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Assessment of Chinook, Chum, and Coho Salmon Escapements in the Holitna River Drainage Using Radiotelemetry, 2002

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USFWS Office of Subsistence Management
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by
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Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

FISHERY DATA SERIES NO. 03-23

ASSESSMENT OF CHINOOK, CHUM, AND COHO SALMON ESCAPEMENTS IN THE HOLITNA RIVER DRAINAGE USING RADIOTELEMETRY, 2002

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ABSTRACT

In 2002, 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. Fifty-nine chinook salmon, 438 chum salmon, and 188 coho salmon were captured fishing with drift gillnets near the mouth of the Holitna River. Of the total fish captured 58 chinook, 130 chum and 130 coho salmon were radio-tagged with esophageal transmitters. Ninety-five chinook salmon radio-tagged in the related Kuskokwim River chinook salmon radiotelemetry project entered the Holitna River and augmented the total number of radio-tagged chinook salmon in the Holitna River. Including those fish fitted with transmitters in the Kuskokwim River chinook salmon project, 144 chinook, 116 chum, and 64 coho salmon fitted with radio transmitters resumed their upstream migrations. 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 four aerial surveys of the Holitna River drainage. Estimated proportions of salmon passing through the weir were 0.23 (95% C.I.=0.16-0.30) for chinook salmon, 0.08 (95% C.I.=0.01-0.15) for coho salmon, and 0.09 (95% C.I.=0.02-0.21) for chum salmon. An estimated 42,902 (SE=6,334) chinook, 542,172 (SE=285,925) chum, and 157,277 (SE=56,624) coho salmon returned to the Holitna River drainage. 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: 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.

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

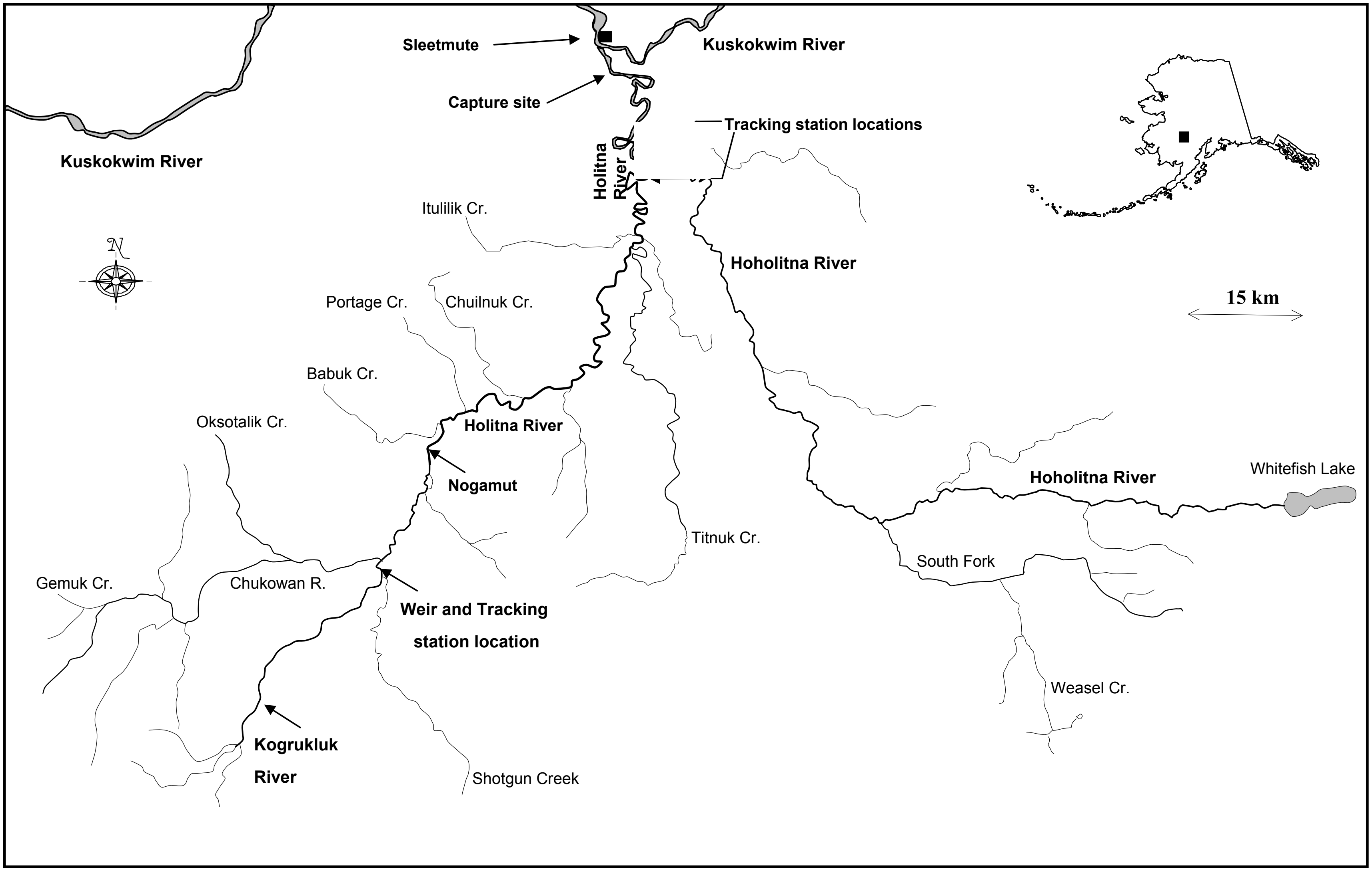

Figure 1.-Map of Holitna River drainage demarcating the capture site, tracking stations, and Kogrukluk River weir, 2002.

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 with a range of 23,593 - 937,299 fish (Burkey et al. 2000). Traditionally, coho salmon 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 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 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 1989-1998 averaged 334,029 chum salmon annually and ranged from 17,026 to 1,138,674 fish. In 1999, returns were poor and only 23,006 chum salmon were reported harvested in the commercial fishery and 47,612 fish in the subsistence fishery. From 1989 to 1998 the average annual chum salmon subsistence harvest was 83,685 fish (Burkey et al. 2000). Sport fishing participation and harvest for all salmon species on the Kuskokwim River are relatively low. The Kisaralik, Kwethluk, Aniak, and Holitna rivers account for the majority of angler effort.

Salmon runs in the Kuskokwim drainage are managed for sustained yields under policies set forth by the Alaska Board of Fisheries (BOF) with subsistence fishing receiving the highest priority. Current information is not adequate to manage salmon runs to produce maximum sustained yields. Management of the commercial and subsistence fisheries is conducted both in season and post-season. Inseason management relies on run-strength indices from commercial catch data, test fisheries, and informal reports from subsistence fishers. Inseason management effectiveness is evaluated with aerial surveys and ground-based projects. However, the size, remoteness, and geographic diversity of the Kuskokwim River presents challenges to monitoring salmon escapements and assessing run strength, and the ground-based projects provide limited information. Aerial spawning-ground surveys have been the most cost-effective means of monitoring salmon escapements, but their usefulness is limited because of known uncertainty and the inconsistent relationship to actual abundance (Burkey et al. 1999). Moreover, the aerial surveys are primarily conducted in the lower Kuskokwim River because visibility is limited by tannins and/or glacial silt in the middle and upper river tributaries. Ground-based projects such as weirs, counting towers, and sonar have only recently been operated in some locations. In 2001 and 2002, seven ground-based projects were conducted. Only three of these projects have collected sufficient data to develop chinook and chum salmon escapement objectives, and only one, the Kogrukluk River weir, located on the upper reaches of the Holitna River drainage (Figure 1), has been used to develop 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 annually 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 may not be valid. 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 observed 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 second 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.

