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

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and

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April 2002

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES

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

by

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Annual Report Summary

Title: Assessment of Chinook, Chum, and Coho Salmon Escapements in the Holitna River Drainage using Radiotelemetry, 2001

Study Number: FIS01-141-1

Investigator(s)/Affiliation(s): Klaus G. Wuttig and Matthew J. Evenson/Alaska Department of Fish and Game, Division of Sport Fish

Management Regions: Yukon-Kuskokwim Delta (5)

Information Type: Stock Status and Trends

Issue(s) Addressed: Lack of stock structure information to support federal subsistence fishery management of salmon

Study Cost: $603,300

Study Duration: June 2001 to June 2004.

Key Words: chinook salmon, chum salmon, coho salmon, *Oncorhynchus tshawytscha*, *Oncorhynchus keta, Oncorhynchus kisutch,* Holitna River, Kuskokwim River, abundance, mark-recapture, radiotelemetry, spawning distribution, escapement

Citation: K. G. Wuttig and M. J. Evenson. 2002. Assessment of Chinook, chum, and coho salmon escapements in the Holitna River drainage using radiotelemetry, 2001. Alaska Department of Fish and Game, Fishery Data Series No. 02-05, Anchorage.

ABSTRACT

In 2001, radiotelemetry was used to estimate the proportion of chinook salmon *Oncorhynchus tshawytscha*, chum salmon *Oncorhynchus keta*, and coho salmon *Oncorhynchus 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 by proportional expansion of the weir counts. We captured 150 chinook salmon, 409 chum salmon, and 276 coho salmon fishing with drift gillnets near the mouth of the Holitna River. Eighty-five chinook salmon, 127 chum salmon, and 115 coho salmon were fitted with radio transmitters and had resumed upstream migrations. Coho salmon were fitted with two types of transmitters, esophageal and externally mounted, to evaluate which allowed for higher rates of sustained upriver movement. Subsequent movements of all radio-tagged salmon were monitored with two stationary tracking stations placed approximately 50 km upstream of the capture site, one tracking station placed at the weir, and by aerial and boat surveys. Estimated proportions were 0.26 (95% C.I.=0.15-0.37) chinook salmon and 0.31 (95% C.I.=0.22-0.40) coho salmon that migrated through the Kogrukluk River weir. The proportion of chum salmon passing through the weir and abundance of chum salmon in the Holitna River drainage were not estimated because sampling biases were apparent and insufficient numbers of chum salmon passed the weir (17) to correct for the bias. An estimated 25,405 (SE=6,207) chinook salmon $\geq$ 650 mm MEF and 63,442 (SE=10,063) coho salmon $\geq$ 510 mm MEF returned to the Holitna River drainage. Between coho salmon fitted with esophageal-implanted and externally-attached radio tags, there was no difference in the proportion of fish that resumed upriver migrations, the proportion of fish that migrated past the Kogrukluk River weir, and the average time required to recover from tagging and migrate to the upstream tracking stations. Esophageal-implanted tags, however, were preferred because they were easier and faster to apply and cause less injury than the externally-attached tags. 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 would be enumerated if the weir were moved to this location. It is recommended, however, that the weir remain at the current site until completion of this study in 2003.

Key words: chinook salmon, chum salmon, coho salmon, *Oncorhynchus tshawytscha*, *Oncorhynchus keta, Oncorhynchus kisutch,* Holitna River, Kuskokwim River, Kogrukluk River, weir, abundance, mark-recapture, radiotelemetry, spawning distribution, escapement, esophageal radio tags, externally attached radio tags.

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 (Burkey et al. 1999). The amount of information provided from current escapement monitoring and run-size assessment projects provide limited information to manage salmon runs for sustained yield (Burkey et al. 1999).

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 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 (38%) of the total subsistence salmon catch (Burkey et al. 1999). The ten-year average (1989–1998) yearly subsistence harvest of chinook salmon is 84,137 fish, which is greater than the average yearly incidental commercial harvests of 27,238 chinook salmon (Burkey et al. 1999).

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 1989 have averaged 514,277 coho salmon annually and ranged from 23,593 to 37,299 fish (Burkey et al. 2000). Traditionally, coho salmon were not as utilized as chinook salmon as a subsistence resource because of poor drying conditions during fall when coho salmon are present, but their importance has grown as freezers have become more available. In 1999, subsistence users harvested 27,753 coho salmon, and harvests averaged 40,004 fish annually from 1989-1998. 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 have 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 (Burkey et al. 2000). Catches from 1989-1998 averaged 334,029 chum salmon annually and ranged from 17,026 to 1,138,674 fish (Burkey et al. 2000). In 1999, only 23,006 were reported harvested in the commercial fishery and 47,612 in the subsistence fishery. From 1989-1998 annual subsistence harvest averaged 83,685 (Burkey et al. 2000). Sport fishing activity 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 sport fish angler effort.

Salmon runs in the Kuskokwim drainage are managed for sustained yields under policies set forth by the Alaska Board of Fisheries 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 present challenges to monitoring salmon escapements and assessing

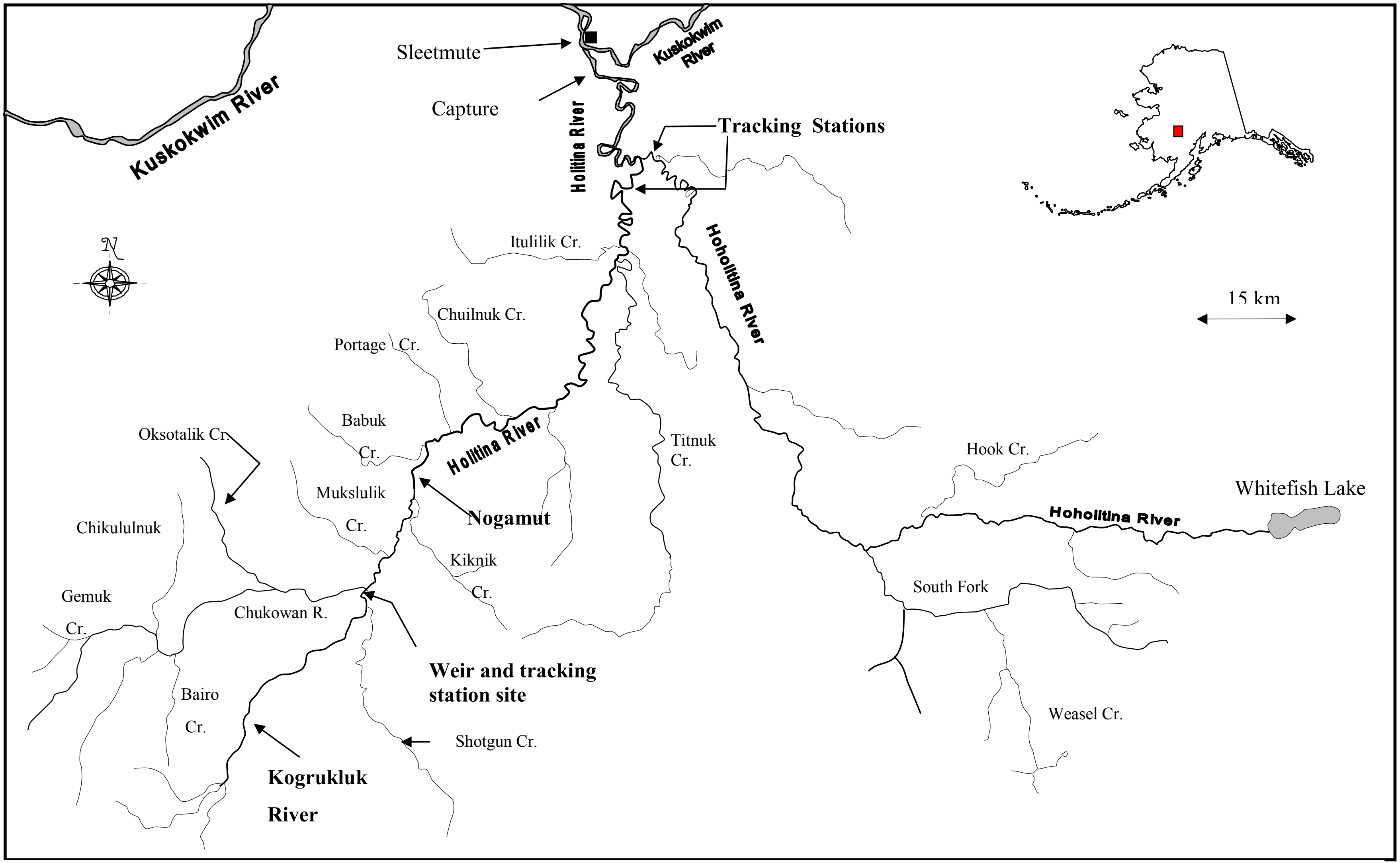

Figure 0-Map of Holitna River drainage demarcating the capture site, tracking stations, and Kogrukluk River weir, 2001.

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. 1999). Moreover, the aerial surveys are primarily conducted in the lower Kuskokwim River because visibility conditions in the tannic stained or glacially occluded middle and upper river tributaries are poor. Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations. In 2001, seven ground-based projects were operated. Only three of these projects have sufficient data to develop chinook 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 an escapement objective for coho salmon (Burkey et al. 1999).

The Holitna River is considered one of the most important producers of chinook, chum, and coho salmon in the Kuskokwim drainage, and also supports spawning populations of pink salmon *O. gorbuscha* and sockeye salmon *O. nerka* (Burr 1999). The Kogrukluk River weir is the oldest continuing salmon escapement assessment project in the Kuskokwim River drainage with chinook, chum, and sockeye salmon having been assessed since 1976, and coho salmon since 1981. The established escapement goals for the Kogrukluk River weir are 10,000 chinook, 30,000 chum, and 25,000 coho salmon.

