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Assessment of Chinook and Chum Salmon Escapements in the Holitna River Drainage Using Radiotelemetry, 2004

Final Report for Study 04-306
USFWS Office of Subsistence Management
Fishery Information Service Division

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

fork length	FL
mideye-to-fork	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

FISHERY DATA SERIES NO. 05-49

ASSESSMENT OF CHINOOK AND CHUM SALMON ESCAPEMENTS IN THE HOLITNA RIVER DRAINAGE USING RADIOTELEMETRY, 2004

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ABSTRACT

In 2004 a radiotelemetry study was performed in the Holitna River drainage. The purpose of the study was to estimate the proportion of Chinook salmon *Oncorhynchus tshawytscha* and chum salmon *O. keta* returning to the Holitna River drainage that passed through the Kogrukluk River weir, and to estimate the abundance of Chinook and chum salmon escaping into the Holitna River drainage. Chinook and chum salmon were captured by fishing with drift gillnets near the mouth of the Holitna River. A portion of the total catch was radio-tagged with esophageal transmitters. Subsequent movements of all radio-tagged salmon were monitored with three stationary tracking stations that logged radio-tagged fish that migrated up the Hoholitna River, the Holitna River upstream of the Hoholitna River, or, the Kogrukluk River past the weir. Radio-tagged salmon were also located during aerial radio-tracking surveys of the Holitna River drainage. The estimate of Chinook salmon abundance was 81,961 fish (SE = 10,150). The proportion of Chinook salmon past the Kogrukluk River weir was 0.23. The estimate of chum salmon abundance was 996,216 fish (SE = 640,754). The proportion of chum salmon past the weir was 0.045. Radio-tagged Chinook and chum salmon were located in numerous areas throughout the Holitna River drainage. Chinook salmon predominantly spawned in first and second order tributaries, and most chum salmon spawned in the mainstem Holitna River.

Key words: abundance, Chinook salmon, chum salmon, escapement, Holitna River, Kogrukluk River, Kuskokwim River, mark-recapture, *Oncorhynchus keta*, *Oncorhynchus tshawytscha*, radio-tag, radiotelemetry, spawning distribution, weir

INTRODUCTION

Management of Kuskokwim River salmon fisheries is complex because of differences in run size and timing, harvesting of mixed stocks, overlapping runs of multiple species, allocation issues, and the immense size of the Kuskokwim River drainage. The amount of information provided from current escapement monitoring and run-size assessment projects provide limited data to use towards managing salmon runs for sustained yield (Burkey et al. 2000).

The Kuskokwim River drains a remote basin of about 130,000 km^2 and flows 1,130 km from the Alaska interior to the Bering Sea. The Holitna River joins the Kuskokwim River approximately 540 km from the mouth of the Kuskokwim River near the village of Sleetmute (Figure 1). The Kuskokwim River supports five species of anadromous Pacific salmon, substantial subsistence fisheries, limited commercial fisheries, and a growing sport fishery.

To meet the demand for Chinook salmon *Oncorhynchus tshawytscha* as a local food source, the directed commercial Chinook salmon fishery in the Kuskokwim River was discontinued in 1987. Incidental catch of Chinook salmon in the commercial chum and sockeye salmon fisheries currently ranks fourth overall in terms of harvest and value to the commercial fishers of the Kuskokwim River. Chinook salmon are particularly valued by local subsistence users, and account for a large percentage of the total subsistence salmon catch. The 10-year average (1993 to 2002) annual subsistence harvest of Chinook salmon was 80,457 fish, which was greater than the average annual incidental commercial harvest of 8,771 Chinook salmon for the same period (Whitmore et al. *In prep a*).

Chum salmon *O. keta* are usually the second most important commercial species in the Kuskokwim River drainage and are targeted during June and July. Catches from 1993 to 2002 averaged 126,690 chum salmon annually and ranged from 1,272 to 605,918 fish. In 2002, returns were poor and only 1,272 chum salmon were reported harvested in the commercial fishery and 49,874 fish in the subsistence fishery. From 1993 to 2002 the average annual chum salmon subsistence harvest was 61,377 fish (Whitmore et al. *In prep a*). Sport fishing participation and harvest for all salmon species on the Kuskokwim River are relatively low. The Kisaralik, Kwethluk, Aniak, and Holitna rivers account for the majority of angler effort.

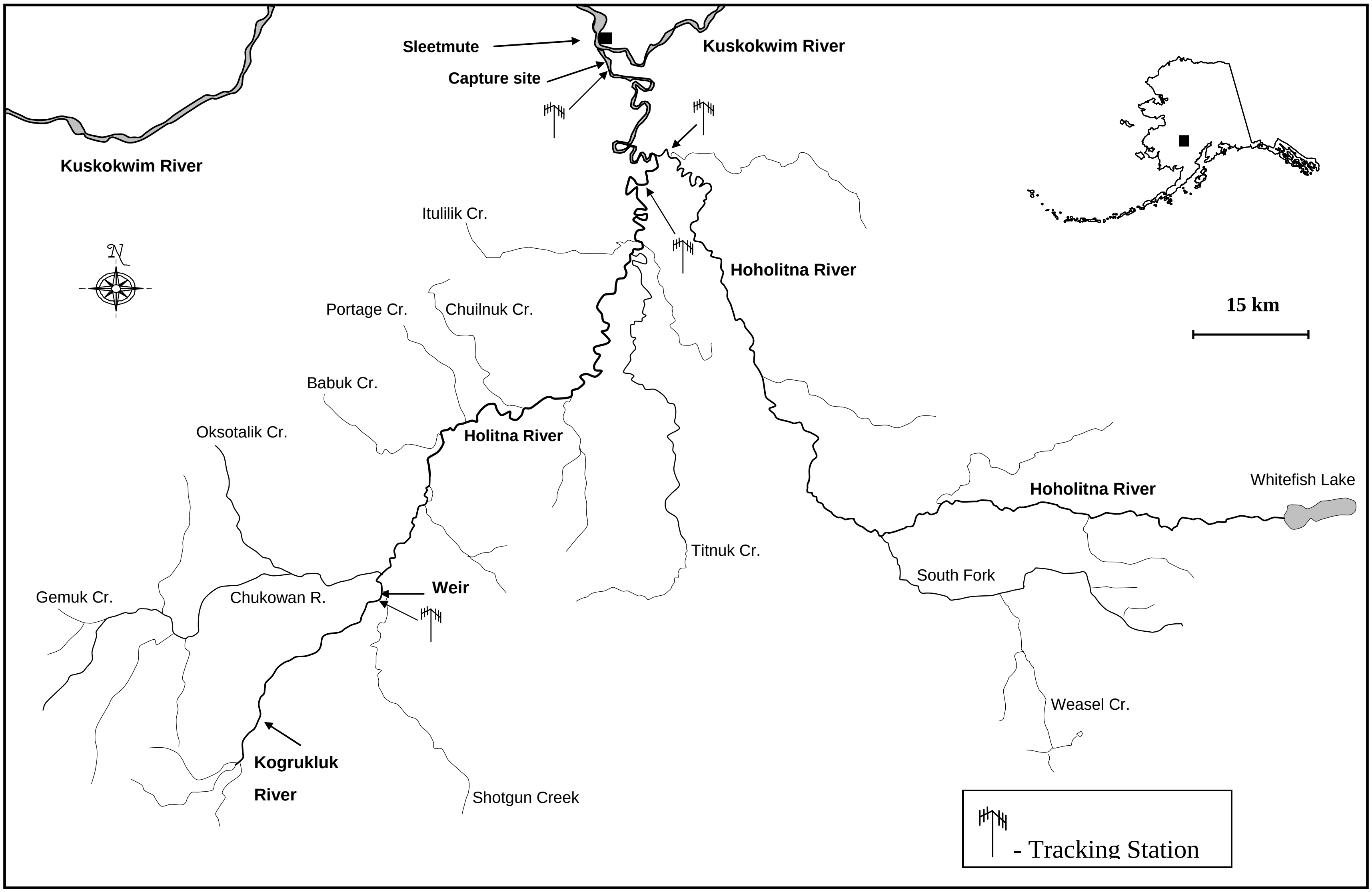


Figure 1.–Map of Holitna River drainage demarcating the capture site, tracking stations, and Kogrukluk River weir, 2004.

As a result of very poor runs and harvests since 1997, and expected poor future runs, the Alaska Board of Fisheries (BOF), designated Kuskokwim River Chinook and chum salmon to be stocks of concern under the Policy for the Management of Sustainable Salmon Fisheries (Ward et al. 2003). Both of these stocks were determined to have yield concerns based on very poor runs and harvests since 1997, and expected poor runs in the near future. A yield concern means a concern that arises from a chronic inability, despite the use of specific management measures to maintain harvestable surpluses above the stocks escapement needs. Salmon runs in the Kuskokwim drainage are managed for sustained yields with subsistence fishing receiving the highest priority. Current information is not adequate to manage salmon runs to produce maximum sustained yields. Management 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.

Inseason management effectiveness is evaluated with aerial surveys and ground-based projects. However, the size, remoteness, and geographic diversity of the Kuskokwim River presents challenges to monitoring salmon escapements and assessing run strength, and the ground-based projects provide limited information. Aerial spawning-ground surveys have been the most cost-effective means of monitoring salmon escapements, but their usefulness is limited because of known uncertainty and the inconsistent relationship to actual abundance (Burkey et al. 2000). Moreover, the aerial surveys are primarily conducted in the lower Kuskokwim River because visibility is limited by tannins and/or glacial silt in the middle and upper river tributaries. Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations. Throughout the four years of this study seven ground-based escapement monitoring projects were conducted in the Kuskokwim River drainage. Only three of these projects have collected sufficient data to develop Chinook and chum salmon escapement objectives, and only one, the Kogrukluk River weir, located on the upper reaches of the Holitna River drainage (Figure 1), has been used to develop escapement objectives for Chinook, chum and coho salmon (Burkey et al. 2000).

The Holitna River is considered one of the most important systems producing Chinook, chum, and coho salmon in the Kuskokwim drainage. The Holitna River is also the most productive tributary of the Kuskokwim River for sport fishing within the upper portion of the watershed and a large fraction of the total effort is directed at salmon. In recent years, the Holitna River has supported approximately half of the fishing effort, harvest and catch in the sport fishery occurring in the upper portion of the Kuskokwim drainage (Burr 1999). Sport fisheries in this area experienced a period of growth in recent seasons, with the volume of guided angling activity directed at salmon showing a marked increase. It is believed the increase in guiding activity resulted from interest in seeking quality salmon fishing opportunities in relatively uncrowded settings.

The Kogrukluk River weir, located in the upper reaches of the Holitna River drainage, is the oldest continuing salmon escapement assessment project in the Kuskokwim River drainage with Chinook, chum, and sockeye salmon having been assessed annually since 1976, and coho salmon since 1981 (Sheldon et al. 2004). The established sustainable escapement goals (SEG) for the Kogrukluk River weir are 5,300 – 14,000 for Chinook, and 15,000 – 49,000 for chum salmon (ADF&G 2004). Because the Kogrukluk River represents such a small percentage of available spawning habitat in the Holitna River drainage, the use of the Kogrukluk River weir as a reliable index for the Holitna River drainage escapement needs to be assessed.

Prior to this project, little was known about the distribution of spawning coho, chum, and Chinook salmon in the Holitna River. Aerial surveys are flown to count Chinook, chum, and coho salmon on a relatively small portion of the mainstem Holitna River, but coho salmon are rarely surveyed because poor weather conditions typically occur during the spawning period. Relatively large spawning aggregations of Chinook salmon have been observed in Holitna River tributaries other than the Kogrukluk River, such as: Shotgun Creek, Chukowan River, and Chuilnuk River. Moreover, the Hoholitna River represents a large fraction of the Holitna River drainage, but prior to this study no information existed on the contribution of Hoholitna River spawning stocks to the drainage-wide escapement.

This was the fourth and final year of this project, which was designed to extend current escapement monitoring activities on the Kogrukluk River by estimating the proportion of Holitna River Chinook and chum salmon runs that pass through the Kogrukluk River weir and subsequently estimating drainage-wide escapement by proportional expansion of the weir counts. Because of the relative importance of the Holitna River to Kuskokwim River salmon escapements, such information contributes substantially to the understanding of Kuskokwim River Chinook and chum salmon runs. This report describes results from 2004. Details of results from the first 3 years of the project (2001-2003) are provided by Wuttig and Evenson (2002); Chythlook and Evenson (2003); and, Stroka and Brase (2004).

