Fishery Data Series No. 07-30

Mark–Recapture Abundance Estimates for Yukon River Chinook Salmon in 2004

by

Ted R. Spencer,

Toshihide Hamazaki,

and

John H. Eiler

May 2007

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

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	METF
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. 07-30

MARK-RECAPTURE ABUNDANCE ESTIMATES FOR YUKON RIVER CHINOOK SALMON IN 2004

by
Ted R. Spencer and Toshihide Hamazaki,
Alaska Department of Fish and Game, Division of Commercial Fisheries, Anchorage

and

John H. Eiler
National Marine Fisheries Service, Auke Bay Laboratory, Juneau

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska 99518

May 2007

This investigation was partially financed by the U.S./Canada Treaty Implementation, Office of Subsistence Management FIS-04-231, Yukon River Treaty Restoration & Enhancement Fund URE 03-04, URE 01-04, URE 18N-04, and U.S./Canada Yukon River Salmon Agreement Studies under Project NA06FP0075.

The Division of Sport Fish Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Since 2004, the Division of Commercial Fisheries has also used the Fishery Data Series. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

Ted R. Spencer and Toshihide Hamazaki
Alaska Department of Fish and Game, Division of Commercial Fisheries,
333 Raspberry Road, Anchorage, Alaska, 99518, USA

and

John H. Eiler
National Marine Fisheries Service, Auke Bay Laboratory,
11305 Glacier Highway, Juneau, Alaska, 99801, USA

This document should be cited as:
Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2007. Mark-recapture abundance estimates for Yukon River Chinook salmon in 2004. Alaska Department of Fish and Game, Fishery Data Series No. 07-30, Anchorage.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Abundance of adult Chinook salmon *Oncorhynchus tshawytscha* passing by the village of Russian Mission was estimated in 2004 as part of a radiotelemetry study on the Yukon River. Drift gillnets were used to capture 2,107 salmon at Russian Mission, 995 of which were marked with plastic spaghetti tags and esophageal radio transmitters. Marked fish were tracked upstream to spawning grounds. Chapman's modification of Petersen's closed-population, two-event mark–recapture experiment was used to estimate abundance. The second sampling event consisted of salmon spawning in select locations or caught in select fisheries representing populations that returned early (bound for Canada), late (bound for the Koyukuk River), and mid run (bound for the Tanana River). Of the 38,369 salmon involved in the second event, 159 carried transmitters for an estimated abundance of 229,739. Diagnostic testing showed this estimate to be consistent. Bootstrap simulation was used to estimate the variance (SE=16,682).

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

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha*, is 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 on the Yukon River to maintain adequate spawning escapements and to provide harvest opportunities**.** The interim escapement objective into Canada for Chinook salmon is 33,000 to 43,000 fish as per the Yukon River Salmon Treaty agreement between the U.S. and Canada. The targeted escapement goal varies by years and is set by the Yukon River Panel. The 2004 target was 28,000 Chinook salmon into Canada and a harvest range of 20–26% of the total allowable catch (TAC) is allocated to Canada when the TAC is between 0 and 110,000 Chinook salmon (JTC 2005).

A variety of methods have been used to assess adult abundance in various tributaries since 1961, including counting weirs (Gisasa River, Kateel River, Tozitna River, Henshaw Creek, 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 estimated or assessed abundance in specific tributaries, the size of the entire run is unknown. Tagging studies using external marks were conducted 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 because of extensive commercial harvests that substantially reduced marked populations. Subsequent studies were moved upriver near Russian Mission (mile 185–251) to mitigate these problems, but insufficient numbers of fish were marked 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 has been indexed with sonar located at Pilot Station since 1986.

The Alaska Department of Fish and Game (ADF&G) and National Marine Fisheries Service (NMFS) have implemented a cooperative radiotelemetry and mark–recapture study to provide information on the stock composition, spawning distribution, run timing, migratory characteristics (Eiler et al. 2004; 2006a; 2006b), and to estimate drainage-wide abundance (Spencer et al. 2003; 2005; 2006) of adult Chinook salmon in the Yukon River. In 2004, abundance of adult salmon passing upstream of Russian Mission into the majority of the Yukon River drainage was estimated with a mark–recapture experiment. This report is a description of that experiment: the methods used, the results obtained, and the testing of assumptions underlying the experiment.

METHODS

FIRST SAMPLING EVENT: FISH CAPTURE AND MARKING

Adult Chinook salmon were captured and marked near the village of 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. (2006b). 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 3, and ended 19 July. Fishing was conducted daily during the day (0900–1700 hours) and the evening (1800–0200 hours); each period was 7.5 hours in duration (plus a 30 minute break). Drift gillnets used 8.5-in mesh constructed with # 21 seine twine (length 46 m, depth 7.6 m, with a hang ratio of 2:1) to capture fish. These larger mesh nets proved effective in capturing the target species with minimum injuries, and with less bycatch of other fish species. Gillnets were fished parallel to the shore and from the surface to the bottom of the river when possible.

During a drift, the net was retrieved as soon as a captured fish was detected. The first Chinook salmon encountered in the still immersed net was removed; the net was cut away if needed to facilitate quick removal. The captured fish was guided into a dip net constructed of soft, small mesh netting, then hoisted immediately into a holding container of fresh water on the boat. The holding container was equipped with a pump circulating fresh river water. If a second or third Chinook salmon was encountered, they too were placed in the holding tank following the same procedures. Any fish remaining in the gill net were released. Crew members, wearing neoprene gloves or with bare hands, carefully examined each retained fish in a submerged neoprene-lined tagging cradle. If visual inspection showed 2 of the fish in the holding tank free of injury, infection, or infestation, they were selected as test subjects and the third fish was released unmarked. If only 1 fish in the tank appeared free of injury, infection, or infestation, it was selected as the test subject and the other 2 were released unmarked. If no fish appeared free of injury, infection, or infestation, no test subject was selected from the tank and all fish were released unmarked. The marked 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, and old major).

Each marked 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. The axillary process was retained for genetic analysis.

Of the 2,107 Chinook salmon caught at Russian Mission, 995 were fitted with pulse-coded radio transmitters in the 150 MHz frequency range (Advanced Telemetry Systems, Isanti, Minnesota). Transmitters were 2.0 cm in diameter, 5.4 cm in length, and weighed 20 g. The transmitter was

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

inserted through the mouth and into the stomach using a plastic tube (0.7 cm diameter) until the transmitter was no longer visible. During the insertion, the fish was not anesthetized. The fish was immediately released after processing. These 995 fish were treated as marked individuals in the mark–recapture experiment.

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 transmitters, and recorded the signal strength, activity pattern (active or inactive), date, time, and location 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. Transmitters that passed the first set of tracking stations, located approximately 62 km upriver from Russian Mission at Paimiut, were considered to have resumed upriver movement. Fish tracked to terminal reaches of the drainage were classified as belonging to distinct spawning stocks. Marked individuals 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 the internet and downloaded into an automated database and GIS mapping program (Eiler and Masters 2000).

Aerial surveys to detect transmitters were flown using helicopter and fixed-wing aircraft equipped with a computer-controlled receiver and four-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 10 km below Russian Mission to the Canadian border and in other selected reaches of the drainage to locate marked individuals that traveled to areas between stations and upriver of stations on terminal tributaries. Fish 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.

SECOND (UPSTREAM) SAMPLING EVENT: TAG RECOVERIES

Commercial and subsistence fishers were encouraged to report any marked fish they had captured and several steps were taken to facilitate this voluntary return of the transmitters and tags. Information about the importance of returning transmitters and 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 transmitter and tag with information about the fish (Appendix B1). A postseason lottery was conducted as an added incentive to return transmitters and 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 transmitters and tags) prizes. Voluntary returns were important in determining the fate of “unknown” fish for distribution information.

Chinook salmon “examined” for marks as part of the second sampling event in the mark-recapture experiment were those passing through a weir in the Gisasa River, passing by a tower on the Salcha River, passing through the flood control dam on the Chena River, and those caught in subsistence fisheries in Canada (Figure 1). Passage up the Gisasa River was a complete count, an expanded estimate from subsampling hours at the Salcha and Chena rivers, and a complete tally of harvest in the Canadian fishery. Because estimated variance of passage for salmon in the Salcha and Chena rivers from subsampling proved negligible in 2004 (CV < 5%; JTC 2005), these expanded estimates of passage were considered to be measured without error. Relative length and relative age compositions of these "inspected fish" were estimated by sampling systematically at the weirs, the fish wheel, and by sampling carcasses in the Anvik, Salcha, and Chena rivers. This information was then downloaded into a database (H. Krenz, Commercial Fisheries Analyst/Programmer, ADF&G, Anchorage; personal communication). "Recaptured" fish in the experiment corresponded to transmitters known to have passed upstream of the weir, the tower, the dam, or to have been recovered from the harvest in the Canadian fishery.

DATA ANALYSIS

Mark–Recapture Population Estimation

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

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

where:

$\hat{N}$ = estimated abundance passing upstream of Russian Mission,
M = the number marked that successfully went upstream of Russian Mission,
C = number of fish "inspected" during the second event, and
R = the number of marked fish recaptured among fish "inspected" upstream in the Gisasa, Chena, and Salcha rivers, and in the Canadian subsistence fishery.

Due to the large-mesh gillnets used at Russian Mission, very few small fish (<520 mm METF) were caught and marked (0.1%) and less than 2% of fish sampled upstream were small fish (<520 mm METF). For this reason, abundance was directly estimated for fish ≥520 mm METF only by censoring those few small fish captured in the two events of the experiment.

