
| Melozitna | 11 | $\hat{\theta}_{t,11} = \dfrac{r_{t,11}}{R_t - \dfrac{C_{t,1}}{1-\sum_{s=1}^{3}\hat{\theta}_{t,s}} - \dfrac{C_{t,2}}{1-\sum_{s=1}^{10}\hat{\theta}_{t,s}}} = r_{t,11} / D_{t,3}$ |
| Nowitna | 12 | $\hat{\theta}_{t,12} = r_{t,12} / D_{t,3}$ |
| Tozitna | 13 | $\hat{\theta}_{t,13} = \dfrac{r_{t,13}}{R_t - \dfrac{C_{t,1}}{1-\sum_{s=1}^{3}\hat{\theta}_{t,s}} - \dfrac{C_{t,2}}{1-\sum_{s=1}^{10}\hat{\theta}_{t,s}} - \dfrac{C_{t,3}}{1-\sum_{s=1}^{12}\hat{\theta}_{t,s}}} = r_{t,13} \Big/ \left[ D_{t,3} - \dfrac{C_{t,3}}{1-\sum_{s=1}^{12}\hat{\theta}_{t,s}} \right] = r_{t,13} / D_{t,4}$ |
| Mid-Yukon | 14 | $\hat{\theta}_{t,14} = r_{t,14} / D_{t,4}$ |
| Entire Tanana | 15-22 | $\sum_{s=15}^{22}\hat{\theta}_{t,s} = \left[ \sum_{f=4}^{6} C_{t,f} + \sum_{s=15}^{22} r_{t,s} \right] \Big/ D_{t,4}$ |

Table 4. -- Continued.

| Stock name | Stock index | Estimates of stock proportions |
| --- | --- | --- |
| Lower Tanana | 15 | $\hat{\theta}_{t,15} = r_{t,15} \Big/ \left[ D_{t,4} - \frac{C_{t,4}}{\sum_{s=15}^{22} \hat{\theta}_{t,s}} \right]$ $= r_{t,15} / D_{t,5}$ |
| Kantishna | 16 | $\hat{\theta}_{t,16} = r_{t,16} / D_{t,5}$ |
| Tolovana | 17 | $\hat{\theta}_{t,17} = r_{t,17} / D_{t,5}$ |
| Mid-Tanana | 18 | $\hat{\theta}_{t,18} = r_{t,18} \Big/ \left[ D_{t,5} - \frac{C_{t,5}}{\sum_{s=15}^{22} \hat{\theta}_{t,s} - \sum_{s=15}^{17} \hat{\theta}_{t,s}} \right]$ $= r_{t,18} / D_{t,6}$ |
| Chena | 19 | $\hat{\theta}_{t,19} = r_{t,19} \Big/ \left[ D_{t,6} - \frac{C_{t,6}}{\sum_{s=15}^{22} \hat{\theta}_{t,s} - \sum_{s=15}^{18} \hat{\theta}_{t,s}} \right]$ $= r_{t,19} / D_{t,7}$ |
| Salcha | 20 | $\hat{\theta}_{t,20} = r_{t,20} / D_{t,7}$ |
| Goodpaster | 21 | $\hat{\theta}_{t,21} = r_{t,21} / D_{t,7}$ |
| Upper Tanana | 22 | $\hat{\theta}_{t,22} = r_{t,22} / D_{t,7}$ |
| Entire Yukon above Tanana | 23-46 | $\sum_{s=23}^{46} \hat{\theta}_{t,s} = \left[ \sum_{f=7}^{14} C_{t,f} + \sum_{s=23}^{46} r_{t,s} \right] \Big/ D_{t,4}$ |

Table 4. -- Continued.

| Stock name | Stock index | Estimates of stock proportions |
| --- | --- | --- |
| Upper Yukon (Rapids) | 23 | $\hat{\theta}_{t,23} = \dfrac{r_{t,23}}{D_{t,4} - \dfrac{C_{t,7}}{1-\sum_{s=1}^{22}\hat{\theta}_{t,s}}} = r_{t,23}/D_{t,8}$ |
| Beaver | 24 | $\hat{\theta}_{t,24} = r_{t,24}/D_{t,8}$ |
| Chandalar | 25 | $\hat{\theta}_{t,25} = r_{t,25}/D_{t,8}$ |
| Entire Porcupine | 26-30 | $\sum_{s=26}^{30}\hat{\theta}_{t,s} = \dfrac{\sum_{s=26}^{30} r_{t,s} + \sum_{f=9}^{10} C_{t,f}}{D_{t,8} - \dfrac{C_{t,8}}{1-\sum_{s=1}^{25}\hat{\theta}_{t,s}}} = \left[\sum_{s=26}^{30} r_{t,s} + \sum_{f=9}^{10} C_{t,f}\right]/D_{t,9}$ |
| Black | 26 | $\hat{\theta}_{t,26} = \dfrac{r_{t,26}}{D_{t,9} - \dfrac{C_{t,9}}{\sum_{s=26}^{30}\hat{\theta}_{t,s}}} = r_{t,26}/D_{t,10}$ |
| Sheenjek | 27 | $\hat{\theta}_{t,27} = r_{t,27}/D_{t,10}$ |
| U.S. Porcupine | 28 | $\hat{\theta}_{t,28} = r_{t,28}/D_{t,10}$ |

Table 4. -- Continued.

| Stock name | Stock index | Estimates of stock proportions |
|---|---|---|
| Canadian Porcupine | 29 | $\hat{\theta}_{t,29} = \dfrac{r_{t,29}}{D_{t,10} - \dfrac{C_{t,10}}{\sum_{s=26}^{30}\hat{\theta}_{t,s} - \sum_{s=26}^{28}\hat{\theta}_{t,s}}}$ $= r_{t,29} \big/ D_{t,11}$ |
| Miner | 30 | $\hat{\theta}_{t,30} = r_{t,30} \big/ D_{t,11}$ |
| Upper Yukon above Porcupine | 31-46 | $\sum_{s=31}^{46}\hat{\theta}_{t,s} = \left[\sum_{f=11}^{14} C_{t,f} + \sum_{s=31}^{46} r_{t,s}\right] \Big/ D_{t,9}$ |
| Upper Yukon (Circle) | 31 | $\hat{\theta}_{t,31} = \dfrac{r_{t,31}}{D_{t,9} - \dfrac{C_{t,11}}{\sum_{s=31}^{46}\hat{\theta}_{t,s}}}$ $= r_{t,31} \big/ D_{t,12}$ |
| Charley | 32 | $\hat{\theta}_{t,32} = r_{t,32} \big/ D_{t,12}$ |
| Kandik | 33 | $\hat{\theta}_{t,33} = r_{t,33} \big/ D_{t,12}$ |
| Lower Canadian Yukon | 34 | $\hat{\theta}_{t,34} = \dfrac{r_{t,34}}{D_{t,12} - \dfrac{C_{t,12}}{\sum_{s=31}^{46}\hat{\theta}_{t,s} - \sum_{s=31}^{33}\hat{\theta}_{t,s}}}$ $= r_{t,34} \big/ D_{t,13}$ |
| Klondike | 35 | $\hat{\theta}_{t,35} = r_{t,35} \big/ D_{t,13}$ |
| Stewart | 36 | $\hat{\theta}_{t,36} = r_{t,36} \big/ D_{t,13}$ |

Table 4. -- Continued.

| Stock name | Stock index | Estimates of stock proportions |
|---|---|---|
| White | 37 | $\hat{\theta}_{t,37} = r_{t,37} / D_{t,13}$ |
| Pelly | 38 | $\hat{\theta}_{t,38} = r_{t,38} / D_{t,13}$ |
| Mid-Canadian Yukon | 39 | $\hat{\theta}_{t,39} = r_{t,39} / D_{t,13}$ |
| Tatchun | 40 | $\hat{\theta}_{t,40} = \dfrac{r_{t,40}}{D_{t,13} - \dfrac{C_{t,13}}{\sum_{s=31}^{46} \hat{\theta}_{t,s} - \sum_{s=31}^{39} \hat{\theta}_{t,s}}}$ $= r_{t,40} / D_{t,14}$ |
| Upper Canadian Yukon | 41 | $\hat{\theta}_{t,41} = \dfrac{r_{t,41}}{D_{t,14} - \dfrac{C_{t,14}}{\sum_{s=31}^{46} \hat{\theta}_{t,s} - \sum_{s=31}^{40} \hat{\theta}_{t,s}}} = r_{t,41} / D_{t,15}$ |
| Nordenskiold | 42 | $\hat{\theta}_{t,42} = r_{t,42} / D_{t,15}$ |
| Little Salmon | 43 | $\hat{\theta}_{t,43} = r_{t,43} / D_{t,15}$ |
| Big Salmon | 44 | $\hat{\theta}_{t,44} = r_{t,44} / D_{t,15}$ |
| Teslin | 45 | $\hat{\theta}_{t,45} = r_{t,45} / D_{t,15}$ |
| Hootalinqua | 46 | $\hat{\theta}_{t,46} = r_{t,46} / D_{t,15}$ |

Table 5. -- Coloration of Chinook salmon captured with drift gill nets and radio tagged in the lower Yukon River near the village of Russian Mission during 2003. Percentages of the weekly totals are in parentheses.

| Capture week | Fish tagged | Iridescent silver | Dull silver | Pre-spawning* |
|---|---|---|---|---|
| 23 | 78 | 78 (100) | 0 (0.0) | 0 (0.0) |
| 24 | 168 | 159 (94.6) | 9 (5.4) | 0 (0.0) |
| 25 | 390 | 312 (80.0) | 75 (19.2) | 3 (0.8) |
| 26 | 236 | 161 (68.2) | 73 (30.9) | 2 (0.9) |
| 27 | 148 | 78 (52.7) | 59 (39.9) | 11 (7.4) |
| 28-29 | 77 | 28 (36.4) | 39 (50.6) | 10 (13.0) |
| Total | 1,097 | 816 (74.4) | 255 (23.2) | 26 (2.4) |

* Ranging from blush (silver with reddish tinges) to pronounced reddish coloration.

Table 6. -- Tracking results for Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission during 2003. Percentages of the total are in parentheses.

| Final status | Number of fish |
|---|---|
| Moved upriver | 1,081 (98.5) |
| Upriver location[1] | 810 (73.8) |
| Harvested in fishery[2] | 271 (24.7) |
| Not located upriver | 16 (1.5) |
| Total | 1,097 |

[1] Fish recorded upriver from the tagging site and not caught in fisheries.
[2] Including fish caught in terminal tributaries.

Table 7. -- Elapsed time and movement rates (km/day) by capture week for radio-tagged Chinook salmon traveling between the Russian Mission tagging area and the Paimiut tracking stations in 2003.

| | | | Average | | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| Capture week | N[1] | Distance[2] (km) | Days | Rate | Lower | Upper |
| 23 | 78 | 46.1 | 1.4 | 37.9 | 34.7 | 41.0 |
| 24 | 165 | 48.2 | 1.7 | 35.1 | 33.2 | 37.1 |
| 25 | 373 | 51.3 | 2.0 | 32.3 | 31.1 | 33.5 |
| 26 | 209 | 47.0 | 1.5 | 33.4 | 31.8 | 34.9 |
| 27 | 120 | 45.9 | 1.8 | 29.1 | 27.2 | 30.9 |
| 28-29 | 67 | 48.7 | 2.2 | 30.3 | 27.5 | 33.1 |
| Combined | 1,012 | 48.6 | 1.8 | 32.9 | 32.2 | 33.6 |

[1] Excluding radio-tagged fish not recorded passing the Paimiut tracking stations.
[2] Average distance from the tagging area to Paimiut; distances for individual fish varied based on the specific location within the area where the fish were captured, tagged, and released.

Table 8. -- Elapsed time and movement rates (km/day) by capture location and distance for radio-tagged Chinook salmon traveling between the Russian Mission tagging area and the Paimiut tracking stations in 2003.

| | | | Average | | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| Capture location | N[1] | Distance[2] (km) | Days | Rate | Lower | Upper |
| Lower section[3] | 54 | 71.3 - 88.2 | 2.0 | 42.8 | 40.1 | 45.5 |
| Lower section[3] | 238 | 62.4 - 69.9 | 2.1 | 38.0 | 36.5 | 39.5 |
| Combined[3] | 292 | 62.4 - 88.2 | 2.1 | 38.9 | 37.6 | 40.3 |
| Upper section[4] | 550 | 40.0 - 46.0 | 1.7 | 31.3 | 30.3 | 32.2 |
| Upper section[4] | 169 | 28.2 - 39.9 | 1.6 | 27.9 | 26.4 | 29.4 |
| Combined[4] | 719 | 28.2 - 46.0 | 1.7 | 30.5 | 29.7 | 31.3 |
| Entire area | 1,012 | 28.5 - 79.7 | 1.8 | 32.9 | 32.2 | 33.6 |

[1] Excluding radio-tagged fish not recorded passing the Paimiut tracking stations.
[2] Distance from the tagging area to Paimiut based on the specific location within the area where the fish were captured, tagged, and released.
[3] Section of the Russian Mission tagging area located in the general vicinity of the village.
[4] Section of the Russian Mission tagging area located about 20 km upriver from the village near an abandoned fish camp.

Table 9. -- Harvests of radio-tagged Chinook salmon in the Yukon River basin during 2003. Percentages of the total are in parentheses.

| Fishing area | Location | Tagged fish |
|---|---|---|
| District 3 | Russian Mission to Holy Cross | 27 (10.0) |
| District 4 | Anvik to Ruby | 56 (20.6) |
| District 4 | Koyukuk River | 4 (1.5) |
| District 5 | Yukon-Tanana confluence to Eagle | 114 (42.1) |
| District 6 | Tanana River[1] | 25 (9.2) |
| Combined U.S. | Russian Mission to Eagle | 226 (83.4) |
| Canada | Yukon River, Border to Dawson | 14 (5.2) |
| Canada | Yukon River, upriver of Dawson | 7 (2.6) |
| Canada | Yukon River tributaries[2] | 21 (7.7) |
| Canada | Porcupine River, Old Crow | 3 (1.1) |
| Combined Canada | Yukon and Porcupine rivers | 45 (16.6) |
| Total | | 271 |

[1] Including sport fishery harvests in the Tolovana, Chena and Salcha rivers.
[2] Including harvests in the Stewart, Pelly and Teslin rivers.

Table 10. -- Regional distribution of Chinook salmon radio tagged in the Yukon River basin during 2003. Fish harvested in terminal reaches of the basin are included. Percentages of the total are in parentheses.

| Region | Final location | Number of fish |
|---|---|---|
| Lower basin[1] | Yukon River main stem[2] | 49 (5.5) |
| | Tributaries | 54 (6.1) |
| | Combined areas | 103 (11.6) |
| Koyukuk River | Upper Koyukuk River main stem[2] | 7 (0.8) |
| | Koyukuk River fishery | 4 (0.5) |
| | Tributaries[3] | 18 (2.0) |
| | Combined areas | 29 (3.3) |
| Middle Yukon River[4] | Yukon River main stem[2] | 8 (0.9) |
| | Tributaries | 13 (1.5) |
| | Combined areas | 21 (2.4) |
| Tanana River | Tanana River main stem[2] | 12 (1.4) |
| | Tanana River fishery | 19 (2.1) |
| | Tributaries[3] | 159 (18.0) |
| | Combined areas | 190 (21.5) |
| Upper basin[5] | Yukon River main stem (U.S.)[2] | 31 (3.5) |
| | Yukon River tributaries (U.S.) | 45 (5.1) |
| | Yukon River main stem (Canada)[2] | 74 (8.4) |
| | Yukon River main stem fishery (Canada) | 21 (2.4) |
| | Yukon River tributaries (Canada)[3] | 318 (36.0) |
| | Porcupine River tributaries (U.S.) | 22 (2.5) |
| | Porcupine River (Canada)[2] | 10 (1.1) |
| | Porcupine River fishery (Canada) | 3 (0.3) |
| | Porcupine River tributaries (Canada) | 17 (1.9) |

Table 10. -- Continued.

| Region | Final location | Number of fish |
|---|---|---|
| Upper basin[5] | Combined areas | 541 (61.2) |
| Total | | 884 |

[1] Section of the Yukon River from Russian Mission to the Yukon-Koyukuk River confluence.

[2] Includes associated tributaries not monitored with tracking stations or aerial surveys.

[3] Includes fish harvested in terminal tributaries.

[4] Section of the Yukon River from Galena to the Yukon-Tanana River confluence.

[5] Section of the Yukon River upriver from the Yukon-Tanana River confluence.

