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Mark-Recapture Abundance Estimates for Yukon River Chinook Salmon in 2003

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	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. 06-31

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ABSTRACT

Abundance of adult Chinook salmon *Oncorhynchus tshawytscha* passing by the village of Russian Mission was estimated in 2003 as part of a radio telemetry study on the Yukon River. Drift gillnets were used to capture 2,312 salmon at Russian Mission, 1,097 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 36,032 large salmon (≥ 650 mm METF) involved in the second event, 146 carried transmitters for an estimated abundance of 261,545 Chinook salmon. Diagnostic testing showed this estimate to be consistent. Bootstrap simulation was used to estimate the variance (SE=18,911).

Key words: mark-recapture, radio telemetry, 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 to maintain adequate spawning escapements and to provide harvest opportunities**.** The interim escapement objective into Canada for Chinook salmon in the Yukon River mainstem 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 2003 target was 25,000 Chinook salmon into the Canadian portion of the Yukon River; this target was increased to 28,000 when a U.S. commercial fishery was initiated. In addition, 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 2004).

A variety of methods have been used to assess adult abundance in various tributaries since 1961, including carcass sampling (Anvik River), counting weirs (Gisasa 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 abundance in specific tributaries, the relative contribution to 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 sample sizes. 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 U.S. and Canada agreed to cooperatively research 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 radio telemetry and mark–recapture study to provide information on the stock composition, spawning distribution, run timing, migratory characteristics (Eiler et al. 2004; 2006), and to estimate drainage-wide abundance (Spencer et al. 2003; 2005) of adult Chinook salmon in the Yukon River. In 2003, abundance of adult salmon passing upstream 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. (2006). The tagging crews consisted of two locally hired contract fishers and two project personnel. Project personnel were responsible for handling and marking fish, while the contract fishers were responsible for operating a boat and deploying a net. Fishing started 3 June, and ended 14 July. Fishing was conducted daily during day (0900–1700 hours) and evening (1800–0200 hours); each period was 7.5 hours in duration. 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 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 handling time. Crew members, wearing neoprene gloves or with bare hands, carefully placed each retained fish in a submerged 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 in 2002 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. The axillary process was retained for genetic analysis.

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

Of the 2,312 Chinook salmon caught at Russian Mission, pulse-coded radio transmitters in the 150 MHz frequency range (Advanced Telemetry Systems, Isanti, Minnesota) were implanted in 1,097. Transmitters 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 diameter) until the transmitter was no longer visible. During the insertion, the fish was not anesthetized. The fish was immediately released after processing. These 1,097 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 radio tagged 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. 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 movements. Fish tracked to terminal reaches of the drainage were classified as belonging to distinct spawning stocks. Marked 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 the internet 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 10 km below Russian Mission to the Canadian border and in other selected reaches of the drainage to locate radio–tagged fish that traveled to areas between station sites and upriver of stations on terminal tributaries. Fish 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 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) 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 fishwheels in Canada just above the border (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 2003 (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 weir, by sampling carcasses in the Salcha and Chena rivers, and by sampling the Canadian catch (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 Abundance Estimation

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

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

where:

$\hat{N}$ = estimated abundance passing upstream of Russian Mission,
M = the number marked that successfully went upstream of Russian Mission,
$\hat{C}$ = estimated number of large 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 the Canadian subsistence fishing.

Due to the large-mesh gillnets used at Russian Mission, very few small fish (< 650 mm METF) were caught and marked. For this reason, abundance was directly estimated for large fish (≥ 650 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 two-stage parametric bootstrap simulation (Efron and Tibshirani 1993) based on 1,000 replications of the mark–recapture experiments and 1,000 replications of sampling programs to estimate relative size composition at each upsteam site. The 1,097 large salmon fitted with transmitters had one of the following 8 fates:

	Fate	X:
1	Disappeared (did not move upstream past Paimiut) ($M' - M$)	16
2	Moved upstream to Tanana, but not to Salcha or Chena rivers	91
3	Moved upstream to remain in U.S tributary, but not in Tanana River	461
4	Moved upstream to Canada, but not inspected	368
5	Moved upstream through weir on the Gisasa River (R_1)	8
6	Moved upstream past towers on the Salcha River (R_2)	56
7	Moved upstream over dam on the Chena River (R_3)	38
8	Were caught in Canadian subsistence fishery (R_4)	44

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 1,097 because a finite number of transmitters were available. A thousand simulation estimates $\hat{C}_k^*$ for numbers of large 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*) and $\hat{p}_k$ (the proportion of that sample comprised of large salmon). An estimate of abundance was calculated for each set of replications such that:

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

where:

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

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

$R_{(b)}^* = \Sigma_{i=5}^{8} X_{i(b)}^*$; 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 large 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.

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 in text table above:

$$\hat{N}_{Tan} = \frac{(X_2 + X_6 + X_7 + 1)(C_2 + C_3 + 1)}{X_6 + X_7 + 1} - 1$$

$$\hat{N}_{Can} = \frac{(X_4 + X_8 + 1)(C_4 + 1)}{X_8 + 1} - 1 \qquad (6)$$

Abundance of small fish (< 650 mm METF) was estimated by prorating estimated abundance of large fish by the average of estimated relative size composition of salmon in the second sampling event:

$$\hat{N}_{<650} = \frac{1 - \bar{p}}{\bar{p}} \hat{N} \qquad (7)$$

where $\bar{p}$ is the fraction of samples pooled across upstream locations comprised of large fish. Such prorating is based on the conditions that large and small salmon were captured with equal probability across all sampling locations in aggregate. Variances and statistical biases in these competing estimates and for estimated abundance of small fish 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 were not used in the analysis. Almost all test subjects were successfully tracked upstream (Eiler et al. 2006), which indicates that condition (b) was met as well. As per condition (c), all transmitters not located moving upstream past the Paimiut stations 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), marked fractions of inspected fish should be similar across sites in the second sampling event if condition (d) has been met. Because condition (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 490 hours to capture 2,312 Chinook salmon at Russian Mission between 3 June and 14 July (Table 1; Figure 4; Appendix C1). The fishing hours included a fourth tagging crew added from 16–21 June and 23–27 June to augment fish capture during the peak of the run. Fish were marked throughout the run (Figure 5), with 1,097 fitted with radio transmitters, 2 fish inadvertently marked only with spaghetti tags, 33 fish died, 1,159 fish were released without any marks, and 21 fish were recaptured at Russian Mission. Catch per unit effort (CPUE) data are presented in Appendix D1. Most captured fish were age 1.4 (69.3%) (Table 2). Mean lengths of marked fish (n = 1,099) were 849 mm (METF) ranging from 530 to 1,075 mm (SD = 83).

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, 204 fish were counted, examined or recovered (Table 3). 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 (271 fish, 24.7%) of all marked Chinook salmon was captured by subsistence fishers (Table 4). From 1,097 marked fish, 1,081 fish resumed upriver migration past the gateway stations at Paimiut. Of these 1,081 fish, the fate of 197 (18.2%) 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 main stem, documented that 67 of the 226 (29.7%) 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 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 captured 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 that few small fish (< 650 mm METF) were recaptured (8 fish or 5.2% of all recaptured fish), the mark–recapture experiment was used to directly estimate only larger fish (≥ 650 mm METF). Therefore, from the 1,081 marked fish that passed the Paimiut stations, 15 small fish were censored for a total of 1,066 marked fish used in the abundance estimate. Comparison of captured fish upstream across sampling locations showed similar size distributions (Figures 6–8).

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 0.32% for large fish passing the counting tower on the Chena River to an estimated 0.47% at the weir on the Gisasa River. This range was not statistically significant ($\chi^2 = 3.25$, df = 3, P = 0.35). Migratory timing of marked fish showed that early migrants past Russian Mission tended to be bound for Canada, midseason migrants tended to head for midriver tributaries, and late migrants tended to tributaries just upstream of Russian Mission (Figure 9).

Abundance Estimates

The estimated abundance of large Chinook salmon passing upstream of Russian Mission is 261,545 (SE = 18,911) and the statistical bias in this statistic is 6.6% as estimated through bootstrapping. This estimate was based on 1,066 marked fish, 36,032 captured fish, and 146 fish recaptured from lower, middle, and upriver locations (Table 6).

