Fishery Data Series No. 03-22

Inriver Abundance of Chinook Salmon in the Kuskokwim River, 2002

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by
Lisa Stuby

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Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

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

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
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	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
And	&
At	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
Trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
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.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
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
standard length	SL
total length	TL
variance	Var

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ABSTRACT

A two-sample mark-recapture experiment was conducted for chinook salmon *Oncorhynchus tshawytscha* in the Kuskokwim River and associated tributaries using radiotelemetry techniques from June–August, 2002. An attempt was made to distribute radio tags over the entire run such that the radio-tagged fish were representative of the entire escapement with respect to size, run-timing, and capture location. Fish were sampled using drift gillnets and fishwheels. Chinook salmon that were radio-tagged constituted the marked sample for the first event. For the second event, fish were counted at four weirs on tributaries of the Kuskokwim River. Radio-tagged chinook salmon that swam past the weirs and were recorded by stationary tracking stations constituted the recaptured marks. Two hundred twenty-eight fish were marked, 14,982 chinook salmon ≥450 mm were estimated to pass through the four weirs, and 33 radio-tagged fish passed through the weirs. The estimate of abundance for chinook salmon ≥ 450 mm for the Kuskokwim River upstream of the Aniak River was 100,733 fish (SE = 24,267). The majority of radio-tagged chinook salmon entered the Aniak and Holitna rivers. Fifty percent of the fish bound for the Aniak, George, Holitna and Hoholitna rivers arrived at the tagging site approximately 8 - 14 days later than those bound for the Kogrukluk River and rivers upstream from McGrath.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, Kuskokwim River, Aniak River, Holitna River, tracking stations, aerial survey, boat survey, mark-recapture, radiotelemetry, escapement, age-sex-length composition.

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, one of the largest subsistence fisheries in the state, commercial fisheries, and a growing sport fishery. Kuskokwim River subsistence users accounted for about a third (34%) of the total salmon harvest throughout the Kuskokwim River drainage in 2000 and a majority of the chinook salmon harvest (Burkey et al. 2001). The ten-year average subsistence harvest (1991 - 2000) of 80,653 chinook salmon far exceeded the average incidental commercial harvest of 18,081 fish (Burkey et al. 2002). The directed commercial chinook salmon *Oncorhynchus tshawytscha* fishery in the mainstem Kuskokwim River was discontinued in 1987 to ensure that subsistence needs were met. The incidental catch of chinook salmon in the commercial fishery currently ranks fourth overall behind sockeye *Oncorhynchus nerka*, chum *Oncorhynchus keta,* and coho *Oncorhynchus kisutch* salmon in terms of harvest and value to the commercial fishers.

The total sport catch, effort, and harvest of chinook salmon in the upper and middle Kuskokwim River area has been relatively low compared to other portions of the state, and annual harvests have typically represented less than 1% of the total harvest of chinook salmon in the Kuskokwim River drainage (Table 1). The largest sport fisheries for chinook salmon occur in the Kisaralik, Kwethluk, Aniak, and Holitna rivers. The 2001 estimated sport harvest of chinook salmon in the Kuskokwim River drainage including and above the Aniak River was 97 chinook salmon (Table 1).

Table 1.-Estimated sport, commercial, and subsistence harvests of chinook salmon in the Kuskokwim River drainage, 1985 – 2001.

	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%

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

[b] Upper Kuskokwim River sport harvest estimates are upriver from the Aniak River, 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).

Salmon runs in the Kuskokwim River area are managed for sustained yields under policies set forth by the Alaska Board of Fisheries with subsistence use receiving the highest priority. Current information is inadequate to manage these salmon runs for maximum sustained yield. Management and assessment of the commercial and subsistence fisheries is conducted both in season and post-season. Inseason management relies on run-strength indices from commercial catch data, test fisheries, and informal reports from subsistence fishers. The effectiveness of inseason management has been evaluated with aerial surveys and 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. Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations and provide limited information. Aerial spawning-ground surveys have been the most cost-effective means of monitoring salmon escapements, but their usefulness is limited due to a high degree of variability due to inconsistent weather, water conditions and varying staff experience (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.

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). In addition to the recent decrease in subsistence harvests, Kuskokwim Area chinook salmon have shown declining escapements. The lowest escapements on record were in 1998, 1999, and 2000 with the 2000 chinook salmon run producing the lowest escapement on record. As a result of the recent 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 Alaska Board of Fisheries designated Kuskokwim River chinook and chum salmon as stocks of concern under the regulatory *Policy for the Management of Sustainable Salmon Fisheries* (Molyneaux 2002).

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). The primary results of the strategic planning exercise were recommendations to acquire more information on spawning escapement throughout the Kuskokwim River drainage and examine stock specific run timing and exploitation (Merritt 2001).

The strategic planning exercise and infusion of funds resulted in the design of a three-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 2001). The Holitna River is the most important tributary for sport fishing in the upper portion of the Kuskokwim River drainage because of the diversity and abundance of resident species, and it is also an important producer of chinook, chum, and coho salmon (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 estimate. Therefore in 2002, this Kuskokwim River mainstem mark-recapture project was implemented to estimate the number of chinook salmon passing upstream of Birch Tree Crossing, (approximately 212 river kilometers (rkm) upriver from the mouth of the Kuskokwim River; Figure 1). This mainstem mark-recapture project is currently funded through 2005, with an eventual goal of using this information to develop escapement goals for this system.

OBJECTIVES

The objectives for this project in 2002 were to:

1. estimate the abundance of chinook salmon in the Kuskokwim River for all waters upstream of Birch Tree Crossing (river km 212) such that the estimate was within ±25% of the actual value 95% of the time; and
2. estimate age, sex, and length compositions of chinook salmon in the Kuskokwim River upstream of Birch Tree Crossing (river km 212) such that all estimated proportions were within five percentage points of the actual proportions 95% of the time.

METHODS

The abundance of chinook salmon migrating upstream past capture sites on the Kuskokwim River near Birch Tree Crossing (river km 212; 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, which 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 were collected from a sample of the chinook salmon that passed through each weir in order to aid in testing assumptions of equal probabilities of capture.

A lottery for cash prizes was used to encourage the return of tags and assist in determining the fates of all 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 Commercial Fisheries Division (CFD) in Anchorage. The public was made aware of the study and the lottery through personal contacts and by posting fliers in public places. Each radio tag had imprinted: “Please return to the nearest Alaska Department of Fish and Game Office, Matt

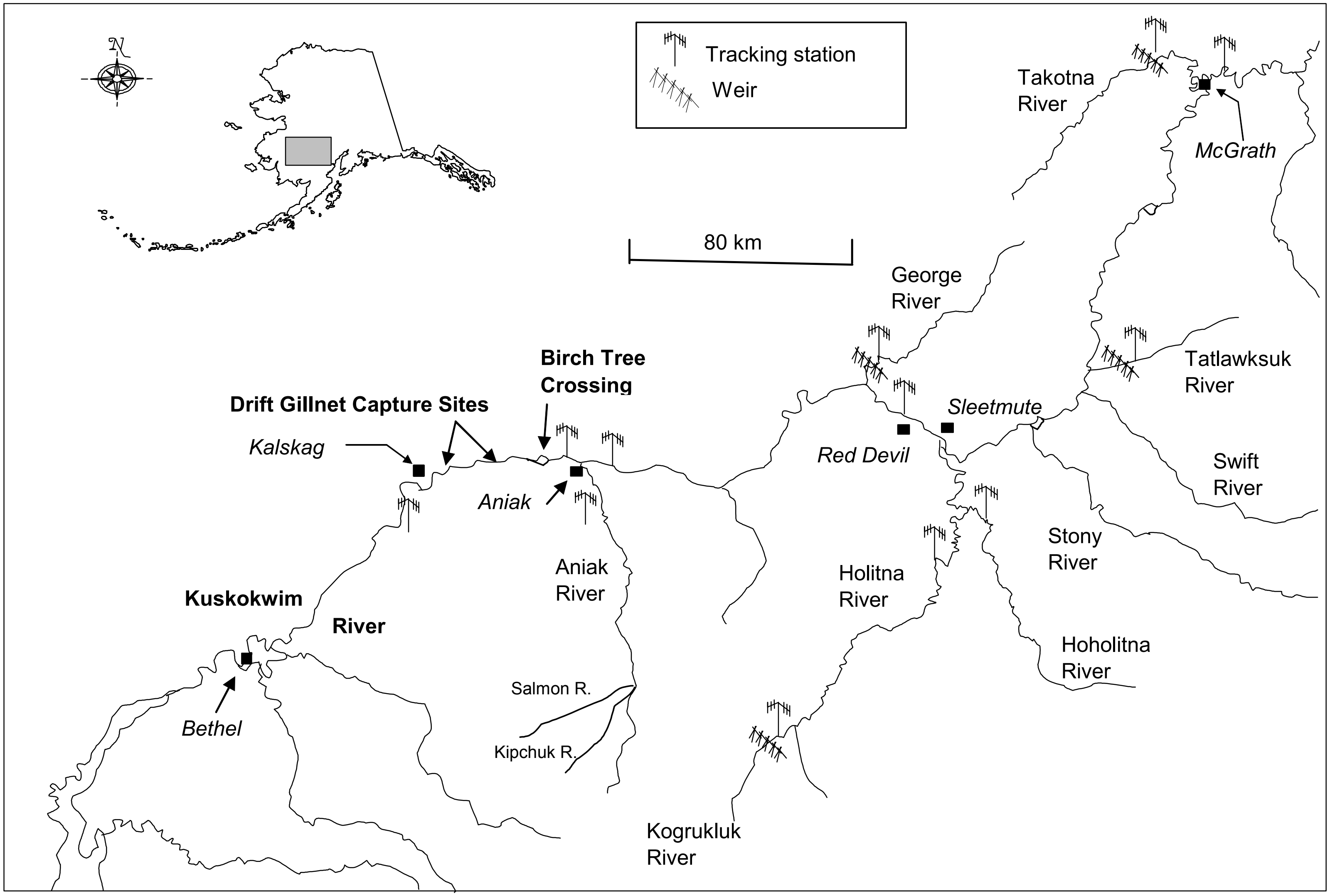

Figure 1.–Map of the Kuskokwim River showing capture sites, weirs, and tracking stations, 2002.