OBJECTIVES

The objectives of this study were to:

1. estimate the proportions of chinook, chum, and coho salmon entering the Holitna River that migrated up the Kogrukluk River (past the weir); and,
2. estimate the abundance of chinook, chum, and coho salmon that migrated into the Holitna River drainage by proportional expansion of the Kogrukluk River weir counts.

An additional project task was to:

1. document chinook, chum, and coho spawning locations in the Holitna River drainage.

METHODS

CAPTURE AND TAGGING

Chinook, chum, and coho salmon were captured by fishing drift gillnets along both banks of a stretch of the Holitna River approximately 2 km upstream from its confluence with the Kuskokwim River (Figures 1 and 2). This was the same site used in 2001. 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 gillnets are typically only fished in the mainstem Kuskokwim River. Sampling was conducted six days each calendar week for chinook and chum salmon from 14 June to 23 July (first sampling period), and from 6 August to 10 September (second sampling period) for coho salmon. 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).

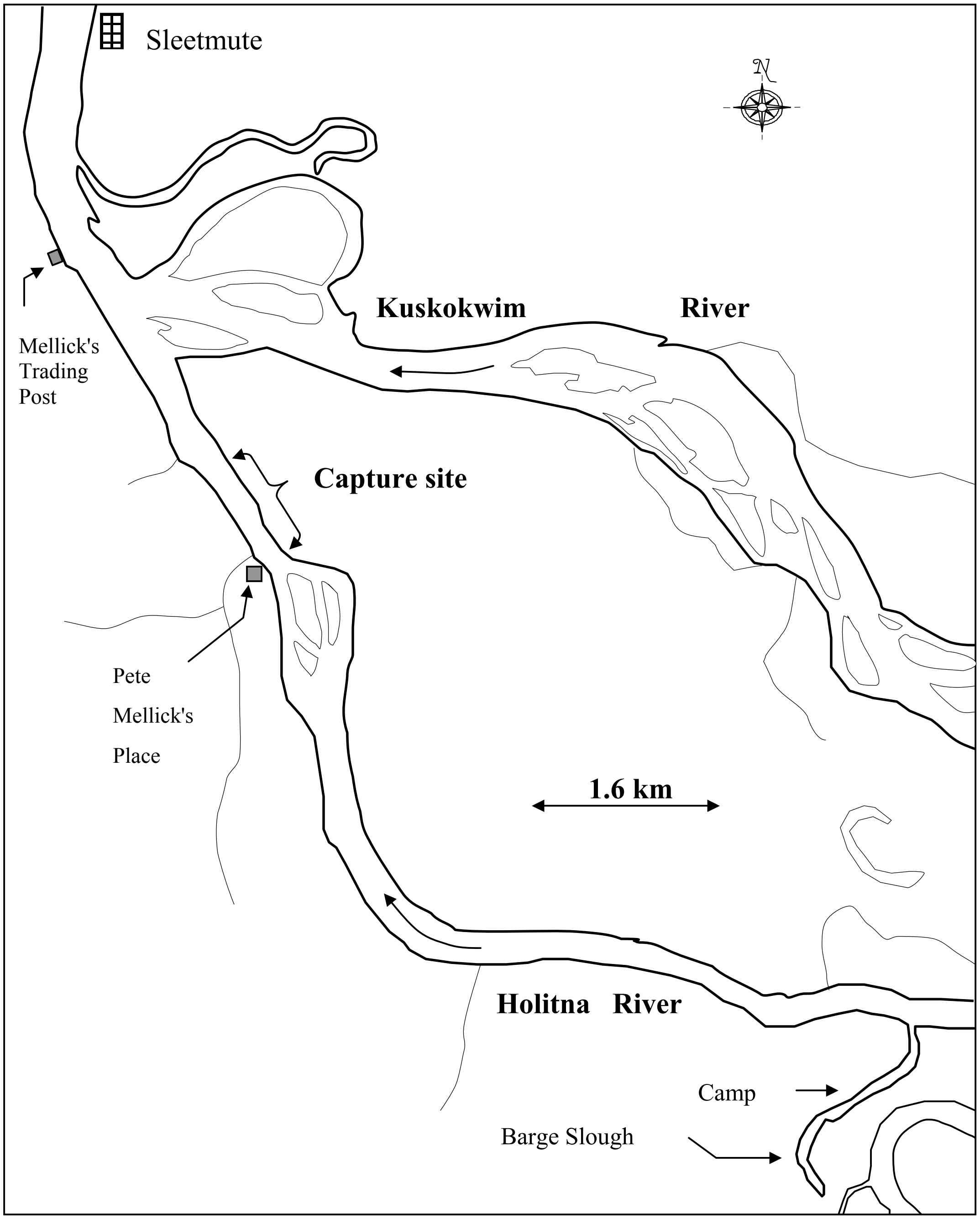

Figure 2.-Map of the confluence of the Holitna River and Kuskokwim River demarcating the capture site. The bracketed arrows show the upper and lower ends of the sampling reach in 2002.

A single three-person crew fished for chinook, chum, and coho 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 drift gillnet was deployed from the bow and the 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 1.5–6.0 m. A 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 starting when the gillnet first entered the water and stopping after the entire gillnet was pulled from the water.

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

Gillnets of varying mesh size and lengths were used 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;

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) 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;

4) 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 6.5 m (22 ft) deep; and,

5) 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 9 m (30 ft) deep.

Nets 1, 2 and 3 (150 ft) were fished from 14 June until the end of the chinook and chum salmon capture event on July 23. The small-mesh nets were fished for 30–60 min and the large-mesh nets were fished for 90–120 minutes each day. The deeper nets (nets 4 and 5) were used whenever water depth was such that the shallower nets were not fishing the depth of the river. Chinook salmon were captured and radio-tagged using both Nets 1 and 3. Chum salmon were captured in both Nets 1 and 3, but only those captured in Net 1 were radio-tagged. Throughout the first sampling period, drift gillnetting for chinook and chum salmon was conducted in the evenings, generally starting by 1600 hours and ending around 2200 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 four hours prior to, and one hour after darkness.

Once a salmon was 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 were to radio-tag 65 chinook salmon, 130 chum salmon, and 130 coho 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. 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 lagged 10 days to ensure tags were distributed over the entire run and in proportion to historic average run strength.

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.

Transmitters were 5.5 cm long, 1.9 cm in diameter, weighed 24 g in air, and had a 30 cm external whip antenna. 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.

All radio-tagged salmon were also given a modified Floy spaghetti tag (Pahlke and Etherton 1998). This secondary tag was used to help identify spawning fates of those fish that lost their radio tag and were later recovered either at the weir or from carcasses on the spawning grounds. The spaghetti tags were uniquely numbered, and constructed of a 5-cm section of Floy tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line. Each species received a uniquely colored tag: yellow (chinook), red (chum), or blue (coho). 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 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 above the weir, approximately 225 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 20 km downstream from the tagging site). This station was used to determine the number of fish that backed down into the mainstem Kuskokwim River after being radio-tagged.