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 is suspect. Currently, little is 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 seen in other Holitna River tributaries such as Shotgun Creek, Chukowan River, and Chuilnuk River. Moreover, the Hoholitna River represents a large fraction of the Holitna River drainage, but no information exists on the contribution of Hoholitna River spawning stocks to the drainage-wide escapement.

This was the first 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 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, a drainage-wide escapement estimate would substantially contribute to the understanding of Kuskokwim River chinook, chum, and coho salmon runs.

OBJECTIVES

The objectives of this study were to:

1. estimate the proportions of chinook, chum, and coho salmon migrating up the Kogrukluk River (past the weir); and,

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.

In addition, project tasks were to:

1. evaluate two methods of tag attachment for coho salmon, esophageal-implanted and externally-attached radio tags, to determine which allows the highest rate of sustained upriver movements and tag retention; and,
2. document chinook, chum, and coho spawning locations in the Holitna River drainage.

METHODS

CAPTURE AND TAGGING

Chinook, chum, and coho salmon were captured on the Holitna River from a single area approximately 2 km upstream from its confluence with the Kuskokwim River (Figures 1 and 2). Fish were captured by drifting gillnets along both sides of the river. Sampling occurred from 16 June to 27 July (first period) for chinook and chum salmon, and from 10 August to 10 September (second period) for coho salmon.

On 16 June, we started fishing at various locations in the lower six miles of the Holitna River to find effective gillnet drift sites for capturing chinook salmon. Chinook salmon were initially targeted because we thought they would be more difficult to capture than chum salmon and they were known to enter Holitna River earlier than chum salmon. Suitable drift 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, meandering flow. No local knowledge of suitable drift areas was available because subsistence gillnets are fished in the Kuskokwim River. Therefore, test fishing was conducted by trial and error by two, two-person crews until 20 June when a suitable drift site free of bottom obstructions was located.

After 20 June, a single three-person crew fished for chinook and chum salmon. One person piloted a 6.1-m (20-ft) boat and two crewmembers positioned in the bow of the boat tended the net. A gillnet was deployed from the bow and the motor was idled in reverse to keep the net from collapsing while drifting downstream. The sampling reach was approximately 1 km in length, and water depth varied from 1.5 – 6.0 m. A gillnet was drifted until either the end of the drift was reached or a fish became entangled in the net. Drift time was monitored with a stopwatch starting when the gillnet first entered the water and stopping after the entire gillnet was pulled from the water.

Attempts were made to sample such that all salmon migrating upstream were vulnerable to capture. 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 so that sampling was proportional to run size, run timing, and size of fish.

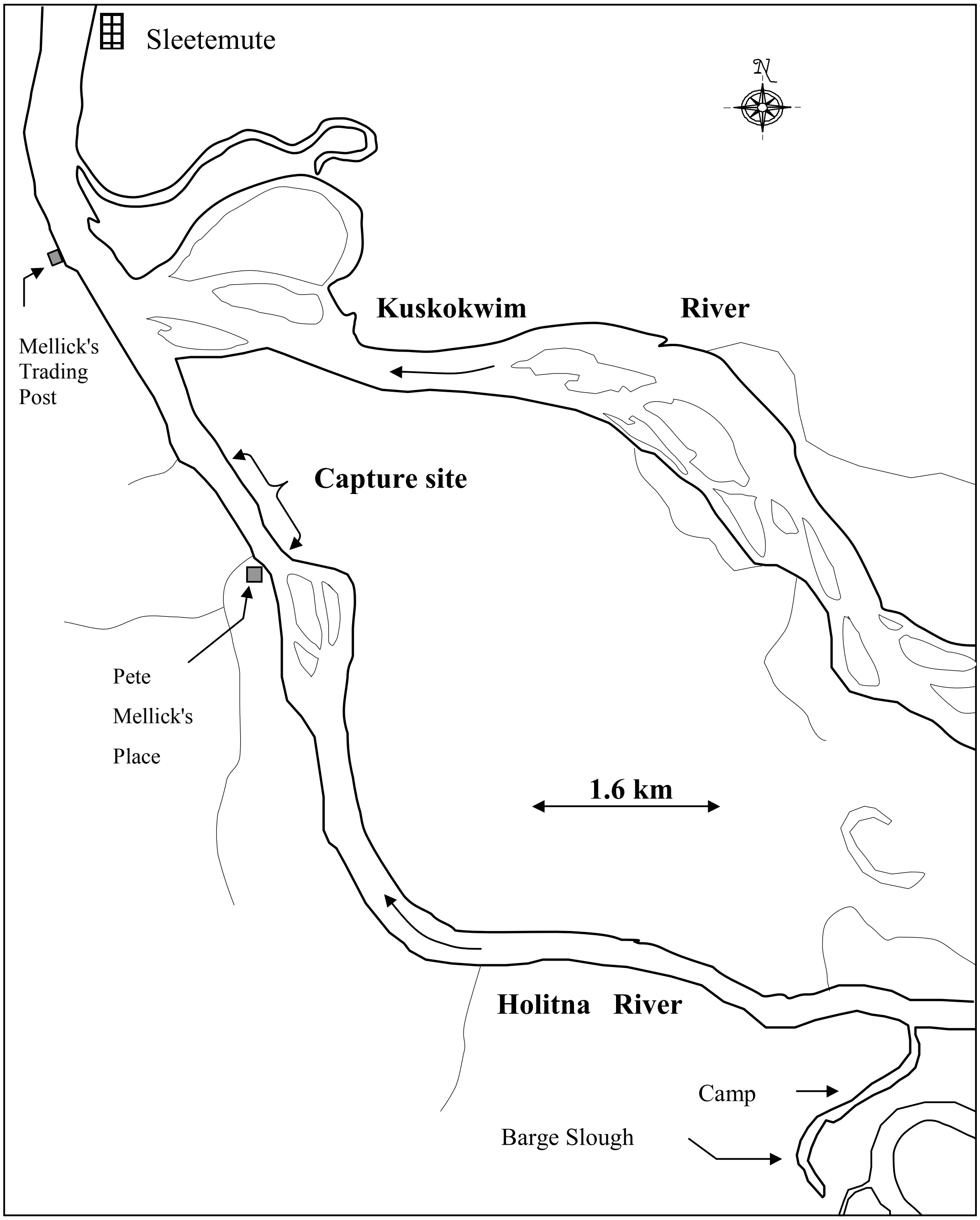

Figure 2.-Map of the confluence of the Holitna River and Kuskokwim River demarcating the capture site. The bracketed arrows show the upper and lower ends of the drift or sampling reach in 2001.

Gillnets of varying mesh size and lengths were used during the first period. These included:

1) 14.6 cm (5.75 in) stretch mesh, made of twisted nylon (cable lay), 30.5 m (100 ft) or 45.7 m (150 ft) long, and 3.0 m (10 ft) deep or 4.5 m (15 ft) deep;
2) 17.1 cm (6.75 in) stretch mesh, made of cable lay, 45.7 m (150 ft) long, and 3.7 m (12 ft) deep;
3) 19.1 cm (7.5 in) stretch mesh, made of braided nylon, 45.7 m (150 ft) long, and 4.0 m (13 ft) deep; and,
4) 20.3 cm (8.0 in) stretch mesh, made of cable lay, 30.5 m (100 ft) or 45.7 m (150 ft) long, and 3.0 m (10 ft) or 4.5 m (15 ft) deep.

Net 4 (150 ft) was fished exclusively from 21 June until catch rates of chinook salmon increased on 24 June. During this period, we were uncertain if catches were low because our gear or capture techniques were ineffective, or because the chinook salmon had not yet arrived in large numbers. After 24 June, catches of chum salmon increased and each sampling day thereafter a small-mesh net (Number 1 or 2) and a large-mesh net (Number 3 or 4) were used. The small-mesh nets were fished for 30–60 min and the large-mesh nets were fished for 90–120 minutes each day. Although attempts were made to fix the amount of fishing effort each day, repairs of torn nets and increased catches of chum salmon caused fishing effort to vary. During the first week of July, chinook salmon catches dropped, and for a three-day period (8–10 July) only large-mesh nets were fished in attempt to increase the capture rate of chinook salmon. Throughout the first sampling period, drift gillnetting for chinook and chum salmon was conducted in the evenings, generally starting by 1700 hours and ending around 2300 hours depending on catch rates.

Coho salmon were captured using the same techniques and drift site used to capture chinook and chum salmon with two exceptions: 1) only a 5.75-in mesh, 150-ft long gillnet (Number 1) was used; and, 2) gillnetting generally occurred 4 h prior to, and 1 h after darkness. From 10-20 August a 10-ft deep gill net was used, but on 21 August it was changed to a 15-ft deep net for the remainder of the sampling period because we thought that coho salmon were avoiding the net by swimming under it.

Once a salmon was entangled in the drifting 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).

Because we anticipated that a greater number of fish would be captured than the number of radio tags available (130 for each species), not every captured fish was implanted with a radio tag. 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.

Quarterly tagging goals were established based on average run timing of each species through the Kogrukluk River weir to ensure tags were distributed over the entire run. It was assumed that travel time between the tagging site and the weir was approximately 5 days.

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio tags were Model Five pulse encoded transmitters made by ATS[1]. Each radio tag was distinguishable by frequency and encoded pulse pattern. Fifty-two frequencies in the 149-151 MHz range with up to 10 encoded pulse patterns per frequency were used.

Esophageal-implanted radio tags were used for all chinook and chum salmon. Transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 24 g in air, and had a 30-cm external whip antenna. These radio tags were inserted through the esophagus 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 was 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 beyond the base of the pectoral fin. Salmon were held by hand against the side of the sampling tub to control fish during tagging.

