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by
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ABSTRACT

A radio telemetry study was conducted on Yukon River chinook salmon from 2000 to 2002 to provide information on stock composition and timing, migration patterns, and the location of important spawning areas. Feasibility work in 2000-2001 determined that drift gill nets were effective for capturing adequate numbers of fish in the lower river, and that the fish responded well to the capture and tagging procedures based on their subsequent upriver movements. A large-scale tagging and basin-wide monitoring program was conducted in 2002. Most (751, 97.8%) of the 768 fish tagged resumed upriver movements, with 270 fish harvested in fisheries and 481 fish tracked to upriver areas using remote tracking stations and aerial surveys. Stock composition estimates were developed for the 2002 chinook salmon return based on the distribution of daily releases of radio-tagged fish weighted for abundance and adjusted for fish harvested in fisheries. The chinook salmon run was composed primarily of Tanana River (20.9%) and upper basin (66.0%) stocks. Canadian-origin fish comprised the largest component of the return (53.4%), with most traveling to reaches of the Yukon River (50.7%) and only small numbers to the Porcupine River (2.7%). Canadian fish in the Yukon River returned to large headwater tributaries (35.5%), small tributaries associated with the main river (4.6%) and reaches of the Yukon River main stem (10.6%). Chandalar River and Sheenjek River fish (5.9%) were important U.S. stocks in the upper basin. Tanana River fish were predominantly Chena River, Salcha River, and Goodpaster River stocks (18.8%), 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 (3.1%). Fish returning to lower basin tributaries (6.3%) were

comprised primarily of Anvik River and Nulato River fish (4.8%). The two major stock groups, Canadian Yukon River and Tanana River fish, exhibited similar run timing with most fish passing through the lower river during the early and middle runs, although differences within regions were observed. In Canada, chinook salmon returning to the Klondike, Stewart, and White rivers 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, although other stocks, particularly Canadian Yukon River fish, were also present during this period. Movement rates for radio-tagged fish averaged 51 km/day. Middle and upper basin stocks traveling through reaches of the Yukon River main stem averaged 54-61 km/day, although slower swimming speeds were recorded as the fish approached their natal streams. Movement rates for lower basin stocks were substantially less, averaging from 31 km/day to 37 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 declined dramatically 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 suspended sediments 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 often provide 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 2001 averaged 136,700 fish in the United States and 11,300 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 2002). From 1961 to 1999, commercial fishing accounted for over 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 study was to provide information on the run characteristics of Yukon River chinook salmon returns including stock composition and 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 drainage. 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 deep 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 full-scale tagging and basin-wide monitoring program was conducted in 2002.

MATERIALS AND METHODS

Fish Capture and Handling

Adult chinook salmon returning to the Yukon River basin were captured with drift gill nets at two sites in the lower river near the villages of Marshall and Russian Mission (Fig. 1). These sites were selected because they 1) consisted of relatively narrow, unbraided sections of river, increasing the probability of capturing a representative sample; 2) were downriver of most known chinook salmon spawning areas (i.e., only fish returning to the Andreafsky River, located approximately 190 km downriver, were not included); and 3) were upriver of significant commercial and subsistence fisheries lower in the basin. Local fishers were contracted to fish the sites from early June to mid-July (Table 1), with project personnel handling the fish and collecting data (Appendix A). Nets constructed with different materials (monofilament and seine twine), mesh sizes (16.5 cm, 19.0 cm, and 21.5 cm), hang ratios (2:1 and 3:1), depths (7.6 m and 9.7 m), and lengths (37 m and 46 m) were used and evaluated in 2000-2001 (Spencer et al. 2003). Gill nets used in 2002 were primarily 21.5 cm-mesh size made with No. 21 seine twine, 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. Similar nets, with monofilament fiber instead of seine twine, were used on a limited basis.

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 (Eiler 1995) manufactured by Advanced Telemetry Systems (Isanti, Minnesota). 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 within 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. Based on work during the feasibility phase of the study, transmitters used in 2001 and 2002 were designed with higher output power (i.e., an increase of approximately 15 dB) to increase reception range. 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). Selected fish were tagged with radio-archival tags, which 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 sex, length (mid-eye to fork of tail), and condition of the fish was also recorded. Data on gender were not used in the analysis because of difficulties in distinguishing the sexes in the lower river due to the lack of distinct external characteristics; information from upriver fisheries indicated that the gender of a large portion of the sample (e.g., 48% in 2002) was misidentified. A tissue sample was taken from the axillary process for genetic stock identification analysis, 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 removal of the net from the water to release, took from 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. 2) located at sites throughout the basin (Table 2, Fig. 3). 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, and a 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. 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 National Oceanic and Atmospheric Administration geostationary operational environmental satellite (GOES) and relayed to a receiving station near Washington DC. (Fig. 2). 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. 3), located approximately 42 km upriver from the Russian Mission tagging site, were considered to have resumed upriver movements. 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 further upriver. Many non-terminal areas were turbid and hard to access, making verification of spawning activity difficult. Tracking station coverage was limited during the feasibility phase of the study. In 2000, stations were operated at the Russian Mission tagging site and four upriver locations: the lower Koyukuk River, lower Tanana River, Chena River and Rampart Rapids. In 2001, stations were operated at five locations on the Yukon River main stem: Paimiut, Yukon-Anvik River confluence, Yukon-Yuki River confluence, Rampart Rapids, and the U.S.-Canada border (hereafter referred to as the Yukon Border). Stations were also activated near the mouth of the Anvik, Innoko, Koyukuk, and Tanana rivers, and at the U.S.-Canada border on the Porcupine River (hereafter referred to as the Porcupine Border). The entire tracking system (Table 2, Fig. 3) was operational in 2002. 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 loss of data from unforseen events (e.g., technical problems with equipment, damage from bears and other causes).

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. Limited tracking was also conducted by boat near the tagging site to document movements of radio-tagged fish immediately after release.

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 45 separate stocks (Fig. 4) are considered in the analysis, and the unknown stock proportions of this mixture on day *t* are denoted by $\theta_t = (\theta_{t,1}, \ldots, \theta_{t,45})'$. Final destinations include 41 terminal spawning areas and 4 non-terminal areas (i.e., U.S. reaches of the Yukon River main stem potentially used for spawning or as a travel 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 $r_t = (r_{t,1}, \ldots, r_{t,45})'$. A total of 15 fisheries that harvest fish upriver from the tagging site were defined during the study (Table 3, Fig. 4); 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. 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 the14 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 $C_t = (c_{t1}, \ldots, c_{t,14})'$ 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 $S_f, \quad f = 1, \ldots, 14$.

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. 4). Counts of fish in the escapements and catches from a daily release are assumed to have the multinomial distribution,

$$p(r_{t,1},\ldots,r_{t,45},c_{t,1},\ldots,c_{t,14}) = \left(\frac{R_t\,!}{\prod_{s=1}^{45} r_{t,s}\,! \prod_{f=1}^{14} c_{t,f}\,!} \right) \prod_{s=1}^{45} \left(\theta_{t,s} \cdot \psi_{t,s}\right)^{r_{t,s}} \prod_{f=1}^{14} \left(\mu_{t,f}\right)^{c_{t,f}}$$
$$\sum_{s=1}^{45} \theta_{t,s}\psi_{t,s} + \sum_{f=1}^{14} \mu_{t,f} = 1, \quad t = 1,\ldots,T, \tag{1}$$

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 probabilities to equal 1, is

$$\log L(r,c;\theta_t,\phi_t) = \kappa + \sum_{s=1}^{45} r_{t,s} \log\left(\theta_{t,s} \cdot \psi_{t,s}\right) + \sum_{f=1}^{14} c_{t,f} \log\left(\mu_{t,f}\right) +$$
$$\gamma\left(\sum_{s=1}^{45} \theta_{t,s}\psi_{t,s} + \sum_{f=1}^{14} \mu_{t,f} - 1 \right), \tag{2}$$

where κ is a constant and γ 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

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

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

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 be $E_{.} = \sum_{i=1}^{T} E_i$.

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 λ_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, ...,T*, from Equation 6,

$$\hat{\omega}_{t,s} = \hat{\pi}_t \hat{\theta}_{t,s}, \quad s = 1, \ldots, 45;\ t = 1, \ldots, T. \tag{7}$$

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

$$\hat{\alpha}_s = \sum_{t=1}^{T} \hat{\omega}_{t,s}, \quad s = 1, \ldots, 45. \tag{8}$$

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, π_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,

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

Bootstrap samples of tagged fish in catches and escapements were used to compute the corresponding bootstrap estimates for stock proportions, such as $\hat{\theta}_t^*$, 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. During 2000, 180 hours were fished from 7 June to 13 July and 760 fish were captured; 303 hours were fished in 2001 from 7 June to 20 July and 2,313 fish were caught (Table 5). Catch trends were similar during the two-year feasibility phase of the study, with higher CPUE observed in 2001 (26.8 at Marshall and 45.1 at Russian Mission) than in 2000 (19.0 at Marshall and 13.7 at Russian Mission). Fishing in 2000 included effort in areas not normally fished, as well as in locations known to be productive based on local experience, which would account for the lower CPUE observed. Record levels of debris in 2000 also hindered fishing efforts. Debris was less of a problem in 2001, even though water levels at the capture sites were relatively high during both years of the feasibility phase.

A total of 428 hours were fished from 9 June to 13 July during the 2002 basin-wide study with 1,310 fish captured (Table 5). Catch rates were substantially less, particularly at the Marshall site, possibly due to lower water levels compared to the first two years of the study, which may have adversely affected fishing. Initially, two shifts (day and night) were fished at Marshall and one shift (night) was fished at Russian Mission. A second shift (day) was fished at Russian Mission from 20 June through 13 July to increase catches. The day crew at Marshall was also relocated to Russian Mission from 5 July to 13 July due to poor catch rates at Marshall. Catch rates in 2002 were higher during the first two weeks of tagging (early to mid-June) and declined steadily during the remainder of the run (Fig. 5).

Most fish captured during the study were 6-year-olds, ranging from 60.6% (2000) to 76.6% (2001) of the sample (Table 6). The remaining fish were primarily 5-year-olds, with smaller numbers of 7-year-olds and 4-year-olds. Fish length for chinook salmon captured at Marshall and Russian Mission averaged 783 mm in 2000, 816 mm in 2001, and 819 mm in 2002. (Table 7).

Limited numbers of fish were radio tagged at Russian Mission during the first two years of the study. The primary focus during this phase was to evaluate the response by chinook salmon to the capture and handling procedures. Fifty-three fish were tagged from 11 June to 30 June 2000; 106 fish were tagged from 18 June to 24 June 2001 (Table 8). Most radio-tagged fish were 6-year-olds ranging from 61.4% (2000) to 76.3% (2001) of the sample (Table 6). The remaining fish were primarily 5-year-olds (33.3% in 2000 and 19.8% in 2001), with a small proportion of 4-year-olds

(1.3% in 2001) and 7-year-olds (5.3% in 2000 and 2.6% in 2001). Length for radio-tagged fish averaged 783 mm (ranging from 490 to 1,000 mm) in 2000, and 806 mm (ranging from 555 to 935 mm) in 2001 (Table 7).

A total of 768 chinook salmon were tagged at Marshall and Russian Mission from 9 June to 13 July during the 2002 basin-wide study (Table 8). Six-year-old and 5-year-old fish were again the dominant age groups tagged (63.2% and 21.2%, respectively), with smaller numbers of 7-year-olds (11.5%) and 4-year-olds (4.1%) (Table 6). Radio-tagged fish in 2002 averaged 819 mm in length, ranging from 400 to 1,060 mm (Table 7).

Fish Response to Tagging

Most fish were tracked upriver from the tagging site during the feasibility phase of the study, including 37 (69.8%) fish in 2000 and 103 (97.2%) fish in 2001 (Table 9). Differences observed between the two years were attributed to improvements in the transmitters used during 2001, which significantly increase detection rates, and the installation of additional tracking stations, which provided better coverage of the basin. Results comparable to 2001 were observed during the 2002 basin-wide study when fish were also tagged with the improved transmitters and all stations were operational (Fig. 3); 751 (97.8%) fish moved past the Paimiut stations in 2002 and traveled to upriver reaches or were caught in upriver fisheries (Table 9, Fig. 6). Seventeen fish (2.2%) did not resume upriver movements after tagging, and either regurgitated their tags or died due to handling, predation, or undocumented encounters with fisheries.

Localized tracking within the capture area indicated that most fish held in eddies of the main river (i.e., areas with limited current) for several hours after tagging, although some fish resumed upriver movements immediately after release. Nineteen fish were recorded passing the tracking station at the Russian Mission tagging site in 2000. These fish averaged 0.8 days to resume upriver movements and move out of the immediate area. Radio-tagged fish in 2001 averaged 2.2 days after release to travel past tracking stations at Paimiut (i.e., 42 km upriver from the capture site), an average movement rate of 22.8 km/day (Table 10). In 2002, Russian Mission fish averaged 1.5 days to pass the Paimiut stations, traveling an average of 33.8 km/day, while fish tagged at Marshall took an average of 3.5 days to pass these stations, a movement rate of 45.8 km/day (Table 10).

Fishery Recoveries

Radio-tagged chinook salmon were harvested in fisheries throughout the Yukon River basin (Appendix B), with harvest rates of 22.6% (2000), 26.8% (2001) and 35.2% (2002) of the tagged sample (Table 9). Most of the tagged fish harvested were caught in U.S. fisheries, with 75.0% to 79.3% of the recoveries during the feasibility phase of the study, and 87.0% of the recoveries during the basin-wide study (Table 11). Aerial surveys, flown over villages along the Tanana River and the Yukon River main stem in 2002, documented that 49 of the 270 (18.2%) fish harvested were not reported by fishers.

Relatively small numbers of fish were recovered in fisheries during 2000 (12 fish) and 2001 (29 fish) due to the limited tagging effort during this phase of the study (Table 11). Harvest rates were comparable downriver of the Yukon-Tanana River confluence in 2000 (58.3%) and 2001

(58.7%). Fewer fish were recovered in the Tanana River and the upper basin (i.e., the Yukon River above the Yukon-Tanana River confluence and the Porcupine River). Percentages of tagged fish similar to 2000 and 2001 were caught in U.S. fisheries from Marshall to Holy Cross (23.0%) and from Anvik to Ruby (27.8%) during 2002. However, 86 (31.8%) tagged fish were harvested in the Yukon River from the Yukon-Tanana River confluence to Eagle, roughly a 3-fold increase from 2001 (Table 11). With the exception of the fishery near Eagle, these fish likely comprised both U.S. and Canadian stocks. Fish caught near Eagle were assumed to be destined for spawning areas in Canada. Twelve (4.4%) fish were harvested in the Tanana River. Thirty-five (13.0%) fish were recovered in the Canadian portion of the basin (Table 11). Thirty-four of these fish were destined for Yukon River spawning areas, with most of recoveries from Dawson, Carmacks, and the Pelly River. One fish was recovered in the Porcupine River near the village of Old Crow.

Distribution of Radio-Tagged Fish

Feasibility Phase 2000-2001

Minimal information was obtained on chinook salmon distribution during the feasibility phase of the study due to both the limited tagging effort (Table 8) and partial tracking station coverage (5 sites in 2000 and 10 sites in 2001). Thirty fish moved upstream in 2000 and were subsequently recorded by upriver tracking stations or caught in terminal fisheries (i.e., harvested after reaching their final destination). Seventeen (56.7%) fish returned to the Tanana River and 13 (43.3%) fish returned to the upper basin (Table 12). At least six of these fish traveled to Canadian reaches, based on information from fishery recoveries and run assessment projects in Canada, including five Yukon River fish and one Porcupine River fish. No fish passed the tracking stations on the Koyukuk River (Table 12).

Eighty-one fish moved upriver in 2001 and were subsequently recorded by tracking stations or harvested in terminal fisheries (Table 12). Eight (9.9%) fish remained in the lower basin (i.e., the Yukon River and associated tributaries downstream from the Yukon-Koyukuk River confluence), including three (3.7%) fish tracked to the Anvik River. No fish passed the Innoko River station. Three (3.7%) fish traveled to the Koyukuk River and nine (11.1%) fish were tracked to reaches of the Yukon River between Galena and the Yukon-Tanana River confluence (hereafter referred to as the middle Yukon River). Twenty-three (28.4%) fish traveled to the Tanana River, including three fish caught in the Tanana River fishery. Nine (11.1%) fish were tracked to U.S. reaches of the upper basin, while 29 (35.8%) fish returned to Canada, including 6 fish caught in the Canadian fishery (Table 12).

Basin-wide Study 2002

Radio-tagged chinook salmon traveled to areas throughout the Yukon River basin in 2002 (Fig. 7). Upper basin fish comprised the largest component of the sample, with 291 (55.0%) fish returning to the upper Yukon and Porcupine rivers (Table 12, Fig. 8). A substantial number of these fish traveled to Canadian reaches, including 215 (40.6%) Yukon River fish and 9 (1.7%) Porcupine River fish. Most (136, 25.7%) Canadian fish were tracked to tributaries of the Yukon River main stem (Appendix C), including the Stewart (21, 4.0%), Pelly (32, 6.0%), Big Salmon (17, 3.2%), and

Teslin (36, 6.8%) rivers (Appendix D). Small numbers of fish were also located in Coal Creek (1, 0.2%), Chandindu River (1, 0.2%), Klondike River (6, 1.1%), White River (8, 1.5%), Tatchun Creek (4, 0.8%), Nordenskiold River (2, 0.4%), Little Salmon River (2, 0.4%), and in areas above the Yukon-Teslin River confluence (7, 1.3%). Fifty-five (10.4%) fish remained in reaches of the Yukon River main stem or traveled to associated tributaries not monitored by tracking stations or surveyed by aircraft (Appendix C). Little information is available on chinook salmon movements in the Canadian portion of the Porcupine River, although two radio-tagged fish were located in lower reaches of the Miner River during cursory aerial surveys of the area.