The estimated abundance of large salmon passing into the Tanana River is 45,247 (SE = 3,061) for the proportional distribution calculation and 48,382 (SE = 3,268) for local experiment calculation (statistical bias in these statistics are 6.5% and 8.6%, respectively). Estimated abundance of large salmon passing into Canada is 100,956 (SE = 8,292) for proportional distribution and 90,037 (SE = 13,458) for the local experiment (statistical bias in these statistics are an estimated 6.6% and 1.7%, respectively) (Table 6).

An abundance estimate for small salmon above Russian Mission was 48,342 (SE = 3,727).

A drainage-wide estimate was developed by including 18,057 Chinook salmon for subsistence (including Russian Mission), 36,928 fish for commercial fishing, and 7,825 fish escapement for the Andreafsky River, the only major Chinook salmon tributary below the tagging site at Russian Mission (Busher and Hamazaki 2005; JTC 2005; T. Lingnau, ADF&G, Anchorage, personal communication). This results in a drainage-wide estimate of 372,697 Chinook salmon returning in 2003 with a harvest rate of 29.1%.

DISCUSSION

The basin-wide telemetry study on Yukon River was designed to provide information on stock composition and timing, migration patterns, location of important spawning areas, and an abundance estimate of the return of Chinook salmon. Different migratory patterns exhibited by stocks as they moved past the tagging sites can hinder tagging a representative sample of the run. Information from radio telemetry work in 2003 (Eiler et al. 2006) showed that Tanana River and upper basin stocks comprised approximately 86% 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, 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 9).

Size-selective sampling with nets, weirs, carcass surveys, fishwheels, 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. Recovery projects using fishwheels 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). 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 (censored) 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 radio telemetry does offer some advantages. Although large numbers of fish are not tagged, we are better able to assess their status. 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 2002–2003 has improved our understanding of Chinook salmon stock composition and movement patterns within the basin and additional years of tagging, aerial tracking, and differing run sizes will provide a better understanding of Chinook salmon distribution and tributary abundance.

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TABLES AND FIGURES

Table 1.–Number of Chinook salmon captured, marked, fitted with a transmitter, died, released untagged, and recaptured in drift gillnets at Russian Mission in 2003.

Tagging Site	Captured	Radio Tagged	Mortalities	Released Untagged	Recaptured at Tagging Sites
Dogfish [a]	1,597	790	20	769	15
Russian Mission	715	307	13	391	6
Total	**2,312**	**1,097**	**33**	**1,160**	**21**

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

Table 2.–Relative age composition of Chinook salmon marked in 2003.

Age [a]	Combined (n = 996)	Dogfish (n = 728)	Russian Mission (n = 268)
1.2	0.004	0.003	0.007
1.3	0.221	0.234	0.187
1.4	0.693	0.674	0.743
1.5	0.081	0.088	0.063
1.6	0.001	0.001	0.000

[a] Age designation using the European notation.

Table 3.–Recoveries of marked Yukon River Chinook salmon by escapement monitoring projects in 2003.

Km from Yukon River Mouth	Location	Project Type	No. Tags	No. Fish Examined	Used In M/R Analysis
365	Russian Mission	radio tagging [a,b]	21	2,312	No
	Projects Upstream of Russian Mission				
512	Anvik River	carcass survey [a]	3	459	No
779	Nulato River	counting tower [a]	15	1,716	No
912	Gisasa River	weir [c]	11 [d]	1,873	Yes
1,570	Henshaw Creek	weir [c]	1	580	No
	District 4 Subtotal		**30**	**4,628**	
1,384	Tanana River near Nenana	fish wheel [a]	2	2,377	No
1,481	Chena River	carcass survey [a]	3	459	No
1,481	Chena River	counting tower [a]	40 [d]	12,500 [e]	Yes
1,553	Salcha River	counting tower [f]	58 [d]	14,600 [e]	Yes
1,553	Salcha River	carcass survey [f]	5	469	No
	Tanana River Subtotal		**108**	**30,405**	
1,096	Tozitna River	weir [g]	5	1,819	No
1,176	Yukon River near Rampart Rapids	fish wheel [c]	3	906	No
	Subdistrict 5b and 5c Subtotal		**8**	**2,725**	
1,981	Yukon River above US/Canada Border	fish wheel [h]	4	1,576	No
2,008	Chandindu River	weir [h]	1	85	No
2,123	Dawson City	test fishery [h]	0	263	No
2,379	Pelly River	weir [h]	7	1,155	No
2,808	Whitehorse	fishway [h]	1	1,443	No
	Canadian Subsistence		45	9,616	Yes
	Canada Subtotal		**58**	**14,138**	
	Upstream Sites Total		**204**	**51,896**	

[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 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.

Table 4.–Voluntary returns of transmitters from fisheries by nearest community in 2003.

Nearest Community	Area	Km from Yukon River Mouth	Number of Transmitters Returned [a]
Alaska			
Russian Mission	Yukon Mainstem	343	4
Holy Cross		449	23
Anvik		510	4
Grayling		541	7
Kaltag		724	6
Nulato		779	17
Koyukuk		1,287	4
Galena		853	17
Ruby		935	5
Tanana		1,118	13
Manley Hot Springs	Tanana River	1,231	3
Nenana		1,384	13
Fairbanks		1,481	8
Rapids/Rampart/Bridge	Yukon Mainstem	1,228	54
Stevens Village		1,363	11
Beaver		1,500	11
Fort Yukon		1,613	12
Circle		1,708	7
Eagle		1,952	7
Canada			
Old Crow	Porcupine River	2,026	3
Dawson City	Yukon Mainstem	2,123	14
Mayo	Stewart River	2,446	4
Carmacks	Yukon Mainstem	2,490	9
Pelly Crossing	Pelly River	2,269	8
Whitehorse	Yukon Mainstem	2,808	0
Teslin	Teslin River	2,808	7
Total Tags Recovered			**271**

[a] Includes transmitters located in villages or fish camps during aerial tracking.

Table 5.–Chinook salmon abundance estimate worksheet in 2003 for large (≥ 650 mm METF) radio tagged fish in 2003.

	Adjusted Number	Adjusted Number Marked	Marked Fraction %
Lower Yukon			
Koyukuk River		**25**	
Gisasa R Weir	1,693	8 [b]	0.47
Middle Yukon			
Tanana River		**185**	
Chena R. RTS/Tower	11,875 [c]	38 [b]	0.32
Salcha R. RTS/Tower	12,848 [c]	56 [b]	0.44
Tanana pooled	**24,723**	**94**	**0.38**
Upper Yukon		**412**	
Canadian [d]	9,616	44	0.46
Drainage-wide total	**36,032**	**146**	**0.41**

[a] Number of Chinook salmon ≥ 650 mm METF.

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

[c] Estimated Chinook salmon escapement into river.

[d] Includes subsistence and test fisheries.

Table 6.–Estimate of abundance for large Chinook salmon above Russian Mission in 2003.

	Estimate	SE	Lower CI	Higher CI	Bias %
Yukon River	261,545	18,911	212,000	284,064	6.6
Tanana River					
Proportional	45,247	3,061	36,841	48,780	6.5
Local experiment	48,382	3,268	38,355	51,260	8.6
Canada					
Proportional	100,956	8,292	80,052	111,840	6.6
Local experiment	90,037	13,458	70,566	122,481	1.7