Both esophageal-implanted and externally-attached radio tags, 65 of each, were given to coho salmon to evaluate which type to use in subsequent years of the study. The evaluation criteria consisted of: 1) ease of deployment; 2) rate of resumed upriver migrations after tagging; and, 3) time required to recover from tagging and migrate to each of the tracking stations. Rates of resumed upriver migrations were tested for homogeneity using contingency table analysis. The test compared the number of radio-tagged coho salmon that resumed upriver migrations after tagging to those that did not by tag type. Mean recovery and travel times to tracking stations by tag type were tested using a two-sample *t*-test.

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 ventral to the dorsal fin with the antenna trailing posterior. The protruding cables were fixed with Peterson disk tags.

All radio-tagged salmon were also given a modified Floy spaghetti tag (Pahlke and Etherton 1998). This secondary tag was used to 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 Floy 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: yellow (chinook), red (chum), or blue (coho). The monofilament was sewn through the musculature of the fish 1-2 cm ventral

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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.

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 tagged fish that migrated up the Hoholitna River, up the Holitna River upstream of the Hoholitna River, or up 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 50.5 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 56-km upstream from the tagging site. The Kogrukluk River station was positioned on a hill, approximately 225 km from the tagging site.

Each tracking station included two gel-cell, deep-cycle batteries, an 80-watt solar array, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, an antenna switching box, a weather-proof metal housing box, and two four-element Yagi antennas (one aimed upstream and the other downstream). 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 for each antenna. Cycling through all frequencies required 5-15 min depending on the number of active tags in reception range. Data were downloaded onto a portable computer every 7-10 d.

The distribution of radio-tagged salmon throughout the Holitna River drainage was further determined by aerial tracking from small aircraft and by boat 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 on one of the data loggers did migrate into a particular stream. Aerial tracking surveys of the Holtina River drainage were conducted on 20–21 July, 5–6 and 29 August, 15–16 September, and 5–6 October. 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 were determined within approximately 200 m. A boat survey of the Holitna River from the Kogrukluk River weir to the mouth of the Chuilnuk River was conducted from 9–10 August.

ESTIMATION OF PROPORTIONS AND ABUNDANCE

Daily tagging rates and fishing effort varied for all three species. Varied tagging rates and fishing effort could potentially have biased the estimates of the proportion of the run migrating past the Kogrukluk River weir if there were discrete spawning aggregations with different run timing. To account for this variation, each radio-tagged fish 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 for all species was the sum of soak times of all nets fished during a day.

Further, differences in size distribution between fish passing the tagging site and fish passing the weir, or unequal probabilities of capture between different sizes of fish at the tagging site could potentially bias the estimates of the proportion of the run migrating past the Kogrukluk River weir. Stratification by size class was used to minimize this source of bias where indicated by diagnostic procedures. The weighted proportion for an individual size class stratum was calculated as:

$$\hat{P}^*_{KR,s} = \frac{\sum_{i=1}^{n_s} w_i \mathrm{I}(destination)}{\sum_{i=1}^{n_s} w_i} \quad (1)$$

where:

$$w_i = \left(\frac{X_i}{h_i x_i}\right)\left(\frac{\sum x_i}{\sum X_i}\right) \quad (2)$$

I(*destination*) = 1 if fish i passed the Kogrukluk River weir and 0 otherwise;

$X_i =$ the number of fish captured on day i;

$x_i =$ the number of fish radio tagged on day i

$h_i =$ the hours of fishing effort on day i; and

$n_s =$ the number of radiotagged fish in size stratum s.

The variance of $\hat{P}^*_{KR,s}$ was estimated using bootstrap resampling procedures (Efron and Tibshirana 1993). Using Equation (1), 2,000 bootstrap estimates of $\hat{P}^*_{KR,s}$ 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 $Var(\hat{P}^*_{KR,s})$.

An unstratified estimate $\hat{P}^*_{KR}$ can be calculated using Equation (1) by replacing n_s with n_t = the total number of radiotagged fish.

The number of salmon in a size stratum s escaping into the Holitna River was estimated by expanding the estimated number of salmon in size stratum s that passed through the Kogrukluk River weir by the proportion of salmon carrying radio transmitters that migrated up the Kogrukluk River as follows:

$$\hat{N}_{Hol,s} = \hat{N}_{KR}\hat{p}_{SA,s} \Big/ \hat{P}^*_{KR,s} = \frac{N_{KRobs}\hat{p}_{SA,s}}{\hat{P}_{KRobs}} \Big/ \hat{P}^*_{KR,s} = \frac{N_{KRobs}\hat{p}_{SA,s}}{\hat{P}_{KRobs}\hat{P}^*_{KR,s}} \quad (3)$$

where: $\hat{N}_{KR} =$ the number of chinook, chum, or coho salmon estimated to have passed the Kogrukluk River weir;

$\hat{p}_{SA,s} =$ an estimate of the proportion of salmon past the Kogrukluk River weir in size stratum s with variance and covariance terms calculated consistent with the size sampling protocol at the weir;

N_{KRobs} = the number of chinook, chum, or coho salmon counted past the Kogrukluk River weir when the weir was operational; and

$\hat{P}_{KRobs}$ = the estimated proportion of the total salmon run counted past the weir during weir operation based on the average proportion of the run passing during missed days from historical run timing curves adjusted for "early", "normal", and "late" run timing.

The variance of $\hat{N}_{KR}$ was approximated using:

$$Var\left(\hat{N}_{KR}\right) \approx \frac{\left(N_{KRobs}\right)^2 Var(\hat{P}_{KRobs})}{(\hat{P}_{KRobs})^4} \qquad (4)$$

where $Var(\hat{P}_{KRobs})$ was the sample variance across years based on historical run timing curves adjusted for run timing.

The variance of the estimated total Holitna River escapement for size stratum *s* was approximated using:

$$Var\left(\hat{N}_{Hol,s}\right) \approx \left(N_{KRobs}\right)^2 \left(\frac{Var\left(\hat{p}_{SA,s}\right)}{(\hat{P}_{KRobs}\hat{P}^*_{KR,s})^2} + \frac{\hat{p}^2_{SA,s} Var\left(\hat{P}_{KRobs}\hat{P}^*_{KR,s}\right)}{(\hat{P}_{KRobs}\hat{P}^*_{KR,s})^4} \right) \qquad (5)$$

where (Goodman 1960):

$$Var\left(\hat{P}_{KRobs}\hat{P}^*_{KR,s}\right) = \hat{P}^2_{KRobs} Var(\hat{P}^*_{KR,s}) + \hat{P}^{*2}_{KR,s} Var(\hat{P}_{KRobs}) - Var(\hat{P}^*_{KR,s}) Var(\hat{P}_{KRobs}). \qquad (6)$$

If diagnostic tests indicated no size stratification was required, the total escapement into the Holitna River $\hat{N}_{Hol}$ and its variance was calculated using Equations (5) and (6) by replacing $\hat{P}^*_{KR,s}$ with $\hat{P}^*_{KR}$ and noting that $\hat{p}_{SA,s} = 1$ and $Var(\hat{p}_{SA,s}) = 0$.

For the unstratified estimate $\hat{P}^*_{KR}$, and sub sequentially $\hat{N}_{Hol}$, to be accurate, several conditions must have been met:

1) the fates of all, or nearly all, radio-tagged fish were known;
2) marking did not affect the behavior (final spawning destination) of fish;
3) stocks of fish were not bank oriented at the capture site;
4) if tagging effort varied, then run-timing was similar for fish spawning in all areas of the Holitna River drainage; 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 Holitina drainage.

To address Condition 1, only those tags that resumed upstream migrations after tagging were used in estimating $\hat{P}^*_{KR}$. The combination of tracking stations, aerial surveys, boat surveys, and sampling of fish at the weir led to the relocation of nearly all tags that resumed upstream migrations after tagging. Furthermore, radio and Floy tags were printed with return information to encourage returns of tags from harvested fish. However, no commercial fishing currently takes place near the village of Sleetmute, subsistence fishing is primarily conducted in the mainstem Kuskokwim River, and only limited sport fishing occurs on the Holitna River. Therefore, it is unlikely that fishers removed radio tags.

Condition 2 could not be tested directly. We assumed that if a radio-tagged salmon migrated upstream past the tracking stations on the Holitna River (56 km upstream) and Hoholitna River (51 km upstream), then handling and tagging had no effect.

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 $\hat{P}^{*}_{KR}$ were needed to correct for bias.

1) Fish were tagged on both the east and west banks. Independence between bank of mark and final spawning destination was tested using a chi-squared test. Final spawning destinations were either the Hoholitna River (eastern drainage) or the Holitna River (western drainage) upstream from the Hoholitna River;

2) Cumulative run-timing distributions (at the capture site) for salmon spawning in the Kogrukluk River and salmon spawning in the remainder of the Holitna River drainage were tested for homogeneity using Kolmogorov-Smirnov (K-S) two-sample tests. Run-timing curves were constructed using the weighted values described by Equation 2.

3) Cumulative length frequency distributions for salmon migrating through the Kogrukluk River weir and salmon spawning in the remainder of the Holitna River drainage were tested for homogeneity using K-S tests.

4) Contingency table analysis was used to test the hypothesis that the sex ratio of radio-tagged salmon that migrated through the weir was the same as all radio-tagged fish that migrated upstream to other areas in the Holitna River drainage.