OBJECTIVES

The specific objectives of the Holitna River salmon escapement monitoring project in 2004 were to:

1. estimate the proportions of Chinook and chum salmon migrating up the Kogrukluk River (past the weir);
2. estimate the abundance of Chinook and chum salmon escaping into the Holitna River drainage; and,
3. document Chinook and chum salmon spawning locations.

An additional project task was to collect the axillary process from each radio-tagged Chinook salmon, and send the fin clips to the Alaska Department of Fish and Game (ADF&G) Genetics Lab to identify stock specific genetic markers.

METHODS

CAPTURE AND TAGGING

In all years of this study Chinook and chum salmon were captured by fishing drift gillnets from both banks of a stretch of the Holitna River approximately 2 km upstream from its confluence with the Kuskokwim River (Figures 1 and 2). Other suitable drift gillnet areas were unavailable due to proximate river conditions (Stroka and Brase 2004). Sampling was conducted six days each calendar week for the entire season. Chinook and chum salmon were sampled concurrently from June 12 to August 7. Chinook and chum salmon were targeted at the same time because local knowledge and all prior years of this study suggested that chum salmon begin to enter the Holitna River within a few days of the arrival of Chinook salmon (Stroka and Brase 2004).

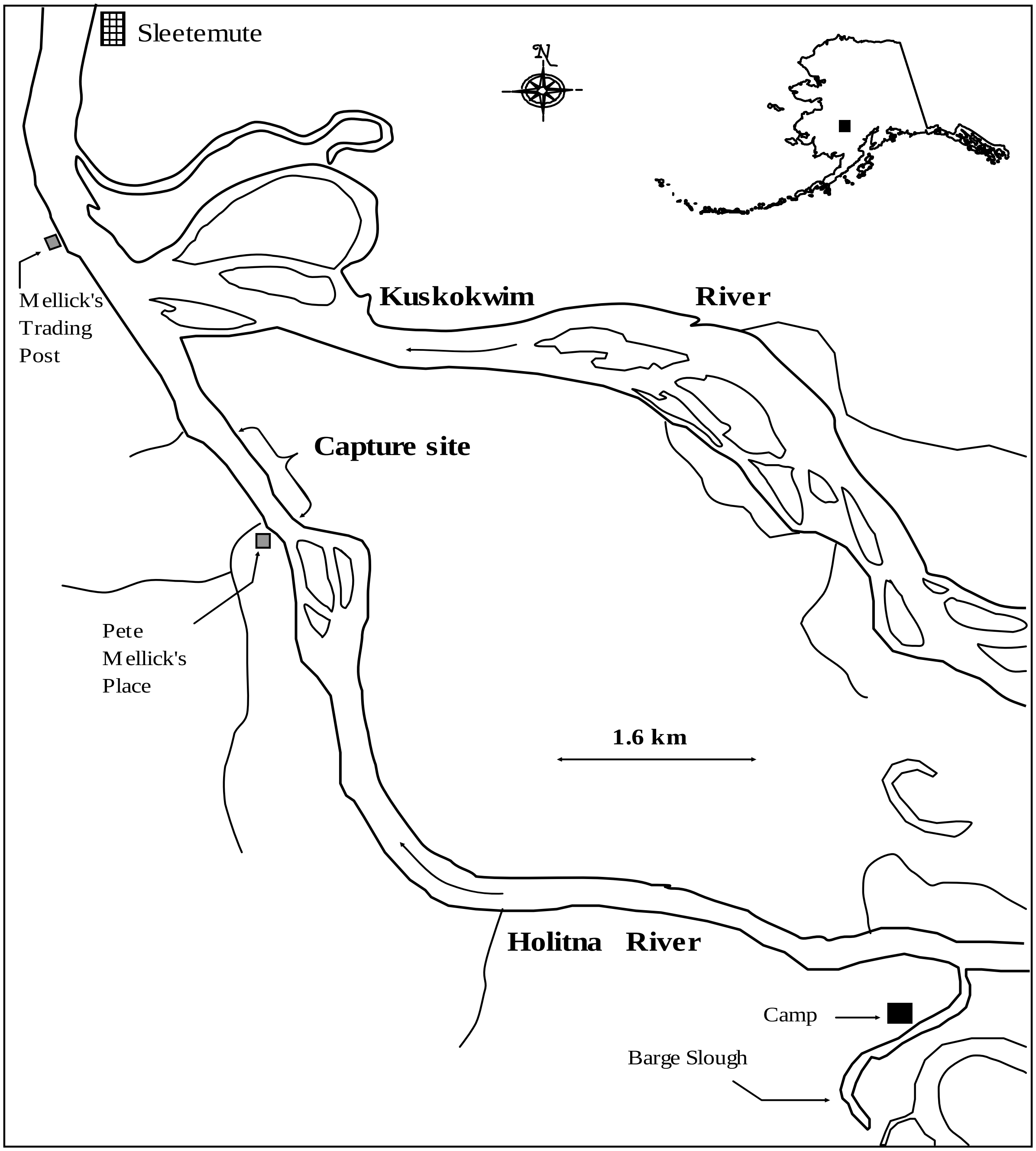


Figure 2.–Map of the confluence of the Holitna and Kuskokwim rivers demarcating the capture site. The bracketed arrows show the upper and lower ends of the sampling reach in 2004.

A single three-person crew fished the drift gillnets throughout the season. One person piloted the 6.1-m (20-ft) boat and two crewmembers positioned in the bow tended the net. For each drift, a gillnet was deployed from the bow and the boat motor was idled in reverse to keep the net perpendicular to shore while drifting downstream. The sampling reach was approximately 1 km in length, and water depth varied from 1.5 to 6.0 m. Each drift gillnet was fished until either the end of the fishing area was reached or a fish became entangled in the net. Drift times were monitored with a stopwatch, drift time began when the gillnet first entered the water and ended when the entire gillnet was pulled from the water.

Sampling was conducted in a manner to minimize the potential for bias with respect to run size, run timing, and size of fish. This required using different sized nets that would capture all sizes of salmon, and fixing the amount of time a net was fished each day over the duration of the run.

Gillnets of varying mesh size and lengths were used throughout the sample period. These included:

1) 5.75 in (14.6 cm) stretch mesh, made of cable lay (twisted nylon), 100 ft (30.5 m) or, 150 ft (45.7 m) long, and 10 ft (3.0 m) deep;
2) 8.0 in (20.3 cm) stretch mesh, made of cable lay, 100 ft (30.5 m) or 150 ft (45.7 m) long, and 10 ft (3.0 m) or 15 ft (4.5 m) deep;
3) 5.75 in (14.6 cm) stretch mesh, made of cable lay, 100 ft (30.5 m) or 150 ft (45.7 m) long, and 22 ft (6.5 m) deep; and,
4) 8.0 in (20.3 cm) stretch mesh, made of cable lay, 100 ft (30.5 m) or 150 ft (45.7 m) long, and 10 ft (3.0 m) or 30 ft (9.0 m) deep.

The small-mesh nets (nets 1 and 3) were fished for 60 minutes each day, and the large mesh nets (2 and 4) were fished for 145 minutes each day. Chinook salmon were captured and radio-tagged using both the large and small mesh nets. Chum salmon were captured in both sizes of nets, however, only those captured with the small mesh nets were radio-tagged. The deeper nets (nets 3 and 4) were used whenever water depth was such that the shallower nets were not fishing the depth of the river. Throughout the sampling period, drift gillnetting for Chinook and chum salmon was conducted in the evenings, generally starting by 1600 hours and ending around 2200 hours.

Once a salmon became entangled in the gillnet, the net was immediately pulled into the boat until the fish was brought on board. The portion of the net containing the fish was placed into a holding tub and the fish was disentangled or cut from the net. All fish were measured to the nearest 5-mm mideye-to-fork (MEF) and sex was determined from external characteristics.

A portion of 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. Vials were stored in a cool, dark place. These tissues were sent to and processed by the ADF&G Commercial Fisheries Division genetics laboratory

Sample size objectives were to radio-tag 65 Chinook and 195 chum salmon. Because a greater number of fish were anticipated to be captured than the number of radio tags available, not every captured fish was implanted with a radio tag. In the first three years of this study, quarterly tagging goals were established based on average run timing of each species through the Kogrukluk River weir, lagged 10 days to ensure tags were distributed over the entire run and in proportion to historic average run strength. For the 2004 season, tagging goals were established based on average run timing of each species at the capture site during 2001-2003, to ensure tags were distributed over the entire run.

The Chinook salmon tagging goals coincided with quartiles of the average run timing pattern based on average catch per unit effort (CPUE). A systematic tagging approach was used for Chinook salmon; the initial tagging rate was two out of every three fish. The tagging rate was evaluated at the end of every time block that corresponded to quartiles of the average run timing pattern from 2001-2003, and when needed, adjusted to ensure that the overall goal was met. In an effort to ensure that tags were deployed in fish throughout the run, we continued to put out tags until our catches and CPUE indicated that the run was near the end.

Similar to 2002 and 2003, Chinook salmon were captured and tagged as part of the 2004 mainstem Kuskokwim River radiotelemetry project (Stuby 2005). In each year, a portion of the 500 mainstem radio-tagged fish migrated to the Holitna River, and were subsequently added to the Holitna River radio-tagged sample to calculate the proportion of Chinook salmon passing by the Kogrukluk River weir and the drainage-wide abundance. Mainstem Kuskokwim River radio-tagged fish were handled in a manner similar to that on the Holitna River. Capture methods differed slightly, in that fish wheels were used as well as drift gillnets in the mainstem project (Stuby 2005).

Similar to the Chinook salmon tagging goals, chum salmon goals coincided with twentieth percentile increments of the average run timing pattern to ensure that run size and strength could be examined on a finer scale. A systematic sampling approach was used to meet the tagging goals. Based on average run size and the tagging schedule, the initial tagging rate was one out of every 2.5 fish (or 2 out of every 5); with the goal that this rate would allow for deployment of tags throughout the run and at least 90% of all tags will be deployed. Because chum salmon run timing tended to be more variable than that of Chinook salmon, we targeted deploying 90% of our chum salmon tags during the expected run to ensure we did not run out of tags in the event of a protracted run.

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

The radio tags used were Model Five pulse encoded transmitters made by ATS[1]. Each radio tag was distinguishable by frequency and encoded pulse pattern. Thirty-five frequencies in the 148 - 149 MHz range with up to 25 encoded pulse patterns per frequency were used. Transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 24 g in air, and had an external whip antenna 30 cm in length.

Radio tags were inserted through the esophagus of the fish and into the upper stomach using a 45 cm polyvinyl chloride (PVC) tube with a diameter equal to that of the radio tags. The end of the PVC tube was slit lengthwise allowing for the antenna end of the radio transmitter to be seated into the tube and held in place by friction. The radio transmitter was pushed through the esophagus and seated using a PVC plunger, which was slightly smaller than the inside diameter of the first tube, such that the antenna end of the radio tag was 1-cm posterior to the base of the pectoral fin. Salmon were held by hand against the side of the sampling tub to control fish during tagging.

[1] Advanced Telemetry Systems, Isanti, Minnesota. Use of this company name does not constitute endorsement, but is included for scientific completeness.

All radio-tagged salmon were also given a modified Floy spaghetti tag. This secondary tag was used to help identify spawning fates of those fish that lost their radio tag and were later recovered either at the weir or from carcasses on the spawning grounds. The spaghetti tags were uniquely numbered, and constructed of a 5-cm section of Floy tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line. Each species received a uniquely colored tag. In 2004 those colors were yellow (chum) and blue (Chinook). 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 fourth fin rays from the posterior of the dorsal fin. The entire handling process required approximately 2-3 min per fish.

Five stationary tracking stations were used to log radio-tagged fish in 2004. Three stations were located to detect fish that migrated up the Hoholitna River; the Holitna River upstream of the Hoholitna River, and on the Kogrukluk River past the weir (Figure 1). A new tracking station for 2004 was placed near the mouth of the Holitna River, in order to determine when Chinook salmon tagged in the Kuskokwim River Chinook salmon radiotelemetry project (Stuby 2005) entered the Holitna drainage (Figure 1). The final tracking station was located on the mainstem Kuskokwim River near Red Devil (approximately 26 km downstream from the tagging site). This station was used to identify fish that backed down into the mainstem Kuskokwim River after being radio-tagged.

The Hoholitna River station was erected on a cut bank 3.5 km upstream from its confluence with the Holitna River and 62 km upstream from the tagging site. The Holitna River station was placed on a cut bank 10 km upstream from the mouth of the Hoholitna River and 68 km upstream from the tagging site. The Kogrukluk River station was positioned on a hill above the weir, approximately 220 km from the tagging site. The new tracking station was placed on a hillside near the mouth of the Holitna River.

