Fishery Data Series No. 05-39

Inriver Abundance of Chinook Salmon in the Kuskokwim River, 2002-2004

Final Report for Study 02-046
USFWS Office of Subsistence Management
Fisheries Information Services Division

by

Lisa Stuby

July 2005

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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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.

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ABSTRACT

Two-sample mark-recapture experiments were conducted from June to August each year from 2002-2004 to estimate abundance of returning Chinook salmon *Oncorhynchus tshawytscha* in waters of the Kuskokwim River upstream from the Aniak River using radiotelemetry techniques. In each year, an attempt was made to distribute radio tags over the total run such that the radio-tagged fish would be representative of the entire run with respect to temporal abundance, size, sex, and stock composition. Fish were sampled using drift gillnets and fish wheels at various locations between Kalskag and the Aniak River. Chinook salmon that were captured and radio-tagged constituted the first sample and fish counted at four weirs on tributaries of the Kuskokwim River constituted the second sample. Radio-tagged Chinook salmon that migrated past the weirs and were recorded by stationary tracking stations constituted the recaptured portion. Aerial surveys of the Kuskokwim River drainage were conducted each year in July and August. From 2002–2004, approximate 97-99% of radio-tagged fish were detected by a combination of aerial surveys and 13 stationary tracking stations. For all three seasons, Aniak River bound Chinook salmon were censored from the final estimate due to strong evidence of bank orientation. The estimate of abundance for Chinook salmon $\geq$450 mm MEF for the Kuskokwim River upstream of the Aniak River was 100,733 (SE = 24,267) for 2002, 103,161 fish (SE = 18,720) for 2003, and 146,839 (SE = 21,980) for 2004. The majority of radio-tagged Chinook salmon entered the Holitna and Aniak rivers. In general, fish migrating farther upriver arrived at the tagging site earlier than those bound for nearby systems.

Key words: aerial survey, Aniak River, abundance estimate, Chinook salmon, Holitna River, king salmon, Kuskokwim River, mark-recapture, *Oncorhynchus tshawytscha*, radio tag, radiotelemetry, tracking stations

INTRODUCTION

The Kuskokwim River drains a remote basin of about 130,000 km^2 along its 1,130-km course from the interior of Alaska to the Bering Sea. The Kuskokwim River supports five species of Pacific salmon as well as commercial and sport fisheries. The subsistence salmon fishery in the Kuskokwim region is one of the largest and most important in the state (Ward et al. 2003). The directed commercial Chinook salmon *Oncorhynchus tshawytscha* fishery in the mainstem Kuskokwim River was discontinued in 1987 to ensure that subsistence needs would be met. The incidental catch of Chinook salmon in the commercial fishery currently ranks fourth overall behind sockeye *O. nerka*, chum *O. keta*, and coho *O. kisutch* salmon in terms of total harvest and value to the commercial fishers.

Catch, effort, and harvest for Chinook salmon in the upper and middle Kuskokwim River area from sport fishing is relatively low compared to other areas of the state (Table 1). The largest sport fisheries for Chinook salmon occur in the Kisaralik, Kwethluk, Aniak, and Holitna rivers. The estimated harvest of Chinook salmon in all waters including and above the Aniak River in 2001 was 97 Chinook salmon, for 2002 was 243 Chinook salmon, and for 2003 was 60 Chinook salmon (Jennings et al. 2004, *In prep a-b*). Between 1993 and 2002, the average sport harvest of Chinook salmon within the entire Kuskokwim River drainage as a proportion of the total utilization of this species was 0.8% and between 1998 and 2002 was 0.6% (Lafferty 2004).

From 1998-2000, Kuskokwim area Chinook salmon showed poor escapements compared to previous years and in conjunction, poor subsistence harvests. The 2001 Kuskokwim area Chinook salmon subsistence harvest increased over the relatively poor harvest in 2000. However, when compared to the 10-year period of 1990 – 1999, the 2001 Chinook salmon subsistence harvest was 11% below average (Burkey et al. 2002). As a result of the low harvests and escapements, federal subsistence funds became available in 2001 to assist in escapement evaluation in the Kuskokwim River (Lafferty 2003). In September 2002, the BOF designated

Table 1.–Estimated sport, commercial, and subsistence harvests of Chinook salmon in the Kuskokwim River drainage, 1985–2004.

	Sport Harvest[a]								
Year	Aniak River	Holitna River	Upper Kuskokwim River[b]	Lower Kuskokwim River[c]	Total Sport	Commercial[d]	Subsistence[d]	Total Harvest	% Sport Harvest
1985				43	43	37,889	43,874	81,806	0.05%
1986				24	24	19,414	51,019	70,457	0.03%
1987				178	178	36,179	67,325	103,682	0.17%
1988				264	264	55,716	70,943	126,923	0.21%
1989	738			978	978	43,217	81,176	125,371	0.78%
1990	285			340	340	53,504	85,979	139,823	0.24%
1991	214			308	308	37,778	85,554	123,640	0.25%
1992	172	23	55	274	329	46,872	64,795	111,996	0.29%
1993	300	68	85	444	529	8,735	87,512	96,776	0.55%
1994	437	40	108	842	950	16,211	93,242	110,403	0.86%
1995	279	19	169	321	490	30,846	96,436	127,772	0.38%
1996	592	256	288	782	1,070	7,419	78,063	86,552	1.24%
1997	795	166	279	942	1,221	10,441	81,577	93,239	1.31%
1998	1,058	54	174	1,183	1,357	17,359	81,265	99,981	1.36%
1999	134	25	36	243	279	4,705	73,194	78,178	0.36%
2000	10	22	55	40	95	444	64,893	65,432	0.15%
2001	12	73	85	16	101	90	73,610	73,801	0.14%
2002	135	53	108	211	319	72	70,219	70,610	0.45%
2003	12	48	48	353	401	150	78,941	79,492	0.50%
2004	NAe	NAe	NA[e]	NA[e]	NA[e]	2,300	NA[e]	NA[e]	NA[e]

a Sport fish harvest estimates from Mills (1986-1994), Howe et al. (1995-1996, 2001a-d), Walker et al. (2003), and Jennings et al. (2004, *In prep a-b*).

b Upper Kuskokwim River sport harvest estimates are upriver from the Aniak River (including the Holitna River drainage), but do not include the Aniak River.

c Lower Kuskokwim river sport harvest estimates are downriver from the Aniak River and include the Aniak River.

d Commercial and subsistence harvest estimates from Burkey et al. (2002), Ward et al. (2003), Whitmore and Bergstrom (2003), and Whitmore et al. (*In prep*).

e Sport harvest and subsistence estimates not available.

Kuskokwim River Chinook and chum salmon stocks of concern under the regulatory Policy for the Management of Sustainable Salmon Fisheries (5 AAC 39.222, 2001; Molyneaux 2002).

Since 2002, Kuskokwim River Chinook salmon runs have shown improvement. The 2002-2004 Chinook and chum salmon runs were large enough to provide Kuskokwim River subsistence fishers the opportunity to harvest the amounts of fish necessary for subsistence use (Bergstrom and Whitmore 2004; Whitmore et al. *In prep*). The sustainable escapement goal of 10,000 fish for the Kogrukluk River weir was met in 2002 and exceeded in 2003. However, at the January 2004 BOF meeting, the Board voted to continue the stock of yield concern classification for Kuskokwim River Chinook salmon. This determination was based on the continued inability, despite the use of specific management measures, to maintain expected yields or harvestable surpluses above a stock's escapement needs from 1998 to 2001 (Bergstrom and Whitmore 2004).

Salmon runs in the Kuskokwim are managed for sustained yields under policies set forth by the Alaska Board of Fisheries with subsistence fishing receiving the highest priority. Inseason management has relied on run-strength indices from commercial catch data, test fisheries, and informal reports from subsistence fishers. The effectiveness of in-season management has been evaluated with aerial surveys and, more recently, ground-based projects. However, the size, remoteness, and geographic diversity of the Kuskokwim River have presented challenges to monitoring salmon escapements and assessing run strength. In addition, the ground-based projects have provided limited information. Aerial spawning-ground surveys have been the most cost-effective means of monitoring salmon escapements, but their usefulness is limited due to their high degree of variability (Burkey et al. 1999). Moreover, the aerial surveys are primarily conducted in the lower Kuskokwim River because the middle and upper river tributaries are generally tannic-stained or glacially-occluded. Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations.

As a result of persistent low escapements, a long-term research program was proposed to examine changes in salmon productivity and the effects on the people who live and utilize this resource along the Kuskokwim River (Merritt 2001). A congressional appropriation in 1998 for salmon research in the Kuskokwim River (Western Alaska Disaster Funds) proposed long term research to: (1) understand stock productivity; (2) evaluate the appropriateness of current management policies and escapement goals during times of low productivity; (3) implement abundance-based management regimes; and, (4) improve preseason forecasts of abundance for industry planning and establishing quotas. Allocation of these funds was contingent on the evaluation of research needs for the Kuskokwim River through a strategic planning exercise using the Analytic Hierarchy Process (Saaty 1990). An ADF&G strategic planning exercise was completed in 2001 and recommendations were made to acquire more information on spawning escapement throughout the Kuskokwim River drainage and examine stock specific run timing and exploitation (Merritt 2001). A follow-up planning exercise that includes a broad range of stakeholders is being conducted by the Bering Sea Fisherman's Association and LGL, Inc. In the course of this planning exercise, stakeholders including the Kuskokwim River Fisheries Resource Coalition (KFRC) endorsed efforts to estimate total returns of Kuskokwim River Chinook salmon.

The strategic planning exercises and infusion of funds resulted in the design of a 4-year project to expand current escapement monitoring activities on the Kogrukluk River by estimating the proportion of Holitna River Chinook, chum, and coho salmon that pass the Kogrukluk River weir and subsequently estimating drainage-wide escapement by proportional expansion of the weir counts (Wuttig and Evenson 2002). The Holitna River is the most utilized tributary for sport fishing in the upper portion of the Kuskokwim River drainage because of the diversity and abundance of Chinook, chum, coho salmon and resident species (Burr 2002).

In addition to the Holitna River salmon enumeration project, weirs were operated on the George, Tatlawiksuk, Takotna, and Kogrukluk rivers to enumerate escapements and to estimate age, sex, and length compositions of migrating salmon. A sonar station on the lower Aniak River provides estimates of total salmon passage but does not differentiate between species. The relative contributions of these tributary escapements to total abundance can not be estimated without a drainage-wide escapement estimate. Therefore in 2002, this Kuskokwim River mainstem mark-recapture project was implemented to estimate the number of Chinook salmon passing upstream of Kalskag (approximately 309 river kilometers (rkm) upriver from the mouth of the Kuskokwim River (Figure 1).

This report summarizes information collected from 2002-2004. The primary goal of this multi-year study is to collect comprehensive estimates of run size for the middle and upper portions of the Kuskokwim River drainage which in conjunction with escapement monitoring projects in the lower River (Kwethluk and Tuluksak rivers) and harvest estimates, can be used to approximate total returns to the Kuskokwim River. This information can be used to evaluate annual exploitation rates and to assess the fraction of the return enumerated by the various weir projects. From this, escapement goals, from which subsistence and sport fisheries can be managed, can be derived or improved. In addition, this project collects information on spawning locations and run timing of Chinook salmon in the middle and upper drainage that may help to identify systems where future escapement monitoring projects might be initiated.

OBJECTIVES

Annual project objectives from 2002-2004 were to:

1. estimate the abundance of Chinook salmon in the Kuskokwim River for all waters upstream of Kalskag; and,
2. estimate age, sex, and length compositions of Chinook salmon in the Kuskokwim River upstream of Kalskag.

METHODS

The abundance of Chinook salmon migrating upstream past capture sites on the Kuskokwim River near Kalskag (Figure 1) was estimated using two-sample mark-recapture techniques. Chinook salmon were captured using drift gillnets and fish wheels throughout the run. Age, sex, and length data were collected from all captured fish. Radio tags were the primary mark and spaghetti tags were the secondary mark. The number of Chinook salmon that retained their radio tags and were detected upstream from the tagging site constituted the first sample. The number of Chinook salmon that passed through weirs on the George, Kogrukluk, Tatlawiksuk, and Takotna rivers became the second sample in the mark-recapture experiment. Radio-tagged fish that migrated through the weirs constituted the recaptured portion of the second sample. Age, length, and sex data collected by ADF&G Commercial Fisheries Division (CFD) staff from a sample of the Chinook salmon that passed through each weir were used to test assumptions of equal probabilities of capture.

