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Assessment of Chinook, Chum, and Coho Salmon Escapements in the Holitna River Drainage Using Radiotelemetry, 2001-2003

Final Report for Study 01-141
USFWS Office of Subsistence Management
Fishery Information Service Division

by
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June 2004

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
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. 04-07

ASSESSMENT OF CHINOOK, CHUM, AND COHO SALMON ESCAPEMENTS IN THE HOLITNA RIVER DRAINAGE USING RADIOTELEMETRY, 2001-2003

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ABSTRACT

From 2001 to 2003 a radiotelemetry study was performed in the Holitna River drainage to estimate the proportion of chinook salmon *Oncorhynchus tshawytscha*, chum salmon *O. keta,* and coho salmon *O. kisutch* returning to the Holitna River drainage that passed through the Kogrukluk River weir, and to estimate the abundance of chinook, chum, and coho salmon escaping into the Holitna River drainage. Chinook, chum, and coho salmon were captured 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 surveys of the Holitna River drainage. Estimates of chinook salmon abundance in each year were: 25,405 fish in 2001, 42,902 fish in 2002 and 42,013 fish in 2003. The proportion of chinook salmon past the weir in each year were: 0.26 in 2001, 0.23 in 2002 and 0.27 in 2003. A useable estimate of chum salmon abundance was only produced in 2002. The 2002 estimate of chum salmon abundance was 542,172 fish. The proportion of chum salmon past the weir in 2002 was 0.09. Estimates of coho salmon abundance in each year were: 63,442 fish in 2001 and 157,277 fish in 2002; an estimate of coho salmon abundance was not produced in 2003. The proportion of coho salmon past the weir in each year was: 0.31 in 2001 and 0.08 in 2002. Radio-tagged chinook, chum, and coho salmon were located in numerous areas throughout the Holitna River drainage. Chinook and coho salmon predominantly spawned in first and second order tributaries, and most chum salmon spawned in the mainstem Holitna River. Numbers of radio-tagged fish located upstream from Nogamut, a proposed replacement site for the Kogrukluk River weir, indicated that larger proportions of the total runs for all three species would be enumerated if the weir were moved to this location.

Key words: abundance, chinook salmon, chum salmon, coho salmon, escapement, esophageal radio tags, Holitna River, king salmon, Kogrukluk River, Kuskokwim River, mark-recapture, *Oncorhynchus keta, Oncorhynchus kisutch*, *Oncorhynchus tshawytscha,* 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 salmon fishery 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 (37%) of the total subsistence salmon catch. The 10-year average (1992–2001) annual subsistence harvest of chinook salmon was 83,621 fish, which was greater than the average annual incidental commercial harvest of 37,480 chinook salmon for the same period (Ward et al. 2003).

Coho salmon *O. kisutch* are the most important species in the commercial fishery in terms of both harvest and value to the fishers. Catches since 1992 have averaged 501,018 coho salmon annually with a range of 32,251 - 1,099,865 fish (Ward et al. 2003). Traditionally, coho salmon

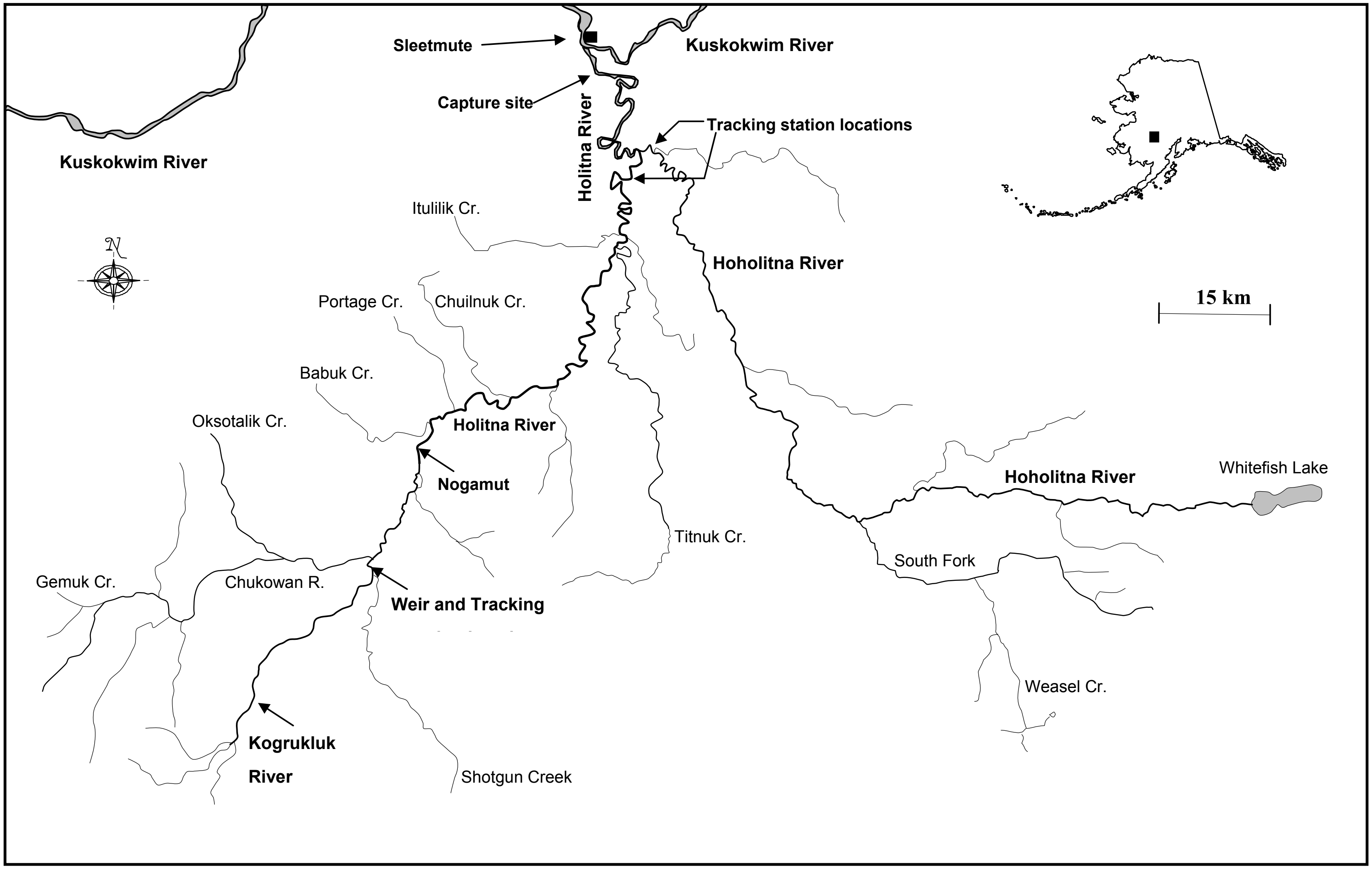

Figure 1.-Map of Holitna River drainage demarcating the capture site, tracking stations, and Kogrukluk River weir, 2003.

were not utilized as a subsistence resource to the extent chinook salmon were because of poor drying conditions during fall when coho salmon are present, but their importance has grown in places as freezers have become more available. In 2001, subsistence users harvested 31,686 coho salmon and harvests averaged 34,322 fish annually from 1992 to 2001. Weak returns of coho and chum salmon in 1997 and 1998 resulted in a federal declaration of economic disaster for communities along the Kuskokwim River and heightened the need for information on coho salmon returns.

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 1992 to 2001 averaged 238,105 chum salmon annually and ranged from 21,893 to 707,212 fish. In 2001, returns were poor and only 21,893 chum salmon were reported harvested in the commercial fishery and 55,371 fish in the subsistence fishery. From 1992 to 2001 the average annual chum salmon subsistence harvest was 66,017 fish (Ward et al. 2003). Sport fishing participation and harvest for all salmon species on the Kuskokwim River drainage are relatively low with five year (1998-2002) average annual harvests of 977 chinook, 132 chum and 1,868 coho salmon, which were approximately 1%, 0.1% and 1.6% of the total inriver harvest of these species respectively (Burr 2004). The Kisaralik, Kwethluk, Aniak, and Holitna rivers account for the majority of angler effort.

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 be "yield concerns" based on very poor runs and harvests since 1997, and expected poor runs in the near future. The term "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. In-season management relies on run-strength indices from commercial catch data, test fisheries, and informal reports from subsistence fishers.

In-season 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 only limited information. Aerial spawning-ground surveys have been the most cost-effective means of monitoring salmon escapements, but their usefulness is limited because of the uncertainty in their relationship to actual abundance (Burkey et al. 2000). Moreover, the aerial surveys are conducted sporadically in many systems because visibility is often limited by tannins, seasonal high water events, and/or glacial silt. Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations. Throughout the three years of this study seven ground-based projects were conducted in the Kuskokwim River drainage. Of these ground based projects, only 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 (ADF&G *In prep)*.

The Holitna River is considered one of the most important systems producing chinook, chum, and coho salmon in the Kuskokwim drainage. In addition to these salmon species the Holitna

River system supports small spawning populations of pink salmon *O. gorbuscha* and sockeye salmon *O. nerka* (Burr 1999). 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. The established escapement goals for the Kogrukluk River weir are 5,300-14,000 chinook, 15,000-49,000 chum, and 13,000-28,000 coho salmon (ADF&G *In prep)*.

Because the Kogrukluk River represents such a small percentage of available spawning habitat in the Holitna River drainage, the validity of using the Kogrukluk River weir as a reliable index for the Holitna River drainage escapement was questioned. 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 third year of a three-year project designed to extend current escapement monitoring activities on the Kogrukluk River by estimating the proportion of Holitna River chinook, chum, and coho 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, chum, and coho salmon runs. This information will assist fisheries managers in identifying and quantifying harvestable surpluses of salmon for subsistence, sport and commercial user groups.

OBJECTIVES

The original objectives of this study were to:

1. estimate the proportions of chinook, chum, and coho salmon migrating up the Kogrukluk River (past the weir)
2. estimate the abundance of chinook, chum, and coho salmon escaping into the Holitna River drainage by proportional expansion of the Kogrukluk River weir counts
3. document chinook, chum, and coho salmon spawning locations

In 2001 an additional project task was to:

1. evaluate two methods of tag attachment for coho salmon, esophageal-implanted and externally-attached radio tags, to determine which allowed the highest rate of sustained upriver movements and tag retention.

In 2003 the study objectives were revised to reflect the fact that the coho salmon component of the study had been removed.

METHODS

CAPTURE AND TAGGING

In all years of the study chinook, chum, and coho 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 difficult to locate because the lower portion of the Holitna River is deep (1.0–7.5 m), wide (approximately 75–200 m), generally has poor water visibility (<1–2 m), and has relatively slow flow through a meandering channel. No local knowledge of other suitable drift areas was available because subsistence drift gillnets are typically only fished in the mainstem Kuskokwim River. Sampling was conducted six days each calendar week for chinook, chum, and coho salmon. In 2003, chinook and chum salmon were sampled from June 10 to July 29. Chinook and chum salmon were targeted at the same time because local knowledge and the 2001 radiotelemetry study suggested that chum salmon begin to enter the Holitna River within a few days of the arrival of chinook salmon (Wuttig and Evenson 2002). In 2001 and 2002, coho salmon were sampled during a second sampling period of August through mid-September.

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, fixing the amount of time a net was fished each day over the duration of the run, and if necessary adjusting the tagging rate to distribute the tags over the entire span of the run and in proportion to run strength.

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
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

In 2003, the small-mesh nets (nets 1 and 3) were fished for 45 minutes each day, and the large mesh nets (2 and 4) were fished for 150 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. In 2001

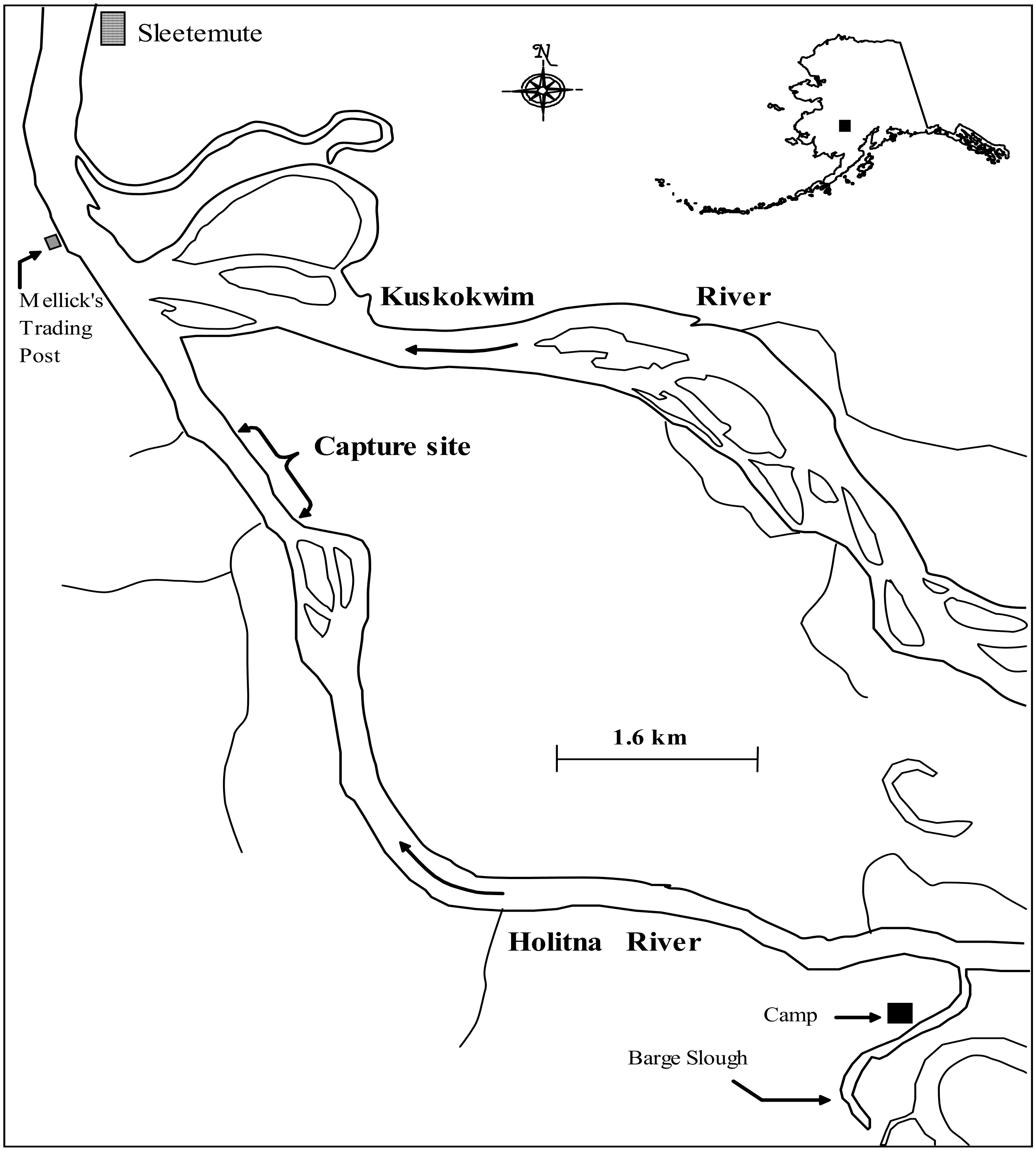

Figure 2.-Map of the confluence of the Holitna and Kuskokwim rivers demarcating the capture site. The bracketed arrows show the upper and lower ends of the sampling reach in 2001-2003.

and 2002, the small mesh nets were fished for 30-60 minutes each day, while the large mesh nets were fished for 90-120 minutes each day. 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.