Table 11. -- Stock composition estimates of the Yukon River Chinook salmon return in 2003 based on the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Bootstrap standard errors (SE) and 95% confidence intervals (CI) based on 10,000 bootstrappings are included.

| Region | Stock group | Estimate (%) | SE | 95% CI |
|---|---|---|---|---|
| Lower basin[1] | Lower Yukon[2] | 4.6 | 0.7 | 3.3, 5.8 |
| | Lower basin tributaries | 4.6 | 0.6 | 3.4, 5.8 |
| Koyukuk River | Gisasa | 1.0 | 0.3 | 0.4, 1.6 |
| | Upper Koyukuk | 1.7 | 0.4 | 0.9, 2.5 |
| | Combined areas | 2.7 | 0.5 | 1.7, 3.7 |
| Middle Yukon River[3] | Mid-Yukon[2] | 0.7 | 0.3 | 0.3, 1.3 |
| | Mid-Yukon tributaries[4] | 1.3 | 0.4 | 0.6, 2.1 |
| Tanana River | Tanana[5] | 3.7 | 0.6 | 2.6, 5.0 |
| | Chena | 4.6 | 0.7 | 3.2, 5.9 |
| | Salcha | 6.5 | 0.8 | 5.0, 8.1 |
| | Goodpaster | 4.2 | 0.7 | 3.0, 5.6 |
| | Combined areas | 18.9 | 1.3 | 16.6, 21.5 |
| Upper Yukon River (U.S.)[6] | Upper Yukon[2] | 3.9 | 0.7 | 2.6, 5.2 |
| | Upper Yukon tributaries | 5.2 | 0.8 | 3.8, 6.8 |
| Upper Yukon River (Canada) | Lower Canadian Yukon[7] | 3.7 | 0.7 | 2.4, 5.1 |
| | Mid-Upper Can. Yukon[8] | 15.6 | 1.2 | 13.3, 18.1 |
| | Stewart | 4.2 | 0.7 | 2.9, 5.6 |
| | Pelly | 10.6 | 1.1 | 8.4, 12.7 |
| | Big Salmon | 8.0 | 1.0 | 6.2, 10.0 |
| | Teslin | 9.4 | 1.0 | 7.3, 11.4 |
| | Combined areas | 51.5 | 1.7 | 48.3, 54.7 |

Table 11. -- Continued.

| Region | Stock group | Estimate (%) | SE | 95% CI |
|---|---|---|---|---|
| Porcupine River | U.S. Porcupine | 2.7 | 0.6 | 1.7, 3.9 |
| | Canadian Porcupine | 3.9 | 0.7 | 2.6, 5.1 |

[1] Section of the Yukon River from Russian Mission to the Yukon-Koyukuk River confluence.

[2] Non-terminal areas and associated tributaries not surveyed during the study.

[3] Section of the Yukon River from Galena to the Yukon-Tanana River confluence.

[4] Including the Melozitna, Nowitna, and Tozitna rivers.

[5] Mainstem areas and associated tributaries including the Kantishna River, Tolovana River, Nenana River and Clear Creek.

[6] Section of the Yukon River from Yukon-Tanana River confluence to Eagle, Alaska.

[7] Mainstem areas and associated tributaries including the Chandindu, Klondike and Sixtymile rivers.

[8] Mainstem areas and associated tributaries including the White River, Tatchun Creek, Nordenskiold River, Little Salmon River, Takhini River and reaches of the Yukon River upstream of Hootalinqua.

Table 12. -- Movement rates (km/day) of Chinook salmon radio tagged in the lower Yukon River during 2003 based on fish passage by tracking stations located at Paimiut and the farthest upriver station site. The 95% confidence intervals (CI) and sample sizes are included.

| Region | Stock group | Average | 95% CI | N |
|---|---|---|---|---|
| Lower basin[1] | Lower Yukon[2] | 36.1 | 30.6, 41.6 | 48 |
| | Lower basin tributaries | 31.2 | 27.2, 35.2 | 54 |
| Koyukuk River | Gisasa | 42.9 | 37.6, 48.2 | 11 |
| | Middle Koyukuk | 51.5 | 46.7, 56.3 | 3 |
| | Upper Koyukuk | 63.1 | 59.3, 66.9 | 15 |
| Middle Yukon River[3] | Mid-Yukon[2] | 49.6 | 38.9, 60.3 | 6 |
| | Mid-basin tributaries | 47.2 | 39.4, 55.0 | 12 |
| Tanana River | Tanana[4] | 46.5 | 38.9, 54.1 | 12 |
| | Middle Tanana tributaries[5] | 53.6 | 50.7, 56.5 | 25 |
| | Chena | 44.8 | 42.7, 46.9 | 40 |
| | Salcha | 45.1 | 43.8, 46.4 | 56 |
| | Goodpaster | 47.0 | 45.3, 48.7 | 36 |
| Upper Yukon River (U.S.)[6] | Upper Yukon[2] | 55.4 | 51.6, 59.2 | 31 |
| | Upper Yukon tributaries | 58.7 | 57.1, 60.3 | 43 |
| Upper Yukon River (Canada) | Canadian Yukon[4] | 48.7 | 47.2, 50.2 | 74 |
| | Klondike | 60.1 | 58.1, 62.1 | 19 |
| | Stewart | 55.9 | 54.1, 57.7 | 30 |
| | White | 58.3 | 56.5, 60.1 | 12 |
| | Pelly | 56.0 | 54.7, 57.3 | 79 |

Table 12. -- Continued.

| Region | Stock group | Average | 95% CI | N |
|---|---|---|---|---|
| Upper Yukon River (Canada) | Little Salmon | 51.2 | 48.3, 54.1 | 17 |
| | Big Salmon | 53.5 | 52.3, 54.7 | 59 |
| | Teslin | 53.4 | 52.2, 54.6 | 71 |
| | Minor Canadian stocks[7] | 52.9 | 51.3, 54.5 | 30 |
| Porcupine River | U.S. Porcupine | 61.3 | 59.0, 63.6 | 22 |
| | Canadian Porcupine | 58.6 | 54.9, 62.3 | 27 |

[1] Section of the Yukon River from Russian Mission to the Yukon-Koyukuk River confluence.
[2] Non-terminal areas and associated tributaries not surveyed during the study.
[3] Section of the Yukon River from Galena to the Yukon-Tanana River confluence.
[4] Including stocks in mainstem areas and associated tributaries not surveyed during the study.
[5] Including the Kantishna, Tolovana, and Nenana rivers, and several small tributaries near Fairbanks.
[6] Section of the Yukon River from Yukon-Tanana River confluence to Eagle, Alaska.
[7] Including the Chandindu River, Tatchun Creek, Nordenskiold River, Takhini River, and headwater areas upriver of Hootalinqua.

Table 13. -- Comparison of movement rates (km/day) of Chinook salmon traveling to tributaries in the Yukon River basin during 2003 based on the passage of radio-tagged fish by tracking stations. Average rates and 95% confidence intervals (CI) between Paimiut and the first station within the region the fish were destined for (i.e., travel primarily through reaches of the Yukon River main stem), and between Paimiut and the farthest upriver station are presented.

| | Paimiut to first regional station[1] | | | Paimiut to terminal station[2] | | |
|---|---|---|---|---|---|---|
| Stock | Location | $\overline{X}$ | CI | Location | $\overline{X}$ | CI |
| Nulato | Yukon-Anvik | 55.2 | 47.2, 63.2 | Nulato[3] | 39.2 | 32.2, 46.2 |
| Gisasa | Lower Koyukuk | 53.1 | 48.7, 57.5 | Gisasa[3] | 42.9 | 37.6, 48.2 |
| Upper Koyukuk | Lower Koyukuk | 58.5 | 54.4, 62.6 | Mid-Koyukuk | 63.1 | 59.3, 66.9 |
| Mid-basin trib.[4] | Yukon-Yuki | 51.8 | 48.1, 55.5 | Trib. mouth | 47.2 | 39.4, 55.0 |
| Chena River | Lower Tanana | 54.4 | 52.3, 56.5 | Chena[3] | 44.8 | 42.7, 46.9 |
| Salcha River | Lower Tanana | 55.9 | 54.3, 57.5 | Salcha[3] | 45.1 | 43.8, 46.4 |
| Goodpaster | Lower Tanana | 60.0 | 58.3, 61.7 | Upper Tanana | 47.0 | 45.3, 48.7 |
| Chandalar | Rampart Rapids | 60.4 | 58.5, 62.3 | Chandalar[3] | 58.3 | 56.5, 60.1 |
| Stewart | Yukon Border | 56.8 | 55.0, 58.6 | Stewart[3] | 55.9 | 54.1, 57.7 |
| Pelly | Yukon Border | 56.9 | 55.6, 58.2 | Pelly[3] | 56.0 | 54.7, 57.3 |
| Big Salmon | Yukon Border | 56.4 | 55.2, 57.6 | Big Salmon[3] | 53.5 | 52.3, 54.7 |
| Teslin River | Yukon Border | 56.0 | 54.7, 57.3 | Teslin[3] | 53.4 | 52.2, 54.6 |

[1] First station within the region containing the final destination of the fish (see Table 2).
[2] Last station passed by the fish prior to reaching its final destination.
[3] Station located near river mouth.
[4] Including the Melozitna, Nowitna and Tozitna rivers.

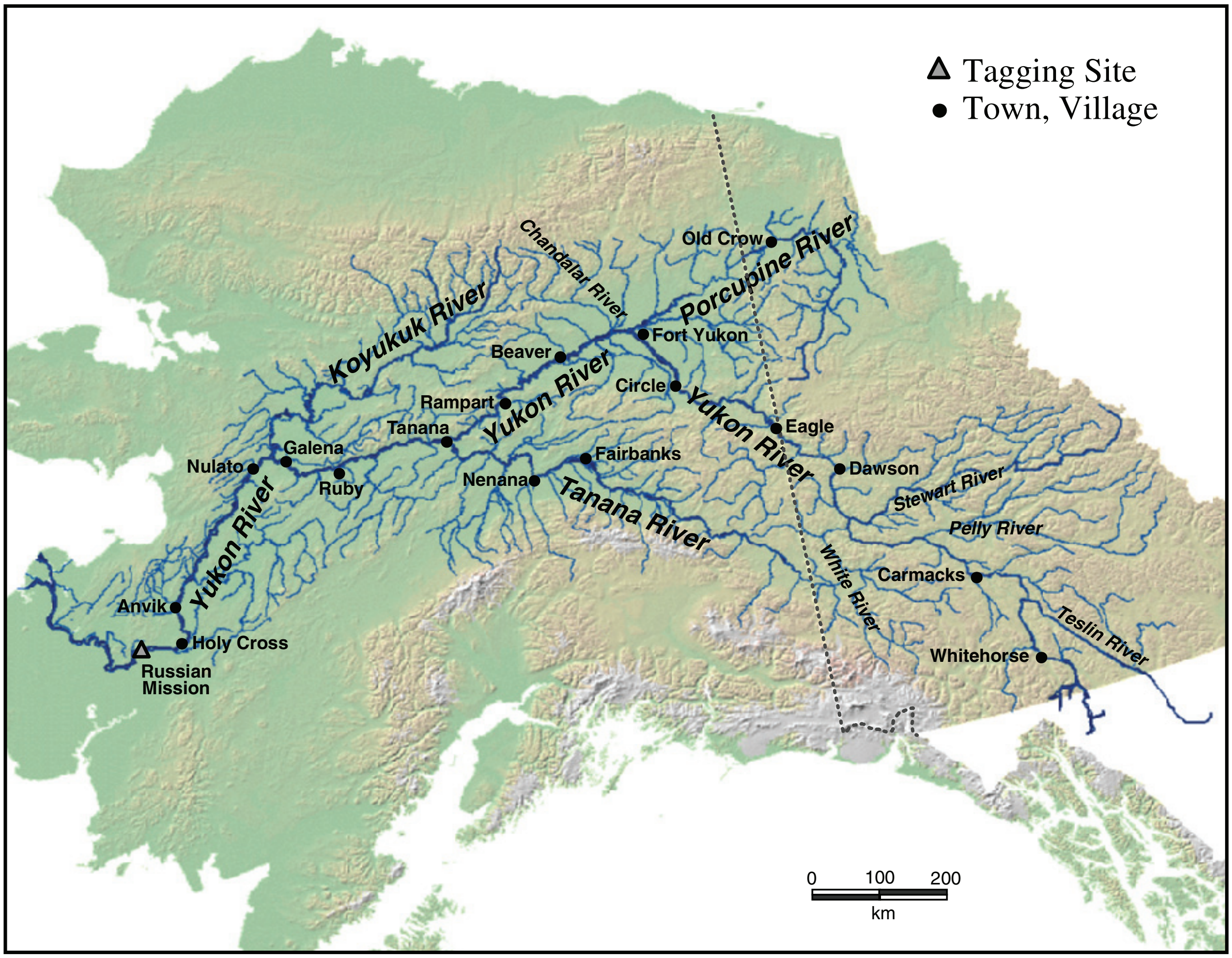



Figure 1. -- Map of the Yukon River basin showing the Yukon River main stem and major tributaries of the drainage. The tagging site and selected towns and villages are also shown.

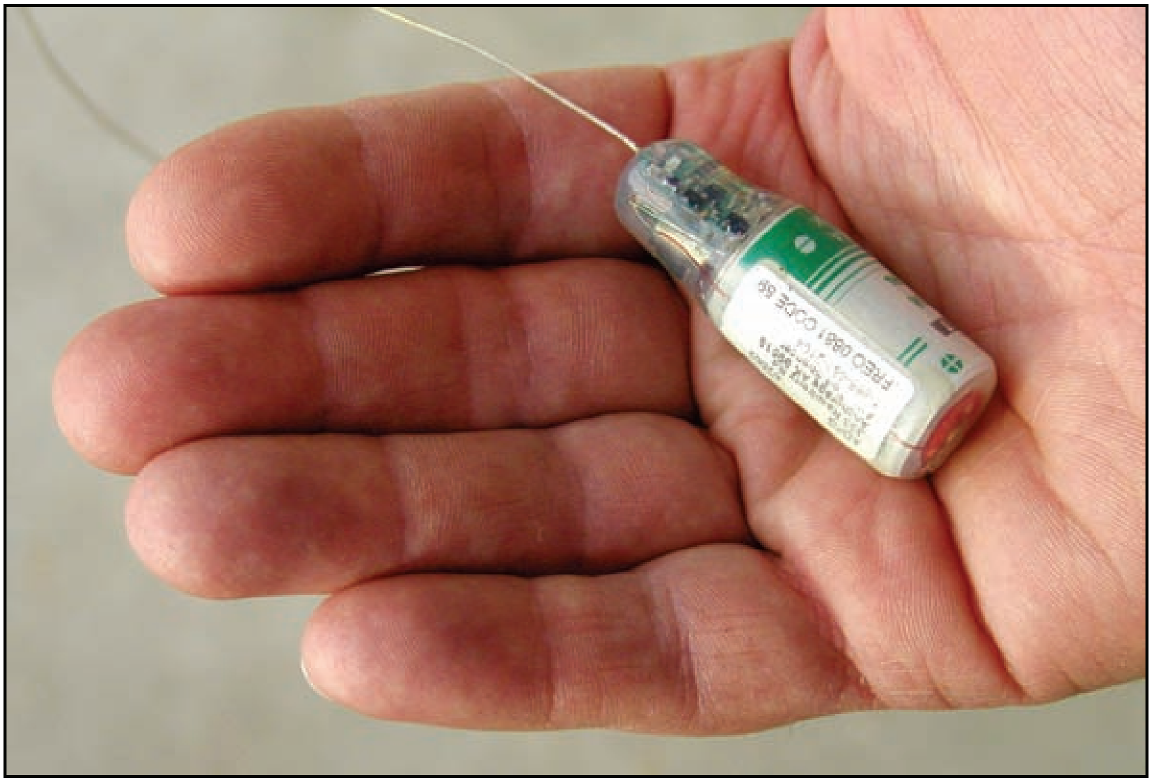



Figure 2. -- Radio transmitter used to tag Chinook salmon in the lower Yukon River near the village of Russian Mission during 2003. The transmitter is gently inserted through the mouth and placed in the stomach.

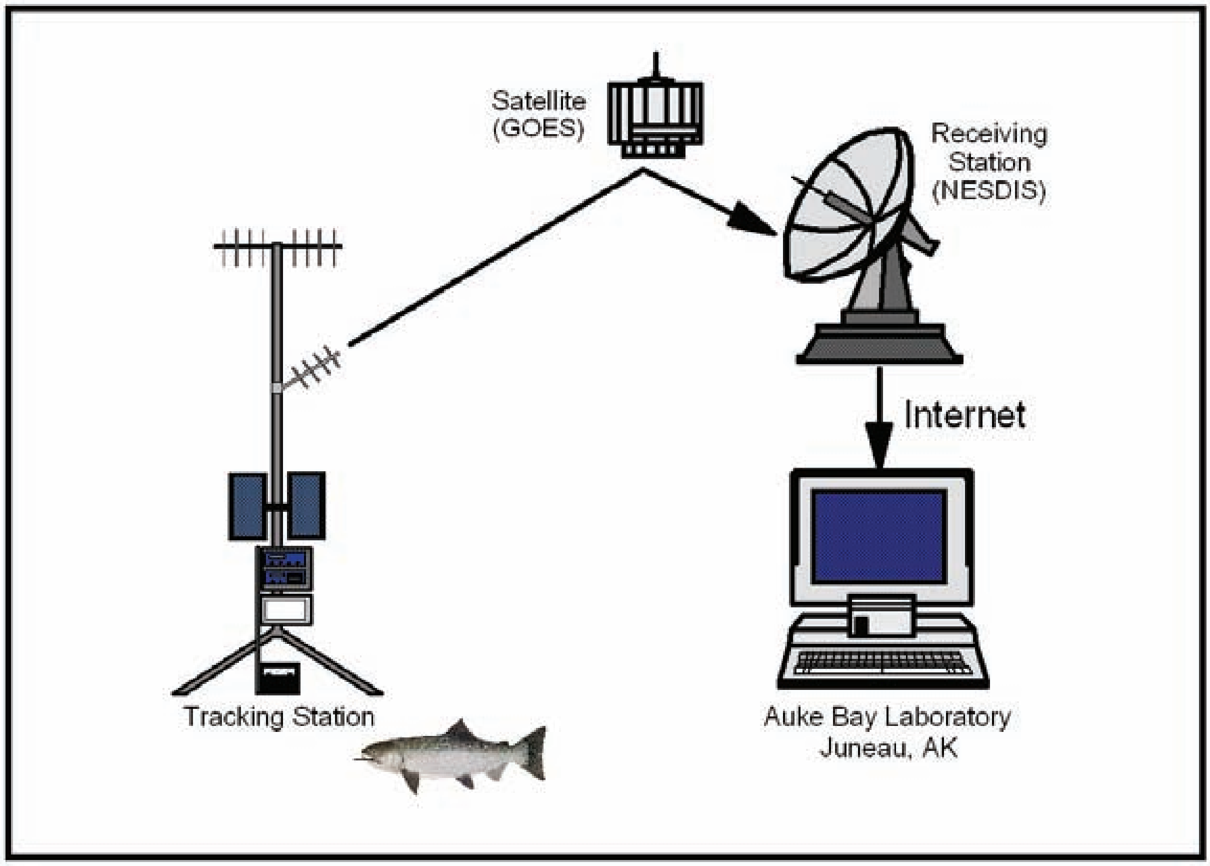



Figure 3. -- Remote tracking station and satellite uplink used to collect and access movement information of Chinook salmon in the Yukon River basin. Radio-tagged fish passing the station sites are recorded, the information is transferred to a receiving station via satellite, and downloaded for in-season analysis.

