Fishery Data Series No. 06-45

Inriver Abundance of Chinook Salmon in the Kuskokwim River, 2005

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by
Lisa Stuby

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

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

Mathematics, statistics

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

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by

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ABSTRACT

A two-sample mark-recapture experiment was conducted to estimate inriver abundance of Chinook salmon *Oncorhynchus tshawytscha* in the middle and upper Kuskokwim River and associated tributaries using radiotelemetry techniques from June to August in 2005. 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 above and below Kalskag. 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. Approximately 98% of radio-tagged fish were detected by a combination of two aerial surveys and 15 stationary tracking stations. Similar to previous years, Aniak River bound Chinook salmon were censored from the final estimate due to strong evidence of bank orientation. An estimate was also calculated for Holitna River bound Chinook salmon using a subset of these data. The estimate of abundance for Chinook salmon $\geq$450 mm MEF for the Kuskokwim River upstream of the Aniak River was 145,373 (SE=15,528) and 72,690 (SE=8,510) for those bound for the Holitna River. The majority of radio-tagged Chinook salmon entered the Holitna and Aniak rivers. In general, radio-tagged fish that migrated farther upriver to spawn were captured at the tagging site earlier than those bound for nearby systems.

Key words: aerial survey, Aniak River, abundance estimate, Chinook salmon, *Oncorhynchus tshawytscha*, Holitna River, king salmon, Kuskokwim River, mark-recapture, 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, and supports five species of Pacific salmon. Chinook salmon *Oncorhynchus tshawytscha* are particularly valued by local subsistence users and account for a large percentage of the total subsistence salmon harvest. In addition, Chinook salmon are one of the most popular species sought out by sport fishers.

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 fishery in the mainstem Kuskokwim River was discontinued in 1987 to ensure that subsistence needs would be met. Yet, 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. Although subsistence fishing occurs along most of the length of the Kuskokwim River, most of the harvest and effort takes place in the lower river in the vicinity of Bethel. The commercial fisheries for chum salmon and sockeye salmon, in which Chinook salmon are harvested incidentally, occur in the lower river in commercial management district W-1.

Salmon runs in the Kuskokwim River drainage are managed for sustained yields under policies set forth by the Alaska Board of Fisheries (BOF) 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. The size, remoteness, and geographic diversity of the Kuskokwim River have presented challenges to monitoring salmon escapements and assessing run strength. 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). Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations.

Catch, effort, and harvest for Chinook salmon in the Kuskokwim River drainage from sport fishing is relatively low compared to subsistence and commercial harvests (Table 1). The largest sport fisheries for Chinook salmon occur in the Kisaralik, Kwethluk, Aniak, and Holitna rivers (Lafferty 2004). Since 1985, the average sport harvest of Chinook salmon within the entire Kuskokwim River drainage has varied between 0.07% and 1.81% of the total harvest of this species (Table 1).

From 1998–2000, Kuskokwim area Chinook salmon showed poor escapements compared to previous years and in conjunction, relatively 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 Kuskokwim River Chinook and chum salmon stocks of yield concern under the *Policy for the Management of Sustainable Salmon Fisheries* (5 AAC 39.222, 2001; Molyneaux *Unpublished*).

Since 2002, Kuskokwim River Chinook salmon runs have shown improvement. The 2002–2005 Chinook and chum salmon runs were large enough to provide for Kuskokwim River subsistence needs (Bergstrom and Whitmore 2004), while still meeting escapement goals. However, at the January 2004 BOF meeting, the BOF continued the determination of Kuskokwim River Chinook salmon as a stock of yield concern. 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). Thus, the 2005 Kuskokwim River Chinook salmon fisheries continued to be identified as stocks of yield concern and managed according to the *Kuskokwim River Salmon Rebuilding Management Plan* (5 AAC 07.365; Linderman and Martz *Unpublished*).

As a result of the low escapements from 1998–2001, the listing of Kuskokwim River Chinook salmon as a stock of concern, and subsequent infusion of federal funding from the Western Alaska Disaster Fund, and the Federal Office of Subsistence Management (OSM), a variety of salmon assessment programs were initiated in the Kuskokwim River. Many of these projects, as well as ongoing department-funded projects, have focused on assessing escapements in tributary systems. In recent years, weirs have been used to enumerate escapements on the Kwethluk, Tuluksak, George, Kogrukluk, Tatlawiksuk, and Takotna rivers. In addition, from 2001-2004 a mark-recapture study was conducted on the Holitna River to estimate abundance of Chinook salmon in that system (Wuttig and Evenson 2002; Chythlook and Evenson 2003; Stroka and Brase 2004; Stroka and Reed 2005). While these tributary assessment projects have contributed greatly to assessing escapement of Kuskokwim River Chinook salmon, the relative contributions of these tributary escapements to total inriver abundance can not be estimated without a drainage-wide escapement estimate. In addition to better understanding the relative contributions of tributary abundance estimates, a mainstem inriver abundance estimate can be used in conjunction with escapement monitoring projects in the lower Kuskokwim River (Kwethluk and Tuluksak rivers) and harvest estimates to approximate total returns to the Kuskokwim River. Total drainage estimates from future run-reconstruction efforts can be used

Table 1.–Estimated sport, commercial, and subsistence harvests of Chinook salmon in the Kuskokwim River drainage, 1985–2005.

	Sport Harvest[a]							
Year	Aniak River	Holitna River	Other Kuskokwim River[b]	Total Sport	Commercial[c]	Subsistence[c]	Total Harvest	% Sport Harvest
1985	12	12	61	85	37,889	43,874	81,848	0.10%
1986	49	0	0	49	19,414	51,019	70,482	0.07%
1987	49	14	167	230	36,179	67,325	103,734	0.22%
1988	164	18	146	328	55,716	70,943	126,987	0.26%
1989	738	156	223	1,117	43,217	81,176	125,510	0.89%
1990	285	0	82	367	53,504	85,979	139,850	0.26%
1991	214	0	187	401	37,778	85,554	123,733	0.32%
1992	172	23	172	367	46,872	64,795	112,034	0.33%
1993	300	68	202	570	8,735	87,512	96,817	0.59%
1994	437	40	662	1,139	16,211	93,242	110,592	1.03%
1995	279	19	243	541	30,846	96,436	127,823	0.42%
1996	641	256	682	1,579	7,419	78,063	87,061	1.81%
1997	801	166	660	1,627	10,441	81,577	93,645	1.74%
1998	1,058	54	322	1,434	17,359	81,265	100,058	1.43%
1999	134	25	145	304	4,705	73,194	78,203	0.39%
2000	10	22	73	105	444	64,893	65,442	0.16%
2001	12	73	205	290	90	73,610	73,990	0.39%
2002	75	37	207	319	72	74,778	75,169	0.42%
2003	12	48	341	401	158	67,788	68,347	0.59%
2004	335	136	386	857	2,300	78,193	81,350	1.05%
2005	NA[d]	NA[d]	NA[d]	NA[d]	4,784	NA[d]	NA[d]	NA[d]

[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, 2006a, 2006b, *In prep*).

[b] Other Kuskokwim River sport harvest estimates are everything reported in the Kuskokwim River drainage excluding the Aniak and Holitna rivers.

[c] Commercial and subsistence harvest estimates from Burkey et al. (2002), Ward et al. (2003), Whitmore et al. (2005), and Linderman and Martz (*Unpublished*).

[d] Sport harvest and subsistence estimates not available.

to estimate exploitation rates and refine escapement goals to better aid in the management of subsistence, commercial, and sport fisheries.

Therefore in 2002, the Kuskokwim River mainstem mark-recapture project was implemented in order to estimate inriver abundance of Chinook salmon passing upstream of the Aniak River (Figure 1). This report documents the fourth year of the Kuskokwim River Chinook salmon enumeration project. The primary goals of this multi-year study have been to collect estimates of run size for the middle and upper portions of the Kuskokwim River drainage and to characterize the age, sex, and length composition of the estimate.

In addition to an inriver estimate of abundance, radio-tagged Chinook salmon from the mainstem project were used to estimate Chinook salmon abundance in the Holitna River drainage. Between 2002 and 2004, approximately 40% - 50% of the Chinook salmon radio-tagged in the mainstem Kuskokwim River traveled into the Holitna River drainage (Stuby 2005; Stroka and Brase 2004; Stroka and Reed 2005). A separate Holitna River mark-recapture project was funded by OSM from 2001-2004 during which Chinook salmon were captured and radio-tagged in the lower Holitna River. From 2002-2004, radio-tagged Chinook salmon from this mainstem project were included as part of the marked population in the Holitna River mark-recapture study. However, because of the large number of radio-tagged fish from the mainstem project that entered the Holitna River, it was determined that abundance of Chinook salmon entering the Holitna River could be adequately estimated without the additional tagging efforts in the lower river.

OBJECTIVES

1. Estimate the abundance of Chinook salmon $\geq$ 450 mm MEF in the Kuskokwim River for all waters upstream of the Aniak River such that the estimate is within $\pm$ 25% of the actual value 90% of the time; and,
2. Estimate age, sex, and length compositions of Chinook salmon $\geq$ 450 mm MEF in the Kuskokwim River upstream of the Aniak River such that all estimated proportions are within 5 percentage points of the actual proportions 95% of the time.

In addition, there were four tasks:

1. Estimate the abundance of Chinook salmon that were bound for the Holitna River system;
2. Document Chinook salmon spawning locations within the Kuskokwim River drainage;
3. Collect the axillary process from each radio-tagged Chinook salmon, which will later be sent to the Alaska Department of Fish and Game (ADF&G) Genetics Lab and be used to help identify stock specific genetic markers; and,
4. Assist with the ADF&G commercial fisheries division (CFD) sockeye salmon radiotelemetry pilot study by providing radiotelemetry expertise, programming the sockeye salmon radio-tag frequencies into the receivers used for the mainstem Kuskokwim River Chinook salmon radiotelemetry project, and incorporate the CFD radio tag frequencies during the July and August aerial surveys.