If fish were bank oriented at the capture site and fishing effort varied by bank, an unbiased estimate of P^{*}_{KR} could not be calculated. If differences in run-timing were found, and sampling effort was not proportional to run strength, the estimate would be temporally stratified. The break point for the strata would be chosen as the point that resulted in the maximum difference in run-timing (days) between two strata. If temporal stratification was required, tests 3 and 4 would be repeated for each stratum to determine if further stratification was warranted.

If the length distributions of salmon sampled at the Kogrukluk River weir were not the same as all spawners in the Holitna River drainage the estimate would be stratified by size. Length data from radiotagged fish and from fish collected from the weir would be stratified so that the proportion of radiotagged spawners would be homogeneous within each stratum or would be grouped into biologically meaningful strata. If valid estimates of total escapement $\hat{N}_{Hol,s}$ for each size stratum were possible, the total number of salmon in the Holitna River drainage would then be estimated as follows:

$$\hat{N}_{Hol} = \sum_{s=1}^{S} \hat{N}_{Hol,s} = N_{KRobs} \sum_{s=1}^{S} \frac{\hat{p}_{SA,s}}{\hat{P}_{KRobs} \hat{P}^{*}_{KR,s}} \tag{7}$$

with approximate variance:

$$Var\left(\hat{N}_{Hol}\right) \approx \left(N_{KRobs}\right)^2 \left[\sum_{s=1}^{S} \left(\frac{Var\left(\hat{p}_{SA,s}\right)}{(\hat{P}_{KRobs}\hat{P}^{*}_{KR,s})^2} + \frac{\hat{p}^{2}_{SA,s} Var\left(\hat{P}_{KRobs}\hat{P}^{*}_{KR,s}\right)}{(\hat{P}_{KRobs}\hat{P}^{*}_{KR,s})^4} \right) + 2 \sum_{s \neq r}^{S} \frac{Cov\left(\hat{p}_{SA,s}, \hat{p}_{SA,r}\right)}{\hat{P}_{KRobs}\hat{P}^{*}_{KR,s}\hat{P}^{*}_{KR,r}} \right] \tag{8}$$

where S was the number of size strata.

If the sex ratio of radio-tagged salmon upstream of the Kogrukluk River weir were different from all radio-tagged fish that migrated upstream after tagging in each strata (if required for length), the estimate would be similarly stratified by sex.

Length and sex data at the weir were collected by Commercial Fishery Division CFD personal and were assumed to be representative of the true proportions for the Kogrukluk River. Sex and length compositions were determined from "pulse" sampling at the weir (Molyneaux and Dubois 1996). Estimates of proportions of fish in composition classes ($\hat{p}_{SA,s}$) were derived by weighting composition estimates from pulse samples by the counted and/or estimated numbers of fish passing the weir on days during and adjacent to pulse sampling days.

AGE-SEX-LENGTH COMPOSITIONS OF GILLNET CATCHES

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

$$p_g = \frac{n_g}{n} \tag{7}$$

where:

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

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

n = total number chinook, chum, or coho salmon captured.

RESULTS

TAGGING AND FATES OF RADIO-TAGGED SALMON

Chinook Salmon

One hundred-fifty chinook salmon were captured between 21 June and 25 July with 90% of the catches occurring before 13 July (Figure 3). The largest daily CPUE (fish per hour) of chinook salmon was 5.9 on 24 June (Appendix A1). The daily application rate of radio tags varied from 0.3 to 1.0 tags per fish caught, and 95 chinook salmon were radio-tagged (Figure 3). Eighty-three radio-tagged chinook salmon resumed upstream migration and were relocated at least one time upstream of the Holitna River and Hoholitna River

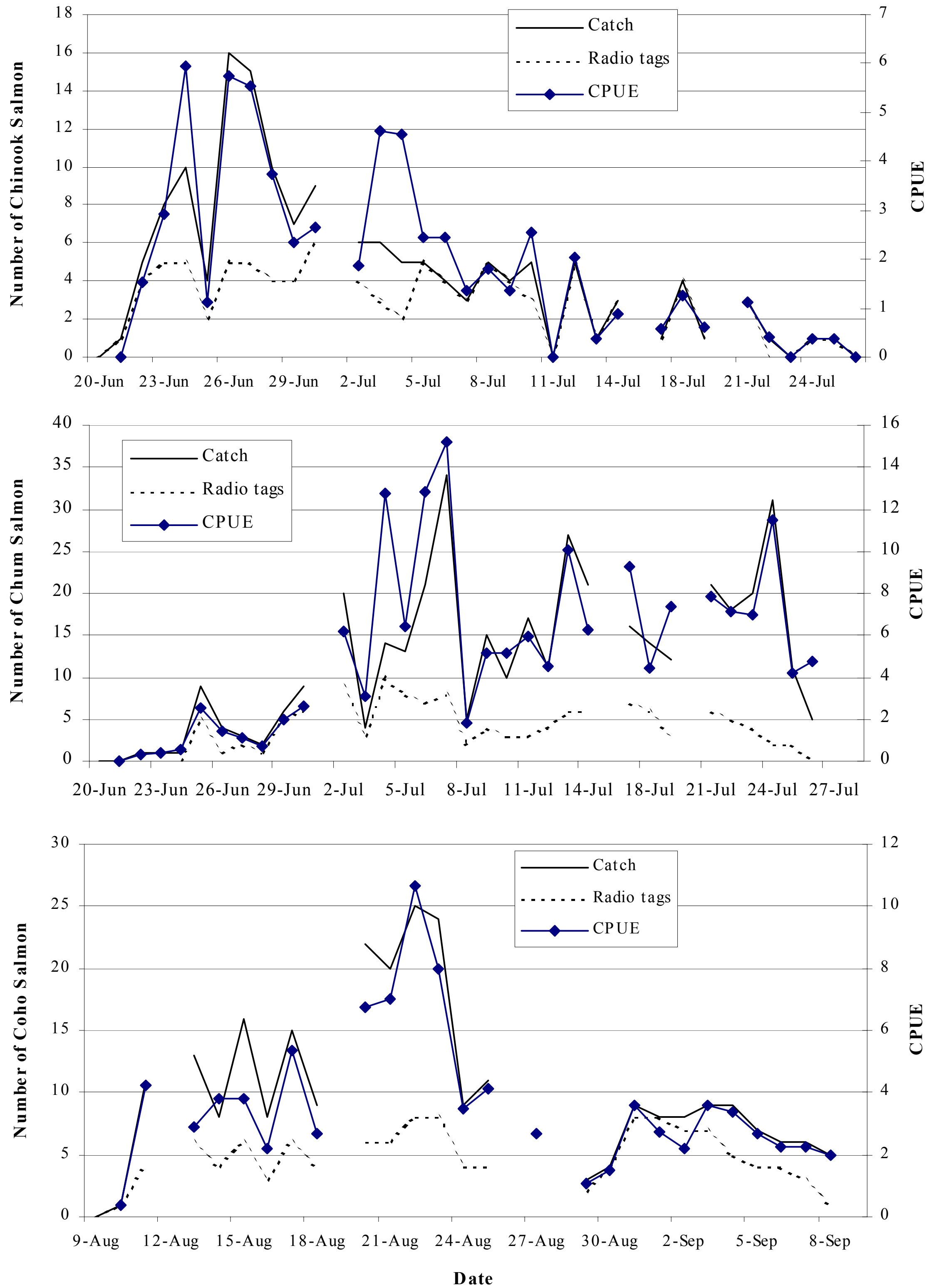

Figure 3.-Daily catch, number of radio tags deployed, and CPUE of chinook (upper chart), chum (middle chart), and coho (lower chart) salmon in the Holitna River, 2001.

tracking stations. These 83 fish were designated as "spawners". Twelve fish were designated as "failures" and were excluded from the experiment. Of these failures, seven fish were thought to have expelled their radio tags near the tagging site (or died), one fish migrated approximately 70 km down the Kuskokwim River after tagging and passed through the George River weir, and four tags were never relocated and were assumed to have either died and drifted down the Kuskokwim River, or migrated to other rivers.

Chum Salmon

Four hundred nine chum salmon were captured between 22 June and 26 July. The largest daily CPUE of chum salmon was 15.2 fish per hour on 7 July (Appendix A1). The daily application rate of radio tags varied from 0.1 to 1.0 tags per fish caught, and 135 fish were radio-tagged (Figure 3). Of the radio-tagged fish, 127 were relocated at least once upstream of the Holitna and Hoholitna river tracking stations. These 127 fish were designated as spawners and the other eight fish were designated as failures and were excluded from the experiment. Two fish were known to have regurgitated their radio tags near the tagging site, and the remaining six tags were never relocated and were assumed to have either died and drifted down the Kuskokwim River, or migrated to other rivers.

Coho Salmon

Two hundred seventy-six coho salmon were captured between 10 August and 10 September. The largest daily CPUE of coho salmon was 10.6 fish per hour on 22 August (Appendix A2). The daily application rate of radio tags varied from 0.2 to 1.0, and 128 coho salmon were radiotagged (Figure 3). Of the radio-tagged fish, 115 were relocated at least one time upstream of the Holitna River and Hoholitna River tracking stations. Thirteen fish were designated as failures and were excluded from the experiment. One fish was thought to have regurgitated its radio tag near the tagging site and the remaining 12 tags were never relocated and were assumed to have either died and drifted down the Kuskokwim River or migrated to other rivers.

Of the 115 radio-tagged coho salmon that resumed upriver migrations, 59 were fitted with esophageal-implanted transmitters and 56 were fitted with externally-mounted transmitters.

DISTRIBUTION AND MOVEMENT OF RADIO-TAGGED SALMON

The tracking stations were efficient at detecting the passage of radio-tagged salmon (Table 1). Of all the radio-tagged chinook and chum salmon known to have passed the lower two tracking stations, only one chum salmon swam past undetected. The Kogrukluk River tracking station was inoperative during the last two weeks of July. Seven radio-tagged chinook salmon that were detected upriver during aerial surveys had migrated past the Holitna River tracking station undetected. The Kogrukluk River tracking station was operative during the entire coho salmon run and was able to detect all the radio-tagged coho salmon that passed through the weir.