Each tracking station was made up of a weather-proof metal housing box that contained either an ATS model 5041 Data Collection Computer (DCC II) with an ATS model 4000 receiver, or a single R4500 Data Collection Computer and receiver combination, an antenna switching box, and two gel-cell, deep-cycle batteries charged by an 80 watt solar array. Two four-element Yagi antennas (one aimed upstream and the other downstream) were mounted on either a metal mast stabilized by guide wires, a convenient tree or any other tall stable object. The DCC II/R4000 and R4500 units were programmed to scan through the frequencies at three-second intervals receiving with both antennas simultaneously. When a radio signal of sufficient strength was encountered the receiver paused for six seconds, at which time the data logger recorded the frequency, code, signal strength, date, and time for each antenna. Cycling through all frequencies required 2-15 min depending on the number of active tags in reception range. Data were downloaded onto a portable computer every 7-10 days.

The distribution of radio-tagged salmon throughout the Holitna River drainage was further determined by aerial tracking from small aircraft to: 1) locate tags in areas other than those monitored with tracking stations; 2) locate fish that the tracking stations failed to record; and, 3) validate that a fish recorded by one of the tracking stations did migrate into a particular stream. In 2004, aerial tracking surveys of the Holitna River drainage were conducted on 13 and 14 July, and 16 and 17 August. Generally, locations of radio-tagged fish were determined with an accuracy of ±1 km, except that locations of radio-tagged fish near a tributary confluence or near the Kogrukluk River weir were determined within approximately 200 m. The greater accuracy in determining locations for the latter radio-tagged fish was accomplished by flying at lower altitudes to reduce the size of the signal cone, flying until maximum signal strength was attained, and circling the aircraft to better triangulate the signal.

Estimation of Proportions and Abundance

For the estimates of the proportion of salmon that entered the Holitna River and migrated past the Kogrukluk River weir to be unbiased, the following conditions must have been met:

1) the fates of all, or nearly all, radio-tagged salmon were known;
2) marking did not affect the final spawning destination of salmon;
3) stocks of salmon were not bank oriented at the capture site;
4) run-timing at the capture site for fish spawning in all areas of the Holitna River drainage was similar, or daily tagging rate and fishing effort were constant during the marking event; and,
5) the sex ratio and/or size distribution of salmon passing the Kogrukluk River weir was not different from the sex ratio and/or size distribution of salmon entering the Holitna River drainage.

To satisfy condition 1, only those tags that resumed upstream migrations after tagging were used in estimating the proportion. The combination of tracking stations, aerial surveys, and sampling of fish at the weir led to the location of nearly all fish that resumed upstream migrations after tagging. Furthermore, radio and spaghetti tags were printed with return information to encourage returns of tags from harvested fish. However, it was unlikely that fishers removed radio tags upriver from the tagging site because in all prior years of the study no commercial fishing occurred near the village of Sleetmute, subsistence fishing was primarily conducted in the mainstem Kuskokwim River, and sport fishing is primarily conducted in the lower portion of the river (below the tracking stations).

Condition 2 could not be tested directly. Only those radio-tagged salmon that migrated upstream past the tracking stations on the Holitna River (66 km upstream) and Hoholitna River (62 km upstream) were used to estimate the proportion. It was assumed that if a fish was able to migrate this distance, then there were no effects from handling and tagging.

To evaluate conditions 3, 4, and 5, a series of tests were conducted for each species. The results of the following tests determined whether adjustments to the estimate were needed to correct for bias:

a) fish were tagged on both the east and west banks and their location of capture was recorded. Independence between bank of mark and final spawning destination was tested using contingency table analysis. Final spawning destinations were evaluated as either the Hoholitna River (eastern drainage) or the Holitna River (western drainage) upstream from its confluence with the Hoholitna River;
b) cumulative run-timing distributions (at the capture site) for radio-tagged salmon spawning in the Kogrukluk River and radio-tagged salmon spawning in the remainder of the Holitna River drainage were tested for homogeneity using Kolmogorov-Smirnov (K-S) two-sample tests (Conover 1980);
c) cumulative length frequency distributions for all radio-tagged salmon were compared to distributions for radio-tagged salmon migrating through the Kogrukluk River weir

and to distribution for samples of all salmon past the weir and tested for homogeneity using K-S tests; and,

d) contingency table analysis was used to test the hypothesis that the sex ratio of radio-tagged salmon that migrated through the weir did not significantly differ from all radio-tagged fish that migrated upstream to other areas in the Holitna River drainage.

Chinook, chum and coho salmon length and sex data were collected at the Kogrukluk River weir by ADF&G Commercial Fishery Division (CFD) personnel. These data were assumed to be representative of the true population proportions for the Kogrukluk River. The number of fish to sample at the weir for sex and length compositions was determined through a proportional sampling design (Molyneaux and Dubois 1996).

For Chinook salmon, condition 4 was satisfied because fishing effort and tagging rates of this species were similar and the run-timing (at the capture site) of Chinook salmon migrating past the weir was similar to the run-timing of fish spawning elsewhere in the drainage. Therefore, abundance of Chinook salmon entering the Holitna River could be estimated using a Petersen-type estimator. In addition to evaluating potential for bias in abundance estimation due to size bias sampling (condition 5), we used the consistency tests described by Seber (1982). Contingency table analyses were used to test three null hypotheses: (1) the probability that a radio-tagged salmon passed the Kogrukluk River weir was independent of when it was marked; (2) the ratio of the number of radio-tagged salmon to non-tagged salmon passing the weir was independent of time; and, 3) for all marked fish recovered during Event 2, time of marking of radio-tagged salmon was independent of when or if it passed the Kogrukluk River weir. Failure to reject at least one of these three hypotheses is sufficient to conclude that a temporally stratified abundance estimator was not required. If all three hypotheses were testable and rejected, the partially stratified estimator described by Darroch (1961) would be necessary to estimate abundance.

Condition 5 was not satisfied, requiring stratification by sex for unbiased estimates of abundance. For each stratum, abundance was estimated using the Chapman modification to the Petersen estimator:

$$\hat{N}'_s = \frac{(\hat{C}_s + 1)(M_s + 1)}{R_s + 1} - 1 \qquad (1)$$

where:

$\hat{N}'_s$ = estimated escapement of Chinook salmon into the Holitna River in stratum s, s =1 to S;

M_s = the number of radio-tagged Chinook salmon in stratum s known to have resumed upstream migration after tagging; and,

R_s = the number of radio-tagged Chinook salmon in stratum s moving past the Kogrukluk weir.

The estimated number of Chinook salmon in stratum *s* that passed the Kogrukluk River weir was calculated:

$$\hat{C}_s = \hat{p}_s C \qquad (2)$$

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

$$\hat{p}_s = n_{Cs} / n_C \qquad (3)$$

where:

n_{Cs} = number of Chinook salmon in sex/size stratum *s* observed of those sampled for composition at the Kogrukluk River weir;

n_C = the total number of Chinook salmon sampled for composition at the weir; and,

C = the number of Chinook salmon counted past the Kogrukluk River weir.

The abundance of Chinook salmon escaping into the Holitna River drainage was estimated as the sum of strata estimates:

$$\hat{N}'_{Hol} = \sum_{s=1}^{S} \hat{N}'_s \, . \qquad (4)$$

Variance and 95% credibility interval for the estimator (equation 4) were estimated using empirical Bayesian methods (Carlin and Louis 2000). Using Markov Chain Monte-Carlo techniques, posterior distributions for the $\hat{N}'_s$ and $\hat{N}'_{Hol}$ were generated by collecting 1,000,000 simulated values of $\hat{N}'_s$ and $\hat{N}'_{Hol}$ which were calculated using equations (1-4) from simulated values of equation parameters. Simulated values were modeled from observed data using the following distributions:

observed $n_{C1}, \ldots, n_{CS}$ ~multinomial $((p_1, \ldots, p_S), n_C)$;

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

where q_s is the probability that a radio-tagged salmon from stratum s passes the weir.

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

$$\overline{N}'_{Hol} = \frac{\sum_{b=1}^{1000000} \hat{N}'_{Hol(b)}}{1000000} \text{; and,} \qquad (5)$$

$$V\hat{a}r(\hat{N}'_{Hol}) = \frac{\sum_{b=1}^{1000000} (\hat{N}'_{Hol(b)} - \overline{N}'_{Hol})^2}{1000000 - 1} \, . \qquad (6)$$

The proportion of Chinook salmon entering the Holitna River that migrated past the Kogrukluk River weir was estimated:

$$\hat{P}'_{KR} = \frac{\sum_{s=1}^{S} \left(R_s / M_s\right) \hat{N}'_s}{\hat{N}'_{Hol}} \; ; \tag{7}$$

and its variance and 95% credibility interval were estimated using methods similar to described in equations 5 and 6, above.

Due to results of diagnostic testing for conditions 3 and 4, estimation of abundance and proportion migrating past the Kogrukluk River weir were estimated differently. To reduce bias associated with unequal tagging rates and fishing effort, each radio-tagged chum salmon was assigned a numeric weight w_i that considered the number of fish captured, the number of fish tagged, and fishing effort for the day (i) it was captured. Fishing effort was the sum of soak times of all nets fished during a day. The proportion of chum salmon migrating past the Kogrukluk River weir was initially calculated as:

$$\hat{P}^*_{KR} = \frac{\sum_{i=1}^{d} \sum_{j=1}^{n_i} w_i \mathrm{I}(destination)_j}{\sum_{i=1}^{d} n_i w_i} \tag{8}$$

where:

$$w_i = \left(\frac{\bar{h}}{h_i}\right)\left(\frac{X_i / \bar{X}}{x_i / \bar{x}}\right) \tag{9}$$

$\mathrm{I}(destination)_j$ = 1 if fish j passed the Kogrukluk River weir when the weir was operational and 0 otherwise;

X_i = the number of fish captured on day i;

$\bar{X}$ = the mean daily number of fish captured over all days of fishing;

x_i = the number of fish radio-tagged on day i;

$\bar{x}$ = the mean daily number of fish radio-tagged over all days of fishing;

h_i = the hours of fishing effort on day i;

$\bar{h}$ = the mean hours of fishing effort per day over all days of fishing (within a period); and,

n_i = the number of radio-tagged fish tagged on day i.

The variance of $\hat{P}^*_{KR}$ was estimated using bootstrap resampling procedures (Efron and Tibshirana 1993). Using Equation (9), 2,000 bootstrap estimates of $\hat{P}^*_{KR}$ were computed after drawing samples of size equal to the number of radio-tagged fish with replacement from the original data, that was comprised of a list of fates of all the radio-tagged fish. The sample variance of these bootstrap replicates was used to estimate $V\hat{a}r(\hat{P}^*_{KR})$.

The abundance of chum salmon could then be calculated by expanding the estimated number of salmon that passed through the Kogrukluk River weir by the weighted proportion of salmon carrying radio transmitters that migrated up the Kogrukluk River:

$$\hat{N}_{Hol} = {N_{KR}}/{\hat{P}^*_{KR}} \tag{10}$$

where: N_{KR} = the number of chum salmon observed to have passed the Kogrukluk River weir.

However, the method described by equation 10 was potentially biased because not all sources of sampling bias can be mediated by the weighting procedures described above. While the weighting procedures are designed to deal with potential bias introduced by unequal probability of capture over time during the marking event, the affects of unequal probability of capture over time during the second event are not addressed. While chum salmon passage at the weir is predetermined, and not a random procedure following the marking event, it is necessary that salmon passage at the weir exhibit some of the characteristics required of the second event of a mark-recapture experiment. Inspection of the data indicated that the probability of a marked fish passing the weir appeared to decline as fish were marked later in the run.

We evaluated the potential for bias in abundance estimation due to unequal probability of capture over time using the consistency tests as described above (Seber 1982). The first two hypotheses were tested, however the third test was not conducted due to insufficient sample size (number of marks recovered). As both null hypotheses were rejected, the methods of Darroch (1961) were used to estimate chum salmon abundance.

An alternative method to estimate the proportion of chum salmon passing the Kogrukluk River weir is based on the Darroch estimate of abundance and total passage counted at the weir:

$$\hat{P}^*_{Dar} = {N_{KR}}/{\hat{N}_{Dar}} \tag{11}$$

where $\hat{N}_{Dar}$ is the estimate of chum salmon abundance based on the Darroch model.