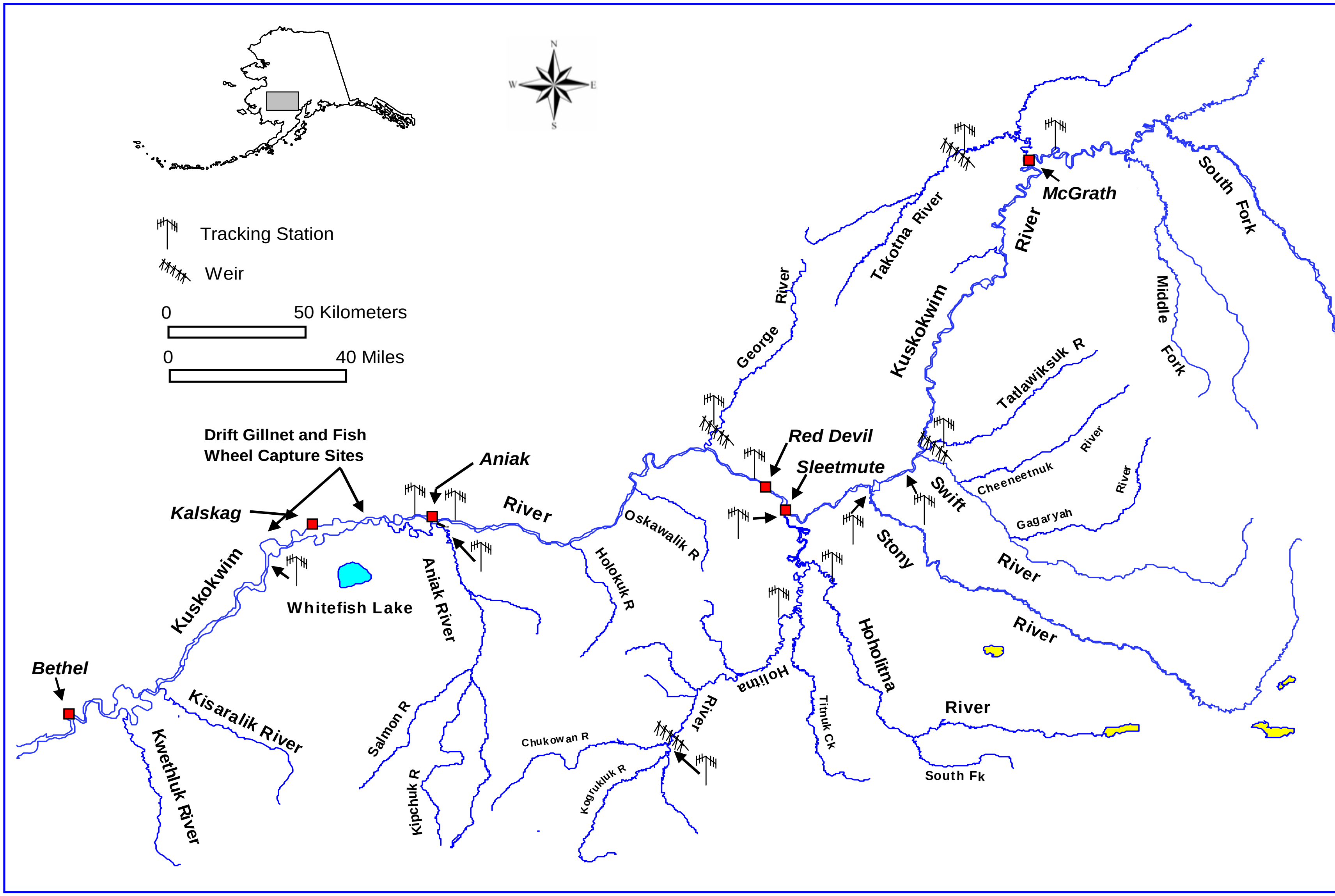

Figure 1.–Map of the Kuskokwim River showing capture sites, weirs, and tracking stations, 2005.

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 CFD staff from a sample of the Chinook salmon that passed through each weir were used to test assumptions of equal probabilities of capture. A lottery for cash prizes was conducted 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 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 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 2005 were conducted approximately 7-8 km above and below Kalskag (Figure 2). Sampling efforts for 2005 commenced on 1 June and continued until 12 August. 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

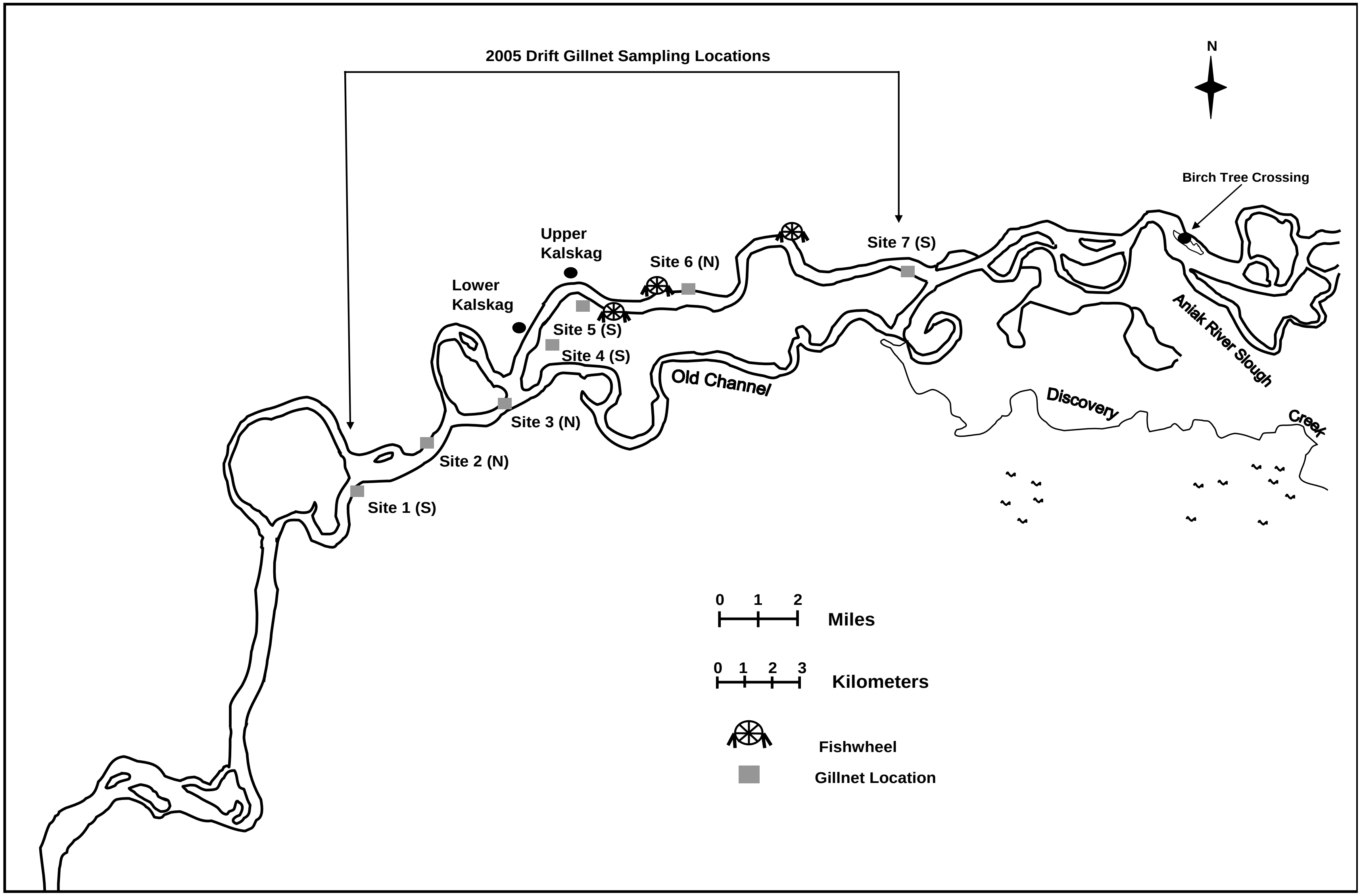

Figure 2.-Map of the drift gillnet and fish wheel tagging locations for Chinook salmon in the Kuskokwim River, 2005. An (S) denotes a south bank and an (N) denotes a north bank location.

3-hour soak time or a 7.5-hour workday was achieved. Three CFD fish wheels were operated 24 hours per day beginning 1 June near Kalskag (Figure 2). Two fish wheels were located along the north bank and one the south bank of the Kuskokwim River. 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.

When a Chinook salmon was captured in a drift gillnet, the net was immediately retrieved into the boat and the fish was removed from the net and 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.

Three scales were removed from the left side of the captured fish approximately two rows above the lateral line along a diagonal line downward from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Welander 1940) and placed on gum cards. Scale impressions were later made on acetate cards and then viewed at 100X magnification using equipment similar to that described by Ryan and Christie (1976). Ages were then determined from scale patterns as described by Mosher (1969). 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 and the vials were stored in a cool, dark place. Later, these tissues were sent to and processed later by the Anchorage CFD genetics laboratory. These samples were added to those from previous years to establish a genetic baseline for Chinook salmon from the Kuskokwim River, identify genetic units for improved conservation and management, and standardize and contribute data to Pacific Rim databases (Templin et al. 2004).

Esophageal-implanted radio tags were used as the primary mark for all 4 years of this study and their size (14.5 x 49 mm) precluded applying them to the Chinook salmon $<$450 mm. 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 $\geq$500 mm, which would ensure compliance with the 2% rule. However, for the 4 years of the project, 53 fish between 455 and 500 mm were given radio tags and of these, 39 were detected into a tributary and only 4 were assumed to have regurgitated their radio tag and/or not survived tagging and handling. Thus fish $\geq$450 mm MEF have a good probability of surviving the stress of tagging and handling and were included in the 2005 sampling effort. Similar results were found in coho salmon on the Holitna River (Wuttig and Evenson 2002; Chythlook and Evenson 2003).

Radio tags were inserted through the esophagus and into the upper stomach of Chinook salmon with an implant device. The device was a 45-cm piece of polyvinyl chloride (PVC) tubing with a slit on one end to seat the radio transmitter into the device. Another section of PVC that fit through the center of the first tube acted as a plunger to position the radio tag. 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. Chinook salmon were tagged while unrestrained in a large tub of water, and tagging was performed without the use of anesthesia. All radio-tagged fish were given a secondary mark of a uniquely numbered, blue 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 14 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 mounted on a 4-15 m mast (depending on the site) 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.

For 2005, six tracking stations were located on the mainstem Kuskokwim River: a station was positioned downstream of the capture sites at approximately rkm 264 near the abandoned village of Uknavik; 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; one was placed at Senka's Landing at approximately 605 rkm; and, the sixth tracking station was located just above McGrath (Figure 1). To identify recaptured fish in the mark-recapture experiment, one tracking station was placed at each of the four weir sites on the George, Kogrukluk, Tatlawiksuk, and Takotna rivers. In addition, a tracking station was placed near the ADF&G sonar site on the Aniak River at approximately 25 rkm upriver from its confluence with the Kuskokwim River, and one was located near the mouth of the Stony River. Lastly, two tracking stations were located on the mainstem Holitna and Hoholitna rivers, and an additional station was placed near the mouth of the Holitna River.