In 2001 and 2002, coho salmon were captured using the same techniques and drift site used to capture chinook and chum salmon with two exceptions: 1) only the 5.75-in mesh, 150-ft long gillnet (net 1) was used; and, 2) the waning daylight dictated that gillnetting could generally only occur four hours prior to, and one hour after darkness.

Once a salmon became entangled in the drift 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 MEF and sex was determined from external characteristics. Three scales were removed from the left side of the 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). 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).

Sample size objectives varied for each year of the study. In 2001, sample size objectives were to tag 130 fish of each species, in 2002 those goals were modified to reflect the objective of 130 tags for chum and coho salmon, and 65 tags for chinook salmon. In 2003, 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. Quarterly tagging goals were established based on the 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. The tagging goal in the first quarter of the run was to put out 25% of the radio tags, in the second quarter another 25% of the tags and so on. As run intensity varied, the tagging rate was adjusted in an attempt to distribute the radio tags over the entire span of the run and in proportion to run strength.

In 2002 and 2003, chinook salmon were also captured and tagged as part of the mainstem Kuskokwim River radiotelemetry project (Stuby 2003 *In prep*). In each year, a portion of the 500 mainstem radio-tagged fish subsequently migrated to the Holitna River, and were 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 2003 *In prep*).

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

In all years of the study 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

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

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.

In 2001, approximately half of the coho salmon were fitted with externally-mounted transmitters in an effort to compare transmitter effects on upriver movements and tag retention. Externally-attached tags were rectangular and were approximately 45 mm in length, 18 mm in width, 10 mm in depth, and had a trailing antenna 34.5 cm in length. Transmitters were attached to each fish by threading two 0.036-in diameter teflon-coated cables anchored to the body of the transmitter through the fish with a hypodermic needle. Tags were placed immediately lateral to the dorsal fin with the antenna trailing posterior. The protruding cables were fixed with Peterson disk tags (Wuttig and Evenson 2002).

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 tag that was uniquely colored from the other salmon tagging projects on the Kuskokwim River. In 2003 those colors were yellow (chinook) and blue (chum). 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.

Three stationary tracking stations 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 (Figure 1). 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. In addition to the three upriver tracking stations, a fourth station was installed on the mainstem Kuskokwim River near Red Devil (approximately 26 km downstream from the tagging site) in 2002. This station was used to aid in determining the number of fish that backed down into the mainstem Kuskokwim River after being radio-tagged.

Each tracking station was made up of a weather-proof metal housing box that contained an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, 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, or were attached to a limbed tree near the waters edge. The receiver and DCC II 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 of location for each antenna. Cycling through all frequencies required 2-15 min depending on the number of active tags in reception range. Data were periodically downloaded onto a portable computer.

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 2003, aerial tracking surveys of the Holitna River drainage were conducted on 19 and 20 July, and 13 and 14 August. In 2001 and 2002, aerial tracking surveys were conducted similarly, with the addition of flights in September and October to determine the distribution of radio-tagged coho salmon. Generally, locations of radio-tagged fish were determined with an accuracy of ±2 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

The statistical analysis methods were slightly different in each year of the study. Details from 2003 are reported here. For details of previous years' statistical analyses see Wuttig and Evenson (2002) and Chythlook and Evenson (2003).

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 behavior (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
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 three years of the study no commercial fishing occurred near the village of Sleetmute, subsistence fishing was primarily conducted in the mainstem Kuskokwim River, and only limited sport fishing occurred on the Holitna River.

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

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

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 was estimated using the Chapman modification to the Petersen estimator (Seber 1982). Condition 5 was not satisfied, requiring stratification by sex and size for unbiased estimates of abundance. For each stratum, abundance was estimated as:

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

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:

$$\hat{C}_s = \hat{p}_s C \tag{2}$$

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

$$\hat{p}_s = n_{Cs} / n_C \tag{3}$$

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:

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

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:

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

$$\hat{Var}(\hat{N}'_{Hol}) = \frac{\sum_{b=1}^{1000000}(\hat{N}'_{Hol(b)} - \overline{N}'_{Hol})^2}{1000000-1} . \quad (6)$$

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

$$\hat{P}'_{KR} = \frac{C}{\hat{N}'_{Hol}} \ ; \quad (7)$$

and (Mood et al. 1974):

$$\hat{Var}(\hat{P}'_{KR}) = C^2 \frac{\hat{Var}(\hat{N}'_{Hol})}{\hat{N}'^{4}_{Hol}} . \quad (8)$$

For chum salmon, condition 4 was not satisfied because the run-timing (at the capture site) of chum salmon migrating past the weir differed from the run-timing of fish spawning elsewhere in the drainage. To reduce bias associated with unequal tagging rates and fishing effort, each radio-tagged chum salmon was assigned a numeric weight w_i corresponding to 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 then calculated as:

$$\hat{P}^*_{KR} = \frac{\sum_{i=1}^{d}\sum_{j=1}^{n_i} w_i \mathrm{I}(destination)_j}{\sum_{i=1}^{d} n_i w_i} \quad (9)$$

where:

$$w_i = \left(\frac{\overline{h}}{h_i}\right)\left(\frac{X_i/\overline{X}}{x_i/\overline{x}}\right) \quad (10)$$

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*;

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

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

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

h_i = the hours of fishing effort on day *i*;

$\overline{h}$ = 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 can 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:

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

where: N_{KR} = the number of chum salmon observed to have passed the Kogrukluk River weir on days the weir was operational for counting;

The variance of the estimated total Holitna River chum salmon escapement was approximated using (Mood et al. 1974):

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

AGE-SEX- LENGTH COMPOSITIONS OF GILLNET CATCHES

Proportions of captured female and male chinook and chum salmon by age and 25 mm length category were calculated as:

$$\hat{p}_g = \frac{n_g}{n} \tag{13}$$

where:

p_g = proportion of all captured chinook or chum salmon in age or length class g;

n_g = number of captured chinook or chum salmon in age or length class g; and,

n = total number chinook or chum salmon captured.

The variances of the proportions of captured female and male chinook and chum salmon by age and 25 mm length category were calculated as:

$$V\hat{a}r\left(\hat{p}_g\right) = \frac{\hat{p}(1-\hat{p})}{n-1} \tag{14}$$

RESULTS

TAGGING AND FATES OF RADIO-TAGGED SALMON

Specific results from 2003 are presented here. Referenced tables and figures show comparisons among years for chinook and chum salmon. Because coho salmon were not sampled in 2003 those results are presented entirely in Appendix A. For complete details of previous years' results see Wuttig and Evenson (2002) and Chythlook and Evenson (2003).

Chinook Salmon

In 2003, 120 chinook salmon were captured in the Holitna River between June 10 and July 29, and 68 were fitted with radio tags (Figure 3). The largest daily CPUE (fish per hour) of chinook salmon was 3.1 on June 26 (Appendix B1). Radio-tagged chinook salmon ranged in size from 575 to 990 mm MEF.

Of the 68 fish radio-tagged in the Holitna River, four were never located upstream. Of these, two fish were known to have backed out into the Kuskokwim River after tagging, and one tagged fish either expelled its tag or died a short distance upstream from the tagging site (~10 km). There was only one tagged chinook salmon that was never relocated and it was assumed to have either died, migrated to another river, or had a tag that failed after implantation.

After examining all tracking station and aerial flight records, a total of 240 radio-tagged chinook salmon were relocated upstream of the Holitna River and Hoholitna River tracking stations. Of the 240 relocated chinook salmon, 64 were radio-tagged as part of the Holitna river project, while 176 were tagged as part of the related Kuskokwim River chinook salmon radiotelemetry project (Stuby *In prep)*. The total of 240 fish was used to calculate the proportion of chinook salmon passing by the weir and drainage-wide abundance.

Chum Salmon

In 2003, 315 chum salmon were captured between June 18 and July 29 (Figure 4) and 191 were fitted with radio tags. The largest daily CPUE of chum salmon was 5.4 fish per hour on July 28 (Appendix B2.). Radio-tagged chum salmon ranged in size from 510 to 685 mm MEF.

Of the 191 chum salmon that were radio-tagged, 167 were relocated at least once upstream of the Holitna River and Hoholitna River tracking stations. Of the 24 fish that did not migrate upstream 18 backed out and were later found in the mainstem Kuskokwim River. Six fish were never relocated and were assumed to have either died, migrated to other rivers, or had tags that failed after implantation. Only the 167 chum salmon that were known to have migrated upstream were used for parameter estimation.

DISTRIBUTION AND MOVEMENT OF RADIO-TAGGED SALMON

In 2003, the tracking stations on the Hoholitna and Kogrukluk rivers were highly efficient at detecting the passage of radio-tagged chinook and chum salmon (Table 1). However, the Holitna River tracking station had a much lower efficiency due to an untimely battery charging problem that occurred from July 3 – 28. Aerial tracking was very effective for locating radio-tagged chinook and chum salmon. The combination of all tracking stations along with aerial tracking surveys accounted for detection of all radio-tagged chinook and chum salmon that resumed upstream migrations.

The chinook salmon that were tagged in the Holitna River averaged 16.3 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 12.6 days to travel between the tagging site and the weir (Table 2).

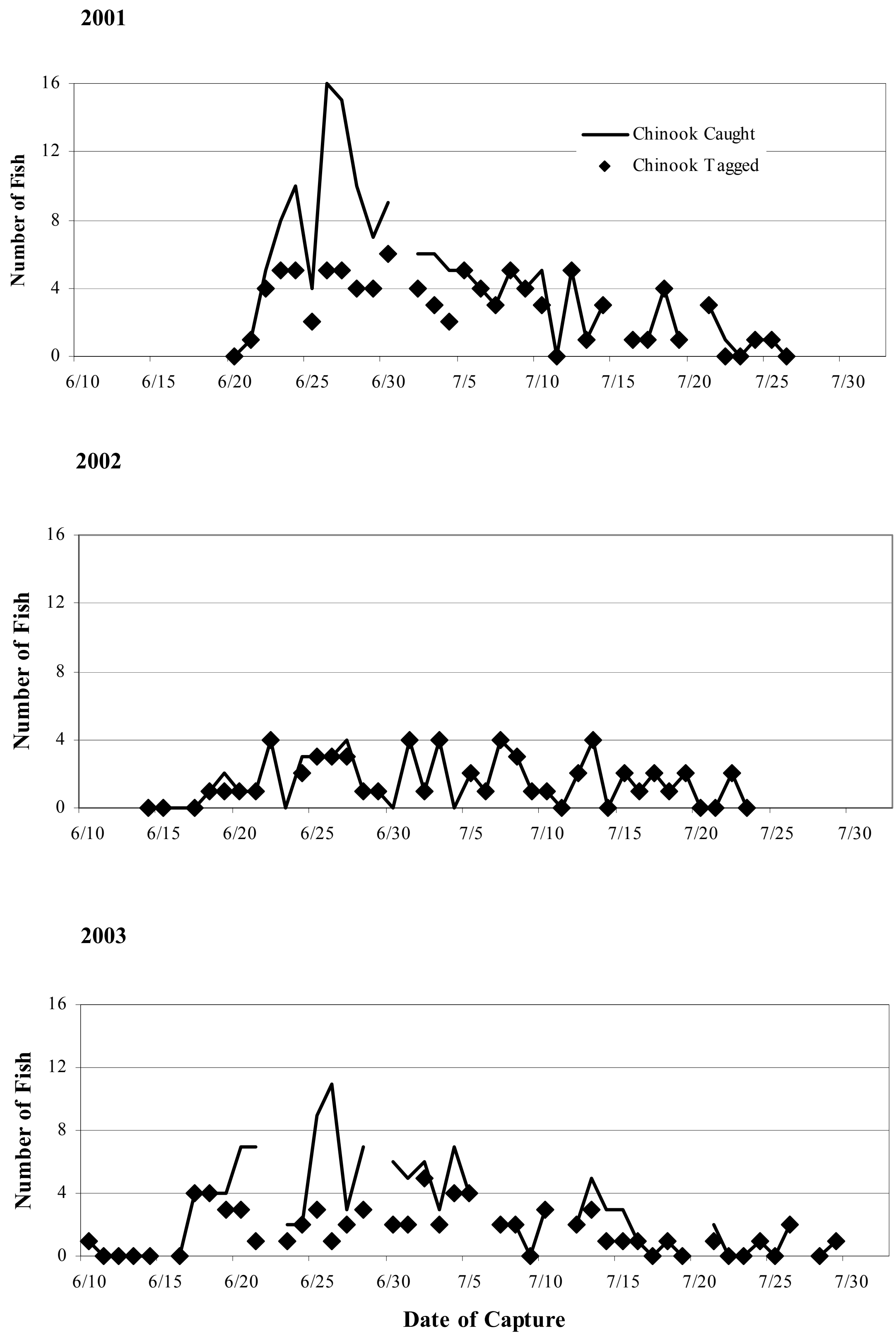

Figure 3.-The daily catch and number of chinook salmon radio-tagged in the Holitna River, 2001–2003.