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

$$V\hat{a}r\left(\hat{P}^*_{Dar}\right) \approx \left(N_{KR}\right)^2 \left(\frac{V\hat{a}r\left(\hat{N}_{Dar}\right)}{\hat{N}_{Dar}{}^4}\right). \tag{12}$$

RESULTS

TAGGING AND FATES OF RADIO-TAGGED SALMON

Specific results from 2004 are presented here. Most referenced tables and figures show results from 2004 only. However, the primary objectives of this project were to evaluate the proportions of salmon above the Kogrukluk River weir, as well as abundance estimates for the Holitna River drainage, therefore tables with these data show all 4 years for comparison purposes. For complete details of previous years' results see Wuttig and Evenson (2002), Chythlook and Evenson (2003), and Stroka and Brase (2004).

Chinook Salmon

One hundred eighty three Chinook salmon were captured in the Holitna River between June 12 and August 7, and 65 were fitted with radio tags (Figure 3). The highest hourly Chinook salmon CPUE in any one day was 4.6 fish on June 25 (Appendix A1). Radio-tagged Chinook salmon ranged in size from 510 to 1,045 mm MEF.

Of the 65 fish radio-tagged in the Holitna River, only one was never located upstream. This fish backed out into the Kuskokwim River after tagging. All radio-tagged Chinook salmon were relocated at least once.

After examining all tracking station and aerial flight records, a total of 172 radio-tagged Chinook salmon were relocated upstream of the Holitna River and Hoholitna River tracking stations. Of the 172 relocated Chinook salmon, 64 were radio-tagged as part of the Holitna river project, while 108 were tagged as part of the related Kuskokwim River Chinook salmon radiotelemetry project (Stuby 2005). The total of 172 fish was used to calculate the proportion of Chinook salmon passing by the weir and drainage-wide abundance.

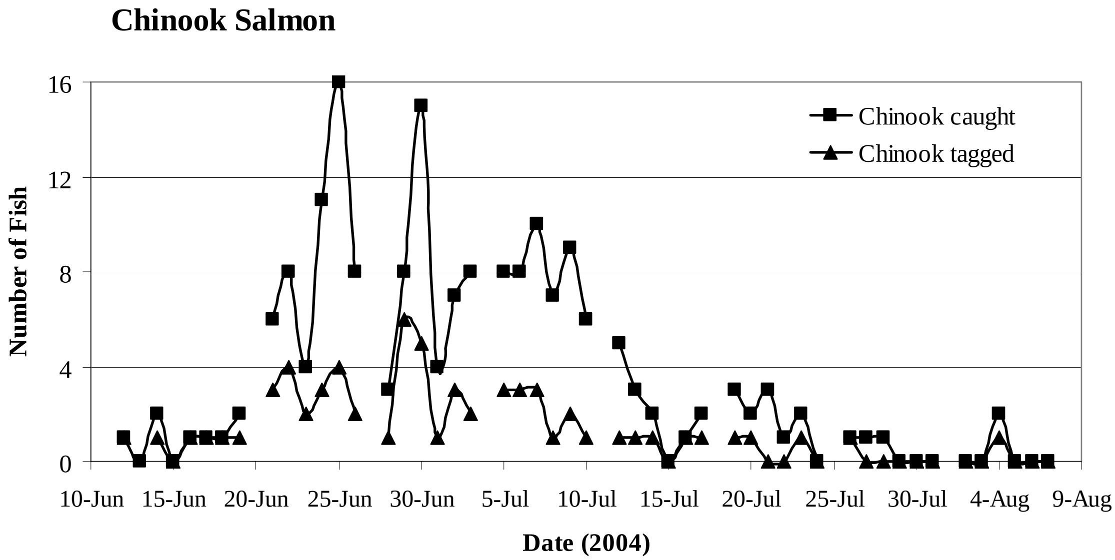
Chum Salmon

Four hundred sixty-five chum salmon were captured between June 12 and August 7 and 180 were fitted with radio tags (Figure 3). The highest hourly chum salmon CPUE in any one day was 5.6 fish on July 15 (Appendix A1). Radio-tagged chum salmon ranged in size from 505 to 680 mm MEF.

Of the 180 chum salmon that were radio-tagged, 156 were relocated at least once upstream of the Holitna River and Hoholitna River tracking stations. Twenty two of the 24 fish that did not migrate upstream backed out of the Holitna River and were later found in the mainstem Kuskokwim River. Two fish were never relocated and were assumed to have died, migrated to other rivers, or had tags that failed after implantation. Only the 156 chum salmon that were known to have migrated upstream were used for parameter estimation.

DISTRIBUTION AND MOVEMENT OF RADIO-TAGGED SALMON

The combination of all stationary tracking stations along with the two sets of aerial tracking surveys accounted for the detection of all radio-tagged Chinook and chum salmon that resumed upstream migrations. The tracking stations were highly successful at detecting the passage of radio-tagged Chinook and chum salmon. Each station was 95%-100% effective at detecting fish



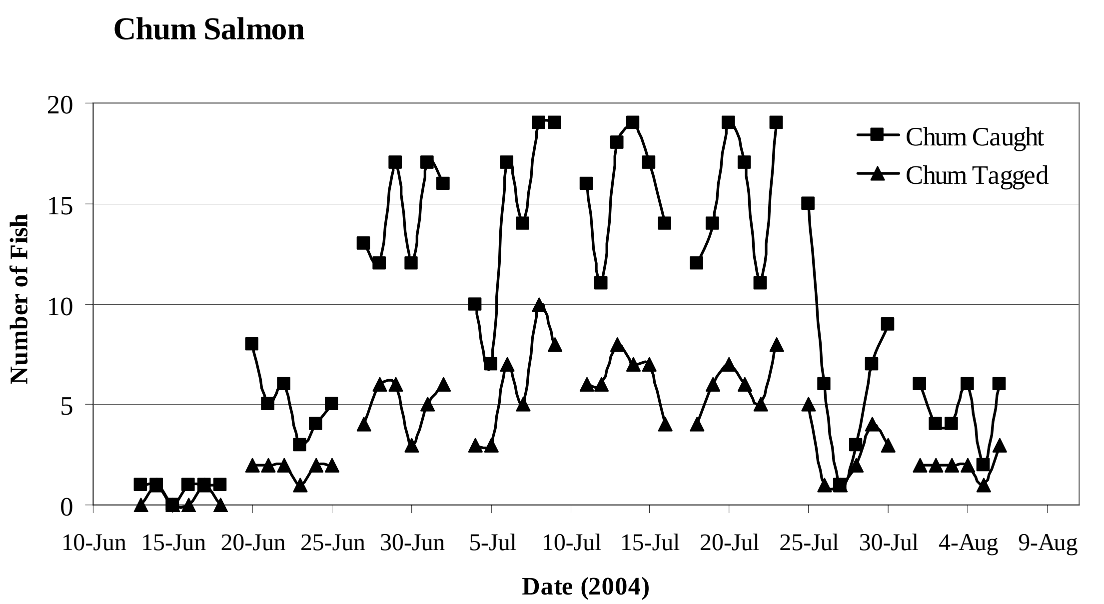


Figure 3.–The daily catch and number of Chinook (upper) and chum salmon (lower) radio-tagged in the Holitna River, 2004

that were known to have passed each site (Table 1). Aerial tracking was also a highly successful means of locating radio-tagged Chinook and chum salmon. Aerial tracking was 97-98% effective at locating Chinook salmon in all areas of the drainage, and 93-97% effective for locating chum salmon in the Holitna and Hoholitna rivers. However aerial surveys were only 50% effective at locating chum salmon in the Kogrukluk River. This may be due to the low number of fish that migrated to the Kogrukluk River, or the fish may have already left the area by the time of the aerial survey.

Table 1.–Efficiency of tracking stations and aerial surveys in detecting radio-tagged salmon in the Holitna River drainage, 2004.

Species	Station	Total number of tags known to pass site[a]	Number of tags located during aerial surveys	Number of tags logged by tracking station	Aerial tracking efficiency	Tracking station efficiency
Chinook						
	Holitna	115	113	115	98%	100%
	Hoholitna	58	57	57	98%	98%
	Kogrukluk	33	32	32	97%	97%
Chum						
	Holitna	120	112	113	93%	95%
	Hoholitna	36	35	36	97%	100%
	Kogrukluk	6	3	6	50%	100%

[a] Includes all fish logged by tracking stations, located from aerial surveys, and captured at the Kogrukluk River weir.

The Chinook salmon that were tagged in the Holitna River averaged 11.8 days to migrate from the tagging site to the Kogrukluk River weir. Chum salmon had a slower travel speed in the lower river, but achieved a higher travel speed in the upper river, averaging 7.8 days to travel between the tagging site and the weir (Table 2).

Table 2.–The number of days taken for radio-tagged salmon to migrate upstream to a tracking station, or time taken to travel between two tracking stations, 2004.

Travel Segment	Species	Number of Radio Tags	Average (days)	SD (days)	Min (days)	Max (days)
Tagging site to Hoholitna station (~62 km)	Chinook	53	1.7	0.15	0.8	5.6
	Chum	43	1.8	0.10	1.1	4.4
Tagging site to Holitna station (~68 km)	Chinook	107	1.5	0.08	0.8	5.6
	Chum	115	1.9	0.08	0.3	6.4
Tagging site to Kogrukluk station (~220 km)	Chinook	44	11.8	0.99	4.5	29.4
	Chum	6	7.8	0.68	5.9	10.7
Holitna station to Kogrukluk station (~ 155 km)	Chinook	44	10.2	0.92	3.5	28.4
	Chum	6	5.9	0.42	4.5	7.6

Aerial tracking surveys throughout the Holitna River drainage identified approximate spawning locations for radio-tagged Chinook and chum salmon (Table 3). During aerial surveys approximately 66% of the radio-tagged Chinook salmon were determined to be spawning in tributaries of the Holitna River, whereas approximately 65% of the radio-tagged chum salmon were determined to be spawning in the mainstem Holitna River, indicating the spatial differences in spawning habitat between the two species.

Table 3.–Final destinations of radio-tagged Chinook and chum salmon in the Holitna River drainage as determined during aerial surveys, 2004.

Tributary or River Section	Chinook	Chum
Hoholitna River drainage		
Mainstem Hoholitna River	49	35
South Fork Hoholitna River	3	1
Hook Creek	2	0
Killae Creek	2	0
Gnat Creek	1	0
Holitna River drainage		
Mainstem Holitna River	47	100
Kogrukluk River	26	5
Shotgun Creek	7	1
Mainstem Chukowan River	16	0
Oksotalik Creek	3	0
Gemuk River	0	0
Bairo Creek	0	0
Chikulunuk Creek	0	0
Enatalik Creek	1	0
Portage Creek	1	2
Bakbuk Creek	0	0
No Name (West side drainage between Bakbuk and Portage Creeks)	2	1
Kiknik Creek	2	0
Taylor Creek	2	2
Itulilik Creek	0	0
Chuilnuk Creek	0	1
Mukslulik Creek	1	1
Titnuk Creek	7	7