Evenson 459-7273". Each spaghetti tag had a toll free number to call for providing information and entering the lottery.

CAPTURE AND TAGGING

The goal of the first sampling event was to capture fish 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 was 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 tags 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 salmon <650 mm. An attempt was made to radio-tag chinook salmon in equal proportions along the north and south banks to ensure that all spatial components of the run had a non-zero probability of capture. Chinook salmon were primarily sampled with large mesh drift gillnets. Fishwheels were used to supplement tagging efforts, especially for the smaller size classes.

Drift gillnets were fished from a riverboat along both the north and south banks of the Kuskokwim River near Birch Tree Crossing. Sampling was conducted at eight drift gillnet locations, and use of a particular site varied with water level and debris accumulation (Figure 2). Sampling was conducted each day with a three-person crew. An 8.0 in mesh size net 29 panels deep and/or an 8.25 in mesh size net 45 panels deep was fished each day. The deeper net (45 panel) targeted mid-channel reaches and was used during high water events, whereas the 29 panel net was fished in near-shore reaches. Nets were constructed of cable-lay material and were 100 to 150 ft in length. Daily soak time varied from three to four hours per day and timing of each drift was recorded. Fishing efforts alternated between banks every 45-min of soak time and half of the daily effort was expended along each bank. Drift gillnetting began each day at 1600 hours and continued until a 3-hour soak time or a 7.5-hour workday was achieved.

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, typically 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 all 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 viewed at 100X magnification using equipment similar to that described by Ryan and Christie (1976). Ages were determined from scale patterns as described by Mosher (1969).

Only chinook salmon that were ≥450 mm MEF were radio-tagged to ensure that the transmitter weighed no more than 2% of the total body weight in water (Winter 1983). Fish that were obviously injured and/or appeared stressed were not 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

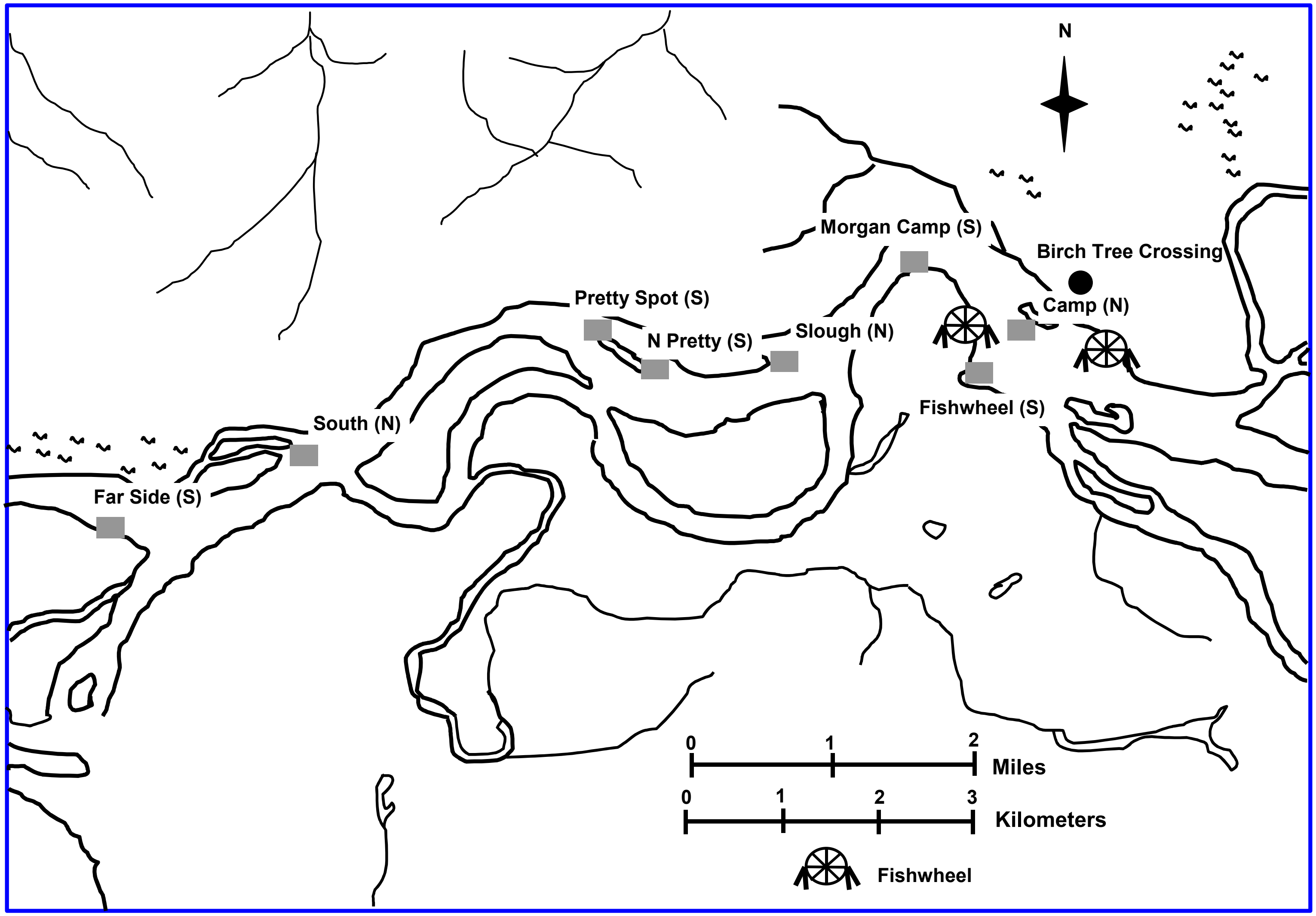

Figure 2.-Map of the drift gillnet (shaded rectangles) and fishwheel tagging locations for chinook salmon in the Kuskokwim River, 2002. An (S) denotes a south bank and an (N) denotes a north bank spot used for drift gillnetting.

given a secondary mark of a uniquely numbered, fluorescent green spaghetti tag constructed of a 5-cm section of tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line (Pahlke and Etherton 1999). 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 did not receive a radio tag were sampled for age, sex, and length (ASL) data; given a left operculum punch, and released. The operculum punch insured that chinook salmon were not sampled twice if captured again in the drift gillnet and/or fish wheels.

Two fish wheels operated 24 hours per day beginning 14 June at Birch Tree Crossing. Prior to this date, all chinook salmon were captured using drift gillnets. The two fishwheels were placed near Birch Tree Crossing (Figure 2) and were used by ADF&G-CFD for mark-recapture studies of chum, coho, and sockeye salmon. The two fishwheels were located along the same stretch of river, but on opposite banks. The fishwheels were sampled by CFD personnel between the hours of 0600 - 1430, and 1800 - 0230 each day. A Sport Fish Division (SFD) technician accompanied CFD personnel during the evening shift and sampled all chinook salmon contained within the live box. Chinook salmon captured during the morning shift were usually not sampled.

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. Fifty frequencies spaced approximately 20 kHz apart in the 149-150 MHz range with 10 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 eleven stationary, ground-based tracking stations similar to that 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 an ATS Model 4051 receiver. Tag signals were received by two, four element Yagi[2] antennas which were oriented such that one faced downstream and one faced upstream so that upstream and downstream movements of fish could be determined. The receiver and DCC II 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 3-s on each antenna, and then tag frequency, tag code, signal strength, date, time, and antenna number were recorded on the DCC II. 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.

A total of 11 tracking stations were used in this study. Four tracking stations were located on the mainstem Kuskokwim River. One each was placed immediately above and below Aniak (12-16 km above the capture site), one was placed downstream of the Holitna River near Red Devil, and the fourth was located just above McGrath (Figure 1). One tracking station was placed at each of the four weir sites on the George, Kogrukluk, Tatlawiksuk, and Takotna rivers. Additionally, a tracking station was placed on the Aniak River near the ADF&G sonar site approximately 25 rkm upriver from its junction with the Kuskokwim River. As part of the Holitna River

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[1] Advanced Telemetry Systems, Isanti, Minnesota.

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

salmon enumeration study, two tracking stations were located on the mainstem Holitna and Hoholitna rivers and were also programmed with frequencies from chinook salmon tagged in this study.

In addition to the stationary tracking stations, radio-tagged chinook salmon were located by aerial-tracking from small aircraft. Two aerial-tracking surveys were conducted from 22–26 July and 26–28 August. During each survey, fish were tracked along the mainstem Kuskokwim River and major tributaries (excluding the Aniak River) from the capture site upstream to McGrath, with particular attention paid to the four tributaries with weirs. On 13 August, an aerial survey was conducted to survey the Aniak River and it's major tributaries. Aerial tracking surveys were conducted with one aircraft, one person (in addition to the pilot), and utilized one receiver/scanner. All 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 antennas, one on each wing strut, were mounted such that the antennas detected signals perpendicular to the direction of travel. Once a tag was located its frequency, code, and coordinates were recorded. The primary purpose of the aerial-surveys was to locate radio-tagged chinook in the mainstem Kuskokwim River that did not appear to have successfully migrated into a spawning stream (e.g., tag loss or handling mortality). In addition, the aerial surveys were utilized to locate tags in spawning tributaries other than those monitored with remote tracking stations, to 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.