Variance and statistical bias in the estimator above were estimated with a parametric bootstrap simulation (Efron and Tibshirani 1993) based on 1,000 replications of the mark–recapture experiments. Confidence intervals were calculated with the percentile method from bootstrap replications. The 995 salmon fitted with transmitters had one of the following eight fates:

	Fate	X:
1	Disappeared (M' - M)	37
2	Moved upstream to Tanana, but not to Salcha or Chena rivers	97
3	Moved upstream to remain in U.S tributary, but not in Tanana River	470
4	Moved upstream to Canada, but not inspected	231
5	Moved upstream through weir on the Gisasa River (R_1)	8
6	Moved upstream past towers on the Salcha River (R_2)	68
7	Moved upstream over dam on the Chena River (R_3)	30
8	Were caught in Canadian subsistence fishery (R_4)	53

The numbers of fish sharing the same fates arose from the multinomial density function with parameters M', $\pi_1,\ldots\pi_8$ where π_i is the probability that a marked fish would have the *i*th fate. A thousand simulated vectors $\{X_1^*,\ldots X_8^*\}$ were each drawn randomly from the analogous multinomial empirical density function with parameters $M', \hat{\pi}_1,\ldots\hat{\pi}_8$ where $\hat{\pi}_i = X_i / M'$. The number of marked fish in the simulation (M') was treated as fixed at 995 because a finite number of transmitters were available. A thousand simulation estimates $\hat{C}_k^*$ for numbers of fish "examined" at upstream location *k* were drawn randomly from a binomial empirical density function with parameters n_k (the sample size of the sampling program at site *k*). An estimate of abundance was calculated for each set of replications such that:

$$N_{(b)}^* = \frac{(M_{(b)}^* + 1)(C+1)}{R_{(b)}^*} - 1 \tag{2}$$

where:

$M_{(b)}^* = M' - X_{1(b)}^*$,

$C = C_{Gis} + C_{Sal} + C_{Che} + C_{Can}$,

$R_{(b)}^* = \Sigma_{i=5}^{8} X_{i(b)}^*$, and

b = denotes the simulation.

Estimated variance and estimated relative statistical bias were approximated as:

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

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

where:

B = 1,000, and

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

Passage into Canada and passage into the Tanana River were estimated separately with two methods based on marked fish. If capture at Russian Mission 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 that passage that reached Canada (or the Tanana River). Given the fates listed in the intext table above, estimated abundance of fish moving up the Tanana River ($\hat{N}_{Tan}$) or into Canada ($\hat{N}_{Can}$) were calculated as

$$\hat{N}_{Tan} = \frac{X_2 + X_6 + X_7}{M' - X_1} \hat{N}$$

$$\hat{N}_{Can} = \frac{X_4 + X_8}{M' - X_1} \hat{N} \tag{5}$$

as per Chapman's modification in this "proportional" experiment.

The second method is based on two-event mark–recapture experiments 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). Again using fates listed in the intext table above:

$$\hat{N}_{Tan} = \frac{(X_2 + X_6 + X_7 + 1)(C_{Sal} + C_{Che} + 1)}{X_6 + X_7 + 1} - 1$$
(6) (6)
$$\hat{N}_{Can} = \frac{(X_4 + X_8 + 1)(C_{Can} + 1)}{X_8 + 1} - 1$$

for this "local" experiment.Variances and statistical biases in these competing estimates were calculated as part of parametric bootstrap simulations.

Tests of Mark–Recapture Assumptions

The Chapman closed population estimator will produce consistent (asymptotically unbiased) estimates of abundance if the following conditions have been met:

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;
c) Marked fish do not lose their marks and all marks are recognized; and
d) 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 sampling events.

Condition (a) was met because every fish above Russian Mission in the Yukon drainage must have passed Russian Mission and tracking information indicated that few fish migrated down river and they were not used in the analysis. Almost all test subjects were successfully tracked upstream (Eiler et al. 2006b), which indicates that condition (b) was met as well. As for condition (c), all transmitters not located moving upstream were censored from the experiment. Because condition (d) relates to space and time, attempts to standardize fishing effort at Russian Mission 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; Eiler et al. 2004; 2006a), marked fractions of inspected fish should be similar across sites in the second sampling event if condition (d) has been met. Because assumption (d) also relates to size of salmon, lengths of captured and recaptured fish were compared to that of marked fish at Russian Mission.

RESULTS

FIRST SAMPLING EVENT: FISH CAPTURE AND MARKING

Gillnets were fished 583 hours to capture 2,107 Chinook salmon at Russian Mission between 3 June and 19 July (Table 1; Figure 4; Appendix C1). Fish were marked throughout the run (Figure 5), with 995 fitted with radio transmitters, 20 fish died, 1,069 fish were released without any marks, and 23 fish were recaptured at Russian Mission (Table 1). Catch per unit effort (CPUE) data are presented in Appendix D1. Most captured fish were age 1.4 (68.4%; Table 2). Mean lengths of marked fish (n=992) were 825 mm (METF) ranging from 395 to 1,060 mm (SD=104).

Second (Upstream) Sampling Event: Tag Recoveries

Marked fish were recaptured 1) at the Russian Mission tagging sites, 2) in upriver escapement monitoring projects, and 3) in U.S. and Canadian fisheries. Above Russian Mission, 231 fish were counted, examined, or recovered (Table 3), however that total includes some fish counted twice in the Chena and Salcha rivers. 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 (332 fish; 33.4%) of all marked Chinook salmon was captured by subsistence fishers (Table 4). From 995 marked fish, 958 fish resumed upriver migration past the gateway stations at Paimiut. Of these 958 fish, the fate of 88 (9.2%) was not determined. Possible causes include mortality, tag malfunction, unreported fishery harvest, or migration to tributaries where aerial surveys were not conducted (Appendix C3). Aerial surveys, flown over villages along the Tanana River and the Yukon River mainstem documented that 84 of the 332 (25.3%) 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.

Mark–Recapture Abundance Estimate

Test of Assumptions

Comparison of size distributions of fish marked downstream and examined or recaptured upstream indicated that all fish upstream had an equal probability of being sampled regardless of their size (Figure 6). Recaptured fish had essentially the same size distribution as marked fish, however, fish examined upstream were decidedly smaller than those captured downstream. This dissimilarity is consistent with the large-mesh gillnets used at Russian Mission which tended to catch larger fish. Considering the large overlap of age-2 fish to age-3+ fish (Figure 7), separation by age was not possible. Also because only 1 small fish was marked, 39 small fish examined, and no small fish recaptured (<520 mm METF), the mark–recapture experiment was used to directly estimate fish ≥520 mm METF. Therefore, from the 958 marked fish that passed the Paimiut stations, 1 small fish was censored for a total of 957 marked fish used in the abundance estimate. Comparison of examined fish upstream across sampling locations showed similar size distributions.

Comparison of marked fractions across sampling locations upstream indicated that all fish regardless of their spawning location had an equal chance of being marked at Russian Mission (Table 5). Fractions ranged from an estimated 0.31% for fish passing the counting tower on the Chena River to an estimated 0.48% for subsistence in Canada. This range was not statistically significant ($\chi^2 = 3.70$, df = 3, P = 0.295). Migratory timing of marked fish showed that early migrants past Russian Mission tended to be bound for Canada, mid-season migrants tended to head for mid-river tributaries, and late migrants tended to go to tributaries just upstream of Russian Mission (Figure 8).

Abundance Estimates

The estimated abundance of Chinook salmon passing upstream of Russian Mission is 229,739 (SE=16,682) and the statistical bias in this statistic is 0.9% as estimated through bootstrapping (Table 6). This estimate was based on 957 marked fish, 38,369 captured fish, and 159 fish recaptured from lower, middle, and upriver locations.

The estimated abundance of salmon passing into the Tanana River is 46,812 (SE=3,254) for the proportional distribution calculation and 50,803 (SE=3,602) for local experiment calculation (statistical bias in these statistic is 0.4% and 0.7%, respectively). Estimated abundance of salmon passing into Canada is 68,178 (SE=5,872) for proportional distribution and 59,415 (SE=7,987) for the local experiment (statistical bias in these statistic is 0.9% and 1.7%, respectively) (Table 6).

A drainage-wide estimate was developed by including 17,542 Chinook salmon for subsistence (including Russian Mission), 52,565 fish for commercial fishing, and 11,531 fish escapement for the Andreafsky River, the only major Chinook salmon tributary below the tagging site at Russian Mission (Busher and Hamazaki 2005; T. Lingnau, ADF&G, Anchorage, personal communication). This results in a drainage-wide estimate of 311,377 Chinook salmon returning in 2004 with a harvest rate of 39.7%.

DISCUSSION

The basin-wide telemetry study on Yukon River Chinook salmon was designed to provide information on stock composition and timing, migration patterns, location of important spawning areas, and an abundance estimate of the return. Different migratory patterns exhibited by stocks as they move past the tagging sites can hinder catching a representative sample of the run. Information from radiotelemetry work in 2004 (Eiler et al. 2006a) showed that Tanana River and upper basin stocks comprised approximately 80% of the return. These groups exhibited similar run timing patterns, with most fish passing through the lower river by 1 July and then declining, while lower basin stocks were comprised primarily of late run fish passing after 25 June. While the upper basin (U.S. and Canadian) component of our tagged fish sample was present throughout the run and comprised the largest component, the timing of marked fish going to recovery projects indicates that sampling bias toward the different stocks can occur if sampling procedures are not done on a consistent basis (Figure 8).

Size-selective sampling with nets, weirs, carcass surveys, fish wheels, and fishways further complicated calculations of a mark–recapture experiment. Marked fish were captured with an 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. Although our use of 8.5-in mesh nets to capture fish for tagging minimized the bycatch of non-targeted species, we were selecting for large fish. However since we did not select marked fish by size, the marked fish are representative of the fish captured at the capture site. 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 (Hubartt and Kissner 1987). Because carcass surveys are a subset of counts and fish wheel data was incomplete or limited, that information was not included in the analysis. 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 and often with incomplete counts. Also, a weir "catches" fish of all sizes with equal probability, but if different stocks exhibit different relative age or size compositions, the stock passing through the weir represent a biased estimate of size composition for all stocks combined. However, since comparison of marked fractions across sampling locations was similar, 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 in that we were better able to assess fates of the marked population. While basin-wide abundance information is critical to effectively manage fisheries for Chinook salmon, obtaining reliable data is extremely difficult due to the remote and logistically challenging nature of the basin and the complex characteristics of the runs. A variety of assessment studies, including Pilot Station sonar in the lower Yukon River and a number of projects in terminal reaches, attempt to provide both basin-wide and regional estimates of abundance, however, the accuracy of these estimates is uncertain. The estimates developed during our study provide a useful comparison with other information from the basin that will help evaluate existing abundance estimates and potentially assist in developing better methods for obtaining reliable data. Information collected in 2002-2004 has improved our understanding of Chinook salmon stock composition and movement patterns within the basin.