Sixty-seven (12.7%) fish were tracked to the U.S. portion of the upper basin, including 50 (9.5%) Yukon River fish and 17 (3.2%) Porcupine River fish (Table 12). Twenty-three (4.3%) fish in the upper Yukon River were tracked to tributaries (Fig. 8). Most of these fish returned to the Chandalar River (19, 3.6%), although small numbers were located in Beaver Creek (1, 0.2%) and the Charley (2, 0.4%) and Kandik (1, 0.2%) rivers (Appendix D). Twenty-seven (5.1%) 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. 8), including 24 (4.5%) fish downriver from Circle and 3 (0.6%) fish upriver from Circle. Most Porcupine River fish returned to the Sheenjek River (12, 2.2%), while two (0.4%) fish were tracked to upper reaches of the Black River and three (0.6%) remained in the Porcupine River main stem or associated tributaries (Appendix D).

Tanana River fish comprised a major component of the sample, with 118 (22.3%) fish returning to this section of the basin. Most (19.5%) Tanana River fish traveled to tributaries in the upper reaches of the drainage (Appendix C), including the Chena (30, 5.7%), Salcha (47, 8.9%), and Goodpaster (16, 3.0%) rivers (Appendix D). Fish were also located in the Kantishna (8, 1.5%) and

Tolovana (2, 0.4%) rivers. Six (1.1%) fish remained in reaches of the Tanana River main stem or traveled to associated tributaries not surveyed, including one fish located in the upper reaches of the drainage (i.e., upriver of the confluence with the Salcha River). Nine (1.7%) fish were recovered in Tanana River fisheries; most (7, 1.3%) were caught near Nenana (Appendix B).

Sixty-nine (13.0%) fish traveled to tributaries in the lower basin (Fig. 8). Anvik River (34, 6.4%) and Nulato River (20, 3.8%) fish were most prevalent, with smaller numbers of fish traveling to the Innoko (5, 0.9%) and Bonasila (10, 1.9%) rivers (Appendix D). Nine (1.7) fish returned to tributaries associated with the middle Yukon River (Fig. 8), including the Melozitna (1, 0.2%), Nowitna (1, 0.2%), and Tozitna (7, 1.3%) rivers (Appendix D). Eleven (2.1%) fish returned to the Koyukuk River (Table 12, Fig. 8), including four (0.8%) Gisasa River fish, one (0.2%) Kateel River fish, and six (1.1%) fish that traveled to the upper reaches of the drainage (Appendix D). Thirty-one (5.9%) fish were last recorded in non-terminal reaches of the Yukon River main stem, including 22 (4.2%) fish in the lower basin and 9 (1.7%) fish in the middle Yukon River (Appendix C). 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 2002 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 (20.9%) and upper basin (66.0%) stocks (Table 13). Canadian fish comprised the largest component of the return (53.4%), with the majority (50.7%)

traveling to reaches of the Yukon River and only a small percentage (2.7%) traveling to the Porcupine River (Fig. 9). Most Canadian fish (40.1%) returned to tributaries of the Yukon River main stem, primarily the Stewart (7.2%), Pelly (9.2%), Big Salmon (5.2%), and Teslin (9.9%) rivers (Fig. 10). Smaller stocks included the Klondike (1.5%), White (4.0%), Tatchun (0.7%), Nordenskiold (0.7%), and Little Salmon (0.2%) rivers and reaches upriver of the Yukon-Teslin River confluence (1.5%) (Appendix E). Canadian fish also remained in reaches of the Yukon River main stem and small associated tributaries (10.6%), including 1.8% downriver from Dawson (i.e., the lower Canadian Yukon River, including fish in Coal Creek and the Chandindu River), 3.9% between Dawson and the Yukon-Tatchun Creek confluence (i.e., the mid-Canadian Yukon River), and 4.9% upriver of the Yukon-Tatchun Creek confluence (i.e., the upper Canadian Yukon River).

Chinook salmon stocks returning to U.S. reaches comprised a substantial proportion (46.6%) of the 2002 run, including 20.9% that were Tanana River fish and 12.6% that were upper basin fish (Table 13, Fig. 9). Fish returning to the Chena (5.2%), Salcha (10.8%), and Goodpaster (2.8%) rivers were the dominant Tanana River stocks (Fig. 11). Tanana River fish also returned to the Kantishna (1.1%) and Tolovana (0.4%) rivers (Appendix E). A small proportion of the return (0.6%) remained in reaches of the Tanana River main stem or traveled to small associated tributaries not surveyed during the study. Upper basin fish traveled to reaches in both the Yukon (9.1%) and Porcupine (3.5%) rivers (Fig. 9). Spawning populations were documented in Yukon River tributaries including Beaver Creek (0.1%), and the Chandalar (3.4%), Charley (0.3%) and Kandik (0.6%) rivers (Fig. 11). Fish also remained in reaches of the Yukon River main stem or small associated tributaries not surveyed during the study (4.6%), including 4.3% downriver from Circle and 0.3% between Circle and Eagle. Most (2.5%) Porcupine River fish returned to the Sheenjek River (Fig. 11). Porcupine

River fish also spawned in upper reaches of the Black River (0.4%), and remained in the Porcupine River main stem or traveled to associated tributaries not surveyed during the study (0.6%). Although no tracking surveys were conducted, spawning chinook salmon were observed by local residents 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 6.3% of the run returned to tributaries in the lower basin (Fig. 9), including the Innoko (0.7%), Bonasila (0.9%), Anvik (2.9%), and Nulato (1.9%) rivers (Fig. 11). Middle Yukon River tributaries comprised 1.6% of the return, with most fish traveling to the Tozitna River (1.2%), 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 (3.7%), with most of these in the lower basin (2.9%). Relatively small numbers of chinook salmon returned to the Koyukuk River (1.5%), with fish traveling to the Gisasa River (0.3%), Kateel River (0.1%), and upper reaches of the drainage (1.1%) (Fig. 11).

Regional differences in run timing were observed for chinook salmon stocks passing through the lower Yukon River. Canadian Yukon River and Tanana River stocks were present throughout the return, but were most abundant early in the run (Fig. 12). A similar pattern was observed for fish returning to tributaries in U.S. reaches of the upper Yukon River, with these stocks prevalent primarily during early and mid-June. Porcupine River stocks in both the United States and Canada were also early and mid-run fish. Koyukuk and middle Yukon River tributary fish were present in small numbers throughout the return. Fish allocated to non-terminal areas in the Yukon River exhibited a similar pattern. Although present throughout the run, fish traveling to lower basin tributaries were more abundant during late June and July (Fig. 12).

Run timing differences were also observed within regions of the basin. Chinook salmon stocks returning to lower Canadian reaches, including the Klondike, Stewart, and White rivers, were primarily early run fish, while the timing of fish returning to the Pelly, Big Salmon, and Teslin rivers was more protracted (Fig. 13). Fish remaining in middle and upper reaches of the Canadian main stem and associated tributaries, including Tatchun Creek, Nordenskiold River, and headwaters areas upriver of Hootalinqua, also exhibited a protracted and somewhat later run timing. Stocks returning to U.S. reaches of the upper basin were primarily early run fish. Most Chandalar and Sheenjek fish passed through the lower river in mid-June (Fig. 14). In the Tanana River, Salcha River chinook salmon were primarily early run fish, although this stock was present throughout the run. The timing of Chena River and Goodpaster River fish was somewhat later. Koyukuk River fish were present throughout the run, with upper headwater stocks observed during the early and late run, and Gisasa River fish present during the middle run. The timing for Anvik River and Nulato River fish, the dominant stocks in the lower basin, was later than that exhibited by middle and upper basin fish (Fig. 14).

Differences were also observed in the daily composition of stocks moving through the lower river (Appendix F). Canadian stocks were predominant throughout the run (Fig. 15), comprising an average of 48.8% 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 56.8% and 40.2% during the first and last half of the run, respectively. Although less abundant than Canadian stocks, Tanana River fish (17.6% daily average) exhibited a similar pattern with daily averages of

23.6% and 11.2% during the first and last half of the run, respectively. Fish returning to tributaries in U.S. reaches of the upper basin also tended to enter the river during the early and middle run. In contrast, fish returning to tributaries in the lower basin were more prevalent later in the run. Although relatively minor in terms of overall abundance (Fig. 9, Table 13), these stocks comprised a substantial portion of the late run with daily composition averaging 25.5% compared to an average of 5.4% during early and mid-June. A similar pattern was observed for fish remaining in non-terminal area, with low daily averages throughout most of the run, and higher levels in July.

Stock composition estimates derived for 2002 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. 16). The greatest difference was observed for Yukon River fish in Canada, with estimates ranging from 50.7% of the return when non-terminal fish were categorized as spawning populations to 56.7% of the return when these fish were considered in-transit to spawning areas farther upriver.

Movement Patterns

Information on chinook movements during the feasibility phase of the study was limited to regional comparisons due to partial tracking station coverage. Radio-tagged fish traveled an average of 51.3 km/day in 2000, ranging from 51.0 km/day for Tanana River fish to 53.3 km/day for upper basin fish (Table 14). The fastest migration rate recorded was 66.8 km/day for a 7-year-old fish returning to the Tanana River. Similar movement patterns were observed in 2001, with radio-tagged fish averaging 51.1 km/day. Tanana River fish traveled an average of 52.4 km/day compared to 52.8 km/day and 54.2 km/day for upper basin fish in the United States and Canada, respectively (Table 14). Small numbers of fish were tracked to lower and middle reaches of the basin. Fish returning to the Koyukuk River averaged 49.2 km/day, while fish tracked to reaches associated with the middle Yukon River traveled an average of 47.7 km/day. In the lower basin, Anvik River fish averaged 14.0 km/day (Table 14). The fastest movement rate recorded in 2001 was 69.5 km/day for a 6-year-old fish returning to the Tanana River.

Complete tracking station coverage in 2002 provided movement information for specific chinook salmon stocks. Upper basin fish traveled an average of 54.2 km/day. Fish returning to the Yukon River in Canada averaged 53.1 km/day, ranging from 49.3 km/day for fish traveling to reaches of the Yukon River main stem to 58.9 km/day for Klondike River fish (Table 15). Similar rates were observed for stocks traveling to U.S. reaches in the upper Yukon River, with averages of 58.6 km/day for tributary fish and 54.1 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 traveled substantially faster than Yukon River fish, averaging 60.4 km/day for U.S. stocks and 63.3 km/day for Canadian stocks (Table 15). Tanana River fish exhibited slower migration rates (47.7 km/day), with Chena River, Salcha River, and Goodpaster River fish ranging from 45.3 km/day to 49.7 km/day, while fish remaining in mainstem areas or associated tributaries not monitored during the study averaged 55.6 km/day. Tributary fish returning to the middle Yukon River averaged 54.8 km/day; the same rate observed for non-terminal fish within this section of the basin. In the Koyukuk River, Gisasa River fish averaged 43.0 km/day, compared to 57.9 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 31.3 km/day, ranging from 21.6 km/day for Innoko River fish to 42.0 km/day for Bonasila River fish (Table 15, Appendix G).

Migration rates recorded for Chena River, Salcha River, and Goodpaster River fish were substantially slower than rates for 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 reflected 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 55.8 km/day and 59.1 km/day (Table 16), movement rates comparable to upper basin fish. A similar phenomenon was observed for other stocks, including Gisasa River fish and fish traveling to Canadian reaches of the Yukon River main stem. 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 often located a substantial distance from areas used for spawning. The average movement rates for fish passing these stations were comparable to rates observed lower in the basin. For example, Stewart River fish averaged 56.8

km/day between tracking stations at Paimiut and the Stewart River (located approximately 20 km from the Yukon-Stewart River confluence), compared to 57.5 km/day for these fish between Paimiut and the Yukon border. A breakdown of the movements for fish traveling between areas of the basin shows a similar pattern, with Tanana River tributary stocks having comparable movement rates to upper basin fish while traveling through reaches of the Yukon River main stem, but exhibiting slower rates after entering the Tanana River and approaching their natal streams (Fig. 17).

DISCUSSION

Management of Yukon River chinook salmon is 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. Results from this study demonstrate that large, basin-wide telemetry studies are feasible and provide useful information. Drift gill nets were effective in capturing adequate numbers of fish in the lower river in suitable condition for tagging, and the number of fish radio tagged in 2002 (i.e., the first year of large-scale tagging) was sufficient to analyze and compare different components of the run. Although problems tracking fish in the lower river were initially encountered during the feasibility phase of the study (Eiler and Holder In press), improved transmitters and receiving equipment developed to address limitations in depth and range reception were used successfully to track chinook salmon movements during their upriver migration. The system of satellite-linked tracking stations, in combination with the automated database and mapping program, was able to collect and summarize telemetry data in-season, making it possible to prioritize field activities and address management issues within the basin. Although technically feasible, large-scale, basin-wide telemetry studies are extremely challenging. The success of this study was largely due to the cooperation of numerous resource agencies and organizations, an adequate feasibility phase to establish suitable procedures and the necessary infrastructure, sufficient funding to support the various components of the project and to address unforeseen technical and logistical problems, and the personal dedication of the participants often working under less than ideal conditions.

A primary assumption in tagging studies is that capture, handling, 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 negligible impact. Chinook salmon radio tagged during this study appeared to respond well to the procedures used, with most resuming upriver movements after release. This was particularly true in 2001 and 2002 when more than 97% of the tagged fish traveled to upriver areas or were recovered in upriver fisheries. The proportion of fish not moving upriver after release (< 3%) is lower than reported for most radio-tagging studies (Burger et al. 1985, Milligan et al. 1985, Johnson et al. 1992). The percentage of fish located upriver in 2000 (70%) was substantially less, although this was probably due to incomplete tracking station coverage within the basin and the use of telemetry equipment less suited for Yukon River studies (i.e., prior to development of improved transmitters and receiving equipment used during 2001 and 2002).

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 study did not exhibit this pattern, with upper basin fish traveling an average of 54 km/day throughout their upriver migration. Untagged chinook salmon in the Yukon River are thought to travel between 48 km/day and 56 km/day based on estimated arrival times of distinct pulses of fish 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 this study. Information from previous tagging studies also suggests that handling had negligible effect. 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), rates comparable to upper basin fish tagged during the 2002 study (54 km/day) even though these latter individuals traveled substantially greater distances after tagging. By comparison, radio-tagged chinook salmon in the Columbia River traveled between 43 km/day and 65 km/day through dam reservoirs in the lower basin (i.e., slow moving water with minimal current), and about half that rate in free-flowing rivers in the upper basin (Bjornn et al. 2000).

A common response observed in tagging studies is for fish to hold in localized areas or drift with the current immediately after release prior to resuming normal patterns of movement. Limited boat tracking near Russian Mission determined that some radio-tagged fish exhibited this behavior, restricting their movements and holding in eddies of the main river for several hours after release presumably to recover from tagging. The initial response (i.e., the movement rate between the tagging site and the Paimiut tracking stations) exhibited by fish tagged at Russian Mission also indicates that the fish experienced a delay or slower swimming speeds immediately after release (Table 10). However, movement rates increased substantially after passing Paimiut (Table 15) suggesting that any adverse effect was limited. The initial response of fish tagged at Marshall also supports this interpretation. These fish exhibited faster movement rates between their tagging site and Paimiut (a distance of about 150 km), suggesting that they had recovered from tagging and were swimming at a more typical rate as they moved farther upriver. Migration rates calculated for chinook salmon stocks (Table 15) were based on the movements of radio-tagged fish upriver from Paimiut to avoid including tagging-induced behavior that would bias the results and not reflect typical movements.

Chinook salmon returning to the Yukon River in 2002 were primarily Tanana River and upper basin stocks, comprising approximately 87% of the return. Telemetry information from 2000-2001 suggests a similar pattern, although these data are not based on representative sampling. Canadian fish were the dominant component in the upper basin, with most (35.5% of the return) traveling to large headwater tributaries, including the Stewart, White, Pelly, Big Salmon, and Teslin rivers. Smaller tributaries also supported spawning populations (4.6% of the return). Substantial numbers of fish remained in Canadian reaches of the Yukon River main stem (10.6% of the return), although turbid conditions made it impossible to verify spawning activity; this component may also include fish spawning in small associated tributaries not surveyed during the study. Chinook salmon spawning has been previously reported in Canadian reaches of the Yukon River main stem (Milligan et al. 1985), suggesting that these fish may represent spawning populations. Small numbers of fish also returned to Canadian reaches in the Porcupine River (2.7%).