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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.

Each tracking station included two gel-cell, deep-cycle batteries charged by 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 of location 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 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. Aerial tracking surveys of the Holitna River drainage were conducted on 24 and 26 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 or near the Kogrukluk River weir were determined within approximately 200 m.

ESTIMATION OF PROPORTIONS AND ABUNDANCE

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

1) the fates of all, or nearly all, radio-tagged salmon were known;
2) marking did not affect the 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; and,
5) the sex ratio and/or size distribution of salmon passing the Kogrukluk River weir was not different from the sex ratio and/or size distribution of salmon entering the Holitna drainage.

Condition 1 could not be tested directly, but 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. It is unlikely that fishers removed radio tags upriver from the tagging site because no commercial fishing was conducted 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 also not be tested directly. Only those radio-tagged salmon that migrated upstream past the tracking stations on the Holitna River (56 km upstream) and Hoholitna River (51 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. Independence between bank of mark and final spawning destination was tested using a chi-squared test. Final spawning destinations were evaluated as either the Hoholitna River (eastern drainage) or the Holitna River (western drainage) upstream from 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; and,

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

Length and sex data at the weir were collected by ADF&G Commercial Fishery Division (CFD) personnel and were assumed to be representative of the true proportions for the Kogrukluk River. Sex and length compositions were determined from proportional sampling at the weir (Molyneaux and Dubois 1996).

For chinook and coho salmon, condition 4 was satisfied because fishing effort and tagging rates of these species were similar and the run-timing (at the capture site) of chinook and coho salmon migrating past the weir was similar to the run-timing of fish spawning elsewhere in the drainage. Therefore the proportions of these species entering the Holitna River that migrated past the Kogrukluk River weir were estimated as:

$$\hat{P}'_{KR} = \frac{n_{KR}}{n} \quad ; \tag{1}$$

and,

$$Var(\hat{P}'_{KR}) = \frac{\hat{P}'_{KR}(1-\hat{P}'_{KR})}{n-1} \tag{2}$$

where:

n_{KR} = the number of radio-tagged fish that migrated past the Kogrukluk River weir when the weir was operational; and,

n = the total number of radio-tagged fish that migrated upstream into the Holitna River drainage after tagging.

For chum salmon, condition 4 was not satisfied because fishing effort and tagging rates were variable and 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 calculated as:

$$\hat{P}^*_{KR} = \frac{\sum_{i=1}^{d}\sum_{j=1}^{n_i} w_i \mathrm{I}(destination)_j}{\sum_{i=1}^{d} n_i w_i} \quad (3)$$

where:

$$w_i = \left(\frac{\bar{h}}{h_i}\right)\left(\frac{X_i/\bar{X}}{x_i/\bar{x}}\right) \quad (4)$$

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

X_i = the number of fish captured on day i;

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

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

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

h_i = the hours of fishing effort on day i;

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

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

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

The abundance of each species of salmon escaping into the entire Holitna River drainage was calculated using one of two different estimators. The necessity of using two estimators stemmed from the fact that only a portion of the escapement (those fish spawning above the Kogrukluk River weir) was examined for marks (not a random sample of the escapement). Selection of a particular estimator was based on whether run timing of fish spawning above the weir was similar to run timing of fish spawning elsewhere in the drainage and whether tagging effort and rate varied over time (condition 4).

Chinook and coho salmon abundance was estimated using the Chapman modification to the Petersen estimator (Seber 1982) because nearly every chinook and coho salmon caught during the tagging event was radio-tagged and run timing (at the capture site) of fish migrating past the weir was similar to run timing of fish spawning elsewhere in the drainage:

$$\hat{N}'_{Hol} = \frac{(C+1)(M+1)}{R+1} - 1$$

$$Var\left[\hat{N}'_{Hol}\right] \cong \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \quad (5)$$

where:

$\hat{N}'_{Hol}$ = estimated escapement of chinook or coho salmon into the Holitna River;

M = the number of radio-tagged chinook or coho salmon known to have resumed upstream migration after tagging;

C = the number of chinook or coho salmon counted past the Kogrukluk River weir when the weir was operational; and,

R = the number of radio-tagged chinook or coho salmon moving past the Kogrukluk weir when the weir was operational.

For this estimator, in addition to the conditions described above, at least one of the following conditions must have been fulfilled:

a. every fish had an equal probability of being captured and radio-tagged during the capture event; or

b. marked fish mixed completely with unmarked fish between the tagging event and the recovery event at the Kogrukluk River weir.

These conditions were evaluated temporally using the consistency tests described in Seber (1982). If the probability of a radio-tagged fish being recovered at the weir was not dependent on the time when the fish was tagged, it was concluded that at least one of these conditions was satisfied. If the marked to unmarked ratio at the weir was not dependent on time and fish tagged over the duration of the run passed the weir, it was concluded that at least one of the conditions was satisfied. If only the earliest or latest fish tagged passed the weir, the second test was not considered a robust diagnostic tool and failure to detect dependence between time and marked to unmarked ratio was not satisfactory evidence that one of the conditions was satisfied. Potential biases due to selective sampling by size or sex were evaluated as described above. If selectivity in sampling was detected, stratified estimates of abundance were calculated and summed to estimate total abundance as described above

Because tagging rate and fishing effort for chum salmon varied during the marking event, condition a was likely not satisfied. Mixing of tagged fish between events (condition b) could not be evaluated directly because sampling was not conducted in all spawning areas in the second event. Therefore, the conditions for the Chapman modification to the Petersen estimator were not met and abundance of chum salmon was 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:

$$\hat{N}_{Hol} = N_{KR} \big/ \hat{P}^*_{KR} \tag{7}$$

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):

$$Var\left(\hat{N}_{Hol}\right) \approx \left(N_{KR}\right)^2 \left(\frac{Var\left(\hat{P}^*_{KR}\right)}{\hat{P}^{*\,4}_{KR}} \right). \tag{8}$$

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:

$$p_g = \frac{n_g}{n} \tag{9}$$

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

Fifty-nine chinook salmon were captured in the Holitna River between 17 June and 23 July (Figure 3). The largest daily CPUE (fish per hour) of chinook salmon was 2.3 on 27 June (Appendix A1). The daily application rate of radio tags was nearly one to one, with 58 of 59 chinook salmon radio-tagged (Figure 3). Radio-tagged chinook salmon ranged in size from 510-1,015 mm MEF. Of the 58 fish radio-tagged in the Holitna River, a total of six were not located upstream. Of these, three fish were known to have backed out into the Kuskokwim River after tagging and passed data logging stations on the mainstem Kuskokwim River, and three tagged fish were never relocated and were assumed to have either died, migrated to other rivers, or had tags that failed after implantation. An additional 92 radio-tagged chinook entered the Holitna River after having been tagged in the related Kuskokwim River chinook salmon radiotelemetry project. Thus, 144 radio-tagged chinook salmon, including those tagged in the Kuskokwim River project, were relocated upstream of the Holitna River and Hoholitna River tracking