The time required to recover from handling and migrate to the Holitna River tracking station was less for chum salmon than for chinook and coho salmon (Table 2). During aerial surveys radio-tagged chinook, chum, and coho salmon were found throughout much of Holitna River drainage. A majority of chinook and coho

Table 1.-Efficiency of tracking stations in detecting passing radio-tagged salmon in the Holitna River drainage, 2001.

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	39	33	39	85%	100%
	Hoholitna	20	19	20	95%	100%
	Kogrukluk[b]	19	16	11	84%	58%
Chum						
	Holitna	92	88	92	96%	100%
	Hoholitna	14	13	13	93%	93%
	Kogrukluk[b]	17	15	14	88%	82%
Coho						
	Holitna	55	52	48	94%	87%
	Hoholitna	22	10	22	45%	100%
	Kogrukluk[b]	38	N/A[c]	36	N/A[c]	100%

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

[b] Tracking station was not operational from July 15 to July 29.

[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.

Table 2.-Time required (days) to recover from tagging and migrate upstream to a tracking station, or time required to travel between two tracking stations, 2001.

Travel segment	Species	Number of radio tags	Average (days)	SE (days)	Min (days)	Max (days)
Tagging site to Hoholitna station						
(~51 km)	Chinook	20	2.1	1.5	1.2	6.1
	Chum	14	3.0	2.7	1.3	10.2
	Coho	24	3.6	2.7	1.7	11.7
Tagging site to Holitna station						
(~56 km)	Chinook	63	3.0	1.7	1.0	7.9
	Chum	118	2.1	0.7	1.2	5.0
	Coho	79	3.4	1.5	1.6	11.0
Holitna station to Kogrukluk station						
(~170 km)	Chinook	13	9.5	3.2	4.7	15.4
	Chum	12	6.6	1.1	4.7	8.0
	Coho	30	8.7	2.6	5.4	17.5
Tagging site to Kogrukluk station						
(~225 km)	Chinook	13	12.5	4.1	6.2	19.3
	Chum	12	9.0	1.4	6.2	11.9
	Coho	30	11.9	3.3	7.0	19.5

salmon were located in tributaries, whereas a majority of chum salmon were located in the mainstem Holitna River (Table 3).

Of the 83 radio-tagged chinook salmon that resumed upstream migrations after tagging, 19 fish passed through the weir. Of the 127 radio-tagged chum salmon that resumed upstream migration after tagging, 17 passed through the weir. Of the 115 radio-tagged coho salmon that resumed upstream migration, 38 passed through the weir. Thirty-four radio-tagged coho salmon were captured at the weir and their radio tags were removed, and four fish avoided capture and continued past the weir.

ESTIMATION OF PROPORTIONS AND ABUNDANCE

Chinook Salmon

Final spawning destination (eastern or western drainage) was independent of bank of capture (χ^2=1.34; df=1; P=0.25; Table 4). There was no difference in run timing at the capture site between radio-tagged chinook salmon spawning above the Kogrukluk River weir and those spawning in the rest of the Holitna River drainage (DN=0.18; P=0.59; Figure 4). Sex ratios of chinook salmon spawning above the Kogrukluk River weir and those spawning in the rest of the drainage were not significantly different (χ^2=0.61; df=1; P=0.80; Table 5). Length distribution of radio-tagged chinook salmon spawning above the Kogrukluk River weir was not significantly different from that of radio-tagged fish spawning in all other areas of the drainage (DN=0.18, P=0.58; Figure 5). However, length distribution of all radio-tagged fish spawning above the Kogrukluk River weir was significantly different from all fish sampled at the weir (DN=0.40; P<0.01; Figure 5). This indicated that sampling with the gillnets was size-selective, and the length distribution of fish passing by the weir may have been different from that of the entire population. Therefore, we censored all chinook salmon < 650 mm MEF counted past the weir for estimating total drainage escapement. This length break was chosen because it was close to the smallest chinook salmon that was radio-tagged (635 mm), and it represented a biologically meaningful break-point because it censored most age 1.1 and 1.2 chinook salmon, based on historical age-sex-length data collected at the weir.

The estimated proportion of chinook salmon migrating into the Kogrukluk River was 0.26 (95% C.I.=0.15-0.37). An estimated 8,622 (SE=767) chinook salmon passed through the weir, and of these, an estimated 0.75 (SE=0.003) were ≥ 650 mm MEF. The estimated abundance of chinook salmon ≥650 mm MEF in Holitna River drainage was 25,405 (SE=6,207).

Chum Salmon

Of the 127 radio-tagged chum salmon that resumed upstream migration after tagging, 17 passed through the weir. An estimated 32,569 (SE=1,743) chum salmon passed the Kogrukluk River weir. An estimate of the proportion of Holitna River chum salmon passing through the Kogrukluk River weir was not calculated for several reasons: 1) we felt tagging effort was not adequately standardized to ignore a difference in run timing detected between Kogrukluk River-bound chum salmon and those bound for other areas; 2) tags were not dispersed proportional to true population length composition; and, 3) small numbers of radio-tagged chum salmon passed the weir. Significant differences were found between: 1) run-timing of radio-tagged chum salmon spawning in the Kogrukluk River and those spawning in the rest of the Holitna River drainage (DN=0.48; P<0.01; Figure 4); 2) length distribution of radio-tagged chum salmon in the Kogrukluk

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

	Species		
Tributary or River Section	Chinook	Chum	Coho
Hoholitna River Drainage			
Mainstem Hoholitna River	15	9	2
Hook Creek	0	0	2
South Fork Hoholitna River	4	2	5
No Name (west of South Fork Hoholitna River)	0	1	2
Weasel Creek	0	0	1
Holitna River Drainage			
Mainstem of Holitna River	20	80	19
Kogrukluk River[a]	15	12	2
Shotgun Creek[a]	1	1	2
Mainstem Chukowan River	6	3	2
Oksotalik Creek	2	0	1
Gemuk River	1	0	2
Bairo Creek	2	0	4
Chikululnuk Creek	1	0	7
Enatalik Creek	1	0	0
Portage Creek	2	0	5
Babuk Creek	1	1	0
No name (West side drainage between Babuk and Portage creeks)	0	3	3
Kiknik Creek	0	0	2
Taylor Creek	0	2	1
Itulilik Creek	1	3	4
Chuilnuk Creek	3	3	2
Mukslulik Creek	1	1	3

[a] Some of the radio tags were removed at the weir. Thus numbers do not reflect the true number that would have spawned in that river.

Table 4.-Number of radio-tagged chinook, chum, and coho salmon migrating up the Holitna River (western drainage) or the Hoholitna River (eastern drainage) by bank of release and results of chi-square tests comparing spawning destinations for fish marked on the east and west banks, 2001.

		Bank of Release	
Salmon species	Migration destination	West	East
Chinook			
	Holitna River (west)	29	29
	Hoholitna River (east)	13	7
	χ^2=1.34; df=1; P=0.25		
Chum			
	Holitna River (west)	28	81
	Hoholitna River (east)	6	8
	χ^2=1.82; df=1; P=0.17		
Coho			
	Holitna River (west)	45	37
	Hoholitna River (east)	7	13
	χ^2=2.54; df=1; P=0.12		