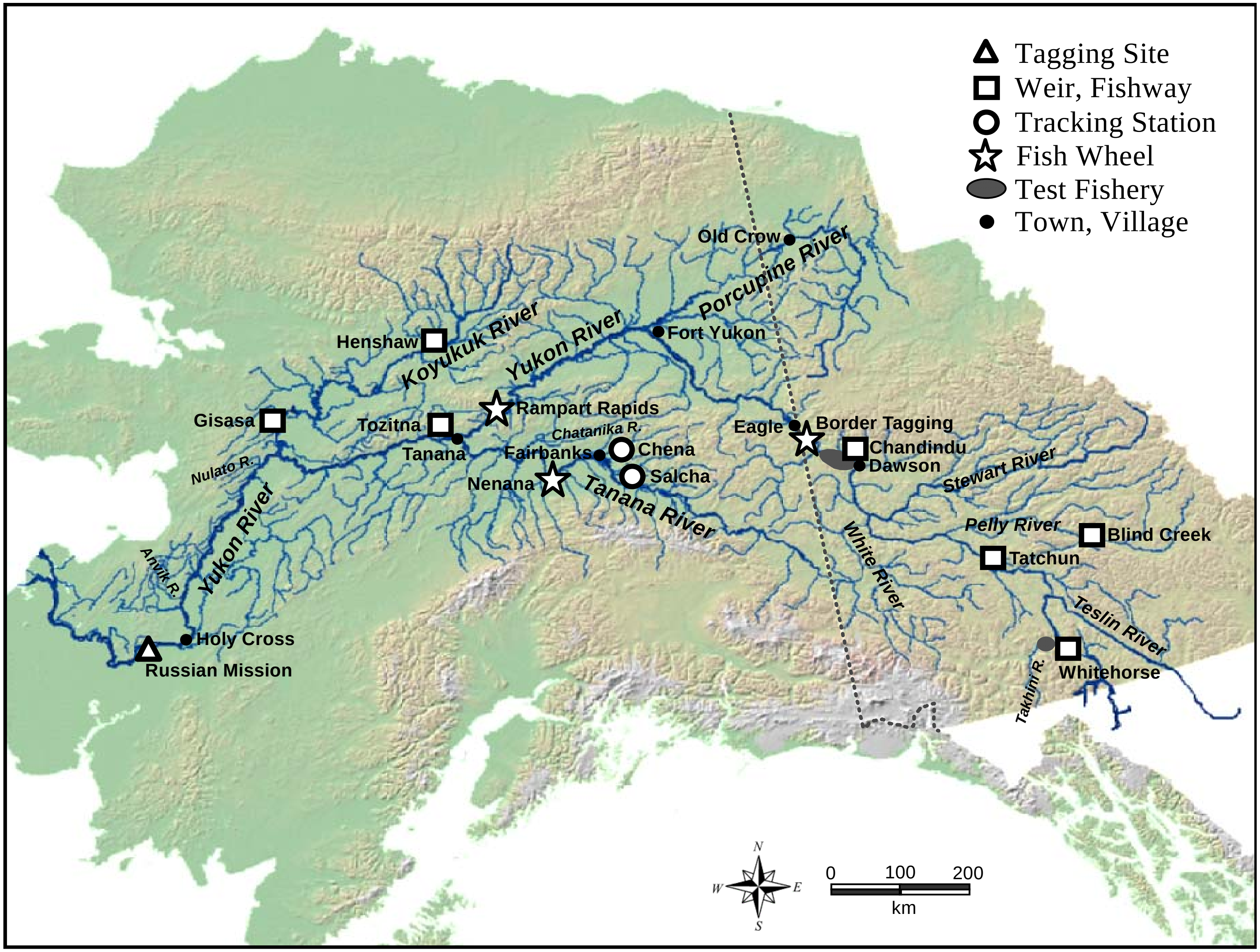


Figure 1.–Yukon River drainage showing the tagging and recovery sites used to develop mark-recapture abundance estimates for Chinook salmon.

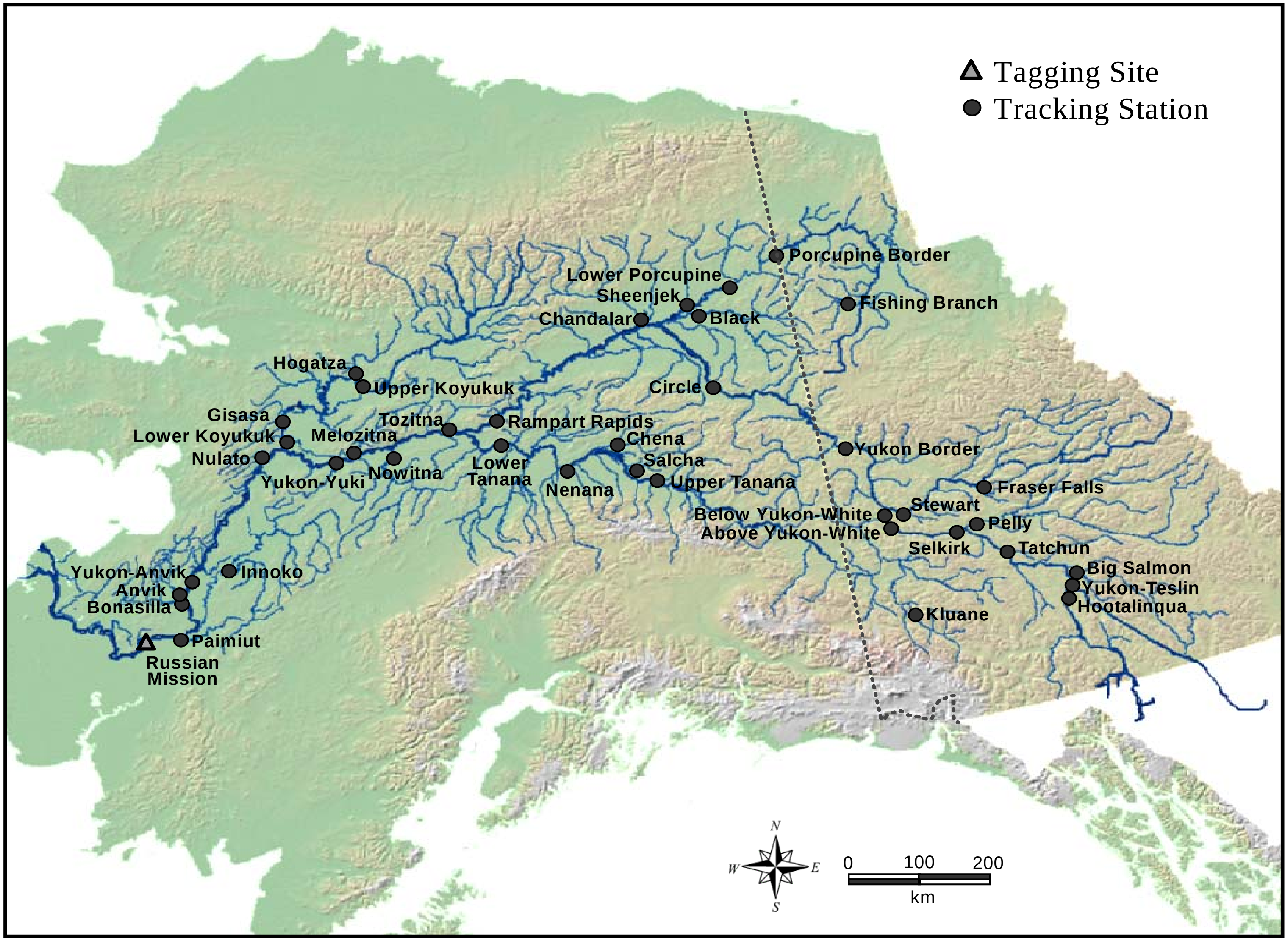


Figure 2.–Yukon River basin showing the location of remote tracking stations used to track the upriver movements of radio-tagged Chinook salmon.