United States stocks were also an important component of the Yukon River chinook salmon return. Similar to the Canadian component, these fish were composed of a combination of major and minor stocks. Chinook salmon returning to the Tanana River (20.9% of the return) were predominantly Chena River, Salcha River, and Goodpaster River fish (18.8% of the return), although minor spawning populations were also documented in the Kantishna, Tolovana, and Nenana rivers. Although spawning has been reported for chinook salmon in U.S. reaches of the upper basin, these populations were previously thought to be insignificant. However, this stock group comprised about 8% of the 2002 return, with Chandalar River and Sheenjek River fish as the primary components (5.9% of the run). Minor stocks were identified in small mainstem tributaries, and fish also remained in non-terminal areas.

Stocks associated with the middle Yukon River were a minor component of the run compared to other regions of the basin. The small middle river tributaries (i.e., the Melozitna, Nowitna, and Tozitna rivers) comprised only 1.6% of the run combined. Although the Koyukuk River drains a large watershed, the percentage of fish returning to this tributary was comparable (1.5%). Lower basin tributary fish were also a relatively minor component of the run, comprising 6.3% of the return. Chinook salmon returning to this region were predominantly Anvik River and Nulato River fish (4.8% of the return), with small numbers of fish traveling to other areas.

Country of origin estimates, based on information from the 2002 telemetry study, indicate that Canadian stocks comprised approximately 53% of the Yukon River return, with most of these fish traveling to the Canadian portion of the Yukon River (50.7%) and a relatively minor component to the Porcupine River. These proportions are 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 2002 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 2002 telemetry study are credible.

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 early and middle run and declining in magnitude during the late run. (Fig. 12). However, differences in run timing were also observed within regions. For example, Stewart River and White River stocks were primarily early run fish, moving through the lower river in early June, while other Canadian stocks, such as the Pelly River, Big Salmon River, and Yukon River main stem, displayed a more protracted run timing that extended into the late run. Lower basin stocks were comprised primarily of late run fish. However, in general, most stocks were not temporally distinct, making it difficult to separate stocks based on run timing.

Run timing and daily stock composition estimates for chinook salmon further illustrated the predominance of Tanana River and upper basin stocks. Canadian fish were the most abundant stock group moving through the lower river during the early and middle run. Although less abundant, Tanana River fish were also a prominent component during this period. Lower basin fish were prominent later in the run, but the Canadian contribution during this period was comparable. A similar pattern occurred when comparing daily stock composition at the Russian Mission tagging site (Fig. 15). Canadian fish were the most prevalent stock group throughout the early and middle run, and were comparable in number or slightly less abundant than lower basin fish late in the run. Tanana River fish displayed a similar pattern to Canadian fish, while fish returning to U.S. tributaries in the upper basin were present primarily during the early and middle run.

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. Stock composition estimates suggest that about 8% of the 2002 return remained in non-terminal areas, including 2.9% in the lower basin, 0.8% in the middle basin, and 4.6% in the upper basin. Stock composition estimates derived for the return assumed that fish in non-terminal areas were spawning in mainstem reaches or small associated tributaries not surveyed during the study due to personnel and funding limitations. 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. Mainstem spawning has been reported for chinook salmon in the Canadian portion of the Yukon River. 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 have 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 (18.2%) of unreported recoveries in 2002. There is ancillary 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, and 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 9), the relatively fast, sustained movement rates observed (Table 15), 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 disease *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 disease 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, relatively few fish (0.5% of the return) remained in reaches of the Tanana River main stem, and several of these were located in likely spawning areas. Tanana River fish may not have been affected by the disease until after reaching their terminal spawning areas, and additional monitoring of fish in these areas may provide additional insights regarding potential impacts. Similarly, mortality due to the disease doesn't address the concentration of non-terminal fish in the lower basin or the general absence of non-terminal fish in the middle basin, although it has been shown that the severity of the disease increases as the fish move farther upriver (Kocan and Hershberger 1999). Another explanation is that non-terminal fish result from a combination of factors, including fish that spawn in associated areas not monitored during the study, or that died while in-transit to spawning areas farther upriver due to undocumented encounters with fisheries, disease, or handling mortality.

Stock composition estimates for the 2002 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. However, estimates that assume all non-terminal fish were in-transit would potentially overestimate upper river stocks. Composition estimates derived for 2002 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 50.7% to 56.7% of the Yukon River return; these proportions are consistent with other estimates reported for the basin.

Migration rates exhibited by different stocks of Yukon River chinook salmon were remarkably similar. Upper basin fish traveling through sections of the Yukon River main stem averaged between 56 km/day and 61 km/day (Table 15). Similar migratory patterns were observed for middle basin fish (54 km/day to 58 km/day). These rates are noteworthy considering the distances traveled by the fish, with stocks returning to the uppermost Canadian headwaters traveling more than 2,300 km prior to reaching spawning areas. Lower basin fish exhibited substantially lower rates than middle and upper basin fish. The slower movements may be associated with the shorter distances these fish are traveling, and 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 they approached their spawning tributaries (Fig. 17). Milligan et al. (1985) reported migration rates of 36 km/day for chinook salmon radio-tagged above the Yukon Border in 1982-83, 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, or tracking methods.

In conclusion, the basin-wide telemetry study was successful in obtaining new information on the distribution, timing, and movement patterns of Yukon River chinook salmon. Adequate numbers of fish were captured, tagged, and tracked to upriver reaches, making it possible to identify and compare the principle components of the return. Stock composition and run timing estimates derived from these data provide a detailed look at the temporal and spatial dynamics of the 2002 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 the disease *Ichthyophonus* on chinook salmon returns. Infrastructure provided by this study, particularly the system of remote tracking stations, has also made it possible to obtain information on other fish species within the basin, including inconnu (*Stenodus leucichthys*) and whitefish (*Coregonus* spp.). Although the study has spanned a 3-year period, large-scale tagging was only conducted in 2002 due to the need to develop the techniques and infrastructure essential for a project of this size and scope. The information presented only provides an initial look at the stock composition and timing of the Yukon River returns. Additional information is needed to further address questions related to study findings and annual variation, particularly in relation to run characteristics during years with greater abundance.

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Table 1. -- Fishing schedule for capturing chinook salmon with drift gill nets in the lower Yukon River near the villages of Marshall and Russian Mission during 2000-2002.

Capture Week	2000	2001	2002
23	7-10 June	7-9 June	
24	11-17 June	10-16 June	9-15 June
25	18-24 June	17-23 June	16-22 June
26	25 June - 1 July	24-30 June	23-29 June
27	2-8 July	1-7 July	30 June - 6 July
28	9-13 July	8-14 July	7-13 July
29		15-20 July	

Table 2. Location of remote tracking stations used to monitor the movements of radio-tagged chinook salmon in the Yukon River. Distances from Paimiut, located 42 km upriver from the Russian Mission tagging site, 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
Upper Yukon River (U.S.)[6]	Rampart Rapids[3,4]	811	292
	Chandalar	1,231	420

Table 2. – Continued.

		Distance Traveled (km)	
Region	Tracking Station	From Paimiut	From Previous Station[1]
Upper Yukon River (U.S.)[6]	Circle[4]	1,401	590
Upper Yukon River (Canada)	Yukon Border[3,4]	1,704	303
	Stewart	1,901	197
	Yukon-White[4]	1,904	200
	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
Porcupine River (Canada)	Porcupine Border[3,4]	1,573	123
	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 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	Porcupine River Fishery, Canada
L	Yukon River near Circle	ADFG District 5d
M	Yukon River near Eagle	ADFG District 5d
M	Yukon River from the Border to Dawson	Yukon River Fishery, Canada
N	Yukon River from Dawson to Carmacks	Yukon River Fishery, Canada
O	Yukon River from Carmacks to Whitehorse	Yukon River Fishery, Canada

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	$\hat{\theta}_{t,4} = r_{t,4} \Big/ \left[R_t - \dfrac{C_{t,1}}{1 - \sum_{s=1}^{3} \hat{\theta}_{t,s}} \right] = r_{t,4} / D_{t,2}$
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	$\hat{\theta}_{t,10} = r_{t,10} \big/ D_{t,2}$
Melozitna	11	$\hat{\theta}_{t,11} = \dfrac{r_{t,11}}{R_t - \dfrac{C_{t,1}}{1-\sum_{s=1}^{3}\hat{\theta}_{t,s}} - \dfrac{C_{t,2}}{1-\sum_{s=1}^{10}\hat{\theta}_{t,s}}} = r_{t,11} \big/ D_{t,3}$
Nowitna	12	$\hat{\theta}_{t,12} = r_{t,12} \big/ D_{t,3}$
Tozitna	13	$\hat{\theta}_{t,13} = \dfrac{r_{t,13}}{R_t - \dfrac{C_{t,1}}{1-\sum_{s=1}^{3}\hat{\theta}_{t,s}} - \dfrac{C_{t,2}}{1-\sum_{s=1}^{10}\hat{\theta}_{t,x}} - \dfrac{C_{t,3}}{1-\sum_{s=1}^{12}\hat{\theta}_{t,x}}} = r_{t,13} \Big/ \left[D_{t,3} - \dfrac{C_{t,3}}{1-\sum_{s=1}^{12}\hat{\theta}_{t,x}} \right] = r_{t,13} \big/ D_{t,4}$
Mid-Yukon	14	$\hat{\theta}_{t,14} = r_{t,14} \big/ D_{t.4}$
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	$\hat{\theta}_{t,19} = r_{t,19} \Big/ \left[D_{t,6} - \frac{C_{t,6}}{\sum_{s=15}^{22} \hat{\theta}_{t,s} - \sum_{s=15}^{18} \hat{\theta}_{t,s}} \right] = r_{t,18} / D_{t,7}$
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	23-45	$\sum_{s=23}^{45} \hat{\theta}_{t,s}^{(d)} = \left[\sum_{f=7}^{14} C_{t,f}^{(d)} + \sum_{s=23}^{45} r_{t,s}^{(d)} \right] \Big/ D_{t,4}^{(d)}$

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	26-29	$\sum_{s=26}^{29}\hat{\theta}_{t,s} = \dfrac{\sum_{s=26}^{29} r_{t,s} + \sum_{f=9}^{10} C_{t,f}}{D_{t,8} - \dfrac{C_{t,8}}{1-\sum_{s=1}^{25}\hat{\theta}_{t,s}}} = \left[\sum_{s=26}^{29} r_{t,s} + \sum_{f=9}^{10} C_{t,f}\right] / D_{t,9}$
Black	26	$\hat{\theta}_{t,26} = \dfrac{r_{t,26}}{D_{t,9} - \dfrac{C_{t.9}}{\sum_{s=26}^{29}\hat{\theta}_{t,s}}} = r_{t,26} / D_{t.10}$
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	$\hat{\theta}_{t,29} = \dfrac{r_{t,29} + C_{t,10}}{D_{t,10}}$
Upper Yukon above Porcupine	30-45	$\sum_{s=30}^{45} \hat{\theta}_{t,s} = \left[\sum_{f=11}^{14} C_{t,f} + \sum_{s=30}^{45} r_{t,s} \right] \Big/ D_{t,9}$
Upper Yukon (Circle)	30	$\hat{\theta}_{t,30} = \dfrac{r_{t,30}}{D_{t,9} - \dfrac{C_{t,11}}{\sum_{s=30}^{45} \hat{\theta}_{t,s}}} = r_{t,30} / D_{t,11}$
Charley	31	$\hat{\theta}_{t,31} = r_{t,31} / D_{t,11}$
Kandik	32	$\hat{\theta}_{t,32} = r_{t,32} / D_{t,11}$
Lower Canadian Yukon	33	$\hat{\theta}_{t,33} = \dfrac{r_{t,33}}{D_{t,11} - \dfrac{C_{t,12}}{\sum_{s=30}^{45} \hat{\theta}_{t,s} - \sum_{s=30}^{32} \hat{\theta}_{t,s}}} = r_{t,33} / D_{t,12}$
Klondike	34	$\hat{\theta}_{t,34} = r_{t,34} / D_{t,12}$
Stewart	35	$\hat{\theta}_{t,35} = r_{t,35} / D_{t,12}$
White	36	$\hat{\theta}_{t,36} = r_{t,36} / D_{t,12}$
Pelly	37	$\hat{\theta}_{t,37} = r_{t,37} / D_{t,12}$

Table 4. -- Continued.

Stock Name	Stock Index	Estimates of Stock Proportions
Mid-Canadian Yukon	38	$\hat{\theta}_{t,38} = r_{t,38} / D_{t,12}$
Tatchun	39	$\hat{\theta}_{t,39} = \dfrac{r_{t,39}}{D_{t,12} - \dfrac{C_{t,13}}{\sum_{s=30}^{45} \hat{\theta}_{t,s} - \sum_{s=30}^{38} \hat{\theta}_{t,s}}} = r_{t,39} / D_{t,13}$
Upper Canadian Yukon	40	$\hat{\theta}_{t,40} = \dfrac{r_{t,40}}{D_{t,13} - \dfrac{C_{t,14}}{\sum_{s=30}^{45} \hat{\theta}_{t,s} - \sum_{s=30}^{39} \hat{\theta}_{t,s}}} = r_{t,40} / D_{t,14}$
Nordenskiold	41	$\hat{\theta}_{t,41} = r_{t,41} / D_{t,14}$
Little Salmon	42	$\hat{\theta}_{t,42} = r_{t,42} / D_{t,14}$
Big Salmon	43	$\hat{\theta}_{t,43} = r_{t,43} / D_{t,14}$
Teslin	44	$\hat{\theta}_{t,44} = r_{t,44} / D_{t,14}$
Hootalinqua	45	$\hat{\theta}_{t,45} = r_{t,45} / D_{t,14}$

Table 5. -- Chinook salmon captured with drift gill nets in the lower Yukon River near the villages of Marshall and Russian Mission during 2000-2002.

Year	Marshall	Russian Mission	Combined
2000	431	329	760
2001	1,294	1,019	2,313
2002	539	771	1,310

Table 6. -- Age composition of chinook salmon captured with drift gill nets and radio tagged near the villages of Marshall and Russian Mission during 2000-2002. Sample size differences between the total number of fish captured (Table 5) and age composition data due to missing or unusable scale samples.

			Age in Years (%)			
Year	Fish Status	N	4	5	6	7
2000	Captured	660	1.4	30.3	60.6	7.7
	Captured and Radio Tagged	53	--	33.3	61.4	5.3
2001	Captured	1,736	1.3	15.4	76.6	6.7
	Captured and Radio Tagged	76	1.3	19.8	76.3	2.6
2002	Captured	708	4.1	21.2	62.8	11.9
	Captured and Radio Tagged	704	4.1	21.2	63.2	11.5

Table 7. -- Lengths (mm) of chinook salmon captured with drift gill nets and radio tagged near the villages of Marshall and Russian Mission during 2000-2002. Sample size differences between total number of fish captured (Table 5) and length data due to missing records.

			Length (mid-eye to fork of tail)	
Year	Fish Status	N	Average	Range
2000	Captured	737	783	470-1,010
	Captured and Radio Tagged	53	783	490-1,000
2001	Captured	2,033	816	440-1,040
	Captured and Radio Tagged	106	806	555-935
2002	Captured	773	819	400-1,060
	Captured and Radio Tagged	768	819	400-1,060

Table 8. -- Weekly and total numbers of chinook salmon captured and radio tagged in the lower Yukon River near the villages of Marshall and Russian Mission during 2000-2002.

	2000	2001	2002		
Capture Week[1]	Russian Mission	Russian Mission	Marshall[2]	Russian Mission	Combined
23					
24	11		46	81	127
25	14	89	85	128	213
26	28	17	93	129	222
27			33	77	110
28			22	74	96
Total	53	106	279	489	768

[1] Actual dates listed in Table 1.

[2] Timing information adjusted to be compatible with fish passage at Russian Mission.

Table 9. -- Tracking results for chinook salmon radio tagged in the lower Yukon River near the villages of Marshall and Russian Mission during 2000-2002. Percentages of the total are in parentheses.

Final Status	2000	2001	2002
Moved Upriver	37 (69.8)	103 (97.2)	751 (97.8)
Upriver Location*	25 (47.2)	74 (70.4)	481 (62.6)
Harvested in Fishery	12 (22.6)	29 (26.8)	270 (35.2)
Not Located Upriver	16 (30.2)	3 (2.8)	17 (2.2)
Total	53	106	768

* Fish recorded upriver from the tagging site and not caught in fisheries.

Table 10. -- Elapsed time and movement rates (km/day) for radio-tagged chinook salmon traveling between tagging sites in the lower Yukon River and the Paimiut tracking stations in 2001 and 2002.

						95% Confidence Interval	
Year	Tagging Site	N[1]	Distance[2]	Days ($\bar{x}$)	Rate	Lower	Upper
2001	Russian Mission	78	42 km	2.2	22.8	20.7	24.9
2002	Russian Mission	364	42 km	1.5	33.8	32.5	35.1
2002	Marshall	195	150 km	3.5	45.8	42.6	49.0

[1] Not including radio-tagged fish not recorded passing the Paimiut tracking stations

[2] General distance from the tagging site; distance used to calculate movement rate based on the actual location where the fish were tagged and released.

Table 11. -- Harvests of radio-tagged chinook salmon in the Yukon River basin during 2000-2002. Percentages of the total are in parentheses.

