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Mark–Recapture Abundance Estimates for Yukon River Chinook Salmon in 2002

by

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Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	$<$
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$log_{2,}$ etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 05-75

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ABSTRACT

Run abundance information is needed to effectively manage salmon returns in the Yukon River basin, however, this type of information is difficult to obtain. Mark–recapture abundance estimates were developed for Yukon River Chinook salmon *Oncorhynchus tshawytscha* as part of a basin-wide telemetry study conducted in 2002. Drift gillnets were used effectively to capture the fish, with 1,310 Chinook salmon caught near the villages of Marshall (539 fish) and Russian Mission (771 fish). Catch per unit effort (CPUE) for each drift was calculated for fish passing the tagging sites. A total of 768 fish were marked with radio transmitters and spaghetti tags. The tagged fish were recovered at the tagging site, in upriver fisheries, and at various escapement monitoring projects within the basin. Chapman's closed population two-sample, mark–recapture estimator was used to estimate the drainage-wide abundance above the tagging sites; 69 radiotagged fish recorded at regional escapement projects and associated fish counts from these areas were the basis for the analysis. The analysis was limited to large fish ≥ 650 mm (METF) in length to account for size selectivity of the capture method favoring larger individuals and limited to fish marked from two fishing crews. Bootstrap analysis of the data estimated a return of 125,255 large Chinook salmon (SE = 14,429). Additional years of tagging and recovery efforts will provide a better understanding of Chinook salmon abundance within the Yukon River basin.

Key words: mark–recapture, radio tracking, Chinook, salmon, *Oncorhynchus tshawytscha*, Yukon River, drift gillnet.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha*, are an important species for subsistence, commercial and sport fisheries, and spawn in tributaries throughout the Yukon River drainage in Alaska and Canada. The United States (U.S.) and Canada manage fisheries to maintain adequate spawning escapements and to provide harvest opportunities**.** The interim spawning escapement objective for rebuilt Chinook salmon returns that spawn in the Yukon River mainstem is 33,000 to 43,000 fish as part of the Yukon River Salmon Treaty agreement between the U.S. and Canada. The targeted escapement varies by year and is set by the Yukon River Panel. The 2002 target was 28,000 Chinook salmon into the Canadian portion of the Yukon River and a harvest range of 20–26% of the total allowable catch (TAC) is allocated to Canada when the TAC is between zero and 110,000 Chinook salmon (JTC 2002).

The need for basin wide abundance information is critical, both for management of U.S. and Canadian fisheries, but also to ensure the treaty mandated Chinook salmon passage into Canada. A variety of methods have been used to assess Chinook salmon run abundance in various tributaries since 1961, including carcass sampling (Anvik River), counting weirs (Gisasa River, Kateel River, and Henshaw Creek in the Koyukuk River drainage; Tozitna River; Blind Creek in the Pelly River drainage; and the Whitehorse fishway), test fisheries (Nenana and Dawson City), counting towers (Nulato, Chena, Salcha and Chatanika rivers) and mark–recapture studies near the U.S.-Canada border. Although these projects estimate abundance in specific tributaries, the relative contribution to the entire run is unknown. Tagging studies using external marks were conducted on Chinook salmon between 1961–1970 to estimate migration rates, drainage-wide abundance, and proportional distribution to major tributaries. However, results from studies conducted in the lower Yukon River near the mouth (1961–1967) were unreliable because of inadequate sampling in braided, lower river channels and extensive commercial harvests that substantially reduced sample sizes. Subsequent studies were moved upriver near Russian Mission (Mile 185–251) to mitigate these problems, but insufficient numbers of fish were tagged resulting in limited information (Geiger 1968; Lebida 1969; Trasky 1973). A lower river test-fishery has operated at Emmonak since 1981, but only records since 1989 are used for drainage-wide run timing (JTC 2002). Drainage-wide abundance estimates have been derived from Pilot Station sonar counts since 1986. However, newer equipment and data analysis procedures have made these counts more comparable since 1995 (Pfisterer 2002).

The U.S. and Canada agreed to conduct cooperative research to determine migratory patterns and population status of Yukon River salmon. As part of this effort, the Alaska Department of Fish and Game (ADF&G) and National Marine Fisheries Service (NMFS) implemented a cooperative radiotelemetry and mark–recapture study to provide information on the stock composition, spawning distribution, run timing, migratory characteristics of Yukon River Chinook salmon (Eiler et al. 2004), and to estimate drainage-wide abundance (Spencer et al. 2003). A major challenge for estimating the abundance of Yukon River Chinook salmon is the size and isolated nature of the drainage, and the limited number of sites with accurate counts of salmon that represent significant proportions of the return. The approach of this study was to use regional areas with several recovery projects as combined recapture sites for calculating the proportion of tagged and untagged fish (Figure 1). The primary objective of the mark–recapture study was to estimate the total annual abundance with the relative precision coefficient of variation less than 20%. Considering the size of the basin, the analysis is severely hindered by the lack of adequate numbers of recoveries representing sizable portions of the run.

METHODS

FISH CAPTURE AND MARKING

Adult Chinook salmon were captured and marked near the villages of Marshall and Russian Mission (Figure 1). Additional information on the study area, capture methods, telemetry equipment used, tagging procedures, data collection, and recording techniques are described in Eiler et al. (2004). The tagging crews consisted of two locally hired contract fishers and two project personnel. Project personnel were responsible for handling and marking of fish, while the contract fishers were responsible for operating a boat and deploying a net. Fishing started June 9, and ended July 13. Fishing was conducted daily during the day (0900–1700 hours) and evening (1800–0200 hours) and each period was 7.5 hours in duration. Drift gillnets were used to capture fish. Based on results from feasibility studies in 2000–2001 (Spencer et al. 2003), gillnets used in 2002 were 8.5 in mesh size constructed with # 21 seine twine (length 46 m, depth 7.6 m, with a hang ratio of 2:1). These nets were used because of their effectiveness in capturing the target species with minimum injuries, and with less bycatch of other fish species. Similar nets, with monofilament fiber instead of seine twine, were used on a limited basis. Gillnets were fished along the shore in locally known drift locations. The most effective fishing seemed to occur where water depth and net depth were comparable, so drift locations were modified with changing water levels.

During a drift, the net was retrieved as soon as a captured fish was detected. The first 3 fish encountered were carefully cut from the net while in the river, brought on board in a dip net constructed with soft, small mesh netting, and placed in a trough of fresh water. The trough was equipped with a pump circulating fresh river water. All remaining fish in the net were released while still in the river to minimize both handling time and potential sampling bias if stocks of fish were poorly mixed. Crew members, wearing neoprene gloves or with bare hands, carefully placed the fish in a neoprene lined tagging cradle. A maximum of 2 fish (with small or no apparent injuries) were processed. The fish were sampled to determine their age through removal of 3 scales from the preferred area of the body (Welander 1940). The scales were mounted on gummed cards and impressions were made in cellulose acetate. Scale impressions were later projected using a microfiche reader with a 40x lens, and estimated ages were reported in European notation (Moore and Lingnau 2002). Fish were measured from mideye to tail fork (METF) to the nearest 5 mm, and the presence and type of injuries were recorded (none, old minor, new minor, old major and new major). Gender was recorded but not used because data collected upriver indicated that the gender of a large portion of the sample (48%) was misidentified. The most common visual error was females misidentified as males (35%).

Each fish was tagged with a uniquely numbered 14 in long external spaghetti tag (Floy Tag and Manufacturing, Inc., Seattle, WA[1]) attached below the dorsal fin (Wydoski and Emery 1983). The tag was filled with a fine cable jeweler's line. All tagged fish were also marked by removing the axillary process and a hole punch in the adipose fin. The axillary process was retained for genetic analysis.

A total of 768 fish were tagged with pulse-coded radio transmitters in the 150 MHz frequency range (Advanced Telemetry Systems, Isanti, Minnesota). Tag dimensions were 2.0 cm in diameter, 5.4 cm in length, and weighed 20 g. The tag was inserted through the mouth and into the stomach using a plastic tube (0.7 cm in diameter) until the transmitter was no longer visible. During the insertion, the fish was not anesthetized. The fish was immediately released after processing. These fish were treated as marked individuals in the abundance study.

TRACKING PROCEDURES

Remote tracking stations (Eiler 1995) were placed on important travel corridors on the Yukon River mainstem and major tributaries (Figure 2). Stations consisted of a computer-controlled receiver (developed by Advanced Telemetry Systems), satellite uplink (Campbell Scientific, Logan, Utah), and self-contained power system (Figure 3). The receiver detected the presence of radiotagged fish, and recorded the signal strength and activity pattern (active or inactive) of the transmitter, date, time, and location of the fish in relation to the station (i.e., upriver or downriver from the site). Sites selected were on important migration corridors and major tributaries of the drainage. Radiotagged fish that passed the first set of tracking stations, 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. Radiotagged fish were considered to have passed a tracking station when the recorded data of signal strength indicated the transition from the downriver antenna to the upriver antenna had occurred. Because tracking sites were located in isolated areas, data were transmitted by satellite uplink to a geostationary operational environmental satellite (GOES) system every hour and relayed to a receiving station near Washington D.C. (Eiler 1995). Data were accessed daily via telephone modem and downloaded into an automated database and GIS mapping program (Eiler and Masters 2000).

Aerial surveys were flown using helicopter and fixed wing aircraft equipped with a computer-controlled receiver and 4-element Yagi receiving antennas mounted on both sides of the aircraft and oriented forward. Tracking receivers contained an integrated global positioning system to assist in identifying and recording locations. Surveys were conducted on the Yukon River mainstem from Marshall to the Canadian border and in other selected reaches of the drainage to

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[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

locate radiotagged fish that traveled to areas between station sites and upriver of stations on terminal tributaries. Test subjects whose transmitters were detected in villages or fish camps during aerial surveys were considered harvested, even if the fisher did not report recovery of the transmitter.

TAG RECOVERY

Commercial and subsistence fishers were encouraged to report any tagged fish they had captured and several steps were taken to facilitate this voluntary return of tags. Information about the importance of returning tags was sent to organizations in villages throughout the Yukon River drainage before the field season (Appendix A1). A letter of appreciation was sent to each person or agency that returned a tag with information about the fish (Appendix B1). A postseason lottery was conducted as an added incentive to return tags with both regional (one $200 prize winner from each of five equal sized regional groupings of recovered tags), and drainage wide (one $500 prize winner from all people who returned tags). Voluntary returns were important in determining the fate of “unknown” fish for distribution information.

Chinook salmon were counted through weirs on Henshaw Creek, and the Gisasa, Kateel, and Tozitna rivers; as catches at fish wheels located on the Tanana River, Yukon River at Rampart Rapids, and the Canadian border, although ASL information was only collected at the border site. Tags were recovered opportunistically from the tagging sites at Marshall and Russian Mission, and during carcass surveys on the Anvik, Chatanika, Chena, Salcha, and Tozitna rivers. Test fisheries at Dawson, Takhini River broodstock sampling, and the fishway at Whitehorse also examined fish and recovered radio tags. Visual counts were conducted from counting towers located on the Chena and Salcha rivers. Subsets of fish from carcass surveys were examined on the Chena and Salcha rivers and ASL data collected. Fish were also recorded by remote tracking stations located on the Gisasa, Tozitna, Chena, and Salcha rivers, and the Yukon mainstem at the Canadian border (Figure 2).