For 2005, CFD conducted a pilot study on sockeye salmon using radiotelemetry techniques. They used two frequencies with 50 codes on each frequency for a total of 100 unique tags. These frequencies were added to the 14 stationary tracking stations used by SFD for the mainstem Chinook salmon radiotelemetry projects. The tracking stations located near the mouth of the Stony River and on the mainstem Kuskokwim River near Senka's Landing were operated

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

by CFD and incorporated the 20 frequencies from the SFD study. Personnel from both divisions cooperated in setting up, downloading, and dismantling the tracking stations at the end of the season.

The tracking stations on the mainstem Kuskokwim River near McGrath, Red Devil, Senka's Landing, and above Aniak as well as tracking stations on the Holitna, Tatlawiksuk, and Stony 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 salmon in the mainstem Kuskokwim River that did not migrate into a spawning stream (e.g., tag loss or handling mortality), locate tagged fish in spawning tributaries other than those monitored with tracking stations, locate 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 2005, two aerial-tracking surveys were conducted from 18–22 July and 2–6 August. 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. Tracking flights in the upper portion of the Kuskokwim River and in other tributary systems were conducted to the extent possible depending on weather, pilot availability, fuel, and funding constraints. 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 by the receiver. The two frequencies used for sockeye salmon from the CFD project were also loaded and tracked, although the flight pattern used in previous years of study did not change as the priority was to locate radio-tagged Chinook salmon.

Boat tracking surveys occurred periodically near the capture/release sites to monitor for tags that had been regurgitated. Keefer et al. (2004 b) 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 at weirs 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 (includes fish that regurgitated tags or backed-out), 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 fisher returned a radio and/or spaghetti tag or verbally reported harvesting a 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 $\geq$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 $\geq$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 the purpose of collecting age, sex, and length data. The composition data collected from fish handled at each weir was used to test model assumptions of equal capture probabilities.

Sampling intensity was not uniform across the four weirs. The catch sample for the Kogrukluk River weir represented 4% of the total count for Chinook salmon, while the catch sample for the Takotna River weir represented 39% of the total count. The catch/total count percentage for the Tatlawiksuk and George river weirs were 15% and 16%, respectively.

Conditions for a Consistent Petersen Estimator

For the estimates of inriver 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 in fish wheels 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 selecting a stratified model for abundance estimation or by censoring of data.

DATA ANALYSIS

Because the sampling intensity was not uniform across the four weirs, the sample data were weighted according to passage prior to conducting tests for size and gender bias as described in Appendix A1. Randomization test procedures as described by Manley (1977) were used to evaluate the Kolmogorov-Smirnov (K-S; Conover 1980) two-sample test statistic when weighted observations were used (C vs R and M vs C tests in Appendix A1) to test for size bias. To evaluate gender bias using weighted observations, we used empirical Bayesian methods (Carlin and Louis 2000) to evaluate if the proportions of females was different between samples. Using Markov Chain Monte-Carlo techniques, posterior distributions and credibility intervals for the difference in the proportion of females between samples were generated, and the likelihood of erroneously rejecting the null hypothesis (no difference) was evaluated by inspection of the null hypothesis relative to the credibility intervals. When un-weighted observations were used to test for size or gender bias (M vs R tests in Appendix A1), conventional K-S test and contingency table test procedures were used to evaluate test statistics.

For 2005 estimates of inriver abundance were unstratified for both the mainstem and Holitna River estimates. The Chapman modification to the Petersen estimator (Chapman 1951) was used:

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

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

where:

$\hat{N}_s$ = estimated abundance of Chinook salmon in size/sex 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 size/sex 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 size/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.

For the mainstem and Holitna River estimates, $S = 1$ and $\hat{C}_s$ was the sum of estimated passage at the four weirs of Chinook salmon $\geq$450 mm MEF.

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 200,000 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:

$$\overline{N} = \frac{\sum_{b=1}^{200,000} \hat{N}_{(b)}}{200,000}\text{; and,} \tag{6}$$

$$V\hat{a}r(\hat{N}') = \frac{\sum_{b=1}^{200,000} (\hat{N}_{(b)} - \overline{N})^2}{200,000 - 1} \tag{7}$$

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

Age, Sex, and Length Compositions

The proportions and numbers of Chinook salmon by ocean-age or sex were estimated from first event sample data after stratifying to eliminate size and gender bias based on the results of diagnostic tests and methods to eliminate bias as described in Appendix A1. Overall proportions and total numbers were then calculated by summing across strata. Composition proportions were first estimated within each stratum using:

$$\hat{p}_{ks} = \frac{n_{ks}}{n_s} \tag{8}$$

where:

$\hat{p}_{ks}$ = estimated proportion of Chinook salmon in group *k* (*k* = 1 to *K) in* stratum *s*;

n_{ks} = number of sampled Chinook salmon in group *k in* stratum *s;* and,

n_s = number of sampled Chinook salmon in stratum *s* in the first event sample.

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

$$\hat{N}_{ks} = \hat{N}_s \hat{p}_{ks} \qquad (9)$$

where the $\hat{N}_s$ were estimated as described in equations 2–5 above.

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

$$\hat{N}_k = \sum_{s=1}^{S} \hat{N}_{ks} , \qquad (10)$$

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

$$\hat{p}_k = \hat{N}_k / \hat{N} . \qquad (11)$$

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 (8-11), were generated by collecting 200,000 simulated values of $\hat{N}_k$ and $\hat{p}_k$ from simulated values of equation parameters. Formulae similar to equations (6) and (7) were used to estimate variance.

Mean lengths and associated sampling variances were calculated for each sex and associated age class *k* using standard sample summary statistics (Cochran 1977). The data files used to estimate the parameters of the Chinook salmon population are listed and described in Appendix B.

RESULTS

Four hundred forty-nine Chinook salmon were captured and radio-tagged in 2005. The daily number of deployed radio tags fairly well followed the predetermined sampling schedule. Of the total radio tags deployed, 39% were deployed in fish captured on the north bank and 61% were deployed in fish captured on the south bank. The discrepancy between banks of capture was as a result of the more productive south bank drift gill net sites and a relatively more productive south-bank fish wheel even though there were two fish wheels operating on the north bank. For 2005, similar sites were fished with drift gillnets and fish wheels as in 2003, when the south/north catch discrepancy for Chinook salmon was significantly less. In general, the sampling objectives were met for tagging fish in the two size classes with respect to bank of capture and size class (Appendices C1 and C2).

Fates were described for the 449 radio-tagged fish (Table 2). Fifty-two radio-tagged fish either lost their tags, were harvested below Aniak, or were never located after tagging (Fate #5). Three hundred ninety seven radio-tagged fish were known to have retained their tags and migrated upstream of the capture site (Fates #1 - #4). Of the 71 fish that were recorded past the two mainstem Kuskokwim River tracking stations near Aniak but were never located in a tributary (Fate #4), 37 were recorded by the mainstem Kuskokwim tracking station at Red Devil.

Table 2.–Final fates of Chinook salmon that were radio-tagged in the Kuskokwim River, 2005.

Fate #	Fate Description	Number of Radio-tagged Chinook Salmon Assigned This Fate
	Fish that survived tagging and handling	
1	Fish harvested above Aniak.	10
2	Fish detected up a tributary that was not monitored with a weir	248
3	Fish that traveled past one of the four tracking stations at weirs on the George, Tatlawiksuk, Kogrukluk, and Takotna rivers.	68
4	Fish that were detected upriver from the tracking station above Aniak, but were not detected into a tributary.	71
	Fish that migrated past the Red Devil tracking station.	37
	Fish that did not migrate past the Red Devil tracking station.	34
	Subtotal	**397**
5	**Fish not detected upstream of the tracking stations near Aniak**	
	Fish harvested below Aniak.	11
	Fish that were not detected by any of the tracking stations and/or by aerial means.	10
	Fish that traveled past downriver station near Uknavik and were never recorded again.	9
	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.	11
	Fish located near Kalskag and/or Fish Wheels and/or Drift Gillnet sites.	11
	Subtotal	**52**
	Total number of fish that were radio tagged.	**449**

The combination of the stationary tracking stations along with the two aerial tracking surveys located 98% of the 449 radio-tagged Chinook salmon. Of these, 382 were detected during one or both aerial surveys. Ninety-six percent of radio-tagged fish were detected by the stationary tracking stations. Ten fish were not detected after tagging by any means.

In 2005, complete daily counts from the weirs comprised almost the entire second event sample. On rare instances where daily counts were not complete, CFD staff interpolated estimates of daily passage. Potential error associated with these estimates was not modeled when calculating estimates of Chinook salmon abundance, as that source of variation was very small relative to other sources of variation in the model used to estimate abundance.

Sixty-eight radio-tagged Chinook salmon swam past the tracking stations at the four weir sites and became part of the recapture portion of the sample. Of these, 49 swam past the Kogrukluk River weir.

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 than Chinook salmon returning to rivers closer to the tagging sites (e.g., the Aniak River); However, there was considerable overlap in the run-timing among the various stocks (Figure 3). Travel times from the capture sites near Kalskag to the tracking stations were highly variable and, as expected, mean travel time increased for those stations placed farther upriver (Figure 4). Mean travel times to the tracking stations placed just above the four weirs showed a lag between the time fish reached the weir (time when signal was first received by the downstream antenna) and the time they migrated upstream past the weir (time when signal was last received by upstream antenna) of between two and nine days.

MARK-RECAPTURE EXPERIMENT

The majority of radio-tagged Chinook salmon that migrated into tributaries (Fates #2 and #3) traveled up the Holitna and Aniak river systems (Table 3; Appendix D). Similar to previous years, the majority (85%) of Aniak River bound Chinook salmon were captured at south bank drift gillnet and fish wheel capture sites.

A series of diagnostic tests were conducted to evaluate the assumption that all fish, regardless of stock, would have equal probability of capture during the first event and that use of weir counts for the second event would not result in apparent violations of that assumption relative to all Kuskokwim river stocks.

To examine the potential for bank orientation at the marking site, we tested the null hypothesis that bank of mark was independent of spawning location for radio-tagged fish. For 2005, the bank of mark was not independent of spawning location when Aniak River fish were compared to spawners from other tributaries (Table 4; χ^2 = 5.29, df = 1, P = 0.02). No data on the mark: unmarked ratio of Aniak River spawners were collected in 2005, thus 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 number marked to 345 fish. No lack of independence was detected in the analysis of the 68 Chinook salmon that traveled into the George, Takotna, Kogrukluk, and Tatlawiksuk rivers, between the bank of mark with their final bank of recapture (Table 5; χ^2 = 1.33, df = 1, P = 0.25).

