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Inriver Abundance, Spawning Distribution, and Migratory Timing of Copper River Chinook Salmon in 2000

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and

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December 2001

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
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-tailfork	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. 01-22

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by

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ABSTRACT

Radiotelemetry and mark-recapture techniques were used to estimate inriver abundance, spawning distribution, and migratory time-density functions of chinook salmon *Oncorhynchus tshawytscha* in the Copper River during 2000. Inriver abundance was estimated using two-sample mark-recapture techniques where radio tags were applied as the primary mark. A total of 536 chinook salmon were captured, radio-tagged, and released during the first sample downstream from the lower boundary of the Chitina subdistrict subsistence (CSS) salmon fishery from 20 May-4 August 2000. Of these, 480 resumed upstream migration after tagging. The second sample consisted of the harvest of 3,011 chinook salmon in the CSS fishery, 191 fish sampled from fish wheels immediately upstream of the CSS fishery, and 193 fish captured with gillnets and dip nets within the CSS fishery. Fifty-three fish with radio tags were recovered during the second sample. Estimated abundance was 21,816 (SE=2,719) chinook salmon ≥ 580 mm MEF for the period 16 June–31 July when the fishery was prosecuted. This estimate was expanded based on CPUE information from the first sample to account for the portion of the run that passed prior to the opening of the CSS fishery. Total abundance was estimated to be 38,047 (SE=7,675) chinook salmon ≥ 580 mm MEF for the period 24 May to 31 July.

The distribution of spawning chinook salmon was apportioned to major drainages using the spawning locations of 318 radio-tagged fish. Estimated proportions of all spawning chinook salmon by major drainage were 0.02 for the East Fork Chistochina River, 0.03 for the Tazlina River, 0.13 for the Chitina River, 0.20 for the Tonsina River, 0.25 for the Gulkana River, and 0.27 for the Klutina River. Spawning areas upstream from the Gulkana River accounted for 0.12 of the total spawning escapement. Proportions of chinook salmon spawning in the major drainages were similar to those estimated in 1999 with the exceptions that the proportion spawning in the Gulkana River increased from 0.12 to 0.25 and the proportion spawning in the Chitina River decreased from 0.20 to 0.12.

Mainstem spawners accounted for 0.86 of all spawning chinook salmon in the Tonsina River and 0.78 of those in the Klutina River. In combination, mainstem spawners in these systems represent a significant proportion (0.38) of the total Copper River escapement. Radiotelemetry studies may be the only effective method of assessing escapement in these systems.

Migratory time-density functions at the capture site varied among the major spawning stocks. Mean date of passage ranged from 5 June for chinook salmon bound for the upper Copper River drainages to 5 July for mainstem spawners in the Klutina drainage. Migratory timing of chinook salmon bound for tributaries in the Tonsina and Klutina rivers was generally earlier than their mainstem spawning counterparts.

The nine streams normally used for aerial survey indices, in total, accounted for 0.40 of chinook salmon migrating into all spawning streams. Because of interannual variation in this proportion and because these streams support stocks with predominantly early run timing patterns, they likely do not provide a consistent nor reliable measure of total drainage escapement.

Key words: chinook salmon, *Oncorhynchus tshawytscha*, Copper River, East Fork Chistochina River, Gulkana River, Tazlina River, Chitina River, Klutina River, Tonsina River, abundance, mark-recapture, radiotelemetry, spawning distribution, aerial surveys, time-density functions.

INTRODUCTION

The Copper River supports a large and important run of chinook salmon *Oncorhynchus tshawytscha*. These fish are harvested by a commercial fishery operating in and near the mouth of the river and also by inriver subsistence and sport fisheries. Recent 5-year annual harvest (1994-1998) by all fisheries has averaged 72,264 chinook salmon (Taube and Sarafin 2001). During this same period, average annual commercial harvest was 57,696, sport harvest was 7,769, and subsistence and personal use harvest combined averaged 6,799 chinook salmon. Average annual harvest of chinook salmon by sport anglers increased from 2,048 for 1977-1988 to 6,102 for 1989-1998. The Gulkana and Klutina rivers account for the majority of the sport harvest.

The return of salmon in the Copper River is managed under guidelines established in: 1) the *Copper River District Salmon Management Plan* (AAC 2000a); 2) the *Copper River Chinook Salmon Fishery Management Plan* (AAC 2000b); and, 3) the *Copper River Subsistence Salmon Fisheries Management Plan* (AAC 2000c). Together, these management plans mandate the Alaska Department of Fish and Game (ADF&G) to manage Copper River salmon to ensure subsistence needs and biological escapement goals are met. During a 1999 meeting, the Alaska Board of Fisheries (BOF) declared that the personal use dip net salmon fishery in the Chitina subdistrict met criteria for customary and traditional subsistence use and mandated the fishery be managed as a subsistence fishery. The Board determined that 130,000 – 150,000 salmon (all species) were necessary for meeting the Chitina subdistrict subsistence needs, and a biological escapement goal of 28,000–55,000 chinook salmon was necessary to ensure high sustained yields of chinook salmon. Prior to these rulings, the commercial fishery was managed to ensure a spawning escapement of 17,500 salmon other than sockeye salmon *Oncorhynchus nerka*, and no species-specific escapement goals or harvest guidelines had been established for chinook salmon.

These management plans necessitate estimates of harvest from all fisheries and abundance of returning fish. Historically, with the exception of a weir count in the Gulkana River in 1996 (LaFlamme 1997), aerial counts in select spawning tributaries have been the sole measure of chinook salmon spawning escapement. Forty different spawning streams have been identified throughout the drainage, but only nine are surveyed on a regular basis. The sonar at Miles Lake provides a total count of all salmon, but does not apportion the count for the various species. This project was the third year of a four-year study in which the first year was a feasibility study. Results of this project should ultimately be used to develop more reliable and cost-effective methods to assess chinook salmon escapements in the Copper River.

OBJECTIVES

The objectives of this study were to:

1. estimate the proportions of spawning chinook salmon in each major spawning tributary (Chitina, Tonsina, Klutina, Tazlina, Gulkana, and East Fork Chistochina rivers) in the Copper River drainage;
2. estimate the proportion of chinook salmon spawning in the nine tributaries assessed during aerial surveys in 2000 (Little Tonsina River, Greyling Creek, St. Anne Creek, Manker Creek,

Mendeltna Creek, Kiana Creek, Gulkana River, East Fork Chistochina River, and Indian Creek); and,

3. estimate the inriver abundance of chinook salmon in the Copper River at the Chitina subdistrict subsistence fishery.

Additional project tasks were to:

1. describe the stock-specific migratory time-density functions (timing profiles) at the entry point to the CSS fishery, where stocks are defined as those chinook salmon spawning in the Chitina, Tonsina, Klutina, Tazlina, and Gulkana rivers, and those spawning tributaries of the Copper River upstream of the Gulkana River (collectively referred to as the Upper Copper River); and,
2. determine the status of radio-tagged chinook salmon located in the mainstem Copper River immediately upstream of the Tonsina River during August as mortalities, migrating fish, or mainstem spawners.

METHODS

STUDY DESIGN

Radiotelemetry and mark-recapture techniques were used to estimate inriver abundance, spawning distribution, and migratory time-density functions of chinook salmon in the Copper River during 2000. Inriver abundance of chinook salmon was estimated using two-sample mark-recapture techniques. The first sample consisted of marking chinook salmon with radio tags (esophageal implants) in the mainstem Copper River immediately downstream from CSS fishery near Chitina, Alaska (Figure 1). The second sample consisted of three components: 1) the harvest of chinook salmon in the CSS fishery; 2) chinook salmon captured with dip nets and gillnets within the CSS fishery; and, 3) chinook salmon sampled in subsistence fish wheels catches located just upstream of the CSS fishery. Marked fish in the second sample were determined from voluntary tag returns from CSS fishers and other upriver fisheries and with a combination of automated tracking stations positioned at strategic points, aerial tracking surveys using fixed wing aircraft, and boat tracking surveys. The proportion of fish spawning in various tributaries was estimated as the ratio of numbers of radio-tagged fish migrating into a specific tributary to the total number of radio tags surviving and migrating into all spawning streams. The farthest upstream location for each fish in a tributary stream was used to identify probable spawning areas. Migratory timing profiles of the major spawning stocks at the entry point of the CSS fishery were identified using the date and time of initial capture.

CAPTURE AND TAGGING METHODS

Sampling to capture and mark chinook salmon was conducted from two locations in the Copper River approximately 1-3 km below the lower boundary of the CSS fishery from 20 May – 4 August 2000 (Figure 2). Chinook salmon were captured by drifting dip nets from a riverboat along the nearshore areas on both the east and west banks. Both east and west drift areas were near long gravel bars with water levels dropping off gradually from shore.

Capture operations were conducted by a three person crew. One person piloted the boat and two crewmembers positioned in the bow of the boat-manned dip nets. Dip nets were commercially manufactured and constructed from solid-core aluminum tubing. Net heads were rectangular-shaped (122 cm wide x 88 cm high) and were attached to tubular fiberglass handles (3-4 m long

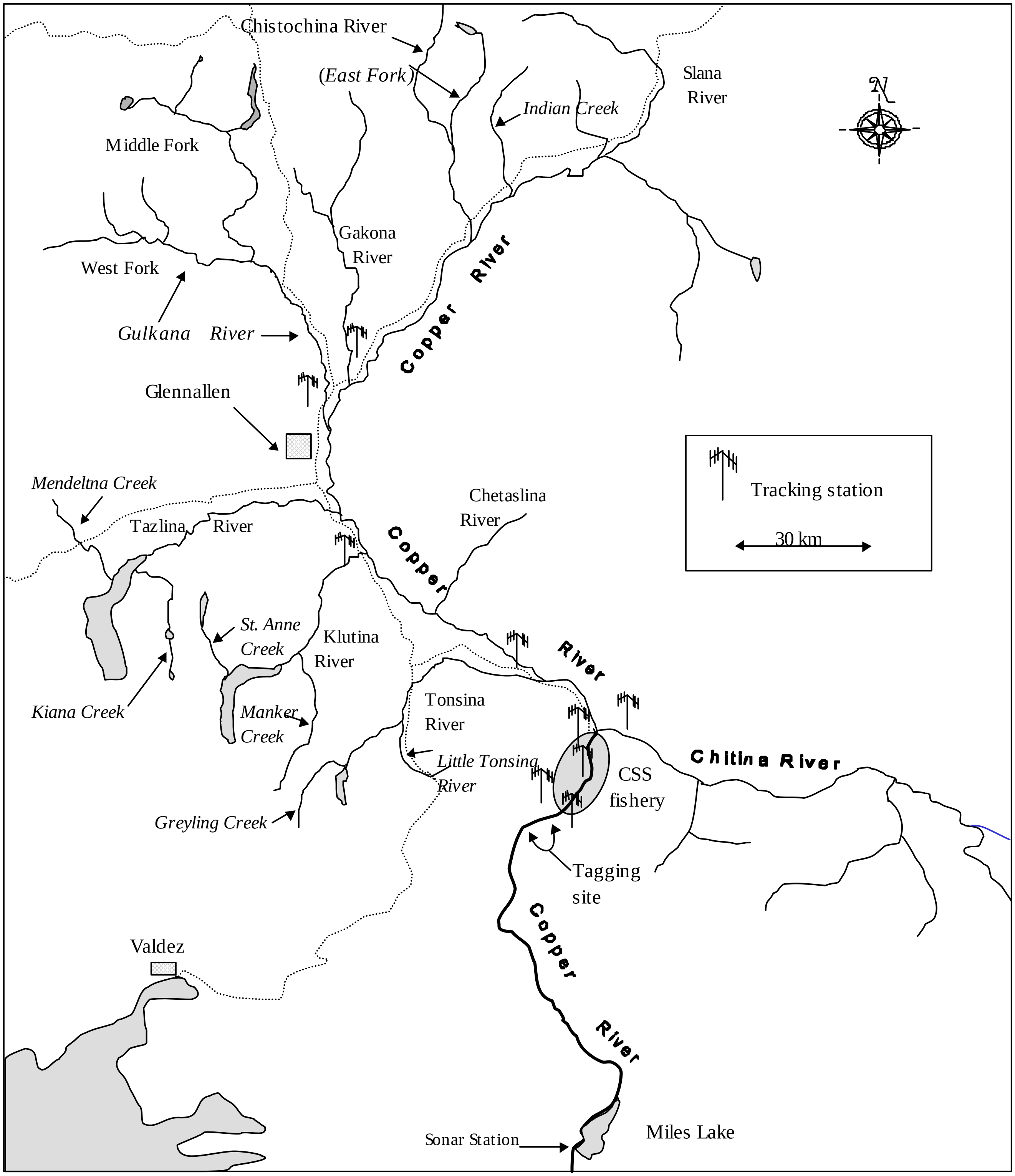

Figure 1.-Map of the Copper River drainage demarcating the tagging site, boundaries of the Chitina subdistrict subsistence fishery, and location of nine radio tracking stations, 2000.