DATA ANALYSIS

Mark–Recapture Population Estimation

Chapman’s closed population two-sample, mark–recapture estimator (Seber 1982) was employed to estimate the drainage-wide population abundance above the tagging sites.

$$\hat{N} = \frac{(\hat{C}+1)(M+1)}{R+1} - 1 \qquad (1)$$

where:

- $\hat{N}$ = estimated large fish abundance in the Yukon River upstream of Russian Mission,
- M = the number of large fish marked and successfully went upstream of Russian Mission,
- $\hat{C}$ = estimated number of large fish examined at the recapture sites, and
- R = the number of large marked fish recovered at the recapture sites (sum of Gisasa, Chena, Salcha, and Canadian subsistence).

Bootstrap Variance Estimation

Variance and statistical bias in $\hat{N}$ were estimated with a parametric bootstrap simulation (as from Efron and Tibshirani 1993). In this study, the simulation was conducted in 4 stages: 1) simulation of the number of marked fish; 2) simulation of numbered recaptured fish; 3) simulation of the number of large fish examined at the recapture sites; and 4) simulation of the abundance of large fish in the Yukon River.

Simulation of the Number of Marked Fish

The number of marked large fish (M') in the simulation was treated as a variate for 2002 because not enough sampling effort was expended to implant all of the 1,000 transmitters available. M' was assumed to have a binomial distribution with $M' \sim B(\hat{N}, \hat{\pi})$ where $\hat{\pi} = M'/\hat{N}$. This was approximated with normal distribution $M' \sim N(M',\sigma)$ where $\sigma^2 = \hat{N}\hat{\pi}(1-\hat{\pi})$.

Simulation of the Number of Recaptured Fish

The marked fish were then assigned to 8 mutually exclusive fates with multinomial distribution $X_i \sim \text{multi}(\pi_i, M')$: 1) disappeared ($\pi_1$); 2) moved upstream to Tanana but not to Chena or Salcha (π_2); 3) moved upstream to remain in a U.S. tributary, but not in the Tanana River (π_3); 4) moved upstream to Canada, but not inspected (π_4), 5) moved upstream through weir on the Gisasa River (R_1) (π_5); 6) moved upstream past towers on the Salcha River (R_2) (π_6); 7) moved upstream over a dam on the Chena River (R_3) (π_8); and 8) were caught in a Canadian subsistence fishery (R_4) (π_9). Probability of each fate was estimated as $\hat{\pi}_i = X_i / M'$ where X_i is the number of large fish in each fate. The simulated number of recaptured fish at 4 streams (R_1^*, R_2^*, R_3^*, and R_4^*) was calculated as $R_i^* = \pi_{i+4}^* \cdot M'^*$. The simulated number of large fish marked and successfully went upstream (M^*) and was calculated as $M^* = M'^*(1-\pi_1^*)$.

	Fate	Number In 2002
1	Disappeared (M' - M)	15
2	Moved upstream to Tanana, but not to Salcha or Chena rivers	18
3	Moved upstream to remain in U.S tributary, but not in Tanana River	227
4	Moved upstream to Canada, but not inspected	105
5	Moved upstream through weir on the Gisasa River (R_1)	3
6	Moved upstream past towers on the Salcha River (R_2)	26
7	Moved upstream over dam on the Chena River (R_3)	17
8	Were caught in Canadian subsistence fishery (R_4)	23

Simulation of the Number of Large Fish Examined at the Recapture Sites

For the third stage of the bootstrap simulation, numbers of fish counted through weirs, past counting towers, and harvested in the Canadian subsistence fishery were fixed to values observed in the experiment. Passage through the weir on the Gisasa River and harvest in the subsistence fishery were each a census. Migrations past the counting tower and over the dam were estimated, however, they were estimated with little measurement error (CV < 5%). The number of large fish inspected at the recapture sites was assumed to come from a binomial distribution $\hat{C}_i \sim \text{B}(C_t, \hat{\pi}_i)$ where C_t is the total number of examined fish, $\hat{\pi}_i$ is an estimated fraction comprised of large salmon ($\hat{\pi}_i = n_{li}/n_i$ where n_{li} is the number of large fish and n_i is a sample size taken of fish at location i,. Simulated estimates $\hat{C}_i^*$ for numbers of large fish "examined" at each upstream location were calculated as $\hat{C}_i^* = C_t \hat{\pi}_i^*$.

Simulation of Abundance of Large Fish in the Yukon River

Given the results from all three stages of simulation, a new estimate of abundance was then calculated for each of the thousand bootstrap samples:

$$N^*_{(b)} = \frac{(M^*_{(b)}+1)(\hat{C}^*_{(b)}+1)}{R^*_{(b)}} - 1 \qquad (2)$$

where:

$\hat{C}^*_{(b)} = \Sigma \hat{C}^*_{i(b)}$,

$R^*_{(b)} = \Sigma R^*_{i(b)}$, and

b = denotes the simulation.

Estimates for all fish and small fish were calculated for each bootstrap sample in the same fashion with substitution of simulated values into the original equations.

Regardless of whether the estimate is for large, small, or all fish, for fish reaching the Tanana River or into Canada, the estimated variance and estimated relative statistical bias were approximated as:

$$v(\hat{N}) = \frac{\sum_{(b)} (N^*_{(b)} - \overline{N}^*)^2}{B-1} \qquad (3)$$

$$\text{Relative Statistical Bias} = \frac{\hat{N} - \overline{N}^*}{\overline{N}^*} \times 100 \qquad (4)$$

where:

B = 1,000 and

$\overline{N}^* = (\Sigma N^*_{(b)}) / B$.

Passage into Canada and passage into the Tanana River were estimated with two methods based on marked fish. If capture at Russian Mission and Marshall had been proportional to passage at that point, the fraction of test subjects moving upriver into Canada (or into the Tanana River) is the estimated fraction of downstream passage that reached Canada (or the Tanana River). The second method is based on a two-event mark–recapture experiment where marked fish from the first event are only those test subjects known to have entered Canada (or the Tanana River) and fish inspected during the second event are only taken in samples from the Canadian subsistence fishery (or in the combined Salcha and Chena rivers). Passage calculated using each method was:

Proportional distribution:

$$N_t = \frac{(R_t)(\hat{N})}{M} \qquad (5)$$

where:

$\hat{N}$ = estimated abundance in Yukon River upstream,

M = the number of fish marked, and

R_t = the number of marked fish recorded in the tributary.

Local experiment:

$$N_t = \frac{R}{R_t}C \qquad (6)$$

where:

R = the number of marked fish recovered at the recapture sites,
R_t = the number of marked fish recorded in the tributary, and
C = the number of fish examined at the recapture sites.

Tests of Mark–Recapture Assumptions

The Chapman closed population estimator is based upon the following assumptions:

a) Recruitment or immigration and emigration or death of unmarked fish does not occur between sampling events;
b) Marking does not affect the fate (mortality, probability of recapture) of a fish; and
c) Marked fish do not lose their marks and all marks are recognized,all fish have an equal probability of capture downstream (first sampling event); or all fish have an equal probability of capture upstream (second sampling event); or marked fish mix completely with unmarked fish between capture locations.

Assumption (a) was met; because every fish above Russian Mission in the Yukon drainage must have passed Russian Mission and tracking information indicate that few fish migrate down river. Almost all test subjects were successfully tracked upstream past sampling sites (Eiler et al. 2004), which indicates that assumption (b) was met as well. As per assumption (c), presence or absence of primary (tags), secondary, and tertiary marks were noted on all fish physically inspected and no tag loss was observed. Fish were not physically inspected at some sites, but were counted from towers or through a weir with "recaptured" fish being those with transmitters recorded upstream of the site. Assumption (c) would be met if all or nearly all marked fish were successfully located in spawning areas upstream from the tagging sites. As per assumption (d) relates to space and time, attempts to standardize fishing at Russian Mission and Marshall were designed to catch fish with equal probability throughout the season. Because the typical migratory timing of Chinook salmon populations past a point in large watersheds has upper basin spawners passing earlier and lower basin spawners passing later (Bendock and Alexandersdottir 1993; Burger et al. 1985; Pahlke and Bernard 1996), marked fractions of inspected fish should be similar across recovery sites if assumption (d) has been met. A χ^2 test was used to examine equal probability of downstream capture among various (lower, mid, and upriver) stocks. As assumption (d) also relates to size of salmon, lengths of captured and recaptured fish at various recovery projects were compared to that of marked fish at Russian Mission and Marshall, using Kolmogorov-Smirnov two-sample tests (K-S test). Failing to reject the K-S test between marked and recaptured fish indicates no size-selectivity during the second (recovery) sampling event. Failing to reject the K-S test between marked and captured fish indicates no size selectivity during the first (marking) sampling event, however size selectivity by the capture method confounds this comparison. Marked fish were captured with a 8.5 in mesh gillnet whereas fish examined upstream were captured by various means including weirs, fish wheels, and carcass surveys at recovery sites. It is likely that fish captured at the tagging sites are biased toward large fish (≥ age 3), while fish wheels may be biased toward small fish and carcass surveys biased toward large fish. Thus, weirs would be the best indicator for size selectivity between marked, captured and recaptured fish.

RESULTS

CAPTURE AND HANDLING

Numbers Captured and Released

Gillnets were fished 428.7 hours to capture 1,310 Chinook salmon at Marshall (539 fish) and Russian Mission (771 fish) between 9 June and 13 July (Table 1; Figure 4; Appendix C1). Fish were tagged throughout the run (Figure 5), with 768 fish radio tagged including, 279 fish at Marshall and 489 fish at Russian Mission. Five fish were inadvertently marked only with spaghetti tags (Marshall 2 fish; Russian Mission 3 fish), 27 fish died (Marshall 9 fish; Russian Mission 18 fish), 499 fish were released without tagging (Marshall 247 fish; Russian Mission 252 fish), and 11 fish were recaptured at the tagging site (Marshall 2 fish; Russian Mission 9 fish). Marshall and Russian Mission catch per unit effort (CPUE) data is presented in Appendix D1–D2.

Age and Length Composition

Most captured fish were age 1.4 in both locations: Marshall 62% (n = 254) and Russian Mission 63% (n = 454) respectively (Table 2). Mean lengths of marked fish (n = 768) were 819 mm (METF) ranging from 400 to 1,060 mm (SD = 95) (Table 6).

Tag Recoveries

Marked fishes were recaptured 1) at the Marshall and Russian Mission tagging sites, 2) in upriver escapement monitoring projects, and 3) in U.S. and Canadian fisheries. Two marked fish were recaptured in Marshall (both tagged at Marshall), 9 fish in Russian Mission (tagged at Marshall: 2 fish; Russian Mission: 7 fish) and were immediately released. Above Russian Mission, 136 fish were counted, examined or recovered in various escapement monitoring sites (Table 3). Because of insufficient recovery numbers, directed tag recovery efforts, or incomplete information, only numbers obtained from the Gisasa River weir, Chena and Salcha tower counts, and Canadian subsistence catch numbers were used for mark–recapture population estimation. The Canadian subsistence numbers include the catch from all the Yukon mainstem and tributary subsistence and test fisheries, excluding Porcupine River fish.

A significant portion (270 fish, 35.2%) of all marked Chinook salmon was captured by subsistence fishers, with most tags coming from Holy Cross (39 fish, 14.4%), Rampart/Rapids area (34 fish, 12.6%), and Kaltag (23 fish, 8.5%) in the U.S. and Dawson City (16 fish, 5.9%) in Canada (Table 4). From 768 marked fish, 751 fish resumed upriver migration past the gateway stations at Paimiut (located 42 km upriver from the Russian Mission tagging site). Aerial surveys were conducted to obtain or verify final locations for all radiotagged fish. Of these 751 fish, the fate of 58 (7.7%) was not determined. Possible causes include tag malfunction, unreported fishery harvest, or movements to tributaries where aerial surveys were not conducted (Appendix C2). Aerial surveys, flown over villages along the Tanana River and the Yukon River mainstem, documented that 49 of the 270 (18.1%) fish harvested were not reported by fishers. An evaluation of sex selectivity in the overall fishery could not be ascertained because of unreliable information collected during both tagging and subsequent subsistence fisher reports. The mean length of all fish tagged was 819 mm and the mean length of tagged fish caught in fisheries was 823 mm.