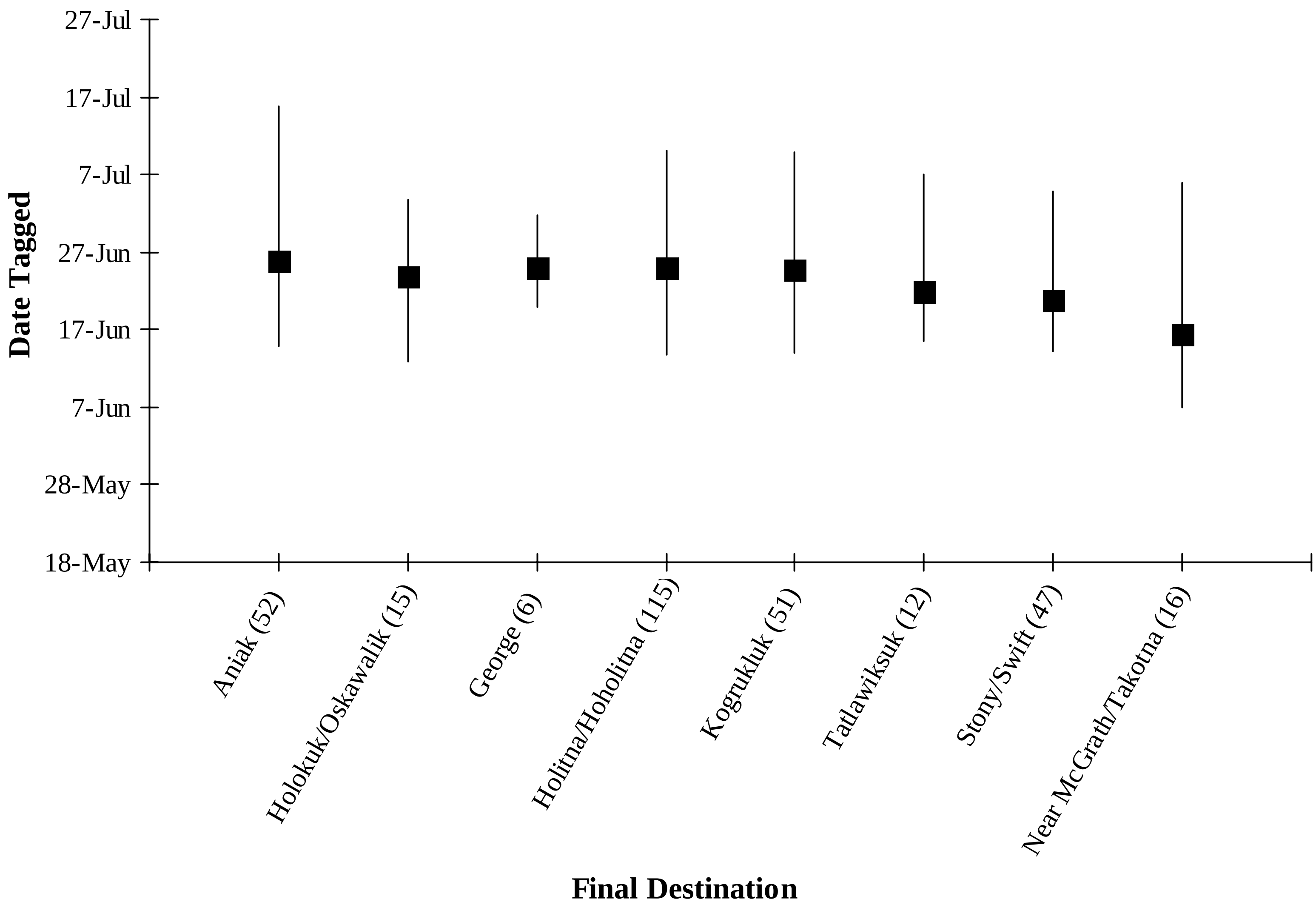

Figure 3.–Median dates of capture (symbol) and 80% range (vertical lines) of Chinook salmon from the Kuskokwim River of known final destinations, 2005. The numbers of fish located in each tributary are presented in parentheses.

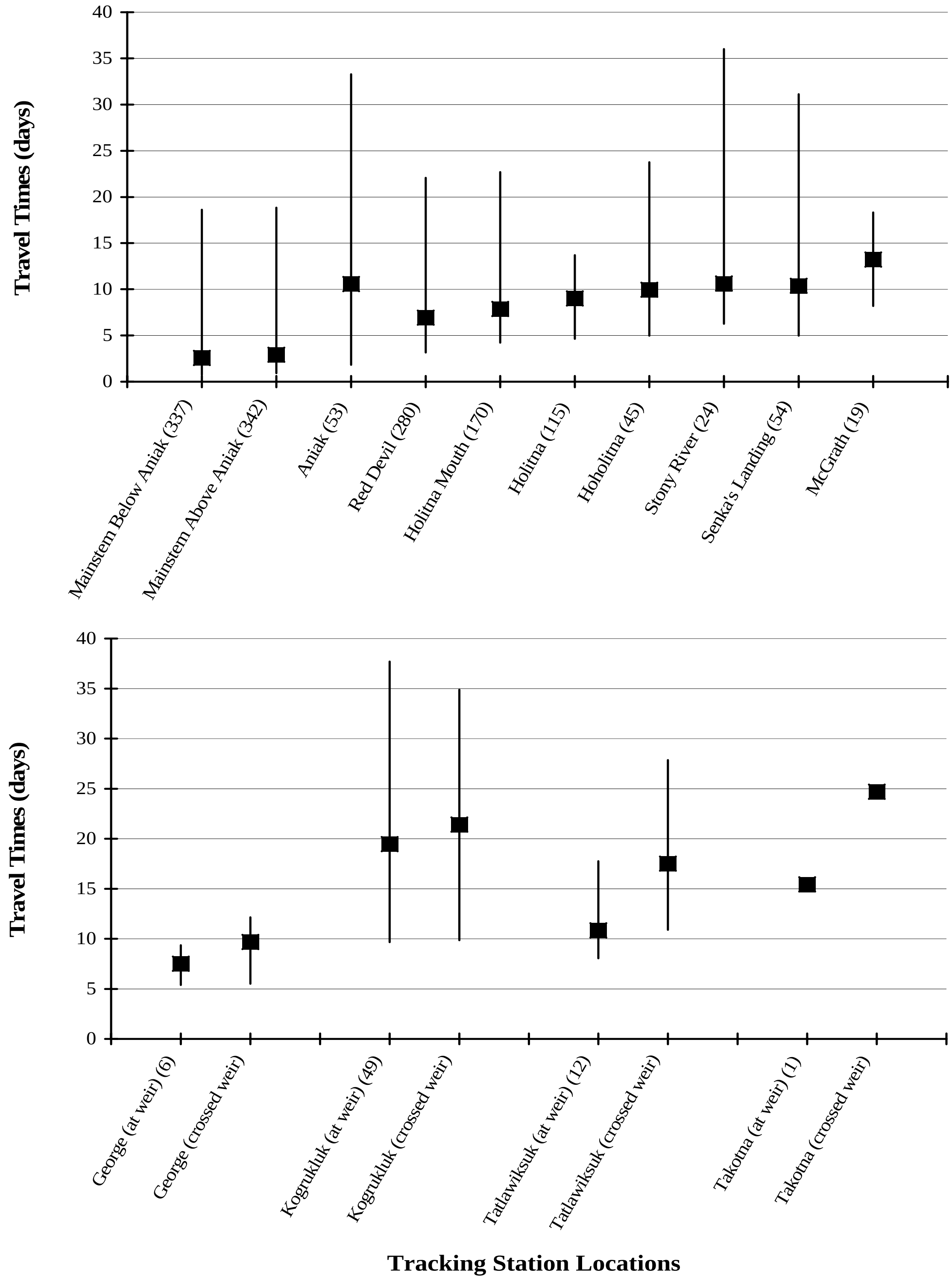

Figure 4.–Mean travel times (symbols) and minimum and maximum travel times (vertical lines) from the capture sites near Kalskag to the tracking stations (top panel). Mean travel times from the capture sites to the four weirs showing time of arrival and time when fish passed upstream of a weir (bottom panel). The numbers of fish recorded at each tracking station are presented in parentheses.

Table 3.-Tagging locations and final destinations of radio-tagged Chinook salmon in the Kuskokwim River, 2005.

	Tagging Method and Location							
Final	Fishwheel			Gillnet				
Destination	North	South	Total	North	South	Total	Total	%Total
Holitna	13	9	22	14	35	49	71	22%
Hoholitna	10	12	22	10	12	22	44	14%
Kogrukluk	5	15	20	14	17	31	51	16%
Holitna River Drainage	**28**	**36**	**64**	**38**	**64**	**102**	**166**	**52%**
Aniak	4	19	23	4	25	29	52	16%
Swift	3	13	16	3	5	8	24	7%
Stony	7	5	12	2	9	11	23	7%
Above McGrath[a]	2	2	4	8	7	15	19	6%
Tatlawiksuk	4	4	8	0	4	4	12	4%
Oskawalik	3	3	6	0	2	2	8	2%
Holokuk	1	1	2	1	4	5	7	2%
George	1	1	2	0	4	4	6	2%
Takotna	0	2	2	0	0	0	2	1%
Vreeland	1	1	2	0	0	0	2	1%
Black	0	0	0	0	1	1	1	0%
ALL	54	87	141	56	125	181	322	

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

Table 4.–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, 2005.

	Final Destinations		
Bank Marked	Kogrukluk, Tatlawiksuk, George, and Takotna Rivers[a]	Aniak River	Total
North	24	8	32
South	47	44	91
Total	71	52	123
	$\chi^2 = 5.29$, df = 1, P =0.02		

[a] Numbers include the 68 recaptures and three fish that swam into the tributaries, but did not cross the weirs.

Table 5.–Contingency table analysis examining independence of bank of marking with bank of recapture for Chinook salmon captured and radio-tagged in the Kuskokwim River, 2005.