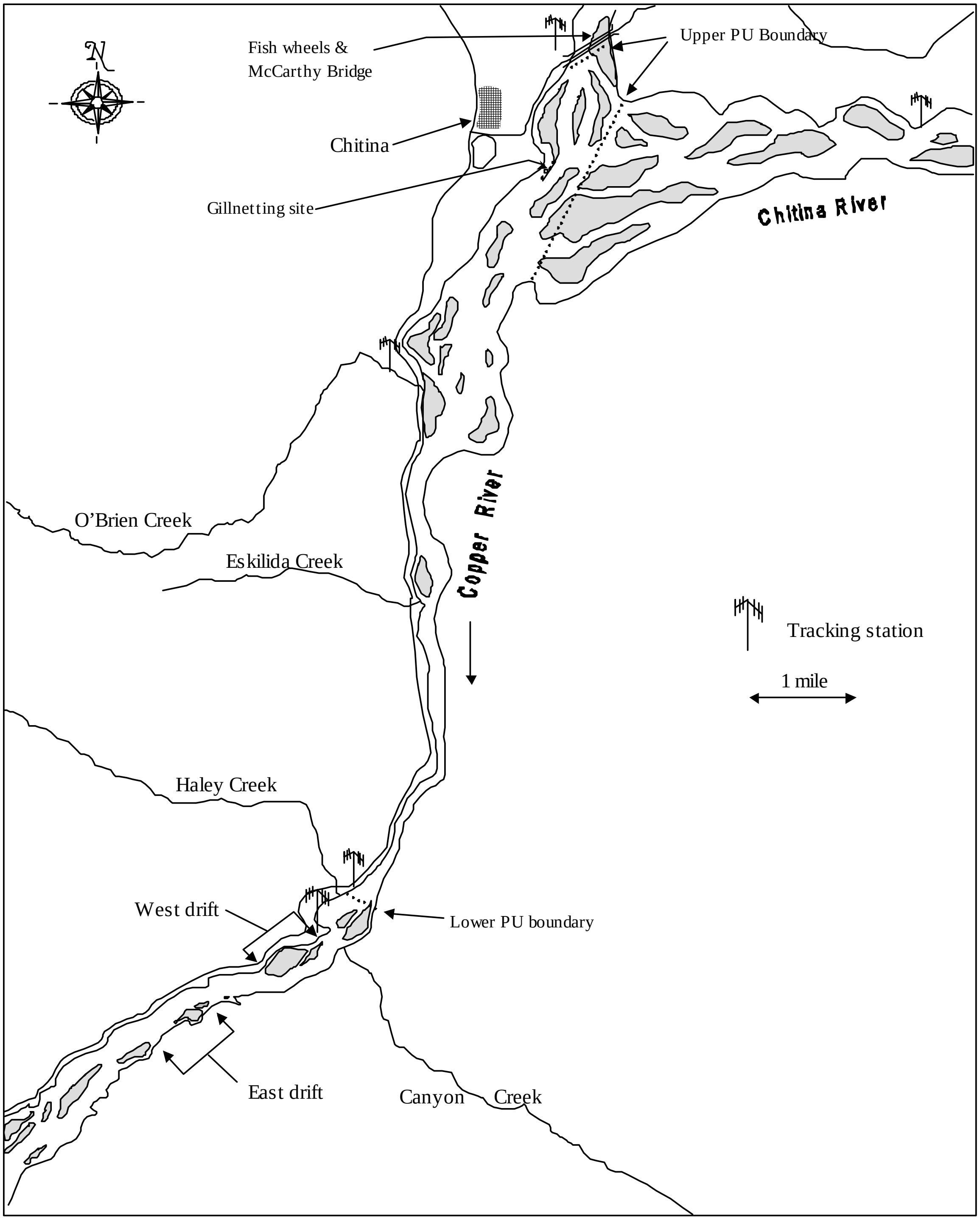

Figure 2.-Map of the study area for the mark-recapture experiment demarcating the capture and tagging location, upriver gillnet and fish wheel sampling sites, boundaries of the CSS fishery, and locations of five tracking stations, 2000.

x 1.3 cm diameter). The attached net bags were constructed with knotted nylon (8.9-10.2 cm stretch measure) and were 1.3 m deep. Plastic shovel handles capping the fiberglass handles facilitated handling and allowed crew members to maintain orientation of the net head perpendicular to the direction of the drifting riverboat. At the start of each drift, the boat was positioned nearshore with the bow facing upstream. Distances the boat was drifted from shore varied depending on water depth and levels. Typically drifts were conducted 3-10 m from shore, but were occasionally conducted as far as 50 m offshore. The boat was then idled downstream, stern first, such that the velocity of the boat was slightly faster than the current at the bottom of the water column. This ensured that the dip nets remained open or "bagged" when facing downstream. The dip nets were positioned vertically in the water column from the side of the boat so that the flat edge of the dip net lightly bounced off the bottom.

Attempts were made to standardize fishing effort to help ensure that all chinook salmon migrating upstream had equal probabilities of capture. From 22 May to 4 August, the protocol was to fish for five hours each day. Occasionally, unforeseen mechanical problems resulted in less than 5 hours of fishing effort being expended. On days when five hours of fishing effort occurred, 2.5 hours of effort were expended between 0900 and 1300 hours and 2.5 hours between 1800 and 2300 hours. During each 2.5 hour session, fishing was alternated between the east and west banks every 45 min for the first 1.5 hours of the session, and alternated every 30 min for the remaining hour of the session. Measurements of fishing effort included the time required to motor upstream to the start of a drift plus the time required to drift back downstream to the bottom of the drift, but did not include time required to sample fish or time spent traveling to the opposite bank.

After capture, chinook salmon were placed into a holding tub until the drift was completed. Duration of the drifts varied from 5 to 20 min depending on water levels and catch rates. Most drifts lasted approximately 15 min. Drifts were terminated early if three chinook salmon were captured to avoid crowding in the holding tub. Upon completion of a drift, the boat was anchored in calm, backwater areas where fish were processed and released. All fish were measured to the nearest 5-mm MEF and sex was determined from external characteristics. All fish received a uniquely numbered, gray spaghetti tag constructed of a 5-cm section of spaghetti tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line (Pahlke and Etherton 1999). The monofilament was sewn through the musculature of the fish 1-2 cm ventral to the insertion of the dorsal fin between the third and fourth fin rays from the posterior of the dorsal fin. 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 it was anticipated that a greater number of fish would be captured than the number of radio tags available, not every captured fish was implanted with a radio tag. Daily tagging rates were varied based on both historic run timing through the CSS fishery and daily catch rates to ensure that enough radio tags were available for deployment over the duration of the run.

Chinook salmon implanted with radio tags were placed in a tagging cradle submerged in a tub of water. 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 fish's esophagus and was seated using a PVC plunger, 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. The entire handling process required approximately two to three minutes per fish.

RADIO-TRACKING EQUIPMENT AND TRACKING PROCEDURES

Radio tags were Model Five pulse encoded transmitters made by ATS[1]. Each radio tag was distinguishable by its frequency and encoded pulse pattern. Fifty-five frequencies spaced approximately 20 kHz apart in the 150-151 MHz range with up to 10 encoded pulse patterns per frequency were used for a total of 550 uniquely identifiable tags available for deployment. Lower than expected catches near the end of the sampling season resulted in not all radio tags being deployed.

Migrating radio-tagged chinook salmon were tracked along the course of the Copper River using nine stationary tracking stations (Figure 1) similar to that described by Eiler (1995). Each station included a marine deep cycle battery, a solar array, an ATS model 5041 Data Collection Computer (DCC II), an ATS model 4000 receiver, an antenna switching box, a water-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, and both antennas received signals simultaneously. When a radio signal of sufficient strength was encountered, the receiver paused for seven seconds, and the date, time, tag frequency, code, and signal strength for each antenna were recorded by the data logger. Cycling through all frequencies required 5-15 minutes depending on the number of active tags in reception range. Data were downloaded onto a portable computer every 7-10 days.

Two stations were placed on the west bank of the Copper River downstream from the CSS fishery. One was placed directly below the lower boundary marker, and the other approximately 500 m downstream. A third station was placed within the CSS fishery on a west-side bluff overlooking the Copper River at O'Brien Creek. A fourth station was placed on the north bank of the Chitina River approximately 6 km upstream from its confluence with the Copper River. A fifth station was placed on a west-side bluff overlooking the Copper River immediately upstream from the upper boundary of the CSS fishery (Figure 2). These five stations, in combination, were used to identify all radio-tagged chinook salmon entering and exiting the CSS fishery. Tagged fish entering the Tonsina, Klutina, and Gulkana rivers were recorded by stations placed near the mouths of these rivers. These three stations had negligible reception of transmitter signals in waters of the mainstem Copper River. A ninth station was placed on the mainstem Copper River approximately 2 km downstream from the mouth of the Gakona River (Figure 1). This station recorded signals from all tagged fish bound for spawning areas upstream of the Gulkana River.

The distribution of radio-tagged chinook salmon throughout the Copper River drainage was further determined by tracking from small aircraft and boat to locate radio-tagged fish in spawning tributaries other than those monitored with tracking stations, to locate fish that the tracking stations failed to record, and to validate that a fish recorded on one of the data loggers did migrate into a particular stream. Aerial tracking surveys of the Copper River and Chitina

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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.

River drainages upstream of the CSS fishery were conducted on 27–30 June, 17–21 July, and 23–26 August. During the August survey, the Copper River from the Chitina River downstream to the Bremner River (downstream of the CSS fishery) was surveyed. An additional survey of the Klutina and Tonsina rivers was conducted on 8 August to aid in determining the proportion of mainstem spawning in each river. 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.

Boat surveys were conducted on the Copper River to define the status of radio-tagged fish located in the mainstem river as mortalities, migrating fish, or mainstem spawners. Three boat surveys were conducted on 2-4, 8-10, and 15-16 August. The mainstem of the Copper River was surveyed from the mouth of the Chetaslina River downstream to approximately 5 km below the Tonsina River mouth. The lower portion of the Tonsina River from the Edgerton Highway Bridge to the Copper River was also surveyed (Figure 1). During each survey, positions of located radio tags were recorded with a global positioning system (GPS). Radio tags located out the water were retrieved when possible. The mainstem river is extremely turbid. Therefore, to determine if radio tags located in the water were in live fish, the boat was driven directly over the area of the strongest signal and the position of the tag was pinpointed again to determine if it had moved. Areas where radio-tagged fish were located were closely examined for indicators of possible spawning activity. Nearby riverbanks were searched for freshly spawned out carcasses, and the water surface was watched for spawning activity. During the latter two surveys, GPS locations of live fish from the previous weeks were reexamined to determine if the fish was still present and alive, and the area was reexamined for indicators of spawning activity. On 27 August, the Copper River from Haley Creek to 2 km downstream from the capture sites was surveyed to search for radio tags that failed to enter the CSS fishery.

TAG RECOVERIES AND UPRIVER SAMPLING

Tag returns from subsistence and sport fishers were encouraged by distributing informational cards with subsistence permits, and by posting flyers around primary fishery access points and at ADF&G offices in Chitina, Fairbanks, and Glennallen. In addition, both radio and spaghetti tags were printed with return information.

In 1999, only radio tags harvested in the CSS fishery and the reported CSS harvest of chinook salmon were used to estimate the marked fraction of the population. During the 2000 field season, it became evident that too few chinook salmon would be harvested by CSS fishers at the end of the season to adequately estimate the marked fraction of the population. This was attributed to a combination of two changes in the management of the CSS fishery in 2000. First, the chinook salmon bag limit was reduced by the BOF from four to one. Second, the subsistence fishing schedule in June 2000 was substantially reduced from the schedule in 1999. June is the period when a majority of the chinook salmon run passes through the fishery. In 2000, the CSS fishery was opened for fishing on 10 June (12 hrs only), 16-18 June, 22-25 June, and continuously after 28 June.

To increase the sample size of fish examined in the second event, "upriver" sampling efforts were initiated. Upriver sampling consisted of inspecting subsistence fish-wheel catches in the area just upstream of the CSS fishery (near the McCarthy Road bridge), capturing fish with dip nets from a drifting boat, and setting gillnets within the area of the CSS fishery. Dipnetting was conducted from 6-10 June, and from 3-8 July. The same capture technique and gear used during the marking was employed. Various stretches of river within the CSS fishery were drifted for approximately 6 hours per day, but capture rates were low. Beginning on 8 July, a gill net was set at a single site off the downstream point of a gravel bar in the area of the CSS fishery, and proved to be a more effective capture technique than dipnetting. Dipnetting was abandoned because it was unproductive and gear was frequently lost. Gillnetting was continued daily through July 20. The gravel bar used for netting was located within the main river channel near the west bank approximately 2 km downstream of the McCarthy Road Bridge (Figure 2). The braided, mono-filament gillnet was 36.6 m long, 3 m deep, and was composed of four 9.1 m panels of alternating mesh sizes of 16.7 cm (6.5 in) and 20.5 cm (8 in). Subsistence fish wheels located at the McCarthy Road Bridge were sampled on 22 and 28 June, 1-22 July, and 27 July. Fish wheels were generally checked in the morning and evening when subsistence fishers tended to collect their catches. Chinook salmon catches were tallied and examined for tags. All unprocessed chinook salmon examined during upriver sampling activities were measured to the nearest 5-mm MEF and sex was determined from external characteristics. Scales for age determination were taken from the fish wheel samples.

Based on location data from the tracking stations, aerial and boat surveys, tag return information, and/or upriver sampling, each radio tag was assigned a final fate (Table 1).

ESTIMATION OF INRIVER ABUNDANCE

Inriver abundance of chinook salmon was estimated using two-sample mark-recapture techniques. Only chinook salmon that were radio-tagged and spaghetti tagged were considered in the experiment. Radio-tagged fish entering the CSS fishery, as determined from the tracking stations located at the lower end of the CSS fishery, constituted marked fish for the first event. The harvest reported in the CSS fishery through a permit system in combination with the upriver fish wheel sampling, gillnetting, and dipnetting constituted the second event. The CSS harvest was estimated from returned permits (Taube and Sarafin *In prep*). The permits require fishers to record the total number of chinook salmon harvested (maximum of one per permit) and the date they were harvested. CSS fishers were required to return or mail in their permits to an ADF&G office at the end of the season. Radio tags from fish harvested in the CSS fishery, sampled from fish wheels, and caught during upriver gillnetting and dipnetting constituted the marked component of the second sample. CSS fishers returning tags were queried for information regarding date and location of capture. Length and sex data from the CSS harvest and up-river sampling were collected as a means to test for selective sampling.