Fishing Area		2000	2001	2002
District 3	Marshall to Holy Cross	3 (25.0)	9 (31.1)	62 (23.0)
District 4	Anvik to Ruby	4 (33.3)	8 (27.6)	75 (27.8)
District 5	Yukon-Tanana confluence to Eagle		3 (10.3)	86 (31.8)
District 6	Tanana River	2 (16.8)	3 (10.3)	12 (4.4)
Combined U.S.	Marshall to Eagle	9 (75.0)	23 (79.3)	235 (87.0)
Canada	Yukon River, Border to Dawson	1 (8.3)	2 (6.9)	15 (5.6)
Canada	Yukon River, upriver of Dawson	1 (8.3)	4 (13.8)	19 (7.0)
Canada	Porcupine River, Old Crow	1 (8.3)		1 (0.4)
Combined Canada	Yukon and Porcupine Rivers	3 (25.0)	6 (20.7)	35 (13.0)
Total		12	29	270

Table 12. -- Regional distribution of chinook salmon radio tagged in the lower Yukon River during 2000-2002. Fish harvested in terminal reaches of the basin are included. Portions of the drainage not monitored due to the partial deployment of tracking stations in 2000 and 2001 are designated (--) . Percentages of the total are in parentheses.

Region	2000	2001	2002
Lower Basin[1]	--	8 (9.9)	91 (17.2)
Koyukuk River		3 (3.7)	11 (2.1)
Middle Yukon River[2]	--	9 (11.1)	18 (3.4)
Tanana River	17 (56.7)[3]	23 (28.4)[3]	118 (22.3)[3]
Upper Yukon River (U.S.)[4]	7 (23.3)	9 (11.1)	50 (9.5)
Upper Yukon River (Canada)	5 (16.7)[3]	29 (35.8)	215 (40.6)[3]
Porcupine River (U.S.)	--	--	17 (3.2)
Porcupine River (Canada)	1 (3.3)[3]		9 (1.7)[3]
Total	30	81	529

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

[2] Section of the Yukon River from Galena to the Yukon-Tanana River confluence and associated tributaries.

[3] Including fishery recoveries.

[4] Section of the Yukon River from the Yukon-Tanana River confluence to Eagle and associated tributaries.

Table 13. -- Stock composition estimates of the Yukon River chinook salmon return in 2002 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 1,000 bootstrappings are included.

Region	Stock Group	Estimate (%)	SE	95% CI
Lower Basin[1]	Lower Yukon[2]	2.9	0.8	(1.6, 4.5)
	Lower Basin Tributaries	6.3	0.8	(4.7, 8.0)
Koyukuk River	Gisasa	0.3	0.2	(0.1, 0.6)
	Upper Koyukuk	1.2	0.5	(0.3, 2.3)
Middle Yukon River[3]	Mid-Yukon[2]	0.8	0.3	(0.3, 1.5)
	Mid-Yukon Tributaries	1.6	0.5	(0.7, 2.8)
Tanana River	Tanana[4]	2.1	0.6	(1.1, 3.3)
	Chena	5.2	1.0	(3.4, 7.4)
	Salcha	10.8	1.7	(7.6, 14.2)
	Goodpaster	2.8	0.8	(1.5, 4.6)
Upper Yukon River (U.S.)[5]	Upper Yukon[2]	4.6	1.0	(2.8, 6.6)
	Upper Yukon Tributaries	4.5	1.1	(2.6, 7.1)
Upper Yukon River (Canada)	Lower Canadian Yukon[4]	3.4	1.0	(1.7, 5.6)
	Stewart	7.2	1.5	(4.2, 10.3)
	Mid-Upper Can. Yukon[4]	15.8	2.4	(11.5,20.6)
	Pelly	9.2	1.7	(6.2, 12.5)
	Big Salmon	5.2	1.2	(2.9, 7.7)
	Teslin	9.9	2.2	(6.0, 14.3)

Table 13. -- Continued.

Region	Stock Group	Estimate (%)	SE	95% CI
Porcupine River	U.S. Porcupine	3.6	0.9	(1.9, 5.6)
	Canadian Porcupine	2.7	1.0	(1.0, 4.8)

[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 mainstem areas and associated tributaries.

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

Table 14. -- Movement rates (km/day) of chinook salmon radio tagged in the lower Yukon River during 2000-2001 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. Sections of the drainage not monitored due to partial deployment of the tracking station system are designated (--).

	2000			2001		
Region	Average	95% CI	N	Average	95% CI	N
Anvik River	--	--	--	14.0	4.4	3
Koyukuk River				49.2		2
Lower Basin-Mid Yukon River[1]	--	--	--	47.7	5.2	8
Tanana River	51.0	3.8	17	52.4	4.0	24
Upper Basin (U.S.)[2]	53.3	4.4	13	52.8	3.3	11
Upper Basin (Canada)	--	--	--	54.2	2.2	29
Total	51.3	2.9	30	51.1	2.4	77

[1] Fish last located by tracking stations on the Yukon River main stem downriver from the Yukon-Tanana River confluence.

[2] Section of the Yukon River upstream from Rampart Rapids.

Table 15. -- Movement rates (km/day) of chinook salmon radio tagged in the lower Yukon River during 2002 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]	37.2	10.2	11
	Lower Basin Tributaries	31.3	3.3	64
Koyukuk River	Gisasa	43.0	3.3	4
	Upper Koyukuk	57.9	12.8	7
Middle Yukon River[3]	Mid-Yukon[2]	54.8	11.3	8
	Mid-Basin Tributaries	54.8	6.8	8
Tanana River	Tanana[4]	55.6	8.2	6
	Chena	49.7	2.4	30
	Salcha	45.3	1.8	47
	Goodpaster	45.6	2.5	16
Upper Yukon River (U.S.)[5]	Upper Yukon[2]	54.1	5.5	27
	Upper Yukon Tributaries	58.6	1.7	38
Upper Yukon River (Canada)	Lower Canadian Yukon[4]	57.9	6.6	8
	Klondike	58.9	7.5	6
	Stewart	56.8	2.2	21
	White	58.7	2.8	8
	Mid-Upper Can. Yukon[4]	49.3	1.0	62
	Pelly	54.6	2.4	32
	Big Salmon	52.5	2.4	17
	Teslin	52.9	1.9	36

Table 15. -- Continued.

Region	Stock Group	Average	95% CI	N
Porcupine River	U.S. Porcupine	60.4	2.5	16
	Canadian Porcupine	63.3	4.6	8

[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.

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

Table 16. -- Comparison of movement rates (km/day) of chinook salmon traveling to tributaries in the Yukon River basin during 2002 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, and between Paimiut and the farthest upriver station are presented.

	Paimiut to First Regional Station[1]			Paimiut to Terminal Station[2]		
Stock	Location	Average	CI	Location	Average	CI
Nulato	Yukon-Anvik	47.4	6.5	Nulato River	35.5	5.1
Gisasa	Lower Koyukuk	51.7	12.8	Gisasa River	43.0	3.3
Upper Koyukuk	Lower Koyukuk	58.4	5.2	Mid-Koyukuk	58.2	12.6
Mid Basin Tribs[3]	Yukon-Yuki	54.3	7.5	Tributary mouth	54.8	6.8
Chena River	Lower Tanana	58.7	2.4	Chena	49.7	2.4
Salcha River	Lower Tanana	55.8	2.0	Salcha	45.3	1.8
Goodpaster	Lower Tanana	59.1	3.8	Upper Tanana	45.6	2.5
Up. Yukon U.S.[4]	Rampart Rapids	60.7	2.3	Tributary mouth	58.6	1.7
Up. Yukon Can.[5]	Yukon Border	55.8	1.0	Tributary mouth	54.4	1.0

[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] Including the Melozitna, Nowitna and Tozitna rivers.

[4] Including Chandalar, Sheenjek, and Black rivers.

[5] Including the Stewart, Pelly, Big Salmon, and Teslin rivers.

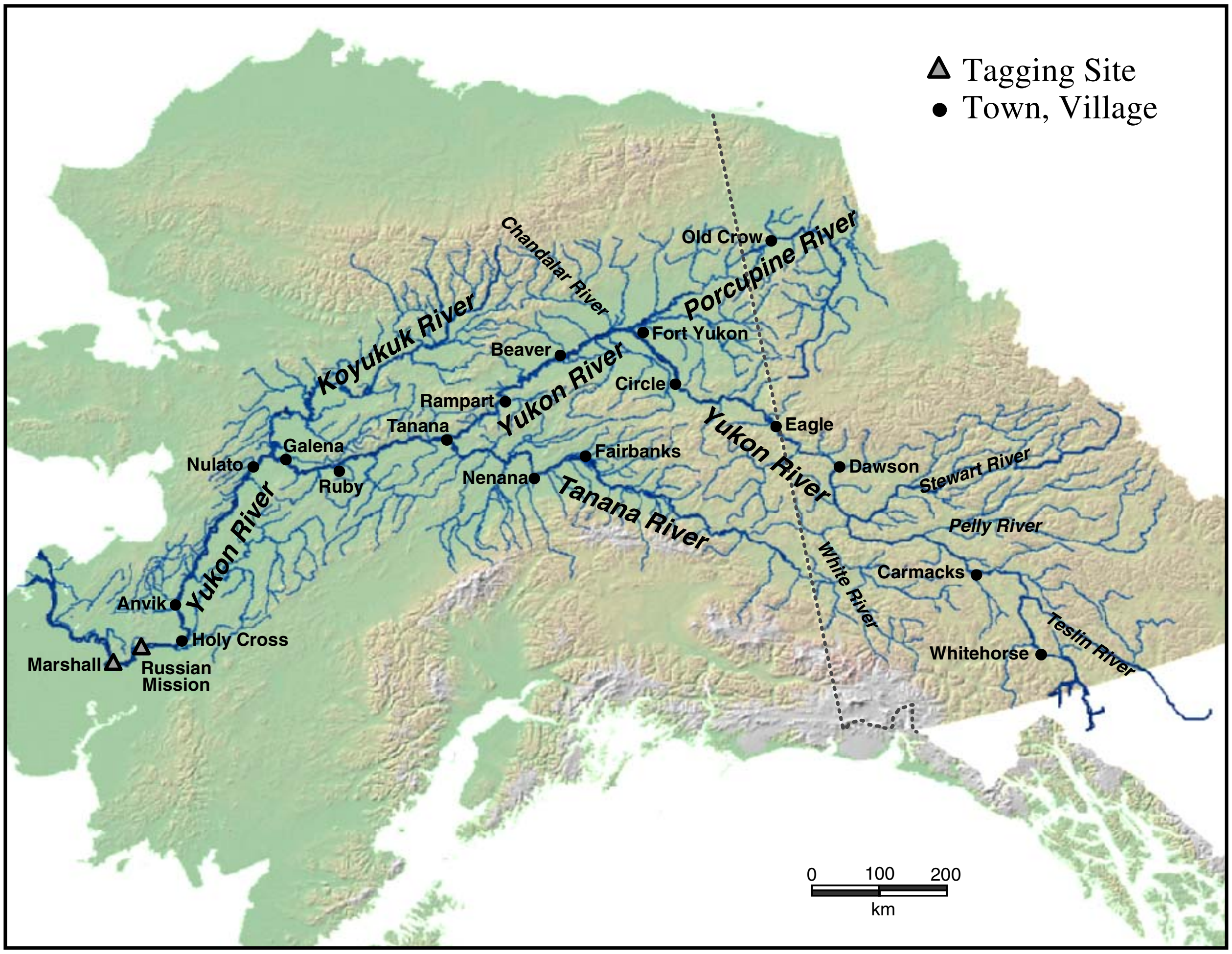

Figure 1. -- Map of the Yukon River basin showing the Yukon River main stem and major tributaries of the drainage, as well as the tagging sites, and selected towns and villages.

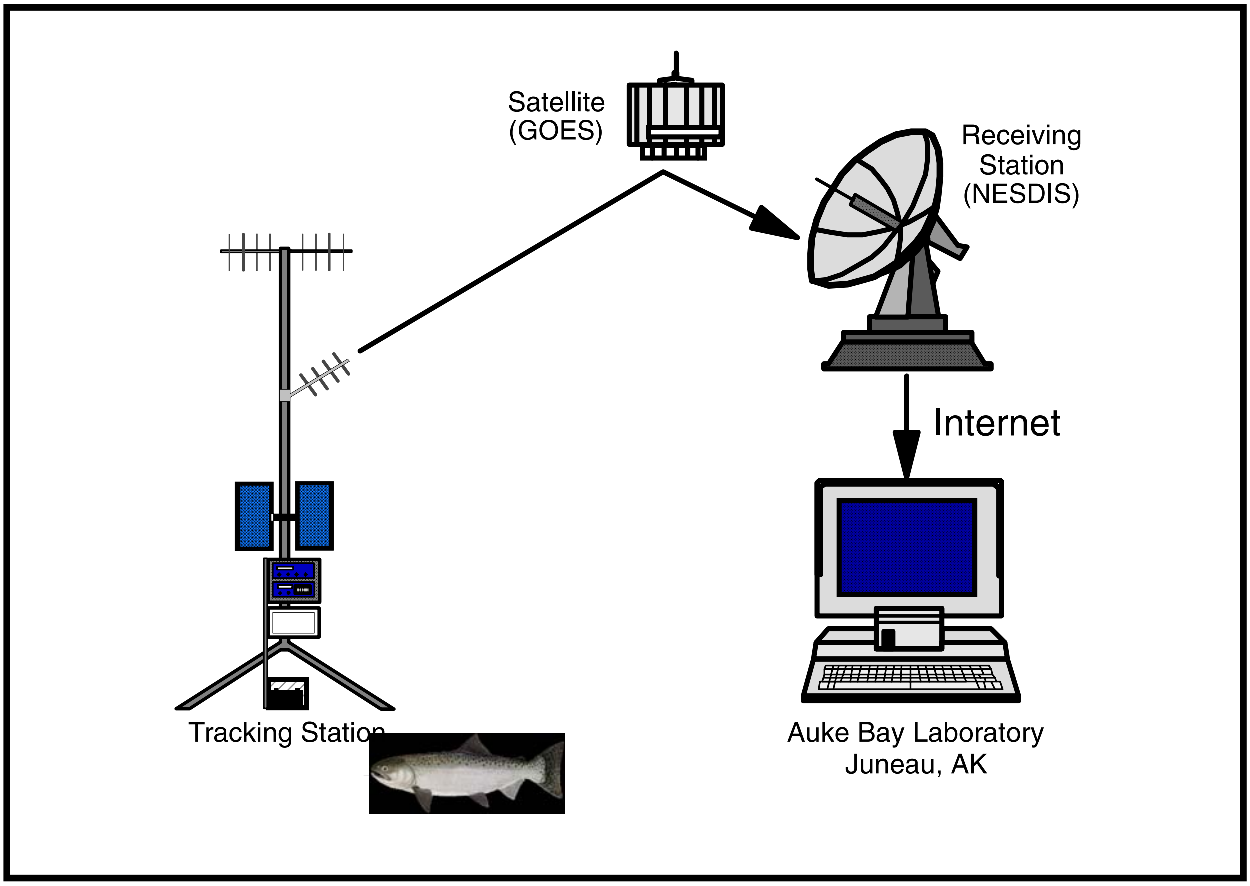

Figure 2. -- Remote tracking station and satellite uplink used to collect and access movement information of chinook salmon in the Yukon River basin. Radio-tagged fish passing the station are recorded; the information is transferred via satellite to a receiving station and downloaded for in-season analysis.

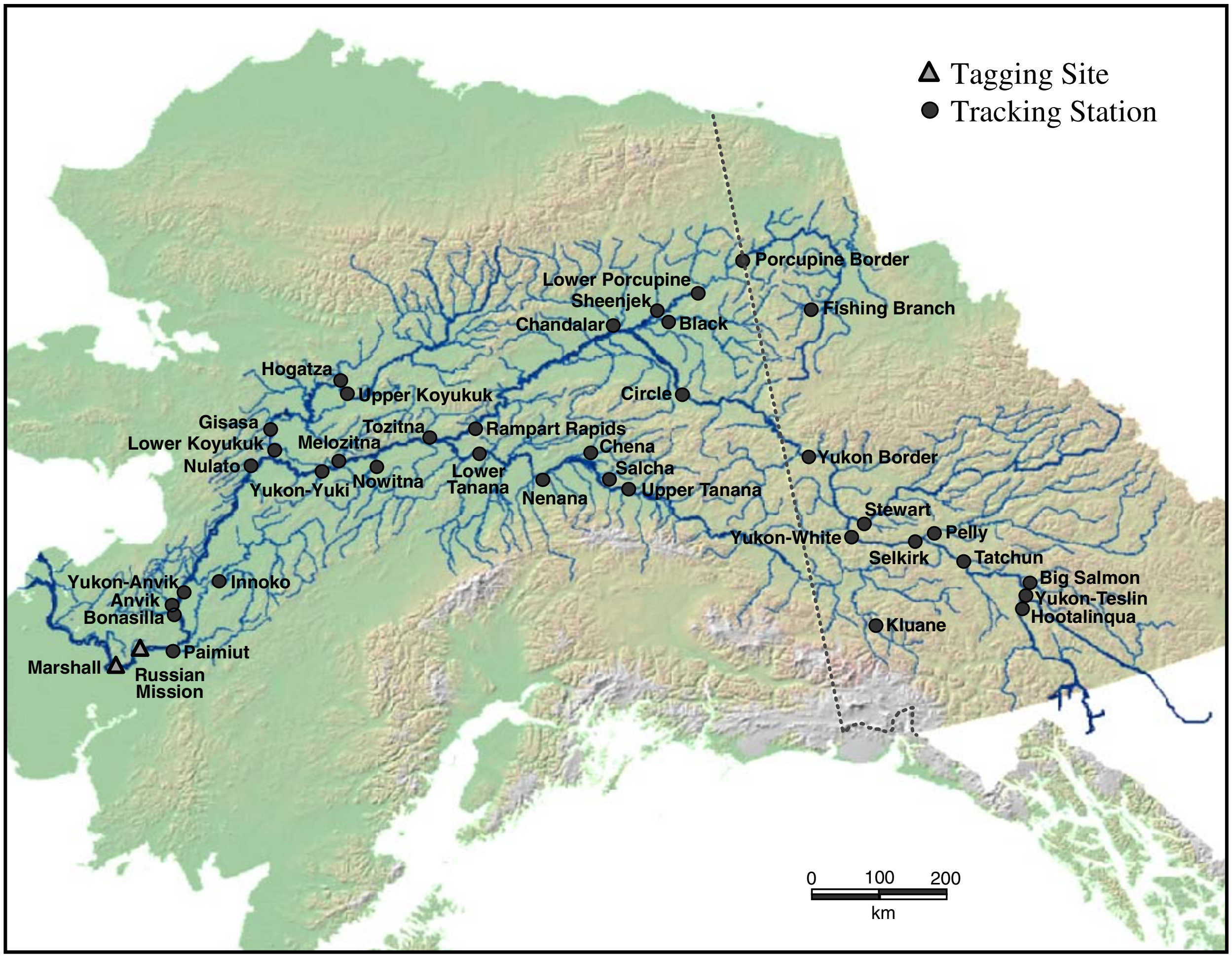

Figure 3. -- Map of the Yukon River basin showing the location of remote tracking stations used to track the upriver movements of radio-tagged chinook salmon.