MARK–RECAPTURE POPULATION ESTIMATE

Test of Assumptions

Comparison of size distributions of fish marked downstream and recaptured upstream indicated that all fish upstream had an equal probability of being sampled regardless of their size, but not downstream (Figure 6). Recaptured fish had essentially the same size distribution as marked fish, however, fish captured upstream were decidedly smaller than those captured downstream (Tables 5 and 6). Considering that few small fish (< 650 mm METF) were recaptured (8 fish or 7.0% of all recaptured fish), the mark–recapture experiment was used to directly estimate only larger fish (≥ 650 mm METF). Comparison of captured fish upstream across sampling locations showed similar size distributions for fish of all sizes (Figures 6–8).

However, due to the small number of fish captured and marked at Marshall, a fourth crew was added at Russian Mission from June 20 through July 13. In addition, the second tagging crew at Marshall was moved to Russian Mission from July 5–13. In Figure 9, the timing of marked fish going to recovery projects indicate the probability of catching the different stocks not in proportion to the run could occur. Because of this, we removed the effort of the third and fourth tagging crews. The estimate removed the sampling error from the marking procedure and produced similar marked fractions of inspected fish across recovery sites (Table 8).

Comparison of marked fractions across sampling locations upstream with two fishing crews indicated that all fish regardless of their spawning location had an equal chance of being marked at Russian Mission and Marshall (Tables 7–8). Fractions ranged from an estimated 0.25% in the Canadian subsistence fishery to an estimated 0.46% for large fish passing a counting tower on the Salcha River. This range was not statistically significant ($\chi^2 = 4.76$, df = 3, P = 0.19). Numbers inspected upstream were reduced from all Chinook salmon to large Chinook salmon only with estimates of size composition from samples taken at or upstream of sites.

Abundance Estimates

The estimated abundance of large Chinook salmon passing upstream of Russian Mission is 125,255 fish (SE = 14,429) and the statistical bias in this statistic is 1.9% as estimated through bootstrapping. This estimate was based on 419 marked fish, 20,875 captured fish, and 69 fish recaptured from lower, middle, and upriver locations (Tables 7–9).

The estimated abundance of large salmon passing into the Tanana River is 18,235 (SE = 1,846) for proportional distribution and 14,932 (SE = 1,312) for the local experiment calculation and the statistical bias in this statistic is 1.1% and 0.9%, respectfully as estimated through bootstrapping. Estimated abundance of large salmon passing into Canadian Yukon Main River is 38,264 (SE = 5,212) for proportional distribution and 51,428 (SE = 10,880) for the local experiment calculation and the statistical bias in this statistic is 1.4% and 4.9%, respectfully as estimated through bootstrapping (Table 9).

By using the formula:

$$(\text{average \% fish} < 650 \text{ mm}) * (\geq 650 \text{ mm estimate})/(1- \text{average \% fish} < 650 \text{ mm}), \tag{7}$$

the abundance estimate above Russian Mission of Chinook salmon < 650 mm METF was 77,423 (95% CI: 60,731–94,115) obtained from the inspected fish at the recovery projects. The total combined abundance estimate is 202,678 (95% CI: 159,434–245,922).

A drainage-wide estimate was developed by including 10,173 (95% CI: 8,386–11,960) Chinook salmon for subsistence, 22,515 fish for commercial fishing (including Marshall), and 7,999 fish escapement for the Andreafsky River, the only major Chinook salmon tributary below the tagging site at Marshall (Brase and Hamner 2003; JTC 2002) (T. Lingnau, Commercial Fisheries Biologist, ADF&G, Anchorage; personal communication). This results in a total drainage-wide estimate of 243,365 (95% CI: 167,820–257,882).

DISCUSSION

Modifying our catch effort by adding an additional crew and moving an existing crew to a better fishing location demonstrably affected the probability of capturing different stocks. Different migratory patterns exhibited by stocks as they move past the tagging sites can also hinder tagging a representative sample of the run. Information from radiotelemetry work in 2002 (Eiler et al. 2004) showed that Tanana River and upper basin stocks comprised approximately 87% of the return. These groups exhibited similar run timing patterns, with most fish passing through the lower river during the early and middle run and then declining during the late run, while lower basin stocks were comprised primarily of late run fish. While the upper basin (U.S. and Canadian) component of our tagged fish sample was present throughout the run and comprised the largest component, our tagging schedule could have affected our results. We began tagging on June 9, but fish were already passing by the site a week earlier. This factor could result in underestimating the Chinook salmon return, especially the upper basin component. By removing the effort of the third and fourth tagging crews, we removed the dissimilar marked fractions of inspected fish across recovery sites (Table 8). Tagging effort was modified in 2003 to address these issues.

Size-selective sampling with nets, weirs, carcass surveys, fish wheels, and fishways further complicate calculations of a mark–recapture experiment. Although our use of 8.5-in mesh gillnets to capture fish for tagging minimized the bycatch of non-targeted species, we were selecting for large fish. Recovery projects using fish wheels select for smaller fish (Meehan 1961) and carcass surveys select for larger fish due to the disparity of size and post-spawning habits between the sexes (Kissner and Hubartt 1986). Presumably, weirs and fishways do not exhibit size selectivity, but only a limited number of these types of projects are operated in the Yukon River basin with a minimal number of fish enumerated. However, since our marked population (censured) was age-1.3 and older fish, results indicate our sampling was representative, thus avoiding bias in our estimates of abundance.

The behavior and movements of Yukon River Chinook salmon are not well understood and could influence abundance estimates. However using radiotelemetry does offer some advantages. Although large numbers of fish are not tagged, we are better able to assess their status. Information collected in 2002 (Eiler et al. 2004) has improved our understanding of Chinook salmon stock composition and movement patterns within the basin. Additional years of tagging, aerial tracking and differing run sizes will provide a better understanding of Chinook salmon distribution and tributary abundance.

ACKNOWLEDGEMENTS

Funding for this study was provided by the Research and Prevention Relative to the 1998 Bristol Bay, Kuskokwim, and Yukon River Salmon Disaster fund, the Alaska Department of Fish and Game (ADF&G), the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Land Management (BLM), Department of Fisheries and Oceans Canada (DFO), Bering Sea Fishermen's Association (BSFA), Yukon River Drainage Fisheries Association (YRDFA), National Park Service (NPS), U.S./Canada Yukon River Grant No. 03NMF4380185, and the Restoration and Enhancement Fund of the Yukon River Panel.

We thank all the ADF&G personnel, including R. Holder, R. Chapell, C. Kerkvliet, R. Driscoll, L. Dunbar and technicians E. Barnhill, T. DeWitt, C. Greene, M. Martz, S. McNeil, P. Robinson, and M. Telouchkina. We also thank A. Coffee, J. Duffy, P. Duffy, J. Edison, L. Fitka, M. Fitka, R. Housler, P. Kozevnikoff, W. Pitka, V. Sergie and A. Stephanoff for invaluable local support of the tagging effort. Pilots S. Gibbens and R. Swisher (Quicksilver Air), D. Lorring (Wrights Air Service), D. Miller (Caribou Air), K. Scholz (Fireweed Helicopters), J. Twedo (Hageland Air), D. Washington (Capitol Helicopters) and J. Webster (Webster Flying Service) provided aerial support for tracking surveys. We thank R. Brown and T. Tanner (USFWS), B. Mercer (B. Mercer and Associates), C. Osborne (Haldane Environmental Services), J. Duncan and G. Couture (Yukon Salmon Committee), and I. Anderton (North Yukon Renewable Resources Council) for their assistance with aerial surveys; B. Mercer and C. Osborne also installed and maintained tracking stations in Canada. We thank B. Busher, K. Boeck, P. Costello, A. Estes, and S. Salasky (ADF&G), K. Van Hatten and G. Beyersdorf (USFWS), P. Milligan and M. E. Jarvis (DFO), K. Gillis and C. Stark (BSFA), and J. Klein (YRDFA) for their help with tag returns. Technical support for the telemetry equipment used during the study was provided by N. Christensen, L. Kuechle, A. Mayer and R. Reichle (Advanced Telemetry Systems). We are grateful to M. Masters (NMFS) for developing and maintaining the database and GIS mapping program used during the study, and providing critical support in processing the data. D. Bernard, D. Crawford, J. Hilsinger, S. McNeil (ADF&G) and J. Pella and M. Masuda (NMFS) provided critical review of this report. We thank L. Brannian and G. Sandone (ADF&G), and M. Dahlberg and J. Helle (NMFS) for administrative support during the study.

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TABLES AND FIGURES

Table 1.–Number of Chinook salmon captured, marked, radio tagged, mortalities, released untagged and recaptured at tagging sites in drift gillnets at the Marshall and Russian Mission tagging sites in 2002.

Tagging Site	Captured	Radio Tagged	Mortalities	Released Untagged	Recaptured at Tagging Sites
Marshall	539	279	9	247	2
Russian Mission	771	489	18	252	9
Total	**1,310**	**768**	**27**	**499**	**11**

Table 2.–Age composition of Chinook salmon tagged in 2002.

	Combined (n = 708)		Marshall (n = 254)		Russian Mission (n = 454)	
Age [a]	Estimate	SE	Estimate	SE	Estimate	SE
1.2	0.04	0.007	0.04	0.012	0.04	0.01
1.3	0.21	0.015	0.18	0.024	0.23	0.02
1.4	0.63	0.018	0.62	0.03	0.63	0.023
1.5	0.12	0.012	0.16	0.023	0.1	0.014

[a] Age designation using the European notation.

Table 3.–Recoveries of marked Yukon River Chinook salmon by escapement monitoring projects in 2002.

Km from Yukon River Mouth	Location	Project Type	No. Tags	No. Fish Examined	Used In M/R Analysis
274	Marshall	radio tagging [a,b]	2	538	
365	Russian Mission	radio tagging [a,b]	9	772	No
			11	**1,310**	**No**
	Projects Upstream of Russian Mission				
512	Anvik River	carcass survey [a]	4	358	No
779	Nulato River	counting tower [a]	0	2,696	No
912	Gisasa River	weir [c]	4 [d]	1,931	Yes
1,022	Kateel River	weir [c]	1	69	No
1,570	Henshaw Creek	weir [c]	0	649	No
	District 4 Subtotal		**9**	**5,703**	**No**
1,276	Chatanika River	carcass survey [a]	1	44	No
1,384	Tanana River near Nenana	fish wheel [a]	2	1,527	No
1,481	Chena River	carcass survey [a]	4	1,064	No
1,481	Chena River	counting tower [a]	30 [d]	6,967 [e]	Yes
1,553	Salcha River	counting tower [f]	47 [d]	8,850 [e]	Yes
1,553	Salcha River	carcass survey [f]	0	323	No
	Tanana River Subtotal		**82**	**18,775**	**No**
1,096	Tozitna River	carcass survey [g]	0	34	No
1,096	Tozitna River	weir [g]	5	1,438	No
1,176	Yukon River near Rampart Rapids	fish wheel [c]	0	838	No
	Subdistrict 5b and 5c Subtotal		**5**	**2,310**	**No**
1,981	Yukon River above US/Canada Border at White Rock	fish wheel [h]	1	1,050	No
1,992	Yukon River above US/Canada Border at Sheep Rock	fish wheel [h]	0	590	No
2,123	Dawson City	test fishery [h]	3	1,036	No
2,765	Takhini River	broodstock [h]	1	78	No
2,808	Whitehorse	fishway [h]	1	605	No
	Canadian Subsistence		34	9,257	Yes
	Canada Subtotal		**40**	**12,616**	**No**
	Upstream Sites Total		**147**	**40,714**	**No**

[a] Recovery project operated by the Alaska Department of Fish and Game.
[b] Recovery project operated by National Marine Fisheries Service.
[c] Recovery project operated by U.S. Fish and Wildlife Service.
[d] Number of radiotagged fish recorded in river.
[e] Estimated escapement.
[f] Recovery project operated by the Bering Sea Fishermen's Association.
[g] Recovery project operated by the Bureau of Land Management.
[h] Recovery project operated by Canada Department of Oceans and Fisheries.