	Bank Recaptured		
Bank Marked	North (George, Takotna rivers)	South (Kogrukluk, Tatlawiksuk rivers)	Total
North	1	22	23
South	6	39	45
Total	7	61	68
	$\chi^2 = 1.33$, df = 1, P = 0.25		

The potential for temporal/geographic violations of the assumption of equal probability of capture were examined during the marking event by evaluating the null hypothesis that marked to unmarked ratios observed during second event sampling was independent of sampling locations. No difference was detected between the marked to unmarked ratios of Chinook salmon counted at the George, Kogrukluk, Tatlawiksuk, and Takotna river weirs (Table 6; χ^2 = 5.10, df = 3, P = 0.16). While this result is sufficient to support the use of a Petersen-type model for abundance estimation (see Appendix A2), further tests were conducted to evaluate the potential for temporal/geographic violations of equal probability of capture during second event sampling. No significant evidence was found to reject the null hypothesis that the probability that a tagged fish was later "recaptured" at a weir was independent of bank of mark (Table 7; χ^2 = 1.60, df = 1, P = 0.21) or independent of gear type (Table 8; χ^2 =3.68, df = 1, P = 0.06). Also, we failed to reject the null hypothesis that time of marking during the first event was independent of probability of recapture during the second event when examining all Chinook salmon marked from the first event (Table 9; χ^2 = 1.11, df = 3, P = 0.77) and when examining only that portion that traveled up the Holitna River drainage (χ^2 = 1.08, df = 3, P = 0.78).

The potential for gender bias during second event sampling was examined by testing the null hypothesis that the probability that a marked fish was "recaptured" was independent of gender. The recapture rates for males (0.29) and females (0.32) were similar (Table 10; χ^2 = 0.65, df = 1, P = 0.42). The recapture rates were also similar for males (0.24) and females (0.20) when we examined only those Chinook salmon bound for the Holitna River drainage (Table 10; χ^2 = 1.93, df = 1, P = 0.16). The potential for gender bias during the marking event was examined by testing the null hypothesis that the proportion of females in our sample of "recaptured" fish was the same as the estimated proportion of females $\geq$450 mm in our second event sample at the four weirs. Because the number of unmarked fish $\geq$450 mm passing through the weirs was estimated, empirical Bayesian methods (Carlin and Louis 2000) were used to test the null hypothesis. The null hypothesis was rejected (P < 0.01) which indicated a Case III situation (Appendix A1) with regard to gender bias.

The potential for size bias during second event sampling was examined by testing the null hypothesis that there was no difference between the length distributions of Chinook salmon marked during the first event and those "recaptured" during the second event. A significant difference was not detected when we examined all fish (D = 0.09, P = 0.74; Figure 5). Similarly, no difference was detected when we examined only those Chinook salmon bound for the Holitna River drainage (D = 0.04, P = 1.00; Figure 5). The potential for size bias during the marking event was examined by testing the null hypothesis that there was no difference between the length distributions of Chinook salmon passed through the weirs during the second event and those "recaptured" during the second event. A significant difference was not detected when all fish were examined (D=0.11, P = 0.62), and likewise no difference was detected when examining only those fish bound for the Holitna River drainage (D = 0.14, P = 0.28). Length distributions of all Chinook salmon marked during the first event and those sampled for age, sex, and length during the second event were not significantly different (D = 0.08, P = 0.14), which confirms the findings above of no detectable size bias sampling during either sampling event.

Table 6.–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, 2005.

River	Unmarked	Marked	Total Catch
George	3,839	6	3,845
Tatlawiksuk	2,908	12	2,920
Kogrukluk	21,951	49	22,000
Takotna	505	1	506
Total	29,203	68	29,271
	χ^2 = 5.10, df = 3, P = 0.16		

Table 7.–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, 2005.

	Bank Marked		
Capture History	North	South	Total
Recaptured	23	45	68
Not Recaptured	117	160	277
Total	140	205	345
	χ^2 = 1.60, df = 1, P = 0.21		

Table 8.–Contingency table analysis comparing recapture rates of Chinook salmon by gear type during the mark-recapture experiment on the Kuskokwim River, 2005.

	Sampling Gear		
Capture History	Gillnet	Fish Wheel	Total
Recaptured	38	30	68
Not recaptured	119	158	277
Total	157	188	345
	χ^2 = 3.68, df = 1, P = 0.06		

Table 9.–Contingency table analysis testing equal catchability by time for Chinook salmon sampled during the mark-recapture experiments in the Kuskokwim River and in the Holitna River, 2005.

Date Tagged	Not Recaptured	Recaptured	Total
Middle and Upper Kuskokwim River			
1 – 15 June	72	18	90
16 – 22 June	68	16	84
23 June – 3 July	67	20	87
4 July - 12 Aug	70	14	84
Total	277	68	345
	χ^2 = 1.11, df = 3, P = 0.77		
Holitna River			
1 – 15 June	26	14	40
16 – 23 June	29	10	39
24 June – 2 July	29	13	42
3 July - 8 Aug	33	12	45
Total	117	49	166
	χ^2 = 1.08, df = 3, P = 0.78		

Table 10.–Contingency table analysis of recapture rates of male and female Chinook salmon sampled during the mark-recapture experiment in the Kuskokwim River and in the Holitna River, 2005.

Capture History	Male	Female	Total
All Areas			
Recaptured	30	38	68
Not Recaptured	107	169	276
Total	137	207	344
Recapture Rate	0.29	0.32	0.20
	χ^2 = 0.65, df = 1, P = 0.42		
Holitna River			
Recaptured	25	24	49
Not Recaptured	46	71	117
Total	71	95	166
Recapture Rate	0.24	0.20	0.30
	χ^2 = 1.93, df = 1, P = 0.16		

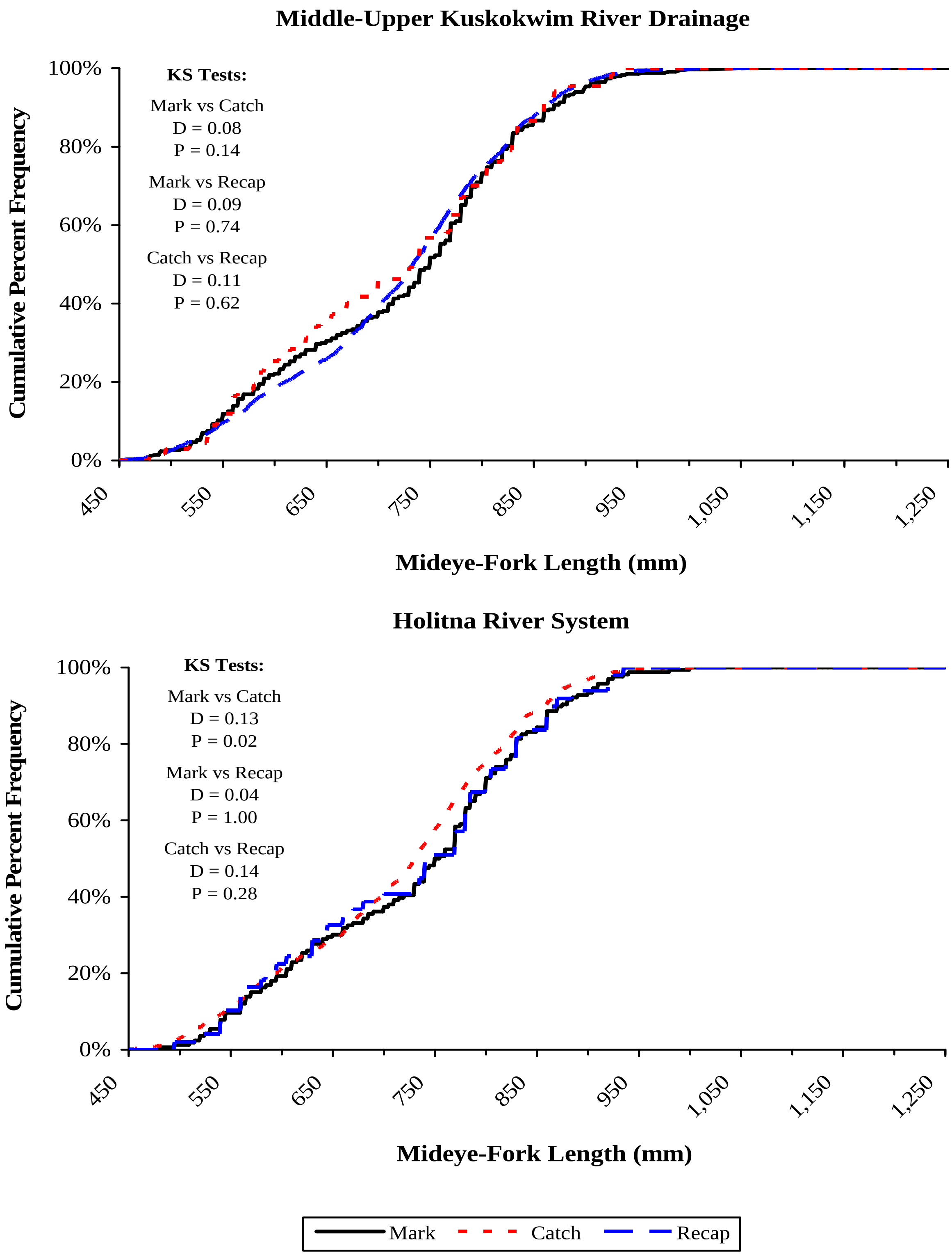

Figure 5.–Cumulative length frequency distributions comparing all Chinook salmon caught during the first (Mark) and second (Catch) events, and all recaptured (Recap) fish caught during the second event from the mark-recapture experiment in the Kuskokwim River and in the Holitna River, 2005.

However, for Holitna River bound Chinook salmon a difference was detected in size distributions between the first and second events (D = 0.13, P = 0.02). As the previous tests that indicated no significant size bias sampling for the Holitna River fish were a result of relatively large sample sizes (49 recaptures), we continue to conclude that size bias sampling was not a problem.

After the series of diagnostic tests to detect violations of the assumptions of equal probability of capture, it was concluded that both the Kuskokwim River and Holitna River experiments were Case III (Appendix A1) experiments due to gender bias sampling during the first event even though such bias was not detected with respect to size.

Using an unstratified model, the abundance of Chinook salmon ≥450 mm for the Kuskokwim River upstream of the confluence of the Aniak River was estimated at 145,373 fish (SE=15,528) with a 95% credibility interval of 119,300 to 181,900. The abundance of Chinook salmon ≥450 mm that entered the Holitna River drainage was estimated at 72,690 fish (SE=8,510) with a 95% credibility interval of 58,790 to 93,320. Approximately 50% 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 showed gender selective sampling occurred during the first event. Sex selective sampling was detected for Chinook salmon <620 mm and may have been a result of uncertainties in correctly assigning sex to small fish. Thus, composition was estimated from the first event (Case III in Appendix A1) after first stratifying length data into all salmon >650 mm, males 450-619 mm, and females 450-619 mm. No evidence of sampling bias was detected within these size/sex strata.