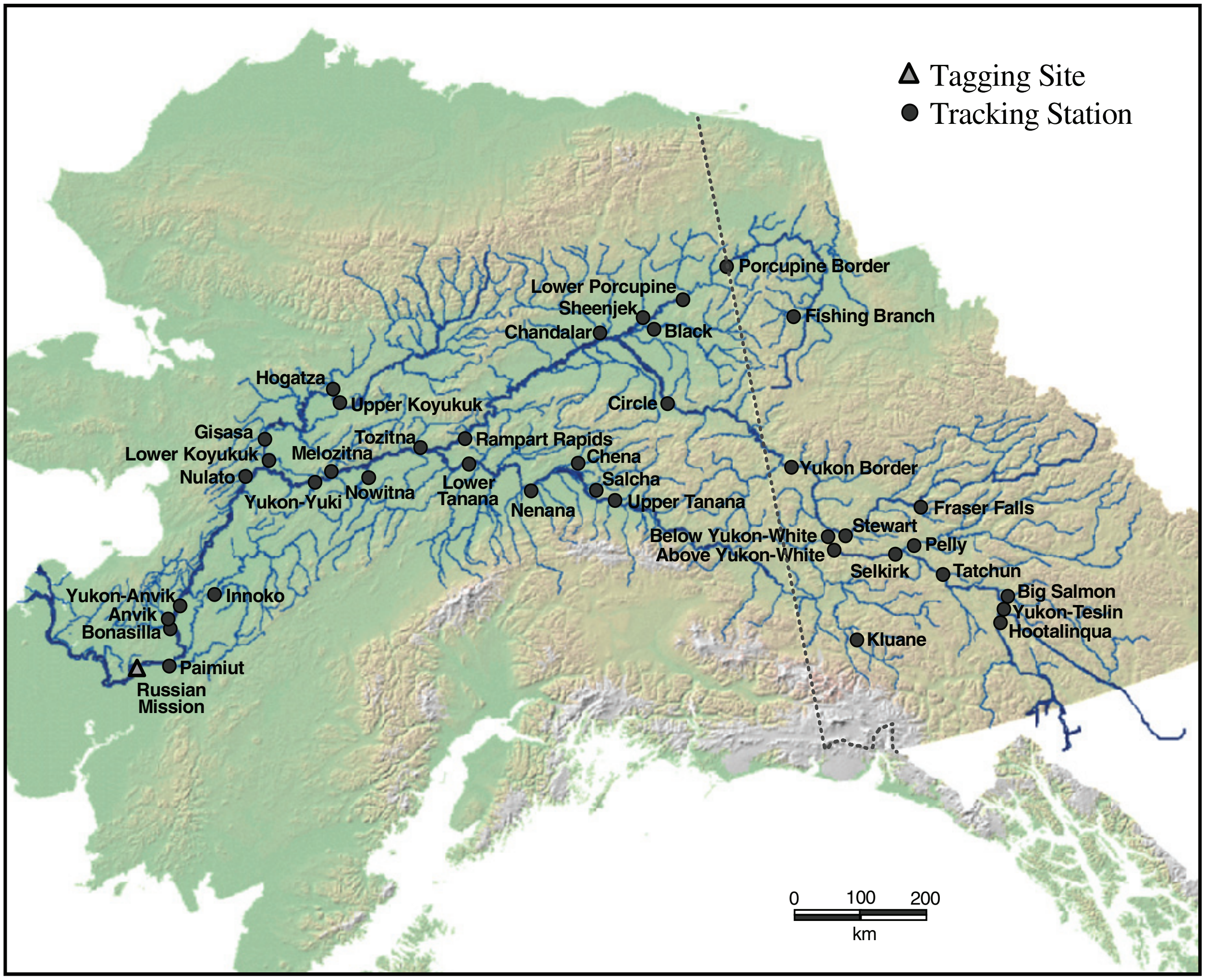



Figure 4. -- Map of the Yukon River basin showing the location of remote tracking stations used to track the upriver movements of radio-tagged Chinook salmon.

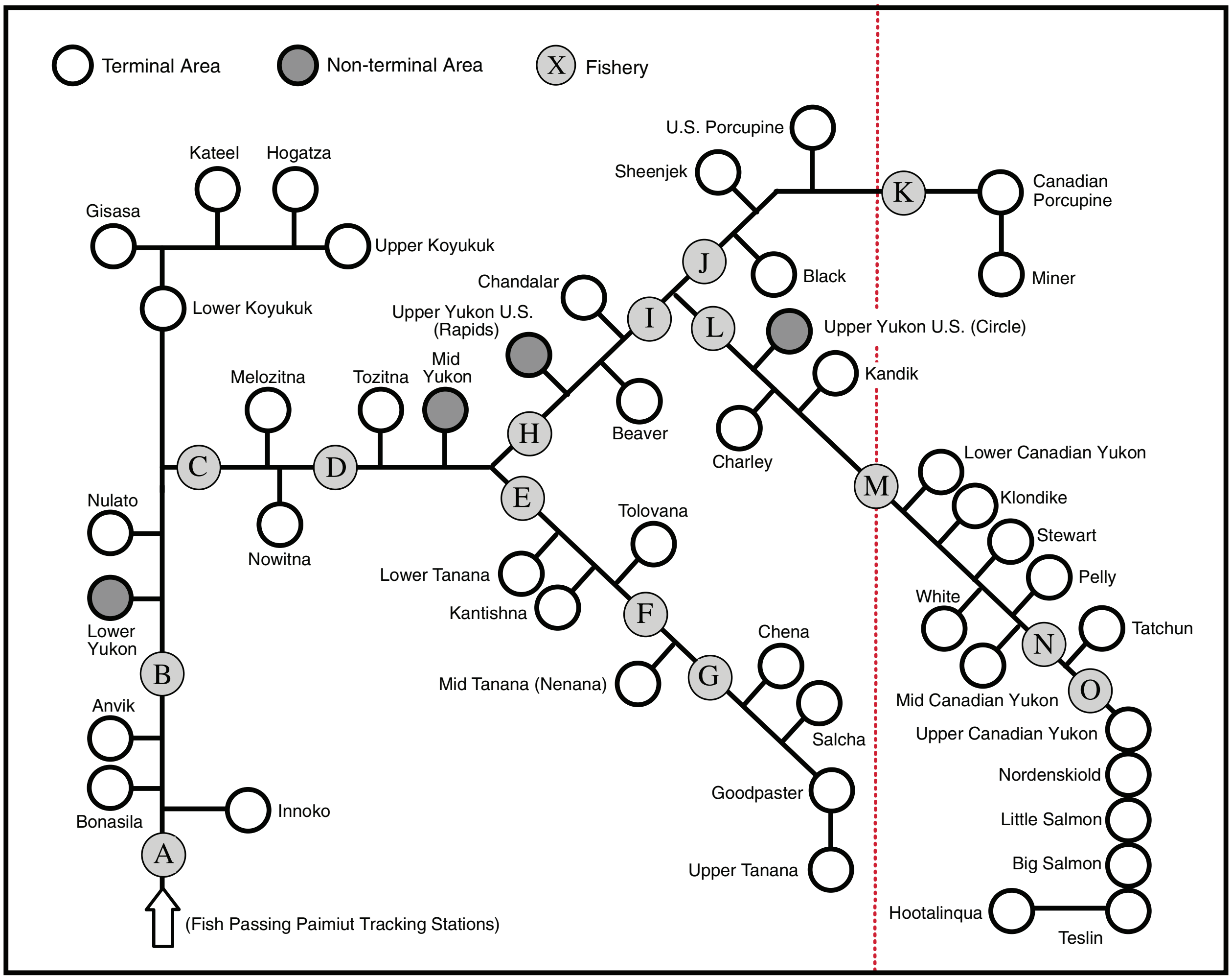



Figure 5. -- Migration model for calculating stock composition estimates of Chinook salmon returns in the Yukon River basin based on the distribution of radio-tagged fish. Spatial relationships of the fisheries and component stocks are indicated. Additional information on the fisheries, labeled as A through O, is contained in Table 3.

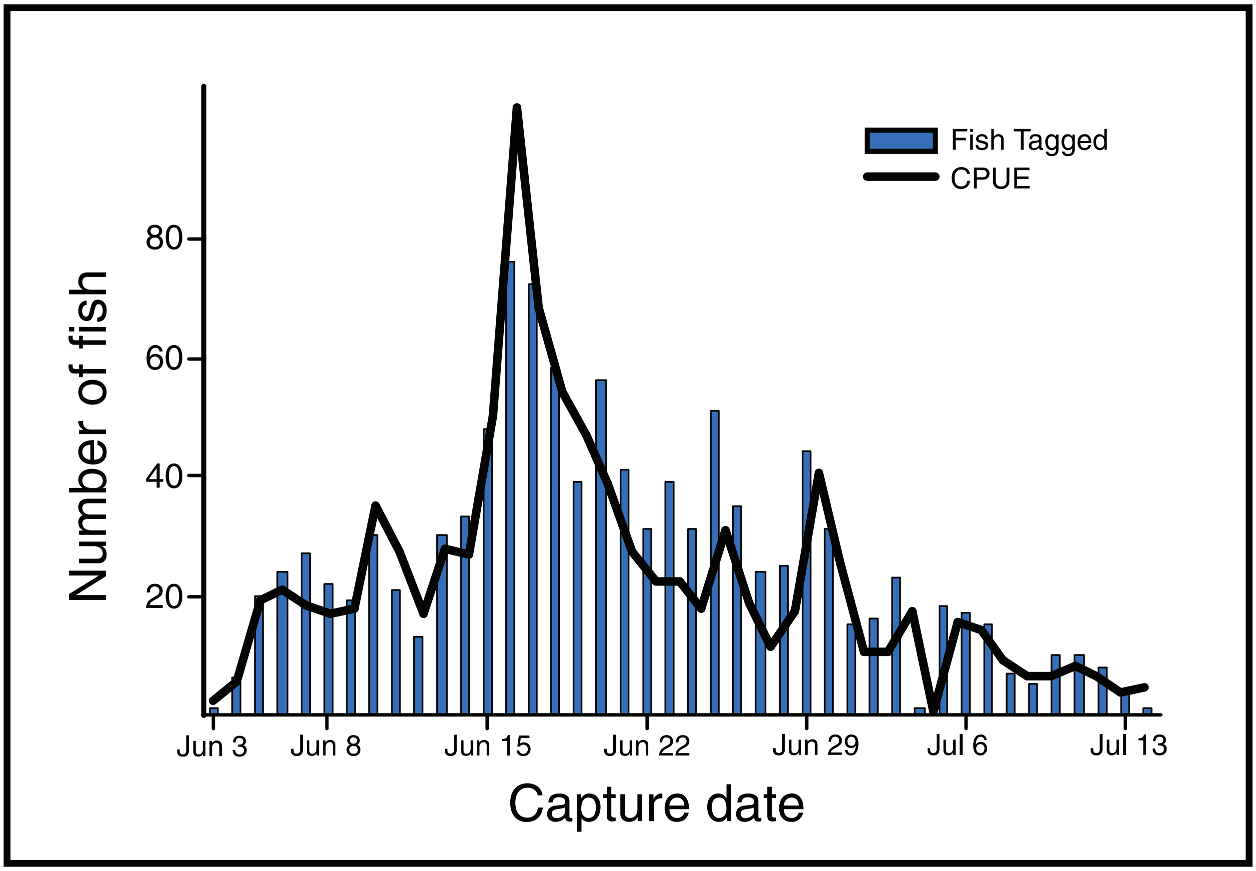



Figure 6. -- Number of Chinook salmon radio tagged per day in the lower Yukon River and daily catch per unit effort (CPUE) information for Chinook salmon captured at the Russian Mission tagging site during 2003.

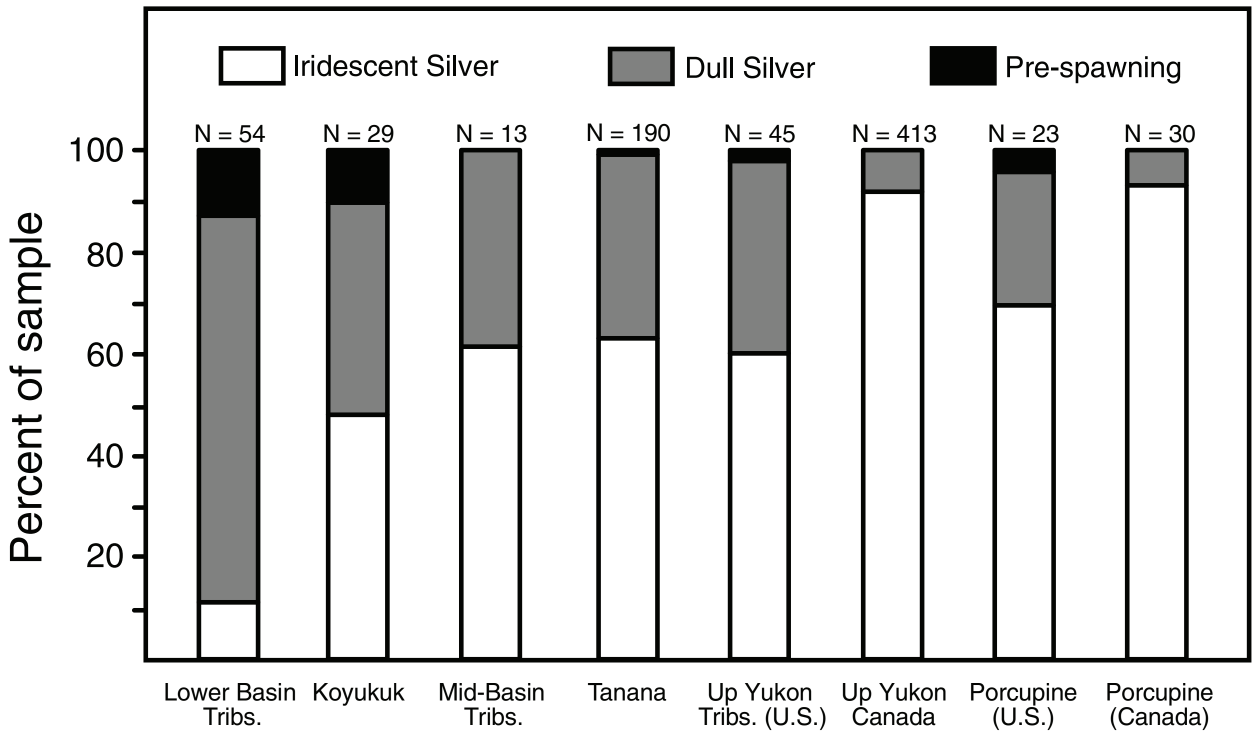



Figure 7. -- Lower river coloration of Chinook salmon captured with drift gill nets and radio tagged near the village of Russian Mission, and tracked to terminal reaches of the basin during 2003. Pre-spawning coloration ranged from blush (silver with reddish tinges) to a pronounced reddish coloration.

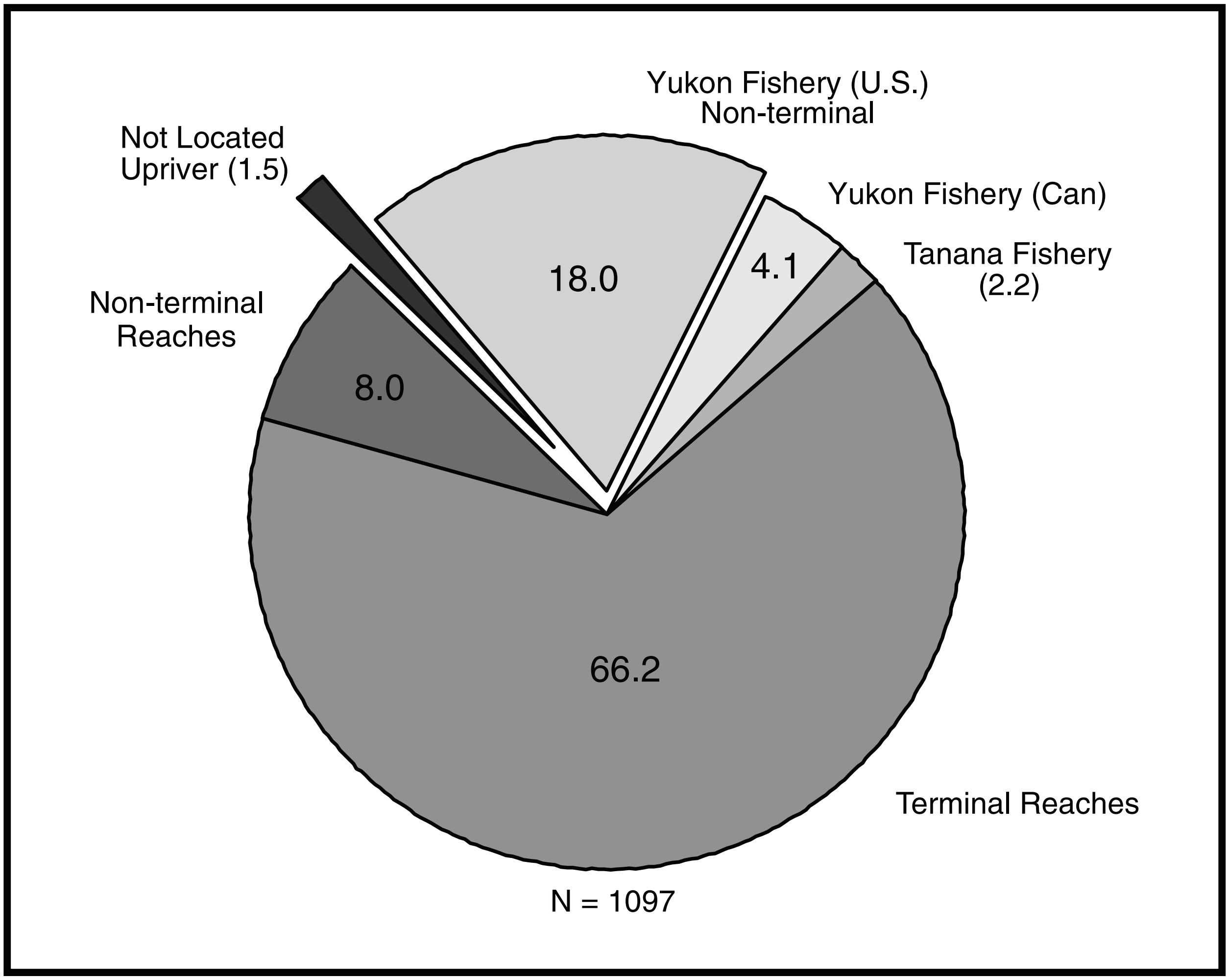



Figure 8. -- Final status of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission during 2003. Percentages of the total number of fish tagged are indicated.