ACKNOWLEDGEMENTS

Funding for this study was provided by the U.S.-Canada Yukon River Treaty Implementation Fund, Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative Fund, ADF&G, and NMFS. Support was also provided by 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, J. Baumer, J. Browning, K. DeYong, R. Driscoll, P. Duffy, M. Eisenman, Y. Kakizaki, K. Maledy, C. Mason, and B. Stephanoff. We also thank Gerald Maschmann (USFWS), T. Ferguson and B. Fost (University of Tennessee) and P. Stephanoff for their assistance with field work. Local assistance provided by A. Alexie, P. Alexie, S. Askoak, J. Changsak, J. Duffy, L. Evan, R. Housler, R. James, P. Kozevnikoff, P. Larson, G. Nickoli, M. Nickoli, N. Pitka, W. Pitka, N. Polty, V. Sergie, A. Stephanoff, and B. Stephanoff for invaluable 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 (USFWS), B. Mercer (B. Mercer and Associates), T. Lingnau and P. Salomone (ADF&G), 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. C. Osborne also assisted with the installation and maintenance of tracking stations in Canada. We thank B. Busher, K. Boeck, P. Costello, A. Estes, and K. Nyberg (ADF&G), G. Beyersdorf (USFWS), P. Milligan and M. 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 and J. Hilsinger (ADF&G) provided critical review of this report. We thank J. Hilsinger and G. Sandone (ADF&G), and J. Helle (NMFS) for administrative support during the study.

REFERENCES CITED

Bendock, T., and M. Alexandersdottir. 1993. Hooking mortality of Chinook salmon released in the Kenai River, Alaska. North American Journal of Fisheries Management 13:540-549.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of Chinook salmon (*Oncorhynchus tshawytscha*) in the Kenai River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 42:(4)693-700.

Busher, W. H., and T. Hamazaki. 2005. Subsistence and personal use salmon harvests in the Alaska portion of the Yukon River drainage, 2003. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A04-33, Anchorage.

Efron, B., and R. J. Tibshirani. 1993. An introduction to the bootstrap, *first edition*. Chapman and Hall, New York.

Eiler, J. H., T. R. Spencer, J. J. Pella, and M. M. Masuda. 2006a. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2004. U. S. Dep. Commerce, NOAA Technical Memo. NMFS-AFSC-165.

Eiler, J. H., T. R. Spencer, J. J. Pella, and M. M. Masuda. 2006b. Stock composition, run timing, and movement patterns of Chinook salmon returning to the Yukon River basin in 2003. U. S. Department of Commerce, NOAA Technical Memo. NMFS-AFSC-163.

Eiler, J. H., T. R. Spencer, J. J. Pella, M. M. Masuda, and R. R. Holder. 2004. Distribution and movement patterns of Chinook salmon returning to the Yukon River basin in 2000-2002. U. S. Department of Commerce, NOAA Technical Memo. NMFS-AFSC-148.

Eiler, J. H., and M. A. Masters. 2000. A database-GIS mapping program for summarizing salmon telemetry data from the Yukon River basin. Pages 138-144 [*in*] J. H. Eiler, D. J. Alcorn, and M. R. Neuman, editors. Biotelemetry 15: Proceeding of the 15th International Symposium on Biotelemetry. Juneau, Alaska USA. International Society on Biotelemetry. Wageningen, The Netherlands.

Eiler, J. H. 1995. A remote satellite-linked tracking system for studying Pacific salmon with radio telemetry. Transactions of the American Fisheries Society 124:184-193.

Geiger, M. F. 1968. Yukon River salmon tagging studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Yukon Stock Separation Report No. 6, Anchorage.

Hubartt, D. J., and P. D. Kissner. 1987. A study of Chinook salmon in southeast Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 32, Juneau. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds-032.pdf

JTC (Joint Technical Committee of the Yukon River US/Canada Panel). 2005. Yukon River Salmon 2004 season summary and 2005 season outlook. Fisheries and Oceans Canada, Stock Assessment and Fisheries Management Section, Yukon and Transboundary Area. Whitehorse, Yukon Territory.

REFERENCES CITED (Continued)

JTC (Joint Technical Committee of the Yukon River US/Canada Panel). 2002. Yukon River salmon season review for 2002 and Technical Committee Report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-44, Anchorage.

Lebida, R. C. 1969. Yukon River salmon tagging studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Yukon Stock Separation Report No. 7, Anchorage.

Meehan, W. R. 1961. Use of a fish wheel in salmon research and management. Transactions of the American Fisheries Society 90(4):490-494.

Moore, H., and T. L. Lingnau. 2002. Origins of Chinook salmon in the Yukon River fisheries, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-30, Anchorage.

Pahlke, K. A., and D. R. Bernard. 1996. Abundance of the Chinook salmon escapement into the Taku River, 1989-1990. Alaska Fisheries Research Bulletin 3:9-20.

Seber, G. A. F. 1982. On the estimation of animal abundance and related parameters, *second edition*. Charles Griffin and Sons, Ltd. London.

Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2006. Mark–recapture abundance estimates for Yukon River Chinook salmon in 2003. Alaska Department of Fish and Game, Fishery Data Series No. 06-31, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds06-31.pdf

Spencer, T. R., T. Hamazaki, and J. H. Eiler. 2005. Mark–recapture abundance estimates for Yukon River Chinook salmon in 2002. Alaska Department of Fish and Game, Fishery Data Series No. 05-75, Anchorage. http://www.sf.adfg.state.ak.us/FedAidPDFs/fds05-75.pdf

Spencer, T. R., R. S. Chapell, T. Hamazaki, and J. H. Eiler. 2003. Estimation of abundance and distribution of Chinook salmon in the Yukon River using mark-recapture and radio telemetry in 2000 and 2001. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 3A02-37, Anchorage.

Trasky, L. 1973. Yukon River salmon tagging studies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Yukon Stock Separation Report No. 8, Anchorage.

Welander, A. D. 1940. A study of the development of the scale of the Chinook salmon (*Oncorhynchus tshawytscha*). Master's Thesis. University of Washington, Seattle.

Wydoski, R. and L. Emery. 1983. Tagging and marking. Pages 215-237 [*in*] L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, MD.

TABLES AND FIGURES

Table 1.–Number of Chinook salmon captured, marked, fitted with a radio transmitter, died, released untagged, and recaptured in drift gillnets at Russian Mission and Dogfish in 2004.

	Captured	Fitted w/ Transmitter	Mortalities	Released Untagged	Recaptured
Dogfish [a]	1,500	714	17	749	20
Russian Mission	607	281	3	320	3
Total	**2,107**	**995**	**20**	**1,069**	**23**

[a] Field camp site located 22 km upstream from Russian Mission.

Table 2.–Relative age composition of Chinook salmon marked in 2004.

	Combined (n = 899)		Dogfish (n = 643)		Russian Mission (n=256)	
Age [a]	**Estimate**	**SE**	**Estimate**	**SE**	**Estimate**	**SE**
1.1	0.001	0.001	0.000	0.000	0.004	0.004
1.2	0.083	0.009	0.084	0.011	0.078	0.017
1.3	0.181	0.013	0.173	0.015	0.203	0.025
1.4	0.684	0.016	0.692	0.018	0.664	0.030
1.5	0.050	0.007	0.050	0.009	0.051	0.014
1.6	0.001	0.001	0.001	0.001	0.000	0.000

[a] Age designation using the European notation.

Table 3.–Recoveries of marked Chinook salmon by escapement monitoring projects in 2004.

Km from Yukon River Mouth	Location	Project Type	No. Fish Recaptured	Examined	Used In M/R Analysis
365	Russian Mission	radio tagging [a,b]	23	2,107	No
	Projects Upstream of Russian Mission				
512	Anvik River	carcass survey [a]	4	340	No
912	Gisasa River	weir [c]	8 [d]	1,774 [e]	Yes
1,570	Henshaw Creek	weir [c]	2	1,248	No
	Lower Yukon River Subtotal		**14**	**3,362**	
1,481	Chena River	carcass survey [a]	10	239	No
1,481	Chena River	counting tower [a]	30 [d]	9,645 [e]	Yes
1,553	Salcha River	counting tower [f]	68 [d]	15,887 [e]	Yes
1,553	Salcha River	carcass survey [f]	43	228	No
	Tanana River Subtotal		**151**	**26,096**	
1,096	Tozitna River	weir [g]	6	1,880	No
1,981	Yukon River above US/Canada Border	fish wheel [h]	1	1,360	No
2,123	Dawson City	test fishery [h]	1	167	No
2,379	Pelly River	weir [h]	3	792	No
2,808	Whitehorse	fishway [h]	2	1,989	No
	Canadian Subsistence		53 [i]	11,088 [j]	Yes
	Canada Subtotal		**60**	**15,396**	
	Upstream Sites Total		**231** [k]	**46,734**	

[a] Recovery project operated by 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 radio tagged 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.
[i] Total marked fish caught in subsistence fishery.
[j] Total number of fish caught in subsistence fishery.
[k] Includes some fish counted twice in Chena and Salcha rivers.

Table 4.–Voluntary returns of radio transmitters from fisheries by nearest community in 2004.

Nearest Community	Area	Km from Yukon River Mouth	Number of Transmitters Returned [a]
Alaska			
Russian Mission	Yukon Mainstem	343	12
Holy Cross		449	32
Anvik		510	5
Grayling		541	15
Kaltag		724	11
Nulato		779	21
Koyukuk		1,287	3 [b]
Galena		853	26
Ruby		935	10
Tanana		1,118	13
Manley Hot Springs	Tanana River	1,231	10
Nenana		1,384	5
Fairbanks		1,481	18
Rapids/Rampart/Bridge	Yukon Mainstem	1,228	40
Stevens Village		1,363	14
Beaver		1,500	12
Venetie	Chandalar River	1,650	1
Fort Yukon		1,613	15
Circle		1,708	4
Eagle		1,952	9
Canada			
Old Crow	Porcupine River	2,026	3
Dawson City	Yukon Mainstem	2,123	25
Minto		2,412	1
Mayo	Stewart River	2,446	3
Carmacks	Yukon Mainstem	2,490	6
Pelly Crossing	Pelly River	2,269	8
Whitehorse	Yukon Mainstem	2,808	0
Teslin	Teslin River	2,808	10
Total Transmitters Recovered			**332**

[a] Includes transmitters located in villages or fish camps during aerial tracks.
[b] Includes radio-tagged fish caught in Koyukuk River.