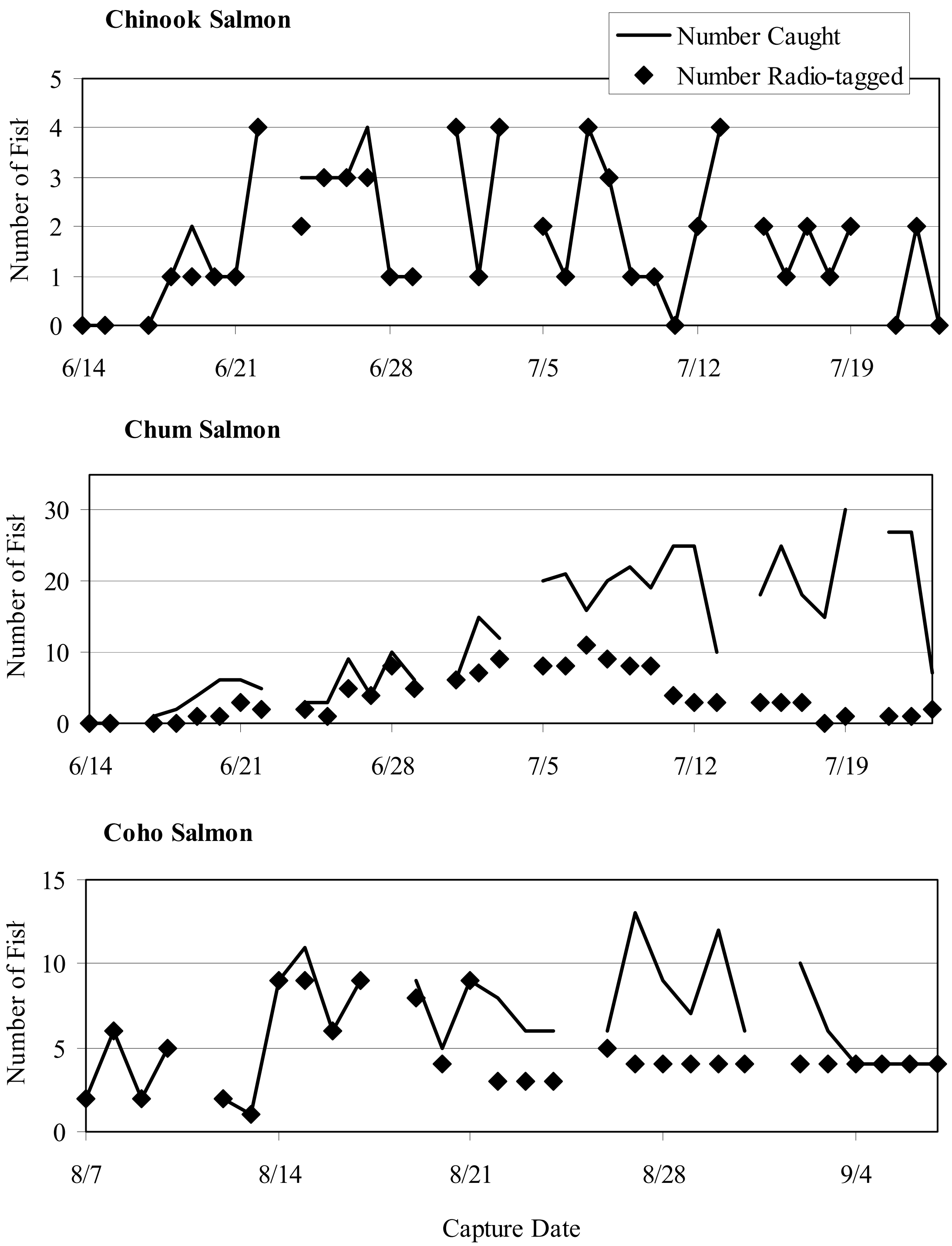

Figure 3.-Daily catch and number of radio tags deployed of chinook (upper chart), chum (middle chart), and coho (lower chart) salmon in the Holitna River, 2002.

stations. These 144 fish were used to calculate proportions passing by the weir and drainage-wide abundance.

Chum Salmon

Four hundred thirty-eight chum salmon were captured between 22 June and 26 July. The largest daily CPUE of chum salmon was 9.5 fish per hour on 11 July (Appendix A1). The daily application rate of radio tags varied from 0.1 to 1.0 tags per fish caught, and 130 fish were radio-tagged (Figure 3). Radio-tagged chum salmon ranged in size from 515-700 mm MEF. Of the 130 chum salmon that were radio-tagged, 116 were relocated at least once upstream of the Holitna River and Hoholitna River tracking stations, and these fish were used for parameter estimation. Of the 14 fish that did not migrate upstream, two fish were known to have regurgitated their radio tags near the tagging site, two backed out and were later found downriver from the mouth of the Holitna River in the mainstem Kuskokwim River, and ten fish were never relocated and were assumed to have either died, migrated to other rivers or had tags that failed after implantation.

Coho Salmon

One hundred eighty-seven coho salmon were captured between 6 August and 7 September. The largest daily CPUE of coho salmon was 6.1 fish per hour on 27 August (Appendix A2). The daily application rate of radio tags varied from 0.3 to 1.0, and 128 coho salmon were radio-tagged (Figure 3). Radio-tagged coho salmon ranged in size from 510 to 670 mm MEF. Of the radio-tagged fish, 64 were relocated at least one time upstream of the Holitna River and Hoholitna River tracking stations. Of the 64 tagged coho salmon that did not migrate upstream, 32 fish backed out of the Holitna River and went past the receiving station at Red Devil, 27 fish were not located, and were assumed to have dropped out of the Holitna River and migrated up the Kuskokwim River, and five tags were located near the capture site and were assumed to have either been regurgitated or the fish died soon after tagging.

DISTRIBUTION AND MOVEMENT OF RADIO-TAGGED SALMON

The tracking stations were highly efficient at detecting the passage of radio-tagged chinook and chum salmon, but were less efficient at detecting passing coho salmon. Of all the radio-tagged chinook and chum salmon known to have passed the lower two tracking stations, only one chinook and two chum salmon swam past undetected. Of the 64 coho salmon known to have passed the two lower tracking stations, eight were not detected (Table 1).

Coho salmon took the least amount of time to recover from handling and migrate to the Kogrukluk River weir, with an average time of 10.7 days. This compared to 15.3 days for chinook salmon and 11.7 days for chum salmon. Chum salmon generally traveled faster than chinook and coho salmon through the other segments of the river (Table 2).

During aerial surveys radio-tagged chinook, chum, and coho salmon were found throughout much of the Holitna River drainage. A majority of chinook and coho salmon were located in tributaries, whereas a majority of chum salmon were located in the mainstem Holitna River (Table 3).

ESTIMATION OF PROPORTIONS AND ABUNDANCE

Chinook Salmon

Final spawning destination (eastern or western drainage) was independent of bank of capture (χ^2=0.01; df=1; P=0.92; Table 4). Run timing at the capture site for radio-tagged chinook

Table 1.-Efficiency of tracking stations in detecting passing radio-tagged salmon in the Holitna River drainage, 2002.

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	75	61	74	81%	99%
	Hoholitna	36	27	36	75%	100%
	Kogrukluk[b]	33	15	33	N/A	100%
Chum						
	Holitna	92	59	90	76%	98%
	Hoholitna	15	15	15	64%	100%
	Kogrukluk[b]	9	7	9	N/A	100%
Coho						
	Holitna	42	41	36	97%	86%
	Hoholitna	17	12	14	71%	82%
	Kogrukluk	5	5	5	100%	100%

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

[b] Aerial survey efficiencies could not be determined because some radio tags were removed from chum and chinook salmon captured at the weir.