Ages were determined for 303 (88%) of the 345 fish sampled. The dominant age class for both males and females was 1.3 (Table 11). Sex composition was split equally between males and females. Lengths of males ranged from 460 to 1,000 mm and lengths of females ranged from 480 to 1,050 mm (Figure 6).

DISCUSSION

This was the fourth year of the Chinook salmon enumeration project on the Kuskokwim River. In each of the previous three years of this study, radio-tagged Chinook salmon bound for the Aniak River demonstrated bank orientation at the marking sites, while no bank orientation was detected among salmon migrating to other spawning tributaries (Stuby 2003-2005). Bank orientation can indicate a significant potential for violation of the assumptions of equal probability of capture and can lead to a biased estimate of abundance. As a result, for 2005 the main objectives pertained to the Chinook salmon abundance above the Aniak River instead of above the tagging sites near Kalskag. 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). For the three previous seasons, tagging effort was relocated from the original location in 2002, to as far downriver in 2004 as was feasible in an attempt at tagging this stock when it was mixed. 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. Sampling farther downstream than was done in 2004 would not be practical because the subsistence and commercial fisheries become more

Table 11.-Estimated proportions, abundance, and mean length at age for male and female Chinook salmon that were marked during the first event near Kalskag, 2005.

						MEF Length (mm)			
Age[a]	Proportion[b]	SE[c]	Abundance[b]	SE[c]	Sample Size[d]	Mean	SE	Min	Max
				Male					
1.2	0.13	0.04	18,127	5,712	23	23	5	460	730
1.3	0.25	0.03	36,247	5,742	63	63	3	485	940
1.4	0.11	0.02	16,612	3,453	31	31	5	630	1,000
1.5	0.01	0.01	1,608	945	3	3	20	780	820
Total	0.50	0.04	72,594	9,901	120	724	2	460	1,000
				Female					
1.1	<0.01	0.00	9	21	1	480	N/A	480	480
1.2	0.01	0.01	1,852	963	30	557	4	490	680
1.3	0.24	0.03	34,459	5,604	82	714	3	520	900
1.4	0.19	0.03	27,875	4,820	53	817	4	590	1,050
1.5	0.05	0.01	6,966	2,070	13	803	8	670	990
2.2	<0.01	<0.01	545	545	2	620	25	615	625
2.3	<0.01	<0.01	536	542	1	715	N/A	715	715
2.4	<0.01	<0.01	536	548	1	780	N/A	780	780
Total	0.50	0.04	72,779	9,790	183	723	2	480	1,050
Total Male and Female			145,373	16,010	303	723	2	460	1,050

[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 abundance estimates were based on the age, sex and length data acquired from the first event sample that was first stratified to eliminate variability in capture probability.

[c] Estimates of SE were derived from posterior distributions of the parameter estimates that were produced using an empirical Bayesian analysis.

[d] Values represent actual fish sampled from the first event. All were ≥450 mm.

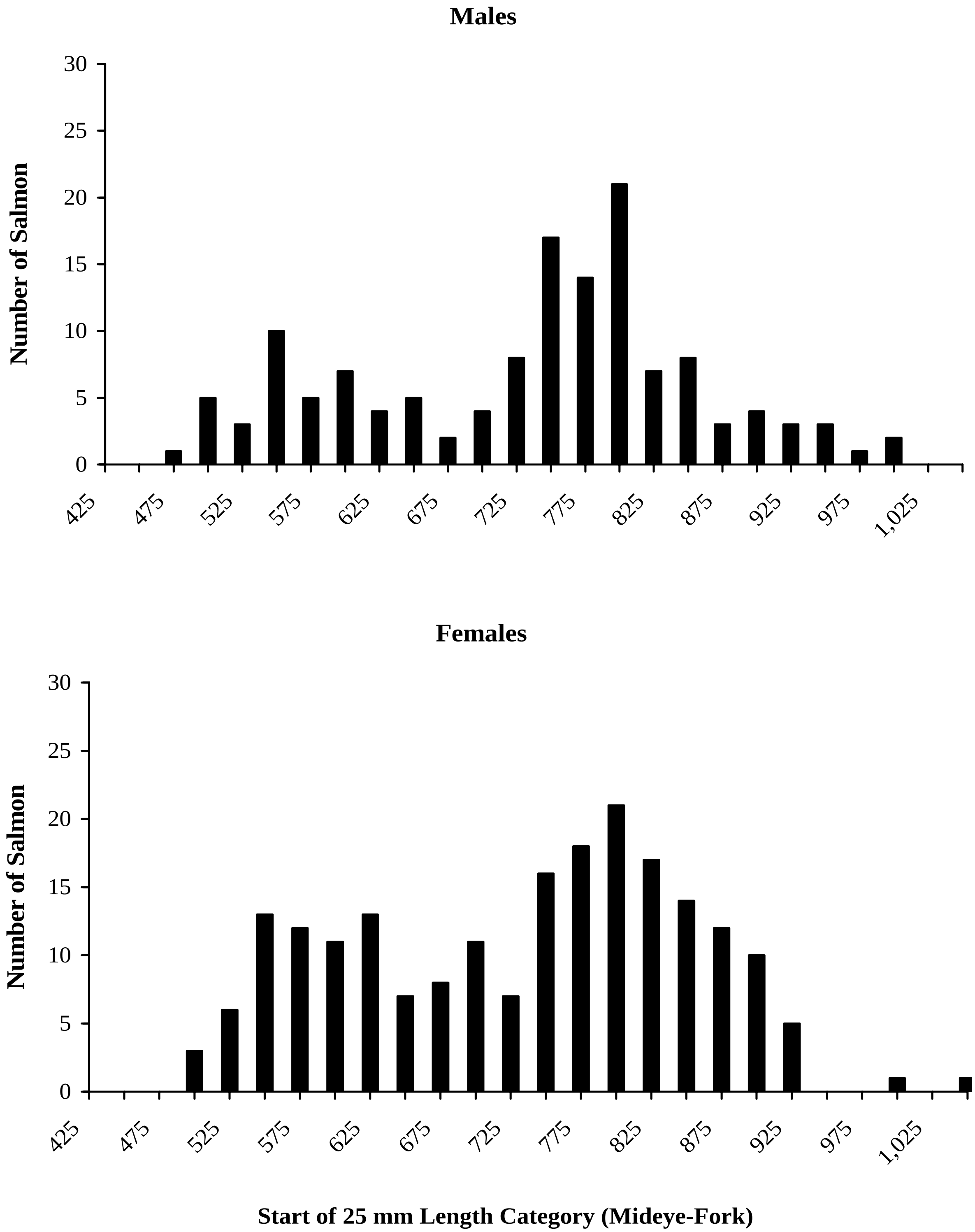

Figure 6.–Length frequency distributions of male and female Chinook salmon that were sampled during the first event near Kalskag, 2005.

concentrated, thus making it more likely that a large number of tagged fish would be harvested. Also, below Kalskag the Kuskokwim River widens and slows and suitable drift net and fish wheel sites (not already occupied by subsistence fishers) would be difficult to locate.

Despite having to exclude the Aniak River Chinook salmon population in the final estimate, the proportion of radio-tagged fish that have traveled into this tributary has given insight into the relative importance of this tributary to the overall inriver abundance. In order to include the Aniak River Chinook salmon in the estimate of total abundance, a second event sampling effort in this tributary is needed in order to evaluate whether Aniak River fish were marked in similar proportion to other Kuskokwim River stocks or, if not, to identify an appropriate model for estimating abundance which would alleviate bias.

Of the total run upstream of the Aniak River, the Holitna River drainage supports far larger escapements than any other tributary. Since the project's inception, the ratio of Chinook salmon in the Holitna River drainage to the Kuskokwim River drainage above the Aniak River has varied from 41% to 56% of the total estimate. Likewise, from 2002–2005, 42% to 48% of the total marked portion and approximately 55% to 72% of the recaptured fish have been bound for this tributary. Because of the relatively large number of radio-tagged fish that travel into this drainage, the Chinook salmon abundance estimates for the mainstem Kuskokwim and Holitna rivers have not been statistically independent because the same marked fish have been used in part for both estimates and the Kogrukluk River weir has been a major part or all of the second sample for both estimates.

For 2005 there was uncertainty in determining the gender of Chinook salmon between 450 and 620 mm during first event tagging, and it was likely that some fish were assigned incorrectly. One age 1.1 and several age 1.2 fish were assigned as females and the proportion of ages was similar between both sexes (Table 11). Usually, males predominate the age 1.3 class and females the 1.4 class. In addition, the length frequency distributions for males has typically shown a much broader spread to the smaller size classes and the females have been more concentrated to larger size classes (Stuby 2003–2005). The departure of the 2005 data from this pattern suggested there were errors in assigning sex to salmon in smaller size classes and resulted in the conclusion of gender bias during first event sampling. As a result, the data were stratified prior to estimating composition parameters in order to minimize the potential for bias in the point estimates.

In addition to a brighter red spawning color, males can also be distinguished from females by their ridged back and hooked upper jaw. The spawning female will typically show a rounder body and the presence of an ovipositor. Males tend to mature at a younger age than do females (Healey 1991), and for stream-type Chinook salmon, can go to sea and return to spawn at a younger age (termed "jacks") than the females of their brood class (Larsen et al. 2004). Usually, two year-old mature females are virtually unknown, and three-year-old mature females are uncommon in spawning runs (Nicholas and Hankin 1988). The incidence of jacks in wild stocks is thought to be less than 5% (Mullan et al. 1992). The CFD personnel operating the four weirs have been instructed to be highly critical of sexing Chinook salmon as females if they are smaller than 720 mm. This conclusion was based on analysis of three years of sex data that were confirmed in the commercial fishery catch samples. These samples indicated that 97.5% of the harvested female Chinook salmon were larger than 719 mm based on a one-sided +5% confidence interval (Linderman et al. 2003). In 2006, similar efforts will be made to critically inspect all fish before assigning sex and to note all fish for which sex is uncertain.