Boat tracking surveys occurred periodically near the capture/release sites to monitor for tags that had been regurgitated. Results from a radiotelemetry study on the Copper River suggested that most fish that expelled tags did so immediately after release (Evenson and Wuttig 2000). During the boat surveys one person monitored a receiver and hand-held H-antenna in the front of a boat and another operated the receiver and DCC II.

ESTIMATION OF ABUNDANCE

Assignment of Fate

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

1. a fish that lost its tag and/or died as result of handling;
2. a fish that survived tagging and handling and was harvested;
3. a fish that survived tagging and handling, was detected up a tributary, and therefore had a known final destination;
4. a fish that traveled past one of the four tracking stations on the George, Tatlawiksuk, Kogrukluk, or Takotna rivers and was therefore designated a recapture;
5. a fish which was known to have migrated upstream past the lower tracking stations, but was not detected in a major tributary; or,
6. a fish that was never located after being tagged and released or whose fate was unknown.

Tagged fish assigned Fates #1 or #6 were not included as part of the marked portion of the experiment. Fish assigned to Fate #2 through #5 were assumed to have survived tagging and handling and therefore constituted the marked sample. Fates of radio-tagged fish were determined after receiving data from tracking stations, aerial and boat tracking surveys, and from tags returned by fishers. All fish located within 5 km of the capture site for 30 days or more after tagging were assigned Fate #1. If a fisherman returned a radio and/or spaghetti tag or verbally reported harvesting the fish then it was assigned Fate #2. All fish detected in a tributary by means of stationary tracking stations and/or aerial surveys were assigned a Fate #3 or #4. All fish that passed one or more of the mainstem tracking stations, but were not detected in a tributary were assigned a Fate #5.

Recapture Sample

The second, or recapture, sample for this mark-recapture experiment was the total number of chinook salmon ≥450 mm counted at the four weirs on the tributary streams (Figure 1). Recaptures were fish assigned a Fate #4. 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 and inspected for marks. Chinook salmon that were not examined in a weir live-trap were counted as they passed through narrow counting gates. Between 100 and 600 chinook salmon were handled at each weir to estimate age, sex, and length compositions. These data were then used to test model assumptions of equal capture probabilities.

Conditions for a Consistent Peterson 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, Assumptions I and II and one of the conditions of Assumption III must have been met.

ASSUMPTION I. Marking and handling did not affect the catchability of chinook salmon.

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 (J. Eiler, National Marine Fisheries Service, Juneau, personal communication). Any obviously stressed or injured fish were not radio-tagged. Radio-tagged fish that were not detected past the lower mainstem Kuskokwim River tracking stations were removed from the experiment. Travel times for tagged fish to move from the capture site to the tracking stations on the mainstem Kuskokwim River were calculated and inspected to investigate how variable they were to make indirect inferences about whether fish were affected by handling.

ASSUMPTION II: 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 III:

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.**

Chinook salmon were captured and tagged over the entire span of the run. Radio tags were implanted into chinook salmon of various sizes and capture occurred along both banks of the river. Catch sampling at the four weirs also occurred over the span of the run. The George and Takotna rivers drained into the north side of the Kuskokwim River and the Kogrukluk and Tatlawiksuk rivers drained into the south side. Sex, length, date, and time of release were recorded for all tagged fish. For the second sampling event, age, sex, and length data were collected from a sample of fish passing through each of the four weirs.

Equal probability of capture was evaluated by size, sex, time, and area. The procedures to evaluate equal probability of capture across sex and size categories are described in Appendix A.

To evaluate the three conditions of Assumption III relative to time and location of capture and to gear type, contingency tables were analyzed as recommended by Seber (1982):

1. Equal probability of capture during the second event was evaluated by comparing ratios of recaptured to not recaptured marked fish from across different tagging periods during the first event;
2. Equal probability of capture during the first event was evaluated by comparing ratios of marked to unmarked fish at each of the four weirs;
3. Independence between bank of capture during the first event and probability of capture during the second event was evaluated by comparing ratios of recaptured to not recaptured marked fish between the two banks of capture during the first event. Independence between bank of mark and bank of recapture was also tested; and,
4. Independence between capture gear used during the first event and probability of capture during the second event was evaluated by comparing ratios of recaptured to not recaptured marked fish between the two gear types.

DATA ANALYSIS

A temporally stratified estimator (Darroch 1961) was selected to estimate abundance based on consistency tests (Seber 1982) for homogeneity of recovery probabilities and marked to unmarked ratios.

Age, Sex, and Length Compositions

The proportions of chinook salmon by ocean-age or sex in the first sample and at each weir were calculated using:

$$\hat{p}_k = \frac{n_k}{n} \tag{1}$$

where:

$\hat{p}_k$ = estimated proportion of chinook salmon in group k,

n_k = number of sampled chinook salmon in group k; and,

n = total number of chinook salmon sampled.

The variance was estimated as:

$$\hat{V}[\hat{p}_k] = \frac{\hat{p}_k(1-\hat{p}_k)}{n-1}. \tag{2}$$

Mean lengths and associated sampling variances were calculated for each sex and associated age class k using:

$$\bar{l}_k = \frac{\sum_{i=1}^{n_k} l_{ki}}{n_k}\text{; and,} \tag{3}$$

$$\hat{V}[\bar{l}_k] = \frac{\sum_{i=1}^{n_k}(l_{ki}-\bar{l}_k)^2}{n_k(n_k-1)} \tag{4}$$

where:

l_{ki} = length of salmon i (i = 1 to n_k) of a given sex and age group k; and,

n_k = number of samples of a given sex and age group k.

A weighted combination of estimated proportions within sex and age groups from all four weirs was calculated:

$$\tilde{p}_k = \sum_{w=1}^{4} T_w \hat{p}_{kw} \Big/ \sum_{w=1}^{4} T_w \tag{5}$$

where:

$\hat{p}_{kw}$ = as described in equation (1) for weir w, w=1 to 4, and

T_w = total number of chinook salmon counted past weir w.

The variance was estimated as:

$$\hat{V}(\tilde{p}_k) = \sum_{w=1}^{4} T_w^2 \hat{V}(\hat{p}_{kw}) \Big/ \left(\sum_{w=1}^{4} T_w\right)^2 \tag{6}$$

The estimated abundance of age and/or size class k was then estimated by:

$$\hat{N}_k = \tilde{p}_k \hat{N}. \tag{7}$$

where $\hat{N}$ is the estimated total abundance of chinook salmon.

The variance for $\hat{N}_k$ in this case was estimated using (Goodman 1960):

$$\hat{V}[\hat{N}_k] = \hat{V}[\tilde{p}_k]\hat{N}^2 + \hat{V}[\hat{N}]\tilde{p}_k^2 - \hat{V}(\tilde{p}_k)\hat{V}(\hat{N}). \tag{8}$$

RESULTS

The total number of chinook salmon handled for the 2002 Kuskokwim River radiotelemetry study was 505 fish. Of the total handled, 461 fish were radio-tagged and 44 fish were either <450 mm and/or were deemed unfit to receive a radio tag. The total number of chinook salmon counted through the four weirs was 15,096 fish and the total number of recaptures was 33 fish. Data were archived as described in Appendix B.

The daily number of deployed radio tags closely followed the predetermined sampling schedule until mid-July (Appendix C1), at which point the chinook salmon run slowed more than anticipated. Of the total radio tags deployed, 44% were deployed in fish captured on the north bank and 56% were deployed in fish captured on the south bank. The objectives for tagging fish in the two size classes with respect to bank of capture tracked predetermined objectives and showed similar patterns (Appendix C2).

Fates were described for all 461 radio-tagged fish (Table 2). Fifty radio-tagged fish either lost their tags or were never located after tagging (Fate #1 or #6). Four hundred eleven radio-tagged fish were known to have retained their tags and migrated upstream of the capture site (Fate #2-#5). Of the 58 fish that were recorded past the two mainstem Kuskokwim River tracking stations near Aniak but were never located in a tributary (Fate #5), 46 continued on past the mainstem Kuskokwim tracking station at Red Devil. Overall, 434 of the 461 radio tags deployed were recorded by at least one of the stationary tracking stations. Between 25 and 27 June a software malfunction rendered the two tracking stations on the Kuskokwim River near Aniak unusable. The tracking station on the George River was inoperable due to mechanical and software problems between 19 July and 7 August. As a result, extra effort was made during the aerial flights to account for radio-tagged fish that migrated into the George River. The three aerial flights detected 267 radio-tagged chinook salmon.

Run timing varied with the various Kuskokwim drainage chinook salmon stocks (Figure 3). In general, the fish that had the farthest to travel (e.g., drainages upriver from McGrath) were the first to be captured and tagged and those with the shortest distance to travel (e.g., Aniak River) arrived later in the season. The chinook salmon that returned to the Aniak, George, Holitna/Hoholitna (combined and excluding the Kogrukluk River), and Stony/Swift (combined) rivers showed similar run timing patterns at the capture site. The Aniak River stocks were first tagged on 17 June and they did not begin to show up in appreciable numbers until about 23 June. The earliest Kogrukluk River bound chinook salmon showed up to the tagging site around the same time as fish bound for other areas of the Holitna River drainage (24 June), but due to the greater distance that needed to be traveled, the Kogrukluk River bound fish arrived in mass much earlier and showed an overall earlier run timing pattern.

On average, a tagged chinook salmon took two days to travel from the tagging site to the mainstem tracking station below Aniak, three days to reach the mainstem tracking station above Aniak, and five days to reach the mainstem tracking station at Red Devil (Figure 4). Many chinook salmon did not travel past the lower tracking station for several days after being caught and tagged. One Aniak River bound fish took 14 days to reach the lower tracking station near Aniak and another passed the upper tracking station 16 days after getting tagged, before being recorded at the Aniak River tracking station. A Chukowan River (Kogrukluk River tributary) bound fish took 13 days to reach the Red Devil tracking station. Transit times from point of capture to the tracking stations on the mainstem Kuskokwim River did not significantly vary

Table 2.-Final fates of chinook salmon that were radio-tagged on the Kuskokwim River, 2002.