Table 2.-Time required (days) to recover from tagging and migrate upstream to a tracking station, or time required for travel between two tracking stations, 2002.

Travel Segment	Species	Number of Radio tags	Average (days)	SE (days)	Min (days)	Max (days)
Tagging site to Hoholitna station						
(~51 km)	Chinook	37	3.8	1.7	1.2	4.0
	Chum	26	1.2	0.1	1.1	3.9
	Coho	24	6.9	0.9	1.5	16.8
Tagging site to Holitna station						
(~56 km)	Chinook	82	7.9	2.5	0.4	18.8
	Chum	104	2.2	0.1	0.6	6.8
	Coho	38	7.8	1.2	1.8	41.5
Holitna station to Kogrukluk station						
(~170 km)	Chinook	35	12.1	1.5	4.4	47.3
	Chum	9	6.0	0.5	3.6	8.9
	Coho	5	7.7	1.0	5.9	11.0
Tagging site to Kogrukluk station						
(~225 km)	Chinook	26	15.3	2.3	7.9	29.0
	Chum	9	11.7	0.5	6.3	10.5
	Coho	5	10.7	2.6	8.7	21.6

Table 3.-Number of radio-tagged chinook, chum, and coho salmon located in tributaries or sections of the Holitna River drainage during aerial surveys, 2002.

	Species		
Tributary or River Section	Chinook	Chum	Coho
Hoholitna River Drainage			
Mainstem Hoholitna River	25	16	12
Hook Creek	1	0	2
South Fork Hoholitna River	4	0	5
No Name (west of South Fork Hoholitna River)	1	0	2
Weasel Creek	0	0	1
Holitna River Drainage			
Mainstem of Holitna River	27	59	24
Kogrukluk River[a]	15	7	1
Shotgun Creek[a]	3	2	2
Mainstem Chukowan River	10	1	1
Oksotalik Creek	2	0	0
Gemuk River	1	0	0
Bairo Creek	0	0	0
Chikululnuk Creek	0	0	0
Enatalik Creek	0	0	0
Portage Creek	3	0	1
Bakbuk Creek	0	3	0
No name (West side drainage between Babuk and Portage creeks)	1	0	0
Kiknik Creek	2	1	1
Taylor Creek	3	2	4
Itulilik Creek	1	3	0
Chuilnuk Creek	0	1	1
Mukslulik Creek	4	1	0
Titnuk Creek	6	11	9

[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, 2002.

		Bank of Release	
Salmon Species	Migration Destination	West	East
Chinook[a]			
	Holitna River (west)	15	11
	Hoholitna River (east)	3	2
	χ^2=0.01; df=1; P=0.92		
Chum			
	Holitna River (west)	39	33
	Hoholitna River (east)	5	6
	χ^2=0.29; df=1; P=0.59		
Coho			
	Holitna River (west)	14	10
	Hoholitna River (east)	5	7
	χ^2=0.89; df=1; P=0.35		

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

salmon spawning above the Kogrukluk River weir and those spawning in the rest of the Holitna River drainage were not significantly different (D=0.24; P=0.05; Figure 4). Sex ratios of radio-tagged chinook salmon spawning above the Kogrukluk River weir and those spawning in the rest of the drainage were not significantly different (χ^2=0.13; df=1; P=0.72; Table 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=0.12, P=0.80; Figure 5). Length distribution of all radio-tagged spawning chinook salmon was not significantly different from all fish sampled at the weir (D=0.20; P<0.01; Figure 5). Of the 144 radio-tagged chinook salmon that migrated up the Holitna River, 33 passed through the weir. The estimated proportion of chinook salmon migrating into the Kogrukluk River was 0.23 (95% C.I.=0.16-0.30), and 10,059 chinook salmon were observed past the weir (Clark and Molyneaux 2003). The estimated abundance of chinook salmon in the Holitna River drainage was 42,902 fish (SE=6,334).

Chum Salmon

Final spawning destination (eastern or western drainage) was independent of bank of capture (χ^2=0.29; df=1; P=0.59; 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=0.72; df=1; P=0.40; Table 5); however, no 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=0.66; P<0.01; Figure 4). Length distribution of all radio-tagged spawning chum salmon was not significantly different from those that spawned above the weir (D=0.20; P=0.88). However, length distribution of all spawning radio-tagged chum salmon was significantly different from all fish sampled at the weir (D=0.53; P<0.01).

Of the 116 radio-tagged chum salmon that resumed upstream migration after tagging, nine passed through the weir. The estimate of the proportion of Holitna River chum salmon passing through the Kogrukluk River weir was 0.09 (95% CI=0.02-0.21), and 51,383 chum salmon were observed past the Kogrukluk River weir (Clark and Molyneaux 2003).

Abundance estimation for chum salmon was problematic due to stark differences in the run timing of fish migrating past the weir compared to run timing of fish spawning elsewhere in the drainage, and because few radio-tagged fish migrated past the weir and none were female. As a consequence, it was not possible to directly estimate abundance for the later portion of the run or for female chum salmon. In addition, because few radio-tagged fish migrated past the weir, estimated drainage-wide abundance was imprecise resulting in an estimated abundance of 542,172 chum salmon (SE=285,925).

Coho Salmon

Final spawning destination (eastern or western drainage) was independent of bank of capture (χ^2=0.89; df=1; P=0.35; 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 (D=0.44; P=0.30; 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=3.71; df=1; P=0.05; Table 5); however, no radio-tagged male coho salmon migrated past the weir. Length