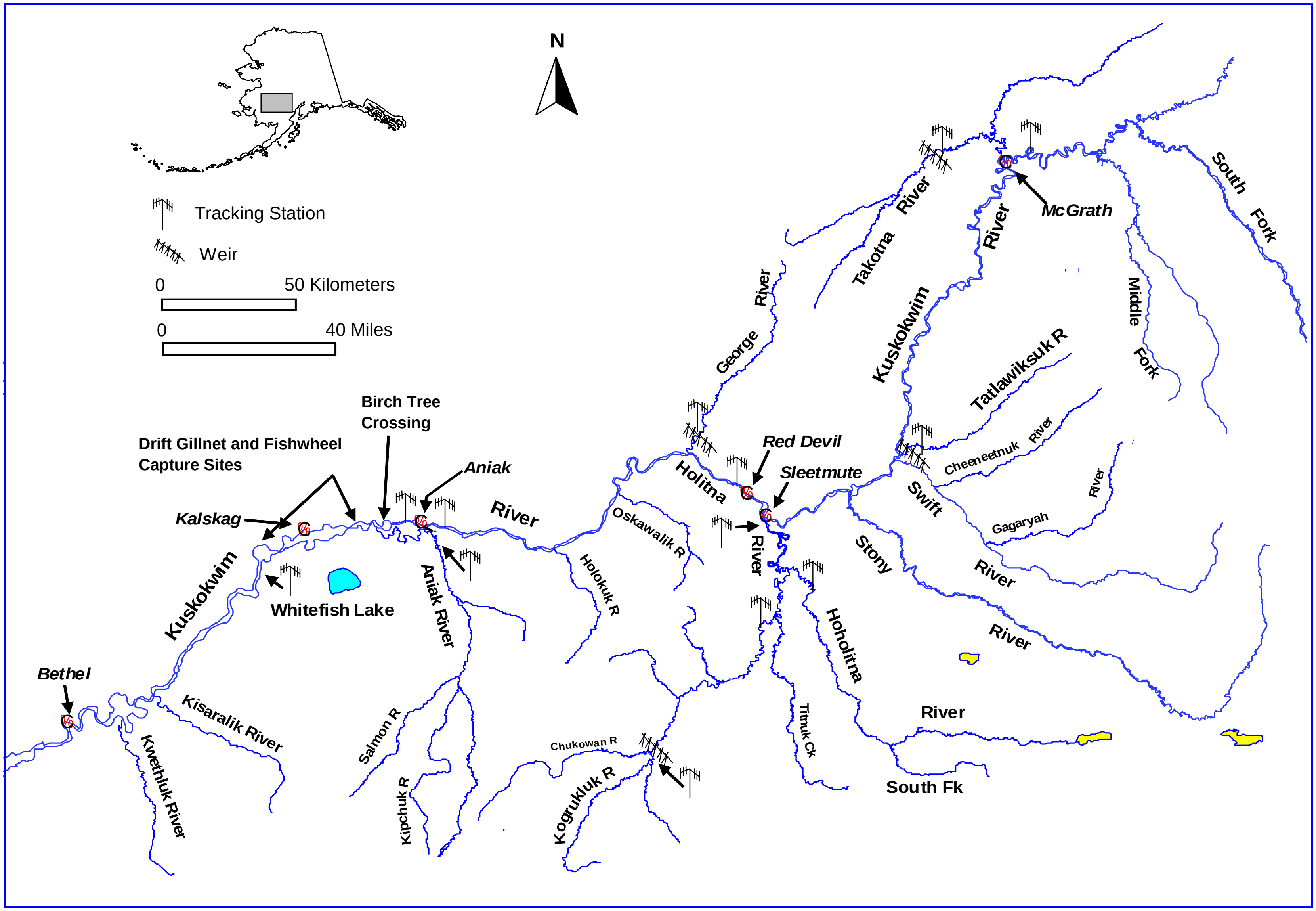

Figure 1.–Map of the Kuskokwim River showing capture sites, weirs, and tracking stations, 2002-2004.

A lottery for cash prizes was established to encourage the return of tags and assist in determining the fates of all radio-tagged Chinook salmon. All subsistence and/or sport fishers who returned radio and/or spaghetti tags were entered into this lottery. The lottery was operated by the ADF&G CFD in Anchorage. The public was made aware of the study and the lottery through personal contacts and by posting fliers in public places throughout the Kuskokwim area. Each radio tag was labeled with a return mailing address as well as a toll free number to call to provide catch information and enter the lottery. Each spaghetti tag was labeled with that same toll free number.

CAPTURE AND TAGGING

The goal of the first sampling event was to capture Chinook salmon and distribute radio tags over the span of the run in proportion to run strength, size composition, and bank of migration. Fishing was conducted six days per week (Sunday-Friday) from start to end of the run. A tag deployment schedule that attempted to distribute tags proportional to run strength was developed based on Kuskokwim River test net data, which had been collected near Aniak from 1992 to 1995 (Burkey et al. 1997). In addition, weekly tagging goals were determined for small (<650 mm) and large (≥650 mm) Chinook salmon. The number of tags that were deployed in fish of each length category was based on historical length data from the four upriver weirs. These data indicated that on average, approximately 20% of the total Chinook salmon escapement past the weirs were <650 mm. Throughout the Chinook salmon run, catches in the Bethel CFD test net fishery were monitored and the tagging schedule was altered in accordance with what CFD was observing with respect to variations in seasonal run strength. An attempt was made to radio-tag Chinook salmon in equal proportions along the north and south banks of the river to ensure that all spatial components of the run had a non-zero probability of capture. Chinook salmon were sampled with large mesh drift gillnets and fish wheels, which in combination captured a broad size range of fish.

Sampling efforts in 2002 were conducted in the vicinity of Birch Tree Crossing, located near the outlet of the Aniak River Slough (Figure 2). Results from the 2002 study suggested that the south-side fish wheel and drift gillnet sites had disproportionately sampled Chinook salmon bound for the Aniak River. Conversely, the north-side fish wheel and drift gillnet sites had captured a much lower proportion of Aniak River bound Chinook salmon compared to the downriver tagging sites. As a result, sampling activities in 2003 were moved downriver, nearer to Kalskag in an attempt to sample and mark salmon downstream from areas where bank orientation was displayed by Aniak River spawners. Although the new sampling sites allowed us to avoid the concentrations of Aniak River fish detected in 2002, Aniak River bound fish still showed marked bank orientation. As a result, the 2004 sampling activities were moved even farther downriver (Figure 2).

In all three years of the study, Chinook salmon were captured using both drift gillnets and fish wheels. Details of sampling locations and schedules for 2002 and 2003 are provided in Stuby (2003, 2004). Sampling efforts for 2004 commenced on 2 June and continued until 29 July. Drift gillnets were fished by a three-person crew from a riverboat along both the north and south banks of the Kuskokwim River near Kalskag. Sampling was conducted at five locations, and use of a particular site varied with water level and debris accumulation (Figure 2). Fishing efforts alternated between banks every 45-min of soak time and half of the daily effort was expended along each bank. Drift gillnetting typically began each day at 1600 hours and continued until a

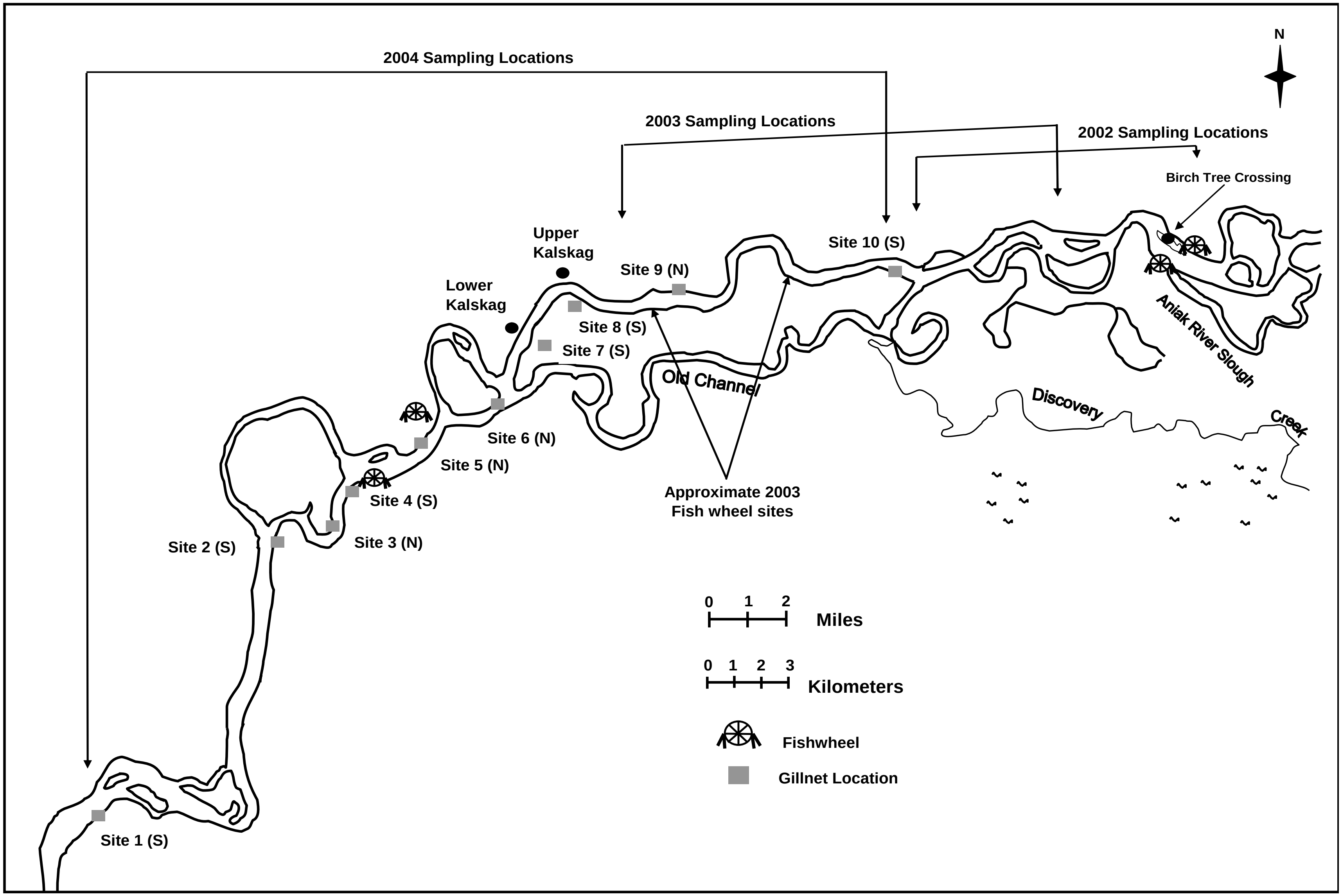

Figure 2.-Map of the drift gillnet and fish wheel tagging locations for Chinook salmon in the Kuskokwim River, 2004, and general sampling locations used in 2002 and 2003. An (S) denotes a south bank and an (N) denotes a north bank location.

3-hour soak time or a 7.5-hour workday was achieved. Two CFD fish wheels were operated 24 hours per day beginning 7 June near Kalskag (Figure 2). The two fish wheels were located along the same stretch of river, but on opposite banks. Each day, salmon were sampled from the fish wheel live boxes between the hours of 0600-1430, and 1800-0230.

Drift gillnets were constructed of cable-lay material and were 100 to 150 ft in length. A gillnet with 8.0 in mesh and 29 panels deep was fished in the near-shore reaches. A gillnet with 8.25 in mesh and 45 panels deep was fished in the mid-channel reaches and during high water events. Before the fish wheels were deployed, drifts were also conducted with a gillnet with 5.5 in mesh and 29 panels deep in an effort to capture and tag smaller size classes to compensate for the CFD fish wheels that were not yet in operation.

When a Chinook salmon was captured in a drift gillnet, the net was immediately retrieved into the boat and the fish was placed into a holding tub. Water in the holding tub was frequently replaced with fresh water, usually after tagging and measuring was completed. All captured fish were measured from mideye to the tail fork (MEF) to the nearest 5 mm and sex was determined from external characteristics. The left axillary process was collected from each radio-tagged Chinook salmon. Each tissue sample was cleaned and immediately placed in an individually labeled vial filled with 100% ethanol. These tissues were collected for later processing by the Anchorage CFD genetics laboratory. For details of this study see Templin et al. (2004).

Esophageal-implanted radio tags were used as the primary mark for all three years of this study and their size (14.5 x 49 mm) precluded applying them to the smallest size classes of Chinook salmon. Winter (1983) recommended against using a transmitter that weighed more than 2% of a fish's total weight. John Eiler (National Marine Fisheries Service, Juneau; personal communication) recommended tagging salmon ≥500 mm, which would ensure compliance with the 2% rule. However, during the 2002 Kuskokwim River Chinook salmon radiotelemetry project, five fish between 455 and 480 mm were given radio tags and were later located in a spawning tributary, proving that they survived the stress of tagging and handling. Similar results were found in coho salmon on the Holitna River (Wuttig and Evenson 2002 and Chythlook and Evenson 2003). Given the objectives and scope of this radiotelemetry project, we attempted to catch and radio-tag Chinook salmon over a broad range of size and age classes. Therefore for 2002-2004, Chinook salmon ≥ 450 mm MEF were radio-tagged.

Radio tags were inserted through the esophagus and into the upper stomach of the fish using a 45-cm plastic tube with an inside diameter equal to that of the radio-tags. The radio tag was pushed through the esophagus and into the stomach such that the antenna end was seated 0.5 cm anterior to the base of the pectoral fin. Tagging was performed without the use of anesthesia. All radio-tagged fish were given a secondary mark of a uniquely numbered, fluorescent green spaghetti tag constructed of a 5-cm section of plastic tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line. The monofilament was sewn through the musculature of the fish 1-2 cm ventral to the insertion of the dorsal fin between the third and forth fin rays from the posterior of the dorsal fin. Fish were then released in quiet water out of the main current. Fish that were obviously injured and/or appeared stressed were not radio-tagged.

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio tags were Model Five pulse encoded transmitters made by ATS[1]. Each radio tag was distinguishable by a unique frequency and encoded pulse pattern. Twenty frequencies spaced approximately 20 kHz apart in the 149-150 MHz range with 25 encoded pulse patterns per frequency were used for a total of 500 uniquely identifiable tags.