Table 5.–Capture-recapture statistics for Chinook salmon ≥520 mm METF in the second (upstream) sampling event in 2004.

	Number Inspected for Marks [a]	Number Recaptured [a]	Recaptured Fraction %
Lower Yukon			
Koyukuk River		**28**	
Gisasa R Weir	1,749	8 [b]	0.46
Middle Yukon			
Tanana River		**195**	
Chena R. RTS/Tower	9,645 [c]	30 [b]	0.31
Salcha R. RTS/Tower	15,887 [c]	68 [b]	0.43
Tanana pooled	**25,532**	**98**	**0.38**
Upper Yukon		**284**	
Canadian [d]	11,088	53	0.48
Drainage-wide	**38,369**	**159**	**0.41**

[a] Number of Chinook salmon ≥ 520 mm METF.
[b] Number of radio tags recorded in river by Remote Tracking Station or aerial tracking.
[c] Estimated Chinook salmon escapement into river.
[d] Includes subsistence and test fisheries.

Table 6.–Estimated abundance of Chinook salmon above Russian Mission, into the Tanana River, and into Canada in 2004.

	Estimate	SE	Lower C 95% I	Higher C 95% I	Bias %
Yukon River	229,739	16,682	202,195	266,833	0.9
Tanana River					
Proportional experiment	46,812	3,254	41,114	54,046	0.4
Local experiment	50,803	3,602	44,311	58,634	0.7
Canada					
Proportional experiment	68,178	5,872	58,805	80,462	0.9
Local experiment	59,415	7,987	47,044	78,409	1.7

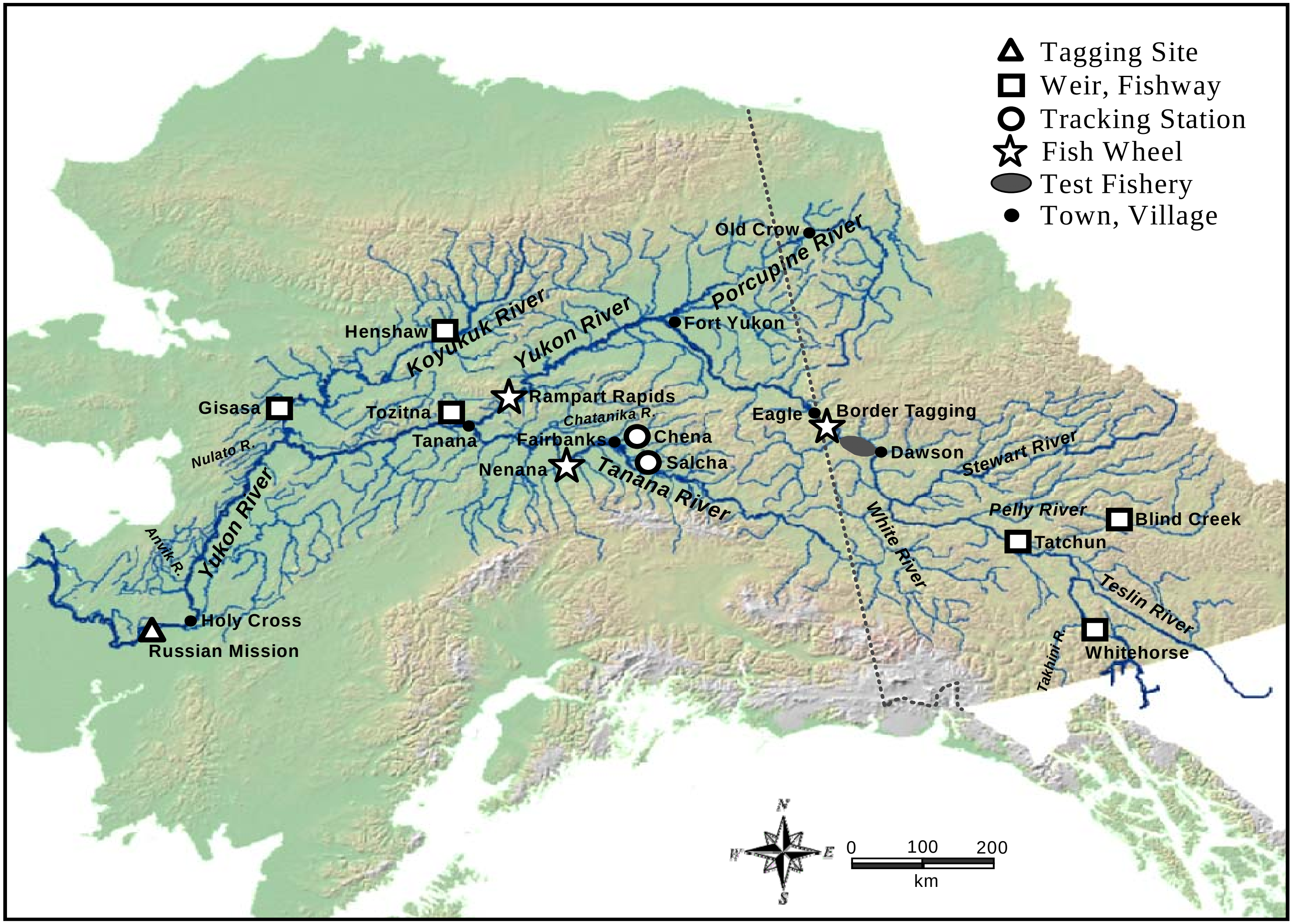


Figure 1.–Yukon River drainage showing the tagging and recovery sites used to develop mark–recapture abundance estimates for Chinook salmon.

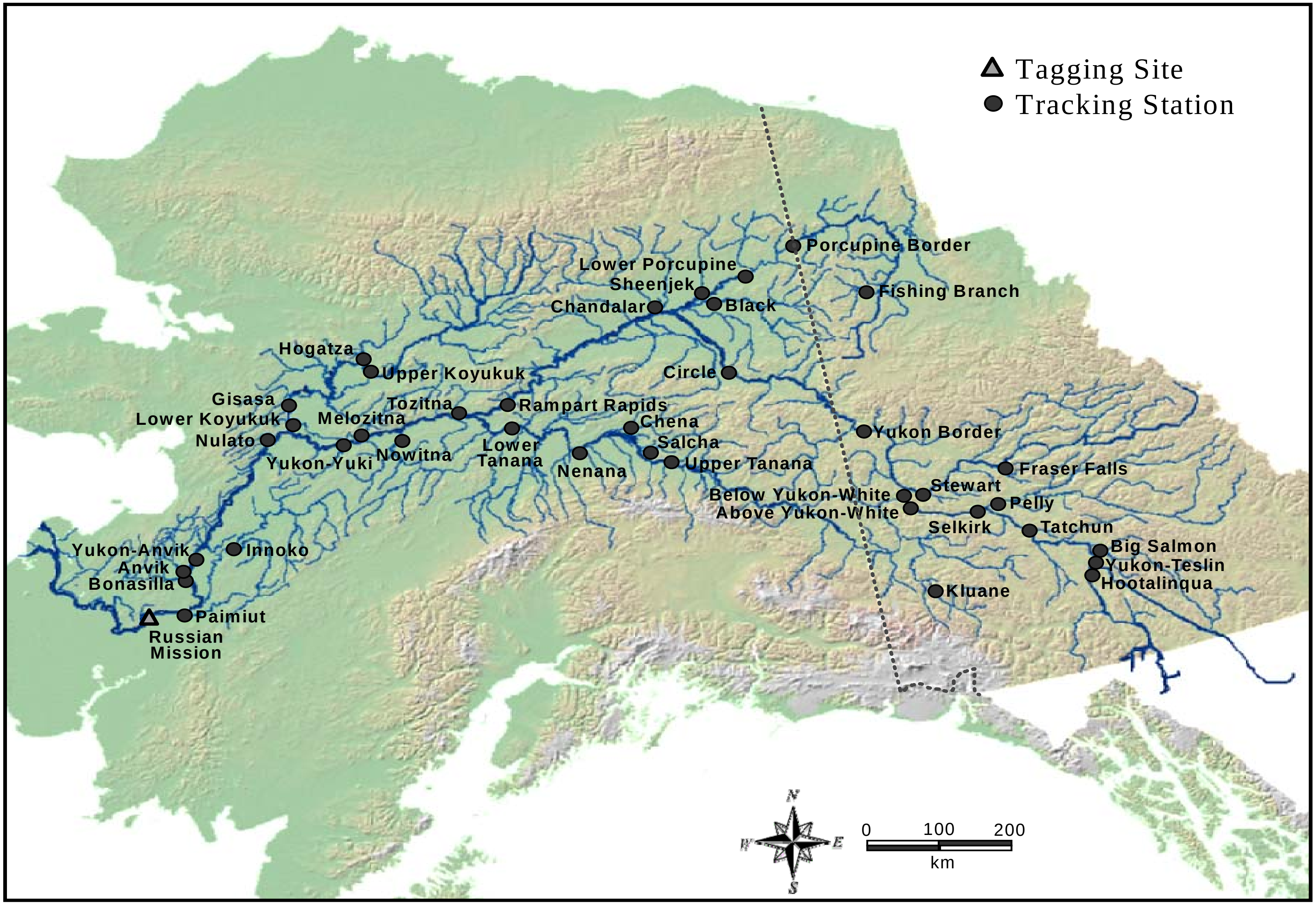


Figure 2.–Yukon River basin showing the location of remote tracking stations used to track the upriver movements of radio-tagged Chinook salmon.