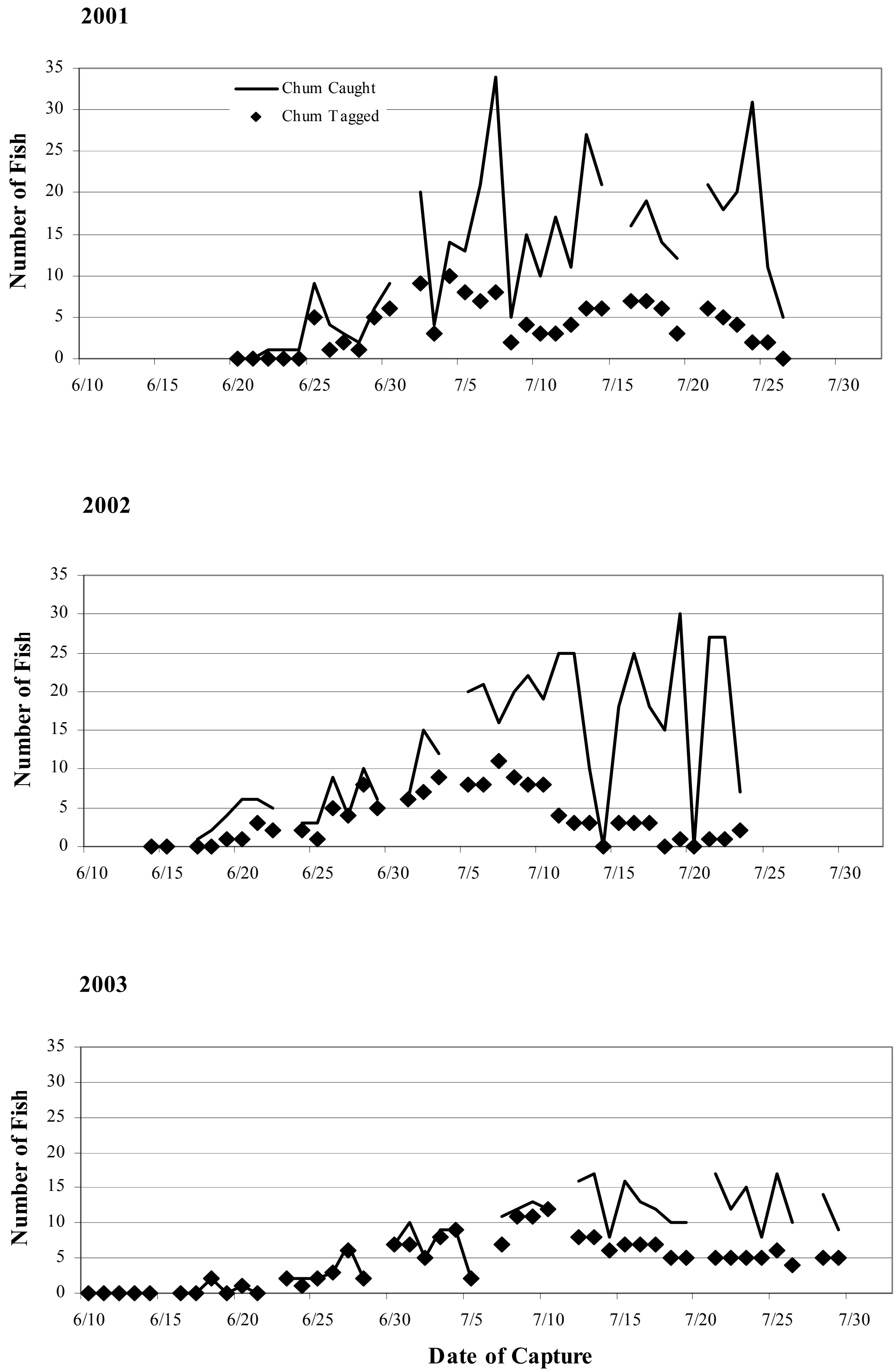

Figure 4.-The daily catch and number of chum salmon radio-tagged in the Holitna River, 2001–2003.

Table 1.-Efficiency of tracking stations and aerial surveys in detecting radio-tagged salmon in the Holitna River drainage, 2001–2003.

Species	Station	2001 Aerial tracking efficiency	2001 Tracking station efficiency	2002 Aerial tracking efficiency	2002 Tracking station efficiency	2003 Total number of tags known to pass site	2003 Number of tags located during aerial surveys	2003 Number of tags logged by tracking station	2003 Aerial tracking efficiency	2003 Tracking station efficiency
Chinook										
	Holitna	85%	100%	81%	99%	174	108	79	62%	45%
	Hoholitna	95%	100%	75%	100%	64	60	62	94%	97%
	Kogrukluk	84%	58%	N/A[b]	100%	72	58	61	N/A[b]	85%
Chum										
	Holitna	96%	100%	76%	98%	125	106	27	85%	22%
	Hoholitna	93%	93%	64%	100%	33	29	33	88%	100%
	Kogrukluk	88%	82%	N/A[b]	100%	13	12	16	N/A[b]	100%
Coho[d]										
	Holitna	94%	87%	97%	86%	-	-	-	-	-
	Hoholitna	45%	100%	71%	82%	-	-	-	-	-
	Kogrukluk	N/A[c]	100%	100%	100%	-	-	-	-	-

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

[b] Number of tags located during aerial surveys and aerial survey efficiency could not be determined because radio tags were removed from chum and chinook salmon captured at the weir.

[c] Number of tags located during aerial surveys and aerial survey efficiency could not be determined because radio tags were removed from coho salmon captured at the weir.

[d] Coho Salmon were not sampled in 2003.

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, 2001-2003.

		2001		2002		2003				
Travel Segment	Species	Number of Radio Tags	Average (days)	Number of Radio Tags	Average (days)	Number of Radio Tags	Average (days)	SD (days)	Min (days)	Max (days)
Tagging site to Hoholitna station (~62 km)	Chinook	20	2.1	37	3.8	66	2.3	2.2	0.6	12.5
	Chum	14	3.0	26	1.2	51	2.5	1.7	1.3	11.9
	Coho	57	3.6	24	6.9	-	-	-	-	-
Tagging site to Holitna station (~68 km)	Chinook	63	3.0	82	7.9	78	3.4	2.7	0.6	16.3
	Chum	118	2.1	104	2.2	29	7.0	8.8	0.4	33.8
	Coho	79	3.4	38	7.8	-	-	-	-	-
Tagging site to Kogrukluk station (~220 km)	Chinook	13	12.5	26	15.3	61	16.3	10.1	5.2	50.8
	Chum	12	9.0	9	11.7	16	12.6	10.0	5.8	34.3
	Coho	30	11.9	5	10.7	-	-	-	-	-
Holitna station to Kogrukluk station (~ 155 km)	Chinook	13	9.5	35	12.1	33	12.8	7.3	5.0	34.8
	Chum	12	6.6	9	6.0	4	5.3	0.6	4.8	6.1
	Coho	30	8.7	5	7.7	-	-	-	-	-

Aerial tracking surveys throughout the Holitna River drainage identified approximate spawning locations for radio-tagged chinook and chum salmon. During aerial surveys approximately 69% of the spawning radio-tagged chinook salmon were located in tributaries off of the mainstem Holitna River, whereas approximately 70% of spawning radio-tagged chum salmon were located in the mainstem Holitna River, indicating the spatial differences in spawning habitat between the two species (Tables 3 and 4).

ESTIMATION OF PROPORTIONS AND ABUNDANCE

Chinook Salmon

The final spawning destination (eastern or western drainage) of radio-tagged chinook salmon was independent of bank of capture (χ^2=1.71; df=2; P=0.43; Table 5). Run timing distributions at the capture site for radio-tagged chinook salmon spawning above the Kogrukluk River weir and those spawning in the rest of the Holitna River drainage were not significantly different (D=0.089; P=0.72; Figure 5). Length distribution of radio-tagged chinook salmon spawning above the Kogrukluk River weir was not significantly different from that of all radio-tagged fish spawning in the drainage (D=0.152, P=0.107; Figure 6). Length distribution of all radio-tagged spawning chinook salmon was not significantly different from all fish sampled at the weir (D=0.072; P=0.36; Figure 6). Chinook salmon ≤580 mm FL were removed from diagnostic testing for sex bias because assignment of sex to these fish is prone to error when examining only external characteristics. After removing the fish ≤580 mm FL, the sex ratios of radio-tagged chinook salmon spawning above the Kogrukluk River weir and those spawning in the rest of the drainage were significantly different (χ^2=10.90; df=1; P<0.01; Table 6). Based on these diagnostics, abundance was estimated by summing estimates for three strata: all fish ≤580 mm FL, males >580 mm FL, and females >580 mm FL.

Of the 244 radio-tagged chinook salmon that migrated up the Holitna River, 64 passed through the Kogrukluk River weir. The estimated proportion of chinook salmon migrating into the Kogrukluk River was 0.27 (95% C.I. = 0.22-0.34), and 11,771 chinook salmon were observed past the weir (Whitmore and Bergstrom 2003). The estimated abundance of chinook salmon in the Holitna River drainage was 42,013 fish (SE=4,981; Table 7).

Chum Salmon

The final spawning destination (eastern or western drainage) of radio-tagged chum salmon was independent of bank of capture (χ^2=2.37; df=2; P=0.31; Table 5). Sex ratios of radio-tagged chum salmon spawning upstream of the Kogrukluk River weir and those radio-tagged fish spawning in all other areas of the drainage were not significantly different (χ^2=2.78; df=1; P=0.10; Table 6); however, only one radio-tagged female chum salmon migrated past the weir.

Run timing at the capture site was markedly earlier for radio-tagged chum salmon spawning above the Kogrukluk River weir than was run timing of those spawning in the rest of the Holitna River drainage (D=0.64; P<0.01; Figure 7). Length distribution of all radio-tagged spawning chum salmon was not significantly different from those that spawned above the weir (D=0.21; P=0.64; Figure 8). However, length distribution of all spawning radio-tagged chum salmon was significantly different from all fish sampled at the weir (D=0.33; P<0.01; Figure 8).

Of the 167 radio-tagged chum salmon that resumed upstream migration after tagging, 13 passed through the weir. During 2003, 23,413 chum salmon were observed past the Kogrukluk River weir (Whitmore and Bergstrom 2003). An estimate of the proportion of Holitna River chum

Table 3.-Number of radio-tagged chinook salmon located in tributaries or sections of the Holitna River drainage during aerial tracking surveys, 2001–2003.

Tributary or River Section	2001	2002	2003
Hoholitna River Drainage			
Mainstem Hoholitna River	15	25	49
South Fork Hoholitna River	4	4	10
Hook Creek	0	1	3
No Name (West of South Fork Hoholitna River)	0	10	0
Weasel Creek	0	0	0
Holitna River Drainage			
Mainstem Holitna River	20	27	74
Kogrukluk River[a]	15	15	54
Shotgun Creek	1	3	10
Mainstem Chukowan River	6	10	19
Oksotalik Creek	2	2	4
Gemuk River	1	1	2
Bairo Creek	2	0	0
Chikulunuk Creek	1	0	0
Enatalik Creek	1	0	1
Portage Creek	2	3	2
Bakbuk Creek	1	0	0
No Name (West side drainage between Babuk and Portage Creeks)	0	1	1
Kiknik Creek	0	2	0
Taylor Creek	0	3	0
Itulilik Creek	1	1	0
Chuilnuk Creek	3	0	5
Mukslulik Creek	1	4	3
Titnuk Creek	0	6	4

[a] Some of the radio tags were removed at the weir, therefore these numbers do not reflect the true number that spawned.

Table 4.-Number of radio-tagged chum salmon located in tributaries or sections of the Holitna River drainage during aerial tracking surveys, 2001–2003.

Tributary or River Section	2001	2002	2003
Hoholitna River Drainage			
Mainstem Hoholitna River	9	16	29
South Fork Hoholitna River	2	0	0
Hook Creek	0	0	0
No Name (West of South Fork Hoholitna River)	1	0	0
Weasel Creek	0	0	0
Holitna River Drainage			
Mainstem Holitna River	80	59	115
Kogrukluk River[a]	12	7	11
Shotgun Creek	1	2	1
Mainstem Chukowan River	3	1	0
Oksotalik Creek	0	0	0
Gemuk River	0	0	0
Bairo Creek	0	0	0
Chikulunuk Creek	0	0	0
Enatalik Creek	0	0	0
Portage Creek	0	0	0
Bakbuk Creek	1	3	0
No Name (West side drainage between Babuk and Portage Creeks)	3	0	0
Kiknik Creek	0	1	0
Taylor Creek	2	2	0
Itulilik Creek	3	3	1
Chuilnuk Creek	3	1	0
Mukslulik Creek	1	1	0
Titnuk Creek	0	11	7

[a] Some of the radio tags were removed at the weir, therefore these numbers do not reflect the true number that spawned.

Table 5.-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, 2003.