Radio-tagged Chinook salmon were tracked as they migrated up the Kuskokwim River using a network of ground-based tracking stations similar to those described by Eiler (1995). Each station consisted of a steel housing box which contained two 12 V deep cycle batteries charged by a solar array, an ATS Model 5041 Data Collection Computer (DCC II) and ATS Model 4000 receiver (R4000), or a single R4500 Data Collection Computer and receiver combination. Tag signals were received by two, four element Yagi antennas oriented with one facing downstream and one facing upstream so that upstream and downstream movements of fish could be determined. The DCCII/R4000 and R4500 units were programmed to scan through the frequencies at 6-s intervals, and could simultaneously receive from both antennas. When a signal of sufficient strength was detected, the receiver paused for 12-s on each antenna, and then tag frequency, tag code, signal strength, date, time, and antenna number were recorded on the DCCIIs and R4500s. The relatively short cycle period helped minimize the chance that a radio-tagged fish would swim past the station site without being detected. Recorded data were downloaded to a laptop computer every 7–20 days.

Throughout all 3 years of the study, five tracking stations were located on the mainstem Kuskokwim River: one tracking station each was placed immediately above and below Aniak (50-55 rkm above the capture site), one was placed downstream of the Holitna River near Red Devil, and the fifth was located just above McGrath (Figure 1). Also in each year of the study, one tracking station was placed at each of the four weir sites on the George, Kogrukluk, Tatlawiksuk, and Takotna rivers, and a tracking station was placed near the ADF&G sonar site on the Aniak River approximately 25 rkm upriver from its confluence with the Kuskokwim River. In 2003, a station was positioned downstream of the capture sites at approximately rkm 264 near the abandoned village of Uknavik. As part of the Holitna River salmon enumeration study, two tracking stations were located on the mainstem Holitna and Hoholitna rivers and in 2004 an additional station was placed near the mouth of the Holitna River.

The tracking stations near McGrath, Red Devil and above Aniak as well as tracking stations on the Holitna and Tatlawiksuk rivers were integrated with Satellite High Data Rate (SAT HDR) transmitters. Each hour these transmitters sent information on tracking station status and a portion of the telemetry data collected to a NOAA geostationary operational environmental satellite (GOES). The satellite in turn relayed the data to a receiving station near Washington DC, where the data could then be accessed via the Internet. This system enabled the project leader to check on the operational status of the stations on a daily basis thereby reducing costs associated with having to travel to the stations.

Aerial-surveys were conducted to locate radio-tagged Chinook in the mainstem Kuskokwim River that did successfully migrate into a spawning stream (e.g., tag loss or handling mortality), locate tags in spawning tributaries other than those monitored with tracking stations, to locate

[1] Advanced Telemetry Systems, Isanti, Minnesota (Product names used in this report are included for scientific completeness but do not constitute product endorsement).

fish that the tracking stations failed to record, and to validate whether a fish recorded on one of the tracking stations did migrate into that particular stream. In 2004 two aerial-tracking surveys were conducted from 12-16 July and 16-20 August. Aerial surveys were conducted during similar dates the previous 2 years. During each survey, fish were tracked along the mainstem Kuskokwim River, in most of the major tributaries between the capture site and headwaters areas upriver of McGrath, and in all waters upstream of the four weirs. Aerial tracking surveys were conducted with one aircraft, one person (in addition to the pilot), and utilized one R4500 receiver/scanner. All transmitter frequencies were loaded into the receiver/scanner prior to each flight. Dwell time on each frequency was 1-2 seconds. Flight altitude ranged from 100 to 300 m above ground. Two H-antennas equipped with a switching box, one on each wing strut, were mounted such that the antennas detected peak signals perpendicular to the direction of travel. Once a tag was located its frequency, code, and coordinates were recorded.

Boat tracking surveys occurred periodically near the capture/release sites to monitor for tags that had been regurgitated. Keefer et al. (2004) has observed that Chinook salmon that regurgitated their transmitters at or near the release site did so within one day after release. Evenson and Wuttig (2000) observed similar behavior from a radiotelemetry study on the Copper River. During the boat surveys one person monitored a hand-held H-antenna in the front of a boat and another operated an R4500 receiver/scanner.

ESTIMATION OF ABUNDANCE

Assignment of Fate

For the purposes of mark-recapture abundance estimation, every radio-tagged fish was assigned one of five possible fates:

Fate 1: a fish that survived tagging and handling and was harvested above Aniak;

Fate 2: a fish that survived tagging and handling and was detected up a tributary that was not monitored with a weir;

Fate 3: a fish that traveled past one of the four tracking stations on the George, Tatlawiksuk, Kogrukluk, or Takotna rivers;

Fate 4: a fish that was known to have migrated upstream past the two tracking stations that were located just above and below Aniak, but was not detected in a major tributary; or,

Fate 5: a fish that was not located either by the tracking stations near Aniak or by aerial means upriver of these tracking stations. Fish of this fate included those that were located or harvested near or downstream of the capture sites, and fish that were never located.

Fish assigned to Fates #1 through #4 were assumed to have survived tagging and handling and were used as the marked sample. Fish assigned Fate #3 constituted recaptured fish. Fates of radio-tagged fish were determined after receiving data from tracking stations, aerial and boat tracking surveys, and from tags returned by fishers. If a fisherman returned a radio and/or spaghetti tag or verbally reported harvesting the fish upriver from Aniak, then it was assigned Fate #1. However, fish harvested near or below Aniak were designated as a Fate #5 and censored from the experiment.

Recapture Sample

The second sample for this mark-recapture experiment was the number of Chinook salmon ≥450 mm that migrated through the four weirs. This number was estimated from the total Chinook salmon count through the weirs adjusted by the proportion of fish sampled that were ≥450 mm. Marked fish in the second sample were fish assigned a Fate #3. Because of the difficulty capturing Chinook salmon in the weir live-traps, only a portion of the Chinook salmon that passed each weir site were handled for age, sex, and length. Chinook salmon age, sex, and length composition data collected from fish handled at each weir were used to test model assumptions of equal capture probabilities.

Conditions for a Consistent Petersen Estimator

For the estimate of abundance from this mark-recapture experiment to be unbiased, certain assumptions needed to have been fulfilled (Seber 1982). The assumptions, expressed in terms of the conditions of this study, respective design considerations, and test procedures are listed below. To produce an unbiased estimate of abundance with the generalized Petersen model, Assumptions I, II, III and one of the conditions of Assumption IV must have been met.

Assumption I: The population was closed to births, deaths, immigration and emigration.

This assumption was violated because harvest of some fish occurred between events. However, we assumed that marked and unmarked fish were harvested at the same rate. Thus, provided there was no immigration of fish between events, the estimate would remain unbiased with respect to the time and area of the first event (estimate of inriver abundance, not escapement). Sampling in both events encompassed the majority of the run, and any immigration of Chinook salmon past the capture site prior to or after the marking event was assumed to be negligible. Marked fish that did not migrate upstream past one of the two tracking stations near Aniak were removed from the experiment.

Assumption II: Marking and handling did not affect the catchability of Chinook salmon in the second event.

There was no explicit test for this assumption because the behavior of unhandled fish could not be observed. However, to minimize the effects of handling, holding and handling time of all captured fish was minimized. In a related study, chum salmon tagged and released in the Yukon River immediately after capture resumed upriver movement faster and traveled farther upriver than fish that had been held prior to release (Bromaghin and Underwood 2004). Any obviously stressed or injured fish were not radio-tagged. Radio-tagged fish that were not detected past the two mainstem Kuskokwim River tracking stations near Aniak were removed from the experiment.

Assumption III: Tagged fish did not lose their tags between the tagging site and the weirs.

A combination of stationary tracking stations and aerial and boat tracking surveys were used to identify radio tags that were expelled. In addition, fish inspected at the four weirs were examined for both a spaghetti tag and/or a radio tag. All fish determined to have regurgitated their tags were culled from the analyses.

Assumption IV: Equal probability of capture.

1. **All Chinook salmon had the same probability of being caught in the first sampling event;**
2. **All Chinook salmon had the same probability of being captured in the second sampling event; or,**
3. **Marked fish mixed completely with unmarked fish between sampling events.**

Equal probability of capture was evaluated by size, sex, time, and area. The procedures to analyze sex and length data for statistical bias due to gear selectivity are described in Appendix A1. To further evaluate the three conditions of this assumption, contingency table analyses recommended by Seber (1982) and described in Appendix A2 were used to detect significant temporal or geographic violations of assumptions of equal probability of capture. Contingency table analyses were also used to test:

1. equal catchability with respect to tagging location. This test evaluated independence between recapture rates and bank of mark. Independence between bank of mark and bank of recapture and between spawning location and bank of mark were also examined; and,
2. equal catchability with respect to sampling gear. This test evaluated independence between gear type and recapture rates.

Significant results from these tests are indicative of potential sampling biases which in some cases can be addressed by censoring or stratification of data (as with Aniak River spawners).

DATA ANALYSIS

The statistical analysis methods were slightly different in each year of the study. Details from 2004 are reported here. For details of previous years' statistical analyses see Stuby (2003, 2004).

In 2004 abundance of Chinook salmon was estimated after stratification by sex to minimize bias. For each stratum, abundance was estimated using the Chapman modification to the Petersen estimator (Chapman 1951) and stratum estimates were summed to estimate total abundance:

$$\hat{N} = \sum_{s=1}^{S} \hat{N}_s \text{, and} \tag{1}$$

$$\hat{N}_s = \frac{(\hat{C}_s + 1)(M_s + 1)}{R_s + 1} - 1; \tag{2}$$

where:

$\hat{N}_s$ = estimated abundance of Chinook salmon in stratum s, $s = 1$ to S;

M_s = the number of radio-tagged Chinook salmon in stratum s known to survive tagging and handling;

R_s = the number of radio-tagged Chinook salmon in stratum s moving past the four weirs; and,

$\hat{C}_s$ = the estimated number of Chinook salmon in stratum s counted past the four weirs.

The estimated number of Chinook salmon in stratum *s* that passed the four weirs was calculated as the sum of estimates for each weir:

$$\hat{C}_s = \sum_{w=1}^{W} \hat{C}_{sw} \ . \tag{3}$$

At each weir, within stratum passage was estimated:

$$\hat{C}_{sw} = \hat{p}_{sw} C_w \tag{4}$$

where the proportion of salmon in stratum *s* was estimated from length composition data collected at the weir:

$$\hat{p}_{sw} = n_{Csw} / n_{Cw} \tag{5}$$

and where:

n_{Csw} = number of Chinook salmon in sex stratum *s* observed of those sampled for composition at weir *w*, *w* = 1 to *W*;

n_{Cw} = the total number of Chinook salmon sampled for composition at weir *w*; and,

C_w = the number of Chinook salmon counted past weir *w* when the weir was operational.

Variance and 95% credibility interval for the estimator (equation 1) were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for the $\hat{N}_s$ and $\hat{N}$ were generated by collecting 100,000 simulated values of $\hat{N}_s$ and $\hat{N}$ which were calculated using equations (1-5) from simulated values of equation parameters. Simulated values were modeled from observed data using the following distributions:

observed $n_{C1w},\ldots,n_{CSw}$ ~multinomial (($p_{1w},\ldots,p_{Sw}$), n_{Cw}); and,

observed R_s ~binomial (q_s, M_s), *s* = 1 to *S*;

where q_s is the probability that a radio-tagged salmon from stratum *s* passed one of the weirs and was treated as a recapture.

At the end of the iterations, the following statistics were calculated:

$$\overline{N} = \frac{\sum_{b=1}^{100,000} \hat{N}_{(b)}}{100,000} \text{; and,} \tag{6}$$

$$V\hat{a}r(\hat{N}') = \frac{\sum_{b=1}^{100,000} (\hat{N}_{(b)} - \overline{N})^2}{100,000 - 1} \tag{7}$$

where $\hat{N}_{(b)}$ is the *b*th simulated observation.

Only actual counts from the weirs were used for the second sample. Those radio-tagged fish that passed through the weir on days when water visibility precluded counting were treated as marks that were not recaptured during the second event.

Age, Sex, and Length Compositions

The numbers of Chinook salmon by ocean-age or sex were estimated first within sex strata and then summed across strata. Composition proportions were first estimated at each weir using:

$$\hat{p}_{ksw} = \frac{n_{ksw}}{n_{Cw}} \tag{8}$$

where:

$\hat{p}_{ksw} =$ estimated proportion of Chinook salmon in group *k* (*k* = 1 to *K),* stratum *s* at weir *w*; and,

$n_{ksw} =$ number of sampled Chinook salmon in group *k,* stratum *s,* at weir *w*.

Estimates were then combined across weirs, weighted by estimated total passage at each weir (weights were treated as fixed values, even though varying uncertainty existed about total passage at each weir):

$$\hat{p}_{ks} = \sum_{w=1}^{W} T_w \hat{p}_{ksw} \Big/ \sum_{w=1}^{W} T_w \tag{9}$$

where:

$\hat{p}_{ks} =$ estimated proportion of Chinook salmon in group *k,* stratum *s*; and,

$T_w =$ total number of Chinook salmon estimated to have passed weir *w*.

The numbers of Chinook salmon in each group within strata were estimated:

$$\hat{N}_{ks} = \hat{N}_s \hat{p}_{ks} \Big/ \sum_{k=1}^{K} \hat{p}_{ks} \ . \tag{10}$$

These estimates were summed across strata to calculate the estimated number of Chinook salmon in group *k* in the escapement:

$$\hat{N}_k = \sum_{s=1}^{S} \hat{N}_{ks} \ , \tag{11}$$

and the proportion of Chinook salmon in group *k* was estimated:

$$\hat{p}_k = \hat{N}_k \big/ \hat{N} \ . \tag{12}$$

Variance for the estimates of $\hat{N}_k$ and $\hat{p}_k$ were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for $\hat{N}_k$ and $\hat{p}_k$, which were calculated using equations (1-5) and (8-12), were generated by collecting 100,000 simulated values of $\hat{N}_k$ and $\hat{p}_k$ from simulated values of equation parameters. The simulated values were modeled from observed data using the following distribution:

observed $n_{11w},\ldots,n_{KSw}$ ~multinomial $((p_{11w},\ldots,p_{KSw}), n_{Cw})$;

in addition to those distributions described above. Formulae similar to equations (6) and (7) were used to estimate variance.