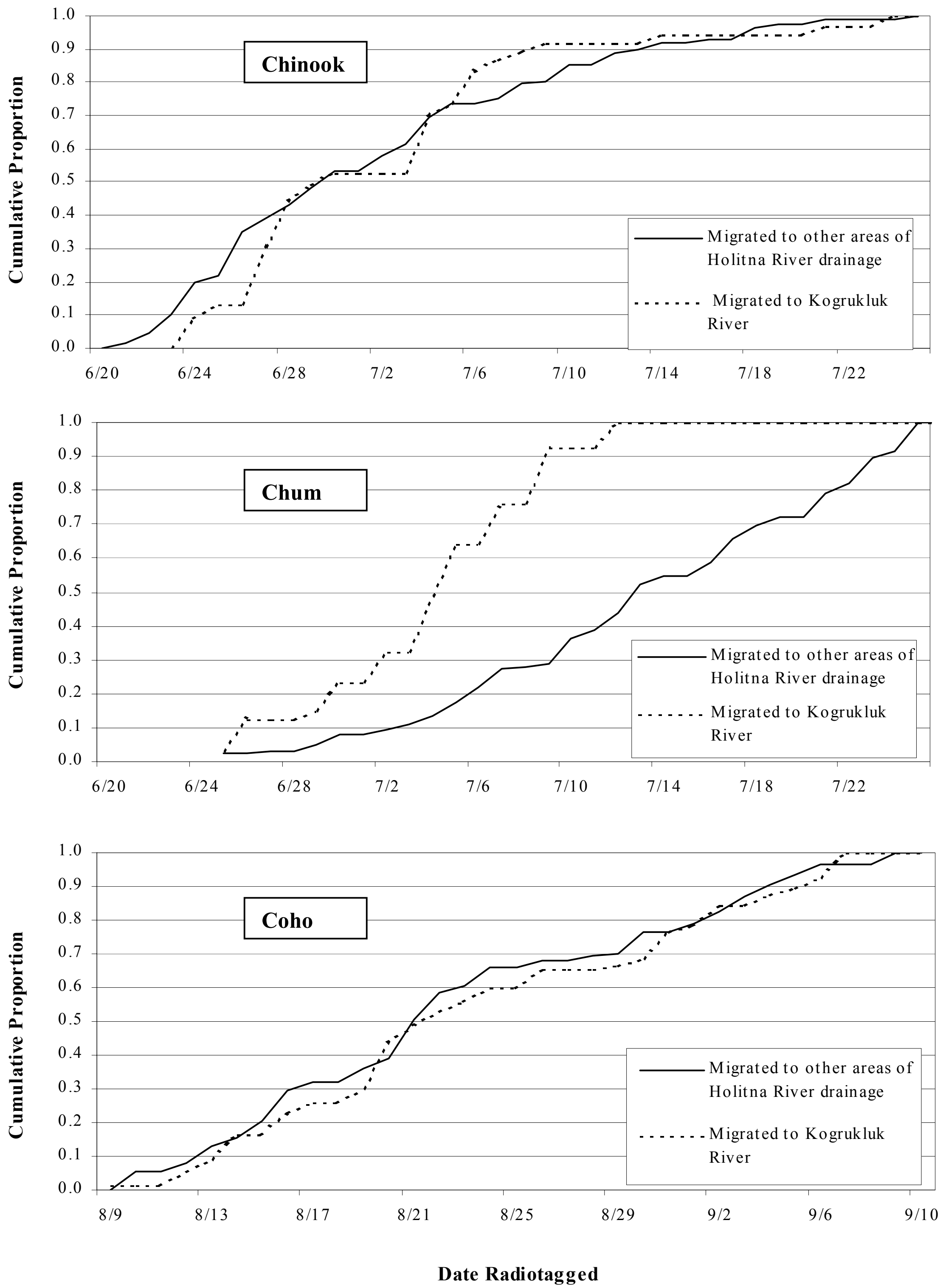

Figure 4.-Migratory-timing profile of radio-tagged chinook, chum, and coho salmon that migrated past the Kogrukluk River weir or migrated to all other areas of the Holitna River drainage, 2001.

Table 5.-Number of radio-tagged male and female chinook, chum, and coho 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, 2001.

		Spawning area	
Salmon Species	Sex	Above Kogrukluk River	All other areas of the Holitna River drainage
Chinook			
	Male	8	29
	Female	11	35
	χ^2=0.61; df=1; P=0.80		
Chum			
	Male	15	79
	Female	2	31
	χ^2=2.06; df=1; P=0.15		
Coho			
	Male	15	37
	Female	23	40
	χ^2=0.75; df=1; P=0.38		

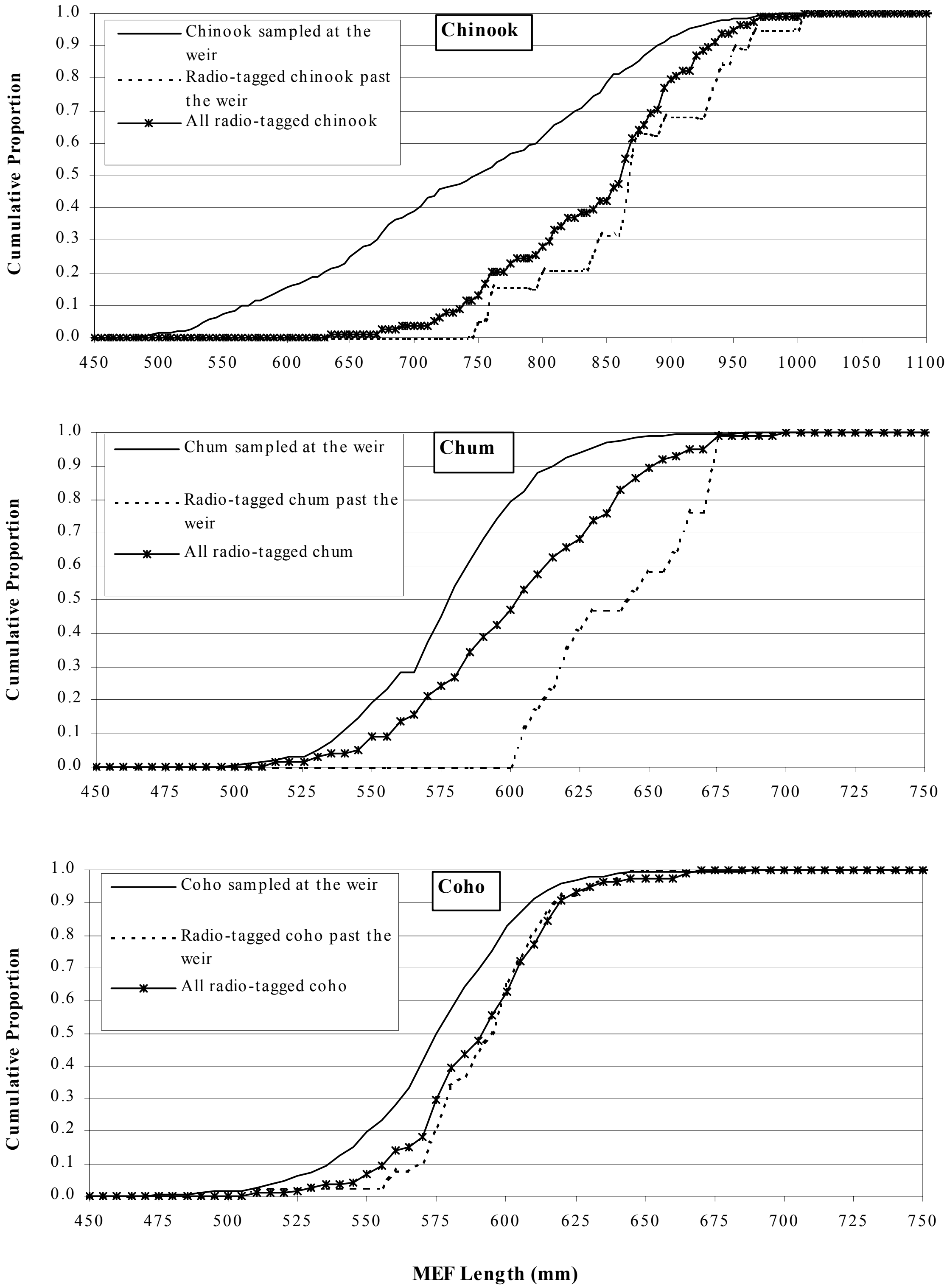

Figure 5.-Cumulative length frequency distribution of all radio-tagged chinook, chum, and coho salmon spawning in the entire Holitna River drainage, all spawning in the Kogrukluk River, and all sampled at the Kogrukluk River weir, 2001.

River and length distribution for radio-tagged fish in all other areas of the drainage (DN=0.46; P<0.01; Figure 5); and, 3) length distribution of all radio-tagged chum salmon spawning in the Holitna River drainage and length distribution of all fish sampled at the weir (DN=0.33; P<0.01; Figure 5).

Final spawning destination (eastern or western drainage) was independent of bank of capture (χ^2=2.54; df=1; P=0.12; Table 4). 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=2.06; df=1; P=0.15; Table 5).

Coho Salmon

Final spawning destination (eastern or western drainage) was independent of bank of capture (χ^2=0.61; df=1; P=0.17; Table 4). Run timing at the capture site of radio-tagged coho salmon spawning upstream of the weir was not significantly different from run timing of radio-tagged coho salmon spawning in all other areas of the Holitna River drainage (DN=0.15; P=0.53; Figure 4). Sex ratios of radio-tagged coho salmon spawning above the weir and radio-tagged fish spawning in all other areas of the drainage were not significantly different (χ^2=0.75; df=1; P=0.38; Table 5). Length distribution of radio-tagged coho salmon was not significantly different from the distribution of radio-tagged fish spawning in all other areas of the drainage (DN=0.08; P=0.96; Figure 5). However, length distribution of all radio-tagged coho salmon spawning upstream of the weir was significantly different from the distribution of all fish sampled at the weir (tagged and untagged; DN=0.40; P<0.01; Figure 5). Therefore, we censored all coho salmon < 510 mm MEF counted past the weir for estimating total drainage escapement. This length break was selected because it was equal to the smallest length of any coho salmon fitted with a radio tag and equal to the length of the smallest radio-tagged coho salmon that passed through the weir.

The estimated proportion of coho salmon ≥510 mm MEF migrating through the Kogrukluk River weir was 0.31 (95% C.I.=0.22-0.40). An estimated 19,963 (SE=740) coho salmon passed through the weir, and an estimated 0.98 (SE<0.01) were ≥510 mm MEF. Estimated abundance of coho salmon ≥510 mm MEF in Holitna River drainage was 63,442 (SE=10,063).

AGE-SEX-LENGTH COMPOSITION OF CAPTURED SALMON

Length and sex composition of captured chinook, chum, and coho salmon varied by mesh size (Appendix B1-B3). Ages were determined for 121 chinook salmon, 365 chum salmon, and 234 coho salmon (Appendix C).

COHO SALMON RADIO TAG EVALUATION

No significant differences were found between the two types of radio tags, esophageal-implanted and externally-attached, when we compared: 1) the proportion of coho salmon that resumed upstream migrations; 2) the proportion of radio-tagged coho salmon that migrated to the Kogrukluk River weir; and, 3) the time required to recover from handling and pass the Holitna River, Hoholitna River, or the Kogrukluk River tracking stations (Table 6).

Table 6.-Performance of esophageal-implanted and externally-attached radio transmitters given to coho salmon in the Holitna River drainage, 2001. Sample sizes are given in parenthesis.