Estimation of Proportions and Abundance

Chinook Salmon

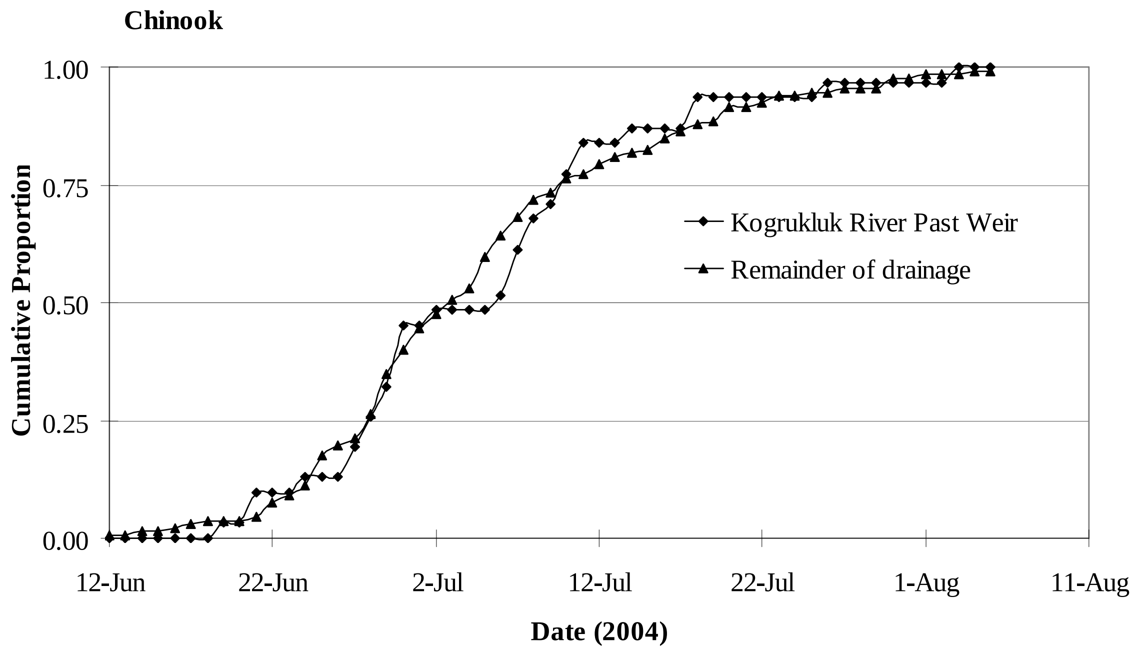
The final destination (eastern or western drainage) of radio-tagged Chinook salmon was independent of bank of capture (females: $\chi^2 = 0.53$; df = 2; P = 0.77; males: $\chi^2 = 5.54$; df = 2; P = 0.06; Table 4). Run timing at the capture site for radio-tagged Chinook salmon located above the Kogrukluk River weir and those located in the rest of the Holitna River drainage were not significantly different (females: D = 0.19; P = 0.82; males: D = 0.18; P = 0.57; Figure 4). Length distribution of radio-tagged Chinook salmon located above the Kogrukluk River weir was not significantly different from that of all radio-tagged fish located in the drainage (females: D = 0.28, P = 0.35; males: D = 0.13, P = 0.88; Figure 5). Length distribution of all radio-tagged Chinook salmon was significantly different from all fish sampled at the weir (females: D = 0.24, P = 0.00; males: D=0.41, P=0.00; Figure 5). The probability that a radio-tagged salmon passed the weir was independent of time of marking ($\chi^2 = 0.14$; df = 3; P = 0.99), satisfying the first consistency tests, so no further tests were required. Sex ratios of radio-tagged Chinook salmon located above the Kogrukluk River weir and those located in the rest of the drainage were significantly different ($\chi^2 = 8.34$; df = 1; P < 0.01; Table 5). So, the data were stratified by sex and abundance was estimated separately for males and females.

Of the 172 radio-tagged Chinook salmon that migrated up the Holitna River, 33 passed through the Kogrukluk River weir. The estimated proportion of Chinook salmon migrating into the Kogrukluk River was 0.23 (95% C.I. = 0.16-0.30; Table 6), and 19,651 Chinook salmon were observed past the weir (Whitmore et al. *In prep b*). The estimated abundance of female Chinook salmon in the Holitna River drainage was 27,598 fish (SE=8,588). The estimated abundance of male Chinook salmon in the Holitna River drainage was 54,363 fish (SE=10,150). The total estimated abundance for Chinook salmon in the Holitna River drainage was 81,961 fish (SE=13,150; Table 7).

Table 4.–Number of radio-tagged Chinook and chum salmon migrating up the Holitna River (western drainage) or the Hoholitna River (eastern drainage) by bank of capture and results of chi-square tests comparing spawning destinations for fish marked on east bank, center river, and west bank, 2004.

Species		Migration Destination	West	Center	East
Chinook[a]	Males	Holitna River (west)	6	11	1
		Hoholitna River (east)	3	3	4
		$\chi^2 = 5.54$; df = 2; P = 0.06			
	Females	Holitna River (west)	3	10	11
		Hoholitna River (east)	2	6	4
		X 2 = 0.53; df = 2; P = 0.77			
Chum		Holitna River (west)	49	54	18
		Hoholitna River (east)	11	12	12
		$\chi^2 = 6.58$; df = 2; P = 0.04			
		Above Kogrukluk Weir	4	1	1
		Remainder of Drainage	56	65	29
		$\chi^2 = 2.28$; df = 2; P = 0.32			

[a] Includes only those fish tagged in the Holitna River.



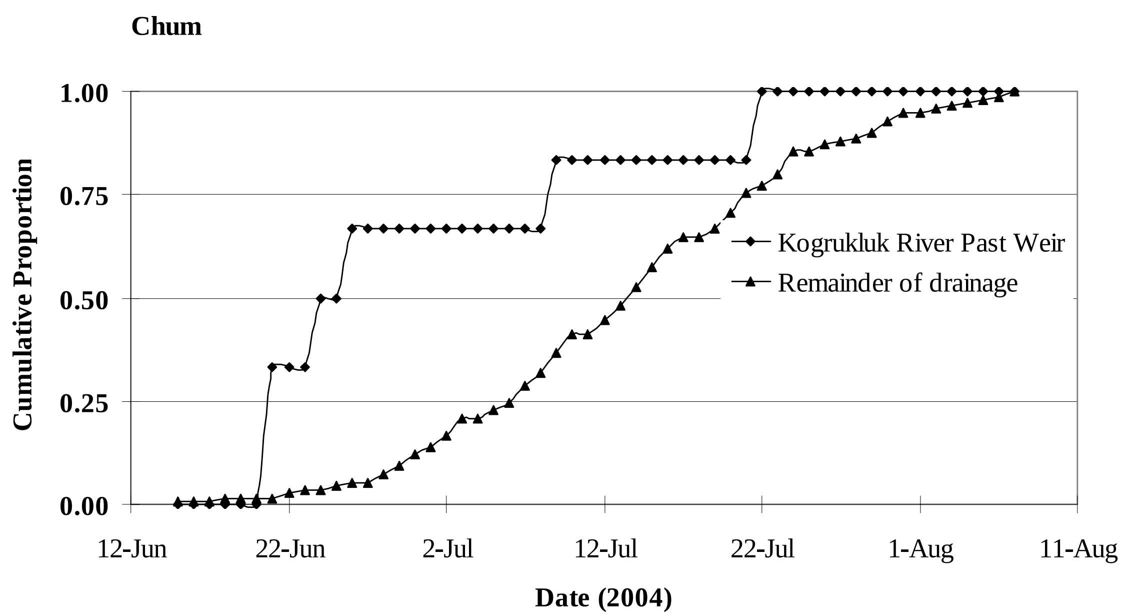
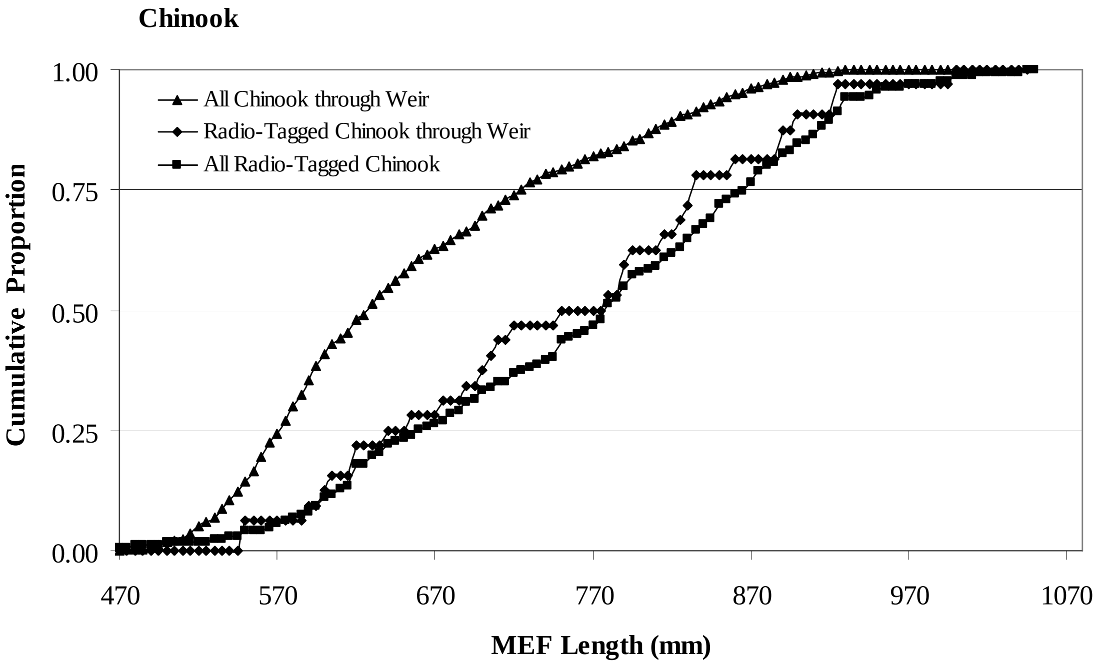


Figure 4.–Migratory timing profile of radio-tagged Chinook and chum salmon at the capture site that migrated past the Kogrukluk River weir or migrated to all other areas of the Holitna River drainage, 2004.



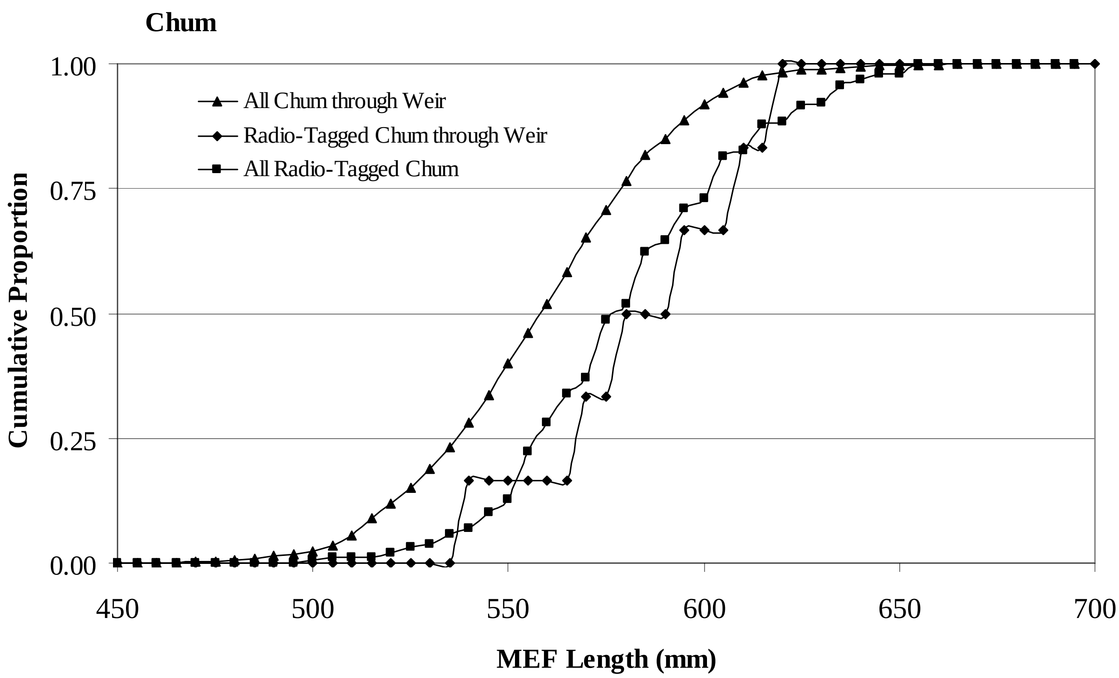


Figure 5.–Cumulative length frequency distributions of all radio-tagged Chinook and chum salmon spawning all areas of the Holitna River drainage, all radio-tagged fish spawning above the Kogrukluk River weir, and all fish sampled at the Kogrukluk River weir, 2004.

Table 5.–Number of radio-tagged Chinook and chum salmon that migrated past the Kogrukluk River weir, or migrated to all other areas of the Holitna River drainage and results of chi-square tests comparing spawning destinations for male and female salmon, 2004.

		Spawning Area	
Salmon Species	Sex	Past Kogrukluk River Weir	All other areas of the Holitna River drainage
Chinook			
	Male	22	54
	Female	11	85
	χ^2 =8.37; df=1; P=0.00		
Chum			
	Male	5	122
	Female	1	28
	χ^2 =0.02; df=1; P=0.90		

Table 6.–Proportion estimates for Chinook and chum salmon that migrated above the Kogrukluk River weir, 2001–2004.

	2001	2002	2003	2004
Species	Proportion (95% C.I.)	Proportion (95% C.I.)	Proportion (95% C.I.)	Proportion (95% C.I.)
Chinook	0.26 (0.15-0.37)	0.23 (0.16-0.30)	0.27 (0.22-0.34)	0.23 (0.16-0.30)
Chum	N/A	0.09 (0.02-0.21)	N/A	0.02 (0.00-0.05)

Table 7.–Abundance estimates for Chinook and chum salmon in the Holitna River, 2001–2004.