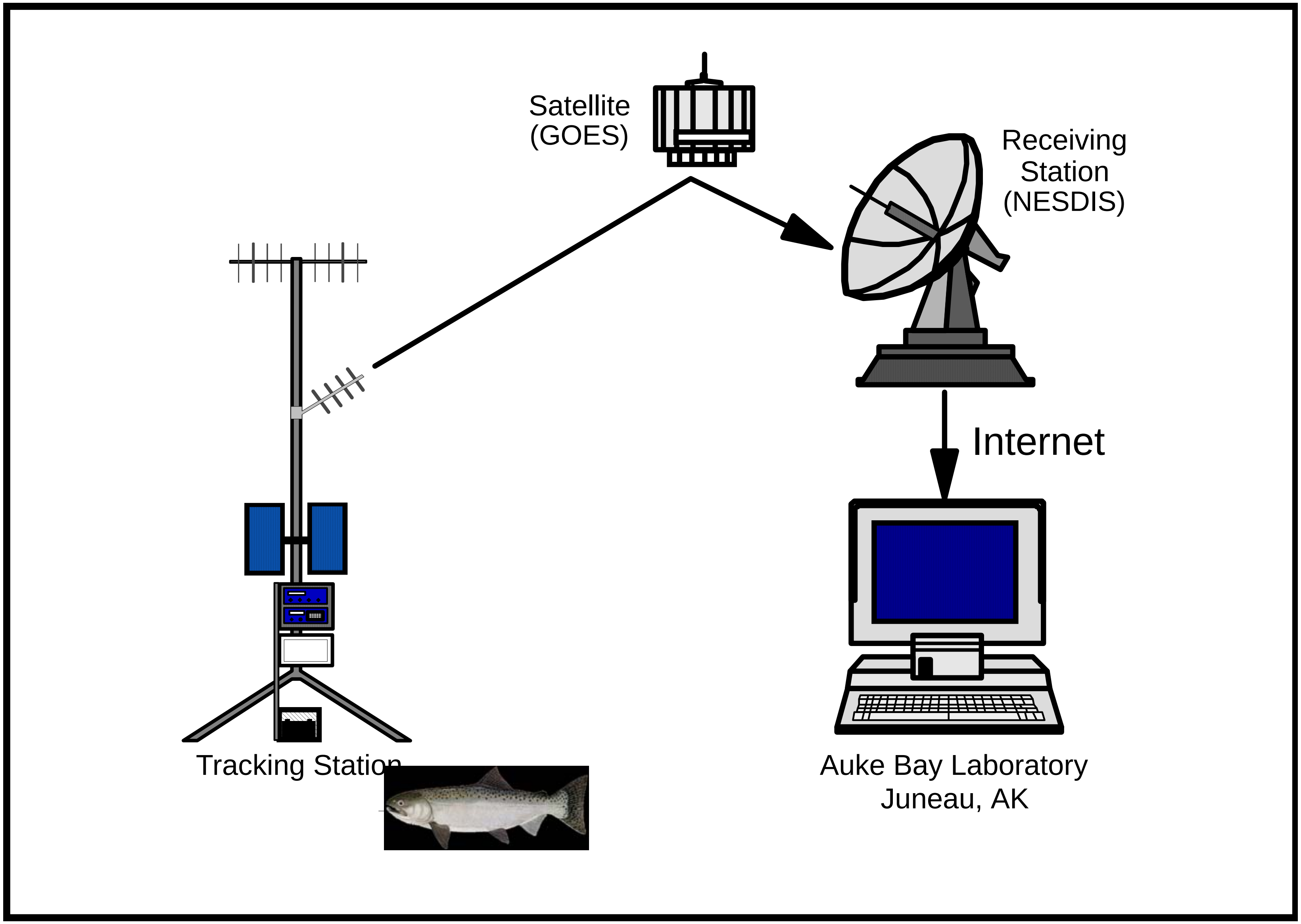


Figure 3.–Remote tracking station and satellite uplink diagram used to collect and access movement information of Chinook salmon in the Yukon River basin.

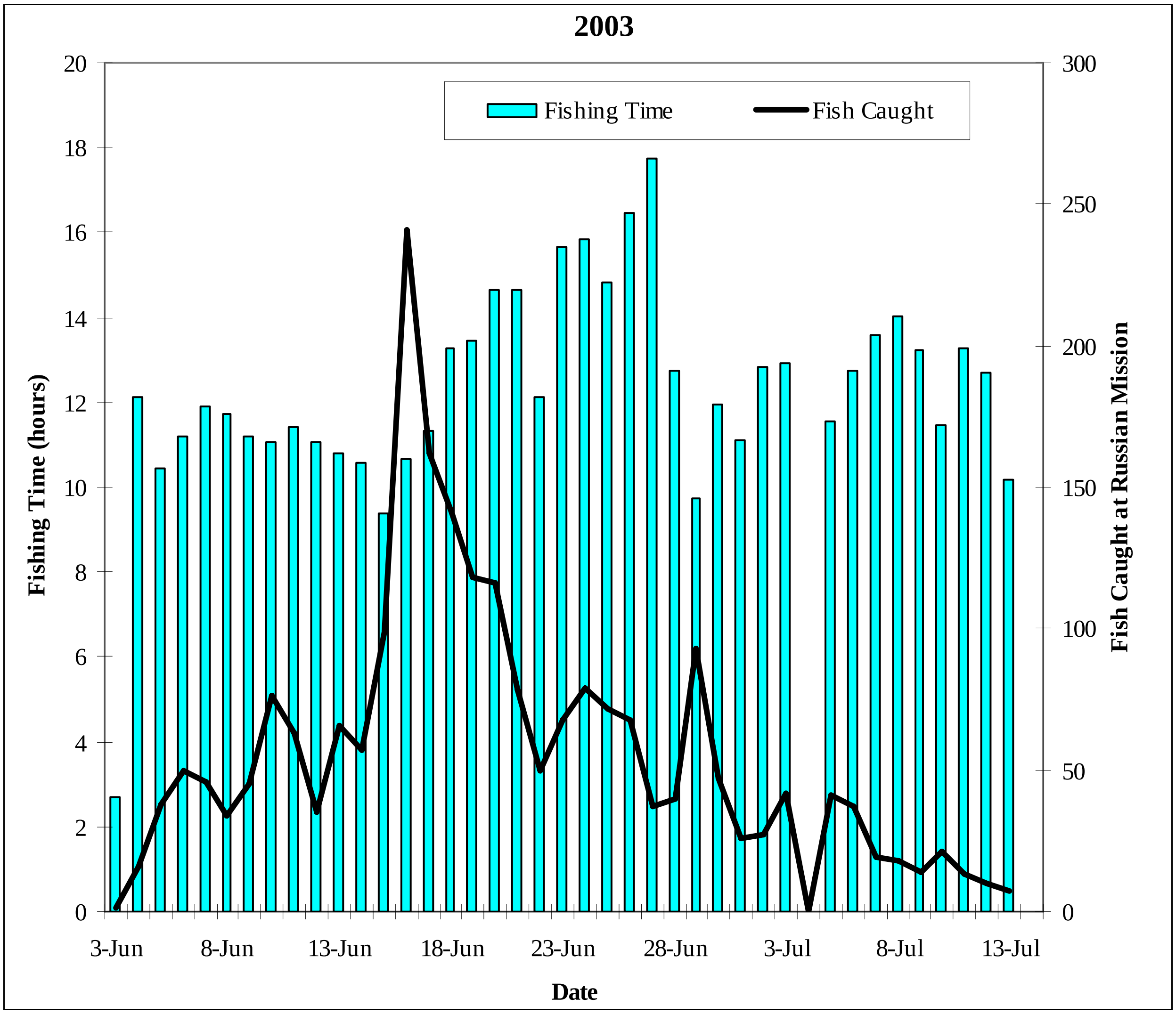


Figure 4.–Daily numbers of Chinook salmon caught at Russian Mission, and the number of hours fished per day in 2003.