Species	Migration Destination	West	Center	East
Chinook[a]	Holitna River (west)	16	19	14
	Hoholitna River (east)	3	9	4
	$\chi^2 = 1.71$; df = 2; P = 0.43			
Chum	Holitna River (west)	48	60	28
	Hoholitna River (east)	14	9	8
	$\chi^2 = 2.37$; df = 2; P = 0.31			

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

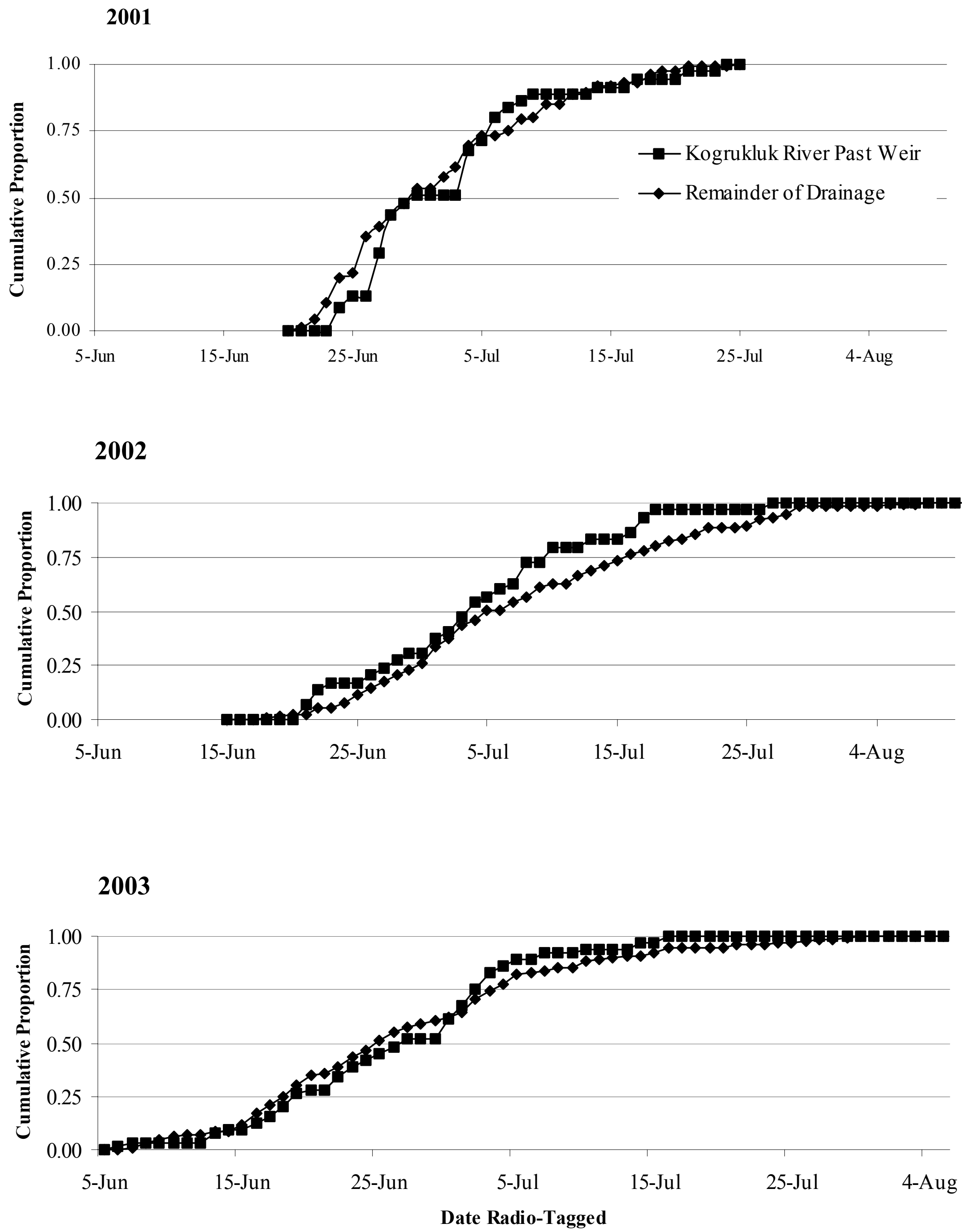

Figure 5.-Migratory timing profile of radio-tagged chinook salmon at the capture site that migrated past the Kogrukluk River weir or migrated to all other areas of the Holitna River drainage, 2001-2003.

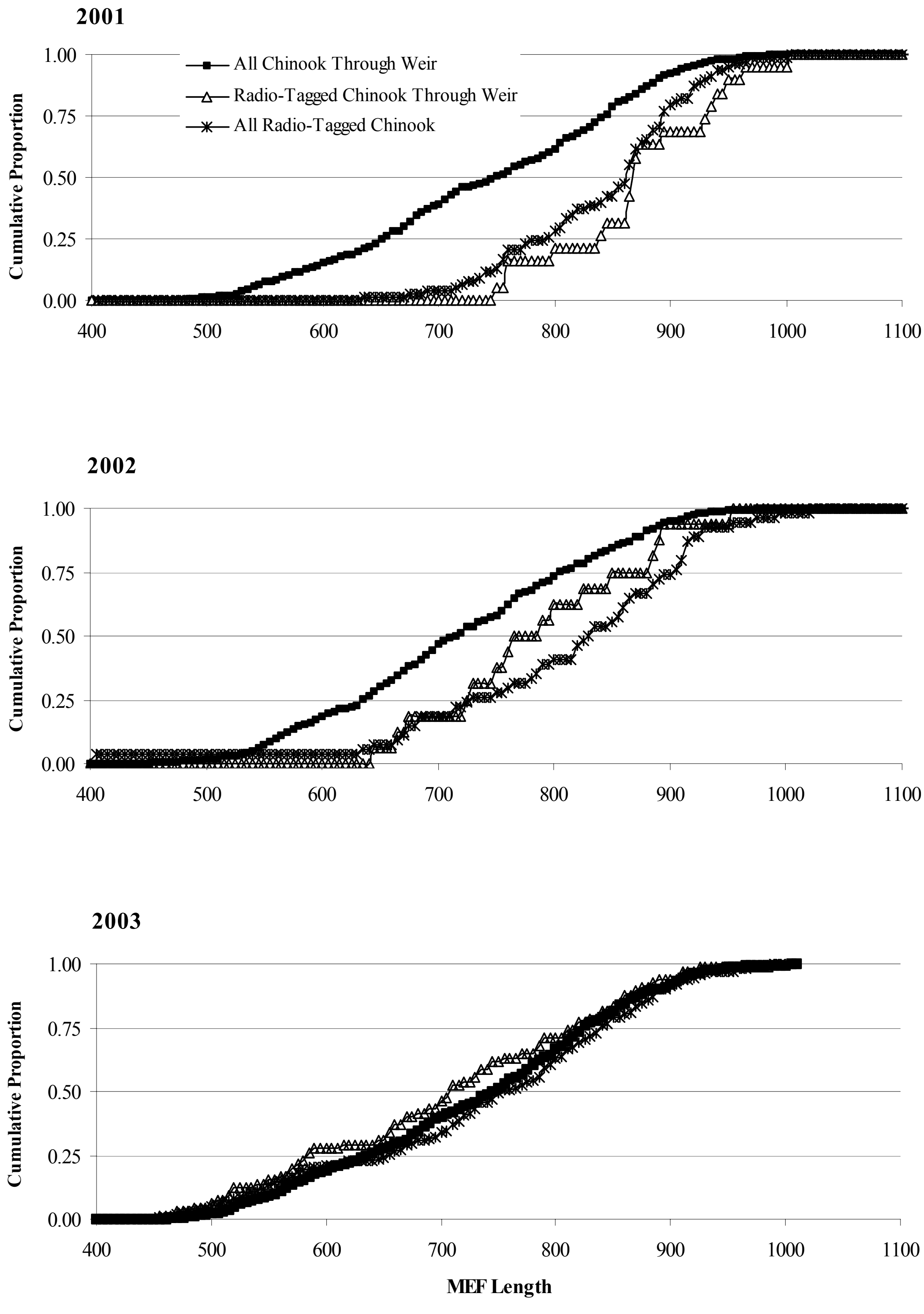

Figure 6.-Cumulative length frequency distributions of all radio-tagged chinook salmon spawning all areas of the Holitna River drainage, all radio-tagged fish spawning above the Kogrukluk River weir, and all fish sampled at the Kogrukluk River weir, 2001-2003.

Table 6.-Number of radio-tagged chinook and chum salmon that migrated to the Kogrukluk River, 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, 2003.

		Spawning Area	
Salmon Species	Sex	Above Kogrukluk River	All other areas of the Holitna River drainage
Chinook			
	Male	39	66
	Female	25	109
	χ^2=10.26; df=1; P=0.001		
Chum			
	Male	12	109
	Female	1	45
	χ^2=2.78; df=1; P=0.10		

Table 7.-Abundance estimates for chinook, chum, and coho salmon in the Holitna River, 2001 – 2003.

	Year		
Species	2001	2002	2003
Chinook	25,405 (SE 6,207)[a]	42,902 (SE 6,334)	42,013 (SE 4,981)
Chum	N/A	542,172 (SE 285,925)	N/A
Coho[b]	63,442 (SE 10,063)[c]	157,277 (SE 56,624)	_

[a] Fish ≥ 650mm only.

[b] Coho were not sampled in 2003.

[c] Fish ≥ 510mm only.

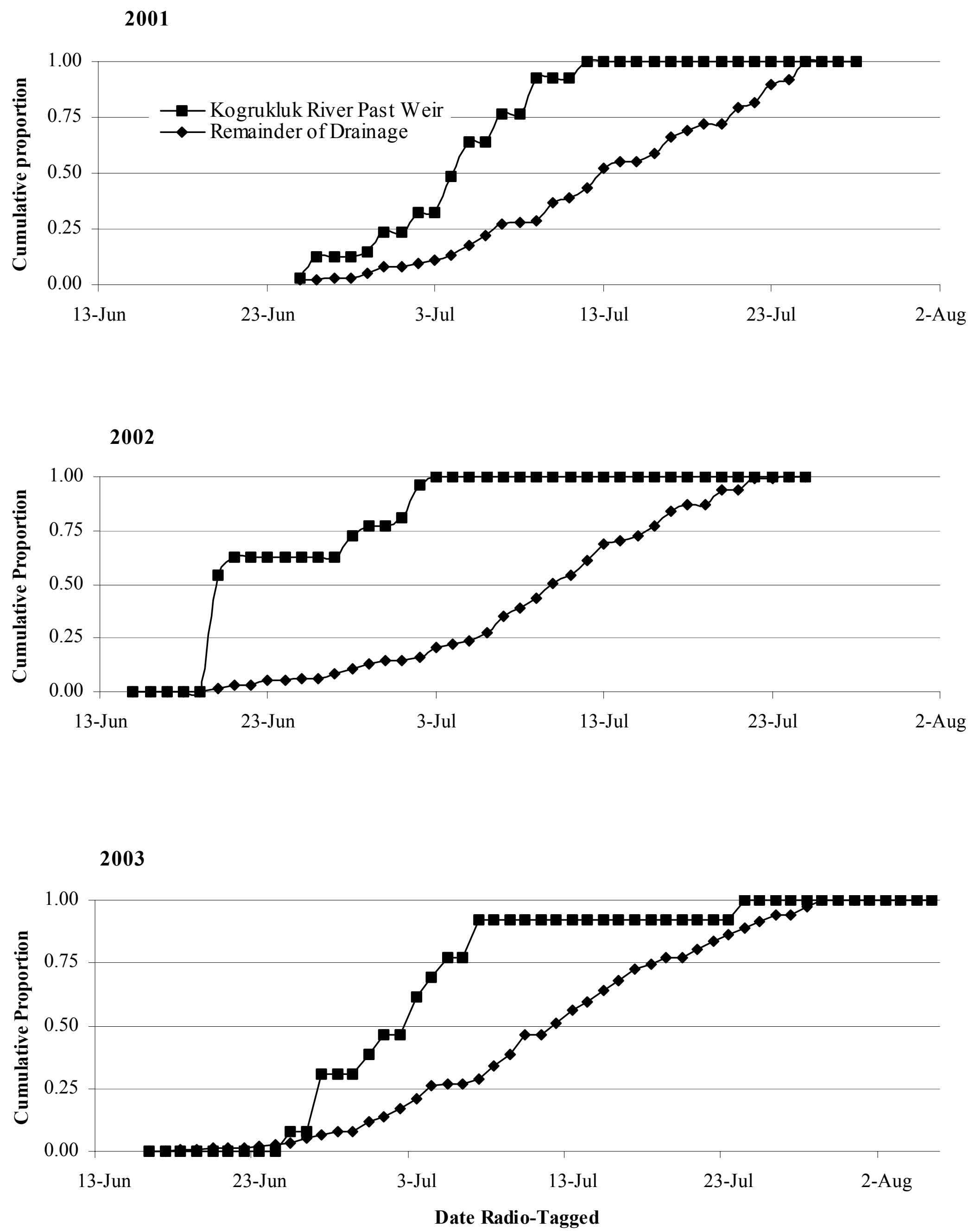

Figure 7.-Migratory timing profile of radio-tagged chum salmon at the capture site that migrated past the Kogrukluk River weir or migrated to all other areas of the Holitna River drainage, 2001-2003.

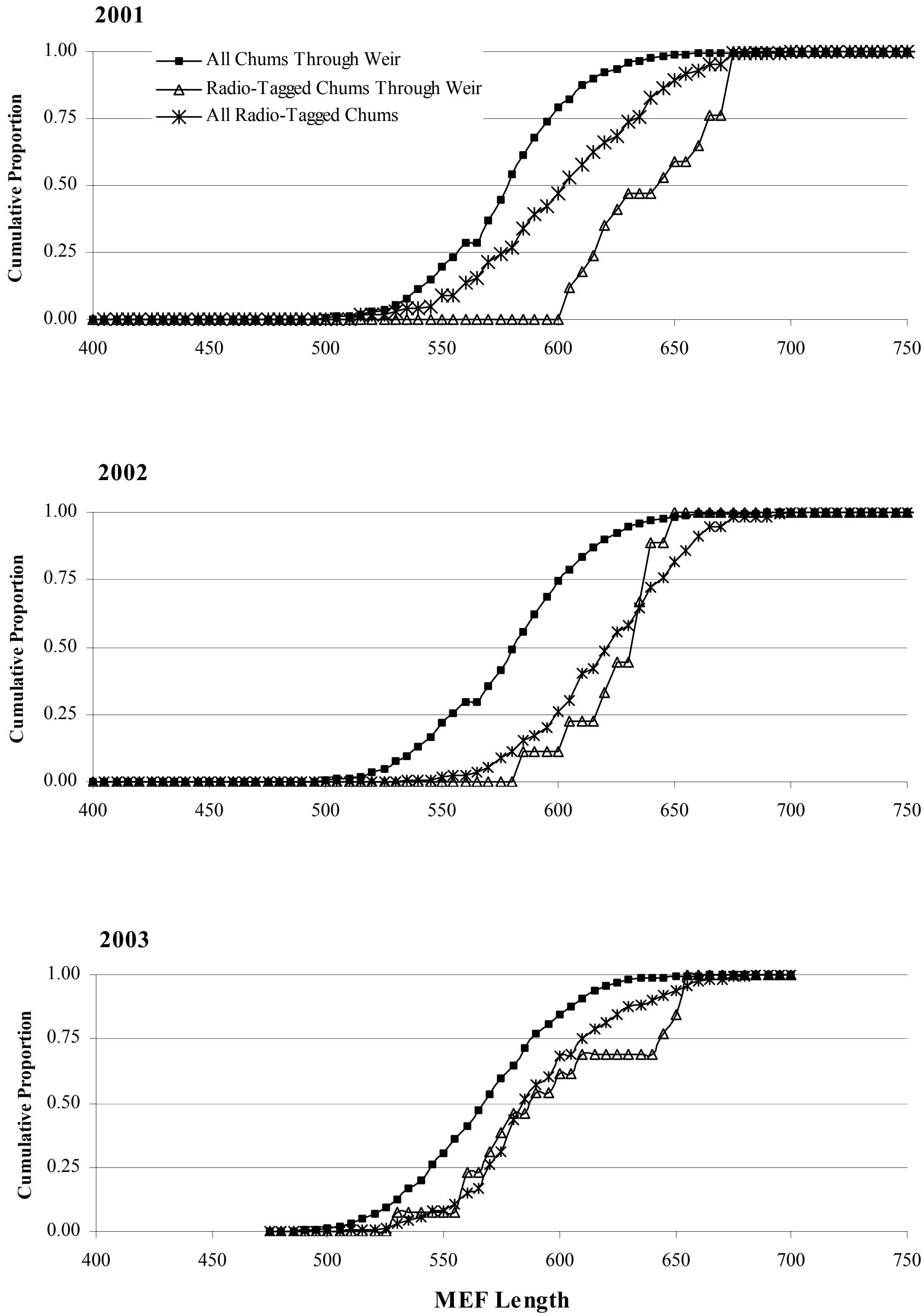

Figure 8.–Cumulative length frequency distributions of all radio-tagged chum salmon spawning all areas of the Holitna River drainage, all radio-tagged fish spawning above the Kogrukluk River weir, and all fish sampled at the Kogrukluk River weir, 2001-2003.

salmon passing the Kogrukluk River weir was not produced because: 1) run timing of Kogrukluk River chum salmon at the tagging site was significantly earlier than other Holitna River stocks; and 2) the relatively high catch observed on the last day of chum salmon tagging strongly indicates that some non-trivial portion of the chum salmon run continued to pass the tagging site after tagging was terminated and these fish had zero probability of being tagged. An estimate of $\hat{P}^{*}_{KR}$ using the prescribed formula would be biased high and no data exists for approximating or correcting for the bias. Because the proportion was not estimated, total abundance of chum salmon in the Holitna River was not estimated. An estimate of abundance using the prescribed formula would be biased low with no method of correcting for the bias.