Table 4.–Voluntary Chinook salmon tag recoveries in fisheries by nearest community in 2002.

Nearest Community	Area	Km from Yukon River Mouth	Number of Tags Recovered [a]
Alaska			
Marshall	Yukon Mainstem	259	16
Russian Mission		343	7
Holy Cross		449	39
Anvik		510	9
Grayling		541	10
Kaltag		724	23
Nulato		779	12
Koyukuk [b]		1,287	6
Galena		853	10
Ruby		935	5
Tanana		1,118	5
Manley Hot Springs	Tanana River	1,231	1
Nenana		1,384	7
Fairbanks		1,481	4
Rapids/Rampart/Bridge	Yukon Mainstem	1,228	34
Stevens Village		1,363	12
Beaver		1,500	5
Fort Yukon		1,613	15
Circle		1,708	6
Eagle		1,952	9
Canada			
Old Crow	Porcupine River	2,026	1
Dawson City	Yukon Mainstem	2,123	16
Mayo	Stewart River	2,446	1
Carmacks	Yukon Mainstem	2,490	9
Pelly Crossing	Pelly River	2,269	7
Whitehorse	Yukon Mainstem	2,808	1
Teslin	Teslin River	2,808	0
Total Tags Recovered			**270**
Estimated Subsistence Catch [c]			42,746

[a] Includes radiotagged fish recorded in villages or fish camps during aerial tracks.

[b] Includes radiotagged fish caught in Koyukuk River.

[c] Alaska catch of Yukon River Chinook salmon (*Source*: Brase and Hamner 2003).

Table 5.–Numbers of Chinook salmon marked at Marshall and Russian Mission by length (METF) and numbers inspected upriver at recovery projects during 2002.

Location	Total	< 650 mm	Percentage	≥ 650 mm	Percentage
Number of Fish Marked					
Radio tagged	768	46	6.0	722	94.0
Number of Fish Captured					
Koyukuk River drainage					
Gisasa (live weir)	570	248	43.5	322	56.5
Kateel (live weir)	69	40	58.0	29	42.0
Tozitna (live weir)	535	248	46.4	287	53.6
Tanana River drainage					
Chena (carcass)	1,069	328	30.7	741	69.3
Salcha (carcass)	323	115	35.6	208	64.4
Total	2,566	979	38.2	1,587	61.8
Number of Marked Fish Captured					
Koyukuk River drainage					
Gisasa (live weir)	4	0	0.0	4	100.0
Kateel (live weir)	1	0	0.0	1	100.0
Tanana River drainage					
Chena (carcass)	30	1	3.3	29	96.7
Salcha (carcass)	47	5	10.6	42	89.4
Canada					
Yukon River (subsistence)	34	2	5.9	32	94.1
Total	116	8	6.9	108	93.1

Table 6.–Lengths of captured and marked fish at recovery projects compared to that of marked fish at Russian Mission and Marshall, using Kolmogorov-Smirnov two-sample test.

Location	Sample Size	Mean	SD	D	P-value
Marshall-Russian Mission	768	819	95		
Gisasa Weir	570	664	120	0.54	<0.001
Captured					
Marked	4	858	112	0.40	0.56
Tanana Combined					
Captured	1,392	729	144	0.29	<0.001
Marked	77	830	101	0.07	1.07
Canada Subsistence [a]					
Marked	34	789	94	0.21	0.12

[a] Captured numbers not available.

Table 7.–Number of radiotagged Chinoook salmon marked in 2002.

2002		
Initial number marked	**768**	
Censured fish (< 650 METF)	46	(6.0)
Removed from total [a]	15	(2.0)
Number marked	**707**	
Fish caught by fourth tagging crew	165	(21.5)
Number marked	**542**	
Fish caught by third tagging crew	123	(16.0)
Number marked	**419**	

Note: Percentages of initially marked sample are in parentheses.

[a] Did not pass gateway station at Paimiut (unknown fate: died, went to unsurveyed lower tributaries, unreported fishery recovery, tagging error or tag malfunctions).

Table 8.–Chinook salmon abundance estimate worksheet in 2002 for large (≥ 650 mm METF) radiotagged fish.

	Number	**Adjusted Number [a]**	**Number Marked**	**Adjusted Number Marked [a]**	**Marked Fraction (%)**	**Adjusted Number Marked [b]**	**Marked Fraction (%)**	**Adjusted Number Marked [c]**	**Marked Fraction (%)**
Lower Yukon									
Koyukuk River			11	11		8		8	
Gisasa River Weir	1,931	1,091	4 [d]	4	0.37	3	0.27	3	0.27
Middle Yukon									
Tanana River			118	107		78		61	
Chena River RTS/Tower	6,967 [e]	4,828	30 [d]	29	0.60	23	0.48	17	0.35
Salcha River RTS/Tower	8,850 [e]	5,699	47 [d]	42	0.74	32	0.56	26	0.46
Tanana Pooled	**15,817**	**10,527**	**77**	**71**	**0.67**	**55**	**0.52**	**43**	**0.41**
Upper Yukon (Canada)			**215**	**208**		**164**		**128**	
Canadian [f]	9,257	9,257	34	32	0.35	29	0.31	23	0.25
Drainage-wide Pooled	**27,005**	**20,875**	**115**	**107**	**0.51**	**87**	**0.42**	**69**	**0.33**

[a] Number of Chinook salmon ≥ 650 mm METF.
[b] Number of Chinook salmon marked by three crews.
[c] Number of Chinook salmon marked by two crews.
[d] Number of radio tags recorded in river by RTS or aerial tracks.
[e] Estimated Chinook salmon escapement into river.
[f] Includes subsistence and test fisheries.

Table 9.–Estimate of abundance for large Chinook salmon above Russian Mission in 2002.

	Estimate	SE	Higher CI	Lower CI	Bias (%)
Yukon River	125,255	14,429	161,353	103,958	1.9
Tanana River					
Proportional distribution	18,235	1,846	22,087	14,792	1.1
Local experiment	14,932	1,312	17,985	12,892	0.9
Canada					
Proportional distribution	38,264	5,212	49,429	29,562	1.4
Local experiment	51,428	10,880	80,249	37,645	4.9

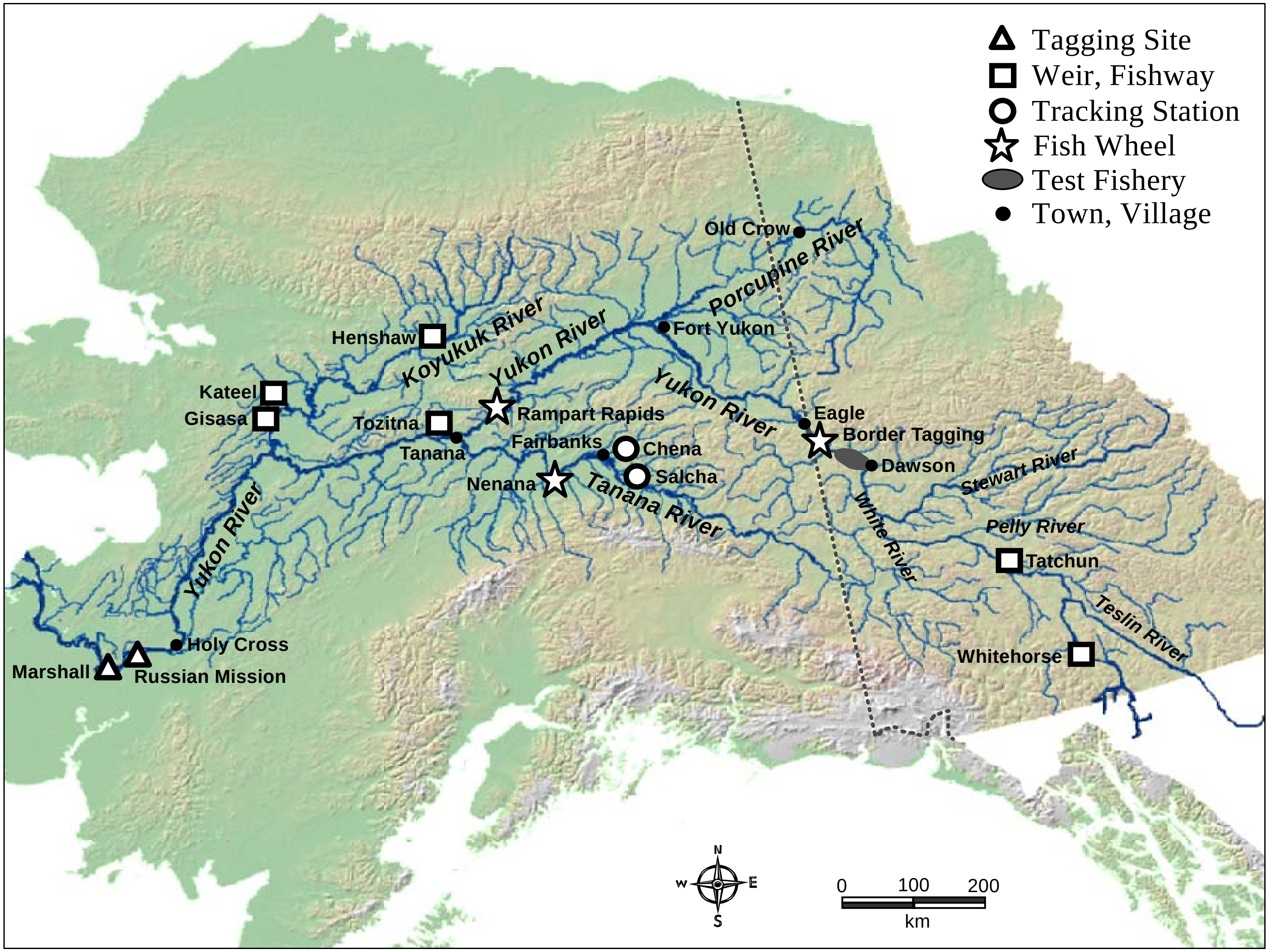


Figure 1.–Yukon River drainage showing tagging and recovery sites used to develop mark–recapture abundance estimates for Chinook salmon.