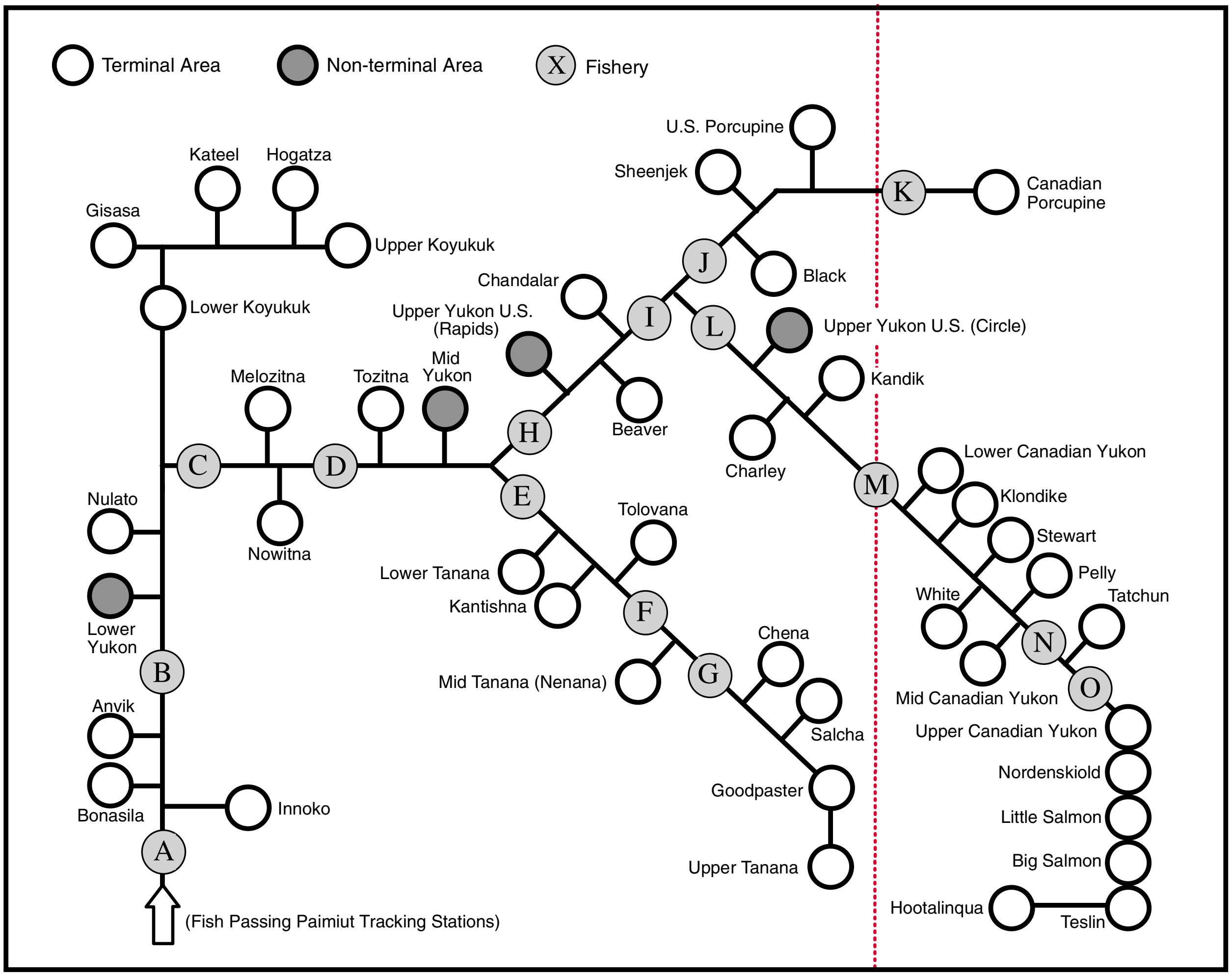

Figure 4. -- Migration model for calculating stock composition estimates of chinook salmon returns in the Yukon River basin based on the distribution of radio-tagged fish. Spatial relationships of the fisheries and component stocks are indicated. Additional information on the fisheries, labeled as A through O, is contained in Table 3.

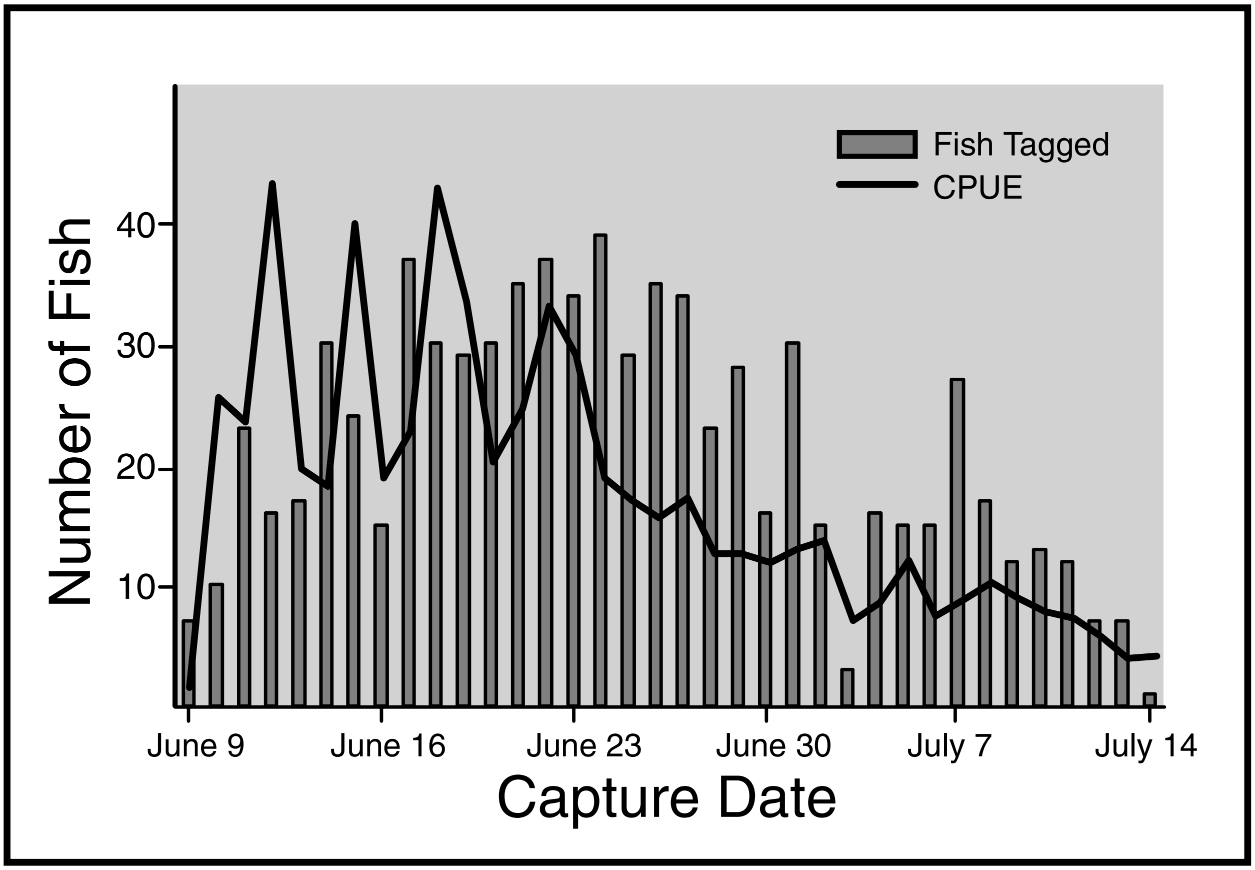

Figure 5. -- Number of chinook salmon radio tagged per day in the lower Yukon River and daily catch per unit effort (CPUE) information for chinook salmon captured at the Russian Mission tagging site during 2002.

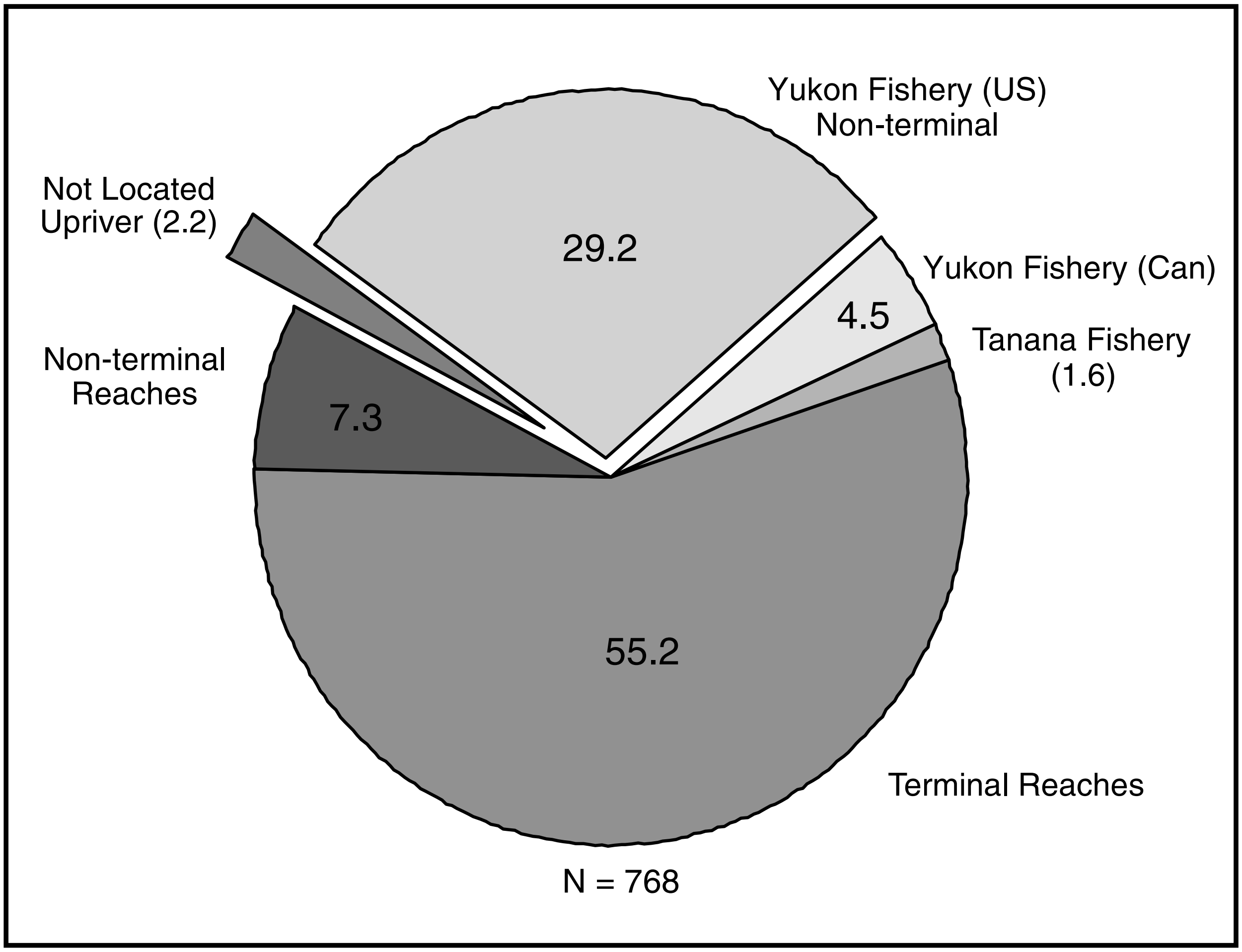

Figure 6. -- Final status of chinook salmon radio tagged in the lower Yukon River near the villages of Marshall and Russian Mission during 2002. Percentages of the total number of fish tagged are indicated.

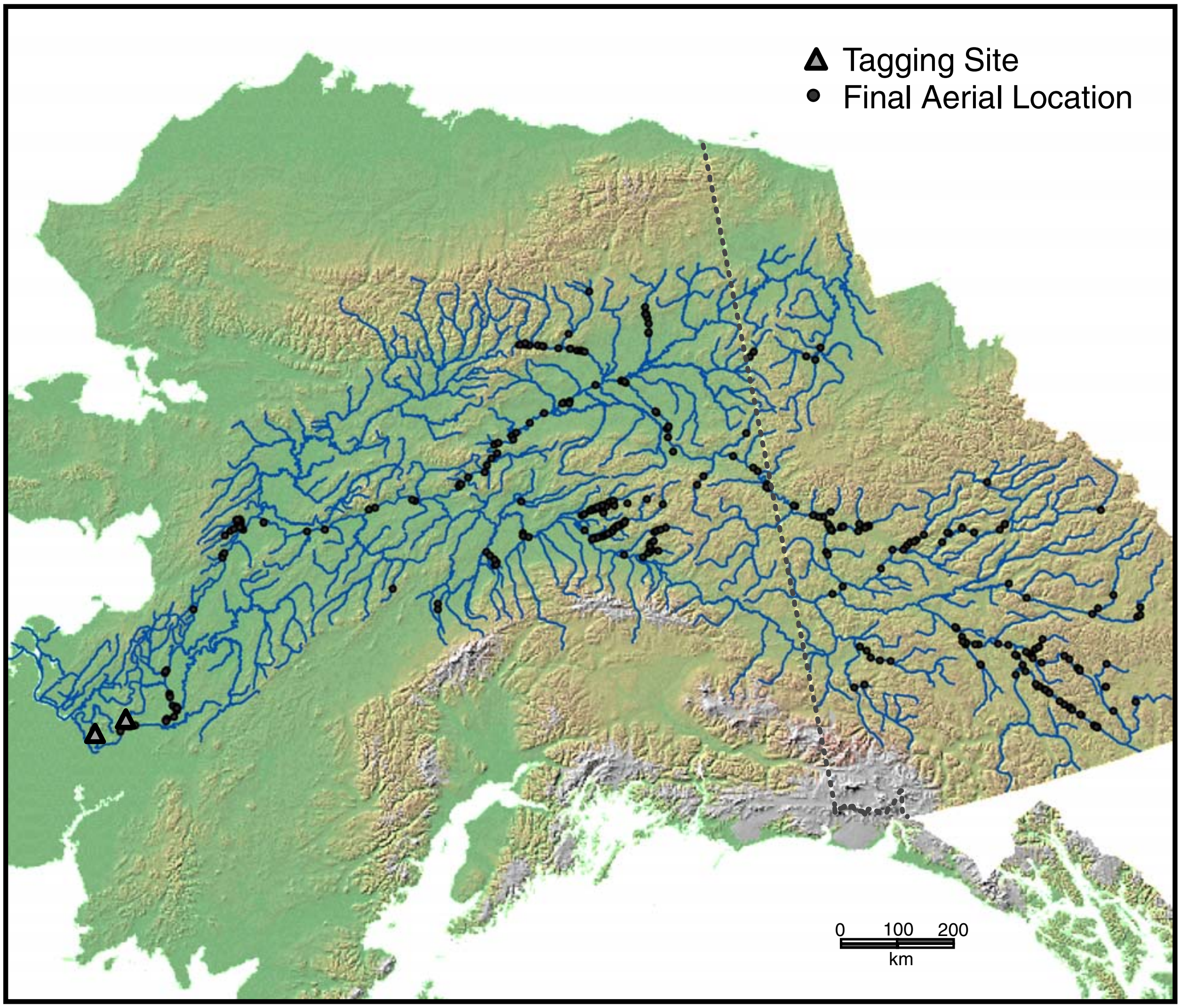

Figure 7. -- Final locations of chinook salmon radio tagged in the lower Yukon River and tracked upriver during their spawning migration based on aerial tracking surveys in 2002.