AGE-SEX-LENGTH COMPOSITION OF CAPTURED SALMON

Diagnostic testing for abundance estimation revealed that gillnet sampling was size-selective for chum salmon, with the smaller size classes captured at a lower rate. The chinook salmon gillnet samples did not exhibit size selectivity. The capture bias towards larger fish indicated that chum salmon compositions estimated from gillnet sampling do not reflect true population proportions.

In 2003, length and sex composition of captured chinook and chum salmon varied by mesh size. The female chinook salmon caught on the Holitna River were on average approximately 35 mm larger than the males (Appendix C1). Female chum salmon were only caught in the small mesh nets, whereas males were caught in both sizes of nets. On average the female chum salmon were approximately 20 mm smaller than the males (Appendix C2).

In 2003, ages were determined for 92 chinook salmon and 289 chum salmon. The majority of returning Holitna River chinook salmon were 5 and 6 year old fish, whereas the majority of chum salmon were 4 year olds (Appendix D1).

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. The sampling schedules in this study were designed to maximize the chance that migrating salmon would be captured and marked in proportion to true population parameters. The methodology used in this study appeared to be an accurate and unbiased way to measure the abundance of chinook and coho salmon in the Holitna River drainage as well as the proportion that enter the Holitna River drainage and migrate past the Kogrukluk River weir. In all three years of the study, the chinook and coho salmon contingency tests illustrated that the sampling was largely unbiased with respect to length, sex, bank of capture and run timing. Accurate measures of chum salmon abundance in the Holitna River and the proportion that entered the Holitna River and migrated past the weir were difficult to devise. Statistically valid abundance and proportional estimates were only produced for one of the three years of the study. Accurate abundance and proportional estimates could not be produced for the other years because significant differences were seen between the run timing and length distribution of chum salmon migrating to the Kogrukluk River. These biases could not be quantified or corrected for.

One of the primary objectives of this project was to determine if estimates of abundance and composition at the Kogrukluk River weir were representative of the returns of chinook, chum, and coho salmon in the Holitna River drainage. The weir count was thought to be representative if: 1) it enumerated a significant portion of the total escapement in the drainage; 2) if the proportion of the total escapement counted at the weir was consistent over time; and, 3) if fish passing by the weir had similar run timing and age, sex, and length composition to fish spawning elsewhere in the drainage. The results from the three years of this study suggest that the Kogrukluk River weir may be a good indicator of chinook salmon returns, but it is likely not a reliable indicator of Holitna River chum salmon returns. All three years indicated that a very small proportion of Holitna River drainage chum salmon spawned above the weir (approximately 5-10%). Run timing patterns and sampling to estimate compositions suggested that there were two temporally defined Holitna River chum salmon stocks, an early and late run. The early run fish were those that were spawning in the headwaters and upper tributaries, such as the Kogrukluk, while the late run fish spawned predominantly in the mainstem. The Kogrukluk River weir primarily counted the early run chum salmon, and therefore was not indicative of the run strength, or composition of late run fish. The proportion of Kogrukluk chum salmon spawners may be even lower than our estimates portray because tagging efforts were stopped before the end of the run in all three years. This was especially true in 2003, when the highest CPUE for chum salmon was recorded on the penultimate day of tagging. The proportions of radio-tagged coho salmon passing the Kogrukluk weir were highly variable between 2001 and 2002; therefore it is difficult to ascertain from this study whether the weir is a reliable indicator of coho salmon returns.

Information from the mainstem Kuskokwim River chinook salmon radiotelemetry project that operated concurrently to this study in 2002 and 2003 (Stuby 2003 *In prep*), corroborate estimates from this study. Chinook salmon abundance estimates for the mainstem Kuskokwim River, upriver from the Aniak River, were 100,733 fish in 2002 and 103,131 fish in 2003. The mainstem chinook salmon study also indicated that 42% in 2002 and 48% in 2003 of the chinook salmon radio-tagged in the mainstem Kuskokwim River, migrated into the Holitna River drainage (radio-tagged fish that migrated up the Aniak River were censored from the total number of chinook salmon tagged due to statistical bias). Our abundance estimates collaborate those results, with 42,902 (43% of total abundance) and 42,013 (41% of total abundance) chinook salmon estimated on the Holitna River in 2002 and 2003 respectively. However, estimates for the Holitna River and mainstem Kuskokwim River are not completely independent as radio-tagged fish from the mainstem project were used to estimate abundance in the Holitna River and the count of chinook salmon at the Kogrukluk River weir were used to estimate abundance in both projects.

A separate and independent study conducted on the mainstem Kuskokwim River estimated inriver abundance of chum, sockeye and coho salmon above the village of Kalskag in 2002 and 2003 (Kerkvliet *In prep a-b*). Mainstem Kuskokwim River chum salmon abundance estimates were 675,659 fish for 2002 and 507,772 fish for 2003. The 2002 Holitna River chum salmon abundance estimate was 542,172 fish and although we did not generate a chum salmon abundance estimate in 2003, the total abundance of chum salmon in the Holtina River in 2003 was likely a minimum of 400,000 fish, based on the data collected and known sources of bias. If our results are compared to the mainstem chum salmon mark-recapture results, it would indicate that approximately 80% of the chum salmon escapement above Kalskag spawns in the Holitna

River drainage; this is unlikely and points to the need to further refine the methods of chum salmon abundance estimation in the Kuskokwim River drainage.

The proportional distribution of chum and chinook salmon throughout the Holitna River drainage remained similar for all three years of the study. The majority of chinook and chum salmon spawned in the Holitna River upstream of Nogamut (Figures 9 and 10). However, a larger proportion of chinook salmon than chum salmon spawned above the weir. The proportional distribution of coho salmon was markedly different between the two years of estimation, likely due to the unexpected high back out rate of radio-tagged fish during the second year. Proportions of fish that spawned in the Chukowan River showed variability over the years of the study for chinook and coho salmon, while it also showed that the Chukowan River constituted a very low portion of the entire chum salmon escapement. The proportions of all species of salmon spawning in the Hoholitna River remained very similar over all years of this study.

The abandoned village site of Nogamut had been proposed as a replacement site for the Kogrukluk River weir. During the three years of this study, the proportions of fish spawning in the Holitna drainage above Nogamut appeared to vary. However, overall results indicated that larger proportions of the total runs for all three salmon species of interest would be enumerated if the weir were moved to this location (Table 8). Due to fiscal and logistic constraints of running a weir on this section of the Holitna River, it is unlikely that the weir will be moved to Nogamut, and instead operations will continue on the Kogrukluk River (D. B. Molyneaux, Alaska Department of Fish and Game, Anchorage, personal communication).

CONCLUSIONS

1. This study successfully addressed project objectives for chinook salmon in 2002 and 2003. The proportion of chinook salmon spawning upstream from the weir and the spawning abundance in the entire drainage was estimated. This was successful largely because of the migration of radio-tagged fish from the Kuskokwim River project, which significantly increased the number of radio-tagged chinook salmon in the river. In 2001, however, we estimated the proportion spawning upstream from the weir and the spawning abundance in the entire drainage for chinook salmon > 650 mm MEF only. This was caused by deploying too few radio tags, as well as tagging too few small size chinook salmon.

2. This study successfully addressed project objectives for chum salmon in 2002. The proportion of chum salmon spawning upstream from the weir and the spawning abundance in the entire drainage was estimated, though low numbers of radio-tagged fish migrated through the weir. In 2001 we did not achieve project objectives for chum salmon, in part due to tagging a disproportionate number of large, predominantly male fish. This along with the small proportion of tags that migrated past the weir prohibited us from correcting for our biased sampling. In 2003 we did not achieve the objectives because we believe that some nontrivial portion of the run had zero probability of being tagged. It is unlikely that the methodology used in this study can be used to consistently estimate total drainage abundance of chum salmon given the marked difference in run timing and composition of fish above the Kogrukluk River weir.

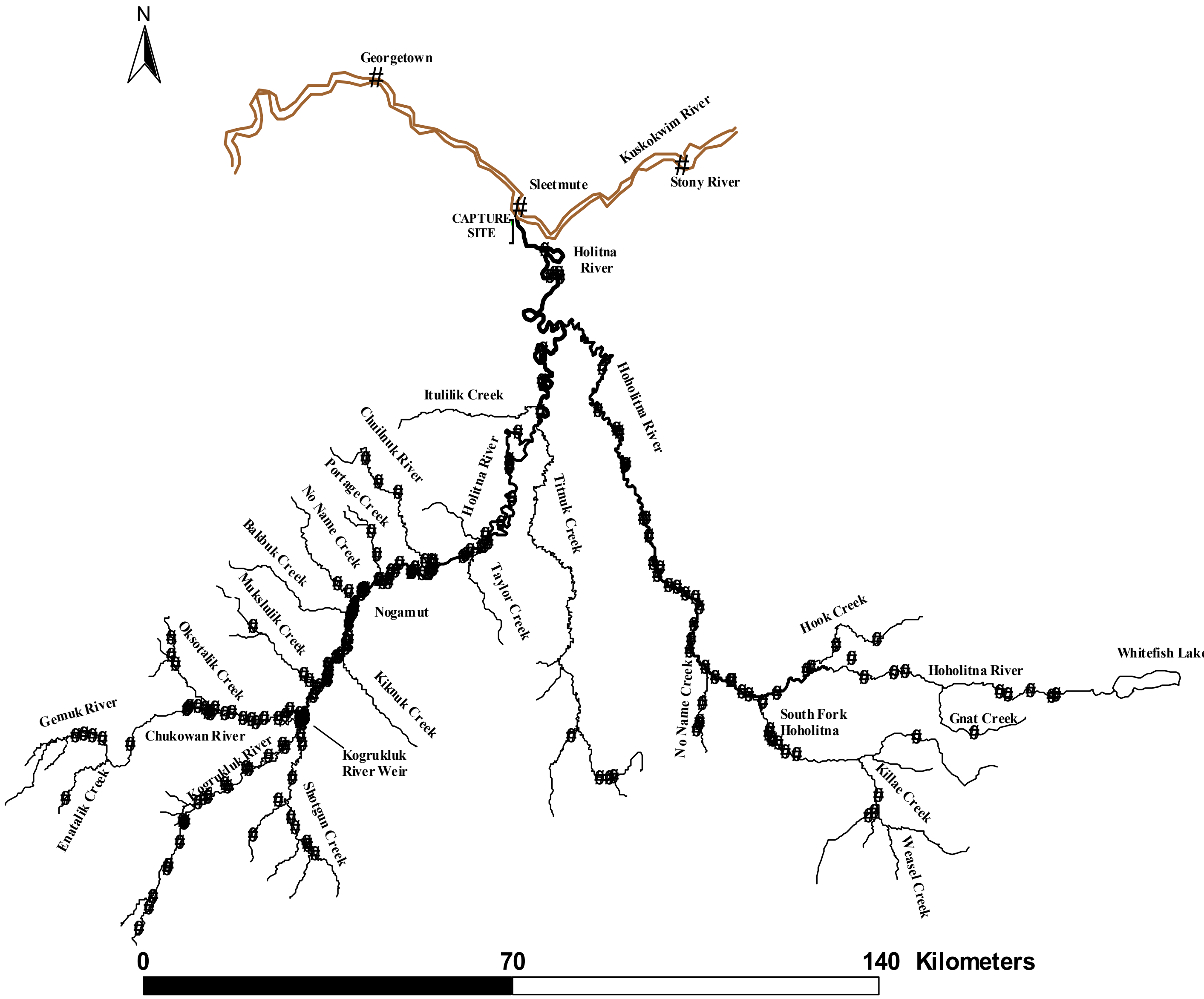

Figure 9.-Map of Holitna River drainage showing final known locations of radio-tagged chinook salmon as determined from aerial surveys, 2003.