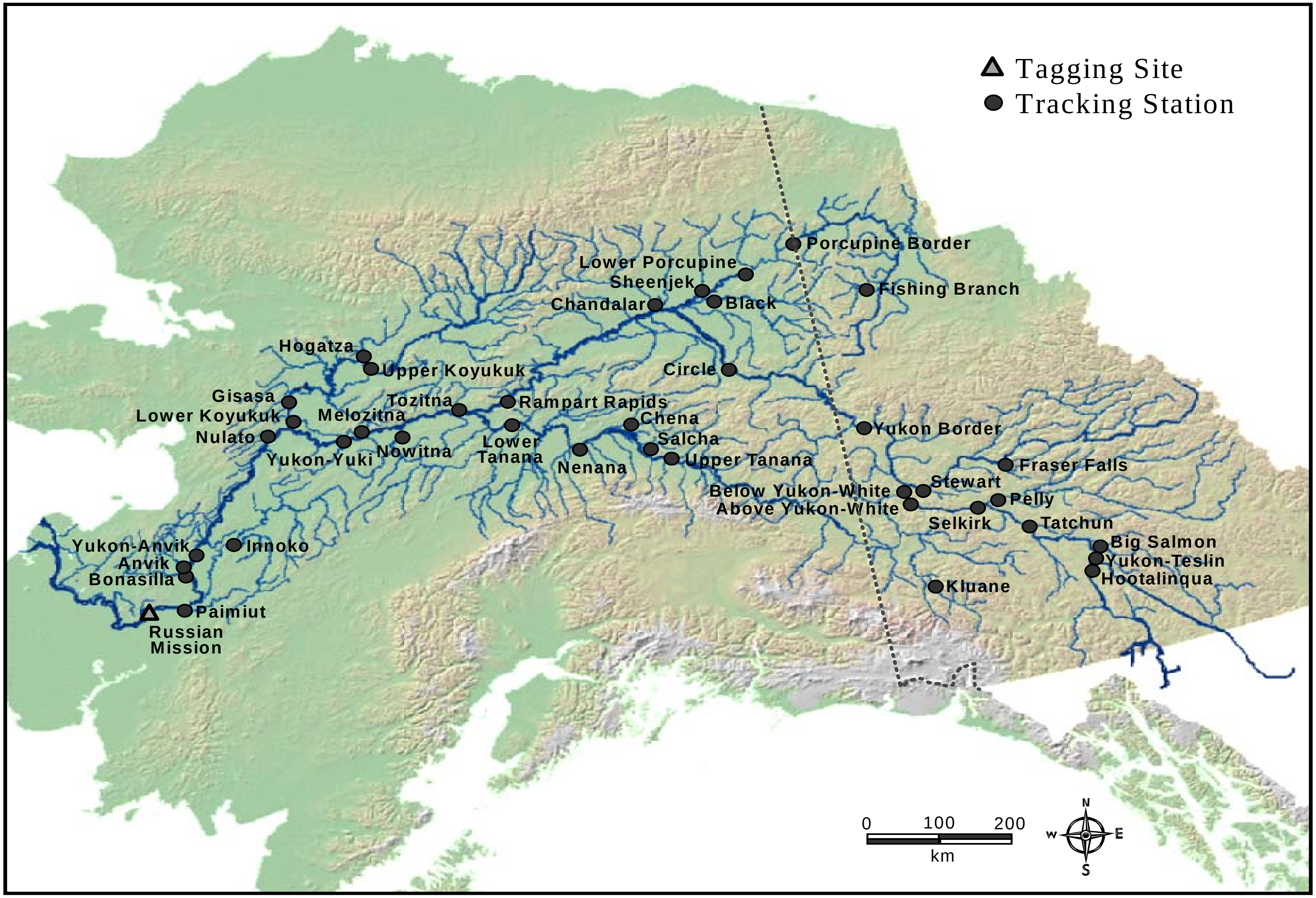


Figure 2.–Yukon River basin showing the location of remote tracking stations used to track the upriver movements of radiotagged Chinook salmon.

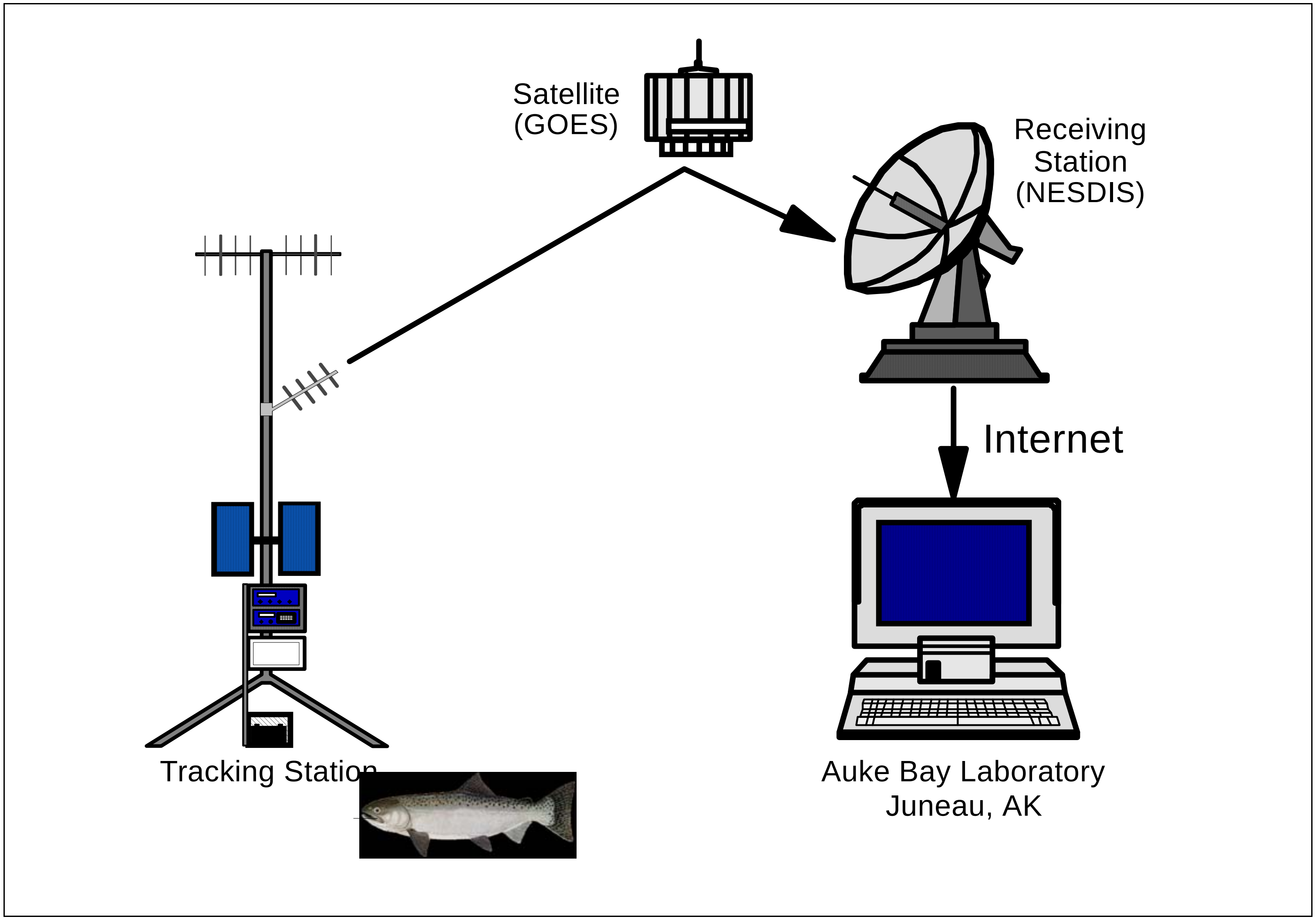


Figure 3.–Remote tracking station and satellite uplink diagram used to collect and access movement information of Chinook salmon in the Yukon River basin.

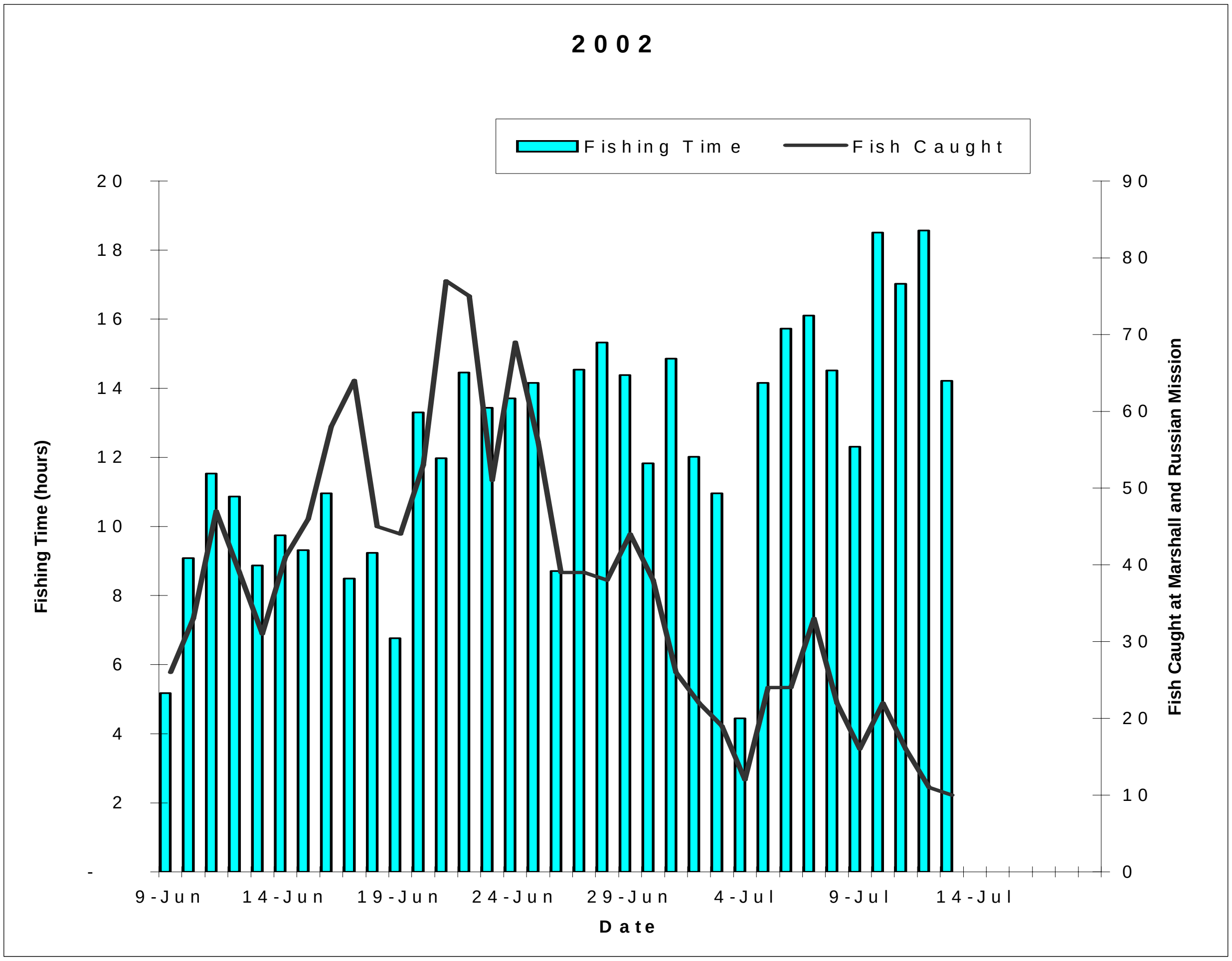


Figure 4.–Daily numbers of Chinook salmon caught at Marshall and Russian Mission, and the number of hours fished per day.