For each weir site, mean lengths and associated sampling variances were calculated for each sex and associated age class *k* using:

$$\bar{l}_{kw} = \frac{\sum_{i=1}^{n_k} l_{kwi}}{n_{kw}} \text{; and,} \tag{13}$$

$$V\hat{a}r\left[\bar{l}_{kw}\right] = \frac{\sum_{i=1}^{n_{kw}} \left(l_{kwi} - \bar{l}_{kw}\right)^2}{n_{kw}\left(n_{kw} - 1\right)} \tag{14}$$

where:

l_{kwi} = length of salmon *i* (*i* = 1 to n_{kw}) at weir *w* of a given sex and age group *k*; and,

n_{kw} = number of samples at weir *w* of a given sex and age group *k*.

Overall estimates of mean lengths for each age class *k* were weighted combinations of estimates from each weir:

$$\bar{l}_k = \sum_{w=1}^{W} U_{kw} \bar{l}_{kw} \Big/ \sum_{w=1}^{W} U_{kw} \tag{15}$$

where U_{kw} was an approximate estimate of abundance of total Chinook salmon in class *k* at weir *w*.

We calculated:

$$U_{kw} = T_w \hat{p}_{kw} \text{ and } V\hat{a}r(U_{kw}) = T_w^2 V\hat{a}r(\hat{p}_{kw})\text{;} \tag{16}$$

where:

$$\hat{p}_{kw} = \frac{n_{kw}}{n_{Cw}} \text{ and } V\hat{a}r(\hat{p}_{kw}) = \frac{\hat{p}_{kw}(1 - \hat{p}_{kw})}{n_{Cw} - 1}. \tag{17}$$

The variance was approximated by (Mood et al. 1974):

$$V\hat{a}r(\bar{l}_k) \cong \sum_{w=1}^{W} \frac{\left(\bar{l}_{kw}\sum_{w=1}^{W} U_{kw} - \sum_{w=1}^{W} U_{kw}\bar{l}_{kw}\right)^2}{\left(\sum_{w=1}^{W} U_{kw}\right)^4} V\hat{a}r(U_{kw}) + \sum_{w=1}^{W} \frac{U_{kw}^2}{\left(\sum_{w=1}^{W} U_{kw}\right)^2} V\hat{a}r(\bar{l}_{kw}). \tag{18}$$

RESULTS

Specific results from 2004 are presented here. Several tables and figures include results from 2002 and 2003 for comparison when appropriate. Details of the 2002 and 2003 results can be found in Stuby (2003, 2004).

The total number of Chinook salmon that were captured and radio-tagged in 2004 was 381 fish. Data regarding fates and mark-recapture analyses were archived as described in Appendix B. The daily number of deployed radio tags closely followed the predetermined sampling schedule. Of the total radio tags deployed, 41% were deployed in fish captured on the north bank and 59% were deployed in fish captured on the south bank. The small discrepancy was as a result of more productive south bank drift gill net sites. In general, objectives for tagging fish in the two size classes with respect to bank of capture for all three seasons tracked predetermined objectives and showed similar patterns (Appendices C1 and C2).

Fates were described for the 381 radio-tagged fish (Table 2). Seventy-three radio-tagged fish either lost their tags, were harvested below Aniak, or were never located after tagging (Fate #5). Three hundred eight radio-tagged fish were known to have retained their tags and migrated upstream of the capture site (Fates #1 - #4). Of the 56 fish that were recorded past the two mainstem Kuskokwim River tracking stations near Aniak but were never located in a tributary (Fate #4), 28 were recorded by the mainstem Kuskokwim tracking station at Red Devil.

In 2004, there were few high water events and no radio-tagged fish that swam past the four weirs had to be censored from the analysis (Table 3). The Kogrukluk, Tatlawiksuk, and Takotna river weirs were operational throughout the season. The George River weir was set up later than usual due to high water. Thirty-nine radio-tagged Chinook salmon swam past the tracking stations at the four weir sites and became part of the recapture portion of the sample.

In general the radio-tagged Chinook salmon that had the farthest to travel (e.g., above McGrath and to the Takotna River) were captured earlier compared to Chinook salmon returning to rivers closer to the tagging sites (e.g., Aniak River and George Creek), although there tended to be much overlap in these results (Figure 3).

MARK-RECAPTURE EXPERIMENT

The majority of Chinook salmon of known final destinations (Fates #2 and #3) traveled up the Holitna or Aniak river systems (Table 4; Appendices D1 and D2). Even though shifting tagging effort downriver from the Birch Tree Crossing sites of 2002 to sites near and then below Kalskag appeared to disperse radio tags more proportional to stock abundance, there was evidence, even for the lowermost tagging locations in 2004, that the majority of Aniak River bound Chinook salmon were still oriented to the south side bank of the Kuskokwim River.

One assumption of the tagging effort was that all fish, regardless of stock, would have equal probability of capture. Detecting bank orientation with diagnostic testing provides evidence that this assumption may be violated. In 2004, the bank of mark was not independent of spawning location when Aniak River fish were compared to spawners from other tributaries (Table 5; $\chi^2 = 7.94$, df = 1, $P < 0.01$). No data on the mark: unmarked ratio of Aniak River spawners were collected in 2004, precluding our ability to conduct further tests confirming the equal probability of capture assumption or to select appropriate estimation models which might accommodate unequal capture probabilities. As a result, the Aniak River bound Chinook salmon were censored from further analyses, reducing the marked portion to 225 fish. No lack of independence was detected in the analysis of the 42 Chinook salmon that traveled into the George, Takotna, Kogrukluk, and Tatlawiksuk rivers, comparing the bank of mark with their final bank of recapture (Table 6; $\chi^2 = 0.03$, df = 1, $P = 0.87$).

Table 2.–Final fates of Chinook salmon that were radio-tagged in the Kuskokwim River, 2002-2004.

		Number of Radio-tagged Chinook Salmon Assigned This Fate		
Fate #	Fate Description	2002[a]	2003	2004
	Fish that survived tagging and handling			
1	Fish harvested above Aniak.	16	10	2
2	Fish detected up a tributary that was not monitored with a weir	304	284	211
3	Fish that traveled past one of the four tracking stations at weirs on the George, Tatlawiksuk, Kogrukluk, and Takotna rivers.	33	75	39
4	Fish that were detected upriver from the tracking station above Aniak, but were not detected into a tributary.	56	77	56
	Fish that migrated past the Red Devil tracking station.	46	62	28
	Fish that did not migrate past the Red Devil tracking station.	10	15	28
	Subtotal	**409**	**446**	308
5	**Fish not detected upstream of the tracking stations near Aniak**			
	Fish harvested below Aniak.	6	14	14
	Fish that were not detected by any of the tracking stations and/or by aerial means.	9	3	10
	Fish that traveled past downriver station near Uknavik and were never recorded again.	3[b]	9	21
	Fish that were detected by the two tracking stations near Aniak and/or by aerial means at or below the two tracking stations near Aniak, but not upriver.	18	26	10
	Subtotal	**52**	**52**	73
	Total number of fish that were radio tagged.	**461**	**498**	**381**

[a] Fate #2, #4, and #5 values updated from the 2002 report. Change did not affect the number of marked fish used in the estimator.

[b] Fish detected by aerial means only.

Table 3.–Summary of 2004 weir operations on the George, Tatlawiksuk, Kogrukluk, and Takotna rivers.

Weir	First Day of Operations	Last Day of Operations	Number of Inoperable Days	Number of Chinook Salmon Counted Past the Weir	Number of Radio-tagged Fish Recorded Past Tracking Stations[a]	Comments
George	27 June	24 September	12	5,108	9	Late start at weir set up due to high water.
Tatlawiksuk	15 June	18 September	0	2,833	5	Number counted also represents total estimate of escapement.
Kogrukluk	21 June	25 September	1	19,651	24	Because only inoperable for one day, estimate of 19,651 included in catch sample as well as representing the total escapement estimate for this drainage.
Takotna	23 June	18 September	0	462	1	Number counted also represents total estimate of escapement.

[a] All radio-tagged Chinook salmon passed when weirs were operational.

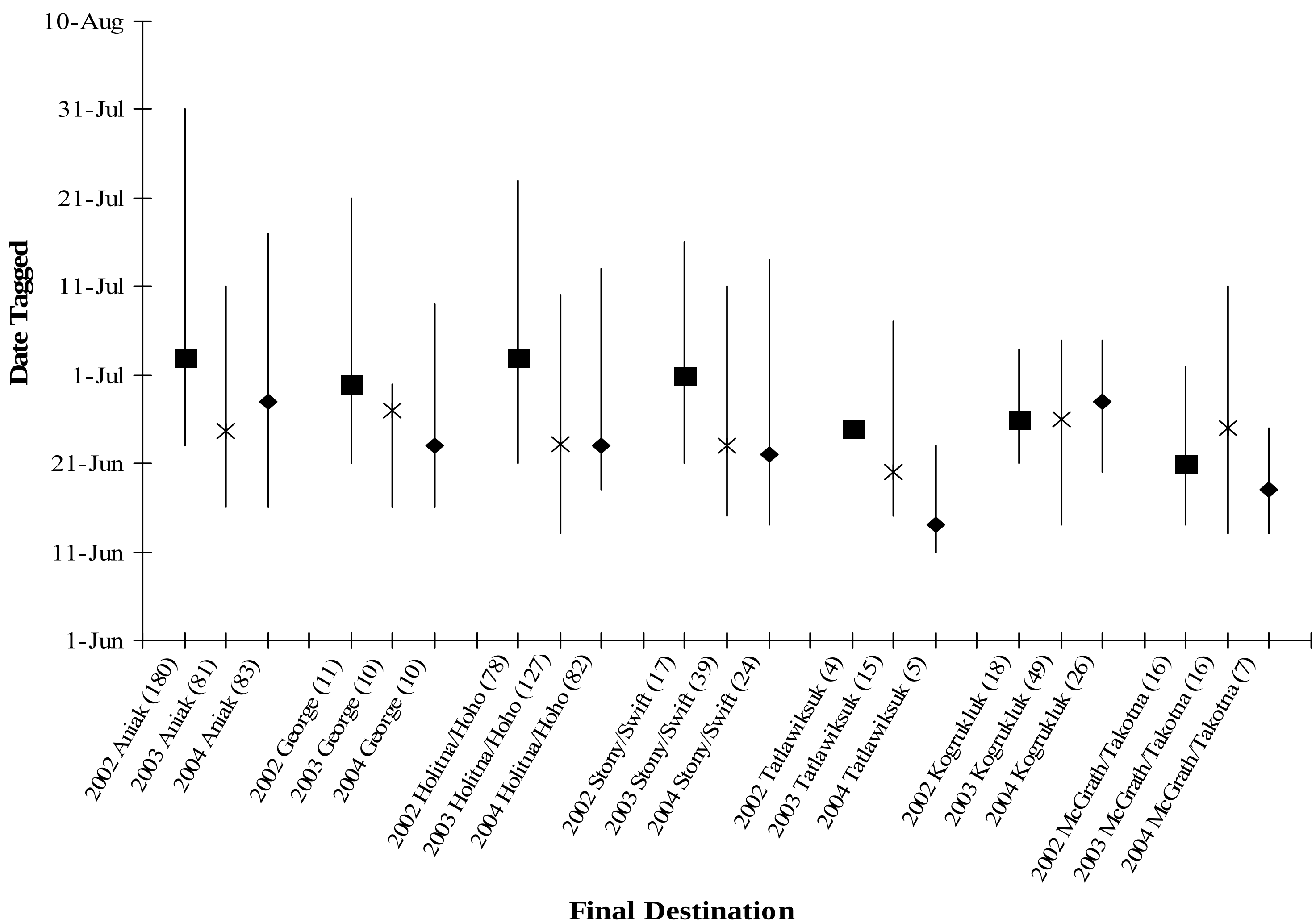

Figure 3.–Median dates of capture (symbol) and 80% range (vertical lines) of Chinook salmon from the Kuskokwim River of known final destinations, 2002-2004. The numbers of fish located in each tributary are presented in parentheses.

Table 4.–Final destinations of radio-tagged Chinook salmon in the Kuskokwim River, 2002-2004. Capture gear and locations provided for 2004.

	2002		2003		2004					
					Fishwheel		Gillnet			
River	Total	%Total	Total	%Total	North	South	North	South	Total	%Total
Holitna	52	16%	82	16%	13	1	10	23	47	12%
Hoholitna	26	8%	45	9%	3	2	11	19	35	9%
Kogrukluk	18	5%	49	10%	4	3	7	12	26	7%
Holitna River Drainage	**96**	**29%**	**176**	**35%**	**20**	**6**	**28**	**54**	**108**	**28%**
Aniak	181	39%	81	16%	6	25	13	39	83	22%
Swift	14	3%	32	6%	4	1	6	6	17	4%
George	12	3%	10	2%	1	0	3	6	10	3%
Holokuk	3	1%	5	1%	1	2	3	4	10	3%
Stony	3	1%	7	1%	2	0	2	3	7	2%
Above McGrath[a]	15	3%	32	6%	0	0	5	1	6	2%
Tatlawiksuk	4	1%	15	3%	1	0	3	1	5	1%
Oskawalik	7	2%	7	1%	0	0	1	1	2	1%
Takotna	1	0%	6	1%	1	0	0	0	1	0%
Vreeland	0	0%	1	0%	0	0	0	0	0	0%
Selatna	1	0%	0	0%	0	0	0	0	0	0%
Sue Creek	0	0%	0	0%	1	0	0	0	1	0%
Inriver Harvest	16	3%	9	2%	0	0	1	1	2	1%
Unknown Final Destination[b]	56	12%	65	13%	11	6	14	25	56	15%
Undetermined Fate	52	11%	52	10%	12	23	16	22	73	19%
ALL	461		498		60	63	95	163	381	

[a] Above McGrath Chinook salmon includes fish that were not detected into a tributary and one inriver harvest.