Conditions for a Consistent Estimator

For the estimate of abundance from this mark-recapture experiment to be accurate, certain conditions must have been met (Seber 1982). These conditions expressed in the circumstances of this study along with their respective design considerations, test procedures, and necessary adjustments for significant test results were that:

Handling and tagging did not make a fish more or less vulnerable to capture in the CSS fishery than untagged fish.

> Design Considerations**:** Holding time of captured fish was kept to a minimum. Obviously stressed fish (fish that were slow to recover from tagging) or injured fish were not tagged. Time required to move from the capture site to the lower boundary of the fishery as well as transit times through the CSS fishery of radio-tagged fish were calculated from information recorded by the tracking stations.

Table 1.-List of possible fates of radio-tagged chinook salmon in the Copper River, 2000.

Fate	Description
Radio Failure	A fish that was never recorded swimming upstream into the Chitina subdistrict subsistence fishery.
CSS Mortality	A fish harvested in the Chitina subdistrict subsistence fishery.
Upriver Fishery Mortality	A fish that was caught during upriver gillnetting or dipnetting.
Subsistence Mortality	A fish harvested in the Glennallen subdistrict subsistence fishery upstream of the McCarthy Road bridge.
Sport Fish Mortality	A fish harvested in one of the sport fisheries.
Spawner	A fish that migrated through the CSS fishery and entered a spawning tributary of the Copper River.
Upstream migrant	A fish that migrated upstream of the CSS fishery, was never reported as being harvested, and was either located only in the mainstem Copper River, or was never located anywhere after passing through the fishery.

Test: There was no explicit test for this assumption because we could not observe the behavior of unhandled fish. However, we compared recapture rates and migration rates between groups of fish affected differently by handling, as reflected in the time required to recover from handling and reach the lower boundary of the CSS fishery. If recapture rates and transit times through the CSS fishery were similar for the two groups, we interpreted this to mean that the effect of handling on tagged fish had abated by the time the fish reached the CSS fishery.

Adjustment: If recapture rates and/or migratory behavior appeared to be related to relative handling effect, and if handling effect and fish size were not related, abundance would be estimated after removing fish severely affected by handling (e.g. seven-day recovery) from the marking and examination events. The number of fish affected severely would later be added to the estimate. If handling effect and fish size were related, the population would be stratified by size and this procedure would be repeated for each size stratum.

There was no selection for tagged fish harvested in the CSS fishery.

Design considerations: In 1999, concerns were raised about CSS fishers selecting for radio-tagged fish to increase their chances of winning a $200 lottery being offered. In 2000 this concern was magnified because the chinook salmon bag limit was lowered from four to one fish. With a reduced bag limit and a lottery, a fisher is more likely to capture additional radio-tagged fish after filling his/her bag. Radio and/or spaghetti tags could be removed, from these incidentally caught fish even though the fish was released alive. Selection for tagged fish would result in an estimate of abundance that would be biased low.

Test; There was no explicit testing procedure for tag selection. However, to minimize the chance of fishers selecting for tags, no lottery reward was offered in 2000. A gray spaghetti tag was used to reduce the likelihood of a fisher easily identifying a tagged fish and selecting it for harvest. Gray tags are less identifiable at time of capture but are easily identifiable when processing a fish.

All tagged fish harvested in the CSS fishery were accurately reported

Design considerations: Tag recoveries were obtained through on-site creel sampling and by voluntary tag returns. Tag recovery forms and instructions for data collection were sent to ADF&G offices in Fairbanks, Delta Junction, Glennallen, Cordova, Palmer, and Anchorage. Informational bulletins were posted at these offices and at strategic positions in and around the CSS fishery. Informational cards encouraging tag returns were distributed with CSS permits issued at ADF&G offices. All radio tags were labeled with information to encourage reporting of harvested tags. If either the radio or spaghetti tag from a harvested fish was not returned, attempts were made to contact the CSS fisher to determine if the fish was harvested (as opposed to the tag being removed and the fish released) and if both tags were attached. Tags that were harvested in the CSS fishery but not reported were identified using the tracking stations located at O'Brien and Haley Creeks. Radio tags removed from the water have a pronounced increase in signal strength compared to tags that are in the water. Criteria for declaring an unreported tag as harvested were: 1) a pronounced and prolonged recording of a signal by a data logger at O'Brien and/or Haley Creek; 2) the radio tag was never recorded or located upstream of the CSS fishery; and, 3) no downstream movement of the radio tag was detected by the tracking station located below Haley Creek after the radio tagged fish had entered the CSS fishery.

Tagged fish did not lose their tags, and there was no mortality of tagged fish between the tagging site and the CSS fishery.

Design Considerations: Two tracking stations were placed at the lower end of the CSS fishery. All fish were double marked with radio tags and individually numbered spaghetti tags. Both tags were requested from CSS fishers. When only one tag was returned, a follow up telephone call was made to find out if the other tag was present.

Adjustment: All radio-tagged fish that did not migrate past the lower tracking stations were removed from the marked sample.

Marked fish mixed completely with unmarked fish across the river and no fish had a zero probability of capture.

Design Considerations: Because sampling in the test fishery and fishing in the CSS fishery was bank-oriented, fish swimming up only the center of the river may not be included in the estimate. Because both banks of the river were sampled during both events, mixing of tagged fish between banks was investigated. Bank of capture for all fish was recorded and bank of recapture was requested from CSS fishers. Bank of capture for unmarked fish in the second sample (from the CSS fishery) was not known

Test: Recapture rates for fish marked on each bank were compared using contingency table analysis. Independence between bank of mark and bank of recapture was also tested.

Adjustment: If there was a center-only segment of the run, the estimate would be biased low and not include the unknown fraction of the population that migrated up the center of the river outside of the sampled areas. No adjustment or test was possible for this condition. However, if marked fish crossed-over between samples, it was inferred that fish not subject to capture in the first event because they were in the center of the channel would at some point swim near shore in the CSS fishery and be vulnerable to capture in the second event. If there was cross-over between sampling events, but the marked fraction was different for the two banks, a geographically stratified estimator such as the method of Darroch (1961) would be used to estimate abundance. If there was no cross-over between sampling events, a stratified Petersen model would be used to estimate abundance.

Fish had equal probabilities of being marked or equal probabilities of being recaptured regardless of their size or sex.

Design Considerations: dip nets, which are efficient at capturing all sizes of chinook salmon, were used in the first event. Sex and length were recorded for all tagged fish. In the second event, age and length data were collected from a sample of fish harvested from the CSS fishery, and from those fish captured during upriver gillnet, dip-net, and fish-wheel sampling.

Test: A test for significant gear bias by sex was based on a contingency table of the number of males and females that were recaptured and were not recaptured. If this test indicated a significant bias, the following tests would be done for males and females, separately. If the test did not indicate a significant bias, males and females would be combined and Kolmogorov-Smirnov two sample tests on cumulative length distributions of: A) all fish marked during the first sampling event and all fish sampled in the second event; and, B) all fish marked during the first sampling event and tagged fish recaptured in the second event would be performed. The null hypothesis was no difference between the distributions of lengths for Test A or for Test B. For these two tests there are four possible outcomes:

Case I: Accept H_o(A), Accept H_o(B). There is no size-selectivity during the first sampling event (when fish were marked) or during the second sampling event (when carcasses were collected).

Case II: Accept H_o(A), Reject H_o(B). There is no size-selectivity during the second sampling event but there is size-selectivity during the first sampling event.

Case III: Reject H_o(A), Accept H_o(B). There is size-selectivity during both sampling events.

Case IV: Reject H_o(A), Reject H_o(B). There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

Adjustment: Depending on the outcome of the tests, one of the following procedures would be used to estimate the abundance of the population:

If the test comparing recapture rates by gender was significant, a stratified estimate of abundance would be estimated for each sex and the two estimates added to estimate total abundance. Results of the tests comparing length distributions would dictate one of the following procedures to estimate abundance.

Case I: An unstratified estimate of abundance would be calculated. Lengths, sexes, and ages from both sampling events would be pooled to improve precision of proportions in estimates of compositions.

Case II: An unstratified estimate of abundance would be calculated, and only lengths, sexes, and ages from the second sampling event would be used to estimate proportions in compositions.

Case III: Both sampling events would be stratified, and abundance would be estimated for each stratum. The estimates of abundance would be added across strata to get a single estimate for the population. Lengths, ages, and sexes from both sampling events would be pooled to improve precision of proportions in estimates of composition.

Case IV: Both sampling events would be stratified and abundance estimated for each stratum. The estimates of abundance would be added across strata to get a single estimate for the population. Also, a single estimate of abundance would be calculated without stratification.

Case IVa: If the stratified and unstratified estimates of abundance for the entire population were dissimilar, the unstratified estimate would be discarded. Only lengths, ages, and sexes from the second sampling event would be used to estimate proportions in composition.

Case IVb: If the stratified and unstratified estimates of abundance for the entire population were similar, the estimate with the larger variance would be discarded. Only lengths, ages, and sexes from the first sampling event would be used to estimate proportions in compositions.

Fish had equal probabilities of being marked regardless of time of capture.

Design Considerations: Near equal fishing effort was expended at all times during the first event. Attempts were made to radio tag chinook salmon proportional to daily catch in the test fishery. Date and time of capture for all fish were recorded.

Test: Marked to unmarked ratios in the second event were compared by week to evaluate if this condition was met. Testing of this assumption required temporal harvest data from the CSS fishery. Temporal harvest data were available from all returned CSS fishery permits. The estimated harvest from unreported permits was assigned to temporal strata in proportion to the distribution of the actual reported harvest.

Adjustment: If the condition was not met, then the condition that marked fish have equal probabilities of being recaptured regardless of when they entered the fishery was examined.

Marked fish had equal probabilities of being recaptured regardless of when they entered the fishery.

Test: Equal catchability was tested by comparison of recapture rates (R/M) by week of entry into the CSS fishery using contingency-table analysis.

Adjustment: If both recapture rates (this test) and marked:unmarked ratios (previous test) differed significantly over the various periods, a temporally stratified estimator such as the method of Darroch (1961) would be used. Consecutive strata having similar recapture rates would be pooled.

Estimator

A Chapman modification of the Petersen two-sample model was used to estimate abundance (Seber 1982). The estimate was germane to the point of entry into the CSS fishery (prior to any inriver harvest of chinook salmon). Because some chinook salmon were tagged and migrated through the CSS fishery prior to its opening, and because no tagged fish were recaptured until 16 June, the estimate only pertains to the period (16 June - 31 July). The estimate was calculated using:

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

$$V[\hat{N}] = \frac{(M+1)(\hat{C}+1)(M-R)(\hat{C}-R)}{(R+1)^2(R+2)}$$

where:

$\hat{N}$ = estimated abundance of chinook salmon from 16 June to 31 July;

M = the number of chinook salmon radio tagged during the first sampling event;

$\hat{C}$ = the estimated number examined during the second sampling event; and,

R = the number of radio-tagged chinook salmon captured during the second event.

The estimated variance of $\hat{N}$ is approximate because $\hat{C}$ was estimated from returned CSS permits. Because the estimate of CSS harvest was very precise (cv < 0.5%), the sampling error in $\hat{C}$ is considered negligible.

To estimate the total inriver chinook salmon run, including those portions of the run before the recovery event began (16 June) and after it terminated (31 July), $\hat{N}$ was multiplied by the inverse of estimated proportion of the run $\hat{P}$ that occurred during the recovery event:

$$\hat{N}' = \hat{N}\hat{P}^{-1} \tag{3}$$

$$\hat{\text{var}}(\hat{N}') = \hat{N}^2\, \hat{\text{var}}(\hat{P}^{-1}) + (\hat{P}^{-1})^2\, \hat{\text{var}}(\hat{N}) - \hat{\text{var}}(\hat{P}^{-1})\, \hat{\text{var}}(\hat{N})\,. \tag{4}$$

The method for estimating $\hat{P}^{-1}$ and its variance used weekly estimates of abundance in the CSS fishery from a Darroch (1961) capture-recapture model with weekly cumulative CPUE data for the weeks of the fishery to model the uncertainty with which CPUE predicts salmon abundance during the fishery. Markov-chain Monte Carlo (MCMC) methods were used to perform a Bayesian analysis (Carlin & Louis, 2000) of the relationship between weekly abundance and CPUE, which was used, in turn, to estimate fish abundance for weeks of the run outside the fishery. The estimate $\hat{P}^{-1}$ and its variance was calculated from the 5,000 MCMC samples drawn from its posterior distribution:

$$\hat{P}^{-1} = \frac{\sum_{i=1}^{S} \tilde{P}_i^{-1}}{S} \quad \text{and} \quad \hat{\text{var}}(\hat{P}^{-1}) = \frac{\sum_{i=1}^{S} \left(\tilde{P}_i^{-1} - \hat{P}^{-1}\right)^2}{S} \tag{5}$$

where:

$S =$ the number of Monte Carlo draws; and

$\tilde{P}_i^{-1}$ is the value of the expansion factor for the *i*th draw. Each $\tilde{P}_i^{-1}$ was calculated:

$$\tilde{P}_i^{-1} = \frac{\sum_{j \in B} \tilde{N}_{ij} + \sum_{j \in D} N_j^* + \sum_{j \in A} \tilde{N}_{ij}}{\sum_{j \in D} N_j^*} \tag{6}$$

where:

N_j^* are weekly estimates of numbers of salmon in the recovery area using a time stratified Darroch (1961) estimation procedure with the capture-recapture data;

$\tilde{N}_{ij}$ is the projected number of salmon in the recovery area during week *j* in the *i*th simulation; and,

B, D, and A are the weeks before, during, and after the second (recovery) event.