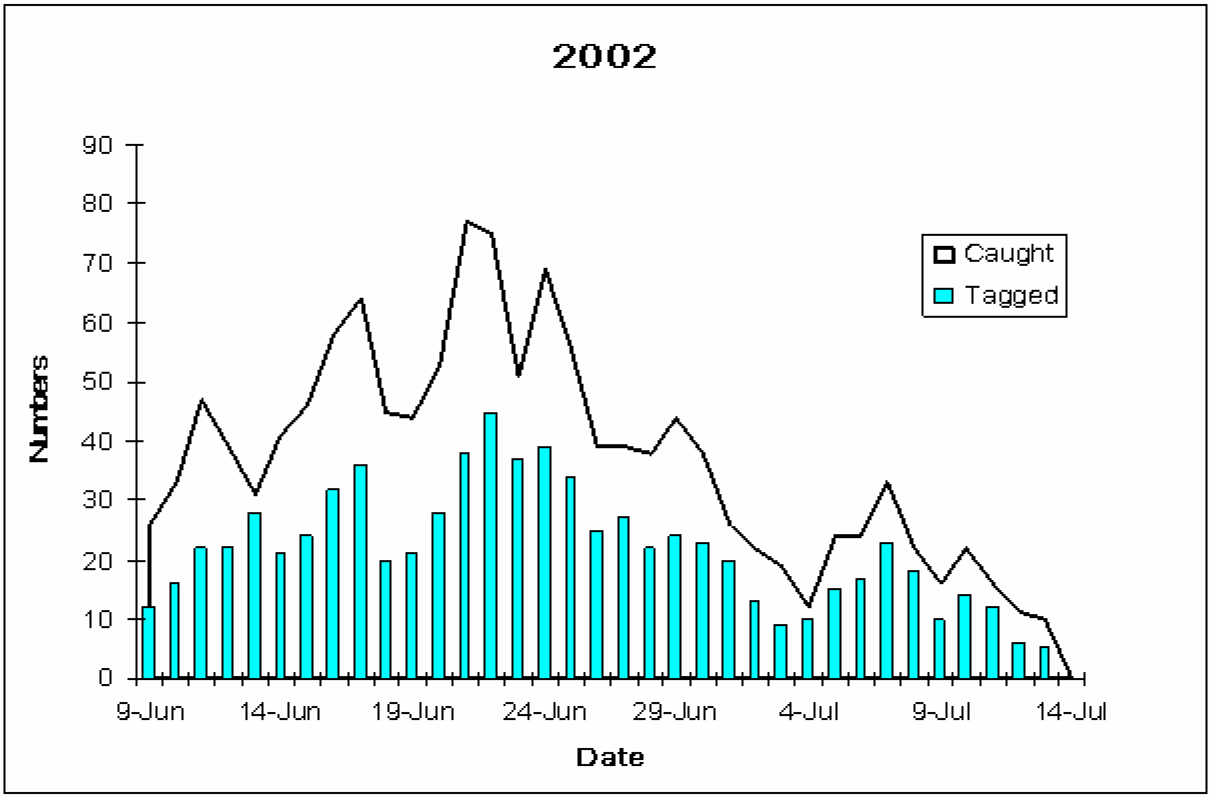


Figure 5.–Daily numbers of Chinook salmon caught and marked at Marshall and Russian Mission.

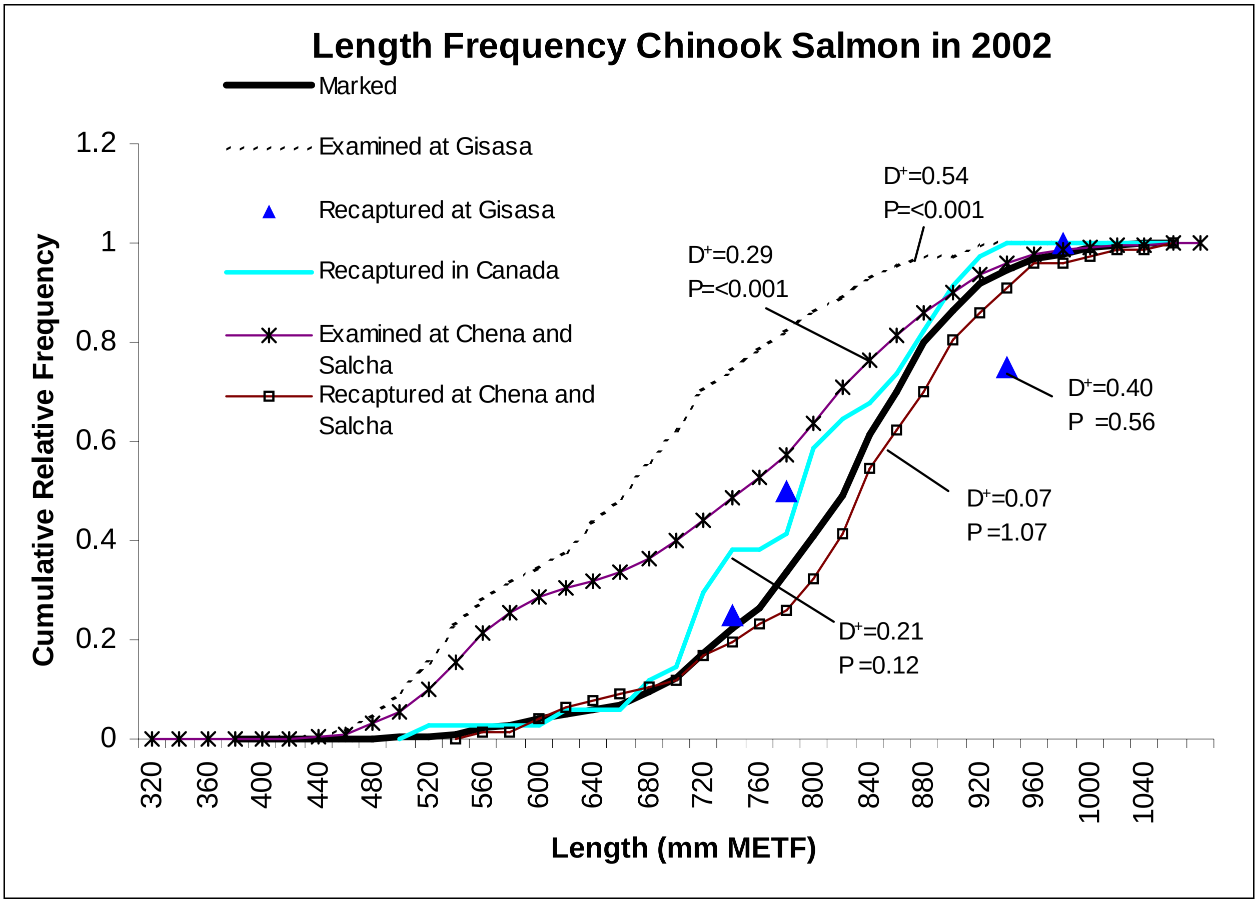


Figure 6.–Cumulative relative length frequencies of Chinook salmon marked at Marshall and Russian Mission in 2002 compared with examined and recaptured fish during sampling in Yukon River recovery projects.

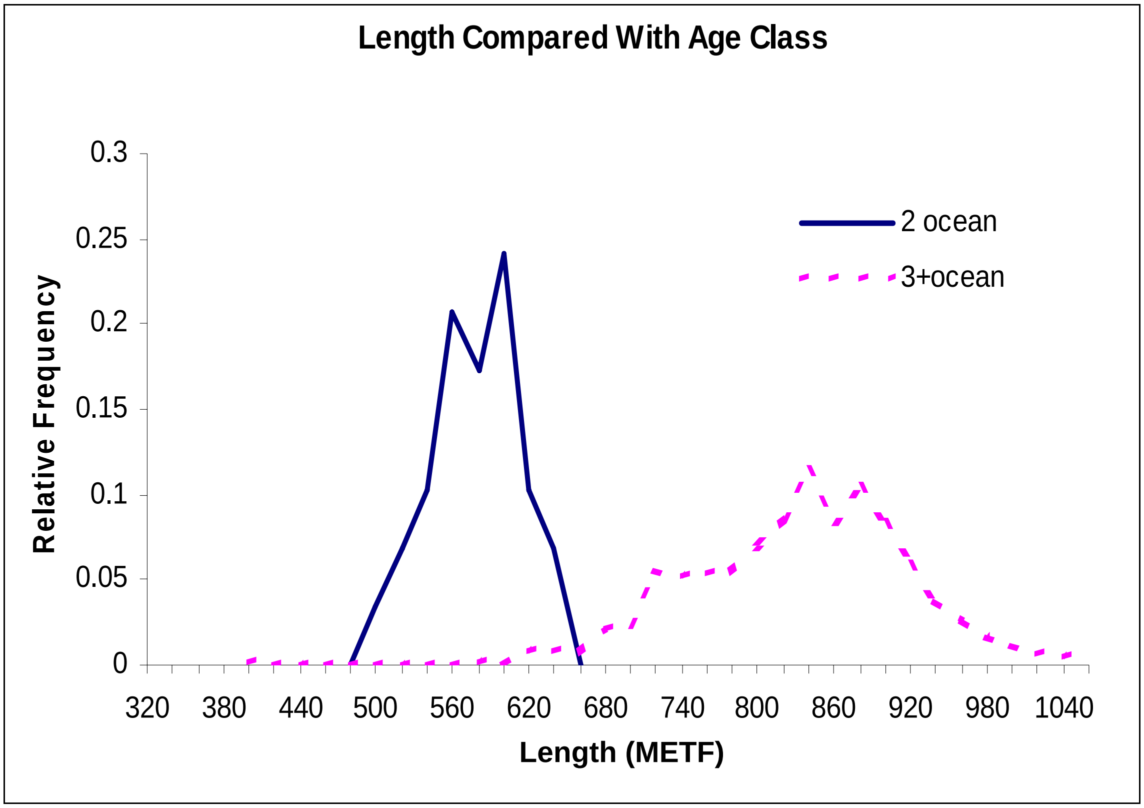


Figure 7.–Relative length frequency (METF), of 2 ocean and 3+ ocean age class Chinook salmon radio tagged at Marshall and Russian Mission in 2002.

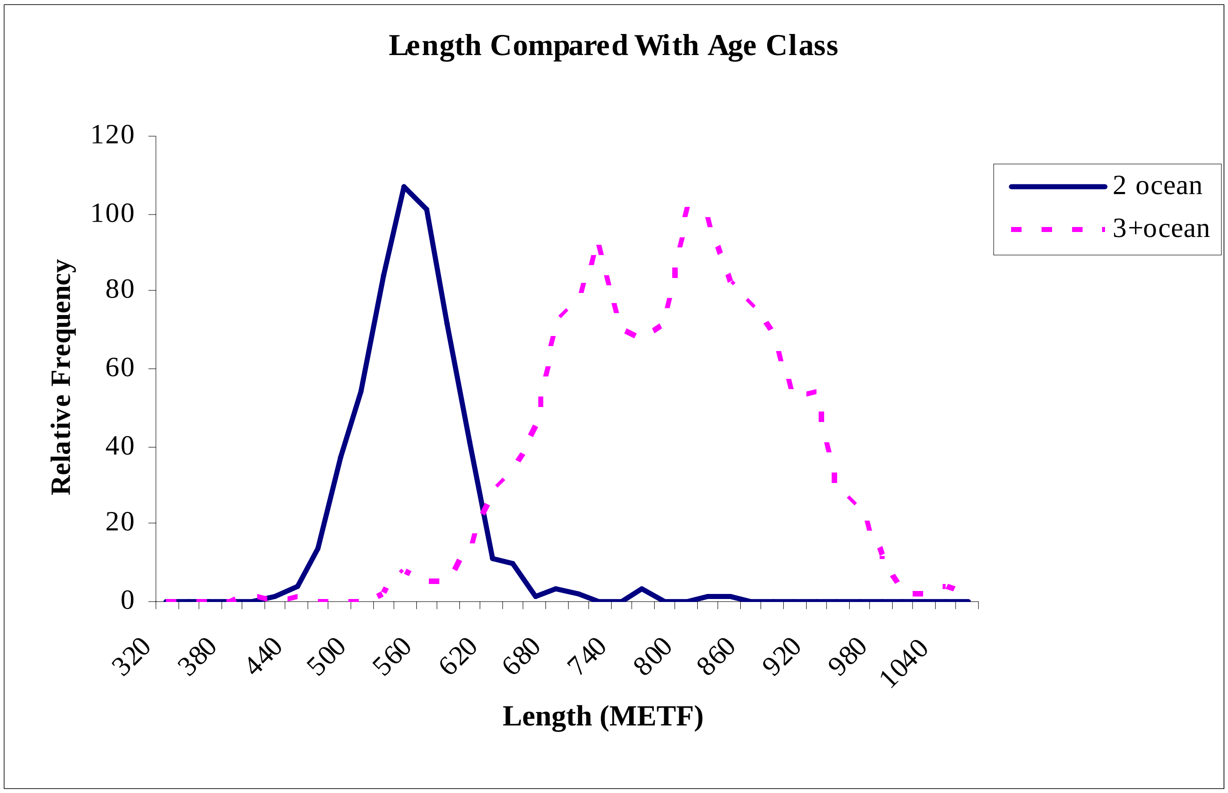


Figure 8.–Relative length frequency (METF), of 2 ocean and 3+ ocean age class Chinook salmon from recovery projects in 2002.