	Tag type		
Performance criteria	Esophageal-implanted	Externally-attached	P-value
Number of fish released	64	64	
Proportion of fish that resumed upriver migrations	0.92 (59)	0.88 (56)	0.97[a]
Proportion of fish that migrated into Kogrukluk River	0.34 (22)	0.25 (16)	0.32[a]
Average time required to recover from tagging and travel to Holitna tracking station (days)	3.01 (23)	3.14 (25)	0.97[b]
Average time required to recover from tagging and travel to Hoholitna tracking station (days)	2.68 (10)	3.77 (12)	0.76[b]
Average time required to recover from tagging and travel to Kogrukluk tracking station (days)	8.71 (17)	10.35 (13)	0.23[b]

[a] Chi-square test.

[b] T-test of equal means.

DISCUSSION

For chinook salmon, we believe that our estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ were unbiased for fish ≥650 mm MEF because there was no difference in run timing or sex ratios between those fish bound for the Kogrukluk River and those fish spawning in the remainder of the Holitna River drainage, and final spawning destination was independent of bank of capture. These were the major assumptions of the procedure for estimation. However, the estimates suffered from two shortcomings. First, a difference in the length composition between tagged and untagged salmon passing the weir, which was a result of using 8-in gillnets that selected for larger fish, required that we censor chinook salmon smaller than 650 mm MEF from the experiment. Second, precision of the estimate suffered because not all the available radio tags (130) were deployed. Although 150 chinook salmon were captured, too few tags were deployed early in the run when catches were large. Because this was the first year of the project, it was difficult to predict a tag application rate that would cover the entire span of the run and still leave tags available to deploy at the end of the run. We anticipated that catch rates during the last week of June would decline gradually, when in fact they dropped off sharply. The radio tag application rate was increased in early July, but only after catches had dropped off.

For chum salmon, we were unable to attain statistically valid estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ because: 1) run timing of chum salmon passing the Kogrukluk River weir was different from run timing of chum salmon that migrated to other areas of the Holitna River drainage; 2) fishing effort was not adequately standardized; 3) tags were not dispersed proportional to true population length composition; and, 4) only a small number of radio-tagged chum salmon passed the weir. Calculation of an unbiased estimate of $\hat{P}^*_{KR}$ would have required temporal stratification, and then further stratification of each temporal stratum into two length strata. The reduction in precision from having to partition the 17 radio tags that passed through the weir into four or more strata was unacceptable. In addition, estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ could have only been calculated for those chum salmon larger than the smallest radio-tagged chum salmon (600 mm MEF) that passed through the weir. Because approximately 80% of the chum salmon sampled at the weir were smaller than 600 mm, the estimates would have only applied to a small proportion of the population.

Although we did not calculate estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ for chum salmon, we believe that the unadjusted estimate of the proportion of radio-tagged chum salmon spawning upstream from the Kogrukluk River weir provided a reasonable approximation of the true proportion because: 1) chum salmon were radio-tagged throughout the run; and, 2) adequate numbers of male and female chum salmon were radio tagged. The similarity between the weighted (10.1%) and unweighted (13.5%) proportion estimates implied that the radio tags were distributed proportional to run strength. Assuming the proportion of chum salmon spawning upstream from the weir was 10.1% and the number of chum salmon past the weir was 32,569, the estimated abundance in the entire Holitna River drainage was roughly 300,000 chum salmon. This estimate is included here to point out that even though the estimate of $\hat{P}^*_{KR}$ may be biased, the magnitude of the chum salmon run was nonetheless quite large. Our assertion that the proportion of chum salmon spawning upstream of the Kogrukluk River weir is small was supported by our observations of chum salmon distributions during aerial tracking surveys in early August. We observed numerous large spawning aggregations of chum salmon distributed in a 50-km stretch of the mainstem Holitna River downstream of the Kogrukluk River, and relatively dispersed, smaller aggregations of chum salmon upstream from the Kogrukluk River weir. Our observations were supported by aerial surveys of chum salmon conducted by CFD personnel, who observed large numbers of mainstem spawners relative to what was counted at the Kogrukluk River weir (P. Salomone, Alaska Department of fish and Game, Commercial Fisheries Division, Bethel, personal communication).

For coho salmon, data analysis did not detect significant bias in estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{total}$ for fish ≥510 mm MEF. Coho salmon were tagged in an approximate proportion to catch, fishing effort was relatively constant, and a small-mesh gillnet was used exclusively that captured a wide range of sizes. Spawning destination was independent of bank of capture and the length composition of radio-tagged coho salmon spawning upstream of the Kogrukluk River weir was not different from length composition of radio-tagged coho salmon spawning in the remainder of the drainage. Observation of coho salmon between the weir and the tagging site during ground tracking from 8–10 August indicated that a small portion of the run was missed prior to the start of sampling. However, it is not likely that missing this small portion of the run would significantly bias the estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$, because there was no difference in run timing between those fish bound for the Kogrukluk River and those spawning in the remainder of the Holitna River drainage.

A critical assumption of this study was that handling and radio-tagging did not affect a fish's final spawning destination. More specifically, our assumption was that radio tagging did not affect fish that were destined to spawn upstream from the Kogrukluk River. Any radio-tagged fish that did not migrate past the weir that would have had they not been tagged would cause the estimate $\hat{P}^*_{KR}$ to be biased low and the estimate of $\hat{N}_{Hol}$ to be biased high. There was no evidence that suggested there were effects from handling for fish that remained in the experiment. Our estimates included only those fish that migrated at least 50 km upstream from the capture site (past the Hoholitna River and Holitna River tracking stations), and the estimates did not include any fish that died immediately or dropped out of the system. Given this distance, it is unlikely that a tagged fish that migrated past the Kogrukluk River weir would have spawned elsewhere had it not been tagged. Similarly, it is also unlikely that fish that migrated into other tributaries such as the Hoholitna River or the Chukowan River would have spawned above the Kogrukluk River weir (or elsewhere) had they not been tagged. Thus, the only radio-tagged fish that could potentially have contributed to bias in the estimates of $\hat{P}^*_{KR}$ would have been those fish that were located in the mainstem Holitna River downstream from the weir that had died prior to spawning. Aerial surveys confirmed that all three species spawn in this section of river, but the radio-tagged fish could not be confirmed as live, spawning fish. Bernard et al. (1999) found evidence that the handling of chinook salmon can result in atypically slow migration rates. Prolonged migrations caused by handling could increase mortality rates by increasing a fish's exposure to fishing and natural mortality factors. Therefore, the likelihood of fish reaching a spawning area in close proximity to the tagging site would be greater than for fish bound for more distant spawning areas such as the Kogrukluk River. However, prolonged migrations were not suspected with any of the species in this study. Chinook and chum salmon required only 2.5 days and coho salmon only 3.0 days on average to recover from capture and tagging and travel 50-56 km from the capture site to the tracking stations on the Holitna and Hoholitna rivers, which seems like a reasonable rate of travel.

The primary objective of this study was to estimate the proportion of the spawning escapement past the Kogrukluk River weir. However, spawning apportionment in other parts of the drainage was of interest in assessing the relative importance of individual tributaries or sections of river. Because some fish may not have been located on their spawning ground on the day the aerial or boat surveys were conducted, the estimates of the proportions spawning in areas other than above the weir were considered minimum estimates. Of particular interest has been the proportion of chinook, chum, and coho salmon spawning in the Hoholitna River drainage, the Chukowan River drainage, and the section of the Holitna River drainage upstream of Nogamut, an abandoned village site located on the mainstem Holina River approximately 30 km downstream from the Kogrukluk River weir. The Nogamut site has been proposed as replacement site for the Kogrukluk River weir as it would likely provide a better index of salmon returns. Radio-tagged fish located during aerial surveys indicated that 46% of the chinook salmon, 25% of the chum salmon, and 48% of the coho salmon in the Holitna River drainage spawned above the Nogamut site (Table 7). Chinook salmon were predominantly located in tributaries of the Holitna River, and only 20 of the 76 tags were located during aerial surveys in the mainstem of the Holitna River. Most of the mainstem spawners were located upstream of Portage Creek. Coho salmon were also found predominantly in tributaries, but tended to be distributed higher in the drainage than chinook salmon, spawning in smaller first and second order tributaries, often within and immediately below beaver dam complexes. Conversely, most chum salmon were found in an approximately 50-km section of the mainstem Holitna River downstream of Kiknik Creek.

The first year of this study suggested that age, sex, and length composition for chum salmon at the Kogrukluk River weir were not representative of the composition of all chum salmon returning to the Holitna River. Since 1981, the percentage of females sampled at the Kogrukluk River weir has declined and has remained low (below 25%) since the late 1980s (Dubois and Molyneaux 2000). In 1997, the percentage of females passing through the weir was only 4%, and in 2001 only 17% of the chum salmon passing the weir were female. Investigations of age, sex, and length composition of chum salmon in other areas of the Holitna River drainage system have not been conducted since 1981. Therefore, it is not known whether the sex ratio in the remainder of the Holitna River drainage has been skewed similar to what has been observed at the weir. The proportion of female chum salmon we captured in the 5.75-in mesh (0.53) suggests that sex ratio of chum salmon returning to the Holitna River drainage was probably higher than the proportion observed at the weir. The cause of the skewed sex ratio observed at the weir is still unknown. It has been speculated that the cause is related to the location of the weir, which is relatively high up in the drainage and above most of

Table 7.-Number of radio tags located and estimated proportion of radio-tagged chinook, chum, and coho salmon in the Chukowan River drainage, Hoholitna River drainage and upstream of Nogamut, 2001.