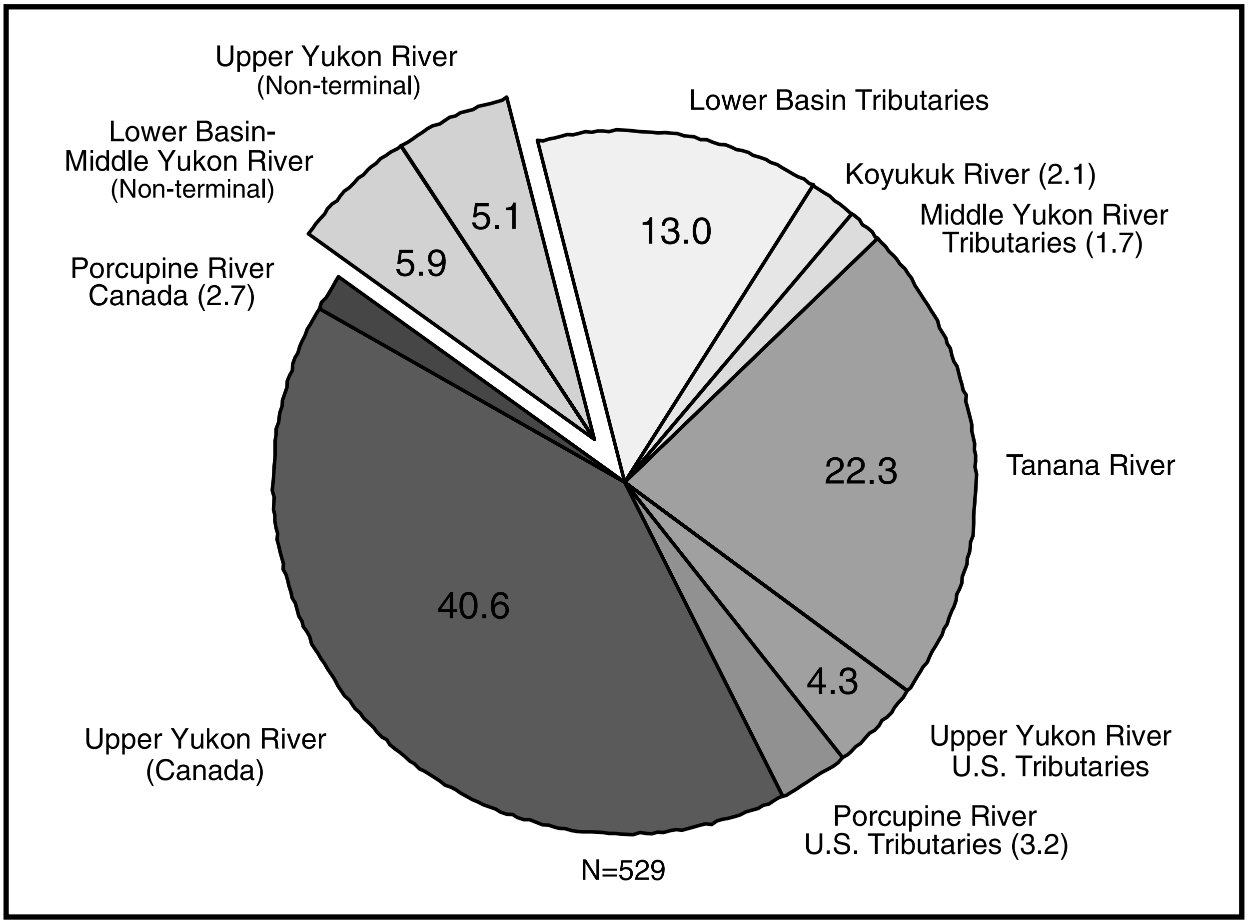

Figure 8. -- Distribution of chinook salmon radio tagged in the lower Yukon River near the villages of Marshall and Russian Mission during 2002 . Percentage of the total number of fish that moved upriver and were not caught in non-terminal fisheries are indicated.

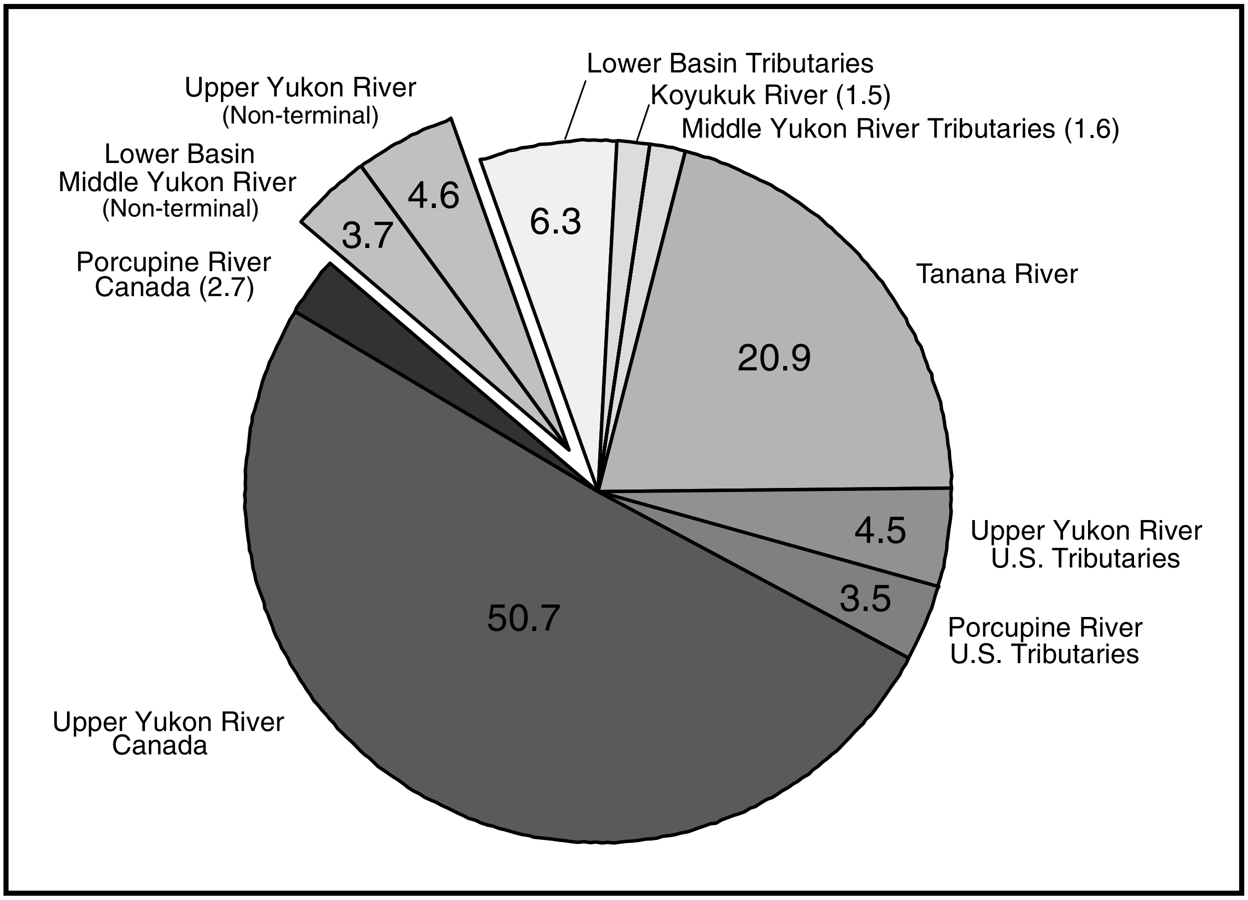

Figure 9. -- Stock composition estimates of the Yukon River chinook salmon return in 2002 based on the distribution of radio-tagged fish (Fig. 8) weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Percentages of the return are indicated.

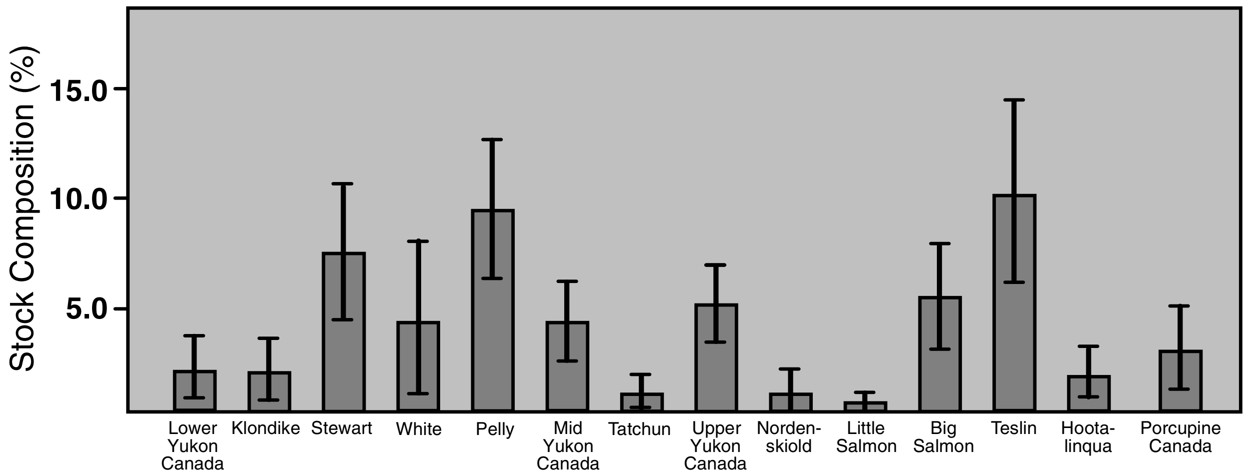

Figure 10. -- Composition of chinook salmon stocks returning to Canadian reaches of the Yukon River basin in 2002, based on the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Composition estimates and 95% confidence intervals are provided.

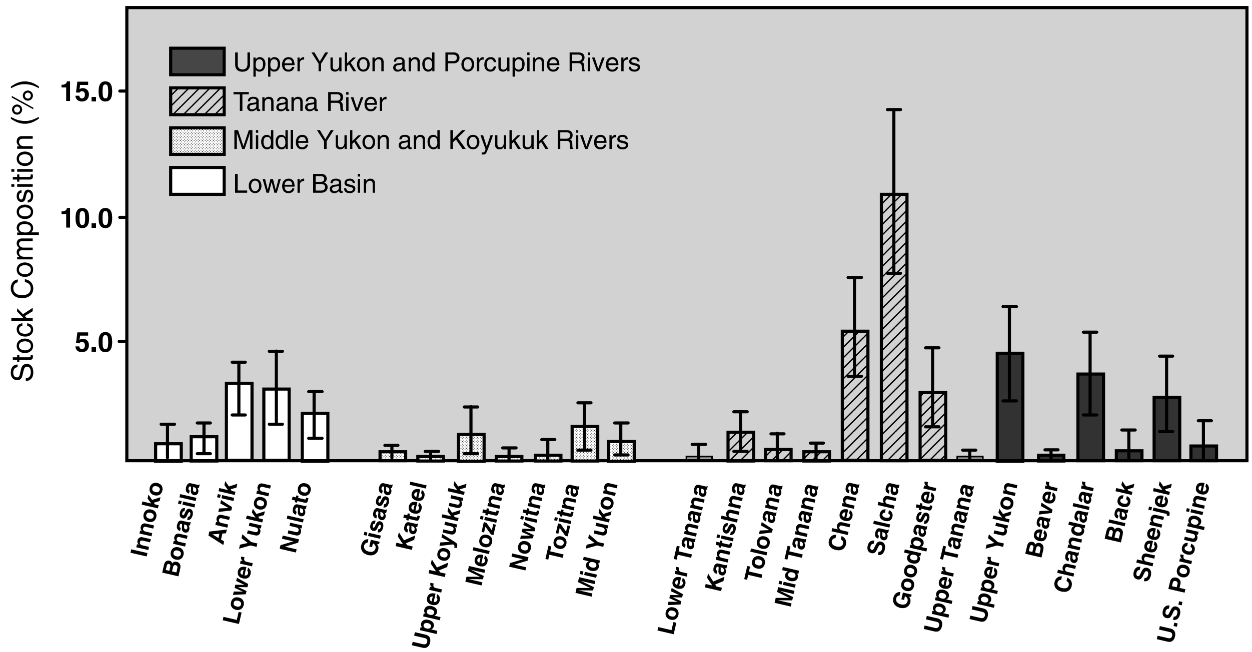

Figure 11. -- Composition of chinook salmon stocks returning to U.S. reaches of the Yukon River basin in 2002, based on the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. Composition estimates and 95% confidence intervals are provided.

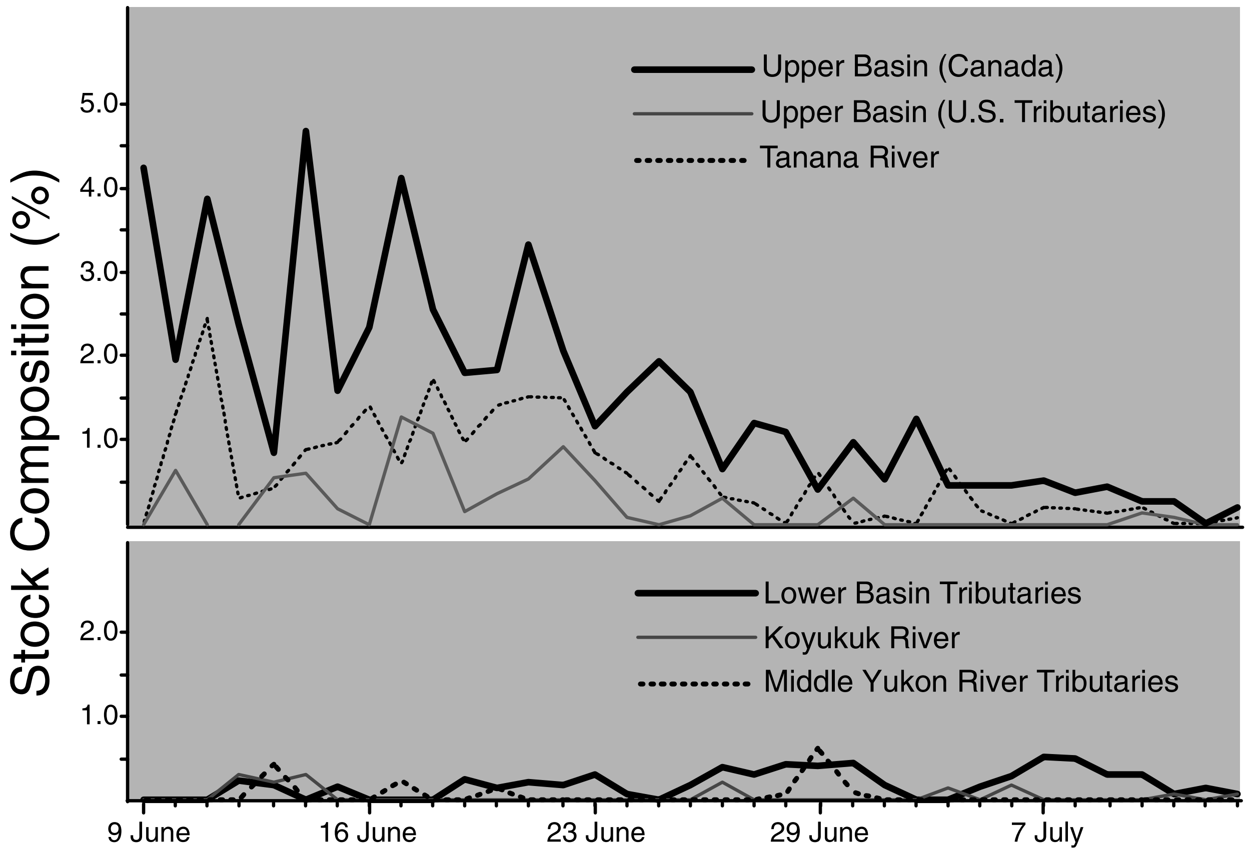

Figure 12. -- Run timing of Yukon River chinook salmon stock groups returning to terminal reaches of the basin in 2002, based on composition estimates for the entire return derived from the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries.