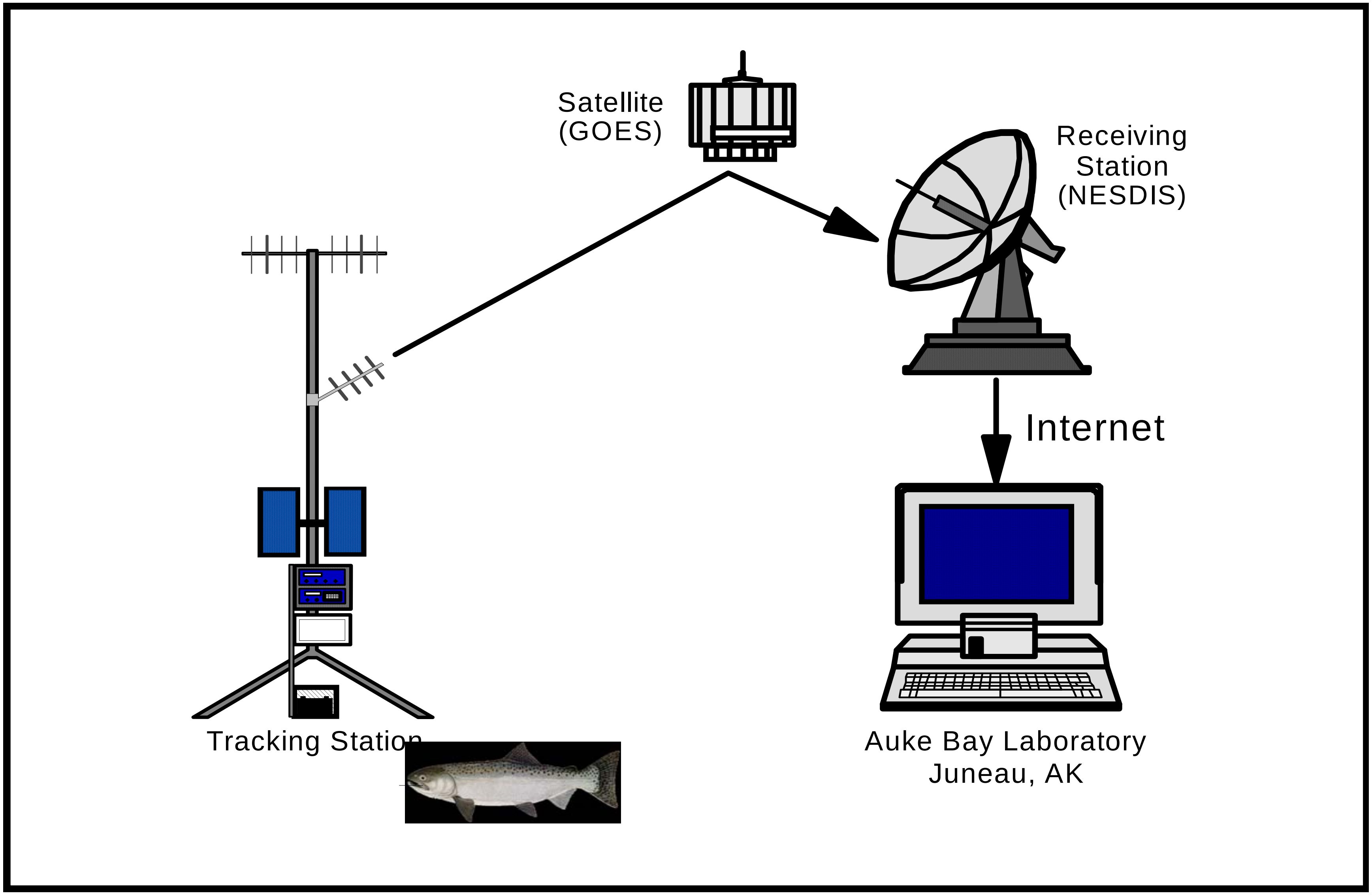


Figure 3.–Diagram of remote tracking stations and satellite uplinks used to collect and access movement information of Chinook salmon in the Yukon River basin.

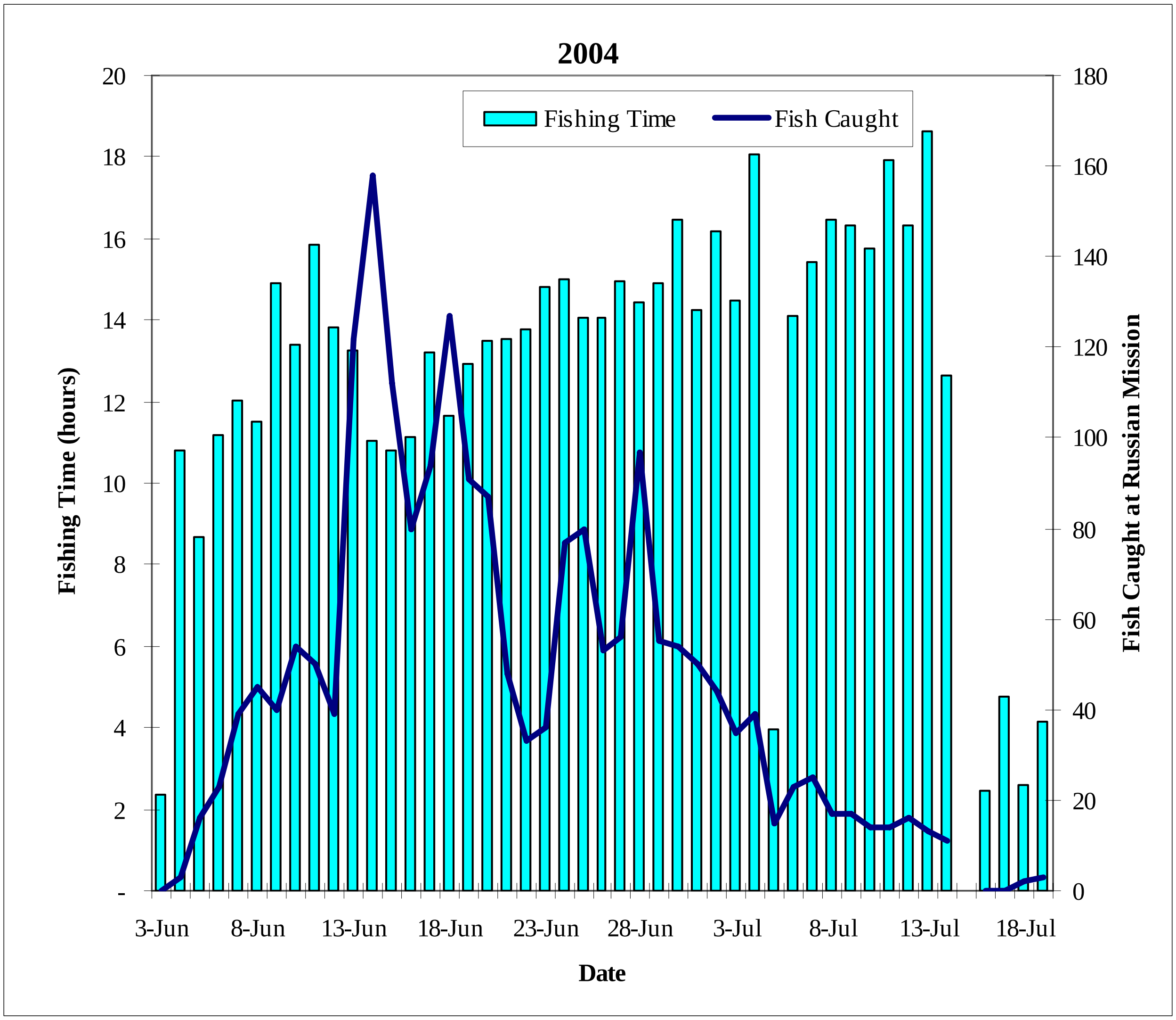


Figure 4.–Daily numbers of Chinook salmon caught at Russian Mission, and the number of hours fished per day in 2004.