Fate #	Fate Description	Number of tagged chinook salmon assigned this fate
1	A fish that lost its tag and/or died as a result of handling.	27
2	A fish that survived tagging and handling and was harvested.	17
3	A fish that survived tagging and handling and was detected up a tributary not monitored with a weir.	303
4	A fish that traveled past one of the four tracking stations on the George, Tatlawiksuk, Kogrukluk, or Takotna rivers (designated a recapture).	33
5	A fish that swam past the two mainstem tracking stations near Aniak but was not detected up a major tributary	58
5a	A fish that swam past the Red Devil Tracking Station.	46
5b	A fish that did not swim past the Red Devil Tracking Station.	12
6	A fish whose fate was unknown.	23
Total Fates		461

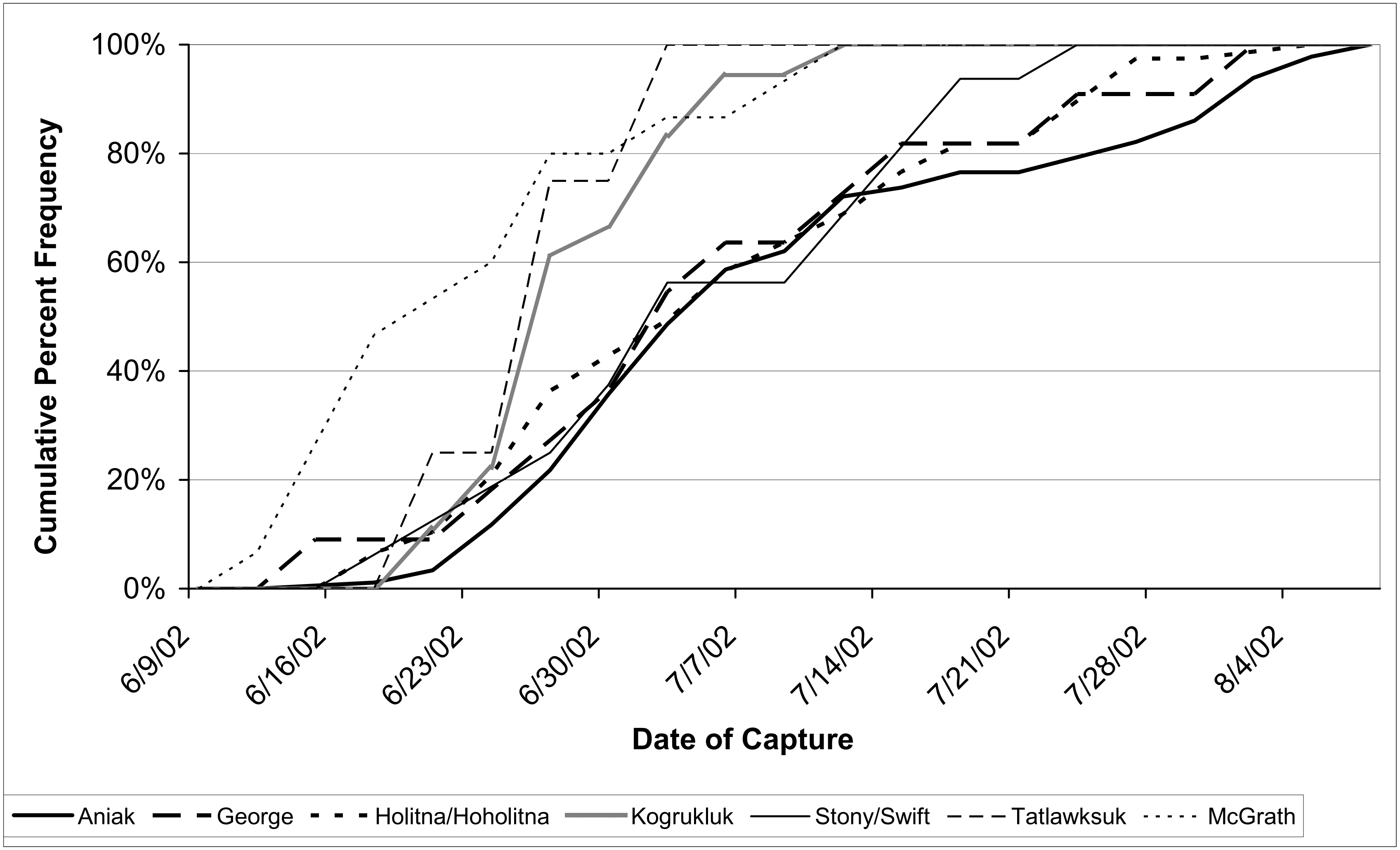


Figure 3.-Cumulative percent frequency of chinook salmon of known final destinations with their respective dates of initial capture, 2002.

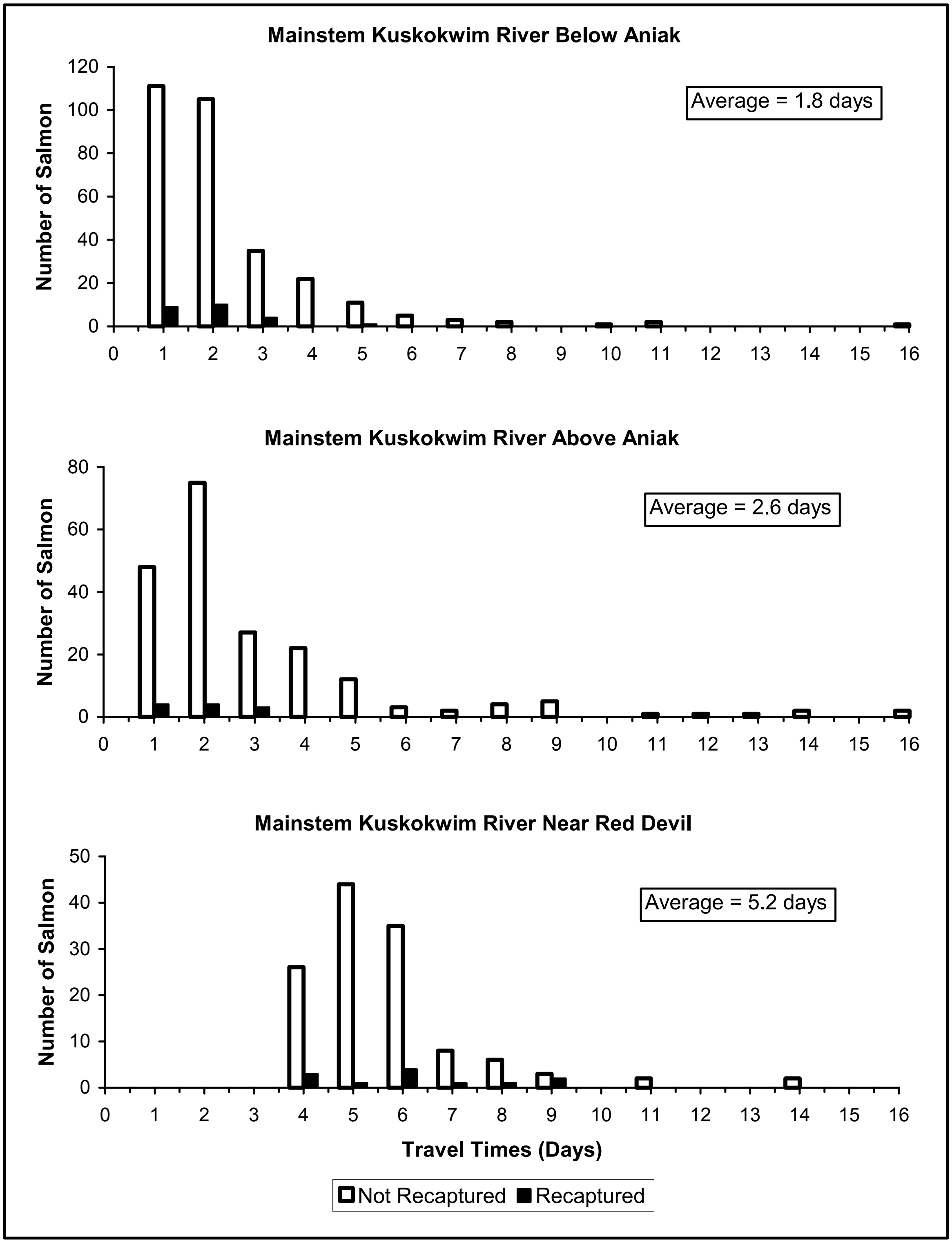


Figure 4.-Travel times for chinook salmon captured and tagged in the Kuskokwim River from the tagging location to three of the mainstem tracking stations during 2002.

between chinook salmon captured with fishwheels compared to those captured with drift gillnets (Figure 5).

ANIAK RIVER BOUND CHINOOK SALMON

The majority of chinook salmon of known final destinations (Fates #3 and #4) traveled up the Aniak (54%) or Holitna (28%) river systems (Table 3). Approximately 73% (132 of 180 fish) of the Aniak River bound chinook salmon were captured and tagged either out of the south bank fish wheel or from drift gillnetting just upriver from the south bank fishwheel. Both sites were located near the mouth of the Aniak River slough (Figure 2). Of these 180 fish, 135 were recorded by the mainstem tracking station that was located just below the village of Aniak. At least twelve chinook salmon bypassed the mainstem tracking stations, probably by swimming up the Aniak River slough. Nineteen fish were first recorded by the Aniak River tracking station during the time period when the lower tracking station was not working, and therefore it was unknown whether or not these fish swam up the mainstem or slough.