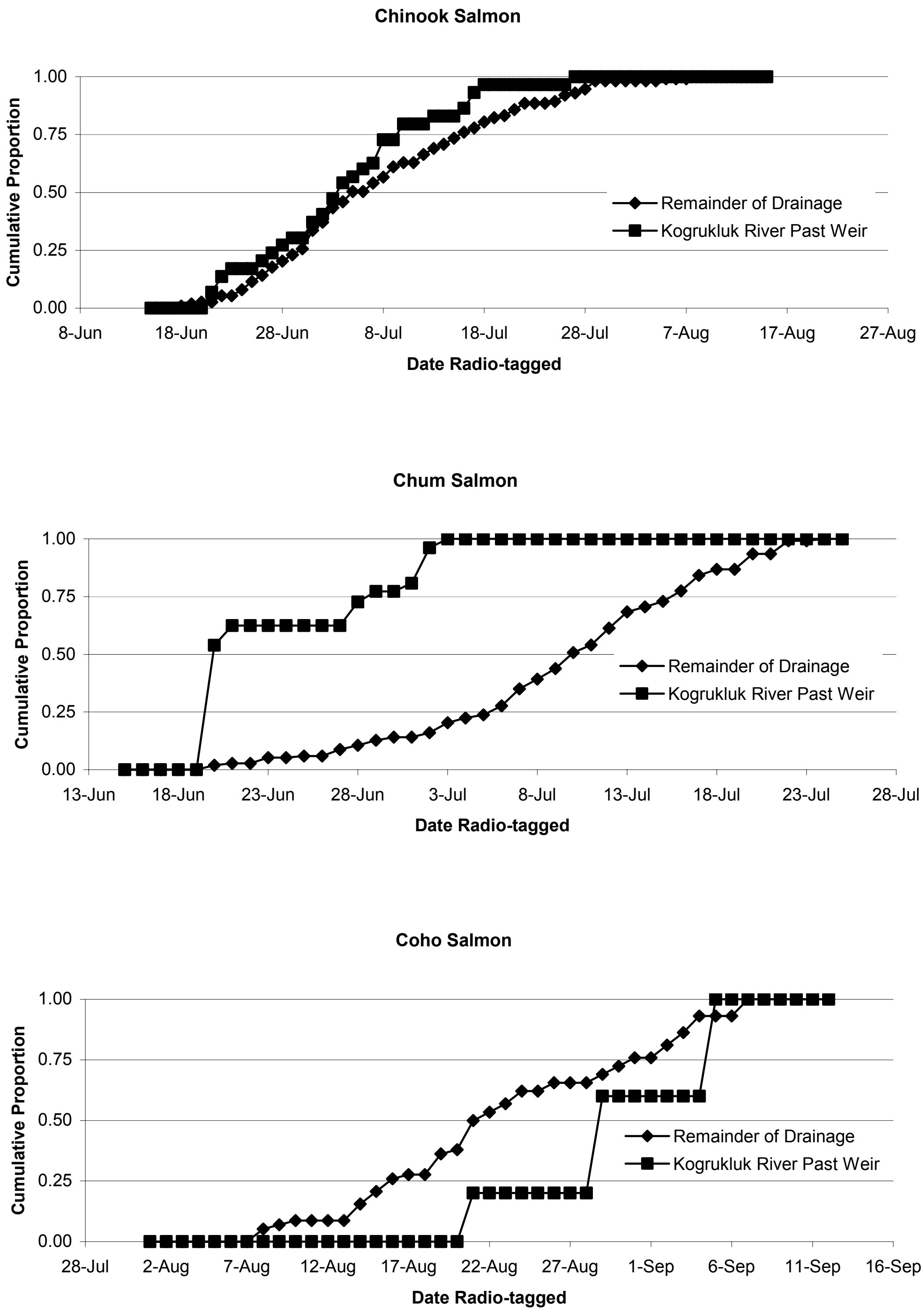

Figure 4.-Migratory timing profile of radio-tagged chinook, chum, and coho salmon at the capture site that migrated past the Kogrukluk River weir or migrated to all other areas of the Holitna River drainage, 2002.

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, 2002.

		Spawning Area	
Salmon Species	Sex	Above Kogrukluk River	All other areas of the Holitna River drainage
Chinook			
	Male	14	51
	Female	19	60
	χ^2=0.13; df=1; P=0.72		
Chum			
	Male	9	99
	Female	0	8
	χ^2=0.72; df=1; P=0.40		
Coho			
	Male	0	26
	Female	5	33
	χ^2=3.71; df=1; P=0.05		

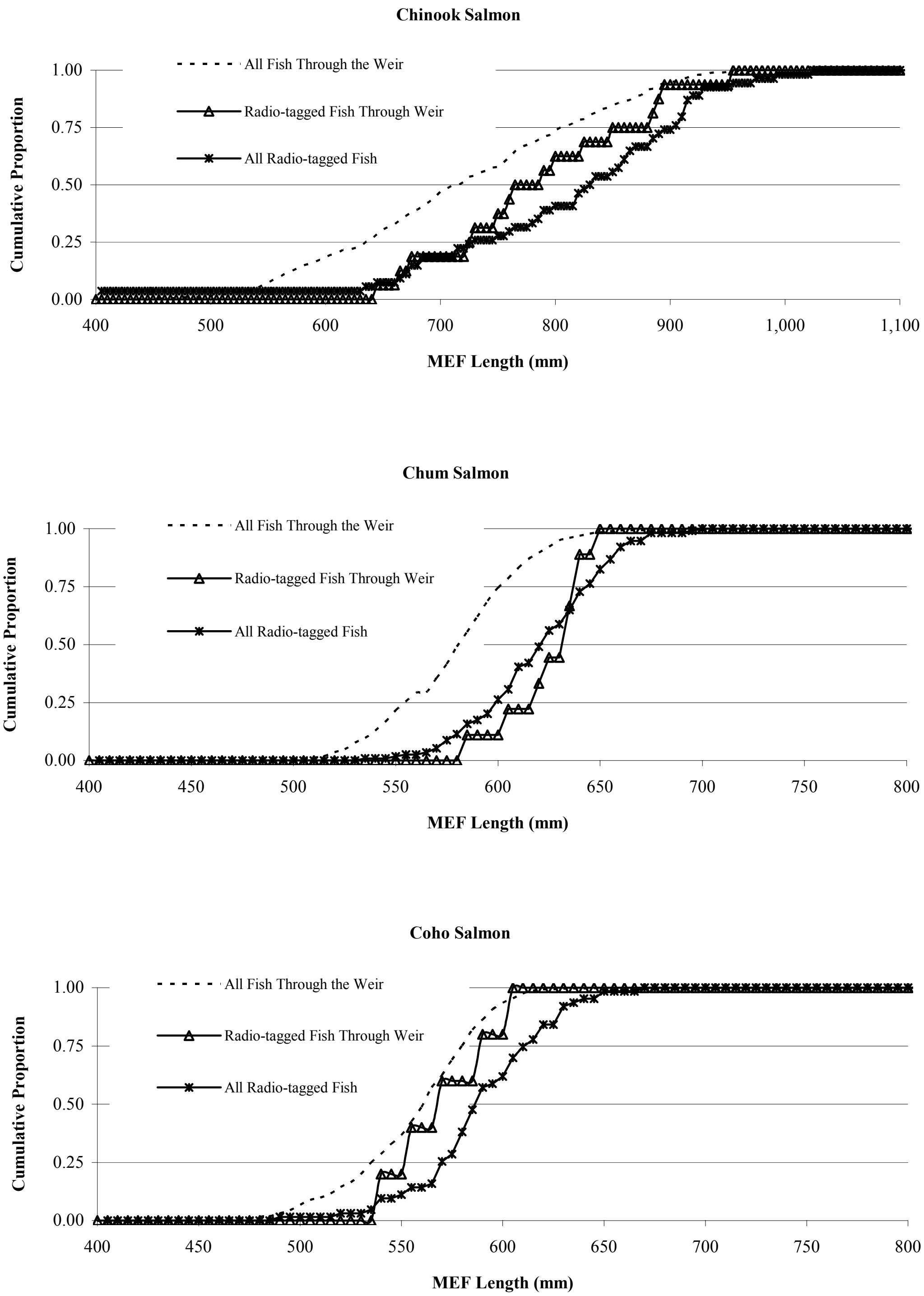

Figure 5.-Cumulative length frequency distributions of radio-tagged chinook, chum, and coho salmon that spawned in the entire Holitna River drainage, compared with both radio-tagged and not radio-tagged chinook, chum, and coho salmon sampled at the Kogrukluk River weir, 2002.

distribution of radio-tagged coho salmon spawning above the Kogrukluk River weir was not significantly different from the distribution of all spawning radio-tagged fish in the drainage (D=0.35; P=0.60 Figure 5). However, length distribution of all spawning radio-tagged coho salmon was significantly different from the distribution of all fish sampled at the weir (D=0.42; P<0.01; Figure 5).

The estimated proportion of coho salmon migrating through the Kogrukluk River weir was 0.08 (95% CI=0.01-0.15), and 14,517 coho salmon were observed past the Kogrukluk River weir (Clark and Molyneaux 2003).