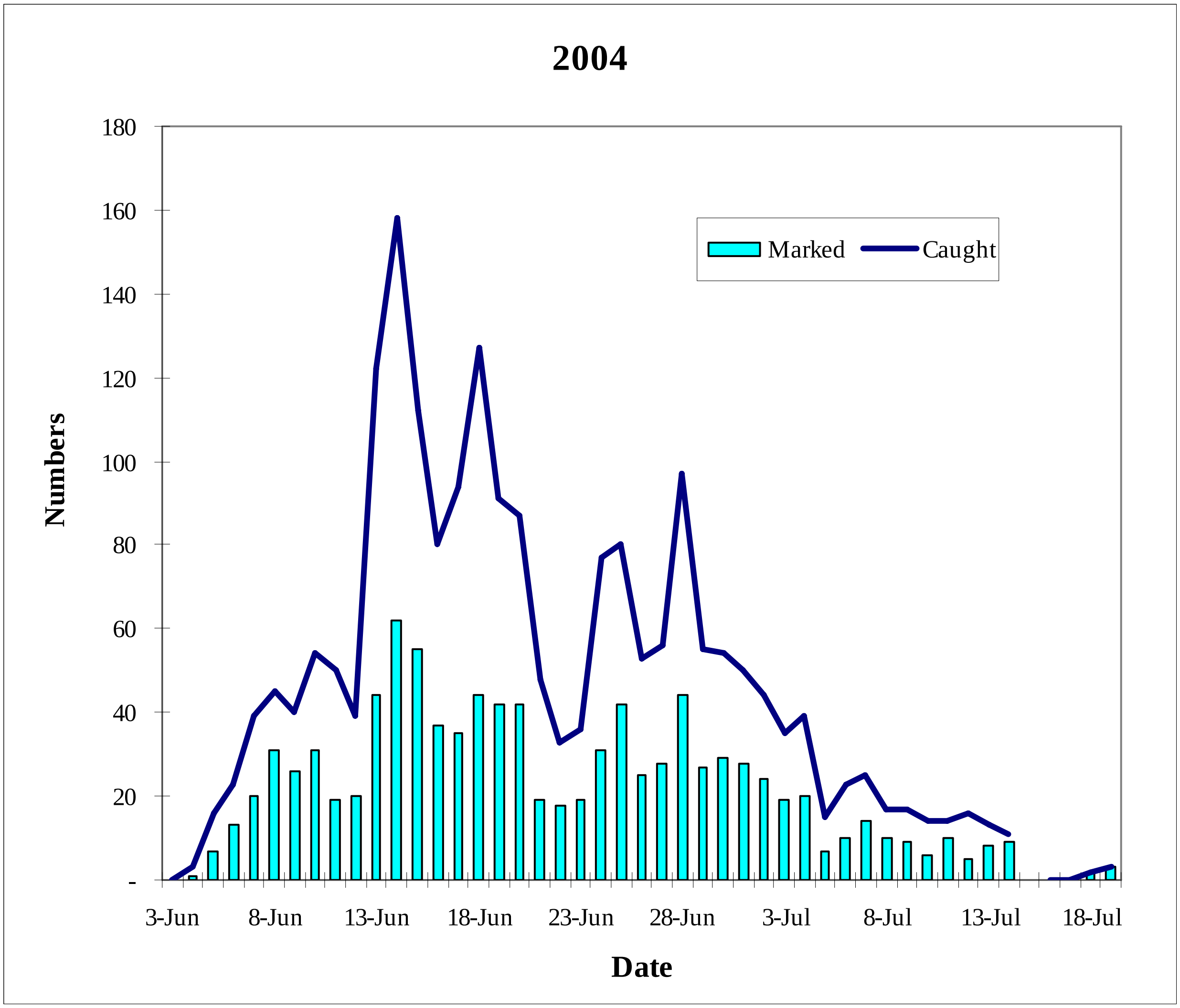


Figure 5.–Daily numbers of Chinook salmon caught and marked at Russian Mission in 2004.

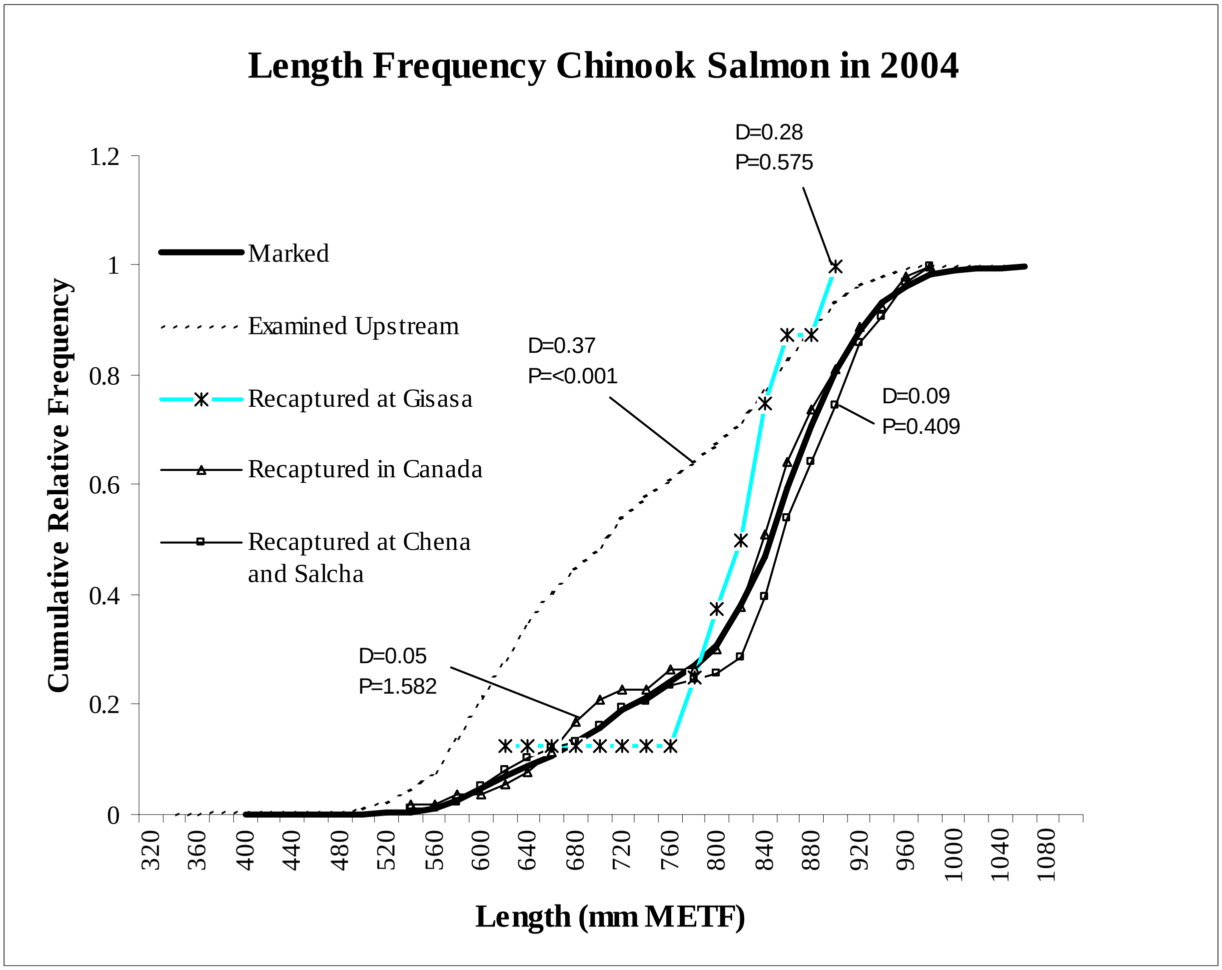


Figure 6.–Cumulative relative length frequencies of Chinook salmon marked at Russian Mission examined and recaptured during sampling in Yukon River recovery projects.

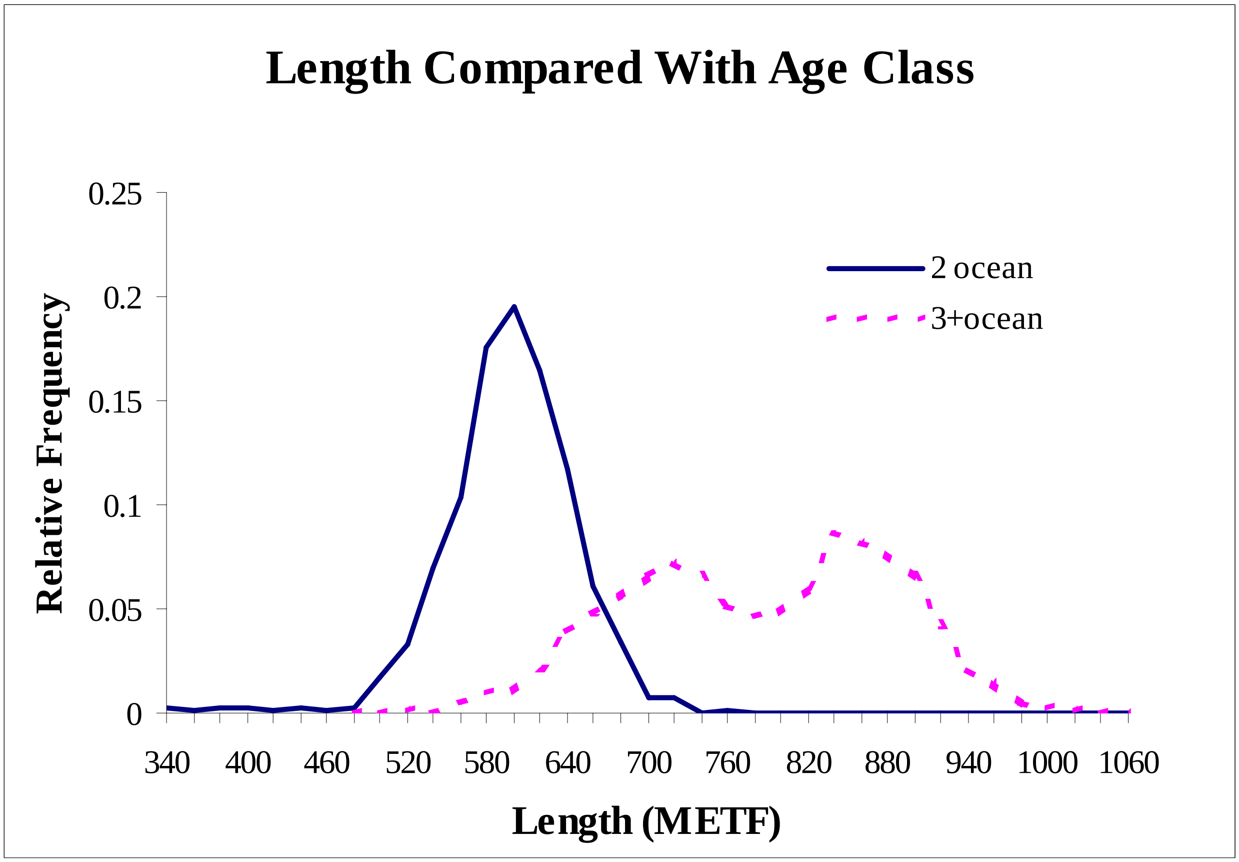


Figure 7.–Relative length frequency (METF), of 2 ocean and 3+ ocean age class Chinook salmon from recovery projects in 2004.