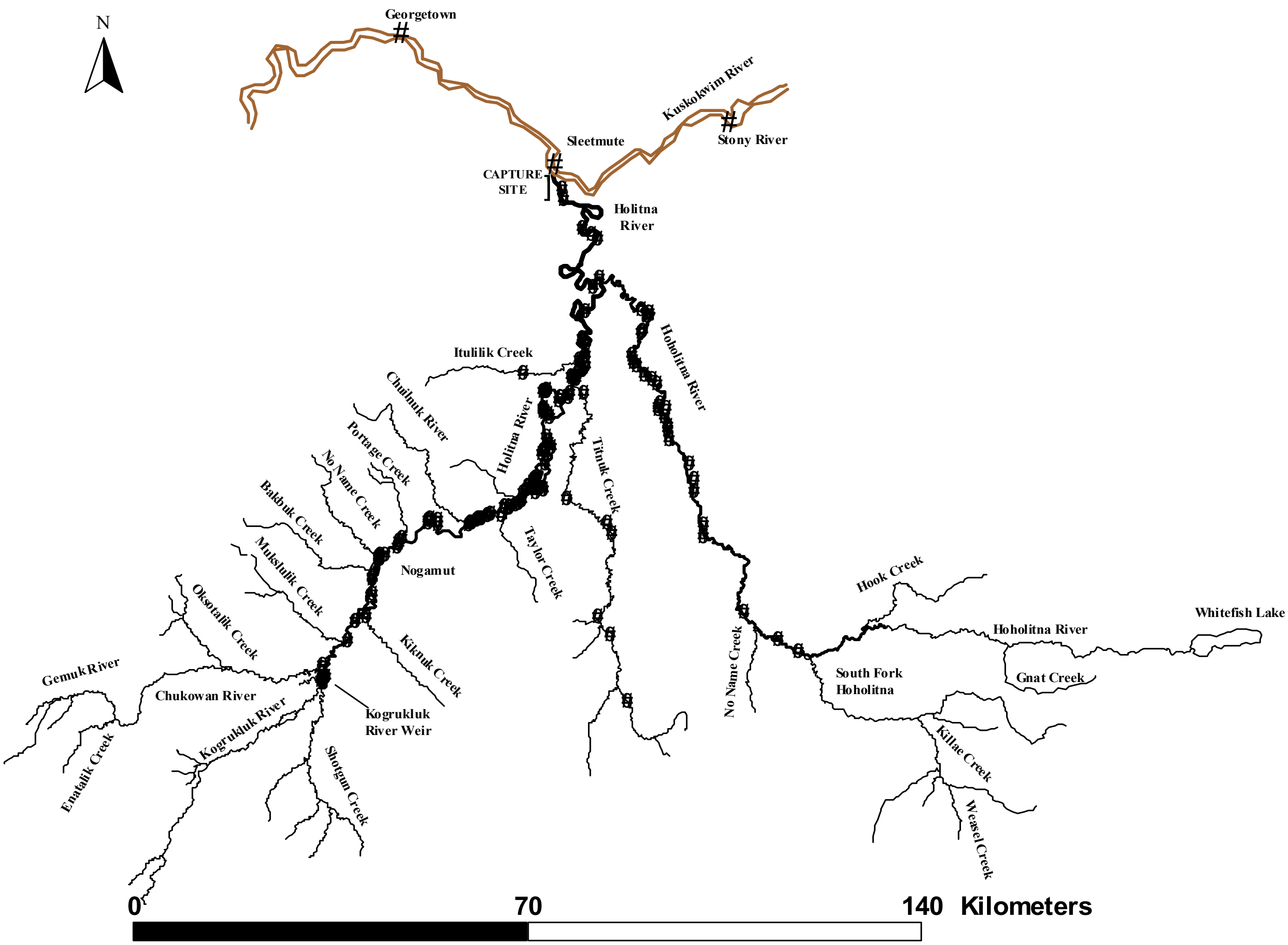

Figure 10.-Map of Holitna River drainage showing final known locations of radio-tagged chum salmon as determined from aerial surveys, 2003.

Table 8.-Number of radio tags and proportion of radio-tagged chinook, chum, and coho salmon in the Chukowan River drainage, Hoholitna River drainage and Holitna River drainage upstream of Nogamut, 2001-2003.

		2001		2002		2003	
Species	Area	Number of Radio Tags Located	Proportion[a]	Number of Radio Tags Located	Proportion[a]	Number of Radio Tags Located	Proportion[a]
Chinook							
	Chukowan River drainage	15	0.17	10	0.07	26	0.11
	Hoholitna River drainage	20	0.26	36	0.24	61	0.25
	Holitna River drainage upstream of Nogamut [d]	39	0.46	40	0.26	86	0.35
	Upstream of Kogrukluk weir	19	0.26	33	0.23	64	0.27
Chum							
	Chukowan River drainage	4	0.02	1	0.01	0	0.00
	Hoholitna River drainage	14	0.10	16	0.14	31	0.16
	Holitna River drainage upstream of Nogamut[d]	36	0.25	20	0.17	21	0.11
	Upstream of Kogrukluk weir	N/A[c]	N/A[c]	9	0.09	N/A[c]	N/A[c]
Coho[b]							
	Chukowan River drainage	16	0.13	1	0.02	-	-
	Hoholitna River drainage	19	0.22	16	0.25	-	-
	Holitna River drainage upstream of Nogamut[d]	58	0.48	10	0.09	-	-
	Upstream of Kogrukluk weir	38	0.31	5	0.08	-	-

[a] Proportions based on aerial survey results, with the assumption that not all radio tags were found.

[b] Coho were not sampled in 2003.

[c] Chum proportions could not be determined.

[d] Includes those fish upstream of weir.

3. This study successfully addressed project objectives for coho salmon in 2001 and 2002. The proportion of coho salmon spawning upstream from the weir and the spawning abundance in the entire drainage was estimated, though in 2002, a large number of fish backed out of the Holitna River, thus reducing the number of fish that could migrate past the weir, and decreasing the precision of the estimate.
4. The results 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 proportions of the returns migrating through the weir and the similarity in run timing and composition of fish passing by the weir compared to fish spawning elsewhere in the drainage. It appears as if the weir may provide an adequate index of coho salmon returns to the drainage as run timing and composition of fish passing by the weir compared to fish spawning elsewhere in the drainage were similar. However, the proportion enumerated by the weir varied substantially between 2001 and 2002. The small sample of radio tagged fish migrating upstream in 2002 and having only conducted the study for two seasons confounded our ability to make definitive statements as to the variability of the coho salmon returns past the weir. Small proportions of returning chum salmon migrated past the Kogrukluk River weir, and run timing and composition of fish passing by the weir are markedly different from fish spawning elsewhere in the drainage in all three years of the study. Thus, the weir likely does not provide a reliable means to estimate run strength and composition for chum salmon the Holitna River drainage.

RECOMMENDATIONS

Precision of the estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ for all species can be improved in subsequent years of this study with slight adjustments to sampling procedures. Based on the 2001 study, Wuttig and Evenson (2002) reported some recommendations for standardizing effort and gear type in order to avoid bias in age/sex/length and run timing. Based on the 2002 study, Chythlook and Evenson (2003) reported some recommendations for future sampling of coho sampling. Those and one new recommendation are provided below:

1. During sampling for chinook and chum salmon, 30 minutes of drift time should be expended each day using the 5.75-in mesh gillnet and 150 minutes expended each day using the 8.0-in mesh gillnet. This should be sufficient to capture adequate numbers of chinook and chum salmon over a broad range of lengths.
2. Radio tags should be distributed across all sizes of salmon such that the length distribution of radio-tagged fish approximates the length distribution of the population. This should be accomplished by tagging chinook salmon caught in both large and small mesh nets, tagging chum salmon caught in the small mesh nets only, and by developing a tagging schedule that apportions radio tags into size classes to ensure that fish of all sizes receive tags.
3. To evaluate the feasibility of placing a weir at Nogamut, a tracking station should be placed at the proposed site. This would allow accurate accounting of all radio-tagged salmon that spawn upstream of Nogamut.

4. To improve the estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ for chum salmon, a larger sample of fish should be radio-tagged. Increasing the number of radio tags available for chum salmon would allow for a more conservative tagging schedule, ensuring that tags are available for deployment throughout the entire run. Further, more tags will allow for more robust testing of estimator assumptions as well as improved precision of the estimate of total abundance.
5. Any future sampling of coho salmon should utilize 150 min of drift time each day with a 5.75-in mesh gillnet to catch an adequate number of coho salmon of all sizes present in the population.
6. For future studies of coho salmon, a new capture site should be used that is farther upstream in the Holitna River. This could potentially decrease the chances of capturing and tagging coho salmon that may be milling or staging for other spawning areas.
7. To improve the estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ for chum salmon, tagging effort should continue until the chum salmon run is diminished, possibly into the month of August. In addition, this will further evaluate how representative the Kogrukluk River weir is for chum salmon escapement in the entire Holitna River drainage.

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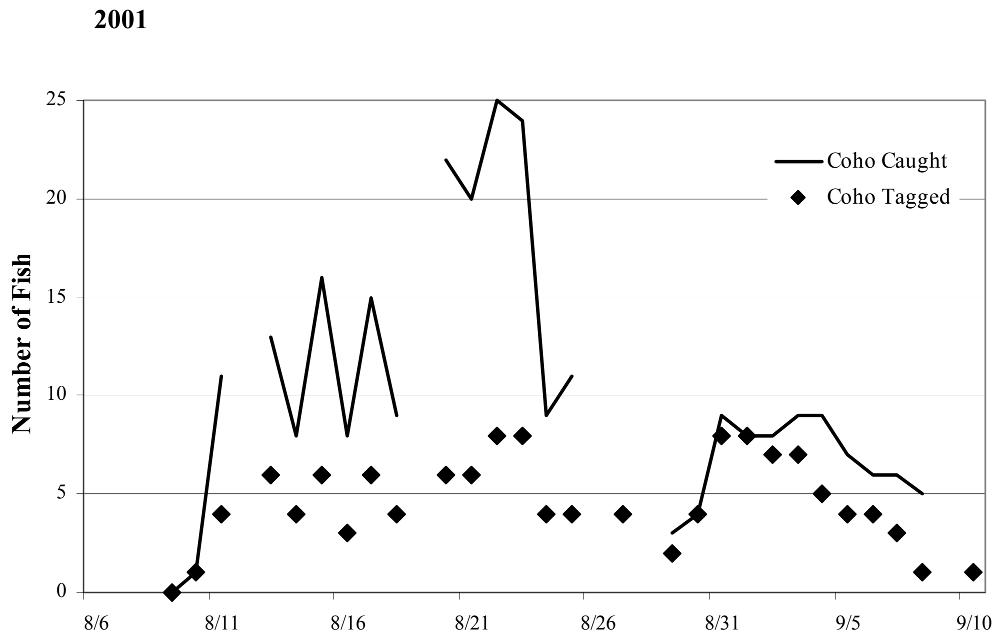
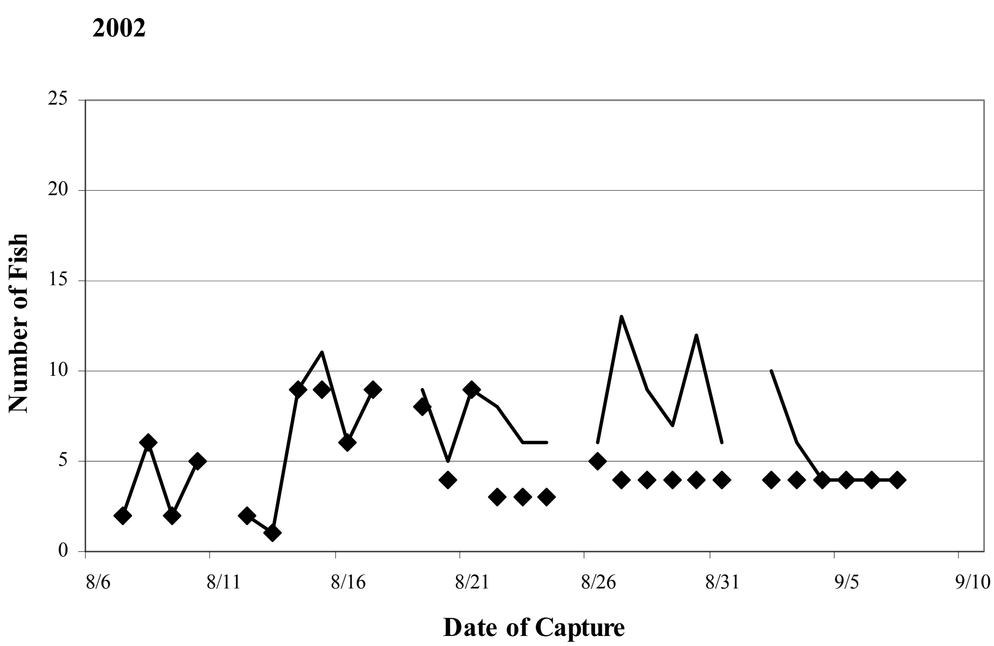
APPENDIX A

Appendix A1.-Daily catch and number of coho salmon radio-tagged in the Holitna River, 2001-2002.