[b] Excludes Chinook salmon that were detected by the tracking station near McGrath.

Table 5.–Contingency table analysis comparing the bank of marking for Chinook salmon that migrated up one of the four tributaries with weirs and up the Aniak River, 2004.

	Final Destinations		
Bank Marked	Kogrukluk, Tatlawiksuk, George, and Takotna Rivers[a]	Aniak River	Total
North	20	19	39
South	22	64	86
Total	42	83	125
	$\chi^2 = 7.94$, df = 1, $P < 0.01$		

[a] Numbers include the 39 recaptures and three fish that swam into the tributaries, but did not cross the weirs.

Table 6.–Contingency table analysis examining independence of bank of marking with bank of recapture for Chinook salmon captured and radio-tagged in the Kuskokwim River, 2004.

	Bank Recaptured		
Bank Marked	North (George, Takotna rivers)	South (Kogrukluk, Tatlawiksuk rivers)	Total
North	5	15	20
South	6	16	22
Total	11	31	42
	$\chi^2 = 0.03$, df = 1, $P = 0.87$		

Because Chinook salmon <450 mm were deemed too small to receive a radio tag, we planned to estimate abundance of salmon ≥450mm by estimating the occurrence of smaller fish at the weirs and censoring these numbers prior to estimating abundance. The smallest of the 1,524 salmon examined at the four weirs for age, sex, and length, was 454 mm, so no censoring was done. There was evidence of sex selectivity during the first event. The recapture rates for males (0.24) and females (0.12) were significantly different (Table 7; $\chi^2 = 5.76$, df = 1, P = 0.02), and the ratio of males:females was different between the marking event and fish sampled at the weirs.

Table 7.–Contingency table analysis of recapture rates of male and female Chinook salmon sampled during the mark-recapture experiment in the Kuskokwim River, 2004.

	Bank Recaptured		
Capture History	Male	Female	Total
Recaptured	25	14	39
Not Recaptured	80	106	186
Total	105	120	225
Recapture Rate	0.24	0.12	0.17
	$\chi^2 = 5.76$, df = 1, $P = 0.02$		

As a result of these tests, we concluded that a gender stratified abundance estimator was required. Length distributions of all Chinook salmon marked during the first event and those sampled for age, sex, and length during the second event were significantly different (D = 0.28, P < 0.01; Figure 4), while there was no difference between the fish marked in the first event and those recaptured during the second (D = 0.06, P = 1.00). These results indicated size selectivity during the first event sampling. When length distributions were compared between males and females separately, similar situations were noted and further stratification within each sex was unnecessary (Figure 5).

A test for independence between time of marking during the first event and probability of recapture during the second event indicated no significant temporal violation of the assumption of equal probability of capture (Table 8; $\chi^2 = 3.84$, df = 3, P = 0.28). In addition, there was no difference in the marked to unmarked ratios of Chinook salmon counted at the George, Kogrukluk, Tatlawiksuk, and Takotna river weirs (Table 9; $\chi^2 = 1.40$, df = 3, P = 0.71). The probability that a tagged fish was seen at a weir was independent of tagging location (Table 10; $\chi^2 = 0.01$, df = 1, P = 0.92) and gear type (Table 11; $\chi^2 < 0.01$, df = 1, P = 0.96).

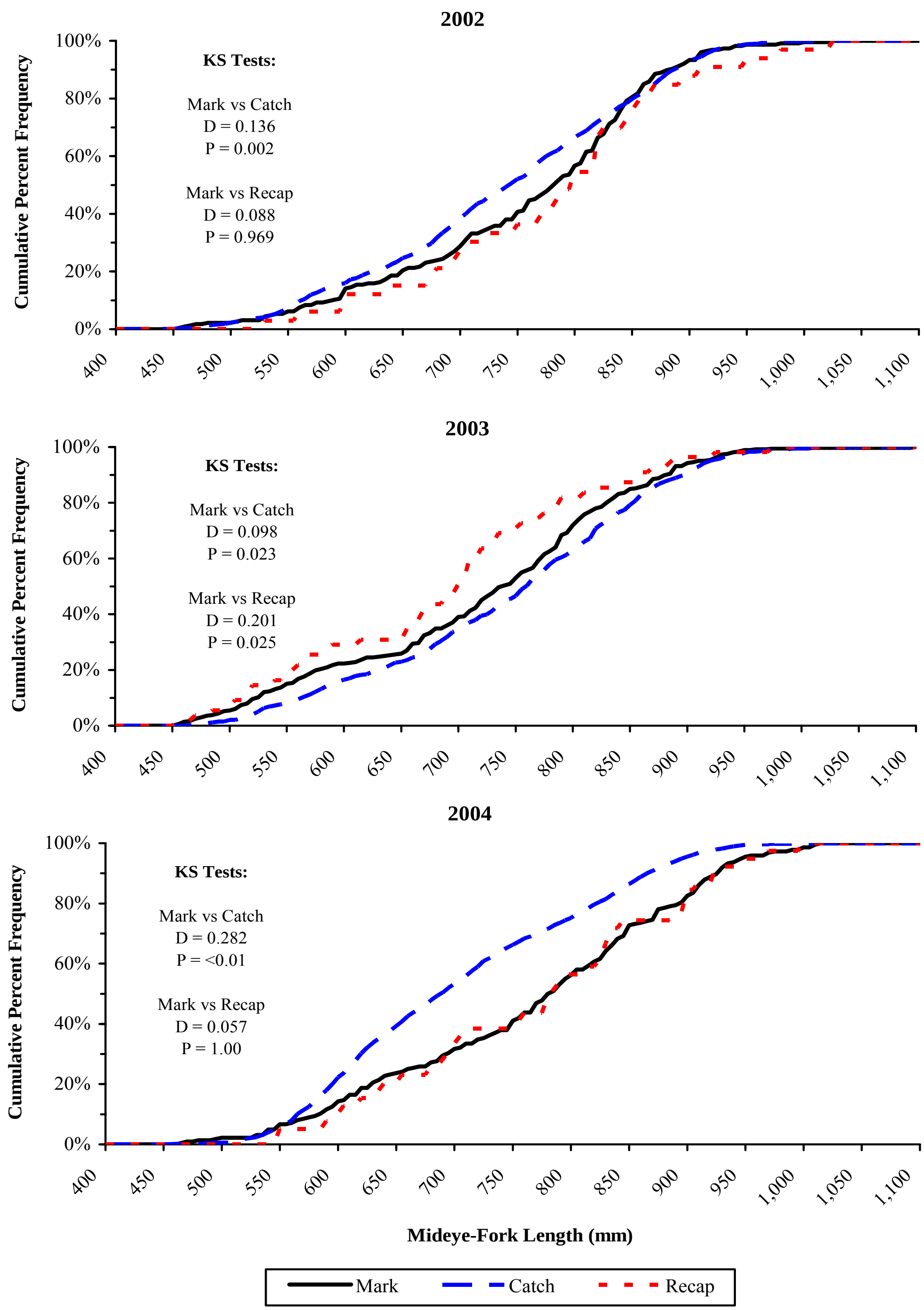

Figure 4.–Cumulative length frequency distributions comparing all Chinook salmon caught during the first (Mark) and second (Catch) events, and all recaptured (Recap) fish caught during the second event from the mark-recapture experiment in the Kuskokwim River, 2002-2004.

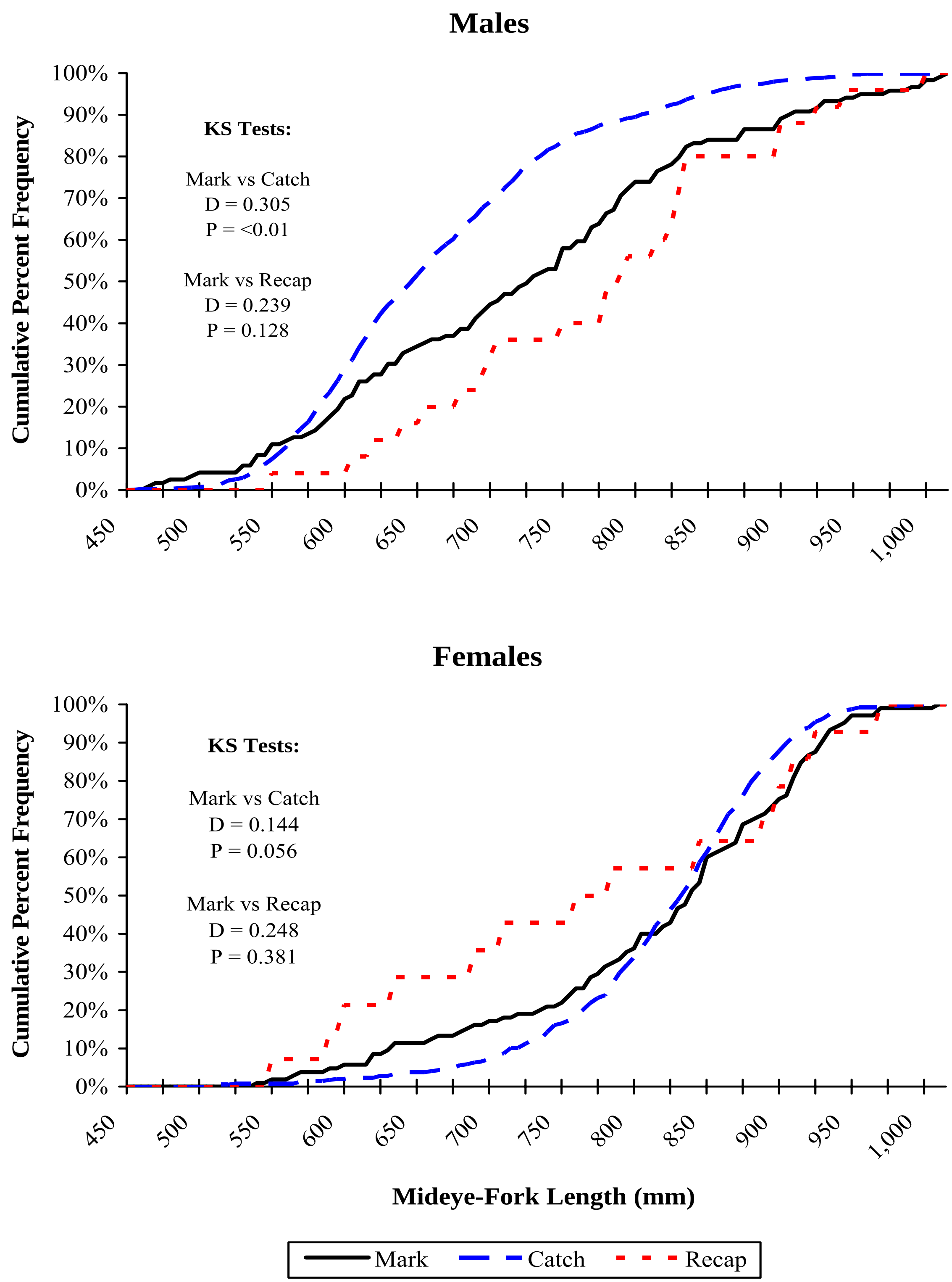

Figure 5.–Cumulative length frequency distributions comparing male and female Chinook salmon caught during the first (Mark) and second (Catch) events, and all recaptured (Recap) fish caught during the second event from the mark-recapture experiment in the Kuskokwim River, 2004.

Table 8.–Contingency table analysis testing equal catchability by time for Chinook salmon sampled during the mark-recapture experiment in the Kuskokwim River, 2004.

Date Tagged	Not Recaptured	Recaptured	Total
7 – 19 June	51	10	61
20 – 23 June	48	11	59
24 June – 3 July	41	13	54
4 - 29 July	46	5	51
Total	186	39	225

$\chi^2 = 3.84$, df = 3, $P = 0.28$

Table 9.–Contingency table analysis comparing marked to unmarked ratios of Chinook salmon counted at the George, Kogrukluk, Tatlawiksuk, and Takotna river weirs during the mark-recapture experiment in the Kuskokwim River, 2004.

River	Unmarked	Marked	Total Catch[a]
George	5,099	9	5,108
Tatlawiksuk	2,828	5	2,833
Kogrukluk	19,627	24	19,651
Takotna	461	1	462
Total	28,015	39	28,054

$\chi^2 = 1.40$, df = 3, $P = 0.71$

[a] George River weir values represent actual counts during the time this weir was operational. The Kogrukluk, George, and Tatlawiksuk river weirs were operational throughout the season. Therefore these values represent the total estimate for passage of Chinook salmon.

Table 10.–Contingency table analysis comparing recapture rates of Chinook salmon marked on the north and south banks of the Kuskokwim River during the mark-recapture experiment, 2004.