One assumption of the tagging effort was that the bank of mark would be independent of the bank of recapture. However, there was concern that including the Aniak River fish could bias the estimate high given that 73% of chinook salmon captured and tagged from the south fishwheel and drift gillnet spot were bound for this river. A comparison between the recaptured fish with respect to bank of mark and the Aniak River bound fish showed a significant relationship for the Aniak River bound fish (Table 4; $\chi^2 = 53.3$, df = 1, $P < 0.01$). As a result, the Aniak River bound chinook salmon were censored from further analyses.

No lack of independence was detected in the analysis of the remaining 33 recaptured chinook salmon comparing the bank of mark with their final bank of recapture (Table 5; $\chi^2 = 0.07$, df = 1, $P = 0.79$).

MARK-RECAPTURE EXPERIMENT

After testing all of the assumptions necessary to acquire an accurate estimate of abundance, the 180 Aniak River chinook salmon and those that were harvested on the Aniak River or near the village of Aniak, were culled from the final analyses, thereby reducing the marked portion for the abundance estimate to 228 fish.

Because chinook salmon <450 mm were deemed too small to radio-tag, all fish of this size and less were censored from the catch sample at the weirs. Of the 1,269 salmon examined at the four weirs for age, sex, and length, 18 were of this size range and all of these came from the George River. Thus, the estimated escapement of 2,444 chinook salmon was adjusted to 2,330 fish for the George River in order to reflect an escapement of $\geq$450 mm chinook salmon. This change correspondingly reduced the total second sample size to 14,982 fish.

The recapture rates for males (0.14) and females (0.15) were not significantly different (Table 6; χ^2=0.01, df=1, P=0.92). Therefore, males and females were combined for the abundance analysis. Length distributions of all chinook salmon marked during the first event and those recaptured during the second event were not significantly different (Figure 6; D=0.09, P=0.97). However, the length distributions of all marked fish and all fish counted through the four weirs were significantly different (D=0.14, $P \leq 0.01$). Thus, there was no size selectivity detected during the second sampling event when fish were counted through the four weirs, but there was size selectivity during the first event.

Table 3.-Tagging locations and final destinations of chinook salmon captured and tagged on the Kuskokwim River, 2002.

				Gillnet Sites									
	Fishwheel Sites			North			South						
Final Destination	South	North	Unknown	Camp	Slough	South	Fishwheel	Morgan Camp	Pretty Spot	Far Side	Unknown	Total	% Total
Aniak	75	12	2	7	0	1	57	5	9	3	9	180	54%
Holitna	5	11	1	13	1	5	4	1	5	3	3	52	15%
Hoholitna	3	5	0	6	0	4	0	0	1	1	6	26	8%
Kogrukluk	0	5	0	6	0	2	1	0	3	1	0	18	5%
Swift/Stony	0	2	0	4	2	3	0	0	1	0	5	17	5%
McGrath	0	1	0	5	2	3	0	0	2	2	0	15	4%
George	2	3	0	2	1	1	0	0	1	1	1	12	4%
Oskawalik	1	1	0	1	1		1	0	1	1	0	7	2%
Tatlawiksuk	1	1	0	1	0	0	0	0	1	0	0	4	1%
Holokuk	0	0	0	0	0	1	0	0	1	0	1	3	1%
Takotna	0	0	0	1	0	0	0	0	0	0	0	1	<1%
Selatna	0	0	0	0	0	1	0	0	0	0	0	1	<1%
Total	87	41	3	46	7	21	63	6	25	12	25	336	
% Total	26%	12%	1%	14%	2%	6%	19%	2%	7%	4%	7%		

Table 4.-Results of a chi-square test that compared the bank of marking for the recaptured and Aniak River bound chinook salmon that were radio-tagged in the Kuskokwim River, 2002.

	Final Destinations		
Bank Marked	Recaptures (Kogrukluk, Tatlawiksuk, and George Rivers)	Aniak River	Total
North	22	20	42
South	11	157	168
Total	33	177[a]	210
	$\chi^2 = 53.291$, df = 1, $P = 0.00$		

[a] This number represents those chinook salmon for with the bank of mark was known.

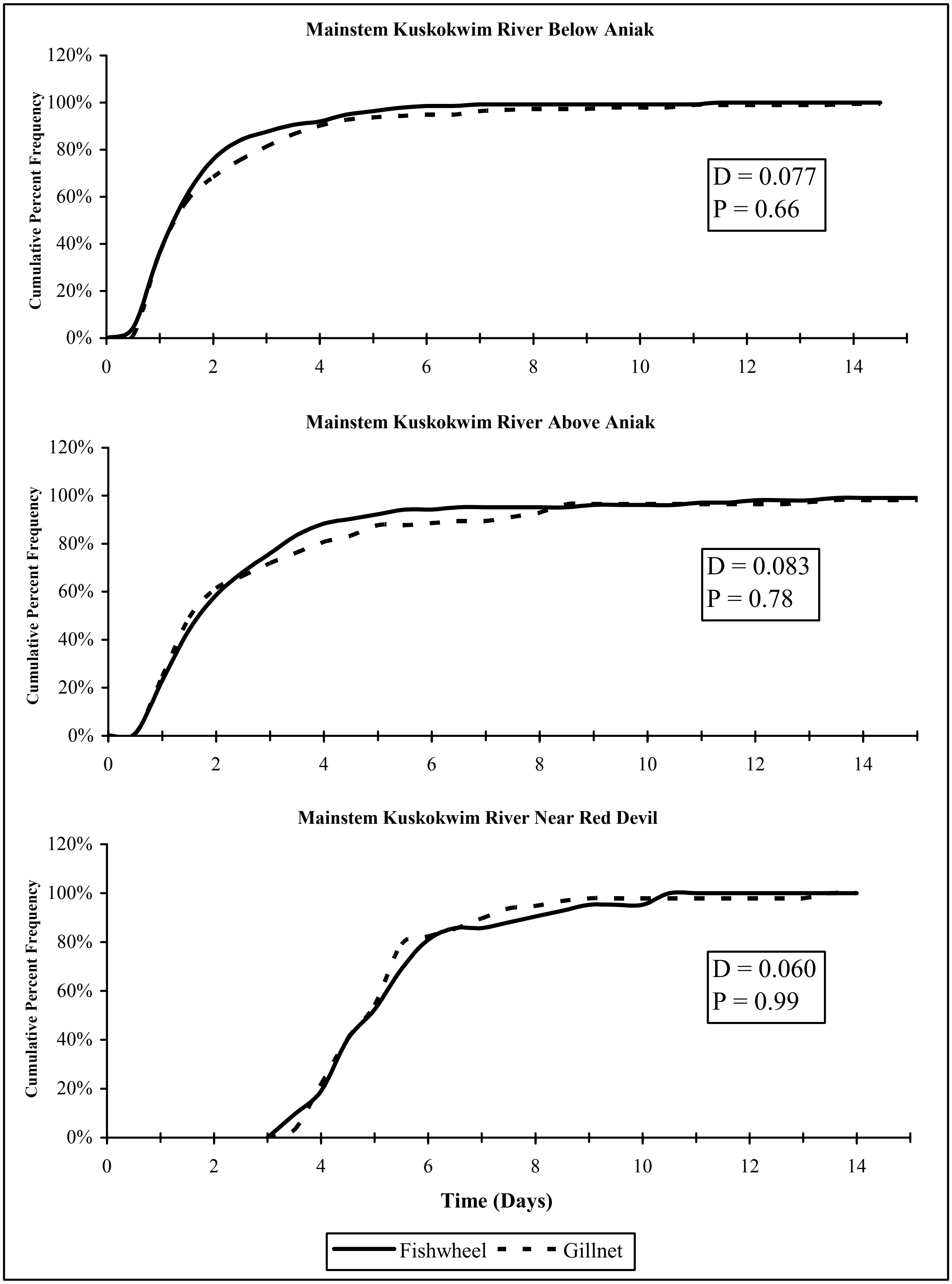


Figure 5.-Travel times from capture site to three tracking stations on the mainstem Kuskokwim River for chinook salmon captured in fishwheels and drift gillnets.

Table 5.-Results of a chi-square test that examined independence of bank of marking with bank of recapture for chinook salmon captured and radio-tagged in the Kuskokwim River, 2002.

	Bank Recaptured		
Bank Marked	North (George River)	Sou (Kogrukluk, Tatlawiksuk Rivers)	Total
North	7	15	22
South	4	7	11
Total	11	22	33

$\chi^2 = 0.07$, df = 1, $P = 0.79$

Table 6.-Capture history and contingency table analysis of recapture rates of male and female chinook salmon sampled during the mark-recapture experiment in the Kuskokwim River, 2002.

Capture History	Male	Female	Total
Recaptured	19	14	33
Not Recaptured	114	81	195
Total	133	95	228
Recapture Rate	0.14	0.15	0.15

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

Pr(M)/Pr(F) = 0.97[a]

[a] Corresponds to the ratio of the recapture rates for males and females.