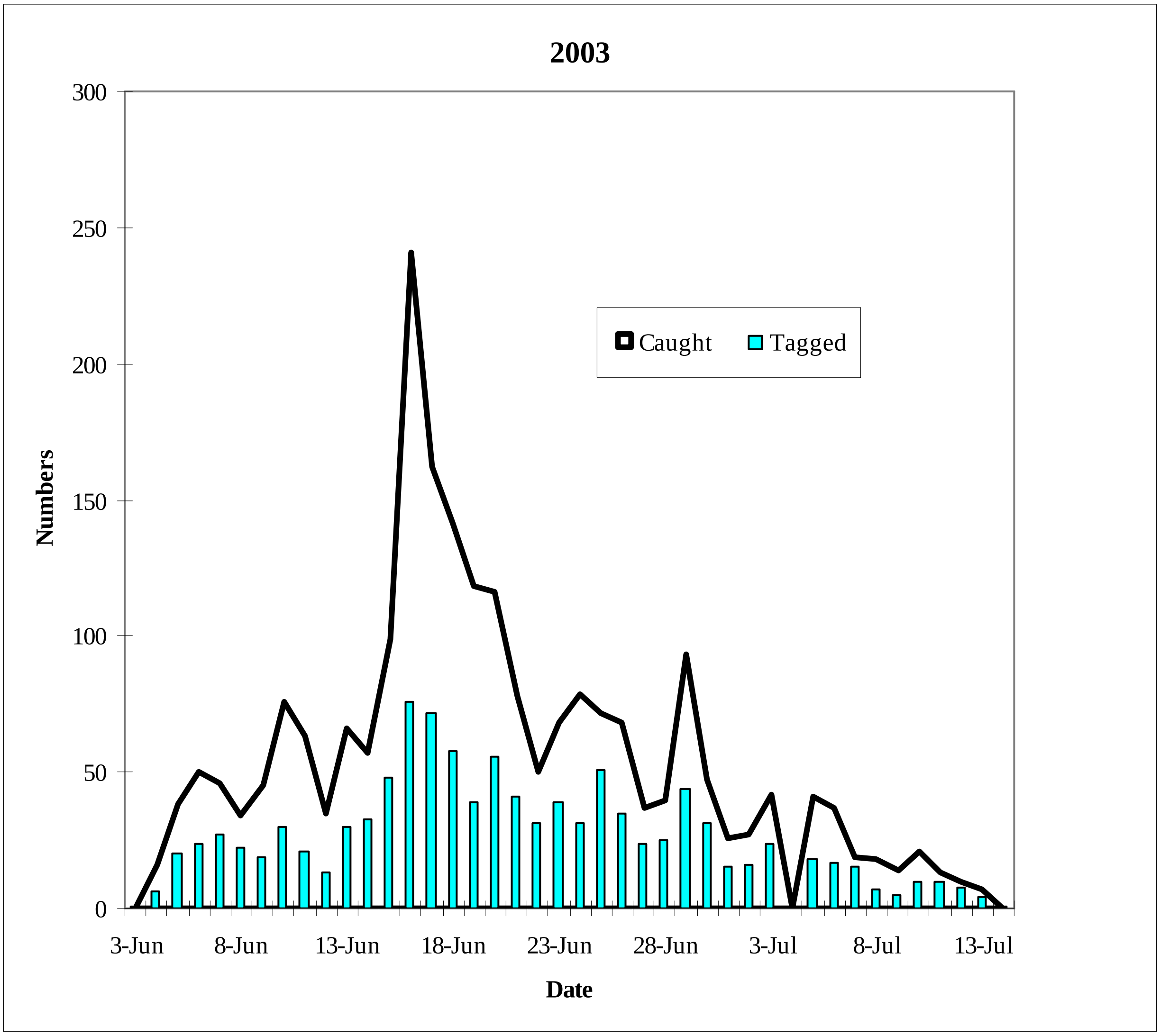


Figure 5.–Daily numbers of Chinook salmon caught and marked at Russian Mission in 2003.

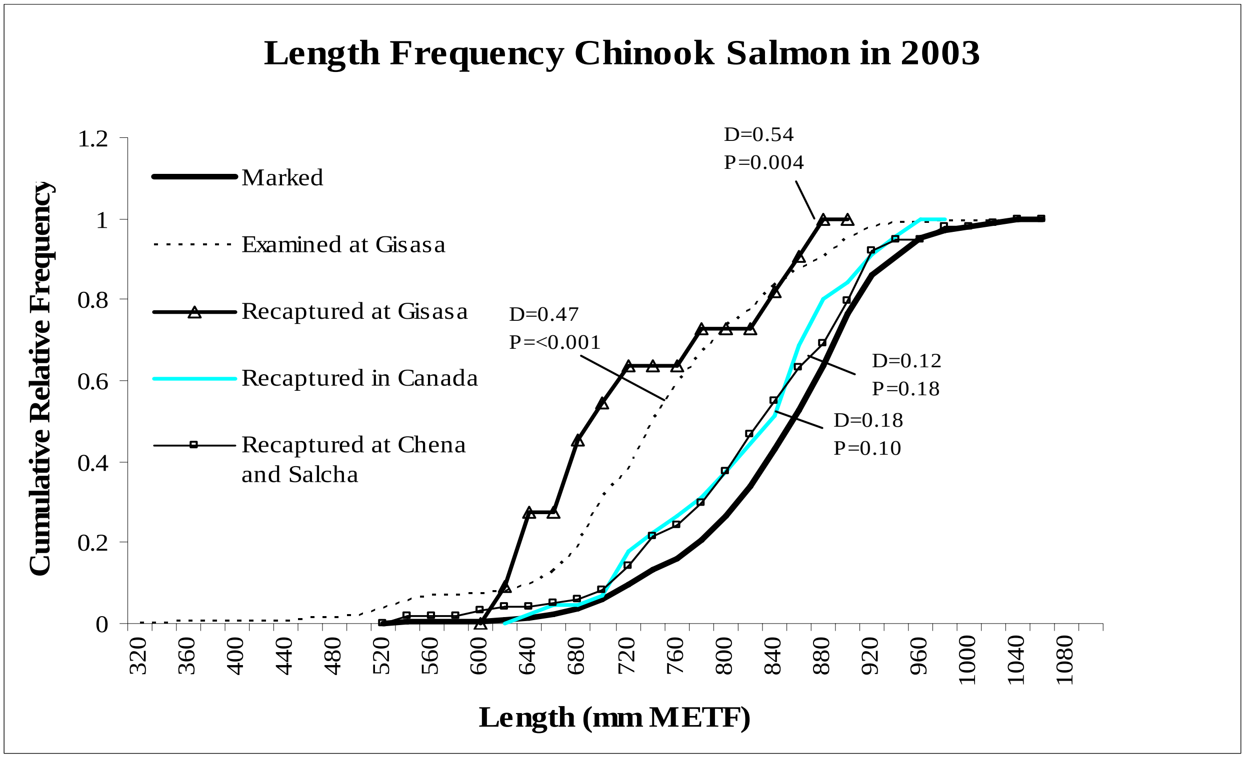


Figure 6.–Cumulative relative length frequencies of Chinook salmon marked at Russian Mission in 2003 compared with examined and recaptured fish during sampling in Yukon River recovery projects.

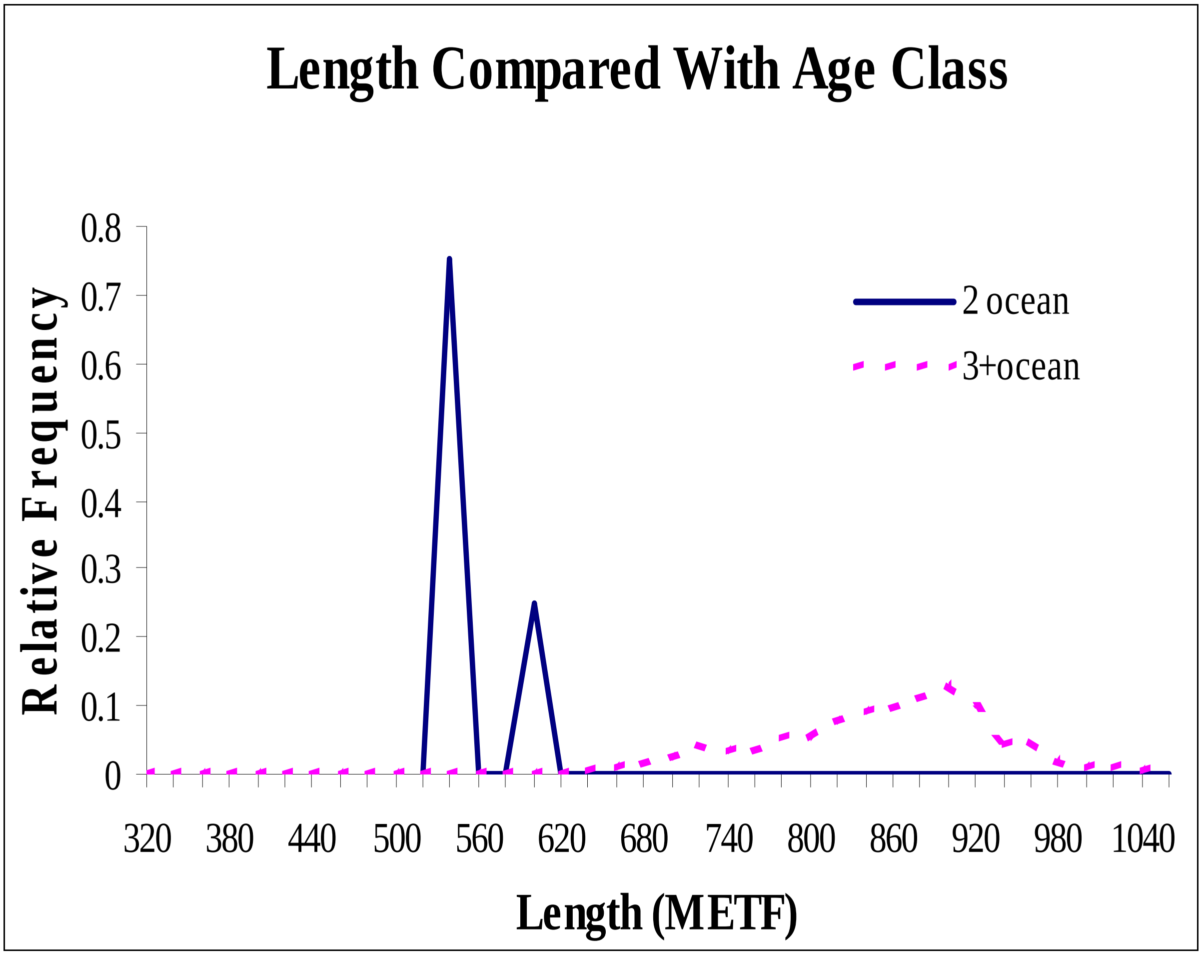


Figure 7.–Relative length frequency (METF), of 2 ocean and 3+ ocean age class Chinook salmon radio tagged at Russian Mission in 2003.