Species	2001	2002	2003	2004
Chinook	25,405 (SE=6,207) *fish ≥ 650mm only	42,902 (SE=6,334)	42,013 (SE=4,981)	81,961 (SE=13,150)
Chum	N/A	542,172 (SE=285,925)	N/A	996,216 fish (SE=640,754)

Chum Salmon

The final destination (eastern or western drainage) of radio-tagged chum salmon was not independent of bank of capture ($\chi^2 = 6.58$; df = 2; P = 0.04; Table 4). Sex ratios of radio-tagged chum salmon located upstream of the Kogrukluk River weir, and those radio-tagged fish located in all other areas of the drainage were not significantly different ($\chi^2 = 0.01$; df = 1; P = 0.91; Table 5). Run timing at the capture site was markedly earlier for radio-tagged chum salmon located above the Kogrukluk River weir than was run timing of those located in the rest of the Holitna River drainage (D = 0.61; P = 0.02; Figure 4). Length distribution of all located radio-tagged chum salmon was not significantly different from those that spawned above the weir (D = 0.13; P = 1.0; Figure 5). However, length distribution of all located radio-tagged chum salmon was significantly different from all fish sampled at the weir (D = 0.32; P < 0.01; Figure 5). The results of these two tests indicated size stratification was not required to estimate abundance.

The hypothesis that the probability that a radio-tagged salmon passed the Kogrukluk River weir was independent of when it was marked was rejected ($\chi^2 = 5.78$; df = 1; P = 0.02) when the first quartile of the run is compared to the last 3 quartiles. The hypothesis that the ratio of the number of radio-tagged salmon to non-tagged salmon passing the weir was independent of time was also rejected ($\chi^2 = 7.67$; df = 2; P = 0.02). The model of Darroch (1961) was selected to estimate abundance as a result of these two tests.

Of the 156 radio-tagged chum salmon that resumed upstream migration after tagging, six passed through the weir. During 2004, 24,201 chum salmon were observed past the Kogrukluk River weir (Whitmore et al. *In prep b*). The estimated proportion of chum salmon migrating into the Kogrukluk River using individual fish weighted daily by catch and effort was 0.05 (95% C.I. = 0.02-0.09). The estimated abundance of chum salmon in the Holitna River drainage was 996,216 fish (SE = 640,754; Table 7). A revised estimate of the estimated proportion of chum salmon migrating into the Kogrukluk River based on this abundance estimate was 0.02 (95% C.I. = 0.0-0.05; Table 6).

AGE-SEX-LENGTH COMPOSITION OF CAPTURED SALMON

Diagnostic testing for abundance estimation revealed that gillnet sampling was size-selective for both Chinook and chum salmon and in both cases, the smaller size classes were captured at a lower rate. Although this selectivity was not problematic in estimating $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ for Chinook salmon, compositions estimated from gillnet sampling do not reflect true population proportions.

In 2004, length and sex composition of captured Chinook and chum salmon varied by mesh size. Male and female Chinook salmon were caught in similar numbers in the both the large and small mesh nets. Female Chinook salmon caught on the Holitna River were on average approximately 35 mm larger than the males (Appendix A2). Male chum salmon were caught at a much higher rate in both the large and small mesh nets compared to the female chum salmon. Only three female chum salmon were captured in the large mesh nets. On average, the female chum salmon were approximately 10 mm smaller than the males (Appendix A3).

In 2004, ages were not determined for either Chinook or chum salmon as part of this project. Ages were, however, determined at the Kogrukluk River weir, representing a much larger sample of fish entering the Holitna River drainage.

DISCUSSION

Accurate estimation of the abundance of salmon in the Holitna River, and the proportion of salmon that enter the Holitna River drainage and migrate past the Kogrukluk River weir, requires that the fish captured and radio-tagged during gillnet sampling are representative of the run with respect to temporal abundance, size and sex composition, and final spawning destinations. These conditions are difficult to evaluate because it is not known if the sample collected at the Kogrukluk River weir, which the gillnet sample can be compared to, is representative of the true population parameters. Where possible, diagnostic tests were used to evaluate conditions necessary for unbiased estimation and adjustments to estimation procedures to minimize bias were used where prescribed. Field sampling efforts were designed to obtain a sample representative of the true population and to collect data to support evaluation of how well samples represented the population. Initial sampling schedules for this study were based on Kogrukluk River weir data, with a time lag incorporated to reach the weir. This year, however, sampling schedules were based on actual average run timing observed at the capture site for both species. This would maximize the chance that migrating salmon would be captured and marked in proportion to true population parameters, and minimize bias that might be incurred using weir return data.

The proportional distribution of Chinook and chum salmon in the Holitna River drainage followed previous year's findings: a large proportion of Chinook salmon and small proportion of chum salmon spawned above the Kogrukluk weir (Table 6; Figures 6 and 7). Chum salmon spawning above the weir continued to show significantly earlier run timing than chum salmon migrating to the remainder of the drainage. This same pattern was seen in previous years of this study, prompting additional efforts this season to assure radio tags were deployed over the entire span of the run and in proportion to run strength. The tagging schedule was based on run timing seen in previous three years of the study, and the tagging rate was changed to a systematic sampling method in an attempt to reduce bias throughout the tagging season. In addition, the season continued into August when, it was felt, that the run was nearly over based on daily catches and declining CPUE rates. The similar proportions seen with these additional steps collaborates the proportions seen in Chinook and chum salmon in the first three years of the study.

While an estimate of abundance for chum salmon was achieved this year, it was only possible to calculate a viable estimate in two out of the four years of this project (Table 7). The difficulty in obtaining an estimate is directly due to the low proportion of Holitna River chums that actually migrate above the Kogrukluk River weir to spawn. With the majority of the chums spawning in the mainstem Holitna and other areas of the drainage, it became quite evident that the Kogrukluk River weir does not provide a precise indicator of total Holitna River run strength. Additionally, it appears the majority of Kogrukluk River bound chum salmon have earlier run timing than chum salmon spawning elsewhere in the drainage, and hence represent an even lower proportion of Holitna River chums as the season progresses.

Accurate and unbiased abundance estimates for Chinook salmon were achieved in each year of the study (Table 7). Contingency tests indicated that sampling methods were largely unbiased with respect to bank of capture and run timing in each year of the project, and biases detected for length and sex could be addressed by stratification prior to estimating abundance.

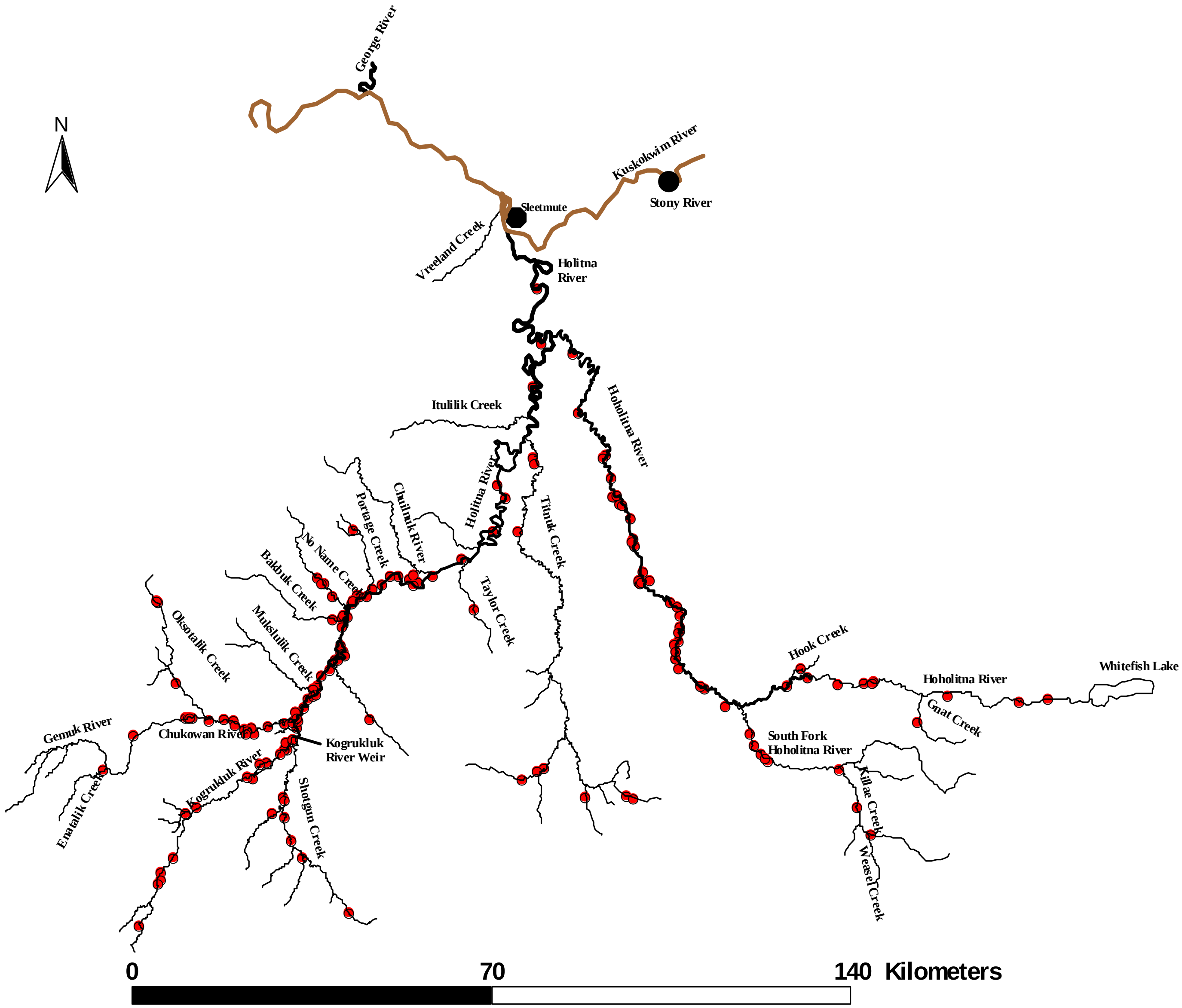


Figure 6.–Map of Holitna River drainage showing final locations of radio-tagged Chinook salmon as determined from aerial surveys, 2004.

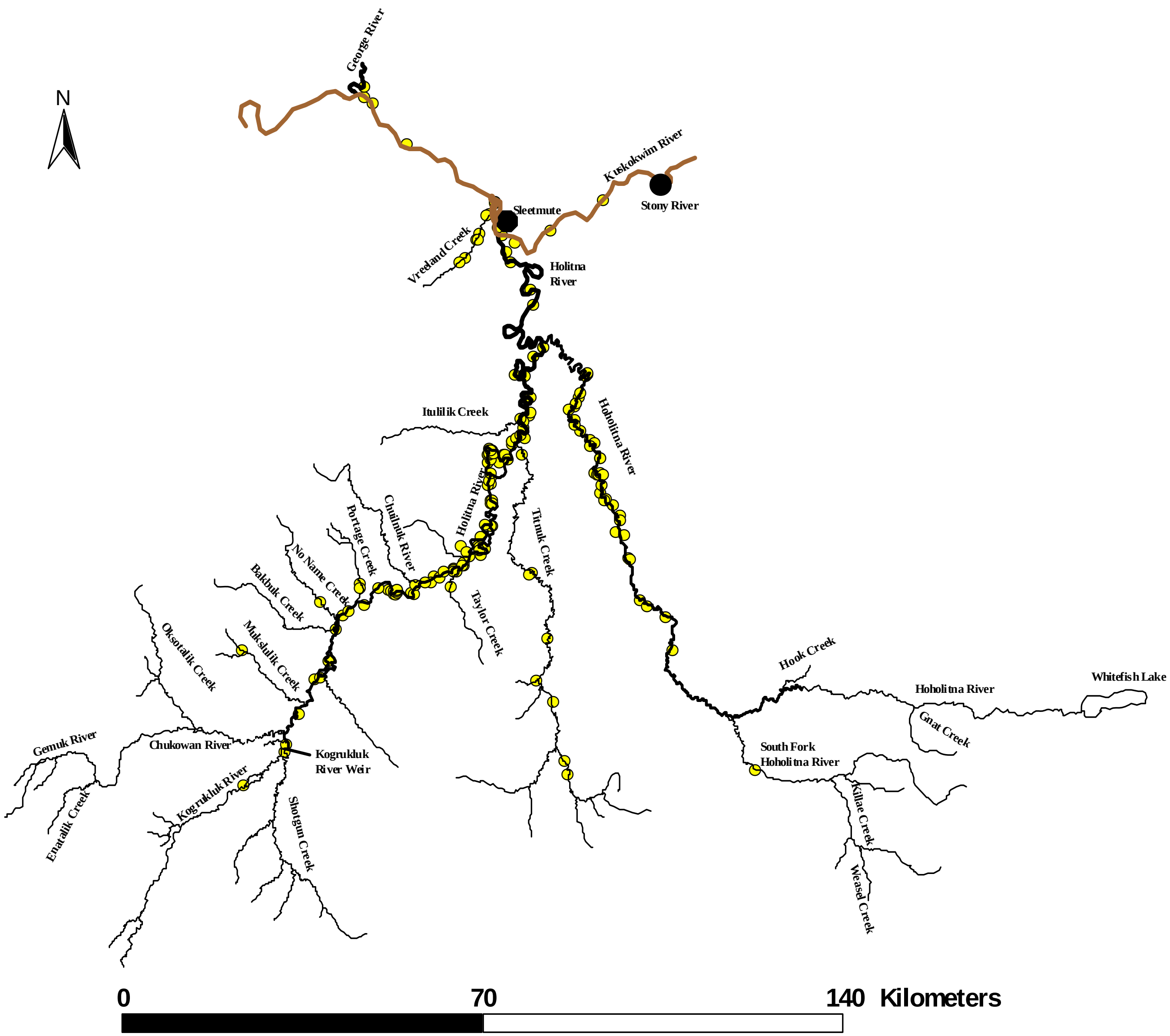


Figure 7.–Map of Holitna River drainage showing final locations of radio-tagged chum salmon as determined from aerial surveys, 2004.