To calculate the $\tilde{N}_{ij}$ the WINBUGS software package (Spiegelhalter et al, 1996) was used to simulate the posterior distribution of the parameters in the following model, given the data $j \in D$,

$$N_j^* = \beta * CPUE_j + \varepsilon_j \text{ where } \varepsilon_j \sim N(0, \boldsymbol{D}\,\sigma^2)$$

where **D** is a diagonal matrix representing any heteroskedasticity in the variance structure. The MCMC posterior distribution for $\hat{\beta}$ was used to generate the necessary projections:

$$\tilde{N}_{ij} = \hat{\beta}_i * CPUE_j. \tag{7}$$

DISTRIBUTION OF SPAWNERS

All radio-tagged fish located in a spawning area ("spawner" fate in Table 1) were assigned to one of six general areas: the Chitina, Tonsina, Klutina, Tazlina, and Gulkana rivers, or upper Copper River drainage. The upper Copper River drainage was defined as all tributaries upstream of the Gulkana River.

The daily radio tagging rate and hours of fishing effort (h_i) in the test fishery varied by day. The count of fish tagged on day *i* having fate j (R_{ij}) was adjusted by dividing by h_i and the tagging rate $\left({}^{x_i}\!/\!{}_{X_i}\right)$ where x_i is the number of fish radio tagged and X_i is the total number of chinook salmon caught on day *i*. The adjusted count was

$$Y_{ij} = \left(\frac{X_i}{h_i x_i}\right) R_{ij}. \tag{8}$$

Among fish that migrated upstream of the capture site, the proportion of fish that had spawning fate *j* was estimated as

$$\hat{P}_j = \frac{\sum_i^{\text{days}} Y_{ij}}{\sum_j^{\text{fates}} \sum_i^{\text{days}} Y_{ij}}. \tag{9}$$

Variance was estimated using bootstrap resampling techniques (Efron and Tibshirani 1993). Bootstrap resampling was conducted in a manner that approximated the systematic nature in which fish were sampled (5-hour time blocks selected each day). All radio-tagged fish were grouped into 2-day blocks. Within each 2-day block the fates were resampled with replacement 5,000 times, yielding 5,000 bootstrap data sets. From each data set, new proportions of spawning distributions $(\hat{P}^*{}_j)$ were calculated. The percentile method was used to estimate confidence intervals.

The same procedure was also used to determine the proportion of chinook salmon spawning in the nine index, aerial survey streams; the Little Tonsina River, Grayling Creek, St. Anne Creek, Manker Creek, Mendeltna Creek, Kiana Creek, Gulkana River, East Fork Chistochina River, and Indian Creek. A chinook salmon was assigned to a index stream if the fish was located in that stream at least once during the aerial surveys.

MIGRATORY TIMING

Migratory timing patterns were described as time-density functions, where the relative abundance of a particular stock *t* that enters into the fishery during time interval *i* is considered discrete and is described by Mundy (1979) as:

$$f(t_i) = {}^{m_i}\!/_{m} \qquad (10)$$

where:

$f(t_i)$ = the empirical probability distribution over the total span of the run for fish spawning in tributary *t*;

m = the total number of radio-tagged chinook salmon that ended up in tributary *t*; and,

m_i = the subset of *m* radio-tagged chinook salmon bound for tributary *t* that were caught and tagged during the *i*th day.

For this analysis, stocks were defined as all chinook salmon spawning in the Chitina, Tonsina, Klutina, Tazlina, and Gulkana rivers, and the upper Copper River drainage. Those fish assigned a fate of spawner (Table 1) were used to determine the time-density functions.

The mean date of passage ($\bar{t}$) into the CSS fishery for a spawning stock was defined as:

$$\bar{t} = \sum_{i=1}^{\ell} t_i f(t_i)\,. \qquad (11)$$

The variance about the mean was defined as:

$$s^2 = \sum_{i=1}^{\ell} (t_i - \bar{t})^2 f(t_i) \qquad (12)$$

where:

t_i = time interval i; and,

ℓ = the number of time intervals (days) during the total span of the run.

RESULTS

CAPTURE AND TAGGING

Seven hundred ninety chinook salmon were captured during sampling conducted between 20 May and 2 August 2000. The first fish was captured on 24 May and the last on 1 August. Two hundred fifty-four chinook salmon were tagged with spaghetti tags only and 536 were tagged with both radio and spaghetti tags. The largest daily CPUE of chinook salmon was 7.1 fish per hour on June 2 (Appendix A1). The daily application rate of radio tags to fish captured varied from 0.5 to 1.0 and tracked daily catches closely (Figure 3).

FATES OF RADIO-TAGGED CHINOOK SALMON

Of the 536 chinook salmon fitted with radio tags, 480 migrated upstream past the capture site and were recorded by one or both of the downstream data loggers as having entered the CSS fishery (Table 2). Fifty-six failed to migrate upstream beyond the capture site and either had expelled tags, died from handling or natural causes, or migrated downstream to other areas. Fifty radio-tagged chinook salmon were harvested in the CSS fishery. Forty-six of the harvested tags were returned by fishers. Four radio-tagged fish were not reported by fishers, but were inferred as harvested based on large signal strength recordings on the data loggers positioned at O'Brien and Haley creeks, which indicated that the tags were removed from the water. Three radio tags were captured within the CSS boundaries during upriver (gillnetting and dipnetting) sampling efforts. Four hundred twenty-seven tagged fish passed through the CSS fishery. All were located at least one time above the fishery by one of the stationary data loggers or during an aerial tracking survey, or were harvested in sport or subsistence fisheries. Thirty-six fish (8.4%) that were known to have passed through the CSS fishery were never reported as harvested or located in a spawning area. Twenty-one tags passed through the CSS fishery but later drifted back downstream. Twenty tags were collected in the mainstem Copper River above the CSS fishery during boat tracking surveys. Thirty-two tagged fish were harvested and returned by fishers in the subsistence fishery (one of which was collected during fish wheel sampling). Three-hundred eighteen tagged fish were documented in spawning areas and 19 of these fish were harvested in sport fisheries (Table 2). Tracking stations were generally very efficient at detecting migrating chinook salmon (Table 3).

CSS FISHERY HARVEST AND UPRIVER SAMPLING

Reported harvest in the CSS fishery during 2000 was 2,971 chinook salmon. The estimated harvest by non-reporting fishers was 40 (SE=17) chinook salmon. Thus, total estimate of harvest for 2000 was 3,011 (SE=17) chinook salmon. During the period 16 June to 31 July an estimated 2,830 (SE = 16) chinook salmon were harvested. Also during this period, thirty-seven chinook salmon were caught upriver with dip nets, 156 fish were captured with gill nets and 191 fish were sampled from fish wheel catches.

INRIVER ABUNDANCE: TESTS OF CONSISTENCY

Handling and marking chinook salmon did not appear to alter their probability of capture in the CSS fishery. Information recorded on the two data loggers located just above the tagging site (at the lower boundary of the CSS fishery) indicated that half of the fish moved from the release site to the lower boundary of the CSS fishery in 2.5 days or less. However, 16% of the tagged fish required ten or more days to move into the fishery after tagging (Figure 4; top panel). One-half of the tagged fish transited through the CSS fishery in 2.5 days or less, and 92% of the fish passed through the fishery in ten days or less (Figure 4; middle panel). A comparison of transit times between fish that exhibited minimal (less than 2 d), moderate (2-7 d), and substantial (greater than 7 d) delays (between time of tagging and entry into the fishery) shows that average transit times were similar for all three categories (Figure 4; bottom panel). Recapture rates between fish exhibiting minimal, moderate, and substantial delays were also similar (χ^2=1.17; df=2; P=0.56; Table 4). These two comparisons suggest that potential stress associated with handling did not influence recapture rates or swimming speed through the fishery.

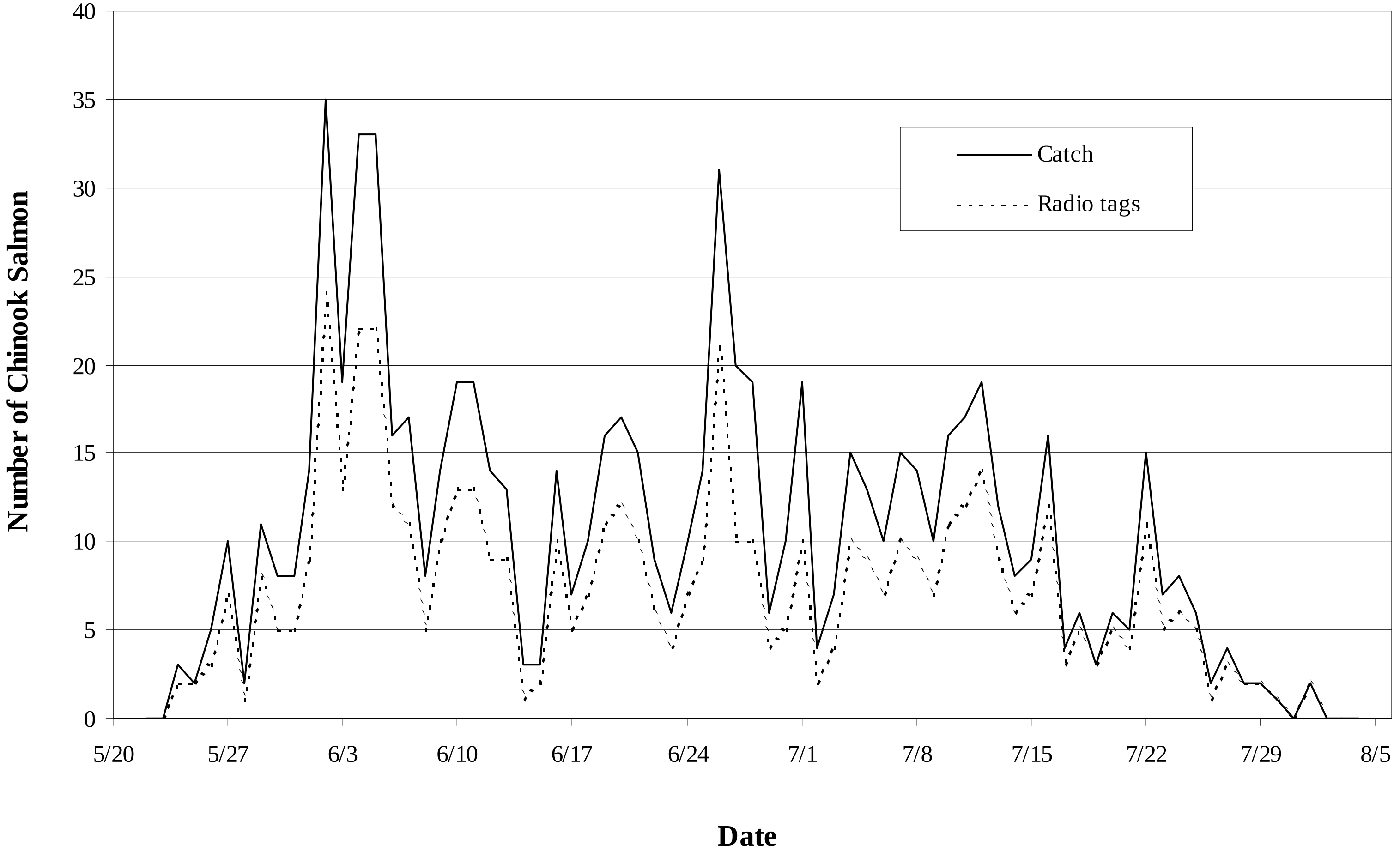

Figure 3.-Number of radio tags deployed each day and total daily catch of chinook salmon in the Copper River, 2000.

Table 2.-Fates of radio-tagged chinook salmon in the Copper River, 2000.

Fate[a]	Number of Tags
Total Deployed	536
Radio Failure	56
Total Entering CSS	480
CSS Mortality	50
Upriver Test Fishing Mortality	3
Total Fish Passing Through CSS	427
Upstream Migrant[b]	77
Subsistence Mortality[c]	32
Spawner	318
Sport Mortalities[d]	19

[a] Refer to Table 1 for definition of fates.

[b] Includes 36 tags that were recorded migrating upstream of the CSS fishery and never located again, 21 tags that passed through the CSS fishery and drifted back downstream, and 20 fish that were found in the mainstem of the Copper River upstream of the CSS fishery.

[c] One of these radio tags was collected during fish wheel sampling.

[d] Radio-tagged fish that were captured by sport fishers in a tributary.

Table 3.-Efficiency of tracking stations in detecting passing radio-tagged chinook salmon in the Copper River drainage, 2000.

Station	Total tags known to pass site[a]	Number located during aerial surveys	Number logged by tracking station	Aerial tracking efficiency[b]	Station efficiency
Upper Copper R.	39	37	39	94.9%	100.0%
Gulkana R	81	67	79	82.7%	97.5%
Klutina R.	83	75	67	90.4%	80.7%
Tonsina R.	65	56	59	86.2%	90.8%
Chitina R.	41	35	41	85.4%	100.0%
Copper R.	381		374		98.4%
O'brien Cr.	422		405		96.0%
Haley Cr. (both stations combined)	480		480		100%

[a] Includes all fish logged by stations, located from aerial and boat surveys, and captured in the fisheries.

[b] Efficiency of aerial tracking was only evaluated for the spawning tributaries.