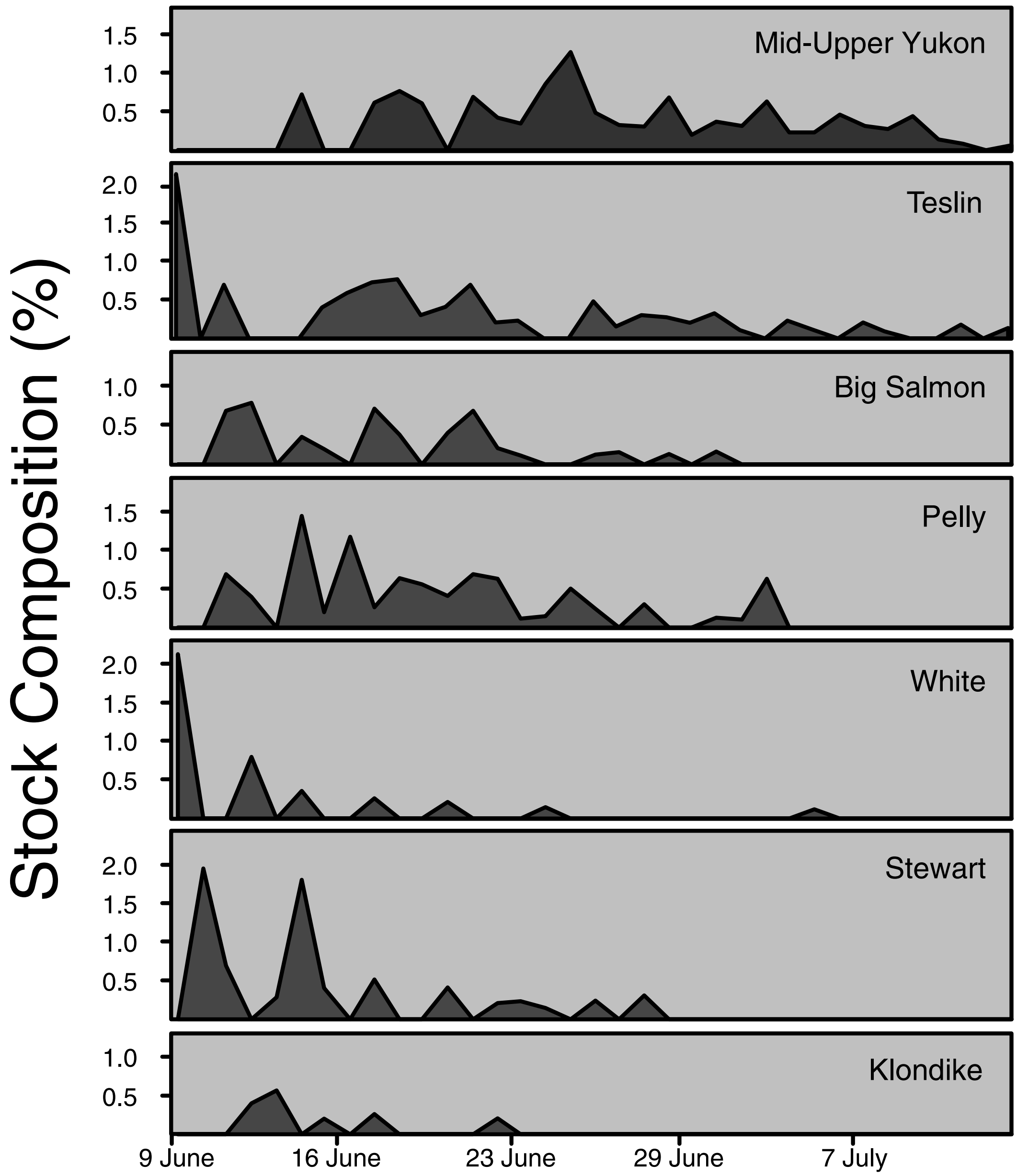

Figure 13. -- Run timing of major chinook salmon stocks in Canadian reaches of the Yukon River basin in 2002, based on composition estimates for the entire return derived from the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries. The mid-upper Yukon stock group represents fish remaining in mainstem areas and associated tributaries.

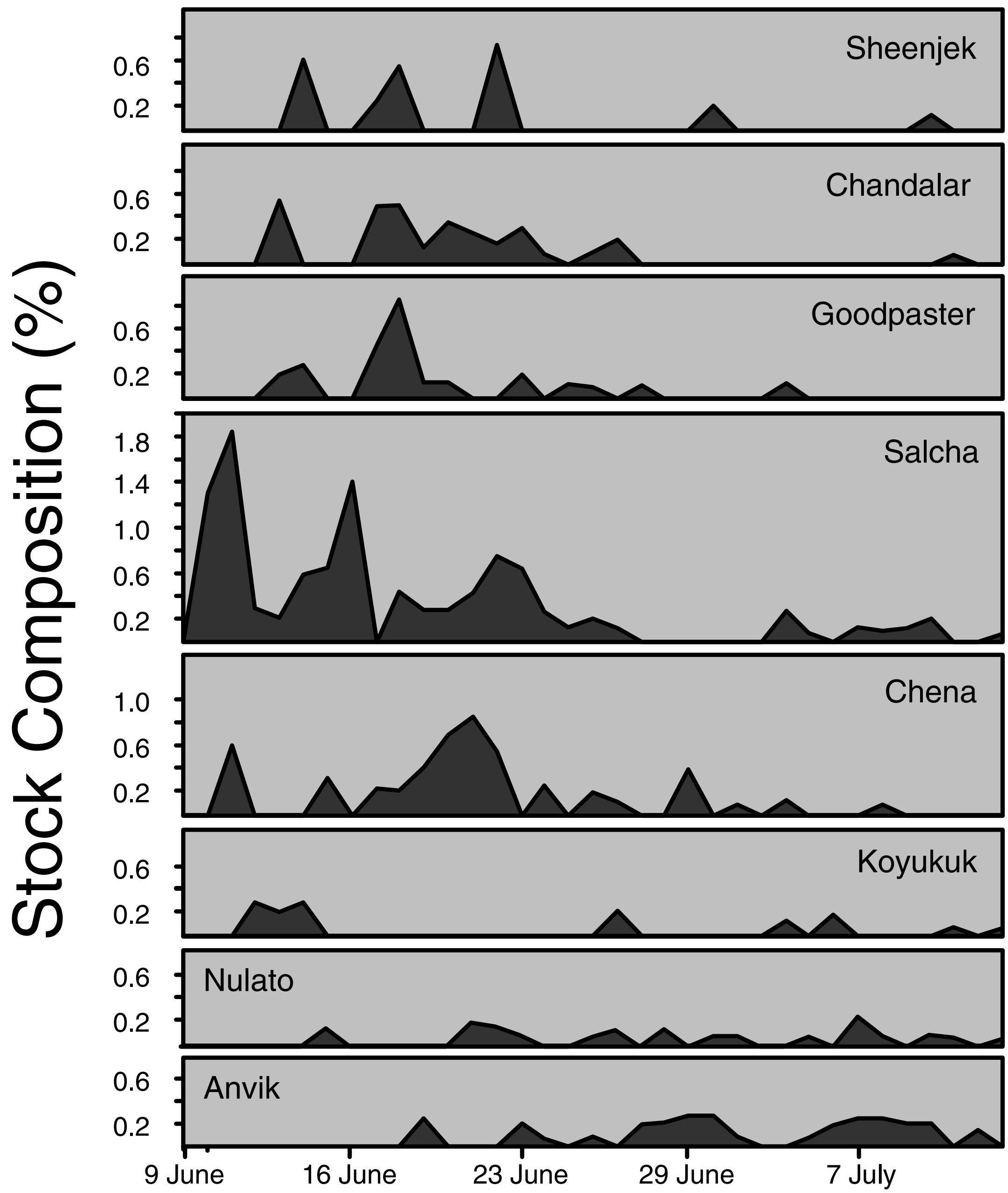

Figure 14. -- Run timing of major chinook salmon stocks in U.S. reaches of the Yukon River basin in 2002, based on composition estimates for the entire return derived from the distribution of radio-tagged fish weighted by catch per unit effort information at the tagging site and adjusted for the harvest of tagged individuals in upriver fisheries.

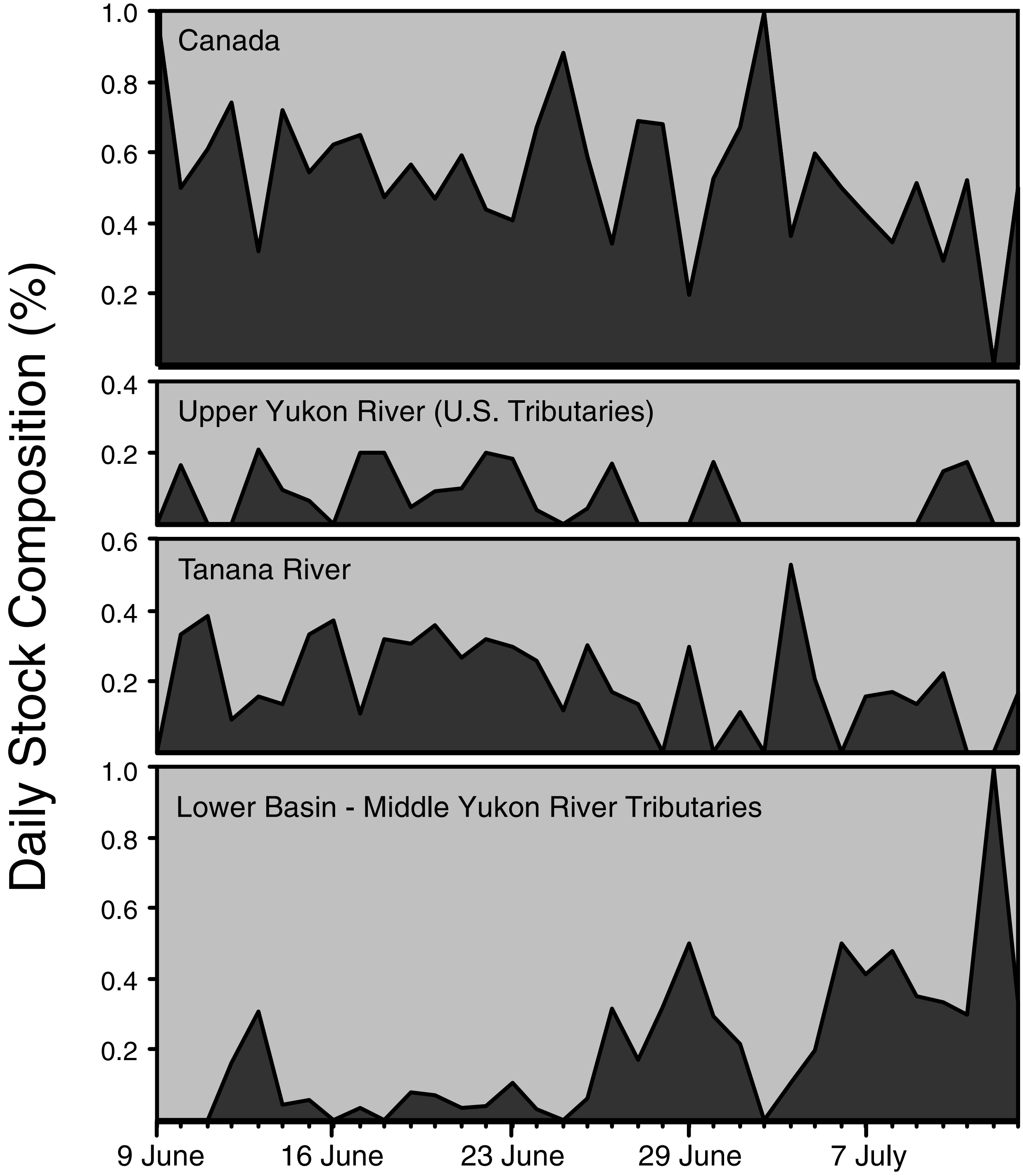

Figure 15. -- Daily stock composition of chinook salmon passing through the lower Yukon River in 2002, based on the observed distribution of radio-tagged fish.

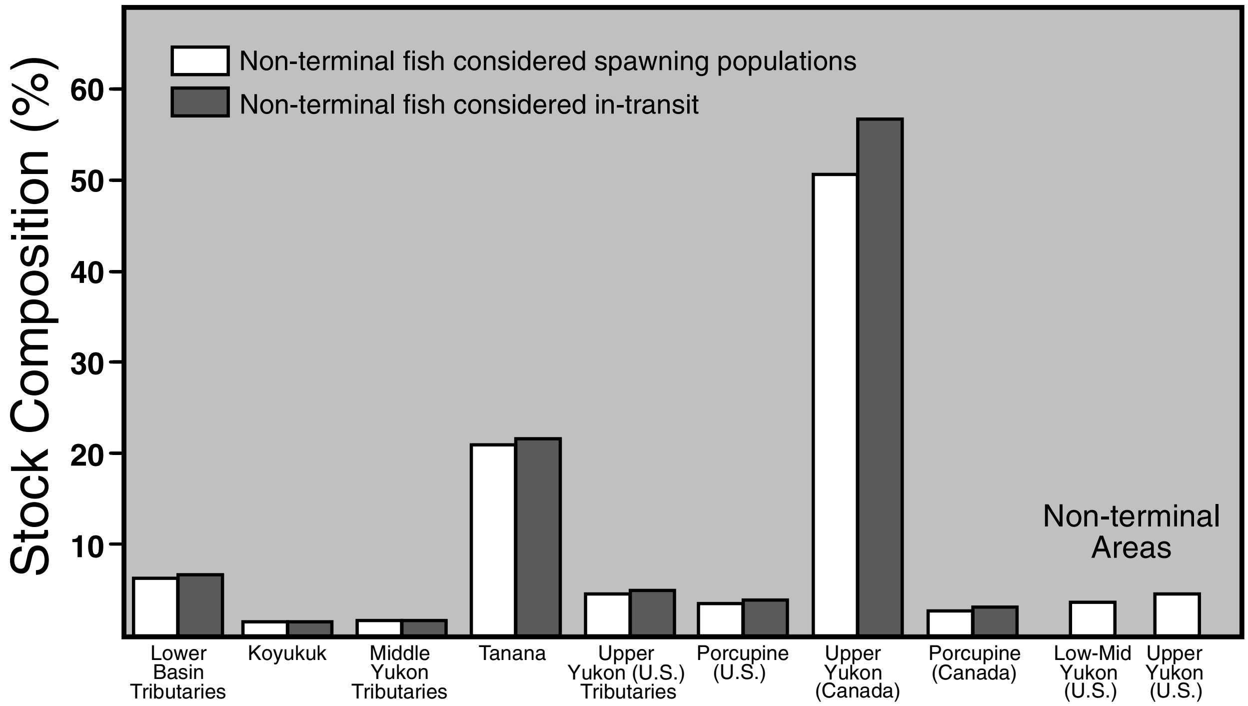

Figure 16. -- Comparison of stock composition estimates of the Yukon River chinook salmon return in 2002 based on the distribution of radio-tagged fish weighted by catch per unit effort information at the capture site and adjusted for the harvest of tagged individuals in upriver fisheries, and the presumed 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.

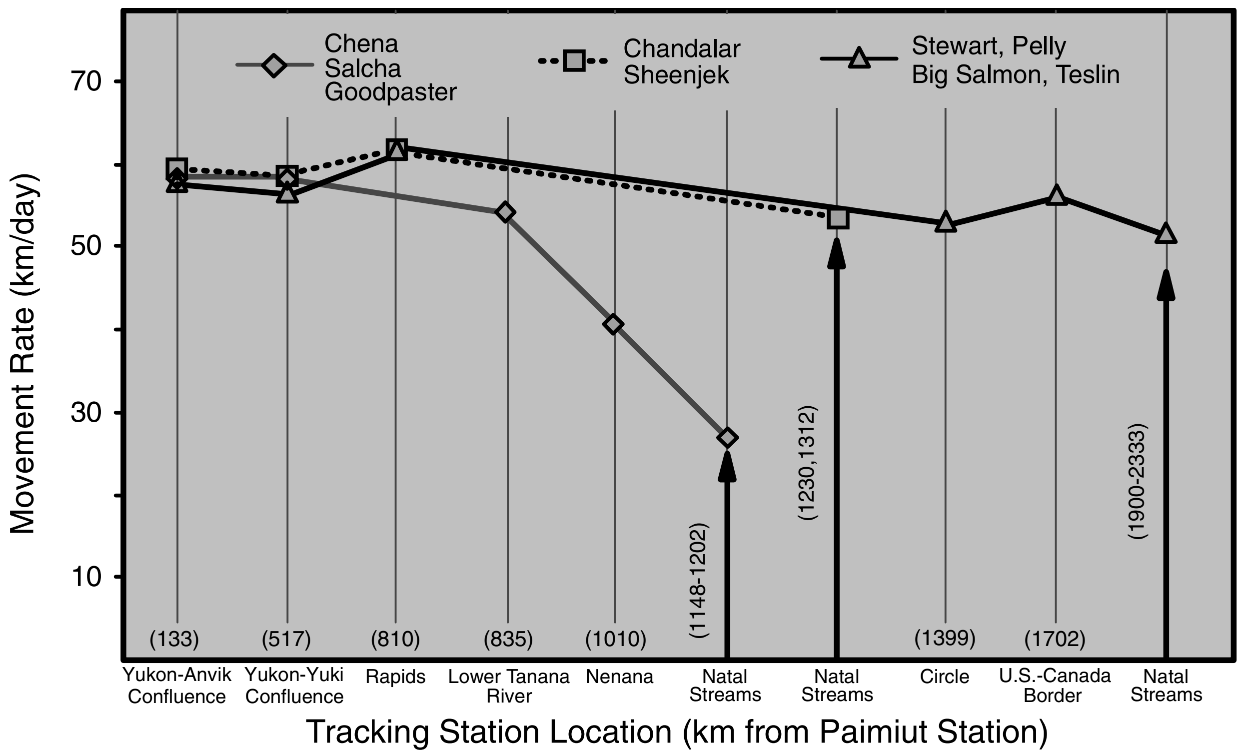

Figure 17. -- Average movement rates (km/day) by area of radio-tagged chinook salmon returning to tributaries in the upper Yukon River basin in 2002. Distances from the Paimiut tracking stations are in parentheses.

Appendix A1. -- Data sheet used to record fishing effort and capture results in the lower Yukon River basin during 2000-2002.