This was the first year that bank orientation bias at the capture site was seen in the Holitna River chum salmon. The final spawning destination of Hoholitna River (east) or Holitna River (west) was dependent on bank of capture. This was not a problem early in the season, but as the summer progressed water levels dropped substantially due to the unseasonably hot and dry weather. The low water level made the east bank less desirable for fish migrating upstream, and subsequently, the catches in the middle of the river channel increased substantially. In contrast to east/west orientation, bank orientation was not detected for fish migrating above the Kogrukluk weir and fish migrating to the remainder of the drainage, so we calculated an estimate of abundance, despite having detected bank orientation late in the run. While potential for bias in the abundance estimate exists, due to the bank orientation, it was our opinion that the potential size of the bias would not be large relative to the large standard error we expected for the abundance estimate.

Two estimates of the proportion of Holitna River chum salmon that passed the Kogrukluk River weir were calculated. The smaller of the two estimates, which was based on an estimate of abundance using a temporally stratified estimator, is recommended as the more reliable of the two numbers.

Aerial radio-tracking surveys indicated proportions of radio-tagged fish that spawned in the Chukowan River showed variability over the years of the study for Chinook salmon (Figure 8), while it also showed that the Chukowan River constituted a very low portion of the entire chum salmon escapement, with no radio tagged chum salmon found in the Chukowan River this year (Figure 9). The radio-tagged proportions of Chinook salmon spawning in the Hoholitna River remained very similar over all years of this study (Figures 8 and 9), but varied by more than a factor of 2 for chum salmon.

Information from the mainstem Kuskokwim River Chinook salmon radiotelemetry project that is operated concurrently to this study in 2002 through 2004 (Stuby 2003-2005) can be used for comparison to estimates from this project, keeping in mind that abundance estimates are not completely independent. The lack of independence is due to radio-tagged fish from the Kuskokwim mainstem project being used in conjunction with radio-tagged fish from the Holitna project to estimate abundance in the Holitna River. Additionally, the count of Chinook at the Kogrukluk River weir was used to estimate abundance for both projects. The percentage of fish radio-tagged in the mainstem Kuskokwim River that migrated into the Holitna River was fairly consistent and large (42-48%) across years. Chinook salmon abundance estimates for the mainstem Kuskokwim River, upriver from the Aniak River, were 100,733 fish in 2002, 103,131 fish in 2003, and 146,839 in 2004 (Stuby 2005). The Holitna River abundance estimates follow similarly, with the exception of 2004, where our abundance estimate of 81,961 exceeds the mainstem project tagged proportion by 8% (56% of total abundance).

The parameters in this study were estimated making the assumptions that the population was tagged in a representative manner and that tagging did not alter the fish's behavior (final spawning destination). Although handling effects were not examined in this study, it is worth noting the effectiveness of using radio telemetry in Chinook and chum salmon studies of similar purpose. Throughout this project, experience and committed resources changed in a manner that positively affected the ability to determine important parameters of the study. With the combination of persons gaining experience in tagging fish and more tracking stations being deployed to cover the test area, the number of radio-tagged fish that were lost (either the radio

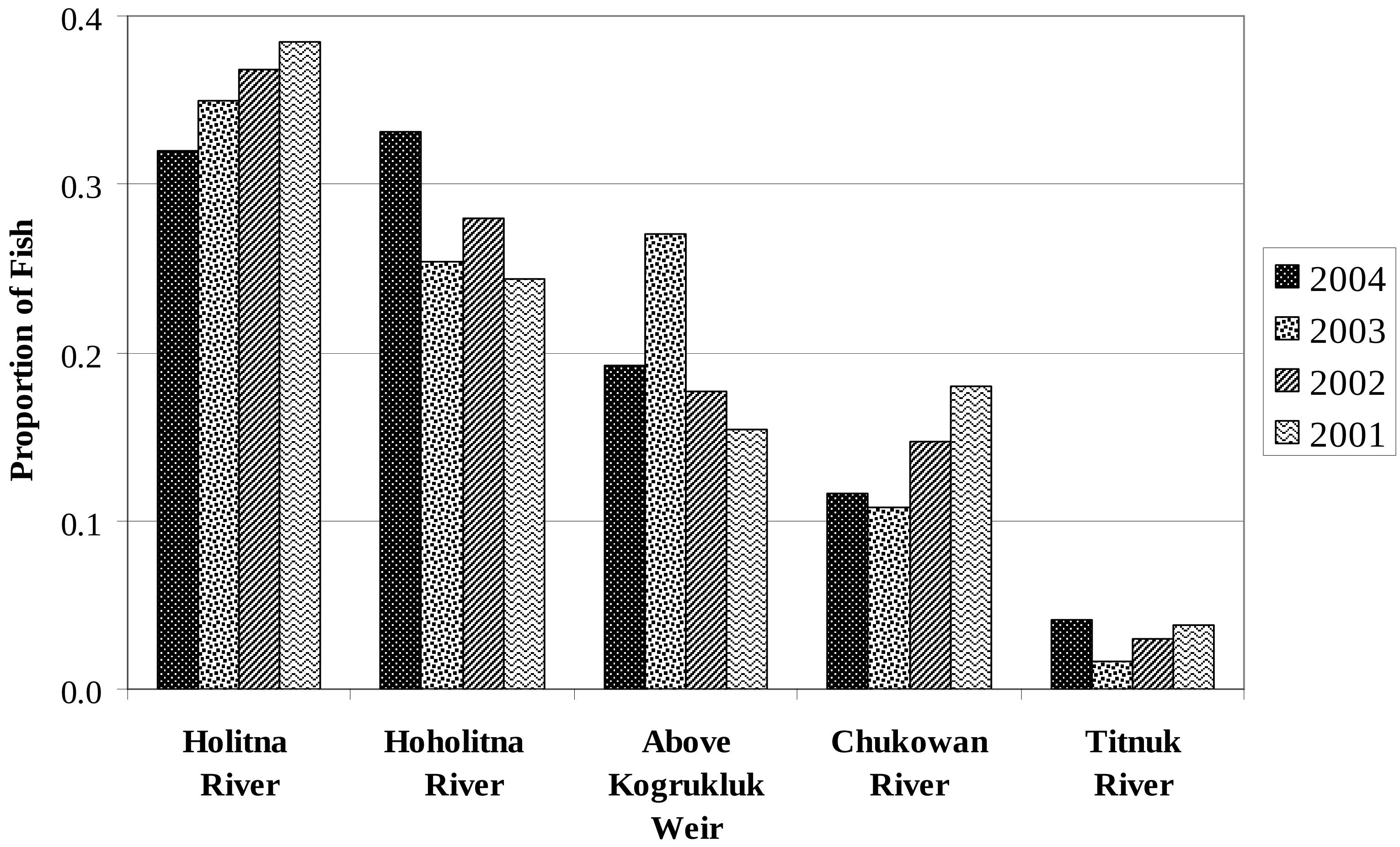


Figure 8.–Proportion of radio-tagged Chinook salmon that were located in the Holitna River drainage, Hoholitna River drainage, above the Kogrukluk River Weir, Chukowan River drainage, and the Titnuk River drainage, 2001-2004. Proportions were calculated from radio-tagged Chinook salmon located during aerial surveys and thus do not include all fish that migrated upstream.

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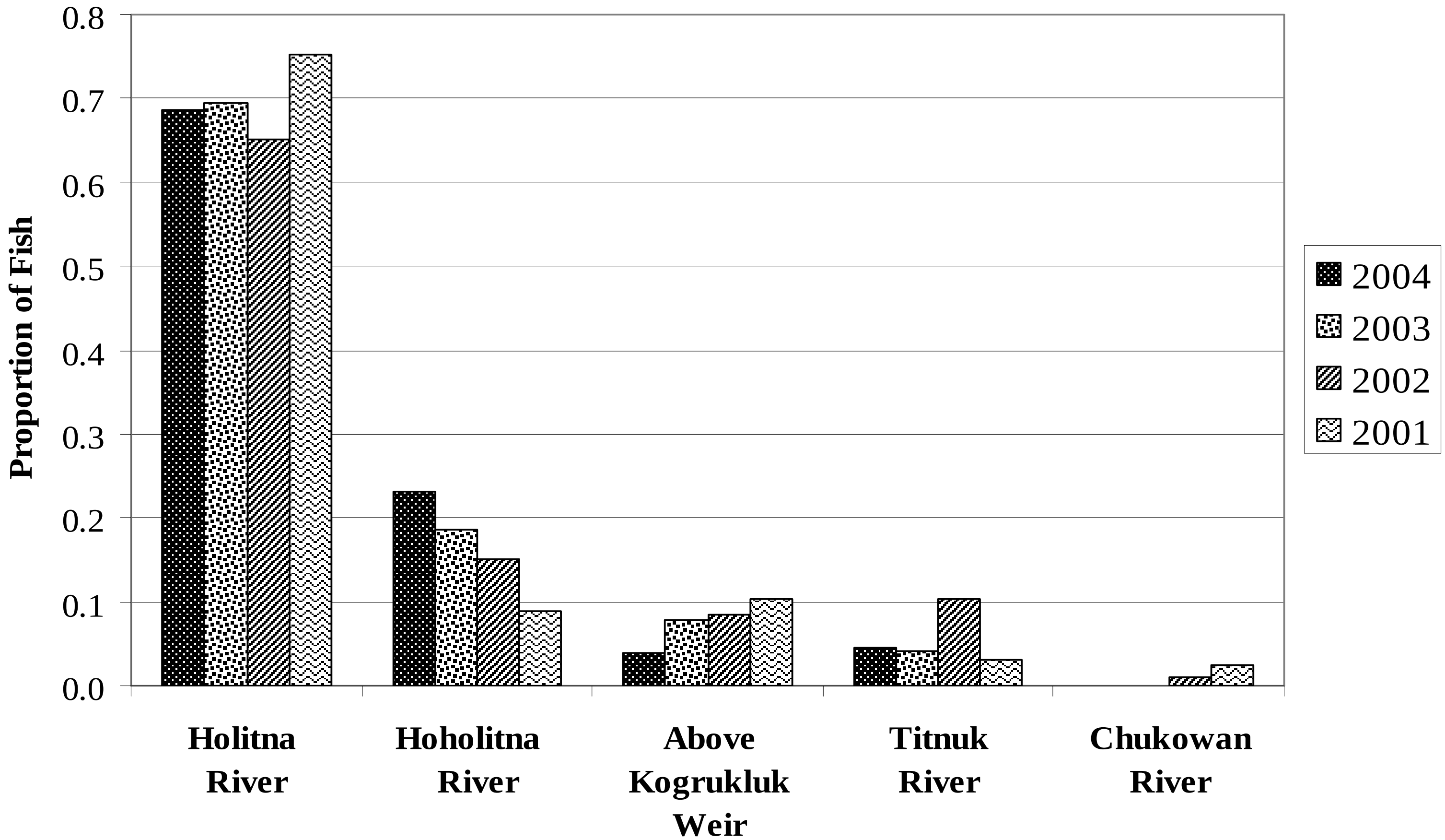

Figure 9.–Proportion of radio-tagged chum salmon that were located in the Holitna River drainage, Hoholitna River drainage, above the Kogrukluk River weir, Titnuk River drainage, and the Chukowan River drainage, 2001-2004. Proportions were calculated from radio-tagged Chinook salmon located during aerial surveys and thus do not include all fish that migrated upstream.

tag failed, fish regurgitated the radio tag, radio-tagged fish backed out of the system and was not found, or completely unknown) decreased from a high of 7% in 2001 to 0% in 2004 for Chinook salmon. Chum salmon went from a 6% failure rate in 2001 to 1% in 2004. The ability to determine the final spawning destination was directly attributed to the combination of tracking stations and aerial radio tracking surveys giving the ability to determine the final destination of each fish. In most years and locations, the tracking stations had a very high detection rate of radio–tagged fish (95-100% in 2004), which might cause one to evaluate the importance of using aerial radio tracking to determine final destinations. However, it is worth noting that radio tracking stations, as with most electronic equipment, may experience failures at unknown or inopportune times. While this did not occur in 2004, it did occur in 2003, and without aerial radio tracking to back up the tracking station data, considerable and insurmountable problems would have been faced. In addition, the aerial surveys have provided a more detailed picture of which tributaries are the important spawning areas than what one would have received from the stationary tracking towers on their own.