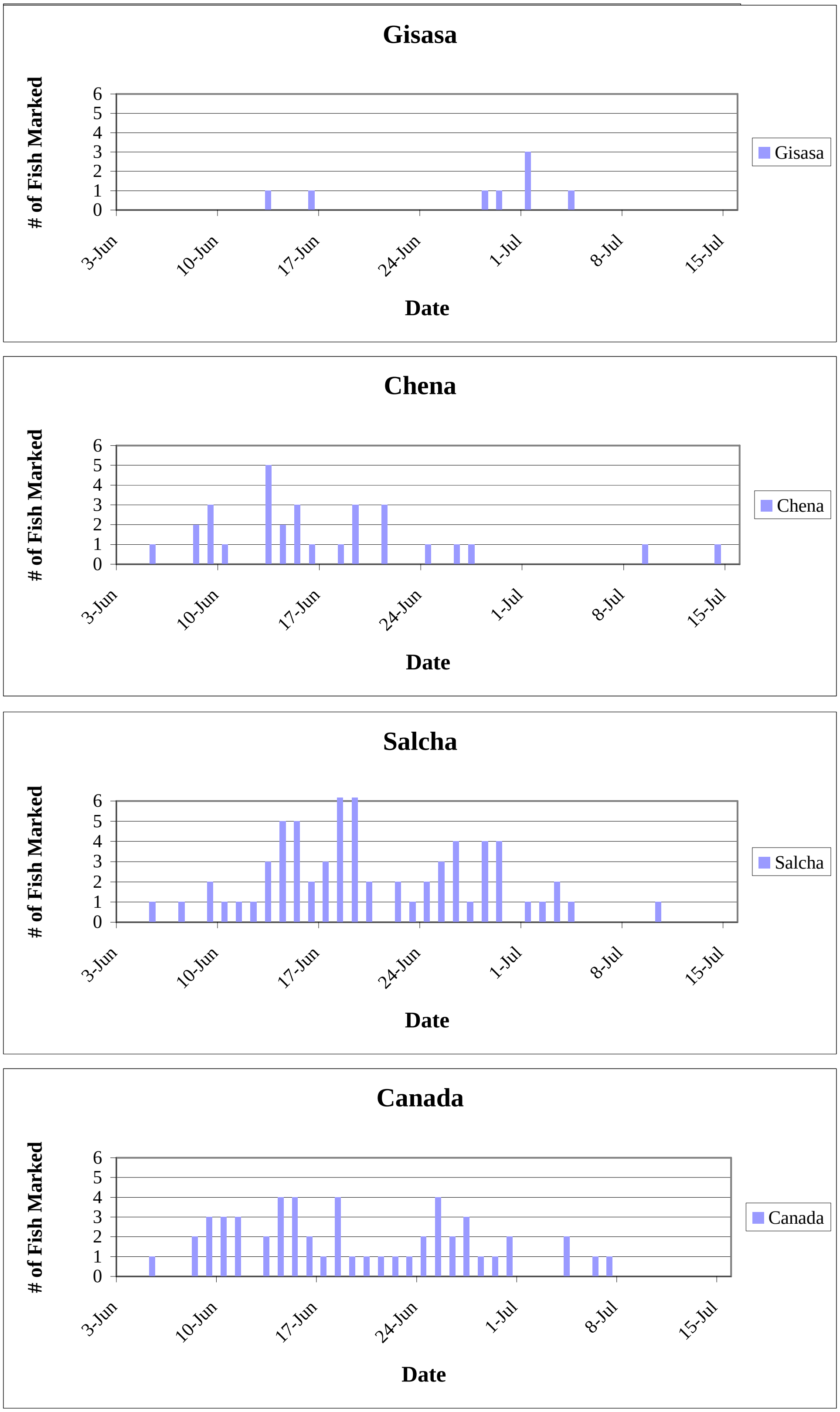
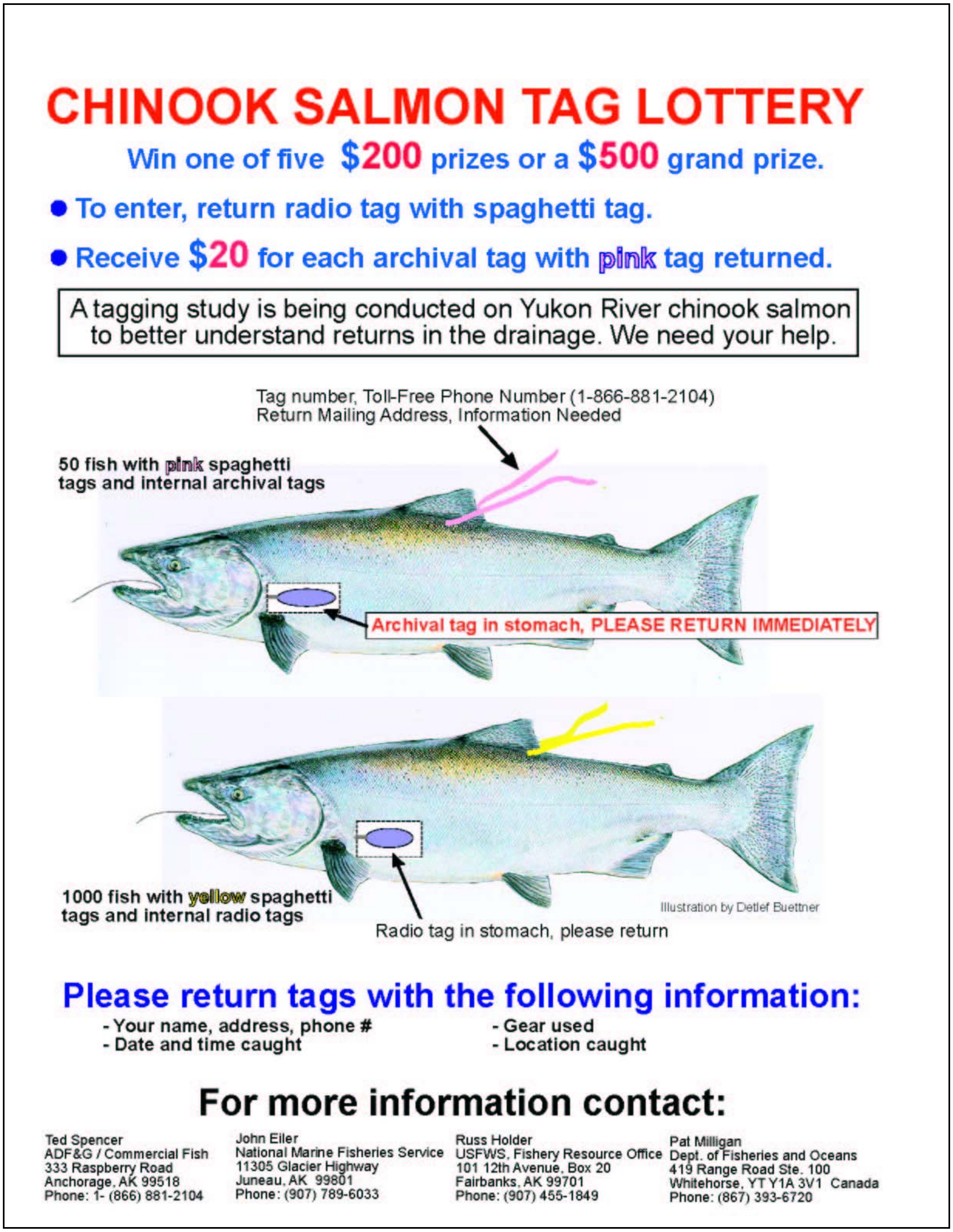


Figure 8.–Timing of marked fish passing Russian Mission destined for recovery projects in 2004.

APPENDIX A. TAG RETURN POSTER

Appendix A1.–Tag return poster used in 2004 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 2004.

STATE OF ALASKA

DEPARTMENT OF FISH AND GAME

DIVISION OF COMMERCIAL FISHERIES

FRANK MURKOWSKI, GOVERNOR

333 RASPBERRY ROAD
ANCHORAGE, ALASKA 99576-1599
PHONE: (907) 267-2105
FAX: (907) 267-2442

December 7, 2004

First Name, Last Name

City, State, Country

Dear First Name:

We greatly appreciate your cooperation in providing information about the tagged Yukon River Chinook salmon that you caught this past summer. This was the fifth and final 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, 2,132 Yukon River Chinook salmon were captured in drift gillnets near the village of Russian Mission. Of these fish, 995 were marked with spaghetti tags and radio transmitters. The Chinook salmon were tracked upriver using radio telemetry and 240 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

(Table Inserted with tag information)

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

- $500 Grand Prize - Frank Carruthers, Tanana
- $200 Week 1 Prize - Keith Workman, Shageluk
- $200 Week 2 Prize - Andrew Henry, Galena
- $200 Week 3 Prize - Sara McConnell, Fairbanks
- $200 Week 4 Prize - Nora Billy, Beaver
- $200 Week 5 Prize - Lena Moon, Teslin

Thank you for participating and supporting the Yukon River Chinook salmon radiotelemetry project. Through your cooperation the tag recovery effort was successful. If you have any questions please feel free to give us a call.

Sincerely,

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

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

APPENDIX C. CAPTURE-RECAPTURE HISTORIES

Appendix C1.–Daily catch and tagging summaries from the Russian Mission tagging sites in 2004.