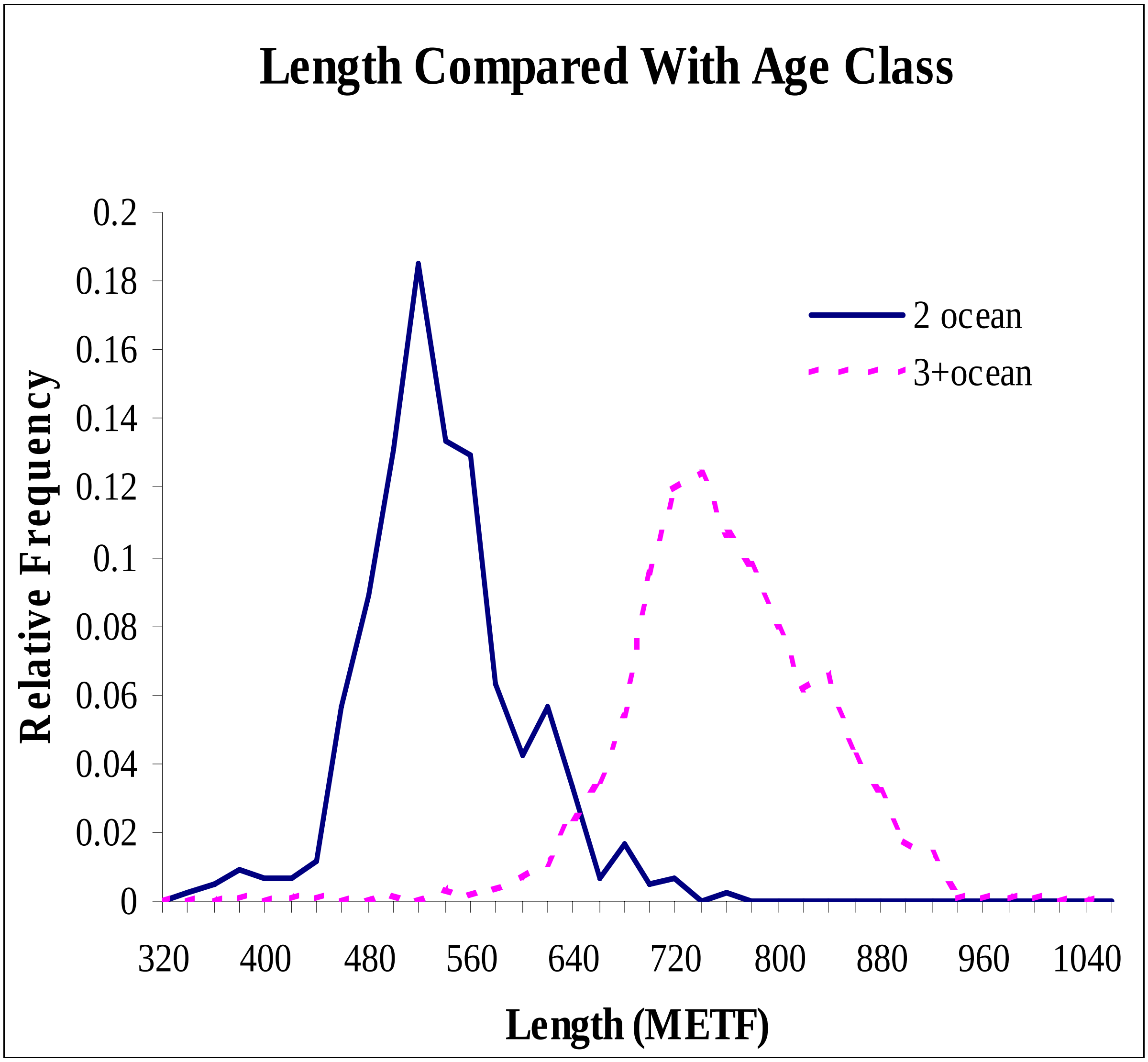


Figure 8.–Relative length frequency (METF), of 2 ocean and 3+ ocean age class Chinook salmon from recovery projects in 2003.