As with chum salmon, drainage-wide abundance estimation for coho salmon was problematic because of the small number of radio-tagged fish that migrated upstream in the Holitna River and because no radio-tagged male coho salmon migrated past the weir. Estimated abundance was 157,277 coho salmon (SE=56,624), and it was assumed that male coho salmon were marked in the same proportion as were females.

AGE-SEX-LENGTH COMPOSITION OF CAPTURED SALMON

Diagnostic testing for abundance estimation revealed that gillnet sampling was size-selective for all three species and in all cases, the smaller size classes were captured at a lower rate. Although this selectivity was not problematic in estimating $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$, compositions estimated from gillnet sampling do not reflect true population proportions. Length and sex composition of captured chinook, chum, and coho salmon varied by mesh size (Appendices B1-B3). Ages were determined for 62 chinook salmon, 412 chum salmon, and 147 coho salmon (Appendix C).

DISCUSSION

Accurate estimation of the proportion of salmon that enter the Holitna River drainage and migrate past the Kogrukluk River weir ($\hat{P}^*_{KR}$) and abundance of fish in the Holitna River drainage ($\hat{N}_{Hol}$) 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. This study was designed to maximize the chance that migrating salmon would be captured and marked in proportion to true population parameters. The key elements of the study design to ensure representative tagging were that sampling was conducted over the span of the run, sampling effort was standardized (if daily fishing effort and tagging rate varied, then each radio-tagged fish was weighted so that each represented a consistent proportion of the total daily catch), sampling was conducted across the entire width of the channel, and various sized gillnets were used to capture all length-classes of salmon in the population.

Even with standardized tag effort (through tag weighting if necessary), temporal changes in catchability could lead to tag deployment that was not proportional to actual abundance. With all other parameters being representative, this would only a problem if the proportion of Kogrukluk River-bound fish available at the capture site varied over time. To evaluate the importance of the assumption that tags were deployed proportional to daily passage at the capture site, the cumulative run timing distribution of salmon that migrated past the weir was compared to the distribution of salmon that migrated to all other areas in the drainage. If these two distributions were similar, then for the purpose of estimating the proportion of fish that migrated past the weir, it was not critical that tags were deployed proportional to true daily abundance. However, if run timing distributions were different, changes in catchability would result in a disproportionate tagging rate of Kogrukluk River fish (either too high or too low) which could potentially bias $\hat{P}^*_{KR}$. During the two years of this study, the run timing patterns at the capture site for fish passing through the weir and fish migrating to other areas of the drainage was similar for chinook and coho salmon, but different for chum salmon. The estimates of $\hat{P}^*_{KR}$ for chum salmon were relatively similar in both years of the study (approximately 0.10). The consistency of these estimates coupled with assessments from aerial surveys that have 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 support the idea that only a small proportion of chum salmon in the Holitna drainage spawn above the weir, and suggest that the estimates of $\hat{P}^*_{KR}$ are likely not severely biased.

Sampling was conducted across the entire width of the channel each day and final destinations of all captured fish were compared to bank of capture to investigate whether fish were mixed or were bank-oriented. In both years of the study there was no evidence of bank-oriented migratory behavior for any of the three species.

Size and gender-selective sampling could bias estimates of the proportion passing through the weir if the composition above the weir differed from other areas of the drainage. Size-selectivity has been apparent in both years of the study for all three species. In both years, the small size classes of each species were under represented in the gillnet sample compared to the sample of all fish examined at the weir. In 2001, size-selectivity necessitated estimating $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ for chinook salmon $\geq$ 650 mm and for coho salmon $\geq$510 mm (Wuttig and Evenson 2002). In this year's study, although few small fish (chinook salmon <650 mm; chum salmon <550 mm; and, coho salmon <510 mm) were captured and radio-tagged compared to the proportions of untagged fish of those same size classes that migrated past the weir, the recovery rates of small fish were similar to those of large fish. This indicates that although the gillnet sampling was size-selective; the migratory behavior of radio-tagged fish (as it relates to migrating past the weir) was consistent with untagged fish. Thus, $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ could be estimated without adjusting for size selectivity.

In both years of the study there has been no evidence for gender-selective sampling for any of the species. However, in both years of the study no radio-tagged female chum salmon and in this year's study no radio-tagged male coho salmon migrated past the weir. Because few radio-tagged fish of either gender passed through the weir (nine chum salmon and five coho salmon), the statistical power of the hypothesis tests of equal tagging rates by gender and spawning destination was small. A larger sample of radio-tagged fish would result in more fish migrating past the weir which would enable more powerful hypothesis testing and allow for estimates of $\hat{P}^*_{KR}$ and $\hat{N}_{Hol}$ to be corrected for through stratification by gender if significant test statistics were obtained.

For coho salmon in 2002, the small sample size was unexpected as there was a surprisingly large number of radio-tagged fish (34) that backed out of the Holitna River and went downriver on the

Kuskokwim past the receiving station at Red Devil. An additional 27 fish were not found after tagging, and likely traveled out of the Holitna River and migrated up the Kuskokwim River rather than downriver past Red Devil. This result was quite different from 2001, when most radio-tagged coho salmon migrated up the Holitna River. The reasons for the difference in the number of fish that backed-out between 2001 and 2002 are unclear as sampling was conducted similarly in both years.

CONCLUSIONS

1. This study successfully addressed project objectives for chinook, chum, and coho salmon for 2002. The proportion of chinook salmon spawning upstream from the weir and the spawning abundance in the entire drainage was estimated. This was successful mainly because of the migration of Kuskokwim River radio-tagged fish into the Holitna River to increase the overall number of radio-tagged chinook salmon in the river. The estimated proportion of chum salmon above the weir and in the entire drainage was also achieved; however, similarly to 2001 there was a very small proportion of chum salmon that made it past the weir. For coho salmon, the large number of fish that backed down past the tagging site resulted in a decrease in the number of fish past the weir, as well as the overall precision of the estimate. Further study is warranted to determine the variability in spawning distribution and run-timing patterns for each species. The results of the first two years of this study suggested that the Kogrukluk River weir 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 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. Those and two new recommendations are given 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-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 and by only tagging chum salmon caught in small mesh nets only, and by developing a tagging schedule that apportions radio tags into size classes to ensure tags given to fish of all sizes.
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 for chum salmon would

increase the precision of the estimate and allow for more robust testing of estimator assumptions.

5. Although no sampling for coho salmon is planned in 2003, any future sampling to repeat this study 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.