The run-timing patterns of the various stocks past the capture site have shown considerable overlap among stocks within a year (Figure 3) and variation within stocks between years. However, the statistics presented in this report are descriptive of the sample of fish given radio tags that were located in a tributary and do not necessarily represent population statistics. Estimating stock specific run timing patterns (for the population) has not been a specific objective of this study for two reasons. First, not every radio-tagged Chinook salmon that migrates upstream of the capture site is located in a spawning tributary. In 2005, 71 of the 397 fish that migrated upstream past the capture site were not located in a spawning tributary, and similar results were observed in other years of the study (Stuby 2003-2005). These fish were not problematic in estimating abundance because of the certainty that they did migrate upstream but did not pass undetected through the weirs, but their unknown status relative to a spawning area could lead to biased estimates of run timing. Given the vastness of the drainage and large cost associated with aerial tracking and fixed receiving stations, increasing the location rate of radio-tagged fish is not feasible.

Second, it is unknown whether the various spawning stocks were captured and radio-tagged at the same rate (relative to their abundance) throughout the run. Even when tagging rates are constant relative to catch, temporal changes in catchability can lead to different tagging rates and biased estimates of run timing. Time varying probabilities of capture were noted in a Copper River Chinook salmon radiotelemetry project and run timing and spawning distribution estimates were corrected for bias by assigning weighted values to each radio-tagged fish (Savereide 2005). Tag weights were calculated as the ratio of a time-specific abundance estimate to the number of radio tags deployed during that time period. This method of bias correction was not attempted in this study because it requires estimating first event capture probabilities by time from marked to unmarked ratios in the second event and, if temporal differences occur, calculating stratified estimates of abundance. In the Copper River study, both sampling events were conducted in the mainstem portion of the river and all spawning stocks were sampled in both events, a large fraction of the population was marked and examined, and the distance between sampling locations was relatively short (91 km; Smith et al. 2005). In this Kuskokwim River study, only four stocks were examined in the second event (at the weirs), the distance between sampling locations was large, and only a small fraction of the population was marked. Thus, estimates of first event capture probabilities were imprecise and did not apply to all spawning stocks. For these reasons and because of the variation in travel time from marking to recovery areas, tests to evaluate homogeneity in first event capture probabilities by time were not thought to be reliable.

Migration timing is an adaptive and heritable behavior (Smoker et al. 1998; Stewart et al. 2002) and has been used to differentiate between Alaskan Chinook salmon stocks (Burger et al. 1985; Wuttig and Evenson 2001). Run-timing differences among salmonids are, at least partially, adaptations to predictable thermal and flow regimes in migration corridors and spawning streams (Healey 1991; Quinn et al. 2002). Chinook salmon, as well as other Pacific salmon species, have been known to time migrations in order to arrive at natal streams just prior to optimal environmental and biological spawning conditions (Keefer et al. 2004a). However, the unpredictability of year-to-year and within season hydrological, meterological, and oceanic conditions prior to and during the migration into a large fresh water drainage like the Kuskokwim River can lead to wide variation in stock-specific run timing. Keefer et al. (2004a) noted a wide variation in both the composition and timing of Columbia River basin Chinook salmon runs and recommended that stock-specific management strategies based on run timing should be conservative.

Swimming speeds of radio-tagged Chinook salmon from the capture site to the various tracking stations varied considerably (Figure 4), with a small proportion of the radio-tagged fish exhibiting various degrees of milling and roaming behavior. It was assumed that capture, handling, and radio-tagging did not affect 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 between dams on the Columbia River as Chinook salmon that were captured as adults and fitted with esophageal implant radio tags. Eiler et al. (2006) reported that Chinook salmon radio-tagged in the Yukon River were likely not adversely affected by tagging as stock groups that traveled long distances to spawning areas had average movement rates that were greater than stocks that traveled shorter distances.

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. For 2006, CFD will be implementing a weir project on the Salmon River, a major tributary of the Aniak River. A tracking station will be positioned near the weir, which will record radio-tagged fish that swim through. It is possible these efforts will allow for inclusion of Aniak River fish in the 2006 mainstem mark-recapture estimate. An additional 30-60 Chinook salmon will be radio-tagged throughout the run near the CFD sonar site and Aniak River tracking station to supplement the mainstem tagging efforts so that a separate mark-recapture experiment can be conducted to estimate abundance in the Aniak River. An estimate of abundance that includes the Aniak River along 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

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

Appendix A1.–Detection of size and/or sex selective sampling during a two-sample mark recapture experiment and its effects on estimation of population size and population composition.

Size selective sampling: The Kolmogorov-Smirnov two sample test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first and/or second sampling events. The second sampling event is evaluated by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R) by using the null test hypothesis of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. A third test that compares M and C is then conducted and used to evaluate the results of the first two tests when sample sizes are small. Guidelines for small sample sizes are <30 for R and <100 for M or C.

Sex selective sampling: Contingency table analysis (Chi^2-test) is generally used to detect significant evidence that sex selective sampling occurred during the first and/or second sampling events. The counts of observed males to females are compared between M&R, C&R, and M&C using the null hypothesis that the probability that a sampled fish is male or female is independent of sample. If the proportions by gender are estimated for a sample (usually C), rather an observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are then compared between samples using a two sample test (e.g., Student's t-test).

M vs. R	**C vs. R**	**M vs. C**
Case I:		
Fail to reject H_o	Fail to reject H_o	Fail to reject H_o
There is no size/sex selectivity detected during either sampling event.		
Case II:		
Reject H_o	Fail to reject H_o	Reject H_o
There is no size/sex selectivity detected during the first event but there is during the second event sampling.		
Case III:		
Fail to reject H_o	Reject H_o	Reject H_o
There is no size/sex selectivity detected during the second event but there is during the first event sampling.		
Case IV:		
Reject H_o	Reject H_o	Either result possible
There is size/sex selectivity detected during both the first and second sampling events.		
Evaluation Required:		
Fail to reject H_o	Fail to reject H_o	Reject H_o

Sample sizes and powers of tests must be considered:

A. If sample sizes for M vs. R and C vs. R tests are not small and sample sizes for M vs. C test are very large, the M vs. C test is likely detecting small differences which have little potential to result in bias during estimation. *Case I* is appropriate.

B. If a) sample sizes for M vs. R are small, b) the M vs. R p-value is not large (~0.20 or less), and c) the C vs. R sample sizes are not small and/or the C vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the second event which the M vs. R test was not powerful enough to detect. *Case I* may be considered but *Case II* is the recommended, conservative interpretation.

C. If a) sample sizes for C vs. R are small, b) the C vs. R p-value is not large (~0.20 or less), and c) the M vs. R sample sizes are not small and/or the M vs. R p-value is fairly large (~0.30 or more), the rejection of the null in the M vs. C test was likely the result of size/sex selectivity during the first event which the C vs. R test was not powerful enough to detect. *Case I* may be considered but *Case III* is the recommended, conservative interpretation.

-continued-

D. If a) sample sizes for C vs. R and M vs. R are both small, and b) both the C vs. R and M vs. R p-values are not large (~0.20 or less), the rejection of the null in the M vs. C test may be the result of size/sex selectivity during both events which the C vs. R and M vs. R tests were not powerful enough to detect. *Cases I, II, or III* may be considered but *Case IV* is the recommended, conservative interpretation.

Case I. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

If stratification by sex or length is necessary prior to estimating composition parameters, then an overall composition parameters (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{ ; and,} \tag{1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + (\hat{p}_{ik} - \hat{p}_k)^2 \hat{V}[\hat{N}_i] \right). \tag{2}$$

where: j = the number of sex/size strata;

$\hat{p}_{ik}$ = the estimated proportion of fish that were age or size k among fish in stratum i;

$\hat{N}_i$ = the estimated abundance in stratum i; and,

$\hat{N}_\Sigma$ = sum of the $\hat{N}_i$ across strata.

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 be fulfilled to meet assumptions of a Petersen estimator:

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

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

I.-Test For Complete Mixing[a]

Area/Time Where Marked	Area/Time Where Recaptured				Not Recaptured
	1	**2**	**…**	**t**	$(n_1$-$m_2)$
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 $(n_2$-$m_2)$				

III.-Test For Equal Probability of Capture During the Second Event[c]

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

[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: H0: Σjθijpj = d, where pj 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, 2005.