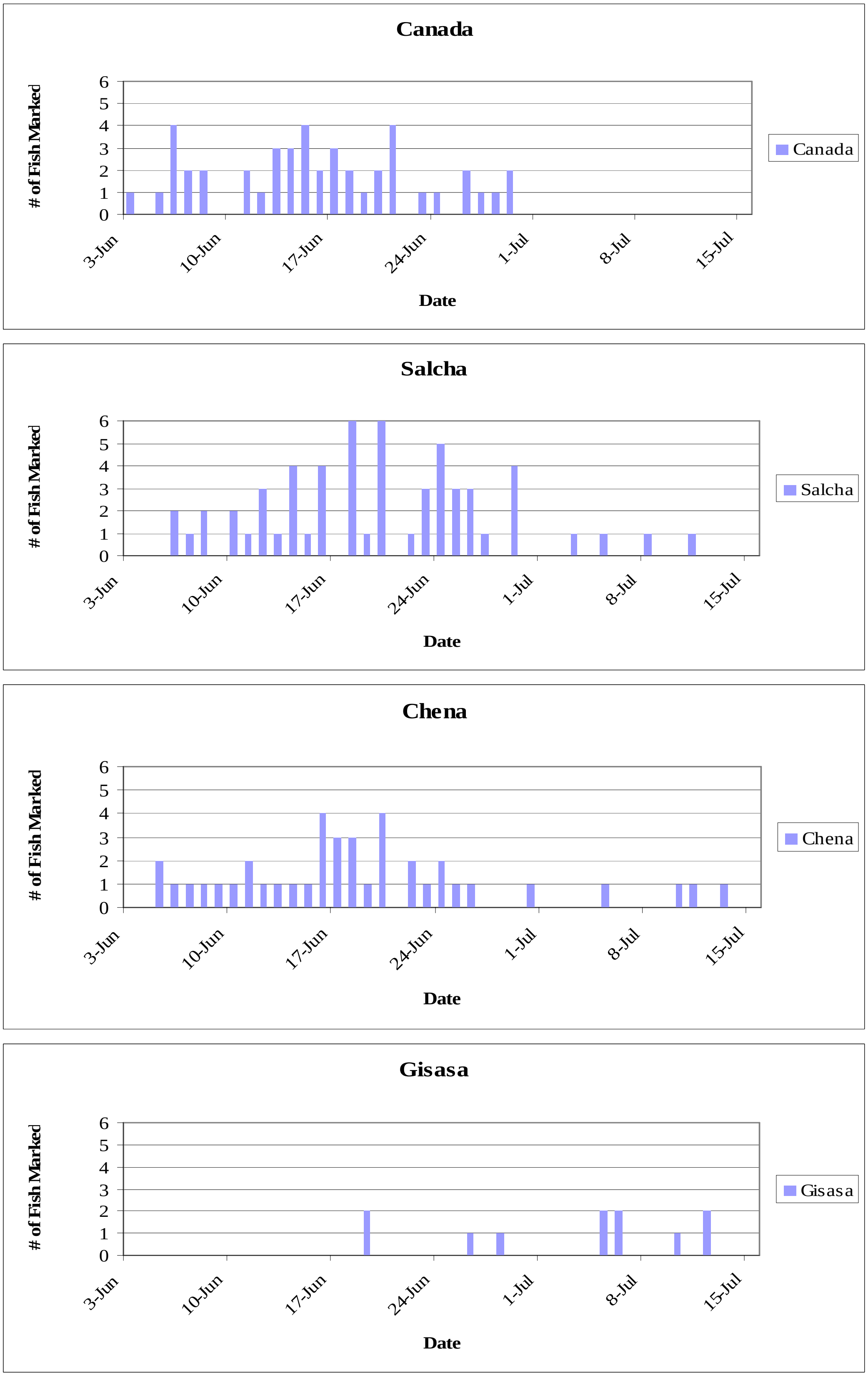
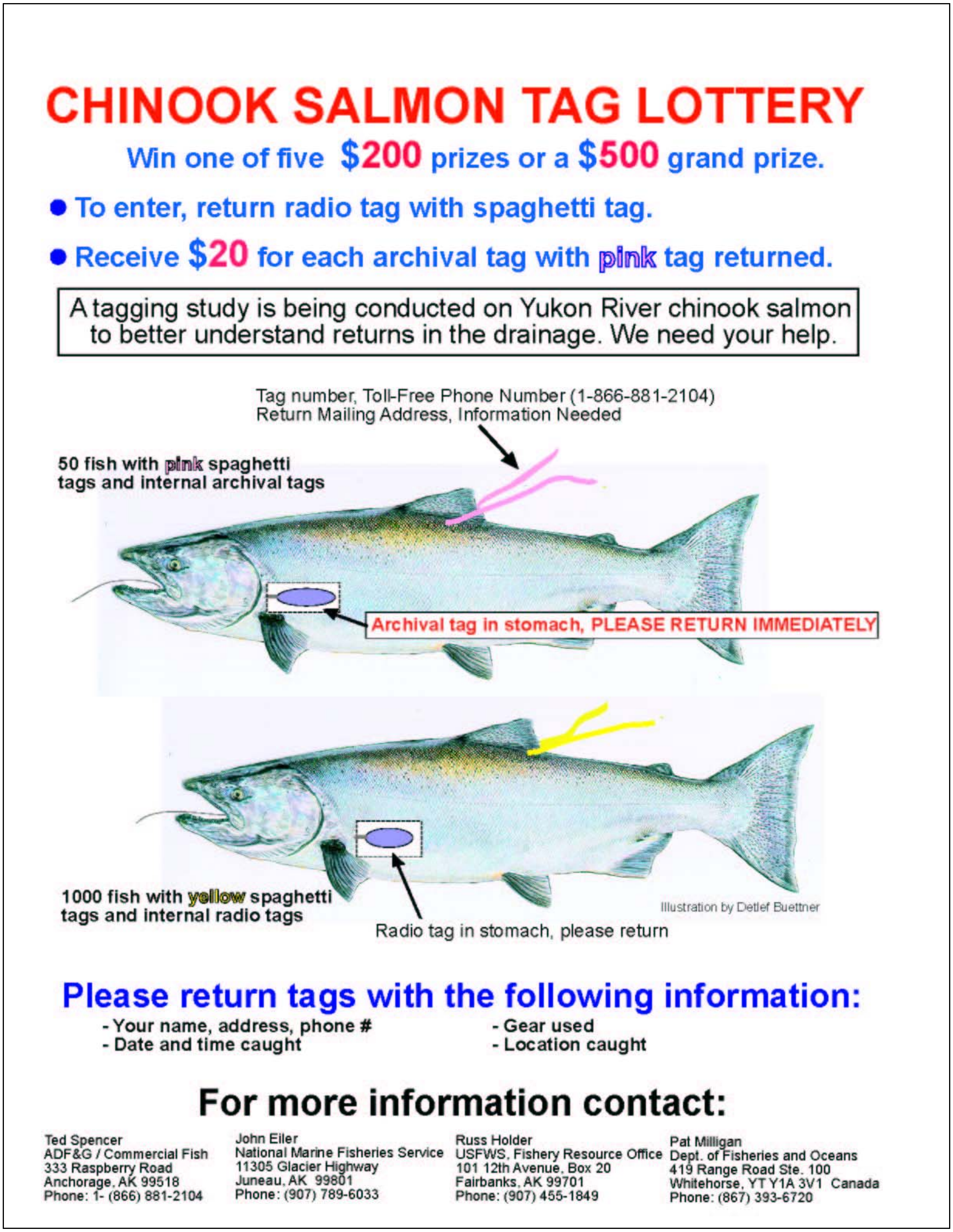


Figure 9.–Timing of marked fish passing Russian Mission destined for recovery projects in 2003.

APPENDIX A. TAG RETURN POSTER

Appendix A1.–Tag return poster used in 2003 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 2003.

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, 2003

Teslin, YT YOA-1BO Canada

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 fourth season of a cooperative radio telemetry program conducted by the Alaska Department of Fish and Game and the National Marine Fisheries Service.

In June and July, 2,312 Yukon River Chinook salmon were captured in drift gillnets near the village of Russian Mission. Of these fish, 1,097 were marked with spaghetti tags and radio transmitters. The Chinook salmon were tracked upriver using radio telemetry, and 210 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
802	6/21/2003	Russian Mission	8/2/2003	Teslin River (caught in Teslin Lake)	42	1427	33.9

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

$500 Grand Prize - Laura Miller, Whitehorse
$200 Week 1 Prize - Adolph Ekada, Nulato
$200 Week 2 Prize - Charlie Campbell, Tanana
$200 Week 3 Prize - Henry W. Wiehl, Rampart
$200 Week 4 Prize - David Stepp, Fairbanks
$200 Week 5 Prize - David Harwood, Whitehorse

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
Fishery 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 tagging sites in 2003.

	Russian Mission [a]							**Dogfish**						
	Chinook salmon							Chinook salmon						
		Tagged		Not tagged					Tagged		Not tagged			
Date	Caught	Radio tagged	Recap.	Mort.	Released alive	Chum salmon	Other fish	Caught	Radio tagged	Recap.	Mort.	Released alive	Chum salmon	Other fish
3-Jun	Did not fish							2	1	0	0	1	1	0
4-Jun	6	2	0	0	4	0	0	10	4	0	0	3	0	0
5-Jun	13	4	0	1	8	0	0	25	16	0	1	9	0	1
6-Jun	12	7	0	0	5	0	0	38	17	1	0	18	0	0
7-Jun	4	1	0	0	3	0	0	42	26	1	0	15	3	0
8-Jun	11	4	0	0	10	7	1	23	18	0	0	9	0	0
9-Jun	10	3	0	0	7	0	0	35	16	0	2	14	0	0
10-Jun	27	6	0	0	21	0	0	49	24	1	1	25	1	0
11-Jun	15	7	0	0	8	2	0	48	14	0	2	31	0	0
12-Jun	15	3	0	1	11	0	0	20	10	1	0	9	0	0
13-Jun	17	8	0	0	9	0	0	49	22	2	0	26	0	0
14-Jun	22	14	0	0	8	0	0	35	19	0	1	12	0	0
15-Jun	39	22	0	1	16	1	0	60	26	0	2	31	0	0
16-Jun	108	32	1	5	63	0	0	133	44	0	1	88	0	0
17-Jun	66	31	0	0	35	3	0	96	41	1	0	51	0	0
18-Jun	41	17	3	0	24	5	0	100	41	1	0	59	6	0
19-Jun	36	14	0	0	21	3	1	82	25	2	0	56	6	0
20-Jun	42	20	0	3	21	2	0	74	36	0	0	39	1	0
21-Jun	26	16	0	1	11	3	0	52	25	0	0	26	23	0
22-Jun	9	5	0	0	5	3	0	41	26	1	0	13	4	1
23-Jun	24	12	0	0	11	2	0	44	27	1	0	20	3	0
24-Jun	26	10	0	0	13	2	0	53	21	0	1	23	7	0
25- Jun	20	16	0	0	8	6	0	52	35	0	0	24	6	1
26- Jun	10	4	0	0	5	2	0	58	31	0	0	22	19	0
27- Jun	6	4	0	0	3	4	0	31	20	0	1	14	14	0
28- Jun	7	5	0	0	2	1	0	33	20	0	0	12	9	0
29- Jun	20	8	1	0	11	2	0	73	36	0	2	30	10	0
30- Jun	7	3	1	0	3	2	0	40	28	1	0	17	5	0
1-Jul	7	2	0	0	5	10	0	19	13	0	2	5	19	0
2-Jul	8	4	0	0	3	3	0	19	12	0	1	6	13	2
3-Jul	15	3	0	0	12	2	0	27	21	0	0	8	23	3
4-Jul[b]	Did not fish													
5-Jul	14	6	0	0	8	1	0	27	12	0	1	12	15	2
6-Jul	11	3	0	0	8	2	0	26	14	1	0	10	13	0
7-Jul	3	3	0	0	0	0	0	16	12	0	0	6	16	0
8-Jul	7	4	0	0	3	4	0	11	3	0	1	6	6	0
9-Jul	3	0	0	1	2	1	0	11	5	0	1	7	15	0
10-Jul	5	1	0	0	4	3	0	16	9	0	0	5	17	0
11-Jul	3	3	0	0	0	3	0	10	7	1	0	4	13	0
12-Jul	0	0	0	0	0	0	0	10	8	0	0	0	4	1
13-Jul	Did not fish							7	5	0	0	4	2	0
14-Jul[b]	Did not fish													
Site total	715	307	6	13	391	79	2	1,597	790	15	20	770	274	11
Project total	**2,312**	**1,097**	**21**	**33**	**1,161**	**3534**	**13**							