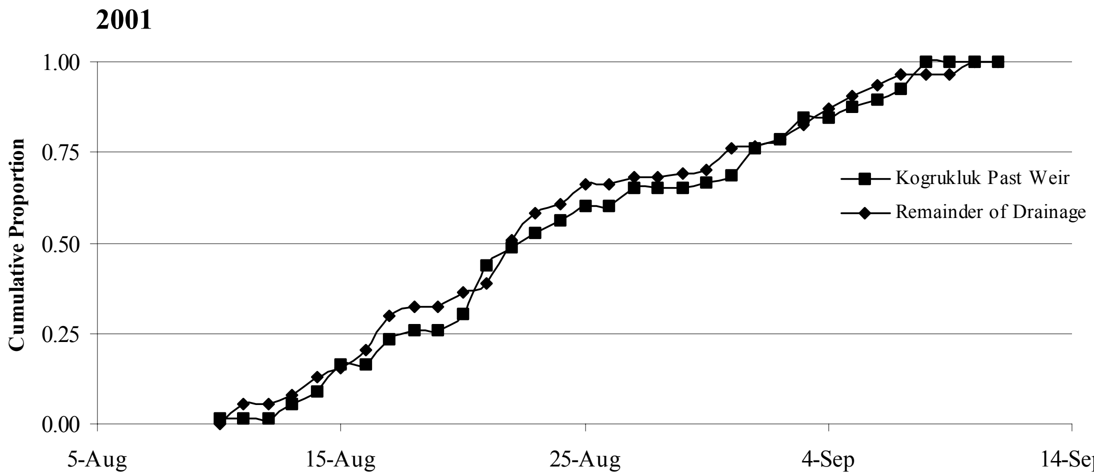
Appendix A2.-Number of radio-tagged coho salmon located in tributaries or sections of the Holitna River drainage during aerial tracking surveys, 2001-2002.[a]

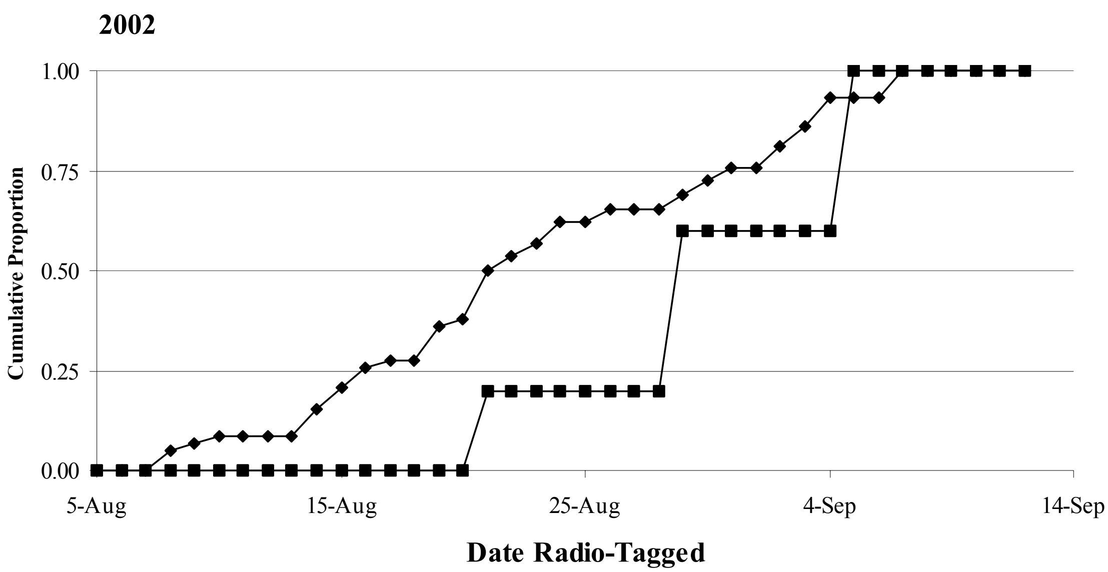
Tributary or River Section	2001	2002
Hoholitna River Drainage		
Mainstem Hoholitna River	2	12
South Fork Hoholitna River	5	5
Hook Creek	2	2
No Name (West of South Fork Hoholitna River)	2	2
Weasel Creek	1	1
Holitna River Drainage		
Mainstem Holitna River	19	24
Kogrukluk River[a]	2	1
Shotgun Creek	2	2
Mainstem Chukowan River	2	1
Oksotalik Creek	1	0
Gemuk River	2	0
Bairo Creek	4	0
Chikulunuk Creek	7	0
Enatalik Creek	0	0
Portage Creek	5	1
Bakbuk Creek	0	0
No Name (West side drainage between Babuk and Portage Creeks)	3	0
Kiknik Creek	2	1
Taylor Creek	1	4
Itulilik Creek	4	0
Chuilnuk Creek	2	1
Mukslulik Creek	3	0
Titnuk Creek	0	9

[a] Coho were not sampled in 2003 season.

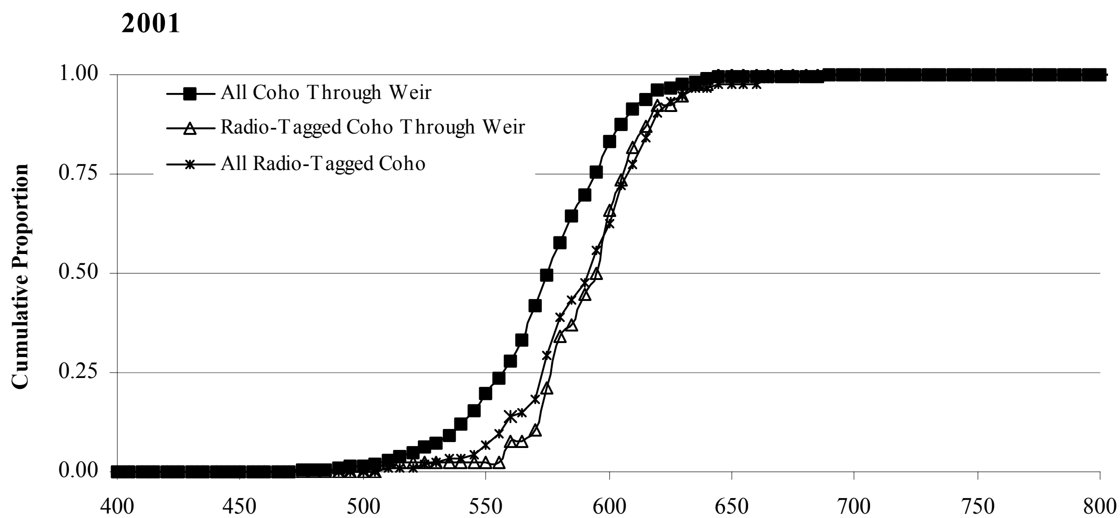
b Some of the radio tags were removed at the weir; therefore these numbers do not reflect the true number that spawned.

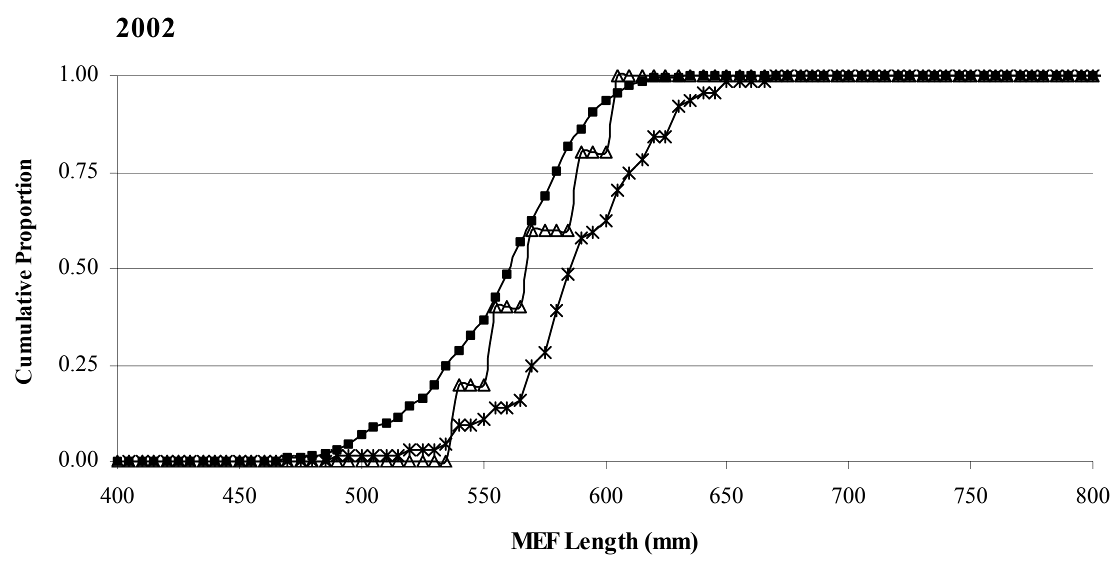
Appendix A3.-Migratory timing profile of radio-tagged coho salmon at the capture site that migrated past the Kogrukluk River weir or migrated to all other areas of the Holitna River drainage, 2001-2002 (coho salmon were not radio-tagged in 2003).





Appendix A4.-Cumulative length frequency distributions of all radio-tagged coho 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, 2001-2002.





Appendix A5.-Catch and length statistics for coho salmon in the Holitna River, 2001 - 2002.

Statistic		2001 All Meshes	2002 All Meshes
All Fish			
Number caught		277	188
	Male	122	91
	Female	155	97
Percent male		44%	48%
Mean length (mm)			
	All (SD)	588 (31)	587 (36)
	Male (SD)	590 (35)	586 (39)
	Female (SD)	586 (26)	587 (32)
Length Range (mm)			
	Male	495 - 670	450 - 670
	Female	505 - 635	490 - 650
Radio-tagged Fish			
Number tagged		128	130
	Male	58	62
	Female	70	68
Percent male		45%	46%
Mean length (mm)			
	All (SD)	594 (27)	587 (34)
	Male (SD)	599 (29)	586 (39)
	Female (SD)	589 (26)	587 (32)
Length range (mm)			
	Male	530 - 670	450 - 670
	Female	510 - 635	490 - 650

Note: Coho salmon were not sampled in 2003.

APPENDIX B

Appendix B1.-Daily fishing effort, catch, number of radio tags deployed, CPUE and weighting factor, for chinook and chum salmon in the Holitna River, 2003.

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
10-Jun	207	151	56	1	1	0	0	0.3	-	0.5	-
11-Jun	208	158	50	0	0	0	0	-	-	-	-
12-Jun	216	154	62	0	0	0	0	-	-	-	-
13-Jun	225	164	61	0	0	0	0	-	-	-	-
14-Jun	256	161	95	0	0	0	0	-	-	-	-
15-Jun						Did not fish					
16-Jun	234	163	71	0	0	0	0	-	-	-	-
17-Jun	203	145	58	4	4	0	0	1.2	-	0.5	-
18-Jun	245	152	93	4	4	2	2	1.0	0.5	0.4	0.8
19-Jun	219	157	62	4	3	0	0	1.1	-	0.6	0.0
20-Jun	196	146	50	7	3	1	1	2.1	0.3	1.2	1.0
21-Jun	203	144	59	7	1	0	0	2.1	-	3.6	-
22-Jun						Did not fish					
23-Jun	201	151	50	2	1	2	2	0.6	0.6	1.0	1.0
24-Jun	192	145	47	2	2	2	1	0.6	0.6	0.5	2.0
25-Jun	225	154	71	9	3	2	2	2.4	0.5	1.4	0.9
26-Jun	214	157	57	11	1	3	3	3.1	0.8	5.4	0.9
27-Jun	205	139	66	3	2	7	6	0.9	2.0	0.8	1.1
28-Jun	220	154	66	7	3	2	2	1.9	0.5	1.1	0.9
29-Jun						Did not fish					
30-Jun	187	130	57	6	2	7	7	1.9	2.2	1.7	1.0
1-Jul	174	123	51	5	2	10	7	1.7	3.4	1.5	1.6
2-Jul	233	154	79	6	5	5	5	1.5	1.3	0.5	0.8
3-Jul	209	113	96	3	2	9	8	0.9	2.6	0.7	1.0
4-Jul	226	132	94	7	4	9	9	1.9	2.4	0.8	0.9

-continued-

Appendix B1.-Page 2 of 2.

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
5-Jul	213	131	82	4	4	2	2	1.1	0.6	0.7	0.5
6-Jul						Did not fish					
7-Jul	193	131	62	2	2	11	7	0.6	3.4	0.8	0.8
8-Jul	171	111	60	2	2	12	11	0.7	4.2	0.9	0.7
9-Jul	204	156	48	0	0	13	11	-	3.8	-	0.6
10-Jul	190	150	40	3	3	12	12	0.9	3.8	0.8	0.5
11-Jul						Did not fish					
12-Jul	197	149	48	2	2	16	8	0.6	4.9	0.8	1.1
13-Jul	216	162	54	5	3	17	8	1.4	4.7	1.2	1.0
14-Jul	222	166	56	3	1	8	6	0.8	2.2	2.0	0.6
15-Jul	204	143	61	3	1	16	7	0.9	4.7	2.2	1.2
16-Jul	204	157	47	1	1	13	7	0.3	3.8	0.7	0.9
17-Jul	202	144	58	0	0	12	7	-	3.6	-	0.9
18-Jul	211	159	52	1	1	10	5	0.3	2.8	0.7	1.0
19-Jul	214	161	53	0	0	10	5	-	2.8	-	1.0
20-Jul						Did not fish					
21-Jul	196	146	50	2	1	17	5	0.6	5.2	1.5	1.8
22-Jul	197	146	51	0	0	12	5	-	3.7	-	1.3
23-Jul	183	139	44	0	0	15	5	-	4.9	-	1.7
24-Jul	170	133	37	1	1	8	5	0.4	2.8	0.9	1.0
25-Jul	200	149	51	0	0	17	6	-	5.1	-	1.5
26-Jul	180	140	40	2	2	10	4	0.7	3.3	0.8	1.4
27-Jul						Did not fish					
28-Jul	157	105	52	0	0	14	5	-	5.4	-	1.8
29-Jul	140	95	45	1	1	9	5	0.4	3.9	1.1	1.3

Appendix B2.-Daily fishing effort, catch, number of radio tags deployed, CPUE and weighting factor, for chinook and chum salmon in the Holitna River, 2002.