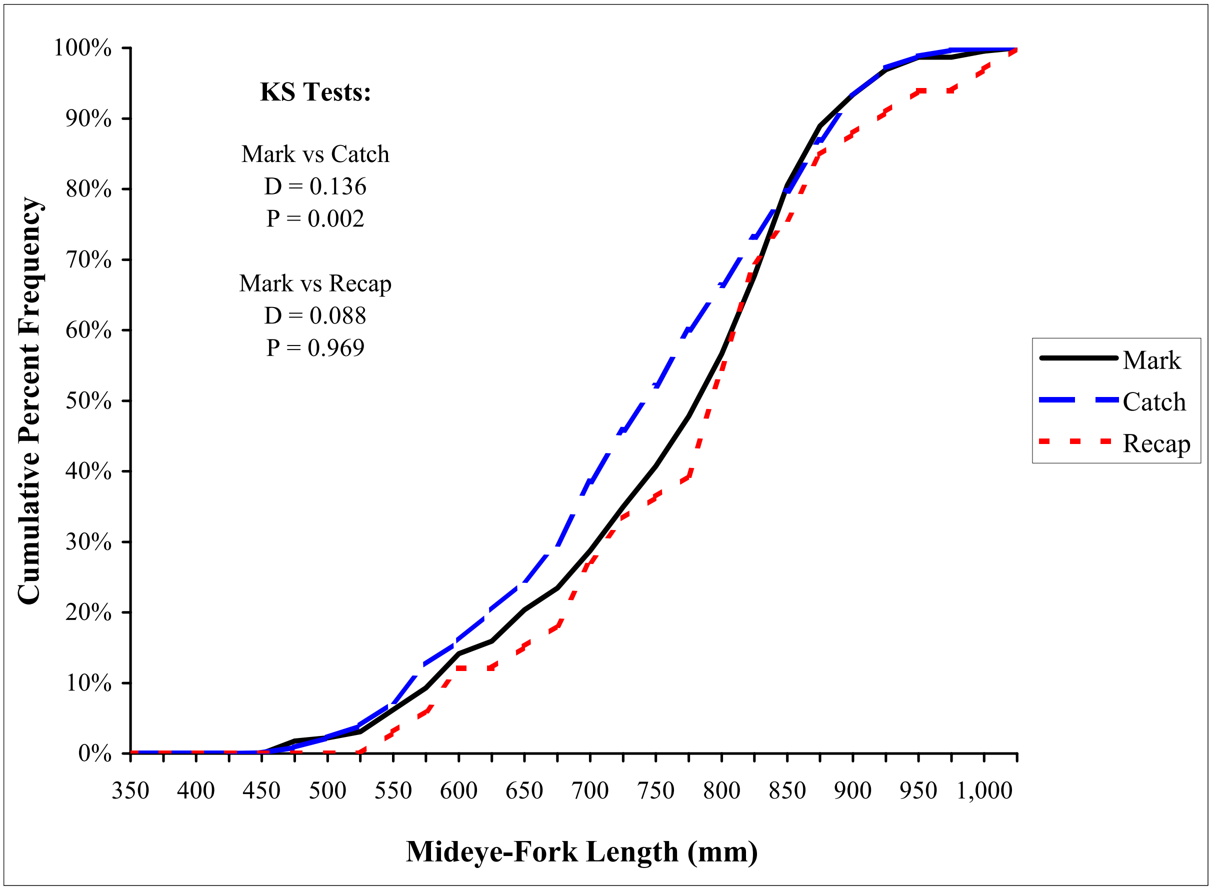


Figure 6.-Cumulative length frequency distributions comparing all chinook salmon caught during the first (Mark) and second (Catch) events, and all recaptured (Recap) fish caught during the second event from the mark-recapture experiment in the Kuskokwim River, 2002.

A test for independence between time of marking during the first event and probability of recapture during the second event detected differences in probabilities of recapture with respect to time (Table 7; χ^2=10.72, df=3, P=0.01). In addition, the marked to unmarked ratios of chinook salmon that were examined at the George River weir were much higher compared to the Kogrukluk and Tatlawiksuk rivers (Table 8; χ^2=7.53, df=2, P=0.03). The George River showed an earlier run-timing curve compared to the Kogrukluk and Tatlawiksuk rivers (Figure 3). The probability that a tagged fish was seen at a weir was independent of tagging location (Table 9; χ^2=0.16, df=1, P=0.69) and gear type (Table 10; χ^2=0.58, df=1, P=0.45). Therefore, a temporally stratified Darroch estimator was used to estimate abundance (Table 11). The abundance of chinook salmon $\geq$ 450 mm for the Kuskokwim River upstream of the confluence of the Aniak River was estimated to be 100,733 fish (SE = 24,267).

Ninety-five chinook salmon that were tagged in the Kuskokwim River traveled up the Holitna River. These fish were added to the 58 fish that were tagged in the mainstem of the Holitna River and an estimate of 42,902 chinook salmon (SE=6,334) was produced for this tributary (Chythlook and Evenson (*In prep*)). Therefore 32% of the total chinook salmon escapement above the confluence of the Aniak River was estimated to be made up of Holitna River drainage stocks.

Age, Sex and Length Compositions

Because sampling in the first event was shown to be size selective, the age, sex, and length compositions representative of this population of chinook salmon with the Kuskokwim River upstream of the confluence of the Aniak River were estimated from chinook salmon collected at the George, Kogrukluk, Tatlawiksuk, and Takotna river weirs (Table 12).

Ages were determined for 90% of the sample. The information from samples collected at each weir was weighted proportional to abundance at each weir. For the 1,269 fish sampled, 0.69 (SE = 0.01) were males and 0.31 (SE = 0.01) were females. The dominant age class for males was 1.3 and the dominant age class for females was 1.4 (Table 12). Lengths of males ranged from 450 – 977 mm and lengths of females ranged from 543 to 1,015 mm (Figure 7). The average size for a radio-tagged chinook salmon sampled with the drift gillnets was 789 mm and that for fish sampled with the fishwheels was 646 mm.

DISCUSSION

Radiotelemetry provides an opportunity for enumerating salmon returns in large, occluded river drainages. By using stationary tracking stations coupled with aerial and boat survey methods, fish movements can be precisely recorded and run-timing information can be determined. These data are not easily collected from deploying and recovering conventional tags. Technicians working at the weirs on the George, Kogrukluk, Tatlawiksuk, and Takotna rivers identified and counted coho, sockeye, and chum salmon and distinguished spaghetti tags on those fish captured and tagged at the Kalskag and Birch Tree Crossing fishwheels. The weir technicians were asked to collect all radio-tagged salmon they saw that passed through the weir. Of the 33 known radio-tagged fish that passed through the weirs, 14 were collected by CFD technicians. Because the chinook salmon were radio-tagged and movement past the weirs could be accurately known, the fact that the CFD technicians may not have been able to examine all tagged chinook salmon was not a concern. The main concern for the second event of this mark-recapture experiment was to

Table 7.-Result of a chi square test for equal catchability by time for chinook salmon sampled during the mark-recapture experiment in the Kuskokwim River, 2002.

Date Tagged	Not Recaptured	Recaptured	Total
10 – 23 June	42	7	49
24 – 30 June	42	15	57
1 – 9 July	46	7	53
10 July – 4 August	65	4	69
Total	195	33	228
	$\chi^2 = 10.72$, df = 3, $P = 0.01$		

Table 8.-Results of a chi-square analysis which compared chinook salmon that were marked and unmarked at the three weirs that had recaptured fish. This test was part of the mark-recapture experiment for the Kuskokwim River, 2002.

River	Unmarked	Marked	Total Catch
George	2,319	11	2,330
Tatlawiksuk	2,233	4	2,237
Kogrukluk	10,081	18	10,099
Total	14,633	33	14,666
	$\chi^2 = 7.53$, df = 2, $P = 0.03$		

Table 9.-Contingency table analysis comparing rates of recapture with north and south banks of capture for the mark-recapture experiment on chinook salmon from the Kuskokwim River, 2002.

Side of River Bank Marked	North	South	Total
Recaptured	22	11	33
Not Recaptured	136	58	194
Total	158	69	227
	$\chi^2 = 0.16$, df = 1, $P = 0.69$		

Table 10.-Contingency table analysis comparing sampling gear to chinook salmon that were recaptured and not recaptured as part of the mark-recapture experiment on the Kuskokwim River, 2002.

Sampling gear	Gillnet	Fishwheel	Total
Recaptured	21	12	33
Not recaptured	137	58	195
Total	158	70	228
	$\chi^2 = 0.58$, df = 1, $P = 0.45$		

Table 11.-Matrix configuration with recaptured chinook salmon set to time strata compared to those fish marked in the first event and captured in the second event of the mark-recapture experiment on the Kuskokwim River, 2002.

	Time Strata			
Time Strata	10 June – 13 July	14 July – 15 Sept.	Not Recaptured	Total Marked
10 – 27 June	13	3	69	85
28 June – 4 August	6	8	129	143
Unmarked	10,498	4,454		
Total Examined	10,517	4,465		

Table 12.-Estimated proportions, abundance, and mean length by sex and age class for chinook salmon in the Kuskokwim River, 2002. The samples were collected from the George River, Tatlawiksuk River, Kogrukluk River, and Takotna River weirs.