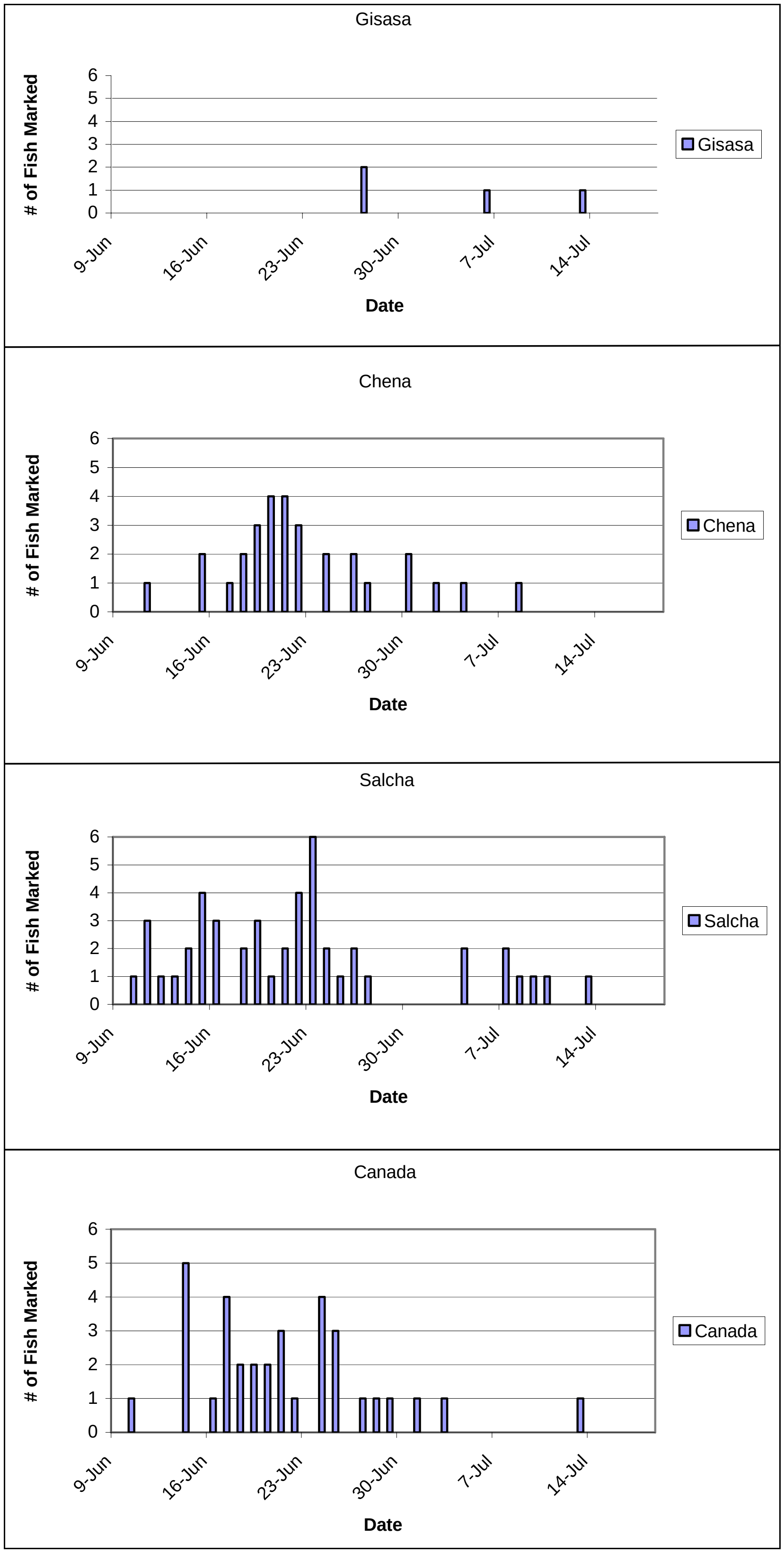
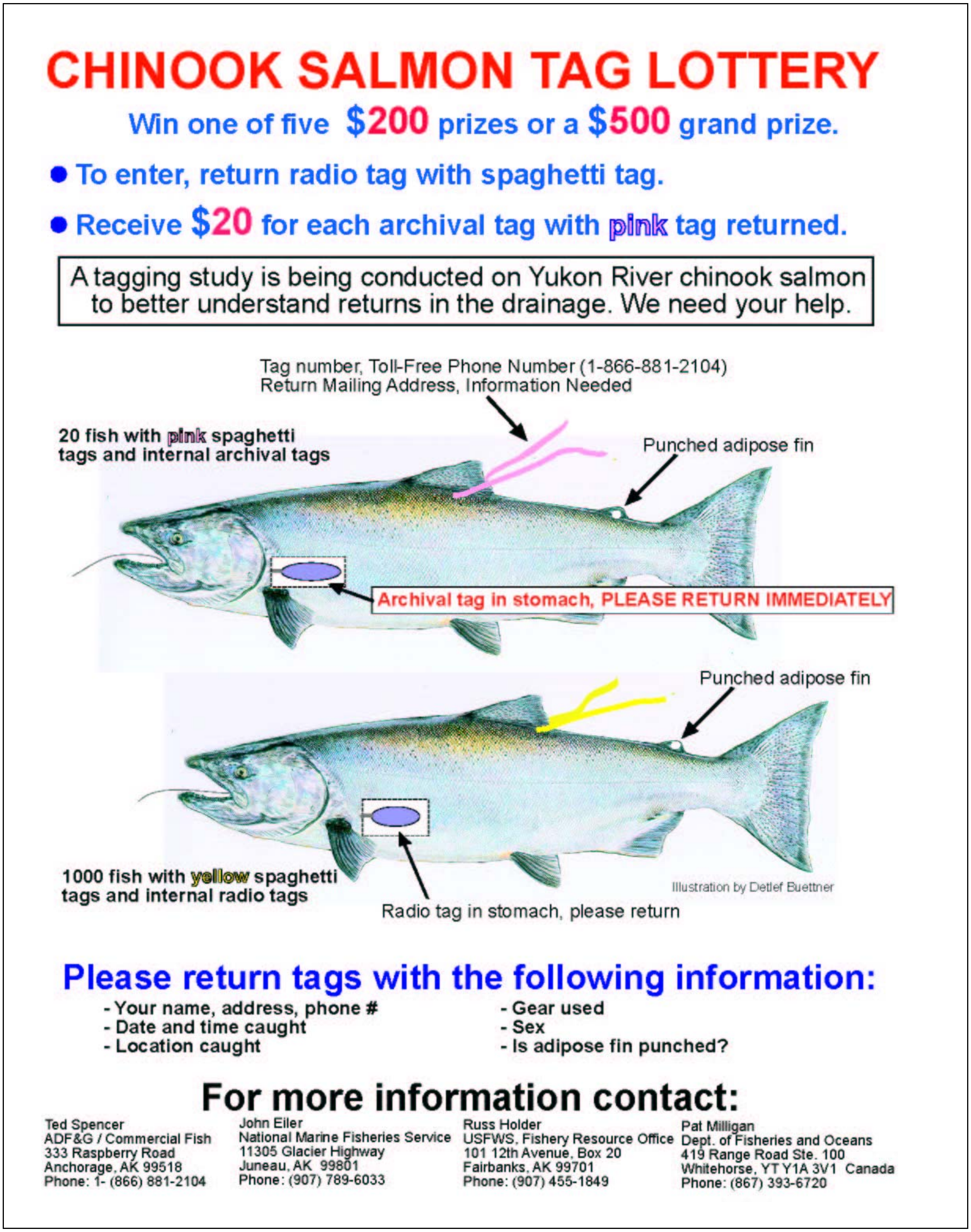


Figure 9.–Timing of marked fish passing Russian Mission destined for recovery projects in 2002.

APPENDIX A. TAG RETURN POSTER

Appendix A1.–Tag return poster used in 2002 to contact and inform fishers and other resource agencies about the project and to encourage tag returns.



APPENDIX B. POSTSEASON PROJECT LETTER

Appendix B1.–Letter sent postseason to fishers and agencies that recovered tags in 2002.

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

COMMERCIAL FISHERIES DIVISION

TONY KNOWLES, GOVERNOR

333 Raspberry Rd.
Anchorage, AK 99518
PHONE: (907) 267-2804
FAX: (907) 267-2442

December 5, 2002

Dear:

We greatly appreciate your cooperation in providing information about the tagged Yukon River Chinook salmon that you caught this past summer. This was the third season of a cooperative radiotelemetry program conducted by the Alaska Department of Fish and Game and the National Marine Fisheries Service. In June and July, 1,310 Yukon River Chinook salmon were captured in drift gillnets near the villages of Marshall and Russian Mission. Of these fish, 768 were marked with spaghetti tags and radio transmitters. The Chinook salmon were tracked upriver using radiotelemetry, and 220 Chinook salmon tags were recovered and reported by volunteers like you.

The following table shows information about the tag(s) that you returned: (If any of the recovery information is incorrect, please let us know.)

Tag Number	Date Tagged	Place Tagged	Date Caught	Place Caught	Days Traveled	Miles Traveled	Mi. per Day
486	7/	Russian Mission	8/1/2002	Allakaket 1 mi below Allakaket	26	728	28

We selected the tag return reward lottery winners and congratulations go to the following people:

$500 Grand Prize - Justin Esmailka, Kaltag

$200 Week 1 Prize - Bergen Demientieff, Holy Cross

$200 Week 2 Prize - Angie Buell, Kaltag

$200 Week 3 Prize - Irene Kangas, Bishop Rock

$200 Week 4 Prize - Peggy Wright, Rampart

$200 Week 5 Prize - Bruce Taylor, Dawson City

Thank you for your participation this past summer and we look forward to continuing this salmon investigation with your help. If you have any questions, please give one of us a call.

Sincerely,

Ted Spencer
Alaska Department of Fish and Game
Biologist
Telephone: (907) 267-2804

John Eiler
National Marine Fisheries Service
Fishery Research Biologist
Telephone: (907)789-6033

APPENDIX C. RADIO TAGS

Appendix C1.–Daily catch and tagging summaries from the Russian Mission and Marshall tagging sites, 2002.