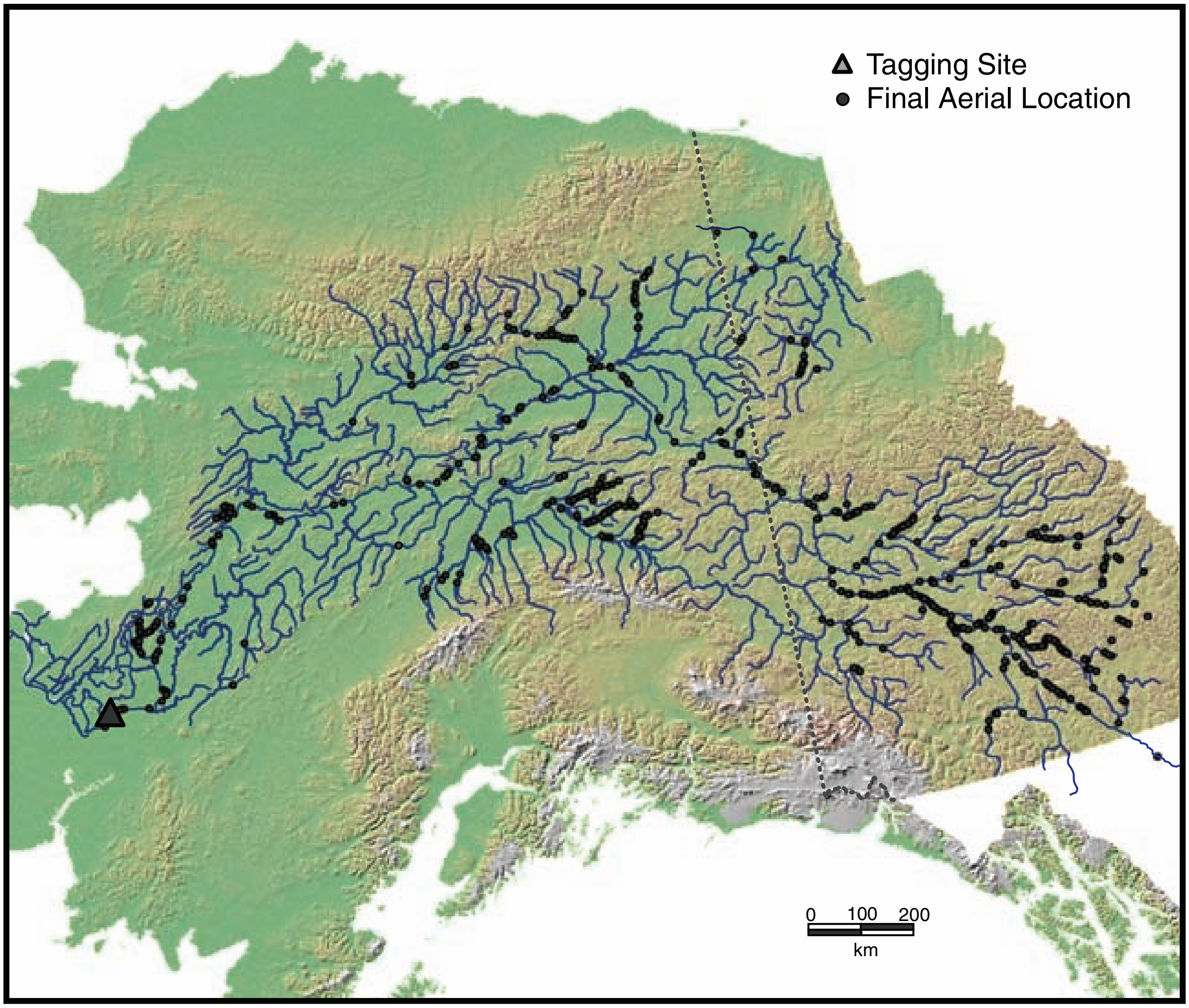



Figure 9. -- Final locations of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked upriver during their spawning migration based on aerial tracking surveys in 2003.

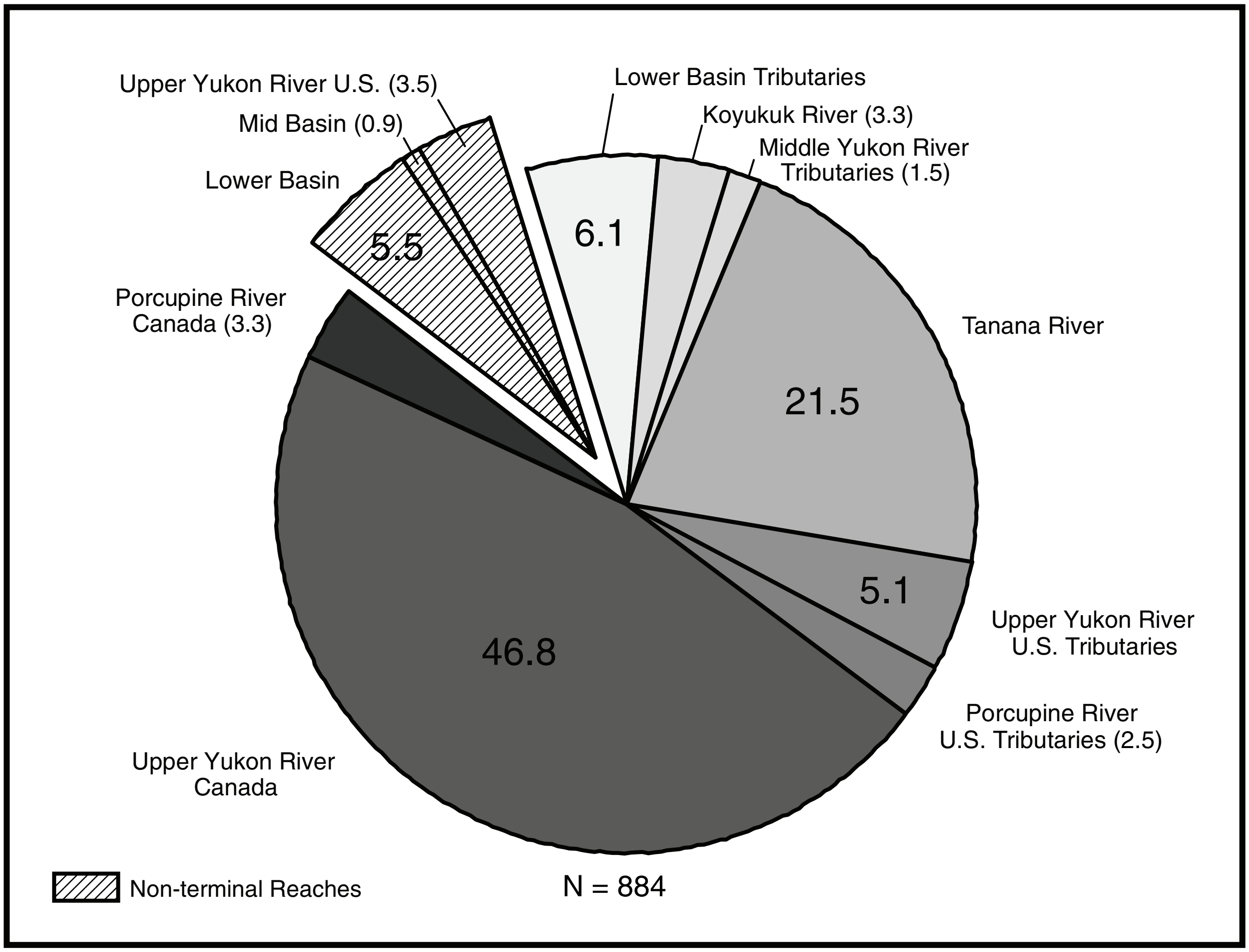



Figure 10. -- Distribution of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission during 2003. Percentages of the total number of fish that moved upriver and were not caught in non-terminal fisheries are indicated.

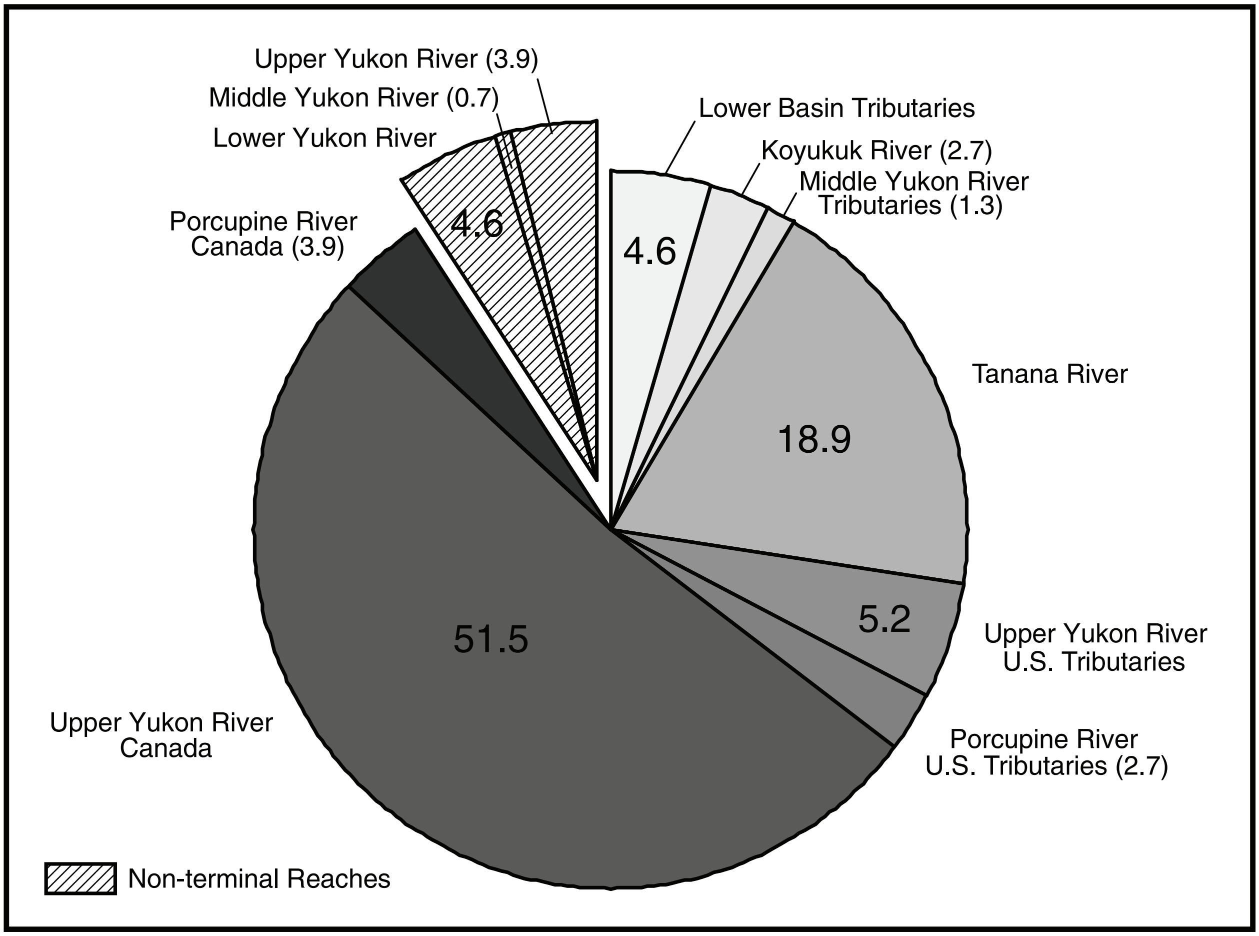



Figure 11. -- Stock composition estimates of the Yukon River Chinook salmon return in 2003 based on the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and accounting for the removal of tagged individuals in upriver fisheries. Percentages of the return are indicated.

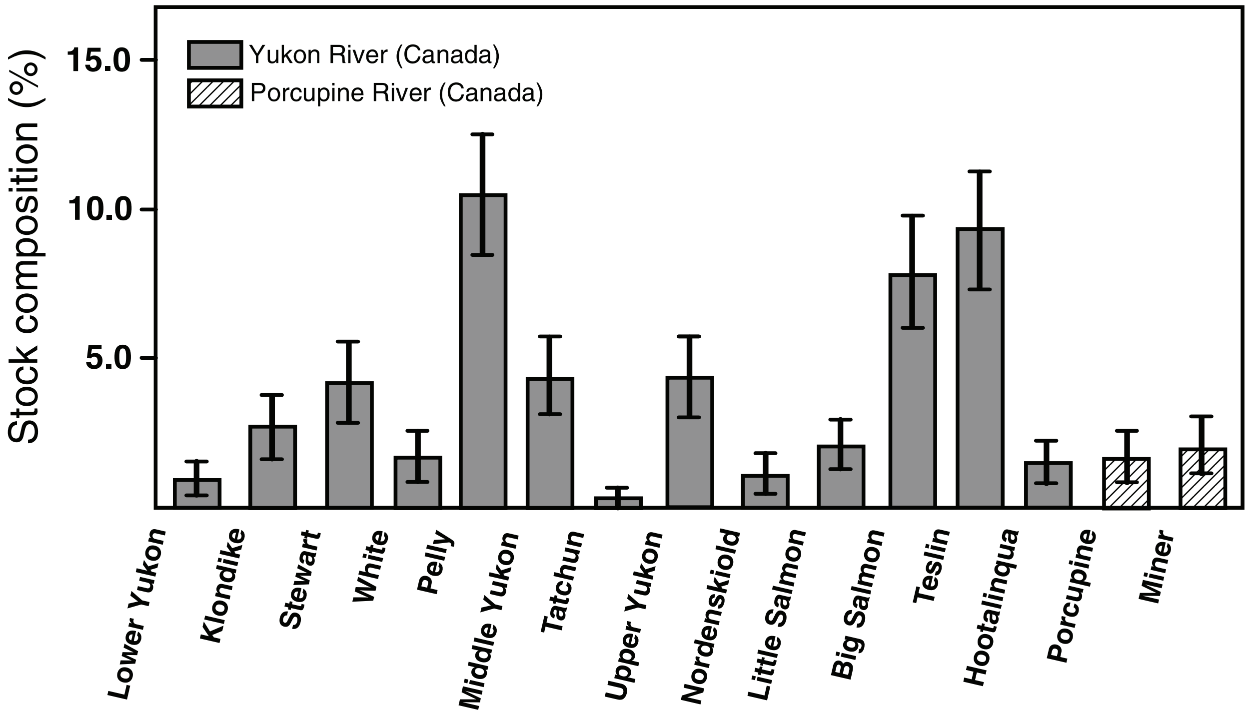



Figure 12. -- Composition of Chinook salmon stocks returning to Canadian reaches of the Yukon River basin in 2003, based on the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Composition estimates and 95% confidence intervals are provided.