Complete header at the start of each shift

Date/Shift: ____________ **% Cloud Cover:** ________ **Page ___ of ___**

Tagging Site: ____________ **Wind Dir/Speed:** ________ **Daily Comments:** ____________

Captain and Crew: ____________ **Water Temp:** ________

Complete one row for each drift

	Drift	Mesh	Net	Drift	Start	Full	Start	Full	Total Caught This Drift				Kings Not Tagged This Drift			
Date	No.	Type	Length	Loc.	Net In	Net In	Net Out	Net Out	King	Chum	Pink	Other	Recap	Released	Mortality	Drift Comments

Appendix A2. -- Data sheet used to record information for chinook salmon captured with drift gill nets and radio tagged in the lower Yukon River basin during 2000-2002. Fish length is recorded as mid-eye to fork of tail (MEFT).

Date/Shift: ________ Tagging Site: ________

Complete one row for each king tagged

				Length	Scale		Genetic						Release				
Drift#	Color	Injuries	Sex	MEFT (mm)	Card#	Col#	Sample	Tag#	Fish#	Freq	Code	Tagger	Latitiude	Longitude	Date	Hr	Comments

Appendix B. -- Fishery recoveries of chinook salmon radio tagged in the Yukon River basin during 2000-2002. Percentages of the total are in parentheses.

		Year		
Fishing Area	Fishery	2000	2001	2002
District 3	Marshall			16
	Russian Mission			7
	Holy Cross	3	9	39
	District 3 Combined	3 (25.0)	9 (31.1)	62 (23.0)
District 4	Anvik	1		9
	Grayling		2	10
	Kaltag		3	23
	Nulato		3	12
	Allakaket (Koyukuk)[1]			1
	Galena	1		13
	Ruby	2		7
	District 4 Combined	4 (33.3)	8 (27.6)	75 (27.8)
District 5	Below Yukon-Tanana confluence			4
	Tanana			2
	Rampart Rapids		1	15
	Rampart			15
	Yukon-Hess Creek confluence			3
	Yukon Bridge		1	11
	Stevens Village			1
	Beaver			4
	Ft. Yukon			16
	Circle		1	6
	Eagle			9
	District 5 Combined		3 (10.3)	86 (31.8)
District 6*	Lower Tanana River	2	1	1
	Tolovana River			1

Appendix B. -- Continued.

Fishing Area	Fishery	Year 2000	2001	2002
District 6*	Nenana		1	7
	Upper Tanana River			1
	Lower Tanana River	2	1	1
	Tolovana River			1
	Nenana		1	7
	Upper Tanana River			1
	Chena		1	1
	Salcha			1
	District 6 Combined	2 (16.7)	3 (10.3)	12 (4.4)
Canada*	Border-Dawson	1	2	14
	Stewart River			1
	Pelly River		3	7
	Minto Landing			1
	Tatchun Creek			1
	Carmacks	1	1	8
	Upper Yukon River			1
	Yukon-Takhini Creek confluence			1
	Old Crow (Porcupine)	1		1
	Canadian Fisheries Combined	3 (25.0)	6 (20.7)	35 (13.0)
Total		12	29	270

* Terminal fishery.

Appendix C. -- Regional distribution of chinook salmon radio tagged in the Yukon River basin during 2000-2002. Fish harvested in terminal reaches of the basin are included. Portions of the drainage not monitored due the partial deployment of tracking stations in 2000 and 2001 are designated (--) . Percentages of the total are in parentheses.

Region	Final Location	2000	2001	2002
Lower Basin[1]	Yukon River main stem[2]		5 (6.2)	22 (4.2)
	Tributaries	--	3 (3.7)	69 (13.0)
Koyukuk River	Upper Koyukuk River main stem[2]		3 (3.7)	6 (1.1)
	Tributaries[3]	--	--	5 (1.0)
Middle Yukon[4]	Yukon River main stem[2]	--	9 (11.1)	9 (1.7)
	Tributaries	--	--	9 (1.7)
Tanana River	Tanana River main stem[2]	13 (43.3)	20 (24.7)	6 (1.1)
	Tanana River fishery	4 (13.4)	3 (3.7)	9 (1.7)
	Tributaries[3]	--	--	103 (19.5)
Upper Yukon[5]	Yukon River main stem (U.S.)[2]	7 (23.3)	9 (11.1)	27 (5.1)
	Tributaries (U.S.)	--	--	23 (4.3)
	Yukon River main stem (Canada)[2]	--	23 (28.4)	55 (10.4)
	Yukon main stem fishery (Canada)	5 (16.7)	6 (7.4)	24 (4.5)
	Tributaries (Canada)[3]	--	--	136 (25.7)
Porcupine River	Porcupine River main stem (U.S.)[2]	--	--	3 (0.6)
	Tributaries (U.S.)	--	--	14 (2.6)
	Porcupine River (Canada)[2]	--		6 (1.1)
	Porcupine River fishery (Canada)	1 (3.3)		1 (0.2)

Appendix C. -- Continued.

Region	Final Location	2000	2001	2002
Porcupine River	Tributaries (Canada)	--	--	2 (0.4)
Total		30	81	529

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

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

[3] Includes fishery harvests 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.

Appendix D. -- Distribution of chinook salmon radio tagged in the lower Yukon River during 2002, including fish caught in terminal fisheries in the U.S. and Canada. Percentages of total are in parentheses.

Region	Final Location	2002
Lower Basin	Yukon River main stem (above Holy Cross)[1]	22 (4.2)
	Innoko River	5 (0.9)
	Bonasila River	10 (1.9)
	Anvik River	34 (6.4)
	Nulato River	20 (3.8)
Koyukuk	Gisasa River	4 (0.8)
	Kateel River	1 (0.2)
	Upper Koyukuk River[1,2]	6 (1.1)
Middle Yukon	Yukon River main stem (above Galena)[1]	9 (1.7)
	Melozitna River	1 (0.2)
	Nowitna River	1 (0.2)
	Tozitna River	7 (1.3)
Tanana	Tanana River fishery	9 (1.7)
	Lower Tanana River (above Manley)[1]	2 (0.4)
	Kantishna River	8 (1.5)
	Tolovana-Chatanika River[2]	2 (0.4)
	Middle Tanana River (above Nenana)[1]	3 (0.6)
	Chena River[2]	30 (5.7)
	Salcha River[2]	47 (8.9)
	Goodpaster River	16 (3.0)
	Upper Tanana River (above Salcha River)[1]	1 (0.2)
Upper Yukon (U.S.)	Yukon River main stem (above Tanana)[1]	24 (4.5)
	Beaver Creek[3]	1 (0.2)
	Chandalar River	19 (3.6)
	Yukon River main stem (above Circle)[1]	3 (0.6)

Appendix D. -- Continued.

Region	Final Location	2002
Upper Yukon (U.S.)	Charley River	2 (0.4)
	Kandik River	1 (0.2)
Upper Yukon (Canada)	Yukon River main stem (above Border)[1]	6 (1.1)
	Yukon River fishery	24 (4.5)
	Coal Creek	1 (0.2)
	Chandindu River	1 (0.2)
	Klondike River	6 (1.1)
	Stewart River[2]	21 (4.0)
	White River	8 (1.5)
	Yukon River main stem (above White River)[1]	5 (0.9)
	Pelly River[2]	32 (6.0)
	Yukon River main stem (above Selkirk)[1]	19 (3.6)
	Tatchun Creek[2]	4 (0.8)
	Yukon River main stem (above Tatchun Cr)[1]	24 (4.5)
	Nordenskiold River	2 (0.4)
	Little Salmon River	2 (0.4)
	Big Salmon River	17 (3.2)
	Teslin River	36 (6.8)
	Yukon River main stem (above Teslin River)[1]	7 (1.3)
Porcupine (U.S.)	Black River	2 (0.4)
	Sheenjek River	12 (2.2)
	Porcupine River (above Sheenjek)[1]	3 (0.6)
Porcupine (Canada)	Porcupine River (above Border)[1]	6 (1.1)
	Old Crow Fishery	1 (0.2)
	Miner River	2 (0.4)
Total		529

[1] Including areas of the mainstem river and tributaries not monitored by tracking stations.

[2] Includes fish caught in terminal fisheries.

[3] Minimum count based on partial aerial survey.

Appendix E. Stock composition estimates of the Yukon River chinook salmon return in 2002 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 1,000 bootstrappings are included.

Region	Stock Group	Estimate (%)	SE	95% CI
Lower Basin[1]	Lower Yukon[2]	2.9	0.8	(1.6, 4.5)
	Innoko	0.7	0.3	(0.1, 1.4)
	Bonasila	0.9	0.3	(0.3, 1.5)
	Anvik	2.9	0.5	(1.9, 4.0)
	Nulato	1.9	0.5	(1.0, 2.8)
Koyukuk River	Gisasa	0.3	0.2	(0.1, 0.6)
	Kateel	0.1	0.1	(0.0, 0.2)
	Upper Koyukuk	1.1	0.5	(0.3, 2.2)
Middle Yukon River[3]	Melozitna	0.1	0.1	(0.0, 0.5)
	Nowitna	0.2	0.2	(0.0, 0.8)
	Tozitna	1.2	0.5	(0.5, 2.3)
	Mid-Yukon[2]	0.8	0.3	(0.3, 1.5)
Tanana River	Lower Tanana River[4]	0.2	0.2	(0.0, 0.6)
	Kantishna	1.1	0.4	(0.4, 2.0)
	Tolovana	0.4	0.3	(0.0, 1.1)
	Mid-Tanana River[4]	0.3	0.2	(0.0, 0.7)
	Chena	5.2	1.0	(3.4, 7.4)
	Salcha	10.8	1.7	(7.6, 14.2)
	Goodpaster	2.8	0.8	(1.5, 4.6)
	Upper Tanana River[4]	0.1	0.1	(0.0, 0.4)
Upper Yukon River (U.S.)[5]	Upper Yukon (Rapids)[2]	4.3	1.0	(2.5, 6.2)
	Beaver Creek	0.1	0.1	(0.0, 0.4)
	Chandalar River	3.4	0.9	(1.8, 5.1)
	Upper Yukon (Circle)[2]	0.3	0.2	(0.0, 0.8)
	Charley River	0.3	0.3	(0.0, 1.0)
	Kandik River	0.6	0.7	(0.0, 2.2)
Upper Yukon River (Canada)	Lower Canadian Yukon [4]	1.8	0.7	(0.6, 3.4)
	Klondike	1.6	0.7	(0.5, 3.2)
	Stewart	7.2	1.5	(4.2, 10.3)
	White	4.0	1.9	(0.8, 7.8)
	Pelly	9.2	1.7	(6.2, 12.5)

Appendix E. -- Continued.

Region	Stock Group	Estimate (%)	SE	95% CI
Upper Yukon River (Canada)	Mid-Canadian Yukon[4]	3.9	0.9	(2.3, 5.9)
	Tatchun	0.7	0.4	(0.1, 1.6)
	Upper Canadian Yukon[4]	4.9	0.9	(3.2, 6.7)
	Nordenskiold	0.7	0.5	(0.0, 1.8)
	Little Salmon	0.2	0.2	(0.0, 0.8)
	Big Salmon	5.2	1.2	(2.9, 7.7)
	Teslin	9.9	2.2	(6.0, 14.3)
	Hootalinqua	1.5	0.6	(0.6, 2.8)
Porcupine River, U.S.	Black	0.4	0.3	(0.0, 1.2)
	Sheenjek	2.5	0.8	(1.2, 4.2)
	U.S. Porcupine[4]	0.6	0.4	(0.0, 1.6)
Porcupine River, Canada	Canadian Porcupine[4]	2.7	1.0	(1.0, 4.8)

[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 F. -- Daily stock composition estimates of chinook salmon passing through the lower Yukon River based on the distribution of radio-tagged fish in 2002.

	Non-Terminal Reaches[1]		Terminal Reaches			
Date	Lower-Mid Yukon	Upper Yukon (U.S.)[2]	Lower Basin-Middle Yukon Tributaries	Tanana River	Upper Basin Tributaries (U.S.)	Canada[2]
9 June	0.000	0.000	0.000	0.000	0.000	1.000
10 June	0.000	0.000	0.000	0.333	0.167	0.500
11 June	0.067	0.075	0.000	0.333	0.000	0.525
12 June	0.000	0.000	0.164	0.093	0.000	0.743
13 June	0.000	0.096	0.279	0.144	0.192	0.288
14 June	0.000	0.046	0.043	0.130	0.092	0.688
15 June	0.000	0.053	0.053	0.316	0.064	0.515
16 June	0.000	0.000	0.000	0.375	0.000	0.625
17 June	0.097	0.035	0.032	0.097	0.176	0.563
18 June	0.000	0.046	0.000	0.308	0.193	0.453
19 June	0.040	0.000	0.074	0.295	0.045	0.545
20 June	0.000	0.045	0.069	0.345	0.090	0.451
21 June	0.000	0.000	0.037	0.270	0.099	0.594
22 June	0.037	0.000	0.037	0.309	0.193	0.424
23 June	0.035	0.035	0.100	0.277	0.173	0.381
24 June	0.000	0.142	0.026	0.223	0.033	0.577
25 June	0.053	0.056	0.000	0.105	0.000	0.786
26 June	0.000	0.040	0.061	0.292	0.040	0.567
27 June	0.037	0.000	0.304	0.165	0.165	0.330
28 June	0.121	0.000	0.150	0.121	0.000	0.607
29 June	0.000	0.131	0.277	0.000	0.000	0.592
30 June	0.000	0.000	0.500	0.300	0.000	0.200
1 July	0.042	0.101	0.252	0.000	0.151	0.454
2 July	0.183	0.000	0.175	0.092	0.000	0.550
3 July	0.000	0.000	0.000	0.000	0.000	1.000
4 July	0.000	0.327	0.071	0.357	0.000	0.245
5 July	0.155	0.090	0.149	0.155	0.000	0.451
6 July	0.286	0.000	0.357	0.000	0.000	0.357
7 July	0.210	0.000	0.328	0.126	0.000	0.336
8 July	0.138	0.069	0.381	0.138	0.000	0.275
9 July	0.091	0.133	0.273	0.106	0.000	0.398
10 July	0.100	0.000	0.300	0.200	0.133	0.267

Appendix F. -- Continued.

Date	Non-Terminal Reaches[1]		Terminal Reaches			
	Lower-Mid Yukon	Upper Yukon (U.S.)[2]	Lower Basin-Middle Yukon Tributaries	Tanana River	Upper Basin Tributaries (U.S.)	Canada[2]
11 July	0.100	0.233	0.200	0.000	0.117	0.350
12 July	0.000	0.667	0.333	0.000	0.000	0.000
13 July	0.143	0.000	0.286	0.143	0.000	0.429
Average	0.055	0.069	0.152	0.176	0.061	0.488

[1] Reaches of the Yukon River main stem and associated tributaries not monitored by tracking stations.

[2] Including reaches of the upper Yukon and Porcupine rivers.

Appendix G. – Movement rates of chinook salmon radio tagged in the Yukon River basin during 2002 based on fish passage by tracking stations located at Paimiut and the furthest upriver station site.

Region	Stock	Average (km/h)	CI (95%)	N
Lower Basin	Lower Yukon[1]	37.2	10.2	11
	Innoko	21.6	23.1	4
	Bonasila	42.0	9.4	10
	Anvik	27.1	4.5	33
	Nulato	35.5	5.1	17
Koyukuk River	Gisasa	43.0	3.3	4
	Kateel	58.7		1
	Upper Koyukuk	57.8	15.9	6
Middle Yukon River	Mid-Yukon[1]	54.8	11.3	8
	Melozitna	43.7		1
	Nowitna	47.8		1
	Tozitna	57.9	7.1	6
Tanana River	Tanana[2]	55.6	8.2	6
	Kantishna	53.1	4.1	8
	Tolovana	45.6		1
	Chena	49.7	2.4	30
	Salcha	45.3	1.8	47
	Goodpaster	45.6	2.5	16
Upper Yukon River (U.S.)	Upper Yukon, Tanana-Circle[1]	53.8	6.1	24
	Upper Yukon, Circle-Eagle[1]	56.7	11.8	3
	Beaver	58.5		1
	Chandalar	56.4	2.5	18
	Charley	60.3		2
	Kandik	66.4		1
Upper Yukon River (Canada)	Lower Canadian Yukon[2]	58.3	7.8	7
	Chandindu	55.6		1
	Klondike	58.9	7.5	6
	Stewart	56.8	2.2	21
	White	58.7	2.8	8
	Mid Canadian Yukon, White-Tatchun[2]	48.7	1.7	23
	Upper Canadian Yukon, Tatchun-Teslin[2]	49.5	1.9	24
	Upper Canadian Yukon, upriver of Teslin[2]	49.8	3.0	7
	Pelly	54.6	2.3	32
	Tatchun	48.3	4.8	4
	Nordenskiold	52.2		2

Appendix G. -- Continued.

Region	Stock	Average (km/h)	CI (95%)	N
Upper Yukon River (Canada)	Little Salmon	52.8		2
River (Canada)	Big Salmon	52.5	2.4	17
	Teslin	52.8	1.9	36
Porcupine River	Black	61.1		2
	Sheenjek	59.9	3.4	11
	U.S. reaches	61.9	10.0	3
	Canadian reaches	63.3	4.6	8

1 Non-terminal areas.

2 Including stocks in mainstem areas and associated tributaries.

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