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

[a] Two crews fished at the Russian Mission site 16 June to 21 June and 23 June to 27 June.

[b] One fish radio tagged after midnight.

Appendix C2.–Numbers of Chinook salmon marked at Russian Mission by length (METF) and numbers inspected upriver at recovery projects in 2003.

Location	Total	< 650 mm	Percentage	≥ 650 mm	Percentage
Number of Fish Marked					
Radio tagged	1,097	15	1.4	1,082	98.6
Number of Fish Captured					
Anvik (carcass)	460	56	12.2	404	87.8
Koyukuk River drainage					
Gisasa (live weir)	511	49	9.6	462	90.4
Henshaw (live weir)	321	85	26.5	236	73.5
Tozitna (live weir)	554	199	35.9	355	64.1
Tanana River drainage					
Chena (carcass)	459	23	5.0	436	95.0
Salcha (carcass)	166	20	12.0	146	88.0
Canada					
Yukon River (fishwheel)	1,229	144	11.7	1,085	88.3
Total	**3,700**	**576**	**15.6**	**3,124**	**84.4**
Number of Marked Fish Captured					
Anvik (carcass)	31	1	3.2	30	96.8
Koyukuk River drainage					
Gisasa (live weir)	11	3	27.3	8	72.7
Henshaw (live weir)	1	0	0.0	1	100.0
Tozitna (live weir)	10	1	10.0	9	90.0
Tanana River drainage					
Chena (carcass)	40	2	5.0	38	95.0
Salcha (carcass)	58	2	3.4	56	96.6
Canada					
Yukon River (subsistence)	45	1	2.2	44	97.8
Total	**196**	**10**	**5.1**	**186**	**94.9**

Appendix C3.–Status of radio tagged sample of Yukon River Chinook salmon during the 2003 spawning migration (in numbers of fish).

	Mainstem			Tributary		
Location	**Estimated Passed [a]**	**Fished [b]**	**Unknown [c]**	**Passed [d]**	**Fished [b]**	**Unknown [c]**
Released	**1,097**		16			
Russian Mission		4				
MS-Paimiut			16			
Total	**1,061**					
MS-Holy Cross		23				
Total	**1,038**					
Lower Basin Tributaries						
Bonasila River				6		
Anvik River		4		31		
Innoko				2		
Total	**995**					
Above Anvik						
MS-Above Anvik			33			
MS-Grayling		7				
MS-Kaltag		6				
Nulato River		17		15		
Total	**917**					
Koyukuk River						
Lower Koyukuk						2
Gisasa				11		
Kateel					3	
Hogatza				1		
Henshaw				1		
Upper Koyukuk				10	1	
Total	**888**					
MS Above Koyukuk						
MS-Galena		17				
MS-Yuki			8			
MS-Ruby		5				
Total	**858**					
Mid River Tributaries						
Melozitna River				1		
Nowitna River				2		
Tozitna River				10		
MS-down river Tanana			12			
Total	**833**					
Tanana River					1	2
Kantishna River				15		
Tolovana River				3	2	
Nenana River				3		
MS-Nenana					15	4
Fairbanks					3	
Chena River				37	3	
Clear Creek				2		
Salcha River				57	1	
Upper Tanana						6
Goodpaster				36		
Total	**643**					

-continued-

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Location	Estimated	Mainstem Fished [b]	Mainstem Unknown [c]	Tributary Passed [d]	Tributary Fished [b]	Tributary Unknown [c]
Above Tanana						
MS-Tanana		5				
MS-Yukon Raven			21			
MS-Rapids		18				
MS-Rampart		17				
MS-Above Rapids						
Hess Creek		2				
MS-Bridge		12				
MS-Stevens Village		11				
Beaver Creek		11		3		
Chandalar River				36		
Total	**507**					
Porcupine River						10
Sheenjek				20		
Black				2		
Lower Porcupine						
Porcupine Border						
Old Crow				2	3	
Whitestone				1		
Fishing Branch				1		
Miner				13		
Total	**455**					
Above Porcupine						
MS-Rapids to Circle						
MS-Fort Yukon		12				
MS-Circle		7	10			
MS-Yukon Circle						
Charley				3		
Kandik				1		
Nation				2		
MS-Eagle		7				
Total	**413**					
Canadian Yukon						
MS Yukon Border			2			
MS Forty Mile			5			
Chandindu River				5		
MS-Dawson City		14				
Klondike River				19		
Stewart River				27	4	
MS-White			6			
White River				12		
MS-Pelly (Selkirk)			27			
PellyRiver				71	8	
MS-Tatchun			34			
Tatchun River				2		
MS-Carmacks		9				
Nordensk River				8		
Little Salmon River				17		
Big Salmon River				59	7	
Teslin River				64		
MS-Whitehorse						
Takhini				6		
S-Hootalinqua			7			
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.

APPENDIX D. CPUE INFORMATION

Appendix D1.–CPUE information from the Russian Mission tagging site in 2003.

Date	No. Chinook Salmon	Minutes Fished	Total Sum of Net Length	CPUE
3-Jun-03	1	161	225	1.49
4-Jun-03	12	728	1,300	3.96
5-Jun-03	40	627	1,175	15.31
6-Jun-03	47	672.5	1,225	16.77
7-Jun-03	44	714	1,250	14.79
8-Jun-03	41	726	1,225	13.55
9-Jun-03	40	671	1,075	14.31
10-Jun-03	78	657.5	1,150	28.47
11-Jun-03	63	686	1,550	22.04
12-Jun-03	37	663.5	1,575	13.38
13-Jun-03	61	648	1,475	22.59
14-Jun-03	58	634.5	1,350	21.94
15-Jun-03	96	563	1,400	40.92
16-Jun-03	223	638.5	1,975	83.82
17-Jun-03	159	681.5	1,875	55.99
18-Jun-03	147	796.5	2,000	44.29
19-Jun-03	126	791	1,975	38.23
20-Jun-03	116	877.5	1,825	31.73
21-Jun-03	82	883	1,950	22.29
22-Jun-03	55	729	1,475	18.11
23-Jun-03	70	928.5	1,775	18.09
24-Jun-03	58	964.5	1,875	14.43
25-Jun-03	94	892.5	1,550	25.28
26-Jun-03	62	977	1,600	15.23
27-Jun-03	40	1065	1,850	9.01
28-Jun-03	44	764.5	1,425	13.81
29-Jun-03	81	584.5	1,125	33.26
30-Jun-03	62	716	1,325	20.78
1-Jul-03	23	667	1,325	8.28
2-Jul-03	27	770.5	1,400	8.41
3-Jul-03	45	775.5	1,250	13.93
4-Jul-03				
5-Jul-03	36	690.5	1,200	12.51
6-Jul-03	36	763.5	1,275	11.32
7-Jul-03	24	815.5	1,275	7.06
8-Jul-03	17	842	1,275	4.85
9-Jul-03	16	793.5	1,350	4.84
10-Jul-03	18	688.5	1,200	6.27
11-Jul-03	16	804.5	1,300	4.77
12-Jul-03	8	761.5	950	2.52
13-Jul-03	9	611.5	625	3.53

Note: The project was not operational on July 4.