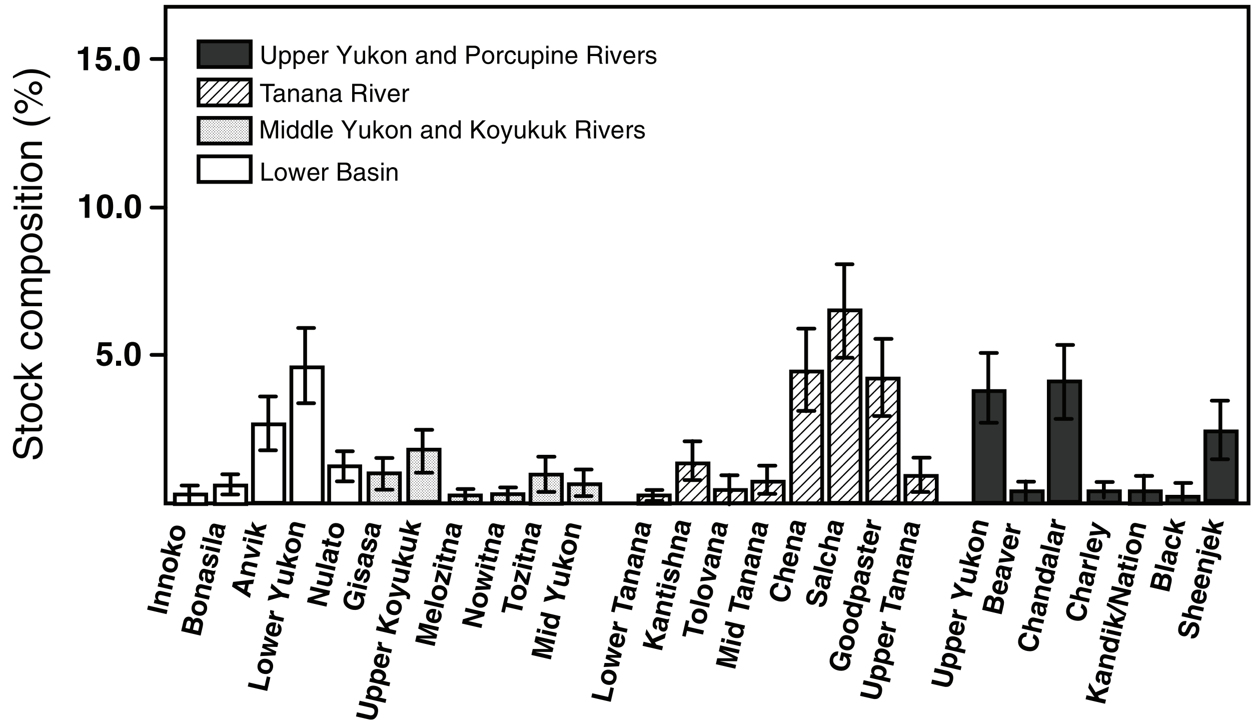



Figure 13. -- Composition of Chinook salmon stocks returning to U.S. reaches of the Yukon River basin in 2003, based on the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Composition estimates and 95% confidence intervals are provided.

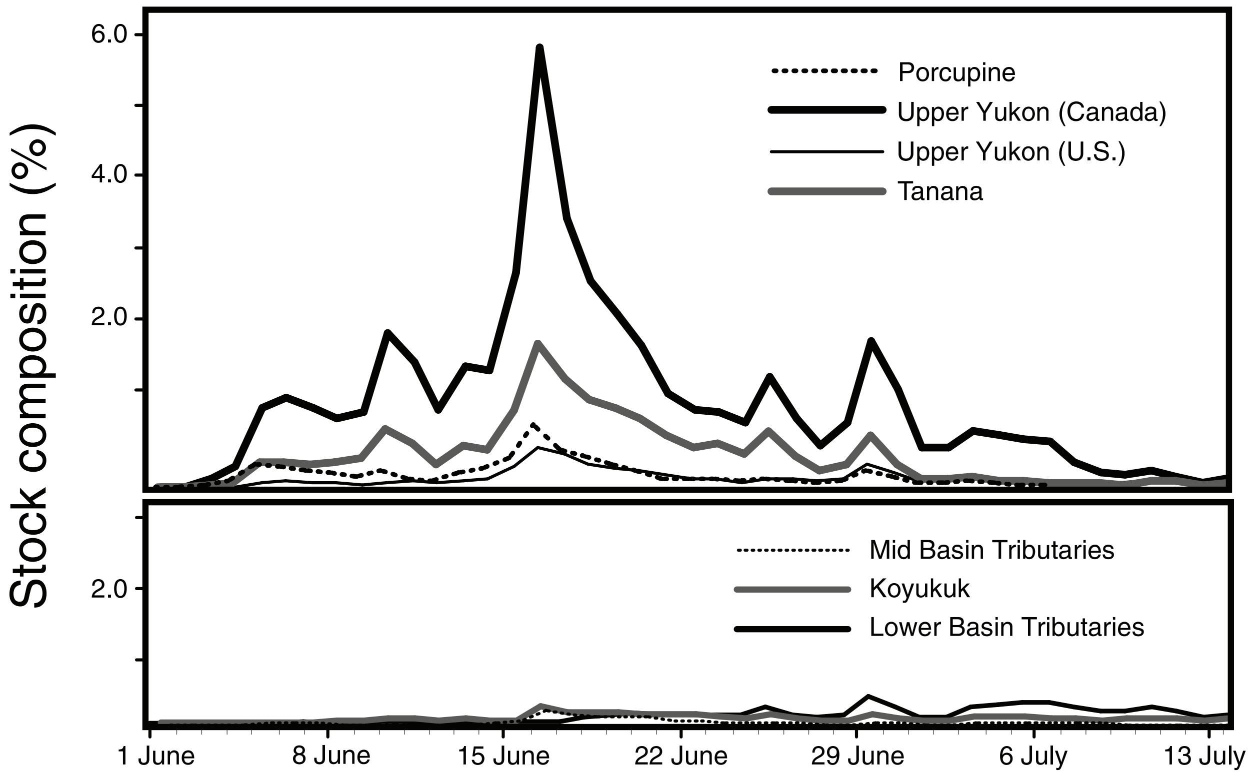



Figure 14. -- Run timing of Yukon River Chinook salmon stock groups returning to terminal reaches of the basin in 2003, based on composition estimates for the entire return derived from the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries.

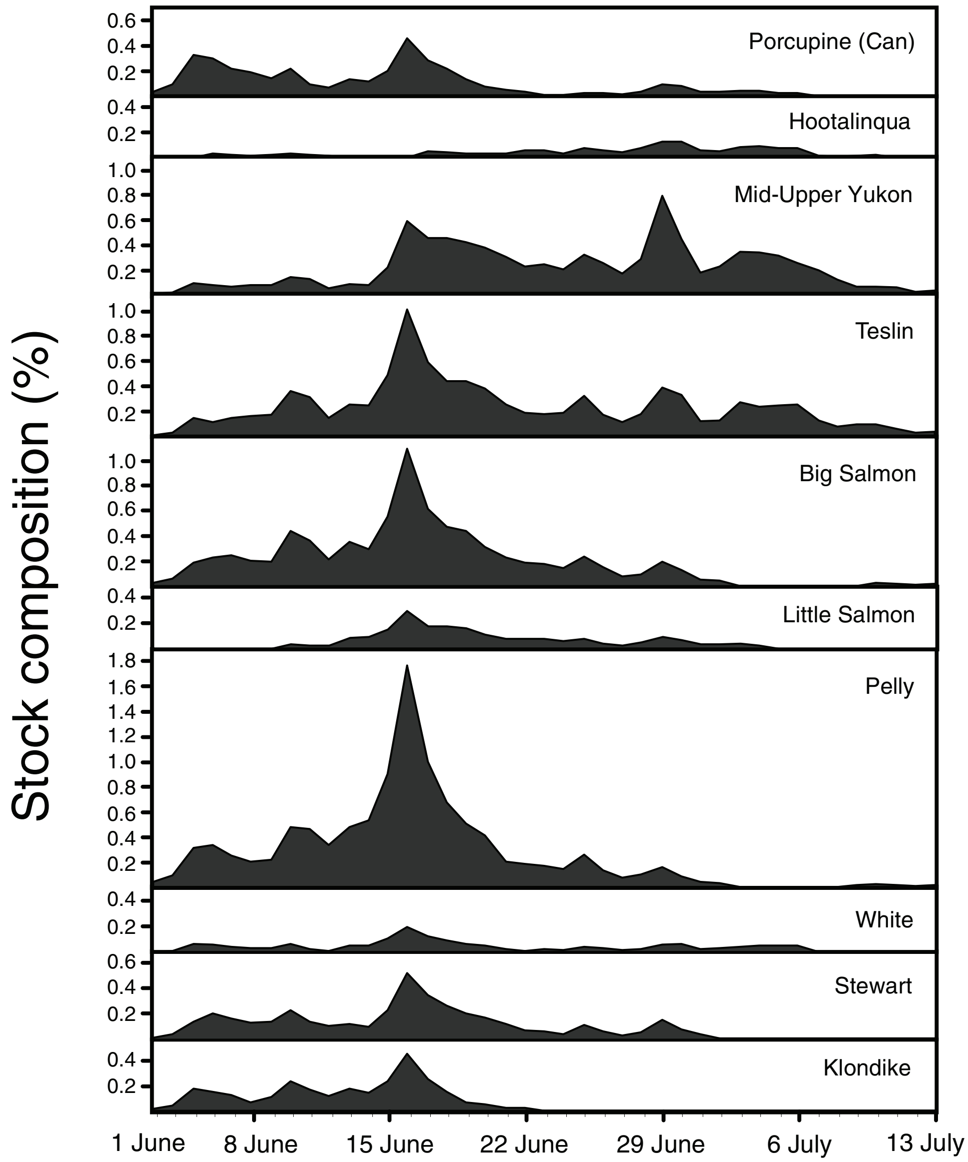



Figure 15. -- Run timing of major Chinook salmon stock in Canadian reaches of the Yukon River basin in 2003, based on composition estimates for the entire return derived from the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and accounting for the removal of tagged individuals in upriver fisheries. The mid-upper Yukon stock group represents fish remaining in main stem areas and associated tributaries.

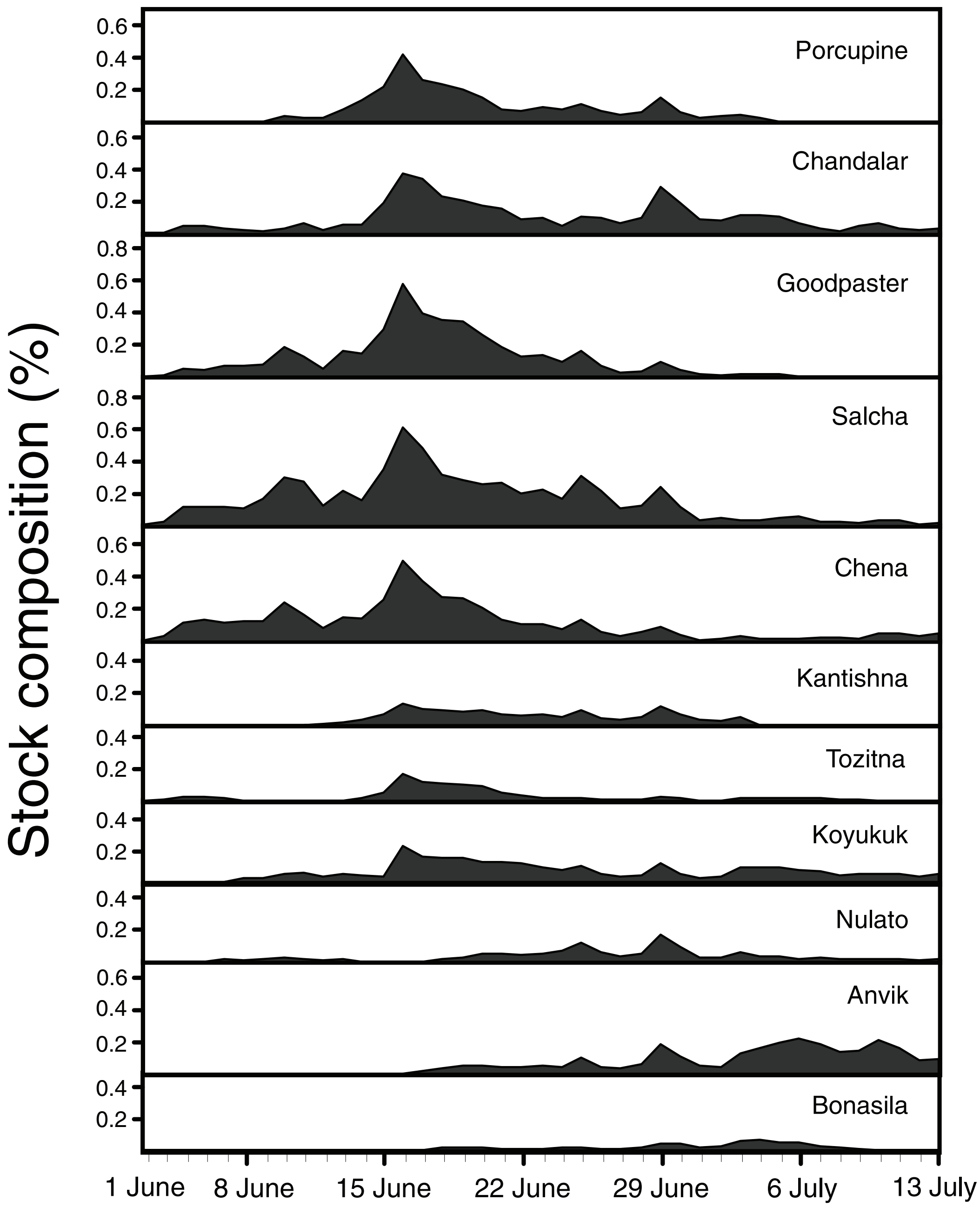



Figure 16. -- Run timing of major Chinook salmon stocks in U.S. reaches of the Yukon River basin in 2003, based on composition estimates for the entire return derived from the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries.

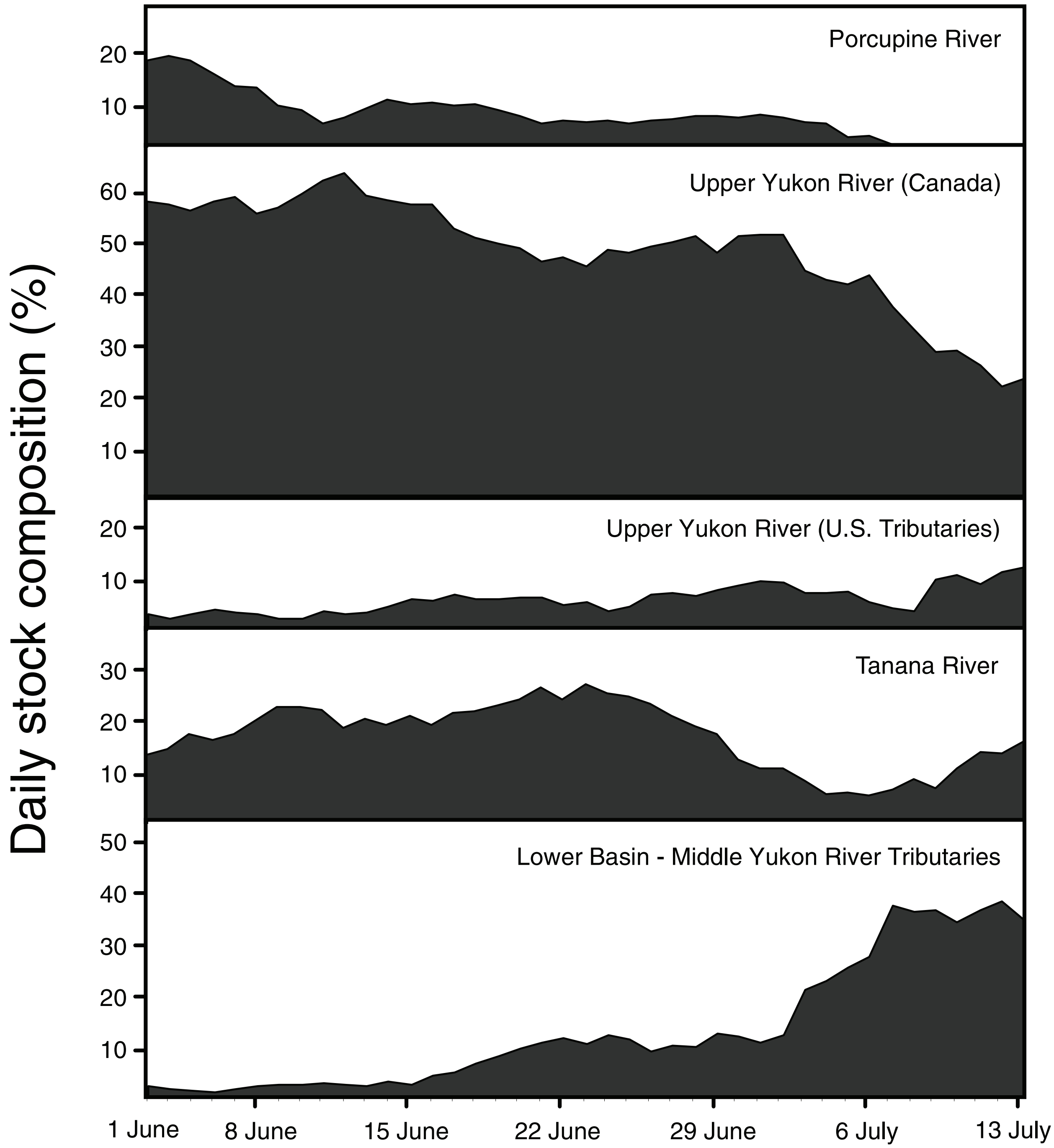



Figure 17. -- Daily stock composition of Chinook salmon passing through the lower Yukon River near the village of Russian Mission in 2003, based on the observed distribution of radio-tagged fish.