	Side of River Bank Marked		
Capture History	North	South	Total
Recaptured	19	20	39
Not Recaptured	89	97	186
Total	108	117	225

$\chi^2 = 0.01$, df = 1, $P = 0.92$

Table 11.–Contingency table analysis comparing recapture rates of Chinook salmon by gear type during the mark-recapture experiment on the Kuskokwim River, 2004.

	Sampling Gear		
Capture History	Gillnet	Fish Wheel	Total
Recaptured	10	29	39
Not recaptured	47	139	186
Total	57	168	225

$\chi^2 = <0.01$, df = 1, $P = 0.96$

After all contingency table analyses were performed and potential sources of bias accounted for, the abundance of Chinook salmon ≥450 mm for the Kuskokwim River upstream of the confluence of the Aniak River was estimated at 146,839 fish (SE = 21,980) with a 95% credibility interval of 115,900 to 201,800 (Table 12).

Table 12.–Estimated abundance with associated standard errors for Chinook salmon in the Kuskokwim River above the mouth of the Aniak River and in the Holitna River, 2002-2004.

	Kuskokwim River Drainage Above the Aniak River		Holitna River[a]		% Mainstem Marked Fish (First Event) that Traveled up the Holitna River
Year	Abundance	SE	Abundance	SE	
2002	100,733	24,267	42,902	6,334	42%
2003	103,161	18,720	42,013	4,981	48%
2004	146,839	21,980	81,961	11,722	48%

[a] Holitna River estimates from Chythlook and Evenson (2003), and Stroka and Brase (2004), Stroka (*In prep*).

One hundred eight Chinook salmon that were radio-tagged in the Kuskokwim River traveled up the Holitna River. These fish were added to the 65 fish that were tagged in the mainstem of the Holitna River and an estimate of 81,961 Chinook salmon (SE = 13,150) was produced for this tributary (Stroka *In prep*; Table 12). Therefore approximately 56% of the total Chinook salmon escapement above the confluence of the Aniak River was estimated to have been made up of Holitna River drainage stocks.

Age, Sex and Length Compositions

Diagnostic tests of length selectivity for males and females indicated that there was no size-selectivity during the second sampling event, but there was size-selectivity during the first (Case II in Appendix A1). The length distributions of marked females and those sampled for age, sex, and length at the four weirs suggest no size selectivity during either event. However, with only 14 female recaptures, there was limited ability for detecting differences in the two distributions (D = 0.144; P = 0.06; Figure 6). Therefore, the age, sex, and length compositions for the population of Chinook salmon in the Kuskokwim River upstream of the confluence of the Aniak River were estimated using Chinook salmon composition estimates at the George, Kogrukluk, Tatlawiksuk, and Takotna river weirs that were adjusted by summing abundance estimates for each sex and age category across the two strata (Equations 11 and 12; Table 13).

Ages were determined for 90% of the 1,524 fish sampled. The dominant age class for males was 1.2. The dominant age class for females was 1.4 (Table 13). Composition estimates were 0.68 (SE = 0.06) males and 0.32 (SE = 0.06) females. Lengths of males ranged from 454 to 1,010 mm and lengths of females ranged from 508 to 992 mm (Figure 6).

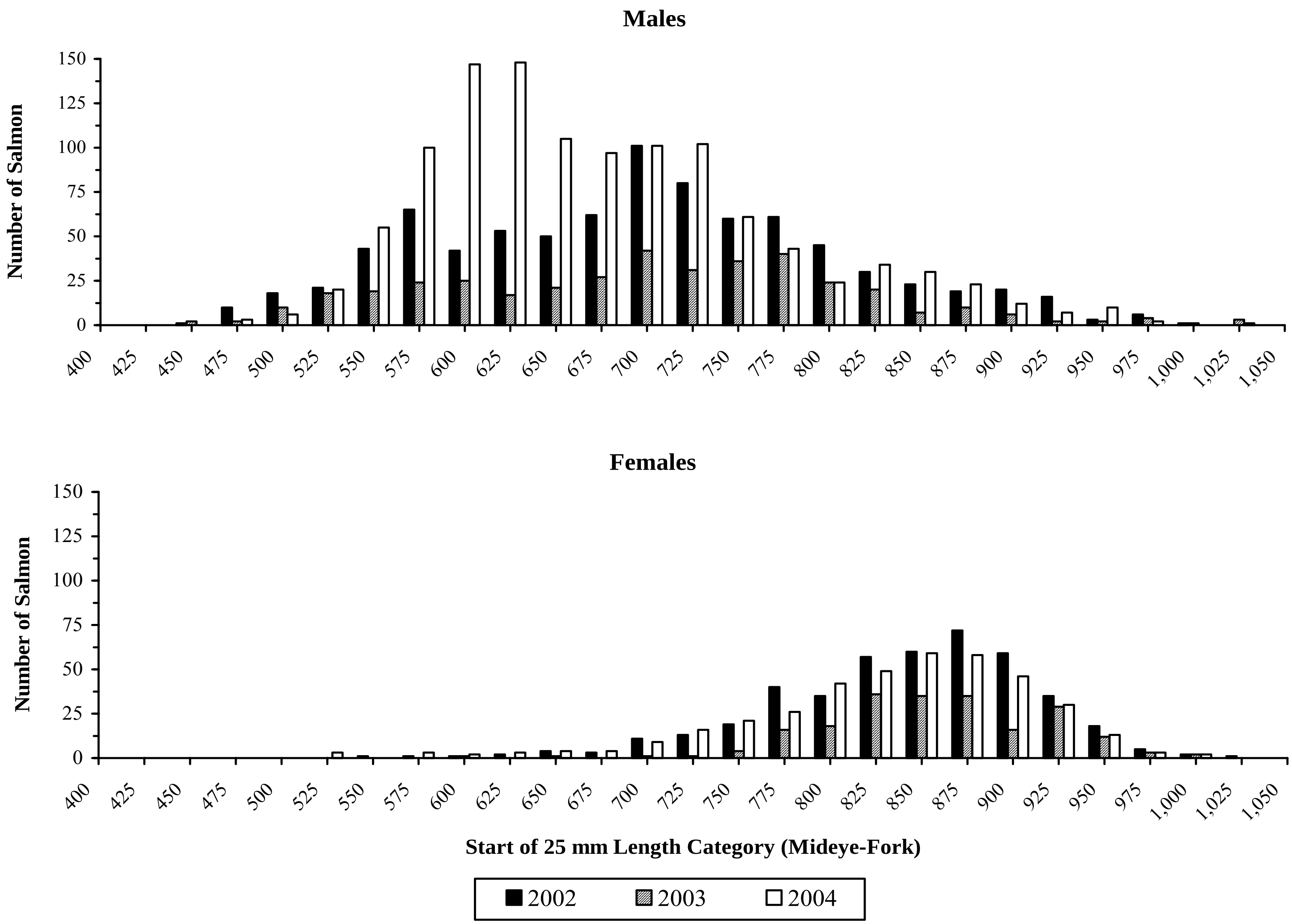

Figure 6.–Length frequency distributions of male and female Chinook salmon sampled at the weirs on the George, Tatlawiksuk, Kogrukluk, and Takotna rivers, 2002-2004.

Table 13.–Estimated proportions, abundance, and mean length at age for male and female Chinook salmon sampled at the weirs on the George, Tatlawiksuk, Kogrukluk, and Takotna rivers, 2004.

						MEF Length (mm)			
Age[a]	Proportion[b]	SE[b]	Abundance[c]	SE[c]	Sample Size[d]	Mean	SE	Min	Max
				Male					
1.1	<0.01	<0.01	92	98	1	490	N/A	490	490
1.2	0.35	0.03	50,800	9,474	492	594	2	454	753
1.3	0.26	0.03	37,464	7,069	387	692	3	553	860
1.4	0.08	0.01	11,805	2,401	139	817	7	555	1,010
1.5	<0.01	<0.01	276	173	3	819	20	780	843
2.2	<0.01	<0.01	92	98	1	660	N/A	660	660
Total[e]	0.68	0.06	100,529	18,430	1,131	658	3	454	1,010
				Female					
1.2	0.01	<0.01	1,290	561	12	567	17	508	641
1.3	0.05	0.01	6,900	2,085	56	765	7	662	872
1.4	0.25	0.05	36,772	9,801	271	848	3	631	980
1.5	0.01	<0.01	1,348	617	9	885	24	825	992
Total[e]	0.32	0.06	46,310	12,250	393	829	4	508	992

[a] Age is represented by the number of annuli formed during river and ocean residence. Therefore, an age of 2.4 represents two annuli formed during river residence and four annuli formed during ocean residence. Because a fish is one year old when the first annulus is formed, an age 2.4 fish is 7 years old.

[b] Proportion and SE were based on the age, sex and length data acquired from the Kogrukluk (806), Takotna (72), Tatlawiksuk (349), and George (297) river weirs.

[c] Abundance and associated SE were derived from a Bayesian analysis which were later adjusted to the Chapman estimate of 146,839 (SE = 21,980) Chinook salmon.

[d] Values represent actual fish sampled at the four weirs, including those <450 mm.

[e] Values represent total Chinook salmon for which sex and age could be determined.

DISCUSSION

This was the third year of the Chinook salmon enumeration project on the Kuskokwim River, and in all three years the main project objectives were achieved with the exception that Aniak River bound Chinook salmon were censored from the analysis in all years due to potential bias associated with bank orientation. Thus, abundance estimates were germane to all waters upstream of the Aniak River, as opposed to all waters upstream of Kalskag as stated in the objectives. In 2002, 44% of the total number of Chinook salmon that were deemed to have survived tagging and handling migrated up the Aniak River compared to 18% for 2003 and 27% for 2004. For 2002, the high numbers of Aniak River bound fish was mostly attributed to a concentration of tagging efforts near the Aniak River Slough. Because salmon in general have a well-developed homing instinct, their choice of spawning river, tributary, and even riffle appears to be guided by long-term memory of specific odors (Groot and Margolis 1991). Thus, sampling in this area was selective for Aniak River fish and selective against fish bound for other areas. In 2003, capture and tagging efforts were relocated farther downriver in an attempt to avoid selecting for Aniak River bound Chinook salmon. As a result, the relative proportion of fish bound for this river was much lower; however, bank orientation of Aniak River fish was still evident. For 2004, operations were moved farther downriver, but with similar results to 2003. The approximate location within the Kuskokwim River drainage where Aniak River bound Chinook salmon begin to detect and respond to their natal water remains unknown; however, sampling farther downstream is not practical because the subsistence fishery becomes more concentrated and it is believed that suitable drift net and fish wheel sites (not already occupied by subsistence fishers) would be difficult to locate. In addition, it is likely that a large number of tagged fish would be harvested.

It was also apparent that in 2002 Aniak River bound Chinook salmon were radio-tagged at a proportionally higher rate than Chinook salmon bound for other areas of the drainage because the proportion of radio-tagged Chinook salmon that traveled up the Aniak River was larger than the proportion of radio-tagged Chinook salmon that traveled up the Holitna River drainage, which is a much larger system and is thought to have a much larger return of Chinook salmon. Aerial survey counts of Chinook salmon for the Aniak, Kipchuk, and Salmon rivers combined were 4,707 for 2002, 6,249 fish for 2003 and 9,614 for 2004 (J. Linderman, Commercial Fish Biologist, ADF&G, Bethel; personal communication). Viewing conditions for the three drainages over the 3 years were good, except the Aniak River in 2002 was fair to poor. These aerial survey data demonstrate that the 2002 Chinook salmon return to the Aniak River may have been similar or smaller in magnitude compared to the 2003 and 2004 returns. However, it remains unclear as to the extent of the bias (if any) in the proportion of Chinook salmon returning to the Aniak River in 2003 and 2004. Overall, the 2003 and 2004 data suggest that this tributary may represent approximately 20% of the total Chinook salmon population in the mainstem Kuskokwim River drainage above Kalskag, assuming the bias for or against tagging Aniak River salmon was not extreme.

Of the total run upstream of the Aniak River, the Holitna River drainage supports by far larger escapements than any other tributary. We compared the mainstem Chinook salmon abundance estimates for 2002-2004 to the Holitna River drainage abundance estimates for these years. Using the abundance estimates, the ratio of Chinook salmon in the Holitna River drainage to the Kuskokwim River drainage above the Aniak River for 2004 (56%) was higher to that observed for 2002 (41%) and 2003 (43%). However, the Chinook salmon abundance estimates for the mainstem Kuskokwim and Holitna rivers are not statistically independent because the same marked fish are used in part for both estimates and the Kogrukluk River weir is part or all of the second sample for both estimates. For example, 42% to 48% of the total marked portion and approximately 55% to 60% of the recaptured fish have been bound for this tributary. In 2004, the four tributaries with weirs enumerated approximately 19% of the estimated run above the Aniak River, and from 2002-2004 the Kogrukluk River weir has comprised approximately 70% of the total weir counts.

The 2004 estimate for inriver abundance of Chinook salmon above the Aniak River was the most precise of the three years. Each year’s sampling strategies and uncontrollable events have presented different challenges and outcomes. In 2002, a large number of radio-tagged Chinook salmon traveled up the Aniak River and were censored from the first sample. In addition, due to the dissimilarity of marked/unmarked ratios of fish sampled at the four weirs, a temporally stratified estimator (Darroch 1961) was required to estimate abundance, resulting in a less precise estimate than desired. In 2003 a proportionately smaller number of Aniak River bound Chinook salmon were censored and the number of marked fish (that migrated upstream of the Aniak River) was substantially higher. However, due to numerous high water events throughout the summer, weir operations were curtailed, so the number of fish examined at the weirs and the number of recaptured fish was lower. Conversely, 2004 was a summer of extremely low water, allowing weirs to remain in operation throughout the entire season. In 2004, the new fish wheel and drift gillnet locations were not as productive for capturing Chinook salmon as sites used in previous years. After censoring out the Aniak River bound Chinook salmon, the number of marked fish was similar to that observed for 2002. However, the relatively large samples from the four weirs led to more precise estimates of inriver abundance and age, sex, and length compositions. Given the size-selectivity associated with gillnet and fish wheel sampling, it was unlikely that unbiased estimates of age, sex, and size compositions could have been obtained from first sampling event for all 3 years of the study.