Date	Total effort (min)	Effort by Mesh Size (min) 5.75 in	6.5 in	7.5 in	8 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
17-Jun	162	66	0	0	96	0	0	1	0	-	0.7	-	-
18-Jun	144	47	0	0	97	1	1	2	0	0.6	1.2	1.5	-
19-Jun	143	45	0	0	98	2	1	4	1	1.2	2.5	2.9	1.8
20-Jun	92	43	0	0	49	1	1	6	1	1.2	7.4	2.9	5.5
21-Jun	158	55	0	0	103	1	1	6	3	0.6	3.5	1.4	0.9
22-Jun	147	51	0	0	96	4	4	5	2	2.5	3.1	1.5	1.2
23-Jun								Did not fish					
24-Jun	159	0	59	0	100	3	2	3	2	1.8	1.8	2.1	0.7
25-Jun	156	0	50	0	106	3	3	3	1	1.7	1.7	1.4	1.3
26-Jun	169	55	0	0	114	3	3	9	5	1.6	4.7	1.3	0.7
27-Jun	163	57	0	0	106	4	3	4	4	2.3	2.3	1.8	0.4
28-Jun	163	55	0	0	108	1	1	10	8	0.6	5.6	1.3	0.5
29-Jun	177	61	0	0	116	1	1	6	5	0.5	3.1	1.2	0.5
30-Jun								Did not fish					
1-Jul	179	56	0	0	123	4	4	6	6	2.0	2.9	1.2	0.4
2-Jul	186	0	63	0	123	1	1	15	7	0.5	7.3	1.2	0.8
3-Jul	202	0	51	0	151	4	4	12	9	1.6	4.8	0.9	0.4
4-Jul								Did not fish					

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Date	Total Effort (min)	Effort by mesh size (min) 5.75 in	6.5 in	7.5 in	8 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
5-Jul	228	0	51	0	177	2	2	20	8	0.7	6.8	0.8	0.6
6-Jul	219	0	69	0	150	1	1	21	8	0.4	8.4	1.0	0.8
7-Jul	221	0	74	0	147	4	4	16	11	1.6	6.5	1.0	0.4
8-Jul	225	61	0	0	164	3	3	20	9	1.1	7.3	0.9	0.6
9-Jul	235	0	59	0	176	1	1	22	8	0.3	7.5	0.8	0.7
10-Jul	231	0	63	0	168	1	1	19	8	0.4	6.8	0.9	0.6
11-Jul	209	0	52	0	157	0	0	25	4	-	9.6	-	1.8
12-Jul	210	0	45	0	165	2	2	25	3	0.7	9.1	0.9	2.3
13-Jul	254	0	47		207	4	4	10	3	1.2	2.9	0.7	0.7
14-Jul							Did not fish						
15-Jul	188	0	68	0	120	2	2	18	3	1.0	9.0	1.2	2.2
16-Jul	265	0	49	0	216	1	1	25	3	0.3	6.9	0.7	1.7
17-Jul	259	0	52	0	207	2	2	18	3	0.6	5.2	0.7	1.3
18-Jul	168	0	0	0	168	1	1	15	0	0.4	5.4	0.9	-
19-Jul	307	0	102	0	205	2	2	30	1	0.6	8.8	0.7	6.5
20-Jul							Did not fish						
21-Jul	283	0	62	0	221	0	0	27	1	-	7.3	-	5.5
22-Jul	272	0	58	0	214	2	2	27	1	0.6	7.6	0.7	5.6
23-Jul	233	0	32	0	201	0	0	7	2	-	2.1	-	0.8

Appendix B3.-Daily fishing effort, catch, number of radio tags deployed, CPUE, and weighting factor for coho salmon in the Holitna River, 2002.

Date	Fishing Effort (min)	Number Caught	Number Tagged	CPUE (Catch/hr)	Weighting Factor
7-Aug	151	2	2	0.79	0.71
8-Aug	159	6	6	2.26	0.68
9-Aug	154	2	2	0.78	0.70
10-Aug	150	5	5	2.00	0.72
11-Aug			Did not fish		
12-Aug	199	2	2	0.60	0.54
13-Aug	207	1	1	0.29	0.52
14-Aug	157	9	9	3.44	0.69
15-Aug	153	11	9	4.31	0.86
16-Aug	179	6	6	2.01	0.60
17-Aug	151	9	9	3.58	0.71
18-Aug			Did not fish		
19-Aug	157	9	8	3.44	0.77
20-Aug	163	5	4	1.84	0.83
21-Aug	142	9	9	3.80	0.76
22-Aug	157	8	3	3.06	1.83
23-Aug	117	6	3	3.08	1.84
24-Aug	173	6	3	2.08	1.25
25-Aug			Did not fish		
26-Aug	156	6	5	2.31	0.83
27-Aug	128	13	4	6.09	2.74
28-Aug	154	9	4	3.51	1.57
29-Aug	145	7	4	2.90	1.30
30-Aug	151	12	4	4.77	2.14
31-Aug	218	6	4	1.65	0.74
1-Sep			Did not fish		
2-Sep	114	10	4	5.26	2.36
3-Sep	165	6	4	2.18	0.98
4-Sep	202	4	4	1.19	0.53
5-Sep	150	4	4	1.60	0.72
6-Sep	156	4	4	1.54	0.69
7-Sep	147	4	4	1.63	0.73

Appendix B4.–Daily fishing effort, catch, number of radio tags deployed, CPUE and weighting factor, for chinook and chum salmon in the Holitna River, 2001.

Date	Total effort (min)	Effort by mesh size (min) 5.75 in	6.5 in	7.5 in	8 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
20-Jun	NA					0	0	0	0	-	-	-	-
21-Jun	NA					1	1	0	0	-	-	0.6	-
22-Jun	197	0	0	0	197	5	4	1	0	1.5	0.3	0.6	-
23-Jun	165	0	0	0	165	8	5	1	0	2.9	0.4	0.9	-
24-Jun	101	0	0	0	101	10	5	1	0	5.9	0.6	1.9	-
25-Jun	215	0	215	0	0	4	2	9	5	1.1	2.5	0.9	0.4
26-Jun	167	0	78	0	89	16	5	4	1	5.7	1.4	1.8	1.2
27-Jun	162	0	78	0	84	15	5	3	2	5.6	1.1	1.8	0.5
28-Jun	161	0	83	0	78	10	4	2	1	3.7	0.7	1.5	0.6
29-Jun	180	0	98	0	82	7	4	6	5	2.3	2.0	0.9	0.3
30-Jun	205	0	121	0	84	9	6	9	6	2.6	2.6	0.7	0.4
1-Jul							Did not fish						
2-Jul	194	93	0	101	0	6	4	20	9	1.9	6.2	0.7	0.6
3-Jul	78	51	0	27	0	6	3	4	3	4.6	3.1	2.4	0.8
4-Jul	66	57	0	9	0	5	2	14	10	4.5	12.7	3.6	1.0
5-Jul	122	110	0	12	0	5	5	13	8	2.5	6.4	0.8	0.6
6-Jul	98	80	0	18	0	4	4	21	7	2.4	12.9	1.0	1.5
7-Jul	134	21	0	113	0	3	3	34	8	1.3	15.2	0.7	1.5

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Date	Total Effort (min)	Effort by mesh size (min) 5.75 in	6.5 in	7.5 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
8-Jul	167	0	0	0	167	5	5	5	2	1.8	1.8	0.6	0.7
9-Jul	176	0	0	0	176	4	4	15	4	1.4	5.1	0.5	1.0
10-Jul	117	0	0	0	117	5	3	10	3	2.6	5.1	1.4	1.4
11-Jul	171	0	61	0	110	0	0	17	3	-	6.0	-	1.6
12-Jul	147	51	0	0	96	5	5	11	4	2.0	4.5	0.6	0.9
13-Jul	161	63	0	0	98	1	1	27	6	0.4	10.1	0.6	1.4
14-Jul	201	61	0	0	140	3	3	21	6	0.9	6.3	0.5	0.8
15-Jul								Did not fish					
16-Jul	104	64	0	0	40	1	1	16	7	0.6	9.2	0.9	1.1
17-Jul	131	40	0	0	91	1	1	19	7	0.5	8.7	0.7	1.0
18-Jul	190	59	0	0	131	4	4	14	6	1.3	4.4	0.5	0.6
19-Jul	98	24	0	0	74	1	1	12	3	0.6	7.3	1.0	2.0
20-Jul								Did not fish					
21-Jul	161	68	0	0	93	3	3	21	6	1.1	7.8	0.6	1.1
22-Jul	152	64	0	0	88	1	0	18	5	0.4	7.1	-	1.2
23-Jul	173	74	0	0	99	0	0	20	4	-	6.9	-	1.4
24-Jul	162	58	0	0	104	1	1	31	2	0.4	11.5	0.6	4.7
25-Jul	157	62	0	0	95	1	1	11	2	0.4	4.2	0.6	1.7
26-Jul	63	63	0	0	0	0	0	5	0	-	4.8	-	-

Appendix B5.–Daily fishing effort, catch, number of radio tags deployed, CPUE, and tagging weight for coho salmon in the Holitna River, 2001.

Date	Fishing Effort (min)	Catch	Radio tags Deployed	CPUE (Catch/hr)	Weighting Factor
9-Aug	88	0	0		
10-Aug	150	1	1	0.40	0.46
11-Aug	155	11	4	4.26	1.23
12-Aug			Did not fish		
13-Aug	270	13	6	2.89	0.56
14-Aug	127	8	4	3.78	1.10
15-Aug	253	16	6	3.79	0.73
16-Aug	216	8	3	2.22	0.86
17-Aug	168	15	6	5.36	1.04
18-Aug	201	9	4	2.69	0.78
19-Aug			Did not fish		
20-Aug	196	22	6	6.73	1.30
21-Aug	171	20	6	7.02	1.36
22-Aug	141	25	8	10.64	1.54
23-Aug	181	24	8	7.96	1.15
24-Aug	156	9	4	3.46	1.00
25-Aug	160	11	4	4.13	1.20
26-Aug			Did not fish		
27-Aug	158	7	4	2.66	0.77
28-Aug			Did not fish		
29-Aug	169	3	2	1.07	0.62
30-Aug	161	4	4	1.49	0.43
31-Aug	150	9	8	3.60	0.52
1-Sep	177	8	8	2.71	0.39
2-Sep	219	8	7	2.19	0.36
3-Sep	150	9	7	3.60	0.60
4-Sep	160	9	5	3.38	0.78
5-Sep	156	7	4	2.69	0.78
6-Sep	161	6	4	2.24	0.65
7-Sep	160	6	3	2.25	0.87
8-Sep	153	5	1	1.96	2.27
9-Sep			Did not fish		
10-Sep	163	3	1	1.10	1.28

APPENDIX C

Appendix C1.–Catch and length statistics for chinook salmon in the Holitna River and radio-tagged chinook salmon that migrated into the Holitna River from the Kuskokwim River chinook salmon project, 2001-2003.

	All Meshes				
	Holitna River			Kuskokwim River[a]	
Statistic	2001	2002	2003	2002	2003
All Fish					
Number Caught	150	59	120	95	176
Male	85	6	28	65	92
Female	65	53	92	32	84
Percent Male	57%	10%	23%	66%	52%
Mean Length (mm)					
All (SD)	831 (101)	821 (102)	794 (103)	734 (120)	711 (132)
Male (SD)	805 (117)	755 (65)	766 (107)	689 (114)	663 (120)
Female (SD)	864 (61)	828 (103)	802 (101)	823 (77)	763 (125)
Length Range (mm)					
Male	510 - 1025	665 - 835	550 - 990	465 - 1025	455 - 890
Female	690 - 1025	585 - 1025	520 - 990	575 - 950	475 - 950
Radio-tagged Fish					
Number Tagged	95	58	68	95	176
Male	46	5	15	63	92
Female	49	53	53	32	84
Percent Male	48%	10%	22%	66%	52%
Mean Length (mm)					
All (SD)	844 (86)	821 (102)	816 (100)	734 (120)	711 (132)
Male (SD)	828 (106)	755 (65)	812 (104)	689 (114)	663 (120)
Female (SD)	859 (60)	828 (103)	816 (100)	823 (77)	763 (125)
Length Range (mm)					
Male	510 - 1015	665 - 835	575 - 990	465 - 1025	455 - 890
Female	690 - 950	585 - 1025	550 - 990	575 - 950	475 - 950

[a] Kuskokwim River chinook salmon project started in 2002.

Appendix C2.-Catch and length statistics for chum salmon by mesh size in the Holitna River, 2001-2003.

Statistic	2001	2002	2003		
				Mesh Size	
	All Meshes	All Meshes	All Meshes	5.75 in	8.0 in
All Fish					
Number Caught	409	438	315	261	54
Male	307	415	256	202	54
Female	102	23	59	59	0
Percent Male	75%	95%	81%	77%	100%
Mean Length (mm)					
All (SD)	603 (37)	613 (35)	595 (35)	590 (32)	616 (37)
Male (SD)	615 (33)	615 (34)	599 (36)	594 (34)	616 (37)
Female (SD)	568 (28)	590 (46)	578 (22)	578 (22)	N/A
Length Range (mm)					
Male	515 - 665	345 - 720	510 - 685	510 - 685	530 - 680
Female	515 - 665	525 - 715	525 - 625	525 - 625	N/A
Radio-tagged Fish					
Number Tagged	133	130	191	189	2
Male	98	118	139	137	2
Female	35	12	52	52	0
Percent Male	74%	91%	73%	72%	100%
Mean Length (mm)					
All (SD)	605 (37)	621 (41)	593 (33)	592 (32)	658 (4)
Male (SD)	616 (33)	622 (40)	598 (35)	597 (34)	658 (4)
Female (SD)	573 (28)	616 (46)	580 (22)	580 (22)	N/A
Length Range (mm)					
Male	515 - 700	345 - 700	510 - 685	510 - 685	655 - 660
Female	515 - 665	555 - 715	525 - 625	525 - 625	N/A

APPENDIX D

Appendix D1.–Age and length statistics for chinook and chum salmon captured at the tagging site in the Holitna River, 2003.

	Age	Sample Size	Proportion	Length (mm) Mean	SD	Min	Max
Chinook							
Male	1.2	0	0.00	-	-	-	-
	1.3	10	0.53	812	106	650	990
	1.4	9	0.47	758	108	575	970
	1.5	0	0.00	-	-	-	-
	2.4	0	0.00	-	-	-	-
	All	19	1.00	787	107	575	990
Female	1.2	0	0.00	-	-	-	-
	1.3	32	0.44	758	116	520	980
	1.4	34	0.47	835	69	650	960
	1.5	6	0.08	882	61	820	990
	2.4	0	0.00	-	-	-	-
	All	72	1.00	805	101	520	990
Chum							
Male	2	0	0.00	-	-	-	-
	3	160	0.71	595	34	510	680
	4	62	0.28	611	37	520	685
	5	2	0.01	625	64	580	670
	All	224	1.00	599	36	510	685
Female	2	0	0.00	-	-	-	-
	3	38	0.69	577	22	525	625
	4	17	0.31	583	21	540	620
	5	0	0.00	-	-	-	-
	All	55	1.00	579	22	525	625

APPENDIX E

Appendix E1.–Data files used to estimate parameters of the chinook, chum, and coho salmon abundance estimates in the Holitna River drainage, 2001-2003.

Data File	Description
2001 Holitna Master.xls[a]	Excel spreadsheets with consolidated sampling, aerial, and tracking station data.
01Holitna Catch Summary.xls[a]	Excel spreadsheets with chinook and chum salmon daily catch information, including CPUE, fishing effort, and tagging rate.
01 Holitna Coho Catch Summary.xls[a]	Excel spreadsheets with coho salmon daily catch information, including CPUE, fishing effort, and tagging rate.
2002 Holitna Master.xls[b]	Excel spreadsheets with consolidated sampling, aerial, and tracking station data. File also includes daily catch information, including CPUE, fishing effort, and tagging rate.
2003 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.

[b] All data files for 2002 season have been previously archived under Fishery Data Series No. 03-23. These are 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.