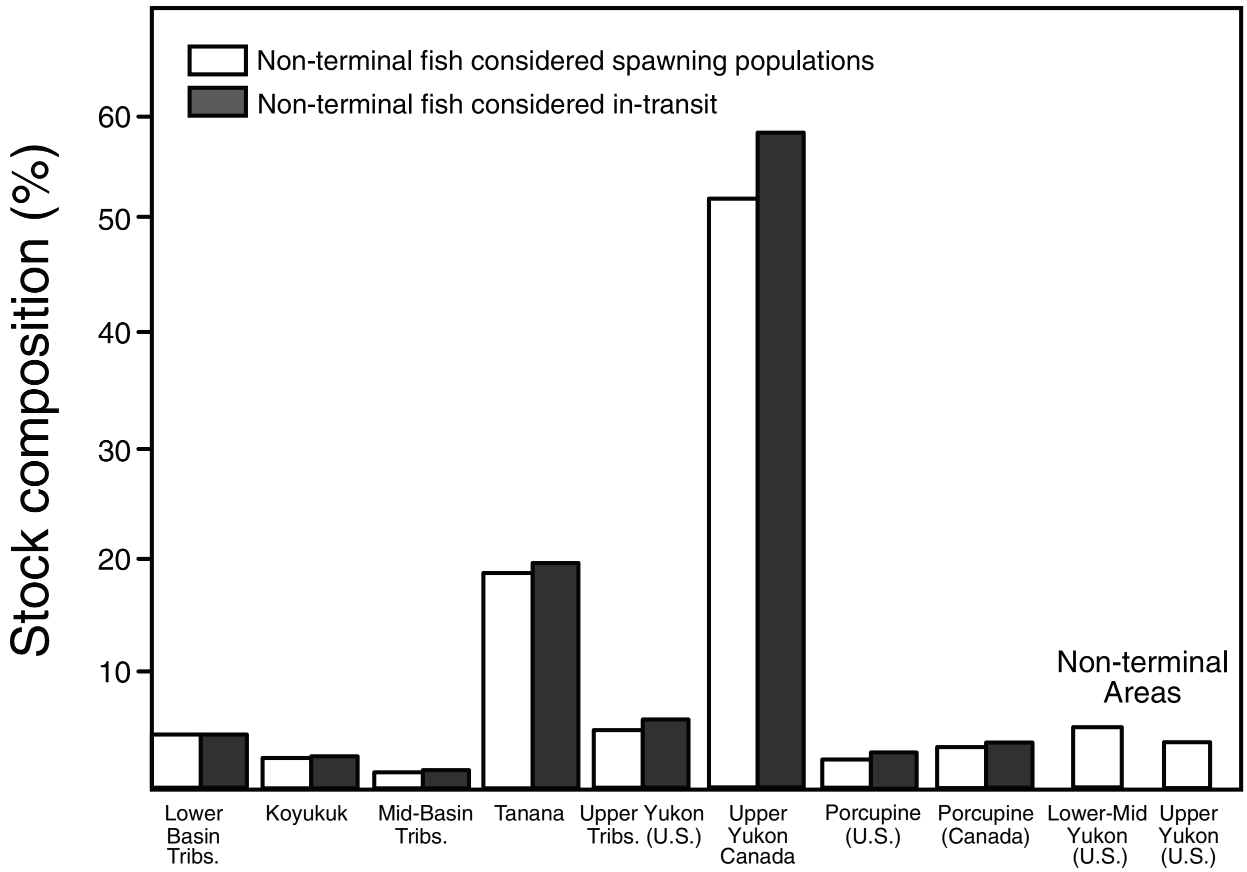



Figure 18. -- Comparison of stock composition estimates of the Yukon River Chinook salmon return in 2003 based on the distribution of radio-tagged fish weighted by catch per unit effort information at the capture site and accounting for the removal of tagged individuals in upriver fisheries, and the presumed status of fish remaining in non-terminal reaches of the Yukon River main stem. Non-terminal areas include associated tributaries not monitored during the study.

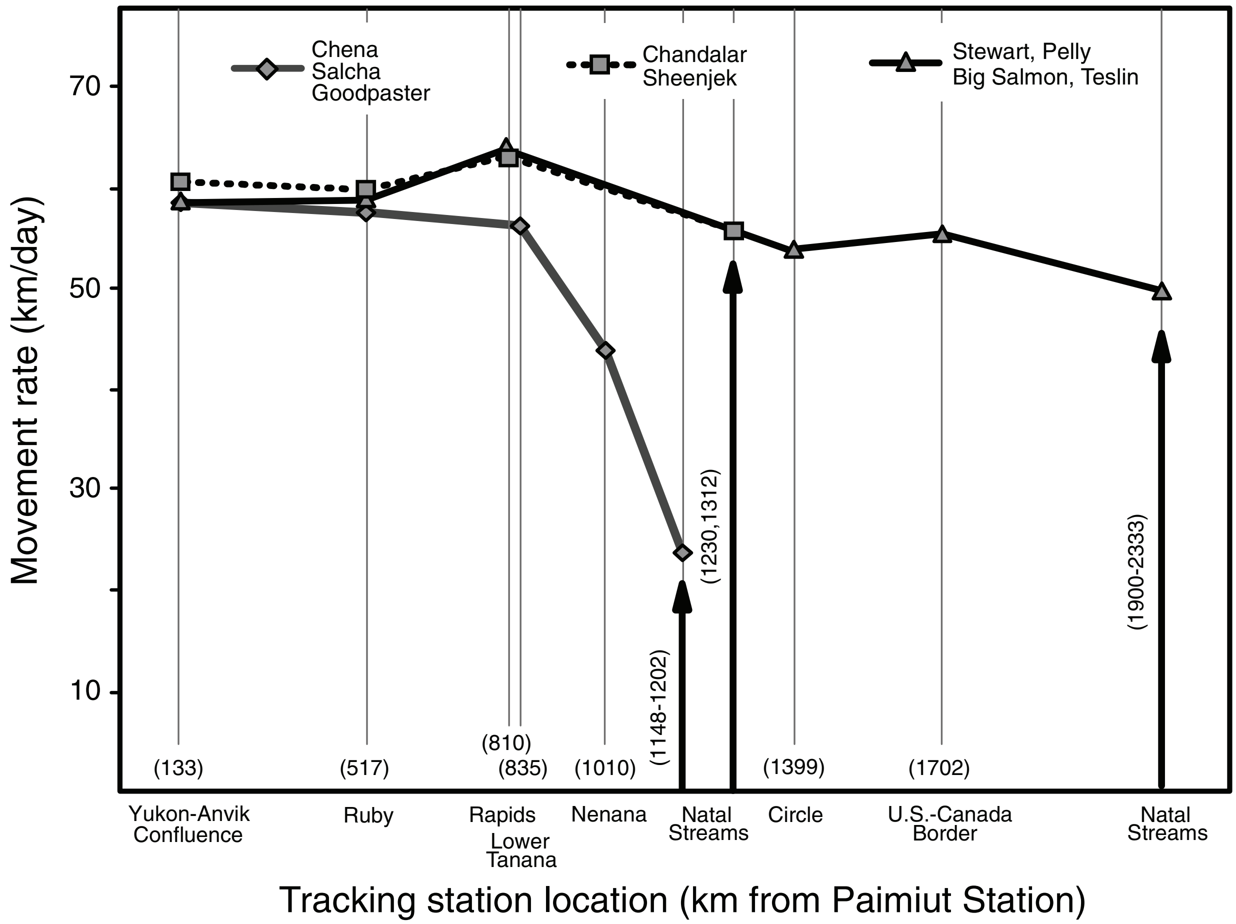



Figure 19. Movement rates (km/day) of radio-tagged Chinook salmon returning to tributaries in the upper Yukon River basin in 2003. Average rates by area and distances from the Paimiut tracking stations are provided.

Appendix A. -- Fishery recoveries of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission during 2003. Percentages of the total are in parentheses.

| Fishing area | Fishery | Tagged fish |
|---|---|---|
| District 3 (U.S.) | Russian Mission | 4 (1.5) |
| | Holy Cross | 23 (8.5) |
| | Combined fisheries | 27 (10.0) |
| District 4 (U.S.) | Anvik | 4 (1.5) |
| | Grayling | 7 (2.6) |
| | Kaltag | 6 (2.2) |
| | Nulato | 17 (6.3) |
| | Huslia, Hughes, Alatna, Allakaket (Koyukuk River)[1] | 4 (1.5) |
| | Galena | 17 (6.3) |
| | Ruby | 5 (1.8) |
| | Combined fisheries | 60 (22.1) |
| District 5 (U.S.) | Tanana | 7 (2.6) |
| | Yukon River (upriver of Tanana) | 5 (1.8) |
| | Rampart Rapids | 18 (6.6) |
| | Yukon River (upriver of Rampart Rapids) | 5 (1.8) |
| | Rampart | 19 (7.0) |
| | Yukon Bridge | 12 (4.4) |
| | Stevens Village | 11 (4.1) |
| | Beaver | 11 (4.1) |
| | Fort Yukon | 11 (4.1) |
| | Porcupine River | 1 (0.4) |
| | Circle | 6 (2.2) |
| | Eagle | 8 (3.0) |
| | Combined fisheries | 114 (42.1) |

Appendix A. -- Continued.

| Fishing area | Fishery | Tagged fish |
|---|---|---|
| District 6 (U.S.) | Lower Tanana River[1] | 1 (0.4) |
| | Tolovana River[1,2] | 2 (0.7) |
| | Nenana[1] | 9 (3.3) |
| | Fairbanks[1] | 9 (3.3) |
| | Chena River[1,2] | 3 (1.1) |
| | Salcha River[1,2] | 1 (0.4) |
| | Combined fisheries | 25 (9.2) |
| Canada | Border-Dawson | 14 (5.2) |
| | Stewart River[1] | 4 (1.5) |
| | Pelly River[1] | 8 (3.0) |
| | Tatchun Creek[1] | 2 (0.7) |
| | Carmacks | 7 (2.6) |
| | Teslin River[1] | 7 (2.6) |
| | Old Crow (Porcupine)[1] | 3 (1.1) |
| | Combined fisheries | 45 (16.6) |
| Total | | 271 |

[1] Fish harvested in tributary of the Yukon River main stem.

[2] Includes fish harvested in sport fishery.

Appendix B. -- Distribution of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission during 2003, including fish caught in terminal fisheries in the U.S. and Canada. Percentages of the total are in parentheses.

| Region | Final location | Tagged fish |
|---|---|---|
| Lower Basin | Yukon River main stem (upriver of Holy Cross)[1] | 49 (5.5) |
| | Innoko River | 2 (0.2) |
| | Bonasila River | 6 (0.7) |
| | Anvik River | 31 (3.5) |
| | Nulato River | 15 (1.7) |
| | Combined areas | 103 (11.6) |
| Koyukuk | Middle Koyukuk River[1] | 2 (0.2) |
| | Gisasa River | 11 (1.2) |
| | Koyukuk fishery | 4 (0.5) |
| | Hogatza River | 1 (0.1) |
| | Upper Koyukuk River[1] | 5 (0.6) |
| | Henshaw Creek | 1 (0.1) |
| | Koyukuk River South Fork | 3 (0.3) |
| | Koyukuk River Middle Fork | 2 (0.2) |
| | Combined areas | 29 (3.3) |
| Middle Yukon | Yukon River main stem (upriver of Galena)[1] | 8 (0.9) |
| | Melozitna River | 1 (0.1) |
| | Nowitna River | 2 (0.2) |
| | Tozitna River | 10 (1.1) |
| | Combined Areas | 21 (2.4) |
| Tanana | Tanana River fishery | 19 (2.1) |
| | Lower Tanana River (upriver of Manley)[1] | 2 (0.2) |
| | Kantishna River | 15 (1.7) |
| | Tolovana-Chatanika River[2] | 5 (0.6) |
| | Nenana River | 3 (0.3) |

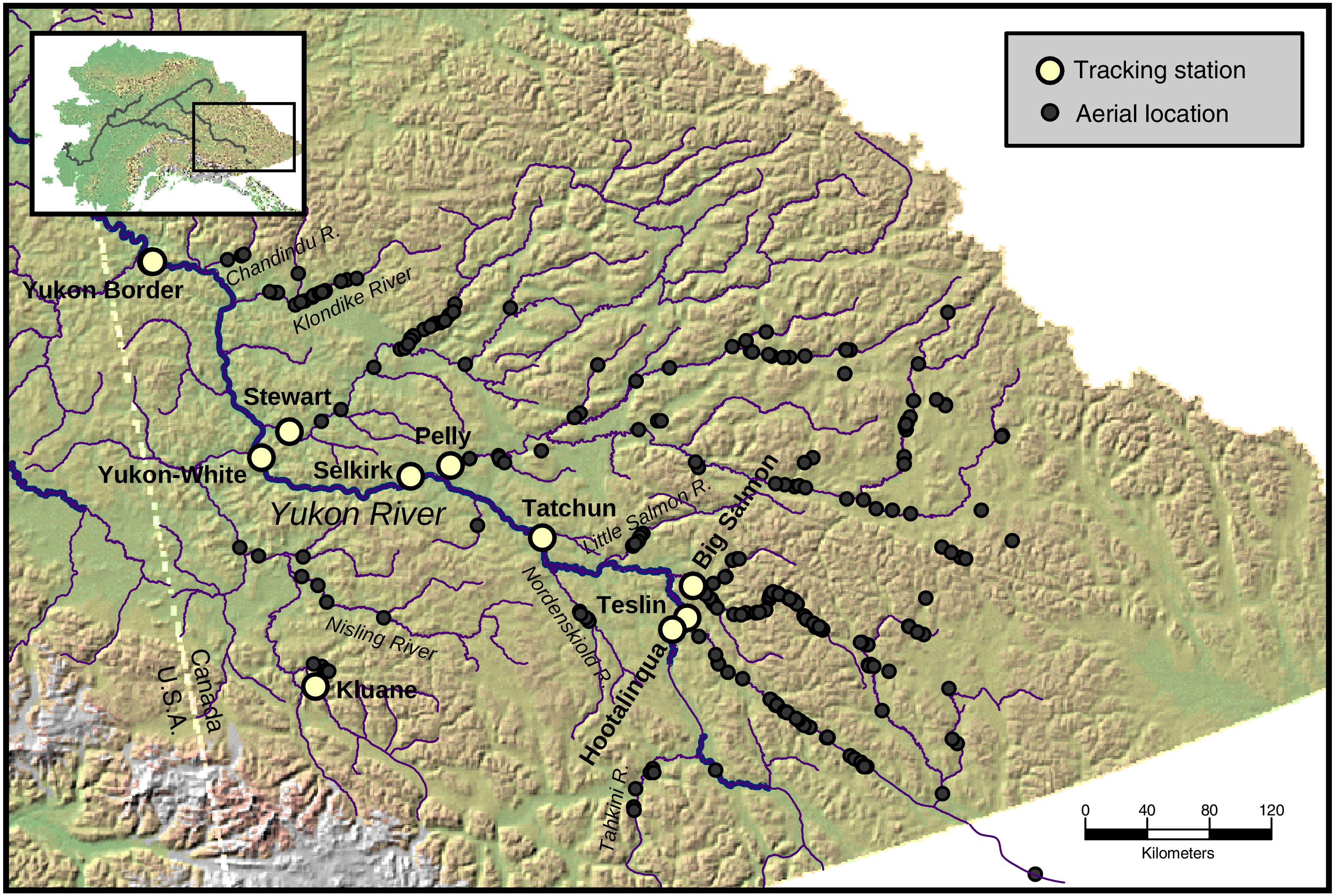
Appendix B. -- Continued.

| Region | Final location | Tagged fish |
|---|---|---|
| | Middle Tanana River (upriver of Nenana)[1] | 4 (0.5) |
| | Chena River[2] | 40 (4.5) |
| | Moose Creek | 1 (0.1) |
| | Salchaket Creek | 1 (0.1) |
| | Salcha River[2] | 58 (6.5) |
| | Upper Tanana River (upriver of Salcha River)[1] | 6 (0.7) |
| | Goodpaster River | 36 (4.1) |
| | Combined areas | 190 (21.5) |
| Upper Yukon (U.S.) | Yukon River main stem (upriver of Tanana)[1] | 21 (2.4) |
| | Beaver Creek | 3 (0.3) |
| | Chandalar River | 36 (4.1) |
| | Yukon River main stem (upriver of Circle)[1] | 10 (1.1) |
| | Charley River | 3 (0.3) |
| | Kandik River | 1 (0.1) |
| | Nation River | 2 (0.2) |
| | Combined areas | 76 (8.6) |
| Upper Yukon (Canada) | Yukon River main stem (upriver of Border)[1] | 7 (0.8) |
| | Yukon River fishery | 21 (2.4) |
| | Chandindu River | 5 (0.6) |
| | Klondike River | 19 (2.1) |
| | Stewart River[2] | 31 (3.6) |
| | White River | 12 (1.4) |
| | Yukon River main stem (upriver of White River)[1] | 6 (0.7) |
| | Pelly River[2] | 79 (8.9) |
| | Big Creek | 1 (0.1) |
| | Yukon River main stem (upriver of Selkirk)[1] | 27 (3.1) |
| | Tatchun Creek | 3 (0.3) |
| | Yukon River main stem (upriver of Tatchun Cr.)[1] | 34 (3.8) |
| | Nordenskiold River | 8 (0.9) |
| | Little Salmon River | 17 (1.9) |