Species	Area	Number of radio tags located	Estimated proportion
Chinook			
	Chukowan River drainage	15	0.17
	Hoholitna River drainage	20	0.26
	Holitna River drainage upstream of Nogamut	39	0.46
Chum			
	Chukowan River drainage	4	0.02
	Hoholitna River drainage	14	0.10
	Holitna River drainage upstream of Nogamut	36	0.25
Coho			
	Chukowan River drainage	16	0.13
	Hoholitna River drainage	19	0.22
	Holitna River drainage upstream of Nogamut	58	0.48

the suitable chum salmon spawning habitat. Females from the mainstem spawning component may be selecting and using suitable habitat prior to reaching the weir and remaining there until death, whereas males may continue to migrate upriver looking for new spawning partners because they remain sexually active longer (Salamone 2000).

The weir may also provide poor information on chum returns because our telemetry data indicated two defined stocks, early and late runs, may be returning to the Holitna River drainage. The early run fish are those that spawn in the headwaters or tributaries of the Holitna River, such as the Kogrukluk and Chukowan rivers, and the late run are those chum salmon that spawn in the mainstem of the Holitna River. The weir only counts a portion of the early run fish and this is only a minor component of the entire run. This along with the disproportionate number of males counted at the weir jeopardizes the usefulness of the Kogrukluk River weir counts as an index of abundance of chum salmon in the Holitna River drainage.

Efforts to relocate the weir site downstream to Nogamut should be postponed until completion of the study to gain a better understanding of the uncertainty in the proportion of the Holitna River returns that would migrate past the proposed site. The results of this study showed that a weir placed at Nogamut would enumerate a higher proportion of the chinook, chum, and coho salmon returning to the Holitna River drainage. However, it is not known how the proportion of salmon spawning upstream of Nogamut varies relative to the proportion of salmon spawning in the Kogrukluk River. For chum salmon, the proposed Nogamut weir site may not provide a reliable index of returns because those fish passing Nogamut would be composed of early run fish, such as those bound for the Kogrukluk River, but only a very small portion of the late run or mainstem spawners.

In 2001, we assumed that the entry timing of fish into the Holitna River would be similar to the historic run-timing of fish at the weir lagged by 5 d to account for travel time. However, our telemetry data indicated that travel time from the mouth to the weir was about 10 d on average for all three species. Consequently, we likely started our sampling for chinook and coho salmon approximately 5 d after the first fish entered the river. Future sampling should be adjusted accordingly to ensure the entire span of the run is sampled.

We preferred the esophageal-implanted radio tags over the externally-attached radio tags for coho salmon. We found no differences between the two types of tags relative to rate of migration, proportion of tags that continued upstream migration, radio signal reception during aerial surveys and by the tracking stations, or in relative spawning distributions throughout the Holitna River drainage. The advantages of the esophageal-implanted tags for coho salmon were that they were easier and faster to deploy and did not appear to injure the fish compared to the externally attached tags. Crewmembers from the Kogrukluk River weir captured many of the radio-tagged coho salmon and reported that most of the fish with external radio tags had holes eroded where the cables were threaded through the fish.

CONCLUSIONS

This study successfully addressed project objectives for coho salmon. For chinook salmon, we estimated the proportion spawning upstream from the weir and the spawning abundance in the entire drainage. However, the number of radio tags deployed was smaller than desired, and because we tagged too few small chinook salmon, the estimates only pertained to chinook salmon > 650 mm MEF. We did not address project objectives for chum salmon because we believe we tagged 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. Further study is warranted to determine the variability in spawning distribution and run-timing patterns for each species. The results of the first year of this study suggested that the Kogrukluk River may provide a good index of chinook and coho salmon returns to the Holitna River drainage, but may not provide reliable information on run strength and composition of chum salmon.

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 our sampling procedures. In future years, fishing effort and gear should be modified as follows:

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-in mesh gillnet. This should be sufficient to capture adequate numbers of chinook and chum salmon over a broad range of lengths.
2. During sampling for coho salmon, 150 min of drift time with a 5.75-in mesh gillnet should be expended each day.
3. 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 and by only tagging chum salmon caught in the small mesh net.
4. 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.

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APPENDIX A

Appendix A1.-Daily fishing effort, catch, number of radio tags deployed, CPUE and tagging weight 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 of Chinook Caught	Number of Chinook Tagged	Number of Chum Caught	Number of Chum Tagged	Chinook CPUE (Catch/hr)	Chum CPUE (Catch/hr)	Chinook Tagging Weight	Chum Tagging Weight
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

-continued-

Appendix A1.-Page 2 of 2.

Date	Total Effort (min)	Effort by mesh size (min) 5.75 in	6.5 in	7.5 in	8 in	Number of Chinook Caught	Number of Chinook Tagged	Number of Chum Caught	Number of Chum Tagged	Chinook CPUE (Catch/hr)	Chum CPUE (Catch/hr)	Chinook Tagging Weight	Chum Tagging Weight
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	0.0	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	0.0	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	0.0	4.8		

Appendix A2.-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)	Tagging Weight
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	off				
10-Sep	163	3	1	1.10	1.28

APPENDIX B

Appendix B1.-Catch and length statistics for male and female chinook salmon by mesh size in the Holitna River, 2001.

		Mesh size			
Statistic	All Meshes	5.75 in	6.5 in	7.5 in	8 in
All fish					
Number caught	150	10	30	18	92
Male	85	6	21	10	48
Female	65	4	9	8	44
Percent male	57%	60%	70%	56%	52%
Mean length (mm)					
All (SE)	831 (101)	771 (165)	791 (116)	802 (113)	856 (75)
Male (SE)	805 (117)	701 (179)	760 (110)	775 (134)	844 (91)
Female (SE)	864 (61)	875 (60)	863 (98)	836 (74)	868 (50)
Length range (mm)					
Male	510-1,025	515-1,015	575-970	510-955	535-1,005
Female	690-1,025	795-935	690-1,025	720-945	715-950
Radio-tagged fish					
Number tagged	95	7	17	13	58
Male	46	3	11	9	23
Female	49	4	6	4	35
Percent male	48%	43%	65%	69%	40%
Mean length (mm)					
All (SE)	844 (86)	849 (114)	808 (78)	798 (125)	864 (68)
Male (SE)	828 (106)	815 (175)	805 (85)	781 (140)	858 (87)
Female (SE)	859 (60)	875 (60)	812 (70)	835 (85)	868 (53)
Length range (mm)					
Male	510-1,015	690-1,015	675-955	510-955	650-1,005
Female	690-950	795-935	690-865	720-925	715-950

Appendix B2.-Catch and length statistics for male and female chum salmon by mesh size in the Holitna River, 2001.

		Mesh Size			
Statistic	All Meshes	5.75 in	6.5 in	7.5 in	8 in
All fish					
Total caught	409	189	63	58	99
Male	307	100	56	58	93
Female	102	89	7	0	6
Percent male	75%	53%	89%	100%	94%
Mean length (mm)					
All (SE)	603 (37)	578 (30)	620 (26)	626 (27)	628 (32)
Male (SE)	615 (33)	589 (32)	622 (26)	626 (27)	631 (29)
Female (SE)	568 (28)	565 (23)	601 (32)	NA	576 (0)
Length range (mm)					
Male	515-720	515-675	565-675	565-675	550-720
Female	515-665	515-620	550-665	NA	540-615
Radio-tagged fish					
Number tagged	133	64	33	20	16
Male	98	33	31	20	14
Female	35	31	2	0	2
Percent male	74%	52%	94%	100%	88%
Mean length (mm)					
All (SE)	605 (37)	580 (30)	625 (26)	629 (27)	632 (32)
Male (SE)	616 (33)	592 (32)	624 (26)	629 (27)	639 (29)
Female (SE)	573 (28)	567 (23)	643 (32)	NA	585 (0)
Length range (mm)					
Male	515-700	515-675	570-675	565-675	590-700
Female	515-665	515-605	620-665	NA	585-585

Appendix B3.-Catch and length statistics for male and female coho salmon captured in 5.75-in mesh gillnets in the Holitna River, 2001.

Statistic		All fish	Radio-tagged fish
Number caught		277	128
	Male	122	58
	Female	155	70
Percent male		44	45
Mean length (mm)			
	All (SE)	588 (31)	594 (27)
	Male (SE)	590 (35)	599 (29)
	Female (SE)	586 (26)	589 (26)
Length range (mm)			
	Male	495-670	530–670
	Female	505-635	510-635

APPENDIX C

Appendix C1.-Age and length statistics for chinook, chum, and coho salmon captured at the tagging site in the Holitna River, 2001.

	Age	Sample Size	Proportion	Length (mm) Mean	SE	Min	Max
Chinook							
Male	1.1	3	0.05	542	33	510	575
	1.2	12	0.19	720	78	580	850
	1.3	28	0.44	824	97	650	1,015
	1.4	20	0.32	874	64	755	1,005
	1.5	0	0.00			0	0
	All	63	1.00	805	117	510	1,015
Female	1.2	3	0.05	742	69	690	820
	1.3	24	0.41	871	50	720	940
	1.4	28	0.48	874	56	790	1,025
	1.5	2	0.03	830	21	815	845
	2.3	1	0.02	920		920	920
	All	58	1.00	864	61	690	1,025
Chum							
Male	2	2	0.01	565	21	550	580
	3	159	0.57	605	31	515	680
	4	117	0.42	632	33	550	720
	5	2	0.01	663	4	660	665
	All	280	1.00	615	35	515	720
Female	2	2	0.02	553	39	525	580
	3	58	0.68	569	25	530	640
	4	24	0.28	576	29	525	665
	5	1	0.01	585		585	585
	All	85	1.00	568	26	515	665
Coho							
Male	1.1	4	0.04	593	35	555	640
	2.1	91	0.89	589	37	495	670
	3.1	7	0.07	586	28	545	635
	All	102	1.00				
Female	1.1	6	0.05	588	24	555	615
	2.1	116	0.88	586	26	505	635
	3.1	10	0.08	598	19	575	630
	All	132	1.00	586	26	505	635