The goal of sport fishery management is to maintain a reliable level of opportunity for anglers to participate in the fisheries throughout the season while ensuring escapement needs are met. Prior to this project, management of the Holitna River drainage relied on sporadic creel surveys and data from the Kogrukluk River weir, without knowing the effectiveness of the weir as an escapement indicator or the impacts of the fishery on escapement in the system. This project helped to elucidate the effectiveness of the weir at indexing total system-wide escapement, as well as reveal the importance of many other tributaries in the Holitna River drainage. With the increase in sport fisheries in recent years, sport fishery managers will be better able to maintain a reliable level of opportunity for anglers throughout the season as well as seasons to come.

CONCLUSIONS

1. This study successfully addressed project objectives for Chinook salmon: the proportion of Chinook salmon spawning upstream from the weir and the spawning abundance in the entire drainage were both estimated in all four years of the study. This was successful primarily because of the relatively large proportion of the run that spawned above the Kogrukluk River weir and the similar run timing of Kogrukluk fish compared to fish spawning in other parts of the drainage. In addition, the large number of radio-tagged Chinook salmon that migrated from the Kuskokwim River project in the latter three years of the study significantly increased the number of radio-tagged Chinook salmon in the river which enabled more precise estimates and greater diagnostic testing power.
2. This study successfully addressed the project objectives of estimating the proportion spawning upstream from the weir and the spawning abundance in the entire drainage for chum salmon in 2002 and 2004; however, the project was unsuccessful in accomplishing these objectives in 2001 and 2003, and in the years estimation was successful, the estimates suffered from poor precision. The sporadic achievement of these objectives and poor precision of the estimates were a result of both small numbers of radio-tagged chum salmon migrating through the weir and a consistently earlier run timing of Kogrukluk bound fish compared to fish spawning in other parts of the drainage.

3. The results of all four years of this study suggest that the Kogrukluk River weir provides a good index of Chinook salmon returns to the Holitna River drainage, due to ample and consistent proportions of the returns migrating through the weir and run timing that is similar to other areas of the drainage. In contrast, small proportions of returning chum salmon migrate past the Kogrukluk River weir, coupled with early run timing of Kogrukluk River bound chum salmon, indicates that the weir provides a less reliable indicator of run strength and/or composition for the Holitna River drainage.

RECOMMENDATIONS

The results of this study have shown that the Holitna River supports large spawning populations of Chinook and chum salmon, and annual monitoring of these populations is warranted. However, continuation of this project as it is currently designed is not recommended. For Chinook salmon, escapement counts from the Kogrukluk River weir adequately index total abundance in the Holitna River drainage. In addition, estimates of inriver abundance from the mainstem mark-recapture and radiotelemetry study (Stuby 2005) provide a more comprehensive account of annual run strength in the Kuskokwim River drainage and the contribution of the Holitna River to the total run and it is recommended that those efforts be continued.

For chum salmon, if estimating total abundance in the Holitna River drainage is desired in the future, alternative mark-recapture designs that do not rely exclusively on second event samples from the Kogrukluk River should be considered.

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APPENDIX A

Appendix A1.–Daily fishing effort, catch, number of radio tags deployed, CPUE and weighting factor, for Chinook and chum salmon in the Holitna River, 2004.

Date	Total effort (min)	Effort by mesh size (min) 5.75 in	8.0 in	Number Chinook Caught	Number Chinook Tagged	Number Chum Caught	Number Chum Tagged	Chinook CPUE (Catch/hr)	Chum CPUE (Catch/hr)	Chinook Weighting Factor	Chum Weighting Factor
12-Jun	209	148	61	1	1	1	0	0.3	0.3	0.3	-
13-Jun						Did Not Fish					
14-Jun	203	142	61	2	1	1	0	0.6	0.3	0.7	-
15-Jun	213	151	62	0	0	1	1	-	0.3	-	0.4
16-Jun	206	60	146	1	1	0	0	0.3	0.0	0.4	0.0
17-Jun	210	61	149	1	1	1	0	0.3	0.3	0.3	0.0
18-Jun	215	63	152	1	1	1	1	0.3	0.3	0.3	0.4
19-Jun	210	64	146	2	1	1	0	0.6	0.3	0.7	0.0
20-Jun						Did Not Fish					
21-Jun	207	61	146	6	3	8	2	1.7	2.3	0.7	1.5
22-Jun	195	51	144	8	4	5	2	2.5	1.5	0.7	1.0
23-Jun	208	62	146	4	2	6	2	1.2	1.7	0.7	1.1
24-Jun	213	64	149	11	3	3	1	3.1	0.8	1.2	1.1
25-Jun	209	61	148	16	4	4	2	4.6	1.1	1.4	0.8
26-Jun	214	58	156	8	2	5	2	2.2	1.4	1.4	0.9
27-Jun						Did Not Fish					
28-Jun	207	61	146	3	1	13	4	0.9	3.8	1.0	1.2
29-Jun	208	59	149	8	6	12	6	2.3	3.5	0.5	0.8
30-Jun	208	59	149	15	5	17	6	4.3	4.9	1.0	1.1
01-Jul	198	50	148	4	1	12	3	1.2	3.6	1.5	1.6
02-Jul	207	61	146	7	3	17	5	2.0	4.9	0.8	1.3
03-Jul	208	62	146	8	2	16	6	2.3	4.6	1.4	1.0
04-Jul						Did Not Fish					
05-Jul	210	65	145	8	3	10	3	2.3	2.9	0.9	1.3

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Date	Total effort (min)	Effort by mesh size (min) 5.75 in	Effort by mesh size (min) 8.0 in	Number Chinook Caught	Number Chinook Tagged	Number Chum Caught	Number Chum Tagged	Chinook CPUE (Catch/hr)	Chum CPUE (Catch/hr)	Chinook Weighting Factor	Chum Weighting Factor
06- Jul	205	59	146	8	3	7	3	2.3	2.0	0.9	0.9
07- Jul	202	61	141	10	3	17	7	3.0	5.0	1.2	1.0
08- Jul	215	63	152	7	1	14	5	2.0	3.9	2.4	1.0
09- Jul	213	62	151	9	2	19	10	2.5	5.4	1.5	0.7
10- Jul	210	64	146	6	1	19	8	1.7	5.4	2.1	0.9
11- Jul						Did Not Fish					
12- Jul	213	67	146	5	1	16	6	1.4	4.5	1.7	1.0
13- Jul	209	63	146	3	1	11	6	0.9	3.2	1.0	0.7
14- Jul	211	60	151	2	1	18	8	0.6	5.1	0.7	0.8
15- Jul	204	60	144	0	0	19	7	0.0	5.6	0.0	1.1
16- Jul	208	62	146	1	1	17	7	0.3	4.9	0.3	0.9
17- Jul	205	61	144	2	1	14	4	0.6	4.1	0.7	1.4
18- Jul						Did Not Fish					
19- Jul	209	62	147	3	1	12	4	0.9	3.4	1.0	1.1
20- Jul	207	61	146	2	1	14	6	0.6	4.1	0.7	0.9
21- Jul	209	63	146	3	0	19	7	0.9	5.5	0.0	1.0
22- Jul	211	64	147	1	0	17	6	0.3	4.8	0.0	1.1
23- Jul	208	61	147	2	1	11	5	0.6	3.2	0.7	0.8
24- Jul	208	63	145	0	0	19	8	-	5.5	-	0.9
25- Jul						Did Not Fish					
26- Jul	205	100	105	1	1	15	5	0.3	4.4	0.4	1.2
27- Jul	206	61	145	1	0	6	1	0.3	1.7	-	2.3
28- Jul	206	62	144	1	0	1	1	0.3	0.3	-	0.4
29- Jul	208	62	146	0	0	3	2	-	0.9	-	0.6

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Date	Total effort (min)	Effort by mesh size (min)		Number Chinook Caught	Number Chinook Tagged	Number Chum Caught	Number Chum Tagged	Chinook CPUE (Catch/hr)	Chum CPUE (Catch/hr)	Chinook Weighting Factor	Chum Weighting Factor
		5.75 in	8.0 in								
30- Jul	208	145	63	0	0	7	4	-	2.0	-	0.7
31- Jul	206	146	60	0	0	9	3	-	2.6	-	1.2
1-Aug						Did Not Fish					
2- Aug	209	146	63	0	0	6	2	-	1.7	-	1.1
3- Aug	204	145	59	0	0	4	2	-	1.2	-	0.8
4- Aug	206	145	61	2	1	4	2	0.6	1.2	0.7	0.8
5- Aug	206	145	61	0	0	6	2	-	1.7	-	1.2
6- Aug	207	146	61	0	0	2	1	-	0.6	-	0.8
7- Aug	209	146	63	0	0	6	3	-	1.7	-	0.8

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Appendix A2.–Catch and length statistics for Chinook salmon sampled in the Holitna River and radio-tagged Chinook salmon that migrated into the Holitna River from the Kuskokwim River chinook salmon project, 2004.

	Holitna River			Kuskokwim River
Statistic	All Meshes	5.75 in	8.0 in	All Gear[a]
All Fish				
Number caught	183	81	102	107
Male	76	39	37	67
Female	107	42	65	40
Percent male	42%	48%	36%	63%
Mean length (mm)				
All (SD)	786(110)	733(112)	828(88)	N/A
Male (SD)	765(107)	734(105)	797(100)	N/A
Female (SD)	801(110)	731(120)	846(75)	N/A
Length Range (mm)				
Male	510-1000	550-1000	510-990	470-1015
Female	570-1045	570-930	585-1045	550-970
Radio-tagged fish				
Number tagged	65	26	39	107
Male	29	13	16	67
Female	36	13	23	40
Percent male	45%	50%	41%	63%
Mean length (mm)				
All (SD)	782(116)	729(122)	817(99)	756(131)
Male (SD)	763(121)	749(132)	775(113)	723(126)
Female (SD)	797(112)	708(112)	847(78)	811(124)
Length range (mm)				
Male	510-1000	565-1000	510-990	470-1015
Female	570-1045	570-910	700-1045	550-970

[a] Gear types used in the Kuskokwim River Chinook salmon project included mesh drift gillnets and fish wheels.

Appendix A3.–Catch and length statistics for chum salmon by mesh size in the Holitna River 2004.

Statistic		All Meshes	5.75 in	8.0 in
All Fish				
Number caught		465	399	66
	Male	380	317	63
	Female	85	82	3
Percent male		82%	79%	95%
Mean length (mm)				
	All (SD)	591(32)	588(30)	613(31)
	Male (SD)	593(33)	589(31)	615(30)
	Female (SD)	582(26)	583(26)	570(40)
Length Range (mm)				
	Male	505-680	505-680	540-680
	Female	505-650	505-650	530-610
Radio-tagged fish				
Number tagged		180	180	0
	Male	145	145	0
	Female	35	35	0
Percent male		81%	81%	N/A
Mean length (mm)				
	All (SD)	588(31)	588(31)	N/A
	Male (SD)	588(32)	588(32)	N/A
	Female (SD)	585(25)	585(25)	N/A
Length range (mm)				
	Male	505-660	505-660	N/A
	Female	550-650	550-650	N/A

APPENDIX B

Appendix B1.–Data files used to estimate parameters of the Chinook and chum salmon abundance estimates in the Holitna River drainage, 2004.

Data File	Description
2004 Holitna Master.xls[a]	Excel spreadsheets with consolidated sampling, aerial, and tracking station data. File also includes daily catch information, including CPUE, fishing effort, and tagging rate.

[a] Data files have been archived at the Alaska Department of Fish and Game, Research and Technical Services, Anchorage, Alaska 99518; and are available from the author, Division of Sport Fish, 1300 College Road, Fairbanks, Alaska 99701.