For the three years of this study, the majority of the fish survived tagging and handling, traveled upriver, and were located in spawning areas or above the tracking station near Red Devil (a significant distance upstream). However, in all three years a small number of fish failed to travel upriver and may have either died as a result of handling or traveled down and spawned in a lower river location. In 2003 and 2004, radio-tagged Chinook salmon were seen at the Kwethluk River weir, which is located approximately 240 rkm downstream from the tagging location (K. Harper, US Fish and Wildlife Service, Soldotna; personal communication). According to Hinch and Rand (2000), because anadromous salmon migrations are energetically expensive, long-distance migrants need to be efficient in their use of energy and minimize swimming costs wherever possible. They found that migrating sockeye salmon swim at speeds that minimize energy costs per distance traveled when swimming in slow-current environments. It would seem that the sort of migratory behavior exhibited by some of the radio-tagged Chinook salmon would lead to a higher risk of mortality through depletion of energy reserves. Thus, we were surprised to observe that some of the radio-tagged Chinook salmon traveled approximately 500 rkm out of their way before reaching their spawning tributaries.

Typically, most of the radio-tagged fish recovered from tagging and handling and traveled directly to their final destinations. However, various degrees of milling and roaming behavior have been observed for approximately 5-10% of radio-tagged Chinook salmon. For example, one of the radio-tagged Chinook salmon swam upstream of the tracking station on the Aniak River, then back down to the mainstem and then migrated upstream to the Holitna River. A relatively large degree of roaming was seen in the Chinook salmon that traveled to the Kwethluk River and lesser degrees of roaming was noted from a number of Chinook salmon that were observed to mill in front of a tracking station for a period of a day or more. Other Chinook salmon were recorded as repeatedly traveling upstream past a stations and then backing down. Similar travel behaviors were observed in 2002 and 2003. It is unknown whether or not the capture and handling and/or the radio tag weight affected the rates of fish movement. According to Matter and Sandford (2003), adult Chinook salmon that had pit tags implanted into them as juveniles showed similar migration rates from dam to dam on the Columbia River as Chinook salmon that were captured as adults and fitted with esophageal implant radio tags. Chinook salmon milling and roaming behavior should be taken into consideration as error when reporting average swimming speeds and assessing run timing behaviors.

Sampling procedures in 2003 and 2004 showed some improvement in dispersing radio tags more proportional to stock abundance compared to 2002. However, the CPUE of 2004 fish wheel and gillnet capture sites was lower compared to previous years. In 2005 CFD is planning on conducting a radiotelemetry feasibility study on sockeye salmon in the Kuskokwim River drainage, therefore the fish wheels will continue operating below the Aniak River. To minimize excessive capture of Aniak River bound Chinook salmon, the lower fish wheel sites from 2003 (near Kalskag) will be utilized. Likewise, the 2003 drift gillnet locations will be utilized. We expect that the Aniak River bound Chinook salmon will again demonstrate significant bank orientation and will have to be censored from the final population estimate as was done in the 2002 - 2004 studies. However, the proportion of radio-tagged Chinook salmon bound for this drainage and the approximate spawning locations gleaned from aerial surveys will continue to add to our knowledge of how radio-tagged Chinook salmon disperse within the Aniak River.

RECOMMENDATIONS

Based on the tagging efforts of the first three years of this project, it is unlikely that a capture area in the vicinity of Kalskag can be found that will not be prone to bank orientation of Aniak River bound Chinook salmon. While moving capture operations farther downriver (e.g., in the vicinity of Bethel) might alleviate problems of bank orientation, it is not recommended because the much larger concentration of subsistence fishers in that area would likely limit suitable fishing areas and cause conflicts with users. In addition, it is likely that a large number of radio-tagged fish would be harvested. The most meaningful improvement that could be made to this project would be to develop a means of estimating abundance of Chinook salmon in the Aniak River. An estimate of abundance for the Aniak River along with this mainstem mark-recapture project and the weir projects in the lower river on the Kwethluk and Tuluksak rivers would provide a nearly complete estimate of total return to the Kuskokwim River. This could be accomplished by either adding a project in the Aniak River that examines a substantial number of Chinook salmon (e.g., weir on a tributary stream) which would allow for inclusion of Aniak River fish in this mainstem mark-recapture estimate, or by conducting an independent mark-recapture experiment in the Aniak River to estimate abundance. A partial enumeration project, such as a weir on a tributary, is preferred over a mark-recapture project provided a tributary that supports a large fraction (e.g., >15%) of the total Aniak River spawning population could be weired. A weir project is preferred over an independent mark-recapture project because it could serve as a platform for other mainstem species projects (e.g., coho, chum, and sockeye salmon mark-recapture and run timing studies), labor costs would be substantially less, and fewer fish would need be handled.

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APPENDIX A.
STATISTICAL TESTS FOR ANALYZING DATA FOR SEX AND SIZE BIAS

Appendix A1.–Statistical tests for evaluating sex and size bias and the assumptions of a two-event mark-recapture experiment conducted on Chinook salmon in the Kuskokwim River, 2002-2004.

The following statistical tests were used to analyze the data for significant bias due to gear selectivity by sex and length.

A test for significant gear bias by sex was based on a contingency table of the number of males and females that were recaptured and were not recaptured. The chi-square statistic was used to evaluate the bias. If this test indicated a significant bias, then the following tests would be conducted for males and females separately. If this test did not indicate a bias, then males and females would be pooled and the following tests performed on the pooled data.

Tests for significant gear bias by size were based on Kolmogorov-Smirnov two sample tests that compared cumulative length frequency distributions of: A) all Chinook salmon marked in the first event and marked fish that passed through the weirs in the second event; and, (B) all Chinook salmon marked in the first event and those Chinook salmon sampled for age, sex, and length at the four weirs (subsample of the total second event sample). The null hypothesis assumed no difference between the distributions of length for Test A or for Test B. For these two tests there were four possible outcomes.

Case I. Accept both A and B.

There was no size-selectivity during either sampling event.

Case II. Accept A and Reject B.

There was no size-selectivity during the second sampling event but there was size-selectivity during the first.

Case III. Reject A and Accept B.

There was size-selectivity during both sampling events.

Case IV. Reject both A and B.

There was size-selectivity during the second sampling event but the status of size-selectivity during the first was unknown.

-continued-

Depending on the outcome of the tests, the following procedures were used to estimate the abundance of the population:

Case I. One unstratified abundance estimate was calculated and lengths, sexes, and ages from both sampling events were pooled in order to improve precision of the proportions in estimating age, sex, and length composition for the sample.

Case II. One unstratified abundance estimate was calculated and the lengths, sexes, and ages were taken from the second sampling event.

Case III. Both sampling events were completely stratified and abundance was estimated for each stratum. Abundance estimates were summed across strata to get a single estimate for the population. Lengths, ages, and sexes from both sampling events were pooled in order to improve precision of composition proportions and a formula was applied to correct for the size bias in the pooled data.

Case IV. Both sampling events were completely stratified and abundance was estimated for each stratum. Abundance estimates were added across strata to get a single estimate for the population. Also, one unstratified estimate was calculated for the population. Lengths, ages, and sexes from the second sampling event were used to estimate proportions in composition and formulae were applied to correct for size bias to the data from the second event.

Appendix A2.–Tests of consistency for the Petersen estimator (from Seber 1982, page 438).

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Of the following conditions, at least one must have been fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mixed completely with unmarked fish between events;
2. Every fish has had an equal probability of being captured and marked during event 1; or,
3. Every fish has had an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic was used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needed to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests were rejected, a temporally or geographically stratified estimator (Darroch 1961) would have been used to estimate abundance.

I.-Test For Complete Mixing[a]

Area/Time Where Marked	Area/Time Where Recaptured				Not
	1	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[b]

	Area/Time Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked $(n_2\text{-}m_2)$				

III.-Test for equal probability of capture during the second event[c]

	Area/Time Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured $(n_1\text{-}$				

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[a] This tests the hypothesis that movement probabilities (θ) from area or time *i* (*i* = 1, 2, ...s) to section *j* (*j* = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$.

[b] This tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among area or time designations: H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum *j* at the time of sampling, and a_i = number of marked fish released in stratum *i*.

[c] This tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among area or time designations: H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section *j* during the second event, and d is a constant.

APPENDIX B.
ARCHIVED DATA FILES

Appendix B1.–Data files used to estimate parameters of the Chinook salmon population in the Kuskokwim River, 2004.

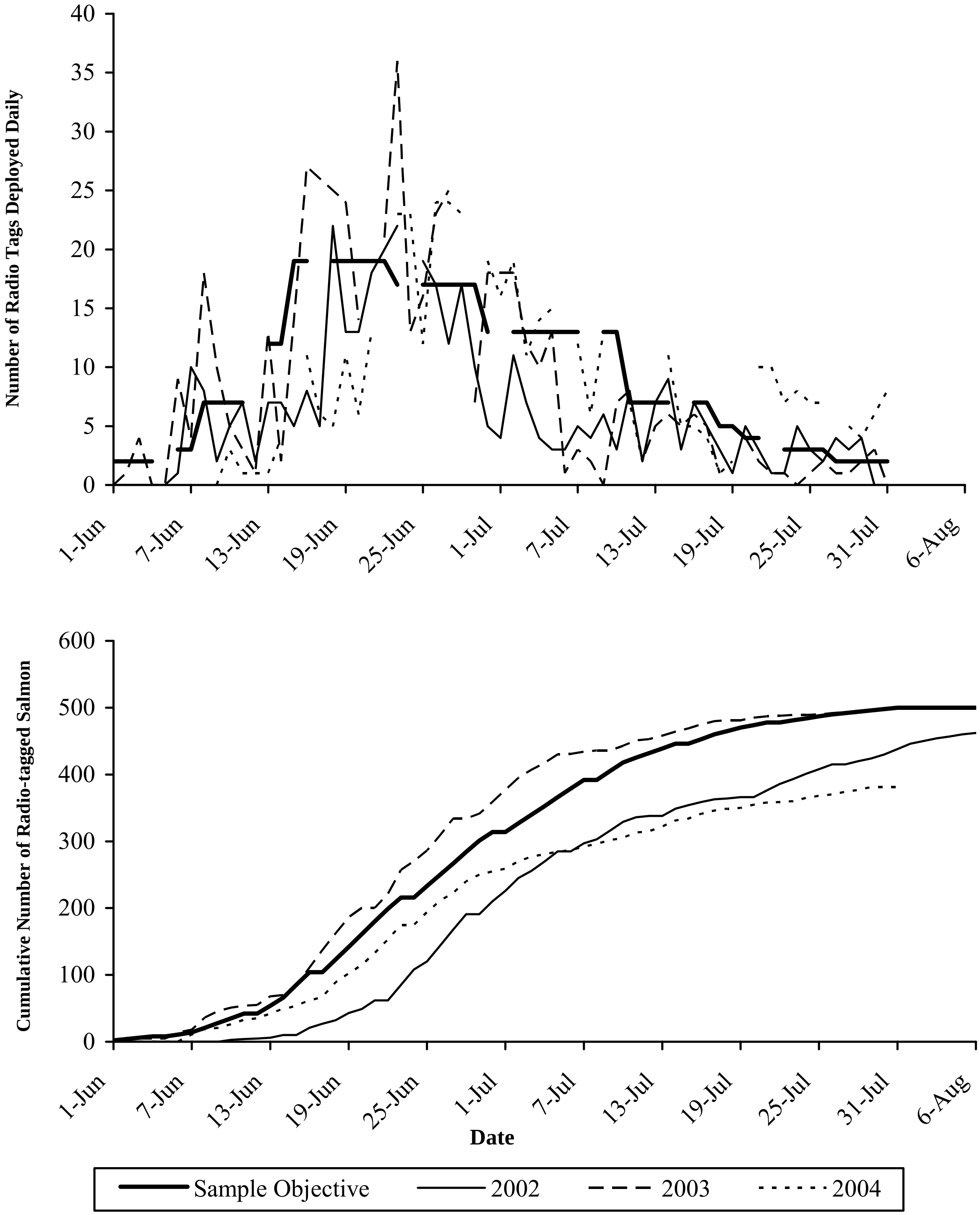
Data File	Description
2004 Geo Kings.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the George River weir, 2004.
04Kog1.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the Kogrukluk River weir, 2004.
2004 Tak Kings.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the Takotna River weir, 2004.
2004 Tat Kings.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the Tatlawiksuk River weir, 2004.
Kusko River Esc Data-Kogrukluk.xls[a]	Excel spreadsheets with daily and historical counts of Chinook salmon passage through the Kogrukluk River weir, 1976-2004.
Kusko River Esc Data.xls[a]	Excel spreadsheets with daily and historical counts of Chinook salmon passage through the George, Tatlawiksuk, and Takotna River weirs, 1995-2004.
2004 Data.xls[b]	Excel spreadsheets with consolidated capture, aerial, and tracking station data. File also includes determination of fates, final destinations of radio-tagged Chinook salmon, travel times of radio-tagged Chinook salmon to the mainstem tracking stations, run timing of radio-tagged fish into the major tributaries of the Kuskokwim River, run timing of genetically distinct stocks, and analyses of run timing and survivability differences between fish sampled with drift gillnets vs. fish wheels, 2004.
ASL 2004.xls[c]	Excel spreadsheets with consolidated age, sex, and length data from the George, Tatlawiksuk, Kogrukluk, and Takotna rivers weirs. File also contains results from contingency table analysis testing for sex bias and the KS tests that examined size bias for the mark-recapture experiment for 2004.
Tagging schedule for 2004.xls[c]	Excel spreadsheets with daily sampling objectives and actual numbers of Chinook salmon captured and radio-tagged in 2004.
Estimate Analysis.xls[c]	Contingency table analyses to test assumptions for the mark-recapture experiment and stratification breaking points for 2004.