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APPENDIX A

Appendix A1.-Daily fishing effort, catch, number of radio tags deployed, CPUE and weighting factor, for chinook and chum salmon in the Holitna River, 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	-	0.65	-	-
18-Jun	144	47	0	0	97	1	1	2	0	0.62	1.24	1.47	-
19-Jun	143	45	0	0	98	2	1	4	1	1.22	2.45	2.91	1.82
20-Jun	92	43	0	0	49	1	1	6	1	1.22	7.35	2.91	5.46
21-Jun	158	55	0	0	103	1	1	6	3	0.58	3.50	1.38	0.87
22-Jun	147	51	0	0	96	4	4	5	2	2.50	3.13	1.49	1.16
23-Jun							OFF						
24-Jun	159	0	59	0	100	3	2	3	2	1.80	1.80	2.14	0.67
25-Jun	156	0	50	0	106	3	3	3	1	1.70	-	1.35	-
26-Jun	169	55	0	0	114	3	3	9	5	1.58	4.74	1.25	0.70
27-Jun	163	57	0	0	106	4	3	4	4	2.26	2.26	1.79	0.42
28-Jun	163	55	0	0	108	1	1	10	8	0.56	5.56	1.32	0.52
29-Jun	177	61	0	0	116	1	1	6	5	0.52	3.10	1.23	0.46
30-Jun							OFF						
1-Jul	179	56	0	0	123	4	4	6	6	1.95	2.93	1.16	0.36
2-Jul	186	0	63	0	123	1	1	15	7	0.49	7.32	1.16	0.78
3-Jul	202	0	51	0	151	4	4	12	9	1.59	4.77	0.94	0.39
4-Jul							OFF						

-continued-

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Date	Total Effort (min)	Effort by Mesh Size (min)				Number Chinook Caught	Number Chinook Tagged	Number Chum Caught	Number Chum Tagged	Chinook CPUE (Catch/hr)	Chum CPUE (Catch/hr)	Chinook Weighting Factor	Chum Weighting Factor
		5.75 in	6.5 in	7.5 in	8 in								
5-Jul	228	0	51	0	177	2	2	20	8	0.68	6.78	-	0.63
6-Jul	219	0	69	0	150	1	1	21	8	0.40	8.40	0.95	0.78
7-Jul	221	0	74	0	147	4	4	16	11	1.63	6.53	0.97	0.44
8-Jul	225	61	0	0	164	3	3	20	9	1.10	7.32	0.87	0.60
9-Jul	235	0	59	0	176	1	1	22	8	0.34	7.50	0.81	0.70
10-Jul	231	0	63	0	168	1	1	19	8	0.36	6.79	0.85	0.63
11-Jul	209	0	52	0	157	0	0	25	4	-	9.55	-	1.78
12-Jul	210	0	45	0	165	2	2	25	3	0.73	9.09	0.86	2.25
13-Jul	254	0	47	0	207	4	4	10	3	1.16	2.90	0.69	0.72
14-Jul							OFF						
15-Jul	188	0	68	0	120	2	2	18	3	1.00	9.00	1.19	2.23
16-Jul	265	0	49	0	216	1	1	25	3	0.28	6.94	0.66	1.72
17-Jul	259	0	52	0	207	2	2	18	3	0.58	5.22	0.69	1.29
18-Jul	168	0	0	0	168	1	1	15	0	0.36	5.36	0.85	-
19-Jul	307	0	102	0	205	2	2	30	1	0.59	8.78	0.70	6.53
20-Jul							OFF						
21-Jul	283	0	62	0	221	0	0	27	1	-	7.33	-	5.45
22-Jul	272	0	58	0	214	2	2	27	1	0.56	7.57	0.67	5.63
23-Jul	233	0	32	0	201	0	0	7	2	-	2.09	-	0.78

Appendix A2.-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			OFF		
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			OFF		
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			OFF		
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			OFF		
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 B

Appendix B1.-Catch and length statistics for chinook salmon caught in the Holitna River and chinook salmon that were radio-tagged in the Kuskokwim River chinook salmon project and migrated into the Holitna River, 2002.

Statistic	Holitna River	Kuskokwim River Project
All fish		
Number caught	59	95
Male	6	63
Female	53	32
Percent male	10%	66%
Mean length (mm)		
All (SD)	821 (102)	734 (120)
Male (SD)	755 (65)	689 (114)
Female (SD)	828 (103)	823 (77)
Length range (mm)		
Male	665-835	465-1025
Female	585-1025	575-950
Radio-tagged fish		
Number tagged	58	95
Male	5	63
Female	53	32
Percent male	10%	66%
Mean length (mm)		
All (SD)	821 (102)	734 (120)
Male (SD)	755(65)	689 (114)
Female (SD)	828(103)	823 (77)
Length range (mm)		
Male	665-835	465-1025
Female	585-1025	575-950

Appendix B2.-Catch and length statistics for chum salmon by mesh size in the Holitna River, 2002.

Statistic	All Meshes	Mesh Size 5.75 in	6.75 in	8 in
All fish				
Number caught	438	22	200	216
Male	415	15	191	207
Female	23	6	8	9
Percent male	95%	71%	96%	96%
Mean length (mm)				
All (SD)	613 (35)	606 (23)	610 (35)	617 (36)
Male (SD)	615 (34)	610 (23)	610 (34)	635 (30)
Female (SD)	590 (46)	597 (24)	621 (56)	560 (28)
Length range (mm)				
Male	345-720	570-650	345-720	565-700
Female	525-715	550-620	555-715	525-600
Radio-tagged fish				
Number tagged	130	6	69	55
Male	118	4	62	52
Female	12	2	7	3
Percent male	91%	67%	90%	95%
Mean length (mm)				
All (SD)	621 (41)	616 (26)	612 (46)	633 (31)
Male (SD)	622 (40)	620 (32)	611 (45)	635 (30)
Female (SD)	616 (46)	608 (18)	627 (58)	595 (5)
Length range (mm)				
Male	345-700	575-650	345-675	565-700
Female	555-715	595-620	555-715	590-600

Appendix B3.-Catch and length statistics of coho salmon captured in 5.75-in mesh gillnets in the Holitna River, 2002.

Statistic		All fish	Radio-tagged fish
Number caught		188	130
	Male	91	62
	Female	97	68
Percent male		48%	46%
Mean length (mm)			
	All (SD)	587 (36)	587(34)
	Male (SD)	586(39)	586(39)
	Female (SD)	587 (32)	587 (32)
Length range (mm)			
	Male	450-670	450–670
	Female	490-650	490-650

APPENDIX C

Appendix C.-Age and length statistics for chinook, chum, and coho salmon captured at the tagging site in the Holitna River, 2002.

	Age	Sample Size	Proportion	Length (mm) Mean	SD	Min	Max
Chinook							
Male	1.2	1	0.25	665	-	665	665
	1.3	2	0.50	758	46	725	790
	1.4	0	-	-	-	-	-
	1.5	1	0.25	835	-	835	835
	2.4	0	-	-	-	-	-
	All	4	1.00	754	74	665	835
Female	1.2	4	0.07	654	54	585	715
	1.3	12	0.21	802	96	675	955
	1.4	26	0.45	883	66	765	1,025
	1.5	1	0.02	860	-	860	860
	2.4	1	0.02	820	-	820	820
	All	58	1.00	838	99	585	1,025
Chum							
Male	2	7	0.02	602	34	555	640
	3	249	0.64	611	35	345	720
	4	133	0.34	625	32	535	675
	5	3	0.01	607	30	575	635
	All	392	1.00	615	34	345	720
Female	2	0	-	-	-	-	-
	3	14	0.70	583	34	525	640
	4	6	0.30	605	61	540	715
	5	0	0.00	-	-	-	-
	All	20	1.00	591	47	525	715
Coho							
Male	1.1	6	0.09	600	42	540	645
	2.1	59	0.86	587	36	510	670
	2.2	0	-	-	-	-	-
	3.1	4	0.06	621	19	595	640
	All	69	1.00	590	36	510	670
Female	1.1	3	0.04	595	17	585	615
	2.1	66	0.85	586	33	490	650
	2.2	2	0.03	580	14	570	590
	3.1	7	0.09	584	36	520	610
	All	78	1.00	586	32	490	650