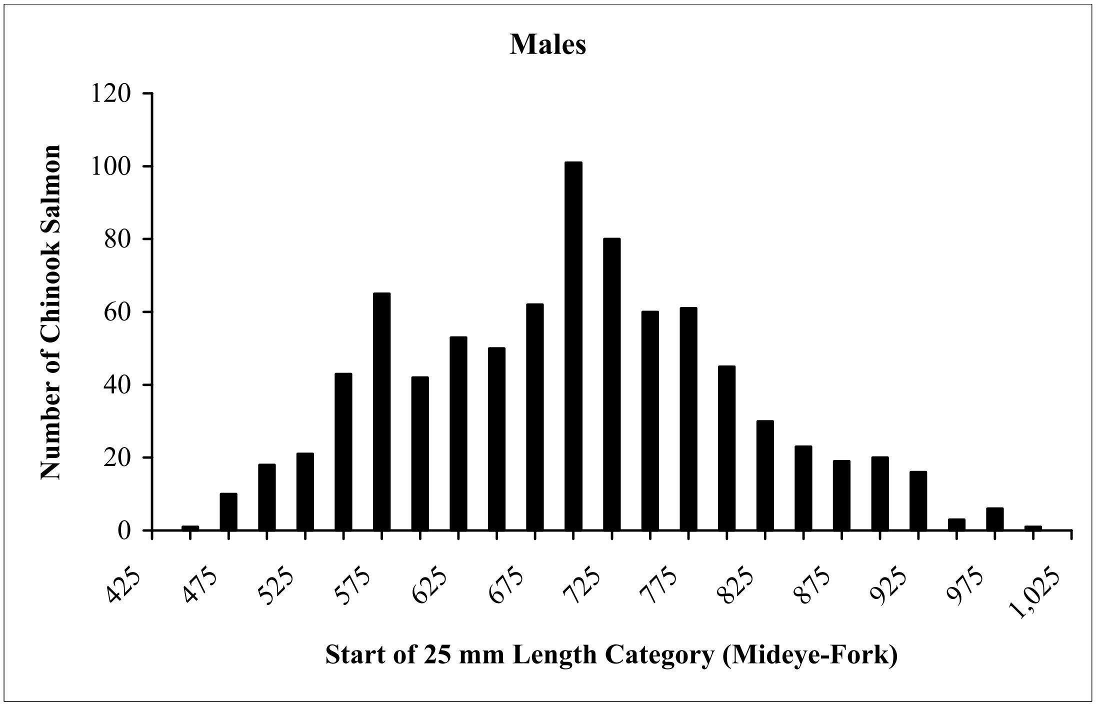
					MEF Length (mm)			
Age[a]	Proportion	SE	Abundance[d]	SE[d]	Mean	SE	Min	Max
			Male					
1.1	0.00	0.00	54	54	571	-	571	571
1.2	0.16	0.01	16,470	5,740	552	4	453	771
1.3	0.36	0.02	36,697	12,615	687	4	518	880
1.4	0.15	0.01	15,330	5,335	783	6	552	972
1.5	0.01	0.00	851	398	911	20	804	977
2.2	0.00	0.00	127	85	509	-	465	560
Total[b]	0.69	0.02	69,529	23,767				
Total Fish[c]	0.69	0.01	69,479	23,747	679	4	450	977
			Female					
1.2	0.00	0.00	97	67	593	_	575	627
1.3	0.04	0.01	3,845	1,459	762	10	543	880
1.4	0.25	0.01	25,106	8,670	843	4	658	979
1.5	0.02	0.00	2,156	834	892	11	742	1,015
Total[b]	0.31	0.02	31,204	10,744				
Total Fish[c]	0.31	0.01	31,254	10,752	836	3	543	1,015

[a] Age is represented by the number of annuli formed during river and ocean residence (i.e. an age of 2.4 represents two annuli formed during river residence and four annuli formed during ocean residence).

[b] Values represent chinook salmon for which sex could be determined, but not age.

[c] Totals include those chinook salmon for which sex could be determined, including those that could not be aged.

[d] Abundance and associated SE were derived from a temporally stratified Darroch estimate of 100,733 (SE = 34,371).



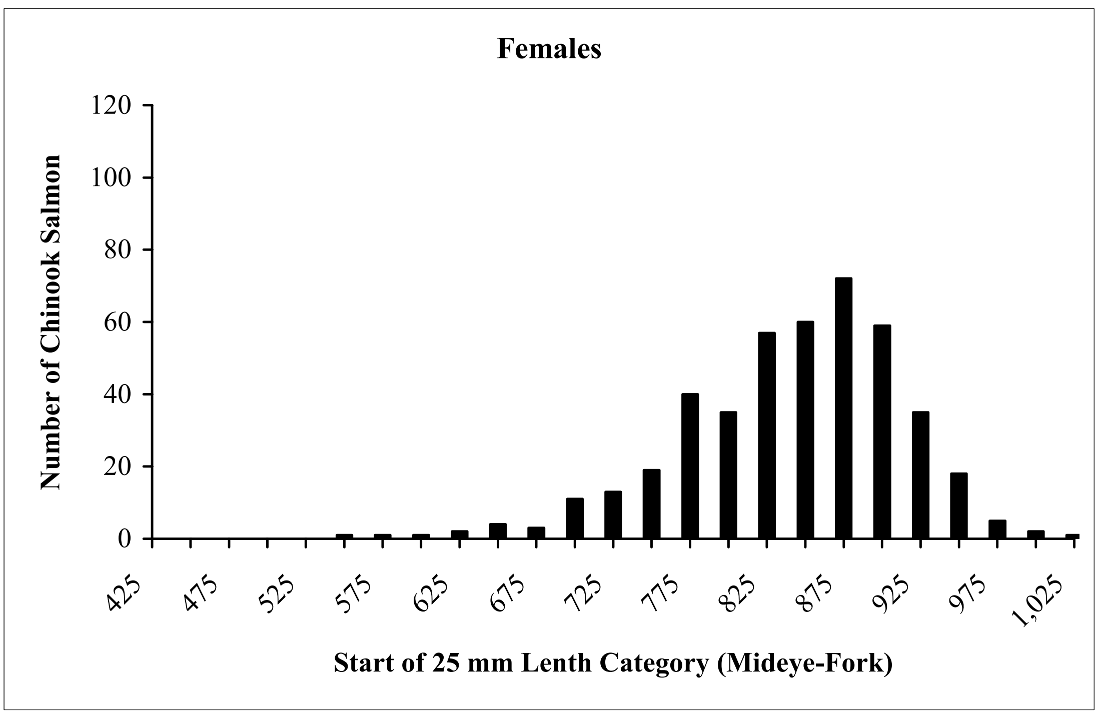


Figure 7.-Length frequency distributions of male and female chinook salmon that were sampled at the weirs on the George, Tatlawiksuk, Kogrukluk, and Takotna rivers.

acquire an accurate count of chinook salmon past the weirs and collect a representative sample of chinook salmon age, sex, and length data.

Because the number of marked fish passing through the weirs was known, the total weir count could be used for the second sample, not just the number actually sampled at the weirs. Therefore, the total number of fish that needed to be tagged in this experiment to acquire a precise estimate of abundance was smaller than what would be needed if conventional tags were used. Although fewer numbers of radio tags were needed than conventional tags in this mark recapture experiment, radio tags are far more expensive than conventional tags. Therefore to be efficient and get the best results from the mark recapture experiment a sampling schedule was developed in the preseason to attempt to deploy the limited number of radio-tags in proportion to the chinook salmon total abundance, capture location and length composition.

Despite the number of advantages of using radio tags as a primary mark for a mark-recapture experiment, the use of radio tags also presents several drawbacks. Although gastrically implanted radio tags are quick to insert and allow the fish to resume movements, these transmitters can be regurgitated. A small proportion of chinook salmon tagged in 2002 were assumed to have done this, because the radio tag was located near the tagging location. To prevent regurgitation care must be taken to place the radio tag sufficiently far back into the stomach to remain seated, but not so far as to damage the stomach wall, which may cause premature mortality. Mellas and Haynes (1985) compared the effects of externally attached, surgically implanted, and gastrically implanted transmitters on swimming performance and behavior of adult rainbow trout *Oncorhynchus mykiss* and white perch *Morone americana*. They concluded that of the three types of transmitters, the gastrically implanted transmitters appeared to affect the study species the least.

The size of the esophageal radio tags precluded applying the tags to the smallest size classes encountered in the study. Marty and Summerfelt (1986) and Greenstreet and Morgan (1989) showed that adverse effects on fish physiology and behavior generally increase as the ratio of transmitter weight to fish weight increases. 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, Wuttig and Evenson (2002) and Chythlook and Evenson (*In prep*) successfully tagged coho salmon that were between 490 and 500 mm. For 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 major tributary proving that they survived the stress of tagging and handling. Although no fish were weighed in this study, the radio-tags may have weighed more than 2% of the total weight for some of these fish. Brown et al. (1999) found swimming performance of rainbow trout was not hampered by the implantation of transmitters weighing up to 12% of the body weight.

The majority of the 461 radio-tagged chinook salmon were deemed to have survived tagging and handling, including fish that took a much higher than average time to pass one of the mainstem tracking stations. Bernard et al. (1999) provided evidence that adult chinook salmon captured and handled in rivers during their upstream migration have a tendency, upon release, to pause or move downstream before resuming their upstream migration. However, almost all the chinook salmon Bernard et al. examined reached their spawning grounds by the normally observed spawning dates.

The relatively large number of radio-tagged chinook salmon that migrated up the Aniak River was unexpected. This coupled with the fact that most Aniak River bound fish were tagged near the mouth of Aniak Slough, led to concern that the south bank fishwheel and drift gillnet sites were disproportionately targeting fish bound for the Aniak River. Conversely, sampling at the adjacent fishwheel and drift site on the north bank was likely selecting against fish bound for the Aniak River. Because salmon in general, have a well-developed homing instinct, and their choice of spawning river, tributary, and even riffle appears to be guided by long-term memory of specific odors (Groot and Margolis 1991), the flow of Aniak River waters into the Kuskokwim River from Aniak Slough (a short distance above the south side fishwheel and nearby drift gillnet site) was likely the cause of the seeming concentration of Aniak River chinook salmon stocks at the tagging sites relative to the other stocks. Very few fish appeared to travel up Aniak Sough and instead proceeded up the Kuskokwim River to the first mainstem tracking station before turning and traveling up the Aniak River.

The time it took for a chinook salmon to recover from handling and tagging stress was similar between the fish captured in drift gillnets or fish wheels. Both gear types have the potential to cause serious injury. Whenever a fish became tangled in a gillnet, it was immediately retrieved. The best way to reduce mortality in a gillnet is to reduce the soak time (Buchanan et al. 2002). During adverse weather conditions when it could be difficult to discern whether a fish was caught, soak time was reduced to 10 minutes. Even during good weather conditions, soak times were usually a maximum of 15 minutes in case a fish was netted but undetectable from the surface. Similarly, the fishwheels were constructed and operated with the purpose of keeping captured fish alive. The live boxes of the fishwheels were large and allowed for fresh water to circulate through. In addition, the sides were padded, which reduced the chance for injury when a fish slid out of the basket and down the chute. Ericksen (2000) used gillnets and fishwheels in a mark-recapture experiment on chinook salmon in the Chilkat River and he did not detect a significant difference in recovery rates between fish captured and marked with either gear.