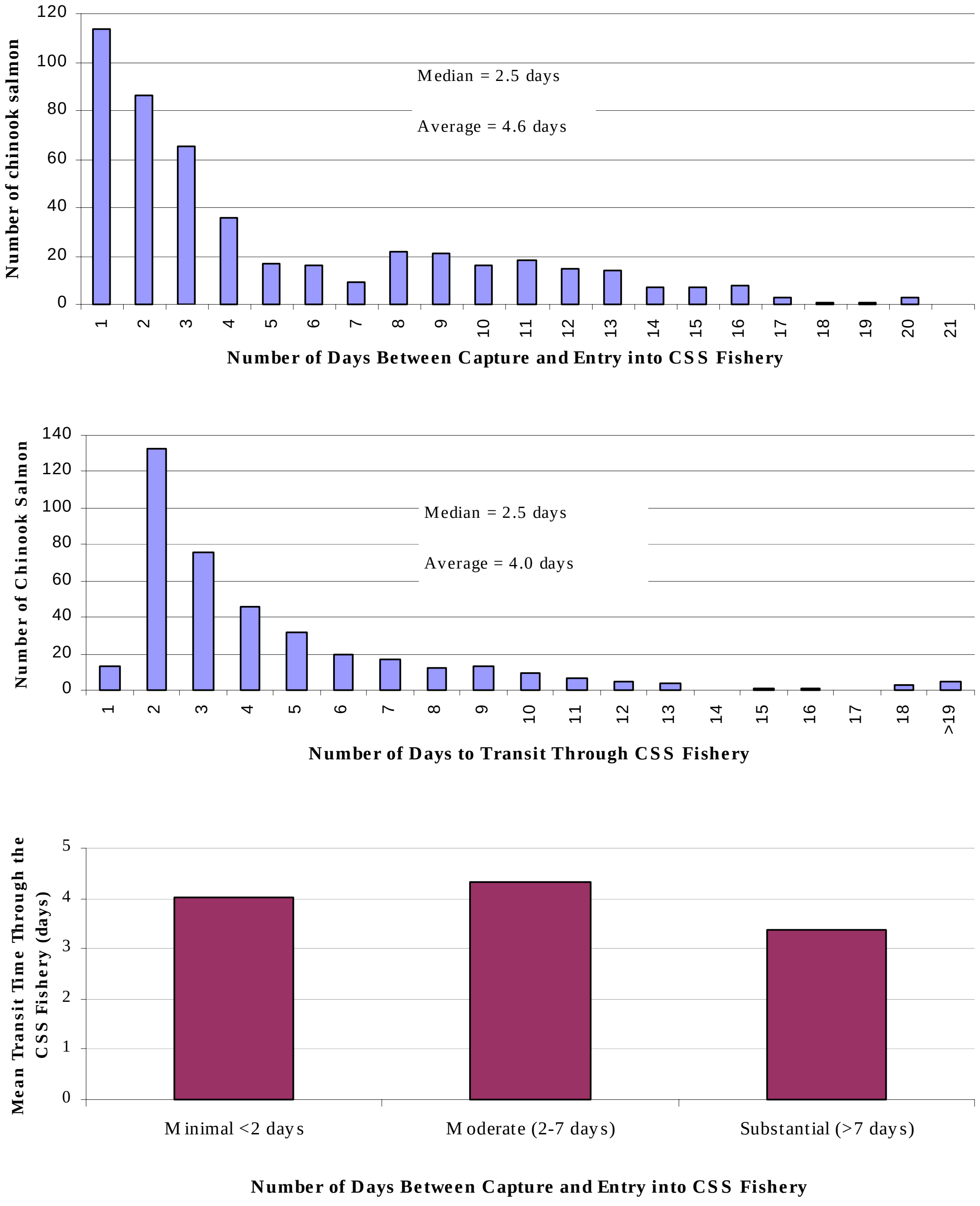

Figure 4.-Delay after handling (top panel), transit times through the CSS fishery (middle panel), and a comparison of mean transit times through the CSS fishery of fish that exhibited minimal, moderate, and substantial delays (bottom panel) for radio-tagged chinook salmon in the Copper River, 2000.

Table 4.-Recapture rates for chinook salmon exhibiting minimal (<2 d), moderate (2-7 d), and substantial (>7 d) delays after handling, 2000.

	Delay After Handling			
	< 2 days	2-7 days	> 7 days	Total
Recaptured	**23**	**13**	**18**	54
Not Recaptured	**177**	**130**	**119**	426
Total	200	144	136	480
Recapture Rate[a]	0.12	0.09	0.13	0.11

[a] Chi-square test for heterogeneity in recapture rates was performed for cells with bold numbers (χ^2=1.17; df=2; P=0.56).

No tags were lost between marking and recapture in the CSS fishery. Of the 536 chinook salmon released with radio tags, 56 never entered the CSS fishery and were removed from the experiment. The remaining 480 tags were documented as either harvested in the CSS fishery or successful migrants through the fishery.

There was evidence that marked fish mixed with unmarked fish between events. Of the radio-tagged chinook salmon returned with bank-of-capture information, more radio tags were recovered on the west bank during the second event than on the east bank. This reflects the larger harvest that occurs on the west bank. Although no data are available regarding harvest by bank in the CSS fishery, the west bank is adjacent to the road and is thought to support greater fishing effort than the east bank. Of the 275 fish marked on the west bank that migrated into the CSS fishery, 17 were recaptured on the west bank and 4 were recaptured on the east bank (Table 5). Of the 271 fish marked on the east bank that migrated into the CSS fishery, 13 were recaptured on the west bank and 3 were recaptured on the east bank. Marked chinook salmon moved equally between banks (Table 6; χ^2=0.645; df=2; P=0.72), and recapture rates of fish marked on each bank were similar (Table 7; χ^2=0.64; df=1; P=0.42).

Further evidence of mixing between banks is inferred from movements of radio-tagged fish that were not recaptured. At the upper end of the CSS fishery boundary, fish must migrate either to the east up the Chitina River or to the west up the Copper River. Of the fish that spawned in the Chitina River, 41% were tagged on the west bank of the river and crossed over to the east bank to complete their migrations. Likewise, of the fish that spawned in the Copper River drainages, 52% were tagged on the east bank and crossed over to the west bank to continue their spawning migrations.

Recapture rates of males (0.13) and females (0.17) were not significantly different (χ^2=0.93; df=1; P=0.33). The proportions of tagged males, recaptured males, and males sampled in the CSS fishery were 0.49, 0.42, and 0.40, respectively.

Cumulative length frequencies for fish of all sizes sampled from the CSS fishery (n=345), up-river dipnetting (n=37), gillnetting (n=156), and fish wheels (n=191) differed (A2kn = 4.345; P=0.01). By pairwise comparison of the four capture methods, only the length distributions of gillnetted and CSS fishery sampled fish differed (Table 8 and Figure 5). Lengths from all four capture methods in the second event were pooled and the cumulative length frequency distribution was not significantly different from that of marked fish (DN=0.060; P=0.27; Figure 5). Cumulative length frequency distributions of fish marked during the first event and fish recaptured in the second event were also not significantly different (DN=0.06; P=0.28; Figure 5).

The smallest chinook captured in the first event was 580 mm MEF, the smallest sampled in the second event (fish wheel) was 410 mm MEF, and the smallest recaptured was 580 mm MEF.

Age compositions of chinook salmon sampled during the first and second events were not significantly different (χ^2=6.84; df=4; P=0.14) with age 1.3 (brood year 1995) dominating both samples (Tables 9 and 10).

Capture and recapture statistics were summarized by week (Tuesday-Monday) for all ten weeks in the experiment (Table 11). Recapture rates ranged from 0.00-0.50 over the ten weeks of the study. Recapture rates were zero for the first two weeks and during the last week only two radio

Table 5.-Capture summaries for chinook salmon released on the east and west banks of the Copper River, 2000.

Capture History	Released West Bank	Released East Bank	Total
Total Marked	275	271	536
Malfunctions	33	23	56
Number Entering CSS Fishery	242	238	480
Recaptured West Bank	17	13	31
Recaptured East Bank	4	3	8
Recaptured, but not Known Where	9	8	16
Total Recaptured	30	24	54
Number Not Recaptured	212	214	426
Recapture Rate	0.12	0.10	0.11

Table 6.-Number of chinook salmon recaptured by bank of release and bank of recapture and chi-square result of test comparing equal movement across the river, 2000.

	Bank of Release	
Bank of Recapture	West	East
West	17	13
East	4	3
Not Recovered	221	222
χ^2=0.645; df=2; P=0.72		

Table 7.-Number of chinook salmon recaptured and not recaptured by bank of release and chi-square result of test comparing recapture rates for fish marked on the east and west banks, 2000.

	Bank of Release	
History of Recovery	West	East
Recaptured	30	24
Not Recaptured	212	214
χ^2 = 0.64; df = 1; P = 0.42		

Table 8.-Pairwise comparisons of cumulative length distributions of second event sampling techniques, 2000. Pairwise tests were Kolmogorov-Smirnov two sample tests.

Method of Capture	Upriver dipnetting (n=37)	Gillnetting (n=156)	Fish wheels (n=191)
CSS fishery (n=345)	DN = 0.11 P = 0.38	DN = 0.14 P = 0.02	DN = 0.09 P = 0.24
Upriver dip netting (n=37)		DN = 0.14 P = 0.49	DN = 0.16 P = 0.35
Gillnetting (n=156)			DN = 0.13 P = 0.15

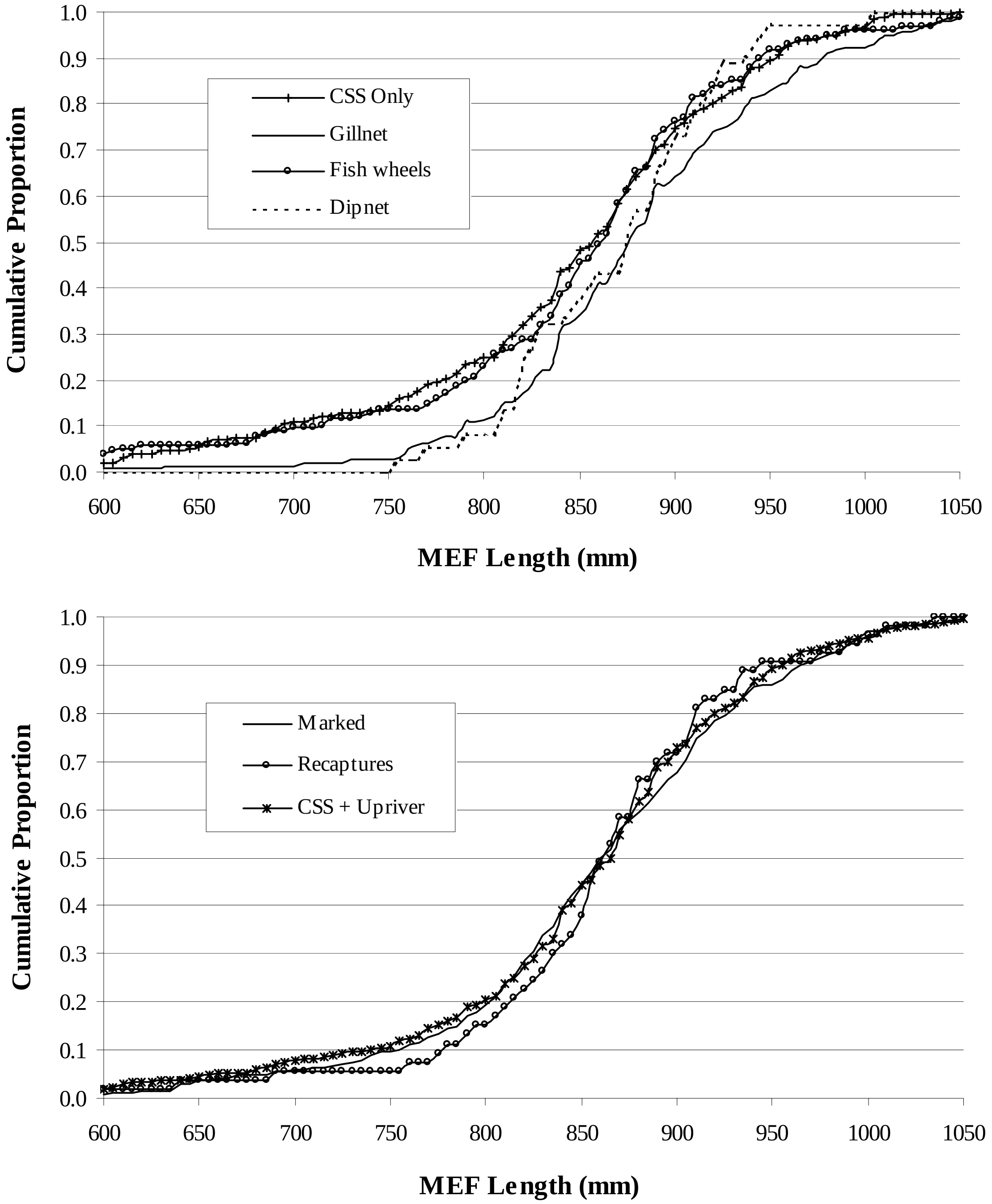

Figure 5.-Cumulative length frequency distributions of all fish examined during the second sample from the CSS fishery, gillnets, fish wheels, and dip nets (top panel), and all fish marked with radio tags during the first sample, all fish examined in the second sample, and all radio-tagged fish recaptured during the second sample (bottom panel), 2000.

Table 9.-Age composition of chinook sampled in the test and subsistence fisheries in the Copper River, 2000.

Brood Year Age[a]	1997 1.1	1996 1.2	1995 1.3	1994 1.4	1994 2.3	1993 2.4	 Total
Test Fishery							
Female	0	7	207	38	4	1	257
Male	1	26	148	35	1	0	211
Total	1	33	355	73	5	1	468
Subsistence Fisheries (CSS fishery and fish wheels combined)							
Female	0	11	143	42	2	1	199
Male	1	11	73	30	0	1	116
Total	1	22	216	72	2	2	315

[a] The notation x.x represents the number of annuli formed during river residence and ocean residence (i.e. an age of 2.4 represents two annuli formed during river residence and four annuli formed during ocean residence).

Table 10.-Numbers of chinook salmon captured in the test and subsistence fisheries by age and brood year and contingency table analysis comparing age composition from the two samples, 2000.