	Russian Mission [a]								Marshall [b]							
	Chinook Salmon								Chinook Salmon							
		Tagged		Not Tagged						Tagged		Not Tagged				
Date	Caught	Radio tagged	Recap.	Mort.	Released Alive	Chum Salmon	Other Fish	Hours Fished	Caught	Radio tagged	Recap.	Mort.	Released Alive	Chum Salmon	Other Fish	Hours Fished
9-Jun	12	7	1	0	3	2	4	2.0	14	5	0	1	8	2	0	3.2
10-Jun	18	10	0	0	7	2	0	3.2	15	6	0	0	9	6	0	5.9
11-Jun	34	16	0	0	17	1	0	3.2	13	6	0	1	7	1	0	8.3
12-Jun	16	10	0	0	4	6	0	3.5	23	12	0	0	8	4	2	7.4
13-Jun	14	12	0	0	3	4	0	3.3	17	16	1	0	3	0	0	5.6
14-Jun	26	16	0	0	10	1	0	2.7	15	5	1	1	8	3	0	7.1
15-Jun	14	10	0	0	5	3	0	3.2	32	14	0	1	16	12	0	6.2
16-Jun	19	10	0	1	6	3	0	4.1	39	22	0	0	14	32	0	5.7
17-Jun	30	16	0	2	14	17	0	2.7	34	20	0	0	14	56	1	5.4
18-Jun	26	15	0	0	11	31	1	2.9	19	5	0	0	14	23	2	7.0
19-Jun	18	9	0	2	5	21	1	3.8	26	12	0	0	14	9	0	3.0
20-Jun	39	23	0	3	14	46	0	6.4	14	5	0	0	8	12	0	6.7
21-Jun	47	26	0	3	16	45	0	6.1	30	12	0	0	19	19	0	6.2
22-Jun	48	29	0	0	19	25	1	6.6	27	16	0	0	10	15	0	7.3
23-Jun	29	23	0	1	7	29	0	7.0	22	14	0	2	8	11	0	6.9
24-Jun	31	21	1	2	7	45	1	8.4	38	18	0	0	22	20	0	5.5
25-Jun	30	17	0	0	14	74	0	8.4	26	17	0	0	8	61	0	5.8
26-Jun	26	18	0	0	8	34	0	6.5	13	7	0	0	6	10	0	2.2
27-Jun	23	17	0	0	6	38	0	8.1	16	10	0	0	6	20	0	6.4
28-Jun	24	17	0	0	6	71	0	8.5	14	5	0	1	8	22	0	6.9
29-Jun	22	16	0	0	6	65	0	8.3	22	8	0	0	14	8	0	6.1
30-Jun	23	13	3	0	7	65	0	7.8	15	10	0	1	4	4	0	4.0
1-Jul	26	20	0	0	6	52	0	8.4	0	0	0	0	0	1	0	6.1
2-Jul	7	7	0	0	0	12	0	5.0	15	6	0	0	9	10	0	7.0
3-Jul	6	3	0	0	4	1	0	3.9	13	6	0	1	5	14	0	7.1
4-Jul	12	10	0	0	2	2	0	4.4				Did not fish				
5-Jul	17	9	0	1	6	21	0	11.5	7	6	0	0	0	3	0	2.7
6-Jul	22	15	0	1	6	28	0	11.9	2	2	0	0	0	5	0	3.8
7-Jul	26	19	1	0	7	39	0	11.7	7	4	0	0	3	9	0	4.4
8-Jul	20	16	1	0	3	10	0	10.6	2	2	0	0	1	0	0	4.0
9-Jul	14	8	0	2	4	10	0	8.8	2	2	0	0	0	1	0	3.4
10-Jul	19	12	1	0	5	12	0	13.2	3	2	0	0	0	1	0	5.3
11-Jul	14	10	0	0	5	5	1	13.0	2	2	0	0	1	2	1	4.0
12-Jul	9	4	1	0	4	5	0	14.8	2	2	0	0	0	5	0	3.8
13-Jul	10	5	0	0	5	7	1	13.3	0	0	0	0	0	1	0	1.0
Site Total	771	489	9	18	252	832	10	247.7	539	279	2	9	247	402	6	181.0
Project Total	1,310	768	11	27	499	1,234	16	428.7								

Note: Mort. = mortalities, Recap. = recaptured.

[a] Two crews fished at the Russian Mission site 20 June to 13 July.

[b] One crew fished at the Marshall site 5 July to 13 July.

Appendix C2.–Status of radiotagged sample of Yukon River Chinook salmon during the 2002 spawning migration (in numbers of fish).

	Mainstem			Tributary		
Location	**Estimated Passed [a]**	**Fished [b]**	**Unknown [c]**	**Passed [d]**	**Fished [b]**	**Unknown [c]**
Released	**768**		17			
Marshall		16				
Russian Mission		7				
MS-Paimiut			9			
Total	**719**					
MS-Holy Cross		39				
Total	**680**					
Lower Basin Tributaries						
Bonasila River				10		
Anvik River		9		34		
Innoko				5		
Total	**622**					
Above Anvik						
MS-Above Anvik			13			
MS-Grayling		10				
MS-Kaltag		23				
Nulato River		12		20		
Total	**544**					
Koyukuk River						
Lower Koyukuk						
Gisasa				4		
Kateel				1		
Hogatza						
Henshaw						
Upper Koyukuk				5	1	
Total	**533**					
MS Above Koyukuk						
MS-Galena		13				
MS-Yuki		2	9			
MS-Ruby		5				
Total	**504**					
Mid River Tributaries						
Melozitna River				1		
Nowitna River				1		
Tozitna River				7		
MS-down river Tanana		1				
Total	**494**					
Tanana River						1
Kantishna River				8		
Tolovana River				1	1	
Nenana River						
MS-Nenana					7	4
Fairbanks					2	
Chena River				29	1	
Clear Creek						
Salcha River				46	1	
Upper Tanana						1
Goodpaster				16		
Total	**376**					

-continued-

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	Mainstem			Tributary		
Location	**Estimated Passed [a]**	**Fished [b]**	**Unknown [c]**	**Passed [d]**	**Fished [b]**	**Unknown [c]**
Above Tanana						
MS-Tanana		4				
MS-Yukon Raven		2	24			
MS-Rapids		18				
MS-Rampart		11				
MS-Above Rapids		2				
Hess Creek		3				
MS-Bridge		10				
MS-Stevens Village		1				
Beaver Creek		4		1		
Chandalar River				19	1	
Total	**276**					
Porcupine River						
Sheenjek				12		
Black				2		
Lower Porcupine						3
Porcupine Border						6
Old Crow					1	
Fishing Branch				0		
Miner				2		
Total	**250**					
Above Porcupine						
MS-Rapids to Circle						
MS-Fort Yukon		14				
MS-Circle		6	3			
MS-Yukon Circle						
Charley				2		
Kandik				1		
MS-Eagle		9				
Total	**215**					
Canadian Yukon						
MS Yukon Border		1	2			
MS Forty Mile		1	5			
Chandindu River				1		
MS-Dawson City		13				
Klondike River				6		
Stewart River				20	1	
MS-White			5			
White River				8		
MS-Pelly (Selkirk)			19			
PellyRiver				25	7	
Minto Landing		1				
MS-Tatchun			23			
Tatchun River				3	1	
MS-Carmacks		8				
Nordensk River				2		
Little Salmon River				2		
Big Salmon River				17		
Teslin River			1	36		
MS-Whitehorse		1				
S-Hootalinqua			6			
Total	**0**					

Note: MS = Yukon River mainstem location.

[a] Number of radio tags in river.

[b] Fish caught in fisheries.

[c] Unknown fate: died, went to unsurveyed small tributaries, unreported fisheries, tagging or tag-malfunctions.

[d] Number of radio tags recorded inriver.

APPENDIX D. CPUE INFORMATION

Appendix D1.–CPUE information from the Marshall tagging site in 2002.

Date	No. Chinook Salmon	Minuets Fished	Total Sum of Net Length	CPUE
9-Jun-02	14	193	275	1.58
10-Jun-02	15	353	550	0.46
11-Jun-02	13	500	525	0.30
12-Jun-02	23	444	475	0.65
13-Jun-02	17	334.5	600	0.51
14-Jun-02	15	425.5	475	0.45
15-Jun-02	32	370	650	0.80
16-Jun-02	39	342	850	0.80
17-Jun-02	34	322	825	0.77
18-Jun-02	19	421	600	0.45
19-Jun-02	26	179.5	425	2.04
20-Jun-02	14	400.5	575	0.36
21-Jun-02	30	369	650	0.75
22-Jun-02	27	439	600	0.62
23-Jun-02	22	411.5	575	0.56
24-Jun-02	38	330	675	1.02
25-Jun-02	26	345	725	0.62
26-Jun-02	13	133.5	225	2.60
27-Jun-02	16	386.5	525	0.47
28-Jun-02	14	412	675	0.30
29-Jun-02	22	365	575	0.63
30-Jun-02	15	239	400	0.94
1-Jul-02	0	388.5	325	0.00
2-Jul-02	15	419	550	0.39
3-Jul-02	12	425	450	0.38
4-Jul-02				
5-Jul-02	7	162	200	1.30
6-Jul-02	2	227	350	0.15
7-Jul-02	7	262.5	350	0.46
8-Jul-02	2	238	250	0.20
9-Jul-02	2	212	150	0.38
10-Jul-02	3	318	175	0.32
11-Jul-02	2	239	225	0.22
12-Jul-02	2	227.5	225	0.23
13-Jul-02	0	58	50	0.00

Note: CPUE information unavailable for one fish. The project was not operational on July 4.

Appendix D2.–CPUE information from the Russian Mission tagging site in 2002.

Date	No. Chinook Salmon	Minutes Fished	Total Sum of Net Length	CPUE
9-Jun-02	12	117.5	325	1.89
10-Jun-02	18	192	500	1.13
11-Jun-02	34	192	425	2.50
12-Jun-02	16	208	350	1.32
13-Jun-02	14	197.5	325	1.31
14-Jun-02	26	159	425	2.31
15-Jun-02	14	189	400	1.11
16-Jun-02	23	315.5	500	0.87
17-Jun-02	33	187.5	400	2.64
18-Jun-02	18	133	350	2.32
19-Jun-02	18	226.5	550	0.87
20-Jun-02	39	397.5	1,000	0.59
21-Jun-02	47	349.5	750	1.08
22-Jun-02	50	428.5	800	0.88
23-Jun-02	29	394.5	775	0.57
24-Jun-02	29	492.5	850	0.42
25-Jun-02	30	504.5	925	0.39
26-Jun-02	26	389	750	0.53
27-Jun-02	23	486	850	0.33
28-Jun-02	24	507.5	900	0.32
29-Jun-02	22	498	775	0.34
30-Jun-02	23	470.5	775	0.38
1-Jul-02	26	503	825	0.38
2-Jul-02	7	302	500	0.28
3-Jul-02	7	232.5	375	0.48
4-Jul-02	12	266.5	500	0.54
5-Jul-02	17	687.5	1,025	0.14
6-Jul-02	22	716.5	1,075	0.17
7-Jul-02	26	704	1,050	0.21
8-Jul-02	20	633	1,013	0.19
9-Jul-02	14	526.5	925	0.17
10-Jul-02	19	792.5	1,325	0.11
11-Jul-02	14	782.5	1,300	0.08
12-Jul-02	9	886.5	1,300	0.05
13-Jul-02	9	795	1,175	0.06

Note: CPUE information unavailable for one fish.