The most significant difference between using a fishwheel or a drift gillnet to capture chinook salmon was the size classes targeted. Because fishwheels consistently fish nearshore and the baskets have a fine mesh, they tend to be more efficient in capturing the smaller size classes (Meehan 1961; Ericksen 1995). Likewise, the 8.0 inch mesh size of the drift gillnets targeted chinook salmon which were approximately 140 mm larger on average than those captured in the fish wheels. Utilizing both gear types enabled proportional sampling of size classes that met the objectives of the pre-season sampling schedule.

CONCLUSIONS

The two main study objectives were met. Abundance of chinook salmon was estimated for all waters upstream of the Aniak River and age, sex, and length compositions were also estimated. Additionally, a comparison could be made between the total estimated chinook salmon abundance for this study and that for the Holitna River, which is one of the major tributaries of the Kuskokwim River. Originally, the chinook salmon abundance estimate was to include the stocks of the Aniak River. However, a disproportionately large number of Aniak River bound fish were tagged near the Aniak River Slough. Lack of a recovery event in the Aniak River prevented us from evaluating the effects of bias and precluded our ability to adjust for bias using analytical methods. Because of the concern for the bias to the overall estimate, these fish were removed from further analysis.

PROJECT CHANGES FOR 2003

Due to the low number of marked fish that migrated above the Aniak River and the correspondingly large number of marked fish migrating into the Aniak River, attempts will be made to tag fish more in proportion to their occurrence by run timing and stock of origin than was achieved in 2002. These include:

1. Sport Fish Division technicians will sample chinook salmon from the north and south bank fishwheels located near Kalskag and the drift gillnetting effort will also take place near Kalskag (Figure 1). This should enable sampling of chinook salmon stocks which are better mixed by avoiding the areas where the Aniak River bound fish appear to concentrate or avoid:
2. an additional tracking station will be placed several miles downriver from Kalskag. This station will record fish which move downriver after being tagged and may reduce the number of fish that may get assigned an unknown fate (Fate #6);
3. drift gillnetting efforts will begin approximately one week earlier in 2003. Sampling earlier will improve the chances that chinook salmon bound for the uppermost portions of the study area will be represented by tagged fish in similar proportions to salmon later in the run;
4. all radio tags and spaghetti tags will be imprinted with the lottery return toll free phone number. In addition, more effort will be extended in public education of the study and lottery in villages north and south of Aniak to decrease the number of fish assigned to an unknown fate; and,
5. carcass surveys will be conducted up the Aniak River and its major tributaries to determine if sites exist where large numbers of spawned-out and dead chinook salmon may be sampled.

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APPENDIX A

STATISTICAL TESTS FOR ANALYZING DATA FOR SEX AND SIZE BIAS

Appendix A.-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.

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 (A) Kolmogorov-Smirnov two sample tests that compared the sizes of chinook salmon that constituted the marked sample (First event) and the recaptured sample (Second event); and, (B) Kolmogorov-Smirnov two sample test that compared the distributions of the lengths of fish sampled for age, sex, and length at the four weirs (subsample of the total catch sample) with the recaptured 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 (Bernard and Hansen 1992).

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.

Case IVa. If the stratified and unstratified estimates of abundance for the entire population were dissimilar, the unstratified estimate would be discarded. Lengths, ages, and sexes from the second sampling event were used to estimate proportions in composition and a formulae was applied to correct for size bias to the data from the second event.

Case IVb. If the stratified and unstratified estimate of abundance for the entire population was similar, the estimate with the larger variance would be discarded. Lengths, ages, and sexes from the first sampling event were used to estimate proportions in compositions and a formula was not applied to correct for the size bias.

APPENDIX B

ARCHIVED DATA FILES

Appendix B.-Data files used to estimate parameters of the chinook salmon population in the Kuskokwim River, 2002.

Data File	Description
02geo1.dat[a]	Data file of age, length, and sex data for chinook salmon sampled at the George River weir, 2002
02kog1.data[a]	Data file of age, length, and sex data for chinook salmon sampled at the Kogrukluk River weir, 2002
02tak1.dat[a]	Data file of age, length, and sex data for chinook salmon sampled at the Takotna River weir, 2002
02tat1.dat[a]	Data file of age, length, and sex data for chinook salmon sampled at the Tatlawiksuk River weir, 2002
Kogrukluk Esc Data.xls[a]	Excel spreadsheets with daily and historical counts of chinook salmon passage through the Kogrukluk River weir, 2002.
Rest Rivers Esc Data.xls[a]	Excel spreadsheets with daily and historical counts of chinook salmon passage through the George, Tatlawiksuk, and Takotna River weirs, 2002.
2002 Data.xls[b]	Excel spreadsheets with consolidated, sampling, aerial, and tracking station data. File also includes determination of fates, final destinations of radio-tagged chinook salmon, contingency table analyses to test assumptions for the mark-recapture analyses, and daily and hourly drift gillnet and fishwheel data for 2002.
2002 ASL.xls[b]	Excel spreadsheets with consolidated age, sex, and length data from the four 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.
2002 Migration Times.xls[b]	Excel spreadsheets with travel times of radio-tagged chinook salmon to mainstem tracking stations. File also contains run timing of radio-tagged fish into the major tributaries of the Kuskokwim River and analyses of run timing and survivability differences between fish sampled with drift gillnets vs. fishwheels.
Darroch.xls[b]	Excel spreadsheets with various test matrices used to generate test geographic and temporal stratified Darroch estimates and determine the best outcome.

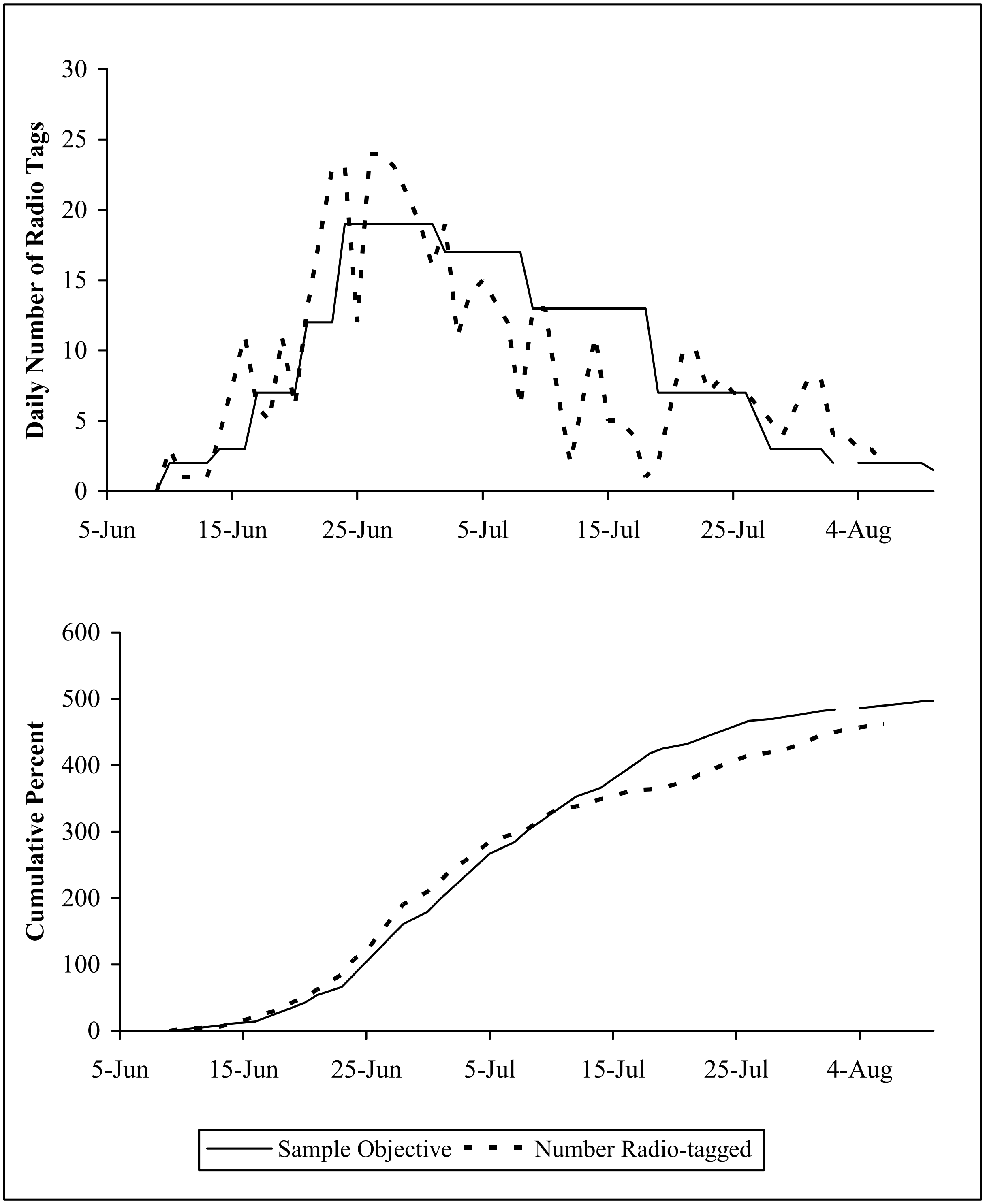
[a] Data files have been archived and are available from the Alaska Department of Fish and Game, Commercial Fisheries Division, 333 Raspberry Road, Anchorage, 99518-1599.

[b] Data files have been archived 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.



Appendix C2.-Size classes sampled on the north and south banks of the Kuskokwim River versus the pre-season objectives (OBJ).