Age[a] Brood Year	3 1997	4 1996	5 1995	6 1992	7 1991
Marking event	1	22	355	78	1
Subsistence fisheries CSS fishery and fish wheels combined	1	22	216	74	2
	χ^2=6.84; df=3; P=0.14				

[a] Age indicates years elapsed since brood year.

Table 11.-Capture summaries for all radio-tagged chinook salmon marked in the Copper River, 2000. Bold cells indicate data used for the mark recapture experiment.

Week of	Week of Recapture[a]										Number	Number	Number not	Recapture
Marking	1	2	3	4	5	6	7	8	9	10	Recaptured	Marked	Recaptured	Rate
1 (May 30-Jun 5)	0	0	0	0							0	74	74	0.00
2 (Jun 6-Jun 12)		0	0	0	0						0	46	46	0.00
3 (Jun 13-Jun 19)			**4**	**0**	**0**	**0**					**4**	**59**	**55**	0.07
4 (Jun 20-Jun 26)				**8**	**1**	**0**	**0**				**9**	**86**	**77**	0.11
5 (Jun 27-Jul 3)					**3**	**2**	**0**	**0**			**5**	**20**	**15**	0.25
6 (Jul 4-Jul 10)						**5**	**4**	**0**	**0**		**9**	**49**	**40**	0.18
7 (Jul 11-Jul 17)							**13**	**0**	**0**	0	**13**	**58**	**45**	0.22
8 (Jul 18-Jul 24)								**8**	**0**	0	**8**	**58**	**50**	0.14
9 (Jul 25-Jul 31)									**4**	0	**4**	**29**	**25**	0.14
10 (Aug 1-Aug 7)										1	1	2	1	0.50
Total Recaptured	0	0	**4**	**8**	**4**	**7**	**17**	**8**	**4**	1	53	480	426	0.11
Number of Unmarked Caught in Second Event	0	**83**	**345**	**369**	**406**	**700**	**731**	**320**	**163**	5				
Total Number Caught During Second Event	0	**83**	**349**	**377**	**410**	**707**	**748**	**328**	**167**	6				
Marked :Unmarked	0.000	0.000	0.012	0.022	0.010	0.010	0.023	0.025	0.025	0.200				

[a] Week of recapture was the same as week of marking. Weeks ran from Tuesday-Monday.

tags were applied. These three weeks were not considered in estimation of abundance. Recapture rates from weeks 3-9 varied to a lesser degree (0.07 to 0.25), and were not significantly different (χ^2=9.31; df=6; P=0.16; Table 12). Marked to unmarked ratios from weeks 3-9 also did not vary significantly by week (χ^2=7.54; df=6; P=0.27; Table 12).

ABUNDANCE ESTIMATE

The tests of consistency detected no significant bias in capture probabilities for the period 16 June to 31 July. Therefore, Chapman's modified Petersen two-sample model (Seber 1982) was used to estimate abundance. An estimated 21,816 (SE=2,719) chinook salmon $\geq$ 580 mm MEF entered the CSS fishery between 16 June–31 July. To account for fish that passed through the fishery prior to this period, the estimate was expanded using CPUE information from the first (marking) sample. It was assumed that negligible numbers of chinook salmon passed through the fishery after 31 July. The estimate of the proportion of the total run migrating through the fishery during the period 16 June-31 July was 0.5734 (SE=0.2788, Figure 6). Total estimated abundance entering the CSS fishery prior to 1 August 2000, was 38,047 (SE=7,675) chinook salmon $\geq$ 580 mm MEF.

SPAWNING DISTRIBUTION

Radio-tagged chinook salmon were located in all of the major drainages (Table 13). The smallest proportion returned to the Tazlina River drainage (0.03) and the largest proportion returned to the Klutina River drainage (0.27). The nine aerial survey index streams accounted for 0.40 of all chinook salmon migrating into tributary streams, with the Gulkana River accounting for most of this proportion (Table 14). During aerial survey flights, chinook salmon were located in 32 different tributary streams (Table 15).

No mainstem spawning activity was observed in the mainstem Copper River. During boat surveys 20 radio-tagged chinook salmon were confirmed as mortalities. All other radio tags found in the mainstem of the Copper River during aerial and boat surveys either had continued their upstream migrations or could not be located again.

Within the Klutina and Tonsina River drainages, most of the radio-tagged chinook salmon were located only in the mainstem reaches of the rivers. It was assumed that these fish were spawning in the main river channel. Mainstem spawners accounted for 78% of all spawning chinook salmon in the Klutina River 86% of those in the Tonsina River (Table 16). Mainstem spawners in these two rivers accounted for 38% of all spawning fish in the Copper River drainage.

MIGRATORY TIMING

The mean date of passage for all chinook salmon captured was 22 June (Figure 7). Migratory time-density functions at the capture site varied among the major spawning stocks (Figure 8). Mean date of passage ranged from 5 June for chinook salmon bound for the upper Copper River drainages to 5 July for fish bound for the mainstem Klutina River (Table 17). Migratory timing of chinook salmon bound for tributaries in the Tonsina and Klutina rivers was earlier than their mainstem spawning counterparts (Figure 9).

DISCUSSION

This study is the second consecutive year that abundance of chinook salmon at the point of entry into the CSS salmon fishery has been estimated, and a similar study design was used during both

Table 12.-Contingency table analyses comparing marked:unmarked and recaptured:not-recaptured ratios during weekly periods for radio-tagged chinook salmon in the Copper River, 2000.

`	May 30 –June 5	June 6 - 12	June 13 - 19	June 20 - 26	June 27 - July19	July 4 - 10	July 11 -17	July 18 -24	July 25 -31	August 1-4
Test for Equal Marked:Unmarked Ratios in the Second Sample										
Marked	0	1	**4**	**8**	**4**	**7**	**17**	**8**	**4**	1
Unmarked	0	46	**371**	**412**	**468**	**770**	**815**	**375**	**187**	36
Marked:Unmarked	0.000	0.000	0.011	0.019	0.009	0.009	0.021	0.024	0.021	0.028
χ^2=7.54; df=6; P=0.27 (for cells with bold numbers)										
Test for Equal Recaptured:Not Recaptured Ratios of Fish Marked in the First Sample										
Recaptured	1	0	**4**	**9**	**5**	**9**	**13**	**8**	**4**	1
Not recaptured	73	46	**55**	**77**	**15**	**40**	**45**	**50**	**25**	1
Recapture Rate	0.000	0.000	0.068	0.105	0.250	0.184	0.241	0.138	0.143	0.500
χ^2=9.31; df=6; P=0.16 (for cells with bold numbers)										

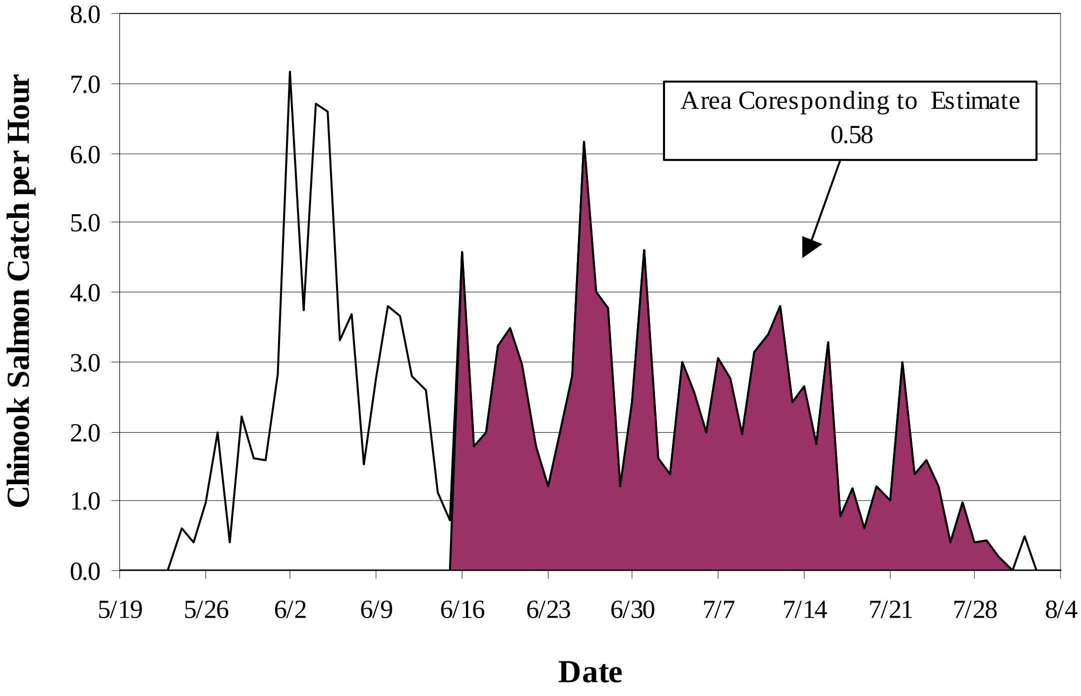

Figure 6.-Catch per unit effort of chinook salmon during the first sample of the mark-recapture experiment and the proportion of the total catch (shaded) corresponding to the period of the abundance estimate in the Copper River, 2000.

Table 13.-Distribution of radio-tagged chinook salmon in major spawning drainages in the Copper River, 2000.

Spawning Stream	Number of Radio Tags	Proportion of all Spawners[a]	Percentile Limits (2.5^{th} - 97.5^{th})
Chitina River	41	0.13	(0.09, 0.16)
Tonsina River	65	0.20	(0.16, 0.25)
Klutina River	83	0.27	(0.22, 0.32)
Tazlina River	9	0.03	(0.02, 0.06)
Gulkana River	81	0.25	(0.21, 0.30)
Upper Copper River Tributaries	39	0.12	(0.09, 0.15)
Total	318	1.00	

[a] Adjusted for daily tagging rates and fishing effort.

Table 14.-Proportions of radio-tagged chinook salmon located in nine aerial survey index streams in the Copper River drainage, 2000.

Spawning Stream	Number of Radio Tags	Proportion of all Spawners[a]	Percentile Limits (2.5^{th}, 97.5^{th})
Indian Cr.	3	0.01	(0.00, 0.02)
E. Fk. Chistochina R.	7	0.02	(0.01, 0.04)
Gulkana R.	81	0.25	(0.20, 0.30)
Mendeltna Cr.	2	0.01	(0.00, 0.02)
Kiana Cr.	7	0.03	(0.01, 0.05)
St. Anne Cr.	5	0.02	(0.00, 0.03)
Manker Cr.	11	0.04	(0.02, 0.07)
Greyling Cr.	8	0.02	(0.01, 0.04)
L. Tonsina R.	1	<0.01	(0.00, 0.01)
Total in Index Streams	**125**	**0.40**	**(0.34, 0.45)**
Other Areas	194	0.60	(0.55, 0.66)
Total in All Streams	318	1.000	

[a] Adjusted for daily tagging rates and fishing effort.

Table 15.-Numbers of radio-tagged chinook salmon located in tributaries of the Copper River during aerial tracking surveys, 1999 and 2000.

	Number of Radio Tagged Chinook Salmon	
Tributary	1999	2000
Upper Copper River Drainage		
Mainstem Copper River	0	6
Ahtell River	2	0
Bone Creek	1	3
Chistochina River (mainstem)	2	4
E. Fork Chistochina River	6	7
No Name (south of E. Fork Chistochina River)	2	1
Sinona Creek	2	2
Gakona River (mainstem)	4	0
Spring Creek	2	4
No Name (opposite Spring Creek)	2	1
Indian River	2	3
Drop Creek	3	1
No Name (east side parallel to Drop Creek)	0	1
No Name (east side opposite Indian River)	2	2
No Name (east side opposite Sinona Creek)	1	1
No Name (east side upstream of Yokneda Lakes)	1	1
Gulkana River Drainage		
Gulkana River (mainstem)	14	58
Middle Fork Gulkana River	3	1
West Fork Gulkana River	3	1
Hungry Hollow Creek	1	0
Paxson Lake Outlet	1	3
No Name (west side US of West Fork)	0	3

-continued-

Table 15.-Page 2 of 2.

	Number of Radio-Tagged Chinook Salmon	
Tributary	1999	2000
Tazlina River Drainage		
Kiana Creek	5	7
Mendeltna Creek	4	2
Klutina River Drainage		
Klutina River (mainstem)	46	58
Manker Creek	13	11
St. Anne Creek	3	5
Mahlo Creek	0	1
Tonsina River Drainage		
Tonsina River (mainstem)	51	45
Greyling Creek	8	8
Little Tonsina River	7	1
Dust Creek	1	1
Bernard Creek	1	0
Chitina River Drainage		
Mainstem Chitina River	0	5
Chakina River	12	8
Gilahina River	3	9
Lakina River	3	1
Monahan Creek	2	2
Tana River	6	1
Tebay River	35	11

Table 16.-Proportions of chinook salmon spawning in the mainstem and tributaries of the Tonsina and Klutina rivers, 2000.

River	Number of Radio Tags	Proportion of Spawners[a]	Percentile Limits (2.5^{th}, 97.5^{th})
Tonsina River			
Mainstem	55	0.86	(0.77, 0.93)
Greyling Creek	8	0.12	
L. Tonsina River	1	0.01	
Bernard Creek	0	0.00	
Dust Creek	1	0.01	
All Tributaries	10	0.14	(0.08, 0.22)
Total	65	1.00	
Klutina River			
Mainstem	49	0.78	(0.69, 0.87)
Manker Creek	11	0.15	
St. Anne Creek	5	0.06	
Mahlo Creek	1	0.01	
All Tributaries	17	0.22	(0.13, 0.31)
Total	83	1.00	

[a] Adjusted for daily tagging rates and fishing effort.