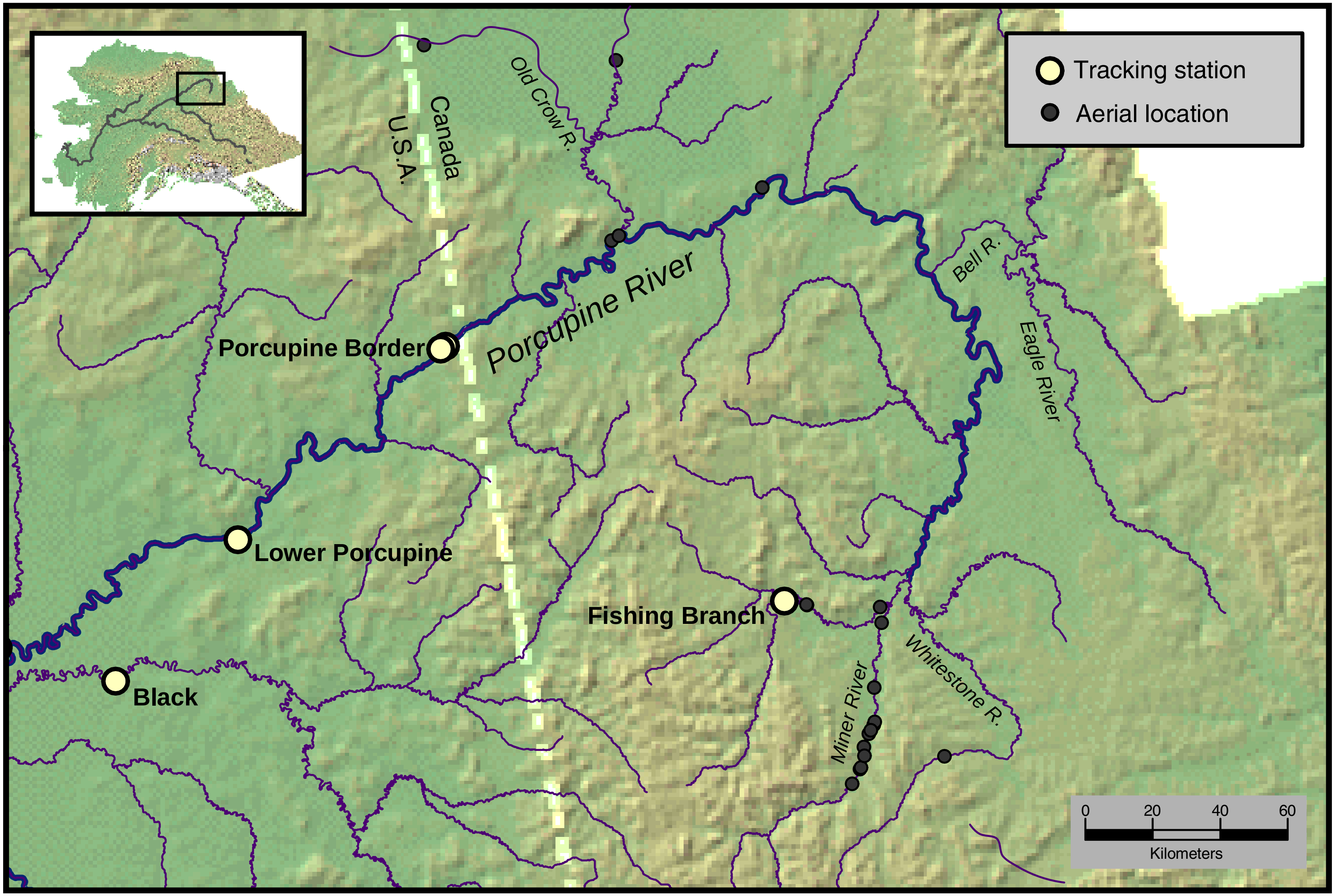
Appendix B. -- Continued.

| Region | Final location | Tagged fish |
|---|---|---|
| | Big Salmon River | 59 (6.7) |
| | Teslin River[2] | 71 (8.0) |
| | Yukon River main stem (upriver of Hootalinqua)[1] | 7 (0.8) |
| | Takhini River | 6 (0.7) |
| | Combined areas | 413 (46.8) |
| Porcupine (U.S.) | Black River | 2 (0.2) |
| | Sheenjek River | 20 (2.3) |
| | Combined areas | 22 (2.5) |
| Porcupine (Canada) | Porcupine River (upriver of Border)[1] | 10 (1.1) |
| | Old Crow Fishery | 3 (0.3) |
| | Old Crow River | 2 (0.2) |
| | Whitestone River | 1 (0.1) |
| | Miner River | 13 (1.5) |
| | Fishing Branch River | 1 (0.1) |
| | Combined areas | 30 (3.3) |
| Total | | 884 |

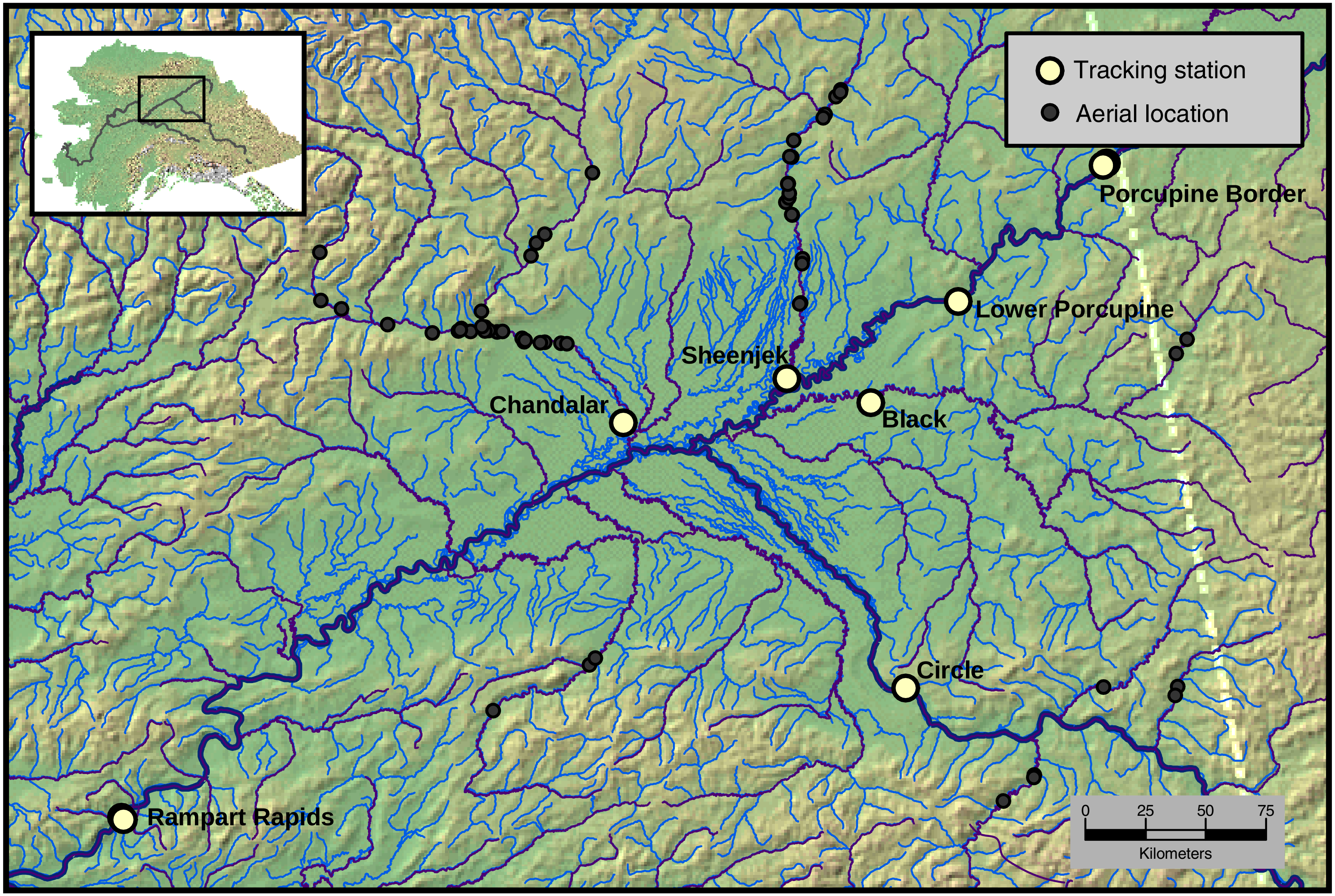
[1] Including associated tributaries not monitored with tracking stations or aerial surveys.
[2] Includes fish caught in terminal fisheries.



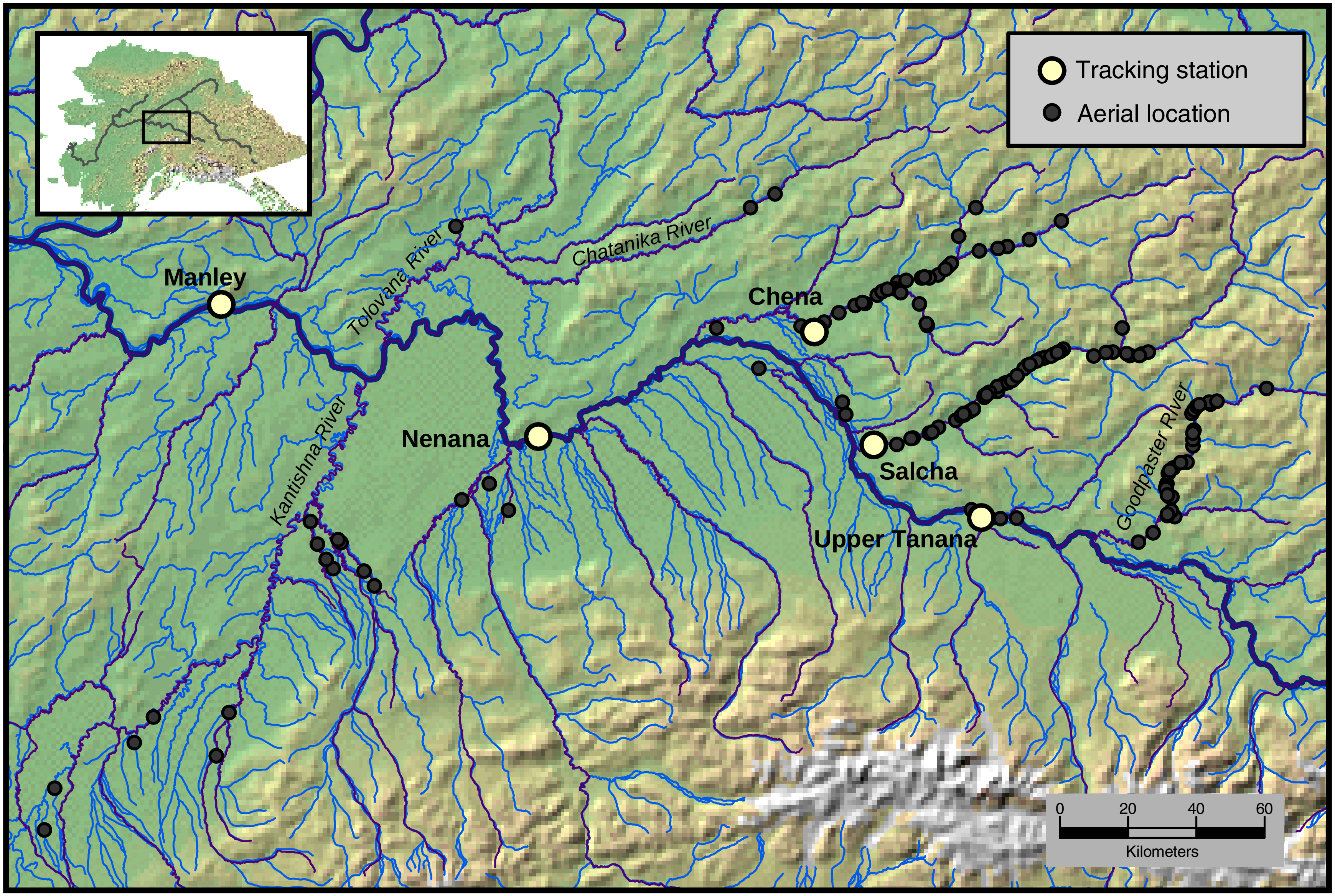

Appendix C. -- Final location of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked to tributaries in Canadian reaches of the Yukon River during aerial tracking surveys in 2003.



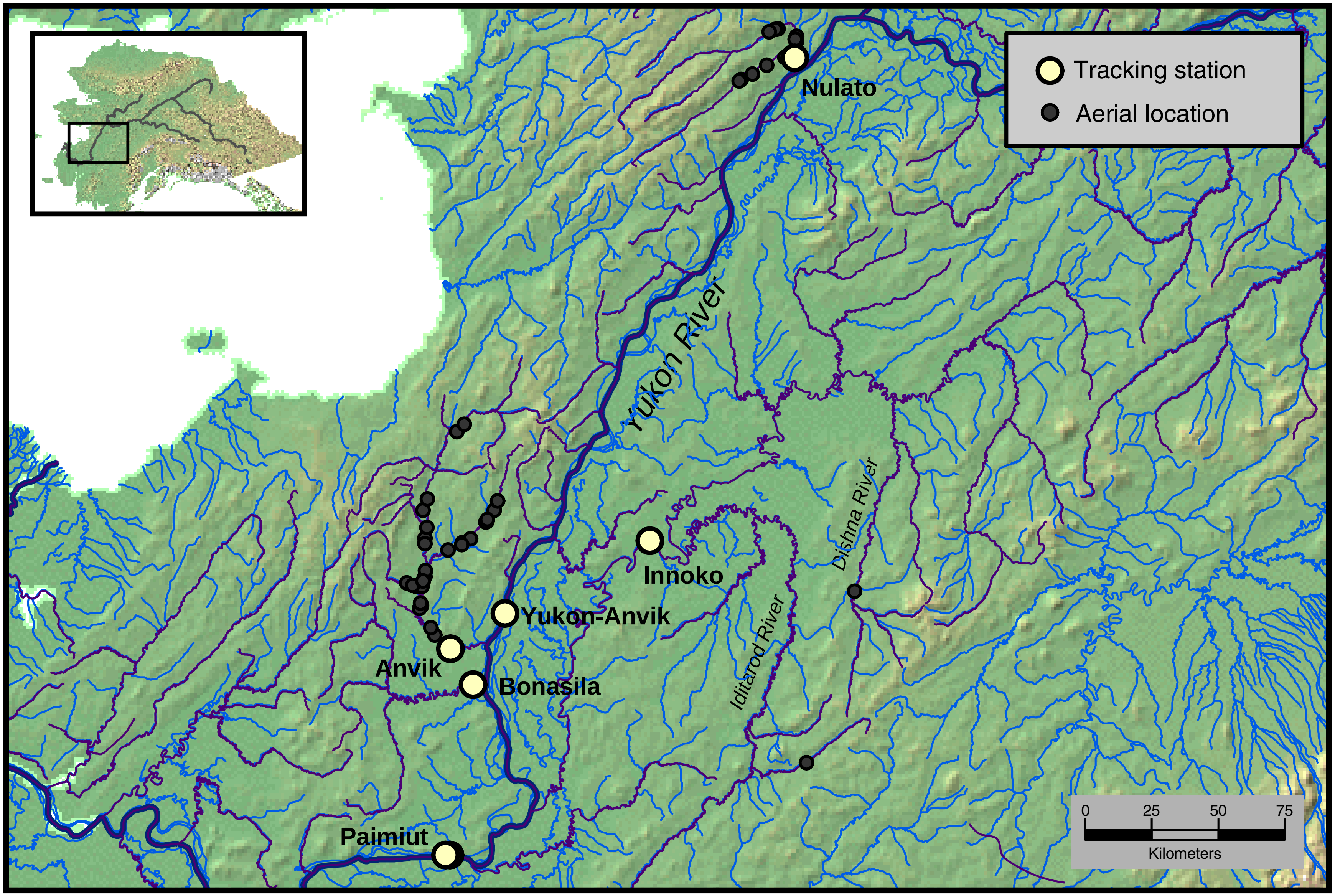

Appendix D. -- Final location of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked to Canadian reaches of the Porcupine River during aerial tracking surveys in 2003.



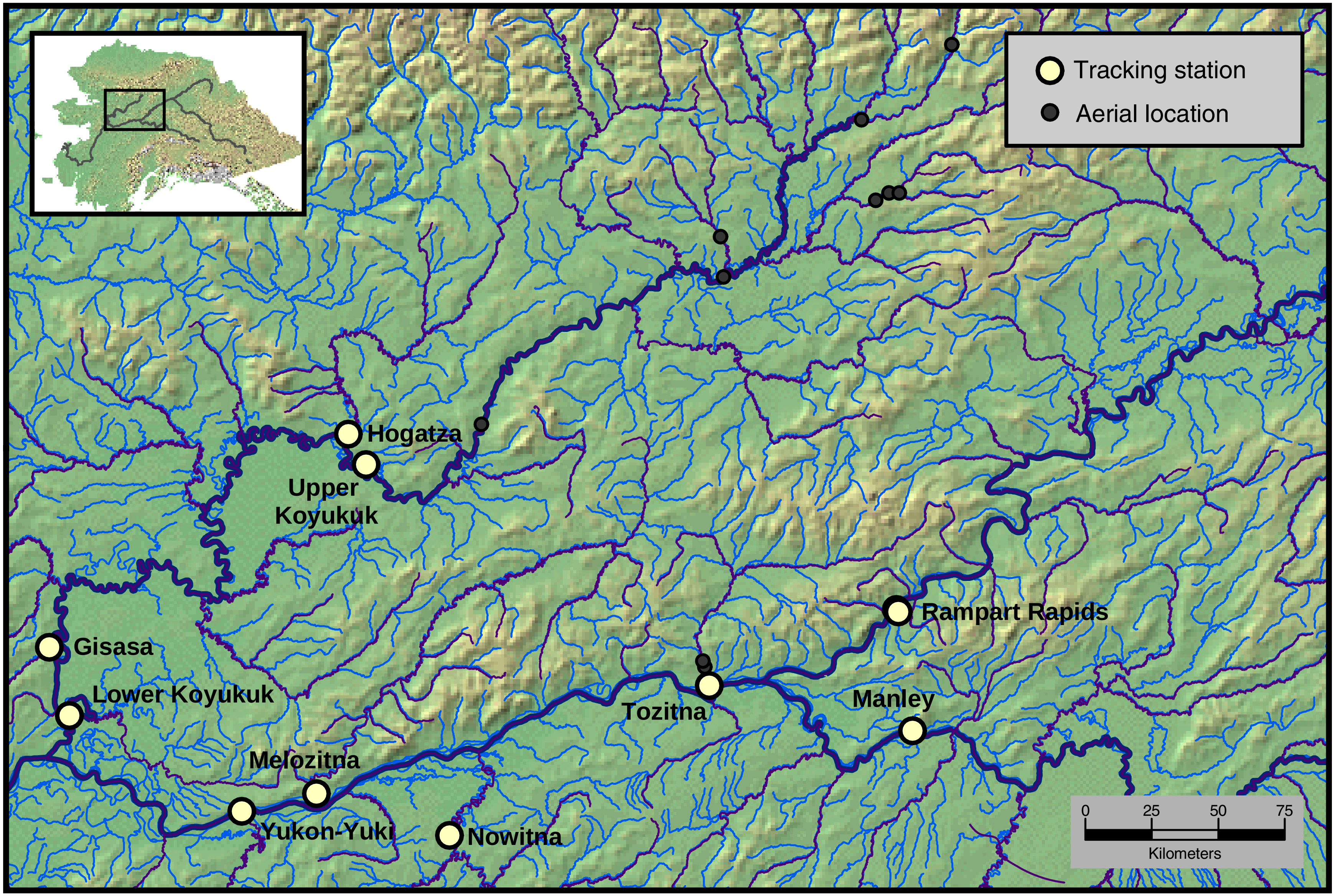

Appendix E. -- Final location of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked to tributaries in U.S. reaches of the upper Yukon and Porcupine rivers during aerial tracking surveys in 2003.