	Russian Mission							Dogfish						
	Chinook salmon								Chinook salmon					
		Tagged	Not tagged						Tagged	Not tagged				
Date	**Caught**	**Radio tagged**	**Recap.**	**Mort.**	**Released alive**	**Chum salmon**	**Crews fished**	**Caught**	**Radio tagged**	**Recap.**	**Mort.**	**Released alive**	**Chum salmon**	**Crews fished**
3-Jun	Did not fish							0	0	0	0	0	0	1
4-Jun	3	1	0	0	2	1	1	0	0	0	0	0	1	2
5-Jun	5	2	0	0	3	2	1	11	5	1	0	5	1	2
6-Jun	10	9	0	0	1	1	1	13	4	0	0	9	6	2
7-Jun	16	9	0	0	7	0	1	23	11	0	0	12	3	2
8-Jun	19	18	0	0	1	0	2	26	13	0	2	11	3	2
9-Jun	19	13	0	0	6	3	2	21	13	0	0	8	4	2
10-Jun	40	26	0	1	13	0	2	14	6	0	1	7	5	2
11-Jun	24	8	0	0	16	2	2	26	10	2	0	14	5	2
12-Jun	18	11	0	0	7	0	2	21	9	1	0	11	4	2
13-Jun	68	24	0	0	44	2	2	54	20	1	1	32	9	2
14-Jun	63	27	1	1	34	10	2	95	35	0	1	59	11	2
15-Jun	28	16	0	0	12	7	2	84	39	1	0	44	28	2
16-Jun	18	7	0	0	11	30	2	62	30	0	2	30	27	2
17-Jun	30	7	0	0	23	11	2	64	28	1	0	35	16	2
18-Jun	37	10	0	0	27	1	2	90	34	0	0	56	20	2
19-Jun	25	12	0	0	13	10	2	66	30	0	0	36	18	2
20-Jun	22	10	0	0	12	27	2	65	32	1	1	31	35	2
21-Jun	8	3	0	0	5	10	2	40	16	2	0	22	33	2
22-Jun	6	2	0	0	4	4	2	27	16	0	0	11	10	2
23-Jun	4	3	0	0	1	6	2	32	16	0	0	16	18	2
24-Jun	20	4	0	0	16	4	2	57	27	0	2	28	10	2
25-Jun	8	4	0	0	4	4	2	72	38	1	1	32	29	2
26-Jun	9	3	0	0	6	6	2	44	22	0	1	21	44	2
27-Jun	11	7	0	0	4	11	2	45	21	1	1	22	41	2
28-Jun	11	5	0	0	6	15	2	86	39	0	0	47	62	2
29-Jun	13	7	0	0	6	24	2	42	20	1	1	20	75	2
30-Jun	10	2	0	0	8	32	2	44	27	0	0	17	75	2
1-Jul	6	3	0	0	3	15	2	44	25	0	1	18	40	2
2-Jul	10	5	1	0	4	10	1	34	19	0	0	15	31	3
3-Jul	12	5	0	0	7	25	1	23	14	0	0	9	23	3
4-Jul	6	2	1	1	2	9	2	33	18	1	0	14	11	2
5-Jul	Did not fish							15	7	1	0	7	8	1
6-Jul	2	1	0	0	1	0	2	21	9	1	0	11	14	2
7-Jul	1	0	0	0	1	2	2	24	14	0	0	10	22	2
8-Jul	7	5	0	0	2	8	1	10	5	1	0	4	9	3
9-Jul	5	2	0	0	3	4	1	12	7	0	0	5	10	3
10-Jul	2	1	0	0	1	5	2	12	5	0	0	7	23	2
11-Jul	5	4	0	0	1	12	1	9	6	0	0	3	22	3
12-Jul	4	1	0	0	3	15	1	12	4	0	2	6	27	3
13-Jul	1	1	0	0	0	8	2	12	7	2	0	3	30	2
14-Jul	1	1	0	0	0	0	1	10	8	1	0	1	16	2
15-Jul	Did not fish							Did not fish						
16-Jul	Did not fish							0	0	0	0	0	4	1
17-Jul	Did not fish							0	0	0	0	0	3	1
18-Jul	Did not fish							2	2	0	0	0	1	1
19-Jul	Did not fish							3	3	0	0	0	1	1
Site Total	607	281	3	3	320	336		1,500	714	20	17	749	888	
Project Total	**2,107**	**995**	**23**	**20**	**1,069**	**1,224** [a]								

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

[a] Includes fish caught with smaller mesh chum nets.

Appendix C2.–Numbers of Chinook salmon marked at Russian Mission by length (METF) and numbers inspected upriver at recovery projects in 2004.

Location	Total	< 520 mm	Percentage	≥ 520 mm	Percentage
Number of Fish Marked					
Radio tagged	995	1	0.1	994	99.9
Number of Fish Captured					
Anvik (carcass)	340	2	0.6	338	99.4
Koyukuk River drainage					
Gisasa (live weir)	540	13	2.4	527	97.6
Henshaw (live weir)	636	16	2.5	620	97.5
Tanana (fish wheel)	97	0	0.0	97	100.0
Tozitna (live weir)	416	8	1.9	408	98.1
Tanana River drainage					
Chena (carcass)	239	0	0.0	239	100.0
Salcha (carcass)	228	0	0.0	228	100.0
Total	2,496	39	1.6	2,457	98.4
Number of Marked Fish Captured					
Anvik	40 [a]	0	0.0	40	100.0
Koyukuk River drainage					
Gisasa (live weir)	8 [a]	0	0.0	8	100.0
Henshaw (live weir)	2	0	0.0	2	100.0
Tozitna (live weir)	8 [a]	0	0.0	8	100.0
Tanana River drainage					
Chena	30 [a]	0	0.0	30	100.0
Salcha	68 [a]	0	0.0	68	100.0
Canada					
Yukon River (subsistence)	53	0	0.0	53	100.0
Total	209	0	0.0	209	100.0

[a] Number of radio tags recorded in river by Remote Tracking Station or aerial tracking.

Appendix C3.–Migration of Chinook salmon fitted with radio transmitters during the 2004 spawning migration (in numbers of fish).

	Mainstem				Tributary	
Location	**Estimated Passed [a]**	**Fished [b]**	**Unknown [c]**	**Passed [d]**	**Fished [b]**	**Unknown [c]**
Released	**995**		37			
Russian Mission		12				
MS-Paimiut			23			
Total	**923**					
MS-Holy Cross		32				
Total	**891**					
Lower Basin Tributaries						
Bonasila River				14		
Anvik River		5		40		
Innoko				6		
Total	**826**					
Above Anvik						
MS-Above Anvik			27			
MS-Grayling		15				
MS-Kaltag		11				
Nulato River		21		11		
Total	**741**					
Koyukuk River						
Lower Koyukuk						5
Gisasa				8		
Middle Koyukuk				5	2	
Henshaw				2		
Upper Koyukuk				5	1	
Total	**713**					
MS Above Koyukuk						
MS-Galena		26				
MS-Yuki			15			
MS-Ruby		10				
Total	**662**					
Mid River Tributaries						
Melozitna River				3		
Nowitna River				3		
Tozitna River				8		
MS-down river Tanana		7				
Total	**641**					
Tanana River						
Kantishna River				9		
Tolovana River				3		
Nenana River				1		
MS-Nenana					10	8
Fairbanks					15	9
Chena River				28	2	
Clear Creek				3		
Salcha River				62	6	
Upper Tanana						11
Goodpaster				28		
Total	**446**					

-continued-

Appendix C3.–Page 2 of 2.

Location	Mainstem			Tributary		
	Estimated Passed [a]	Fished [b]	Unknown [c]	Passed [d]	Fished [b]	Unknown [c]
Above Tanana						
MS-Tanana		6				
MS-Yukon Raven			20			
MS-Rapids		16				
MS-Rampart		15				
MS-Above Rapids		5				
Hess Creek		2				
MS-Bridge		4				
MS-Stevens Village		14				
Beaver Creek		12		3		
Chandalar River				13	1	
Total	**337**					
Porcupine River						10
Sheenjek				6		
Black				1		
Lower Porcupine						1
Coleen River				3		
Porcupine Border						1
Old Crow				1	3	
Whitestone				1		
Miner				3		
Total	**318**					
Above Porcupine						
MS-Fort Yukon		15				
MS-Circle		4	3			
MS-Yukon Circle						
Charley				1		
Nation				2		
MS-Eagle		9				
Total	**284**					
Canadian Yukon						
MS Yukon Border			3			
Chandindu River				2		
MS-Dawson City		25				
Klondike River				12		
Stewart River				24	2	
MS-White		25	12			
White River				12		
MS-Pelly (Selkirk)			16			
PellyRiver				40	8	
Minto Landing		1				
MS-Tatchun			24			
Tatchun River				3		
MS-Carmacks		5				
Nordensk River				2		
Little Salmon River				3		
Big Salmon River				25		
Teslin River			2	39	10	
MS-Whitehorse				5	1	
Takhini						
S-Hootalinqua				8		
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 passing the tracking station or recorded in the river.

APPENDIX D. CATCH PER UNIT OF EFFORT

Appendix D1.–Catch-per-unit-of-effort information from the Russian Mission tagging site in 2004.

Date	No. Chinook Salmon[a]	Minutes Fished	Total Sum of Net Length	CPUE
2-Jun-04				
3-Jun-04	0	146.5	175	0.00
4-Jun-04	3	655	1210	1.11
5-Jun-04	17	518.5	1000	7.87
6-Jun-04	22	675	1274	8.32
7-Jun-04	39	721.5	1252	14.74
8-Jun-04	49	689	1166	19.40
9-Jun-04	36	895.5	1617	10.05
10-Jun-04	55	794	1775	16.62
11-Jun-04	50	938.5	1725	12.79
12-Jun-04	38	957	1923	9.53
13-Jun-04	124	763.5	1950	38.98
14-Jun-04	160	665.5	1850	57.70
15-Jun-04	108	646	1475	40.12
16-Jun-04	79	669	1472	28.34
17-Jun-04	93	800	1900	27.90
18-Jun-04	131	701	1700	44.85
19-Jun-04	91	779	1725	28.04
20-Jun-04	85	803.5	1750	25.39
21-Jun-04	49	820	1525	14.34
22-Jun-04	33	826	1350	9.59
23-Jun-04	33	889.5	1500	8.90
24-Jun-04	86	900	1700	22.93
25-Jun-04	71	838	1725	20.33
26-Jun-04	55	844.5	1725	15.63
27-Jun-04	64	886.5	1625	17.33
28-Jun-04	95	868	1675	26.27
29-Jun-04	49	896	1575	13.13
30-Jun-04	55	984	1725	13.41
1-Jul-04	51	864	1475	14.17
2-Jul-04	42	982	1700	10.26
3-Jul-04	35	868.5	1450	9.67
4-Jul-04	39	1085	1875	8.63
5-Jul-04	15	236.5	525	15.22
6-Jul-04	22	857	1350	6.16
7-Jul-04	27	916.5	1525	7.07
8-Jul-04	16	990.5	1450	3.88
9-Jul-04	17	1013	1525	4.03
10-Jul-04	14	971.5	1425	3.46
11-Jul-04	14	1070	1525	3.14
12-Jul-04	16	960	1400	4.00
13-Jul-04	15	1111	1475	3.24
14-Jul-04	9	726.5	950	2.97
15-Jul-04				
16-Jul-04	0	147.5	200	0.00
17-Jul-04	0	287	400	0.00
18-Jul-04	2	156	225	3.08
19-Jul-04	3	250	375	2.88

Note: The project was not operational on July 15.

[a] Includes Chinook salmon caught with chum salmon nets on July 18.