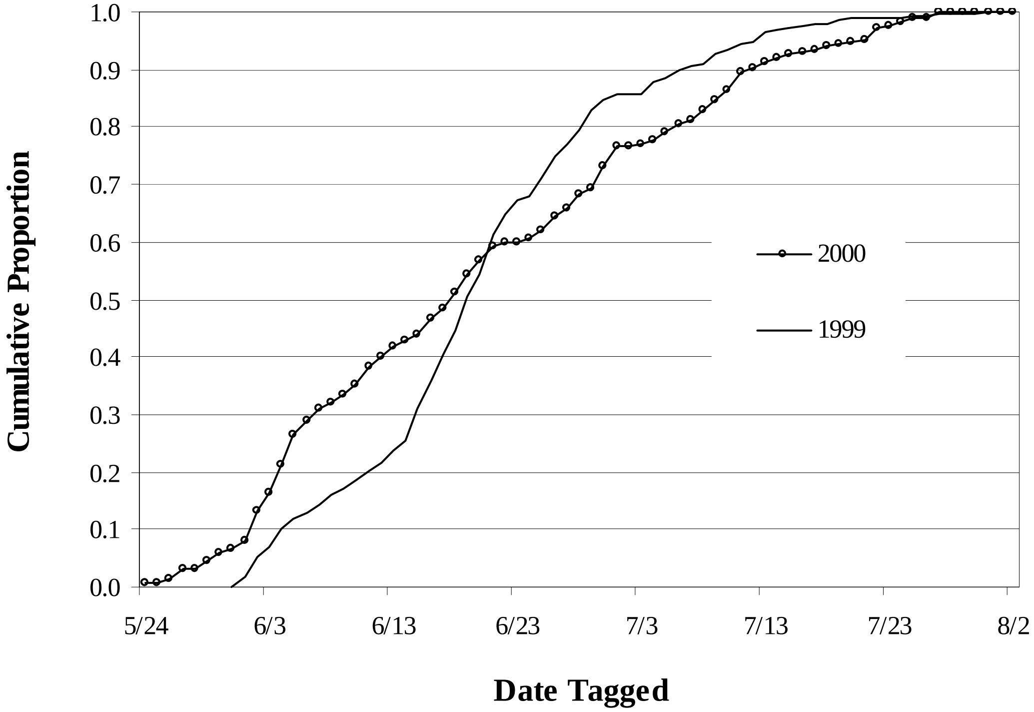

Figure 7.-Migratory-timing profiles of all radio-tagged chinook salmon at the capture site, 1999 and 2000.

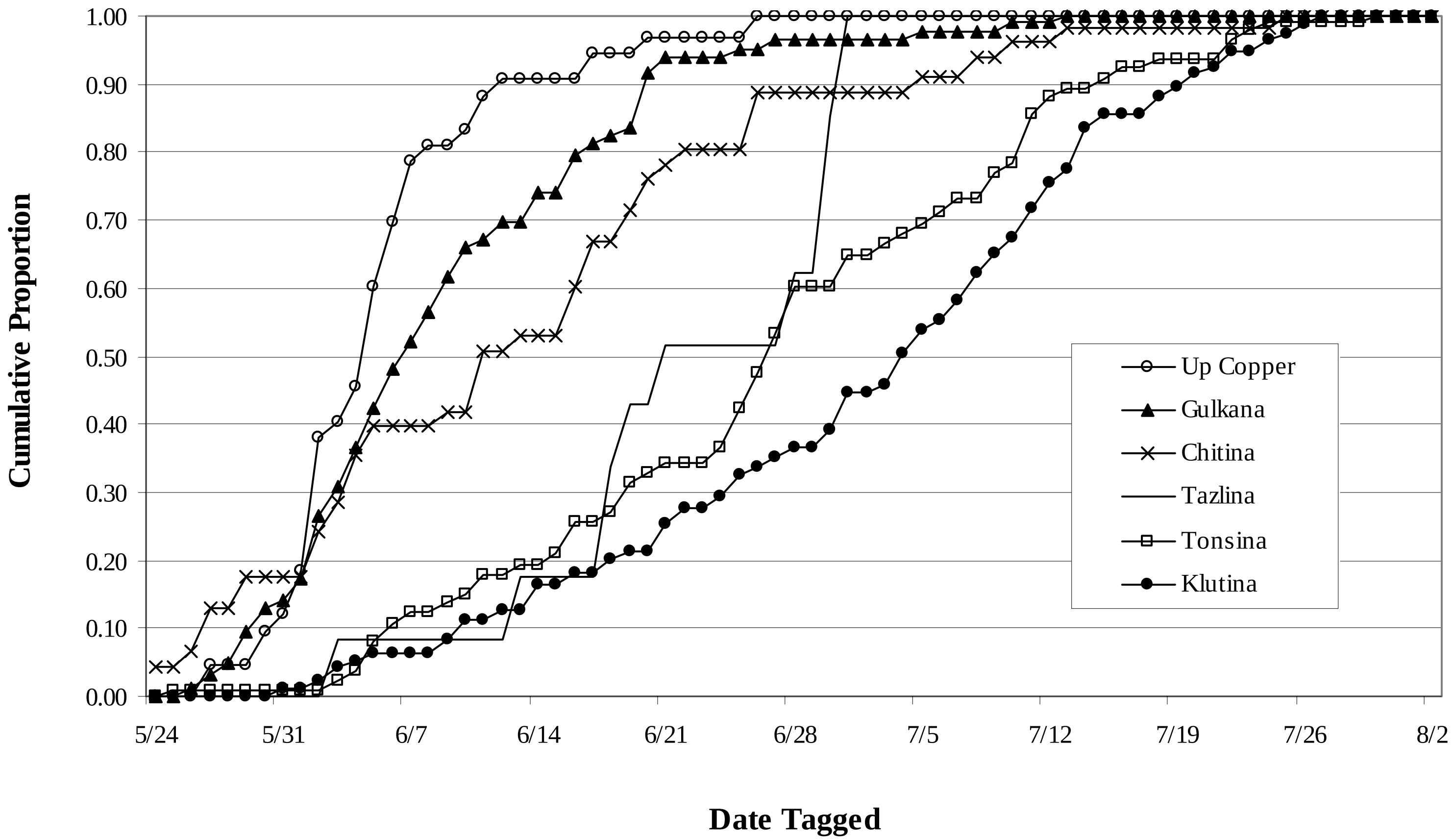

Figure 8.-Migratory-timing profiles of chinook salmon at the capture site for the major stocks in the Copper River drainage, 2000.

Table 17.-Statistics regarding the migratory timing of the major chinook salmon spawning stocks in the Copper River, 2000.

Spawning Stock	Duration (No. of Days)	Mean Date of Passage ($\bar{t}$)	SE ($\bar{t}$)
Upper Copper River	5/27 - 6/26 (30)	6/5	6.1
Gulkana River	5/27 - 7/13 (47)	6/9	9.3
Chitina River	5/24 - 7/25 (62)	6/13	13.9
Tazlina River	6/13 - 7/1 (18)	6/22	8.4
Tonsina River (All)	5/29 - 7/30 (62)	6/27	13.7
Mainstem	5/29 - 7/30 (62)	6/14	13.0
Tributaries	6/3 - 7/11 (38)	6/29	12.2
Klutina River (All)	5/26 - 7/27 (62)	7/1	15.2
Mainstem	6/9 - 7/27 (48)	7/5	12.0
Tributaries	5/29 - 7/11 (30)	6/13	10.8

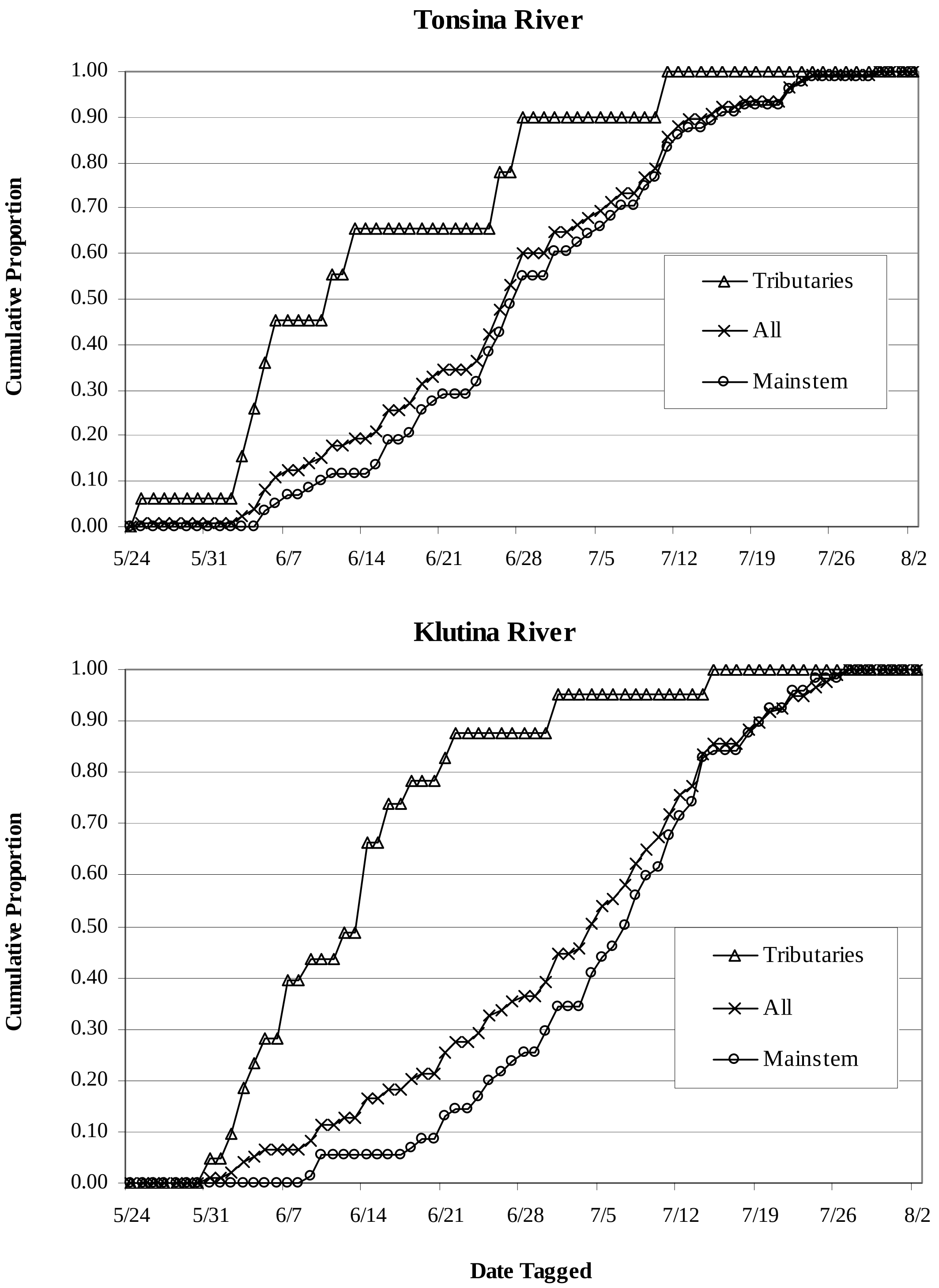

Figure 9.-Migratory-timing profiles of chinook salmon in the Tonsina and Klutina rivers for tributary and mainstem spawners, 2000.

years. The abundance estimate in this study is assumed to be unbiased based on tests of consistency previously described. However, several factors could not be explicitly tested that could potentially bias the abundance estimate. These factors include misreported harvest, unreported harvest, illegal harvest, and selection for tagged fish.

Misreported harvest of chinook salmon would occur if a CSS fisher harvested a chinook salmon, returned a permit, but did not report the chinook salmon harvest on their permit. Such occurrences would bias the abundance estimate low. The degree to which this occurred was not known, but was assumed small.

Unreported chinook salmon harvest (not returning a permit) could also bias the abundance estimate. A change in the permitting system in 2000 resulted in a permit return rate of 94.2% versus 96.6% in 1999. In 1999, permit holders were required to report their harvest after each trip, whereas in 2000, permits could be returned at the end of the season. The number of chinook salmon harvested by persons who do not return permits is estimated based on trends of harvest rates from multiple mailings of reminder letters to persons who do not return permits by the end of the season. Because the return rate of permits was so high, it is unlikely that nonreported harvest significantly biased the estimate of abundance.

Harvest of chinook salmon by persons who fished illegally (i.e. did not obtain a permit) is only of consequence to the estimate if a tagged fish was captured. Tagged fish are used in the estimation whether they were reported or not, whereas unmarked fish that are not reported are not. The occurrence of illegal, or unreported harvest that includes tagged fish would bias the estimate low.

Misreporting radio-tagged chinook salmon harvested by CSS fishers would bias estimates of abundance high if a chinook salmon with a radio tag was harvested and recorded on the permit, but the tag was not returned. The likelihood of a harvested radio tag not being accounted for is low because of the information provided by the tracking stations. Tracking stations located at the upper and lower boundaries of the CSS fishery and at O’Brien Creek were able to detect all tagged fish that entered and exited the fishery. Nearly all radios from tagged fish captured by CSS fishers (46 of 50) were voluntarily returned. Four tags were inferred as harvested based on large signal strength recordings at O’Brien and/or Haley Creek. The addition of a tracking station placed at O’Brien Creek in 2000 substantially enhanced our ability to discern radio tags removed from the water (harvested) from those that remained in fish migrating upstream.