[a] Data files have been archived and are available from the Alaska Department of Fish and Game, Commercial Fisheries Division, 333 Raspberry Road, Anchorage, 99518-1599.

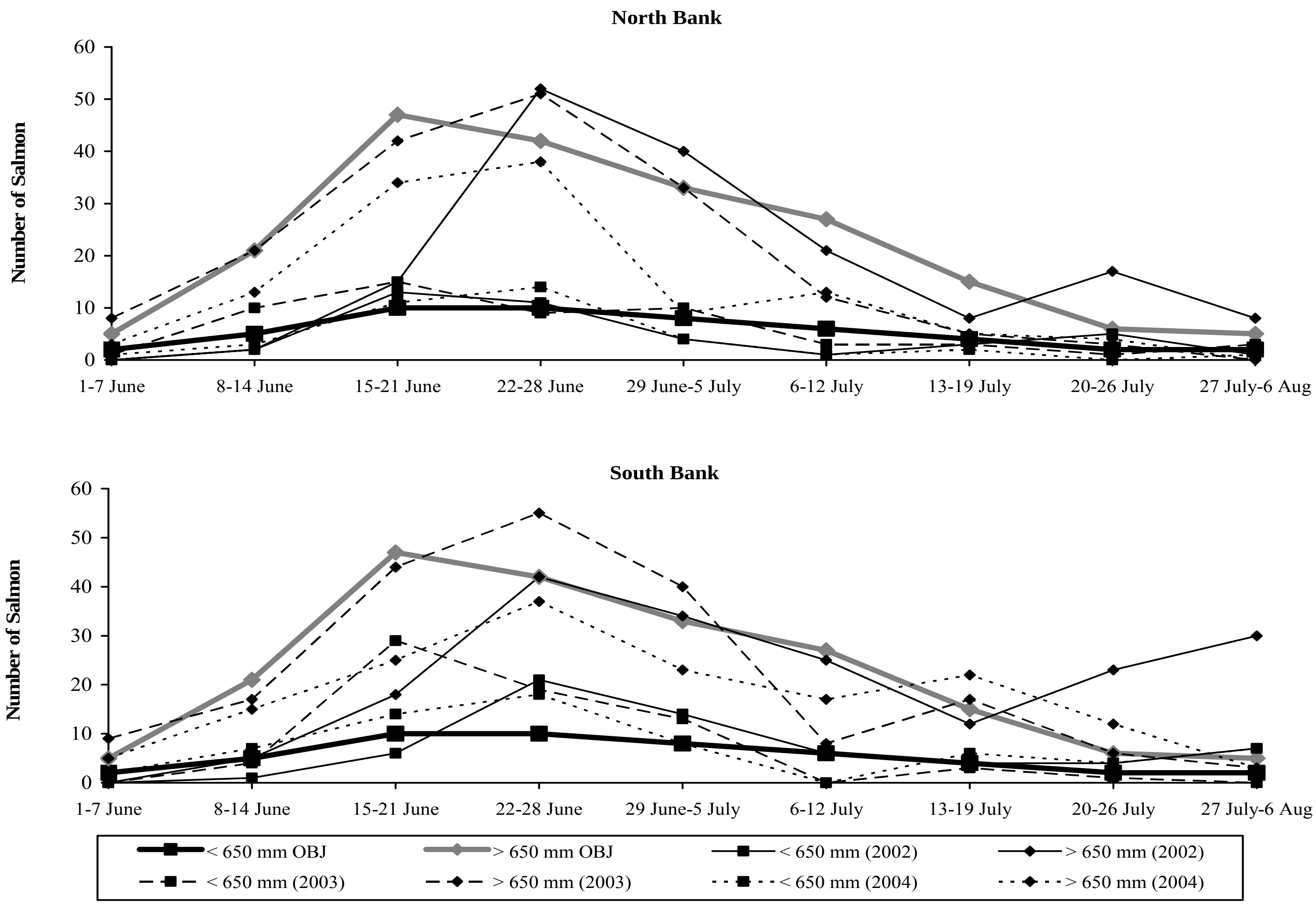
[b] Data files have been archived and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage 99518-1599.

[c] Data files have been archived at the Alaska Department of Fish and Game, Division of Sport Fish, 1300 College Road, Fairbanks, Alaska 99701 and are available from the author.

APPENDIX C.
SAMPLING OBJECTIVES AND ACTUAL DAILY NUMBER OF CHINOOK SALMON SAMPLED

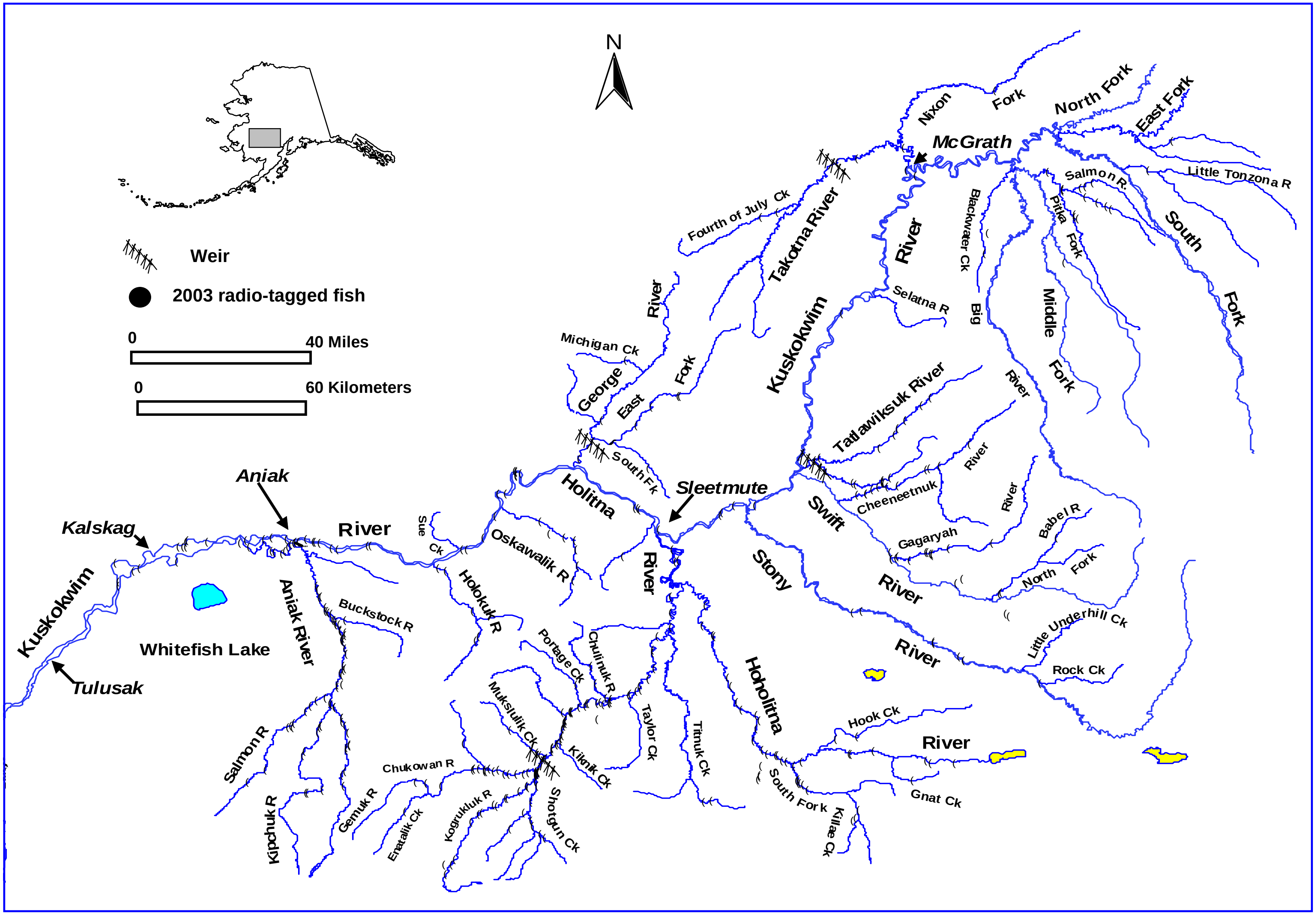


Appendix C1.–Daily and cumulative number of Chinook salmon that were radio-tagged in the Kuskokwim River versus the sampling objective for 2002-2004.

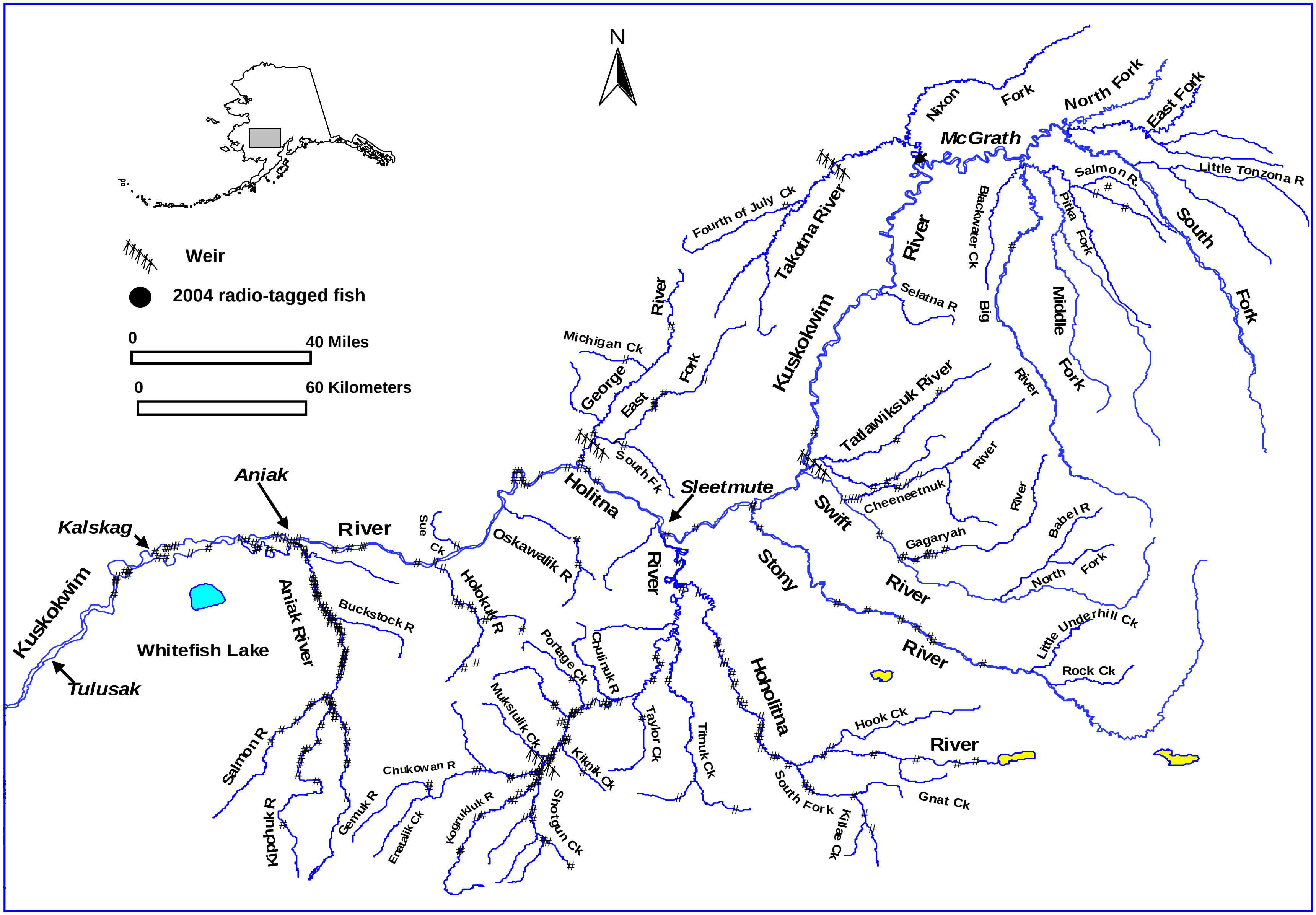


Appendix C2.–Chinook salmon size classes sampled and radio-tagged on the north and south banks of the Kuskokwim River (Actual) versus the pre-season objectives (OBJ) for 2002-2004.

APPENDIX D.
APPROXIMATE UPPERMOST EXTENT OF CHINOOK SALMON DETECTED DURING THE JULY AND AUGUST AERIAL SURVEYS



Appendix D1.–Map of the Kuskokwim River drainage showing the approximate uppermost final locations of radio-tagged Chinook salmon that were detected during the July and August aerial survey flights in 2003.



Appendix D2.–Map of the Kuskokwim River drainage showing the approximate uppermost final locations of radio-tagged Chinook salmon that were detected during the July and August aerial survey flights in 2004.