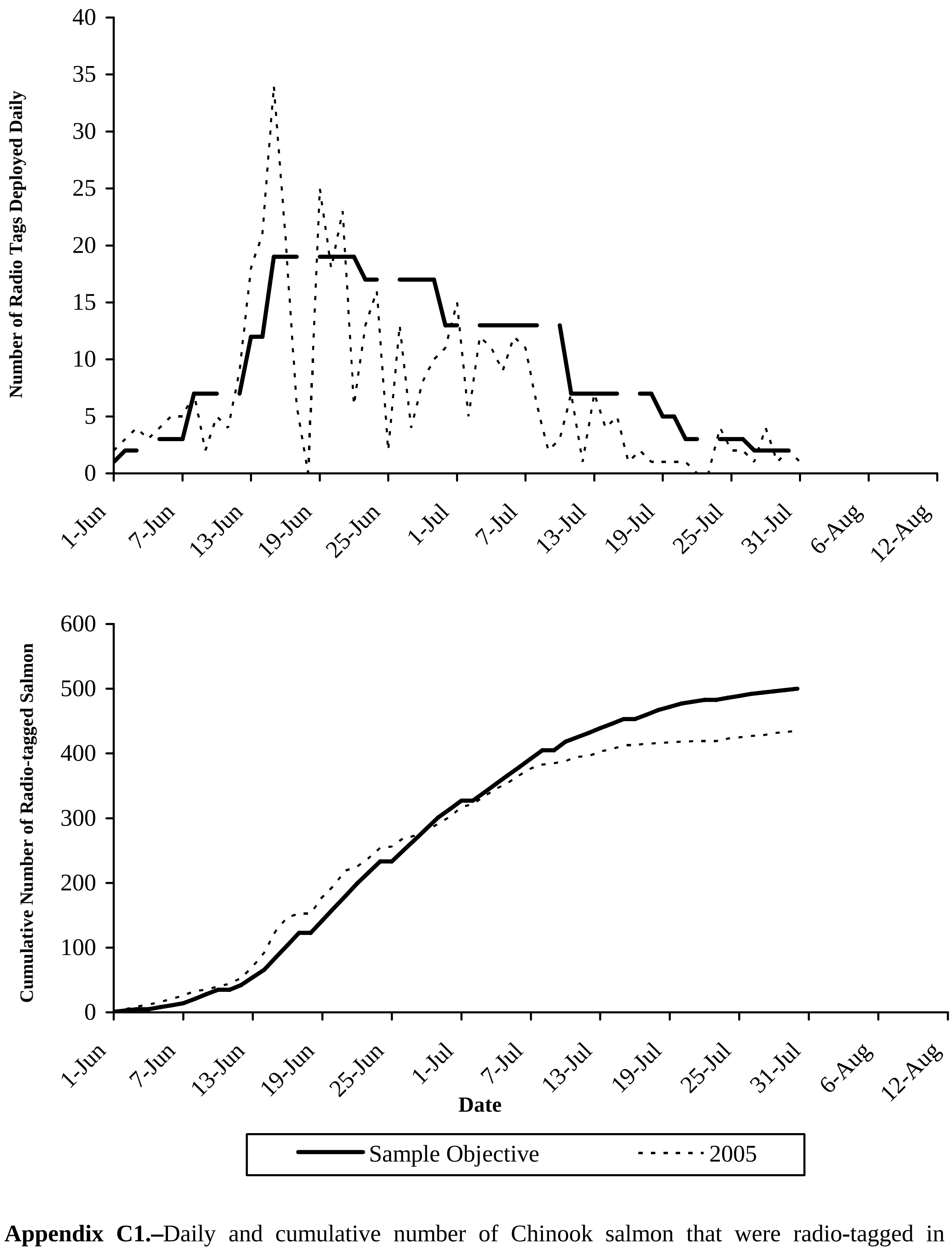
Data File	Description
2005 George Kings.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the George River weir, 2005.
2005 Kogrukluk King.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the Kogrukluk River weir, 2005.
2005 Takotna King.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the Takotna River weir, 2005.
2005 Tatlawiksuk King.dat[a]	Data file of age, length, and sex data for Chinook salmon sampled at the Tatlawiksuk River weir, 2005.
Kusko River Esc Data-Kogrukluk.xls[a]	Excel spreadsheets with daily and historical counts of Chinook salmon passage through the Kogrukluk River weir, 1976-2005.
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, 1995-2005.
2005 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, and analyses of bank of mark to final fate.
ASL 2005.xls[c]	Excel spreadsheets with consolidated age, sex, and length data from the George, Tatlawiksuk, Kogrukluk, and Takotna river 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 2005.
Tagging schedule and totals for 2005.xls[c]	Excel spreadsheets with daily sampling objectives and actual numbers of Chinook salmon captured and radio-tagged in 2005.
Estimate Analysis 2005.xls[c]	Contingency table analyses to test assumptions for the mark-recapture experiment, 2005.
Migration Times 2005.xls[c]	Excel spreadsheets include travel times of radio-tagged Chinook salmon to all of the tracking stations, run timing of radio-tagged fish into the major tributaries of the Kuskokwim River, and analyses of run timing differences between fish sampled with drift gillnets vs. fish wheels, 2005.

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

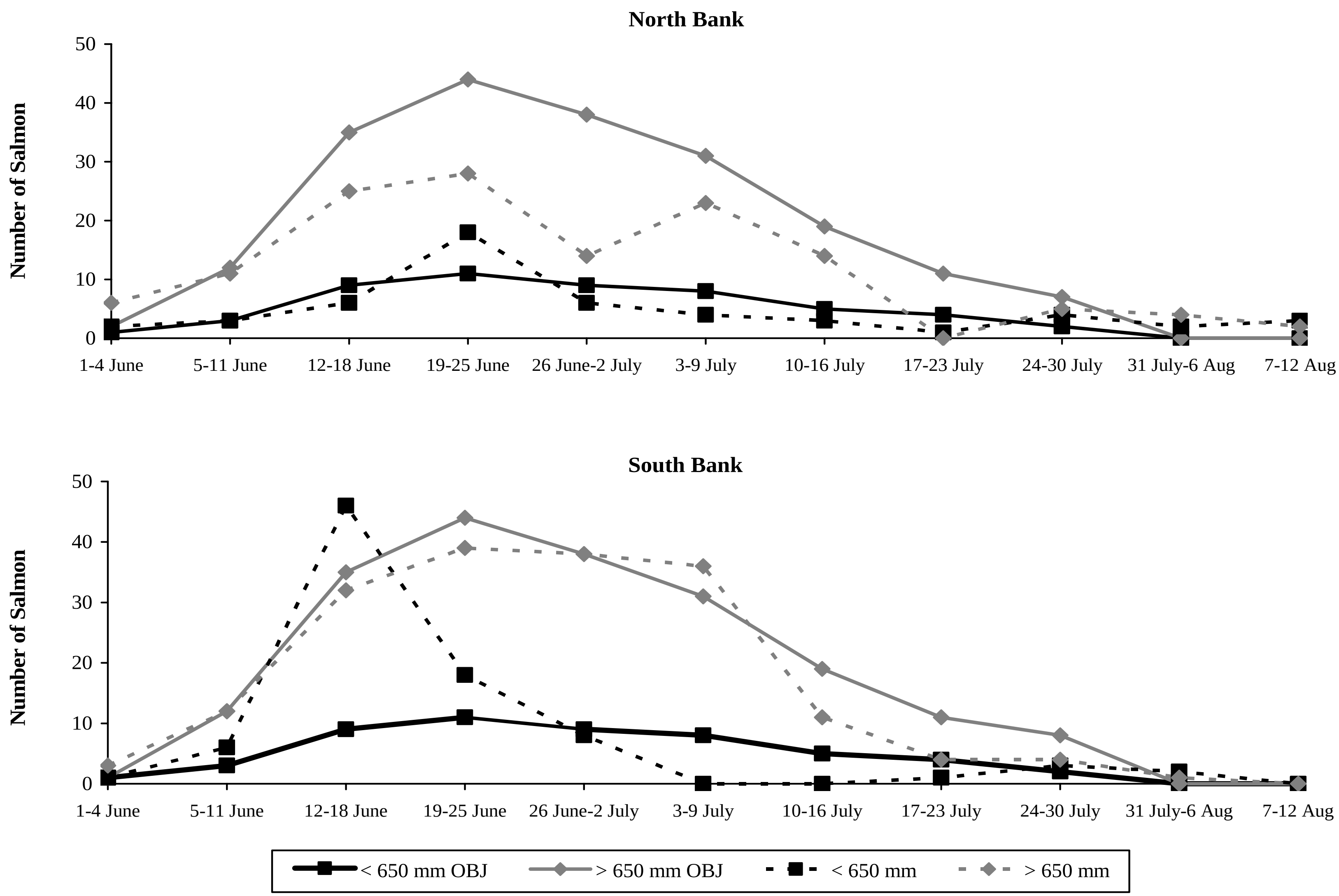
[b] Data files have been archived and are available from the Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services, 333 Raspberry Road, Anchorage 99518-1599.

[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

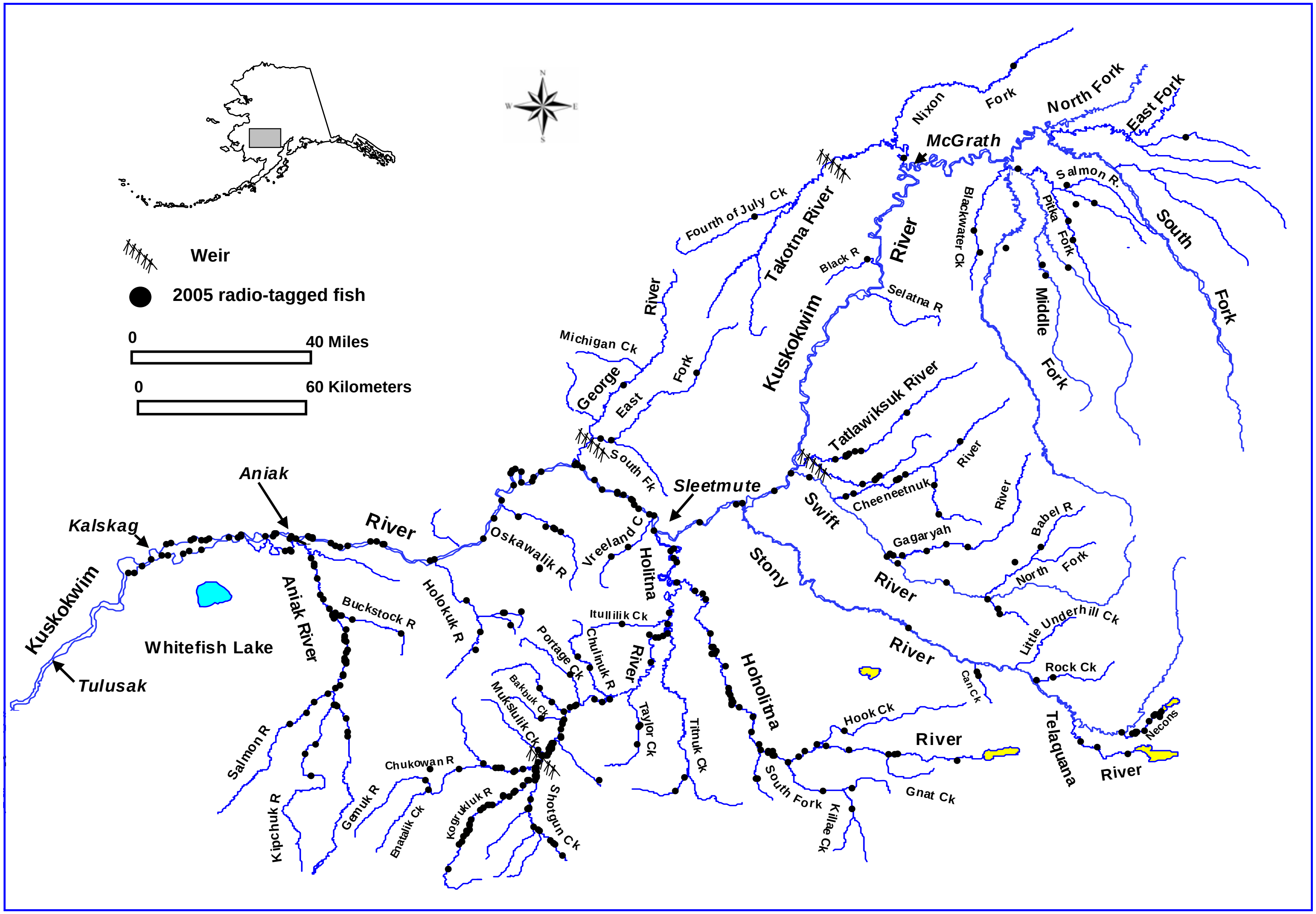


Appendix C1.–Daily and cumulative number of Chinook salmon that were radio-tagged in the Kuskokwim River versus the sampling objective for 2005.



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 2005.

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 2005.