Appendix F. -- Final location of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked to Tanana River tributaries during aerial tracking surveys in 2003.




Appendix G. -- Final location of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked to lower basin tributaries during aerial tracking surveys in 2003.




Appendix H. -- Final location of Chinook salmon radio tagged in the lower Yukon River near the village of Russian Mission and tracked to middle basin tributaries during aerial tracking surveys in 2003.

Appendix I. -- Stock composition estimates of the Yukon River Chinook salmon return in 2003 based on the distribution of radio-tagged fish weighted by catch per unit effort information at the Russian Mission tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Bootstrap standard errors (SE) and 95% confidence intervals (CI) based on 10,000 bootstrappings are included.

| Region | Stock group | Estimate (%) | SE | 95% CI |
|---|---|---|---|---|
| Lower Basin[1] | Lower Yukon[2] | 4.6 | 0.7 | 3.3, 5.8 |
| | Innoko | 0.2 | 0.1 | 0.0, 0.5 |
| | Bonasila | 0.5 | 0.2 | 0.2, 1.0 |
| | Anvik | 2.6 | 0.5 | 1.7, 3.5 |
| | Nulato | 1.3 | 0.3 | 0.7, 1.9 |
| Koyukuk River | Gisasa | 1.0 | 0.3 | 0.4, 1.6 |
| | Hogatza | 0.1 | 0.1 | 0.0, 0.3 |
| | Upper Koyukuk | 1.6 | 0.4 | 0.8, 2.4 |
| Middle Yukon River[3] | Melozitna | 0.1 | 0.1 | 0.0, 0.2 |
| | Nowitna | 0.2 | 0.2 | 0.0, 0.6 |
| | Tozitna | 1.0 | 0.3 | 0.4, 1.7 |
| | Mid-Yukon[2] | 0.7 | 0.3 | 0.3, 1.3 |
| Tanana River | Lower Tanana[4] | 0.2 | 0.1 | 0.0, 0.5 |
| | Kantishna | 1.4 | 0.4 | 0.7, 2.2 |
| | Tolovana | 0.5 | 0.2 | 0.1, 1.0 |
| | Mid-Tanana[4] | 0.7 | 0.3 | 0.2, 1.3 |
| | Chena | 4.6 | 0.7 | 3.2, 5.9 |
| | Salcha | 6.5 | 0.8 | 5.0, 8.1 |
| | Goodpaster | 4.2 | 0.7 | 3.0, 5.6 |
| | Upper Tanana[4] | 0.9 | 0.3 | 0.4, 1.6 |
| Upper Yukon River (U.S.)[5] | Upper Yukon ( Rapids)[2] | 2.6 | 0.5 | 1.5, 3.6 |
| | Beaver Creek | 0.4 | 0.2 | 0.0, 0.8 |
| | Chandalar | 4.1 | 0.7 | 2.8, 5.4 |
| | Upper Yukon (Circle)[2] | 1.3 | 0.4 | 0.6, 2.1 |
| | Charley | 0.4 | 0.2 | 0.0, 0.8 |
| | Kandik/Nation | 0.4 | 0.2 | 0.0, 0.9 |
| Upper Yukon River (Canada) | Lower Canadian Yukon [4] | 0.9 | 0.3 | 0.4, 1.7 |
| | Klondike | 2.8 | 0.6 | 1.6, 3.9 |
| | Stewart | 4.2 | 0.7 | 2.9, 5.6 |
| | White | 1.7 | 0.5 | 0.8, 2.6 |
| | Pelly | 10.6 | 1.1 | 8.4, 12.7 |

Appendix I. -- Continued.

| Region | Stock group | Estimate (%) | SE | 95% CI |
|---|---|---|---|---|
| Upper Yukon River (Canada) | Mid-Canadian Yukon[4] | 4.4 | 0.7 | 3.1, 5.8 |
| | Tatchun | 0.3 | 0.2 | 0.0, 0.7 |
| | Upper Canadian Yukon[4] | 4.4 | 0.7 | 3.1, 5.8 |
| | Nordenskiold | 1.2 | 0.4 | 0.5, 2.1 |
| | Little Salmon | 2.1 | 0.5 | 1.2, 3.2 |
| | Big Salmon | 8.0 | 1.0 | 6.1, 10.0 |
| | Teslin | 9.4 | 1.0 | 7.4, 11.4 |
| | Hootalinqua | 1.5 | 0.4 | 0.8, 2.4 |
| Porcupine River, U.S. | Black | 0.3 | 0.2 | 0.0, 0.7 |
| | Sheenjek | 2.4 | 0.5 | 1.5, 3.5 |
| Porcupine River, Canada | Canadian Porcupine[4] | 1.7 | 0.5 | 0.9, 2.7 |
| | Miner | 2.1 | 0.5 | 1.2, 3.1 |

[1] Section of the Yukon River from Russian Mission to the Yukon-Koyukuk River confluence.
[2] Non-terminal areas.
[3] Section of the Yukon River from Galena to the Yukon-Tanana River confluence.
[4] Including stocks in mainstem areas and associated tributaries.
[5] Section of the Yukon River upriver from the Yukon-Tanana River confluence.

Appendix J. -- Daily stock composition estimates of Chinook salmon passing through the lower Yukon River near the village of Russian Mission based on the distribution of radio-tagged fish in 2003.

| | Non-terminal reaches[1] | | Terminal reaches | | | |
|---|---|---|---|---|---|---|
| Date | Lower-middle Yukon | Upper Yukon (U.S.)[2] | Lower basin-middle Yukon tributaries | Tanana River | Upper basin tributaries (U.S.)[2] | Canada[2] |
| 3 June | 0.0833 | 0.0000 | 0.0213 | 0.1279 | 0.0265 | 0.7410 |
| 4 June | 0.0694 | 0.0165 | 0.0141 | 0.1410 | 0.0165 | 0.7425 |
| 5 June | 0.0549 | 0.0132 | 0.0114 | 0.1708 | 0.0263 | 0.7234 |
| 6 June | 0.0577 | 0.0235 | 0.0099 | 0.1587 | 0.0347 | 0.7155 |
| 7 June | 0.0551 | 0.0288 | 0.0160 | 0.1711 | 0.0288 | 0.7002 |
| 8 June | 0.0493 | 0.0428 | 0.0211 | 0.1976 | 0.0256 | 0.6636 |
| 9 June | 0.0448 | 0.0509 | 0.0224 | 0.2236 | 0.0172 | 0.6412 |
| 10 June | 0.0221 | 0.0580 | 0.0221 | 0.2218 | 0.0251 | 0.6511 |
| 11 June | 0.0207 | 0.0468 | 0.0276 | 0.2163 | 0.0391 | 0.6495 |
| 12 June | 0.0234 | 0.0589 | 0.0234 | 0.1810 | 0.0397 | 0.6736 |
| 13 June | 0.0259 | 0.0648 | 0.0216 | 0.1994 | 0.0551 | 0.6334 |
| 14 June | 0.0217 | 0.0537 | 0.0289 | 0.1877 | 0.0873 | 0.6207 |
| 15 June | 0.0224 | 0.0445 | 0.0225 | 0.2054 | 0.0967 | 0.6086 |
| 16 June | 0.0239 | 0.0420 | 0.0417 | 0.1881 | 0.0912 | 0.6131 |
| 17 June | 0.0410 | 0.0386 | 0.0466 | 0.2114 | 0.0996 | 0.5629 |
| 18 June | 0.0405 | 0.0377 | 0.0647 | 0.2141 | 0.0975 | 0.5455 |
| 19 June | 0.0479 | 0.0298 | 0.0785 | 0.2256 | 0.0958 | 0.5226 |
| 20 June | 0.0505 | 0.0184 | 0.0942 | 0.2362 | 0.0955 | 0.5053 |
| 21 June | 0.0578 | 0.0169 | 0.1043 | 0.2598 | 0.0841 | 0.4771 |
| 22 June | 0.0720 | 0.0180 | 0.1128 | 0.2373 | 0.0753 | 0.4846 |
| 23 June | 0.0684 | 0.0180 | 0.1017 | 0.2651 | 0.0896 | 0.4572 |
| 24 June | 0.0561 | 0.0157 | 0.1193 | 0.2487 | 0.0725 | 0.4878 |
| 25 June | 0.0636 | 0.0230 | 0.1124 | 0.2440 | 0.0735 | 0.4835 |
| 26 June | 0.0558 | 0.0265 | 0.0892 | 0.2292 | 0.0992 | 0.5001 |
| 27 June | 0.0574 | 0.0221 | 0.1002 | 0.2049 | 0.1043 | 0.5110 |
| 28 June | 0.0615 | 0.0302 | 0.0977 | 0.1858 | 0.0952 | 0.5296 |
| 29 June | 0.0655 | 0.0339 | 0.1241 | 0.1688 | 0.1091 | 0.4986 |
| 30 June | 0.0704 | 0.0517 | 0.1159 | 0.1205 | 0.1030 | 0.5385 |
| 1 July | 0.0669 | 0.0590 | 0.1059 | 0.1034 | 0.1176 | 0.5472 |
| 2 July | 0.0707 | 0.0529 | 0.1191 | 0.1022 | 0.1149 | 0.5402 |
| 3 July | 0.0958 | 0.0668 | 0.2071 | 0.0784 | 0.0884 | 0.4634 |
| 4 July | 0.1138 | 0.0804 | 0.2244 | 0.0517 | 0.0796 | 0.4502 |
| 5 July | 0.1227 | 0.0703 | 0.2526 | 0.0558 | 0.0694 | 0.4293 |

Appendix J. -- Continued.

| | Non-terminal reaches[1] | | Terminal reaches | | | |
|---|---|---|---|---|---|---|
| Date | Lower-middle Yukon | Upper Yukon (U.S.)[2] | Lower basin-middle Yukon tributaries | Tanana River | Upper basin tributaries (U.S.)[2] | Canada[2] |
| 6 July | 0.1128 | 0.0656 | 0.2729 | 0.0501 | 0.0484 | 0.4501 |
| 7 July | 0.1376 | 0.0186 | 0.3729 | 0.0612 | 0.0372 | 0.3724 |
| 8 July | 0.1635 | 0.0329 | 0.3595 | 0.0818 | 0.0329 | 0.3293 |
| 9 July | 0.1558 | 0.0379 | 0.3636 | 0.0641 | 0.0947 | 0.2840 |
| 10 July | 0.1409 | 0.0260 | 0.3393 | 0.1040 | 0.1040 | 0.2859 |
| 11 July | 0.1285 | 0.0288 | 0.3637 | 0.1336 | 0.0863 | 0.2590 |
| 12 July | 0.1257 | 0.0362 | 0.3810 | 0.1315 | 0.1085 | 0.2171 |
| 13 July | 0.1115 | 0.0388 | 0.3455 | 0.1552 | 0.1164 | 0.2327 |

[1] Reaches of the Yukon River main stem and associated tributaries not monitored by remote tracking stations.
[2] Including reaches of the upper Yukon and Porcupine rivers.

Appendix K. -- Movement rates of Chinook salmon radio tagged in the Yukon River basin during 2003 based on fish passage by tracking stations located at Paimiut and the farthest upriver station site.

| Region | Stock | Average (km/h) | CI (95%) | N |
|---|---|---|---|---|
| Lower Basin | Lower Yukon[1,2] | 36.1 | 30.6, 41.6 | 48 |
| | Innoko | 36.1 | -- | 2 |
| | Bonasila | 45.6 | 26.4, 64.8 | 6 |
| | Anvik | 24.2 | 20.1, 28.3 | 31 |
| | Nulato | 39.2 | 32.2, 46.2 | 15 |
| Koyukuk River | Gisasa | 42.9 | 37.6, 48.2 | 11 |
| | Middle Koyukuk | 51.5 | 46.7, 56.3 | 3 |
| | Upper Koyukuk | 65.1 | 59.6, 70.6 | 8 |
| | Henshaw | 61.1 | -- | 1 |
| | South Fork | 66.7 | 62.1, 71.3 | 3 |
| | Middle Fork | 57.4 | -- | 2 |
| Middle Yukon River | Mid-Yukon[1,3] | 49.6 | 38.9, 60.3 | 6 |
| | Melozitna | 41.4 | -- | 1 |
| | Nowitna | 54.9 | -- | 2 |
| | Tozitna | 46.1 | 35.6, 56.6 | 9 |
| Tanana River | Lower Tanana[4,5] | 39.7 | -- | 2 |
| | Kantishna | 55.3 | 51.7, 58.9 | 15 |
| | Tolovana | 50.3 | 43.0, 57.6 | 5 |
| | Middle Tanana[4,6] | 56.1 | 50.2, 62.0 | 4 |
| | Nenana | 50.9 | 21.0, 80.8 | 3 |
| | Small tributaries near Fairbanks | 52.9 | -- | 2 |
| | Chena | 44.8 | 42.7, 46.9 | 40 |
| | Salcha | 45.1 | 43.8, 46.4 | 56 |
| | Goodpaster | 47.0 | 45.3, 48.7 | 36 |
| | Upper Tanana[4,7] | 42.3 | 33.4, 51.2 | 6 |
| Upper Yukon River (U.S.) | Upper Yukon, Tanana-Circle[1,8] | 56.8 | 52.3, 61.3 | 21 |
| | Upper Yukon, Circle-Eagle[1,8] | 52.4 | 44.7, 60.1 | 10 |
| | Beaver | 65.1 | 59.7, 70.5 | 3 |
| | Chandalar | 58.3 | 56.5, 60.1 | 34 |
| | Charley | 55.2 | 51.9, 58.5 | 3 |
| | Kandik | 62.0 | -- | 1 |
| | Nation | 60.8 | -- | 2 |
| Upper Yukon River (Canada) | Lower Canadian Yukon[4] | 54.3 | 48.4, 60.2 | 7 |
| | Chandindu | 53.6 | 48.9, 58.3 | 5 |
| | Klondike | 60.1 | 58.1, 62.1 | 19 |
| | Stewart | 55.9 | 54.1, 57.7 | 30 |

Appendix K. -- Continued.

| Region | Stock | Average (km/h) | CI (95%) | N |
|---|---|---|---|---|
| Upper Yukon River (Canada) | White | 58.3 | 56.5, 60.1 | 12 |
| | Mid-Canadian Yukon, White-Tatchun[4] | 47.4 | 44.9, 49.9 | 33 |
| | Pelly | 56.0 | 54.7, 57.3 | 79 |
| | Tatchun | 46.3 | 35.0, 57.6 | 3 |
| | Upper Canadian Yukon, Tatchun-Teslin[4] | 48.7 | 46.7, 50.7 | 34 |
| | Big Creek | 54.9 | -- | 1 |
| | Nordenskiold | 56.5 | 53.3, 59.7 | 8 |
| | Little Salmon | 51.2 | 48.3, 54.1 | 17 |
| | Big Salmon | 53.5 | 52.3, 54.7 | 59 |
| | Teslin | 53.4 | 52.2, 54.6 | 71 |
| | Upper Canadian Yukon, upriver of Teslin[4] | 52.5 | 50.3, 54.7 | 7 |
| | Takhini | 51.2 | 47.2, 55.2 | 6 |
| Porcupine River | Black | 61.1 | -- | 2 |
| | Sheenjek[9] | 61.3 | 58.8, 63.8 | 20 |
| | Canadian reaches | 54.4 | 45.6, 63.2 | 10 |
| | Old Crow River | 55.5 | -- | 2 |
| | Whitestone River | 56.9 | -- | 1 |
| | Miner | 62.1 | 58.4, 65.8 | 14 |

[1] Non-terminal areas and associated tributaries not surveyed.
[2] Section of the Yukon River from Russian Mission to the Yukon-Koyukuk River confluence.
[3] Section of the Yukon River from Galena to the Yukon-Tanana River confluence.
[4] Including fish in mainstem areas and associated tributaries.
[5] Section of the Tanana River from the Yukon-Tanana River confluence to Nenana.
[6] Section of the Tanana River from Nenana to the Tanana-Salcha River confluence.
[7] Section of the Tanana River upriver from the Tanana-Salcha River confluence.
[8] Section of the Yukon River upriver from the Yukon-Tanana River confluence.
[9] Based on fish movements past tracking stations at Rampart Rapids.

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