Selection for radio tags by participants of the CSS fishery would bias the estimate low by inflating the marked-to-unmarked ratio. This could occur in two ways. First, a fisher could catch a tagged fish, remove the radio tag (and return it), but release the fish and continue fishing. Alternatively, a fisher could release untagged fish until a tagged fish was captured. The latter was a concern in 1999 because of a $200 lottery reward offered for returned radio tags. In 2000 there was little incentive to continue fishing for tagged fish because the lottery was discontinued. To further alleviate this concern, the color of the spaghetti tags was changed from bright yellow to gray. Several fishers reported not being able to see the gray spaghetti or radio tags until the fish was being processed. In 2000 the bag limit was reduced from four to one and the risk for tag selection increased. It was more likely that having already caught a chinook salmon, and while trying to fill their sockeye salmon bag limit, CSS fishers would catch a tagged chinook salmon, remove the tag, and release the fish alive. As a means to detect selection for tags, follow-up phone calls were made to CSS fishers that left contact information to query them as to whether or not they harvested the tagged fish. In one instance a CSS fisher had caught a radio-tagged fish, removed the radio tag, and released the fish with the spaghetti tag still attached, and mailed in the radio tag as if it were harvested.

For this study design to be effective, frequent fishery openings, especially in June, are required. In 2000, the fishing season was substantially restricted during June compared to 1999 and a large fraction of the chinook salmon run (41%) could not be directly estimated with mark-recapture techniques. In 2000, the method used to estimate the proportion (and its associated variance) of the run accounted for with the mark-recapture study ($\hat{P}$) differed from that used in 1999. In 1999 it was assumed that catchability in the first event was constant and the proportion accounted for by the mark-recapture experiment was the simple ratio of cumulative CPUE during the experiment to the total cumulative CPUE. The associated variance was then estimated by bootstrapping the observed between-day variation in CPUE (Evenson and Wuttig 2000). It was thought that this method using the 2000 data did not account for all of the variation. Because the estimate of abundance nearly doubled from the mark recapture estimate when the period prior to the fishery was included, variation should have increased more than 1%. Although the test comparing weekly marked:unmarked ratios indicated that marking had been proportional to run strength, there was considerable variation in the relationship between CPUE and abundance (Figure 10). Therefore, we felt that the relationship between weekly estimates of abundance and weekly cumulative CPUE data better captured the uncertainty in estimating total abundance (Figure 10). In 2000, precision decreased from 21% for the estimate of abundance for the period 16 June to 31 July, to 34% for the estimate of total abundance. The 2000 method incorporated two sources of uncertainty. The variation in the modeled linear relationship between weekly abundance from CPUE (process error) is confounded with the variation in the estimates of weekly abundance estimates (measurement error). It is likely that the true relationship between CPUE and salmon abundance has greater precision than demonstrated.

The 1999 estimates of $\hat{P}$ and total abundance have subsequently been adjusted to reflect the change in methods. In 1999, the estimated proportion of fish that passed during the fishery was 0.901 (SE=0.0861). Total abundance was estimated as 32,082 (SE=4,776) chinook salmon greater than 570 mm MEF.

Upriver sampling was conducted to supplement the CSS fishery harvest in the second sample and met with mixed success. Upriver dipnetting from a drifting boat proved challenging and capture rates were low (0–2 fish/day). Gillnetting was productive, especially considering that fish were captured near the end of the run. Capture rates typically varied from 4–8 fish/h. Sampling of fish wheels required little additional effort and 5–15 fish per day were examined during July. This sampling would likely be much more effective in June as substantially fewer fish wheels are in operation in July compared to June and the wheels are less effective at capturing fish in July because of higher water. No difference in selectivity between fish sampled from wheel samples and dip nets was detected. However, the gill net was more selective for larger fish than the other capture techniques.

Use of radio tags as the primary mark allowed for explicit testing of certain assumptions that is not possible with conventional tagging methods. Given that the fate of all tags relative to their migration into, harvest in, or migration through the CSS fishery was known, key experimental factors such as tag loss, emigration, and mortality were known with certainty and those tags were removed from the experiment. In 1999, 4% (n=14) of all radio tagged fish failed to resume

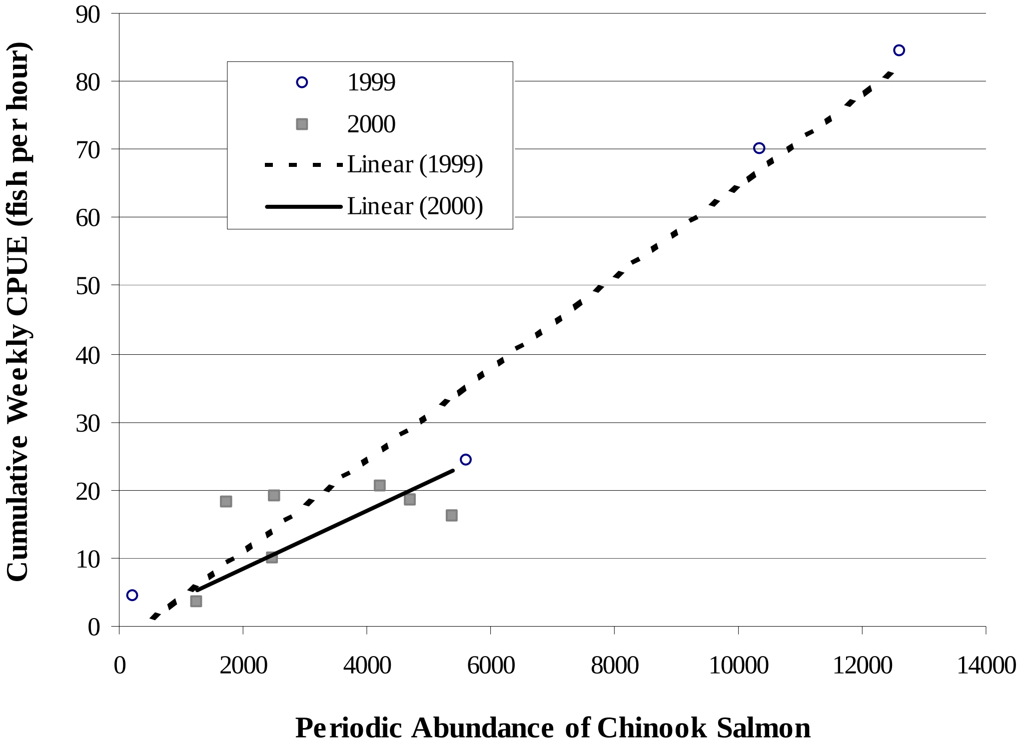

Figure 10.-Periodic estimates of abundance of chinook salmon and cumulative periodic CPUE for 1999 and 2000. Periodic refers to a single week or pooled weeks.

upstream migration and were censored from the experiment. In 2000, the proportion that failed to resume upstream migration increased to 10% (n=56). Similar failure or retreat rates of chinook salmon have been observed in other studies (Eiler et al. 1991; Bendock and Alexandersdottir 1992; Pahlke and Bernard 1996; and Bernard et al. 1999). Although the failure rate in this study was similar to that observed in other studies, the relatively large number of failures raises the question of whether handling affects the probability of capture in the second event for those fish that migrate into the fishery. Because we do not know how unmarked fish behave, the only insight we have into handling-induced changes in capture probability come from marked fish. Recapture rates for fish that exhibited minimal versus substantial delay after handling were similar as were their transit times through the fishery. This suggests that handling did not influence capture probability. The assumption is that delay after handling is a relative measure of the degree of stress a handled fish experienced. Stressed fish may be more likely to migrate nearshore where water velocities are slower and may be more vulnerable to capture by dipnetters. A similar comparison between delay after handling and transit time to the Gulkana River (140 km from the CSS fishery) also suggested that handling did not affect swimming speed (Figure 11).

During 1999 and 2000, 36 and 20 radio-tagged chinook salmon were only located in the mainstem portion of the Copper River. These fish were located between the Gulkana and Chitina rivers during aerial surveys. Several small aggregations of radio tags (2-5 tags) were located throughout the section, and one large cluster each year (10-15 tags) was located upstream from the mouth of the Tonsina River. These fish were designated as spawners in 1999 because they had migrated at least 20 km from the capture site, had been located in the same general area at least two times over a two week period, and had not previously migrated into a tributary stream.

The ground-based investigations conducted in 2000 to determine the spawning status of the radio tags located in the mainstem river revealed no evidence of spawning activity in the mainstem Copper River. Of the radio tags that were recovered, all but one were found alone, lying on, or shallowly buried in a sand bar not in association with the host fish. One tag was pulled from a carcass lying among other unspawned carcasses. These findings suggested that the radio tags located in the mainstem Copper River in both 1999 and 2000 were either expelled and/or were associated with fish that died prior to spawning. The fact that other untagged carcasses were found in the same area suggests that some of the tagged fish may have died from natural causes. However, Gary and Haynes (1979) found that the percent return to spawning grounds of chinook salmon fitted with internal radio tags was significantly less than fish tagged with only spaghetti tags, and suggested handling-induced mortality. Bernard et al. (1999) found evidence that handling of chinook salmon on the Taku and Kenai rivers resulted in atypically slow migration rates. Prolonged migrations could result in increased mortality rates because of a general decrease in a fish's fitness and increased exposure to fishing and natural mortality factors. If handling-induced changes in swimming speeds increase a fish's risk of mortality, the likelihood of a tagged fish entering a spawning drainage in close proximity to the tagging site would be greater than for fish bound for more distant spawning areas. If this were true in this study, the estimated proportions of chinook salmon spawning in the lower river drainages (the Chitina and Tonsina rivers) would be biased high and the upper river stocks (Upper Copper and Gulkana drainages) biased low.

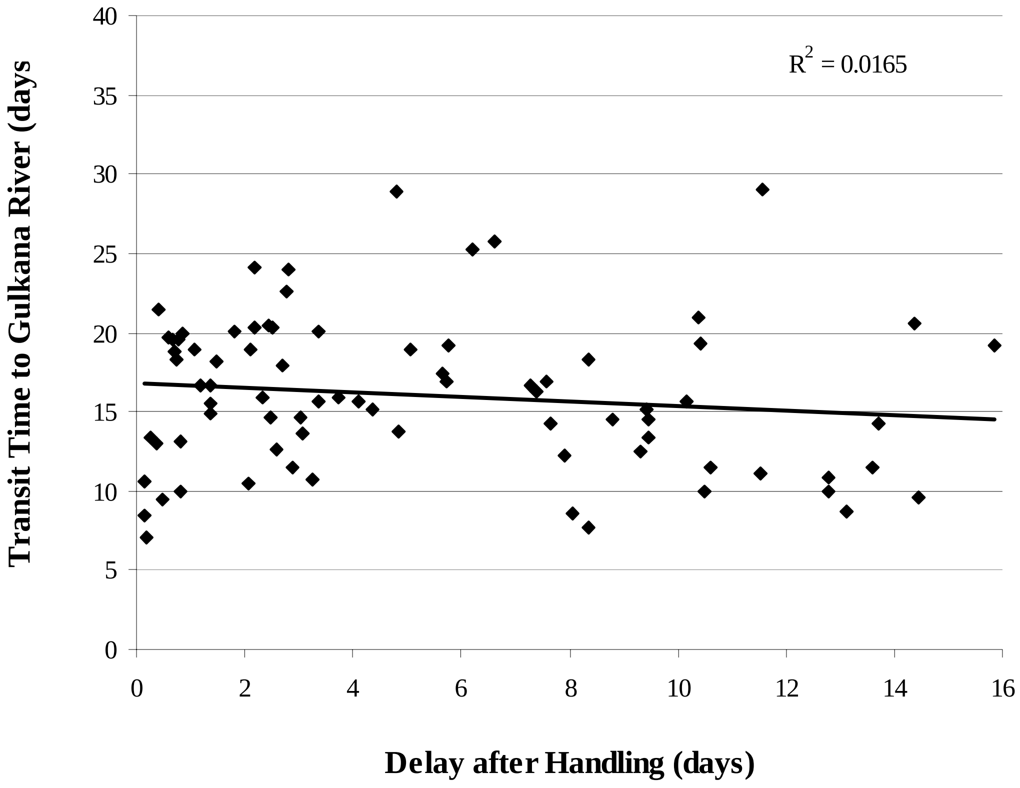

Figure 11.- Delay after handling versus transit time from the lower boundary of the CSS fishery to the mouth of the Gulkana River of radio-tagged chinook salmon, 2000.

References to chinook salmon spawning in mainstem, glacial rivers are sparse. Koski et al. (1993) noted radio-tagged chinook salmon in the mainstem Nass River that were believed to be spawning, and at least one spawning area in the mainstem Taku River was documented (J. Eiler, National Marine Fisheries Service, Auke Bay, personal communication). Chinook salmon are known to spawn in the Kenai River (Burger et al. 1984) and in the Tonsina and Klutina rivers (this study), which are glacial in origin. However, these three systems are all buffered by large lakes that reduce the turbidity and extreme summer flows that occur in the mainstem Copper River.

Based on the investigations in this study, fish were likely incorrectly designated as mainstem spawners in 1999. Therefore the 1999 apportion estimates for the remaining major spawning areas were deemed biased low and were recalculated (Table 18).

The distribution of chinook salmon spawning in the Copper River drainage in 2000 was marked similar to that observed in 1999 with some exceptions. In both years of the study the Klutina River represented the largest proportion of the total drainage escapement, and the Tazlina River the smallest proportion. Notable differences from 1999 to 2000 were observed in the Chitina, Gulkana, and Tonsina drainages. The proportion spawning in the Gulkana River increased from 12% to 25%, whereas the proportion spawning in the Chitina River decreased from 20% to 12%. The proportion spawning in the Tonsina River was similar to that in 1999, but the number of radio-tagged fish found in the Little Tonsina River decreased from seven fish in 1999 to one fish in 2000.

Based on the distribution of the radio tags throughout the Copper River drainage, the nine aerial-surveyed spawning streams, which have traditionally been used to evaluate escapement, likely do not provide a reliable nor consistent measure of total drainage escapement. The proportion of all spawning fish represented by the nine aerial index streams varied from 26% in 1999 to 39% in 2000. The Gulkana River was largest contributor to the aerial escapement count in the index streams in 1999 (47%) and 2000 (63%), but represented only 12% and 25%, respectively, of the total drainage escapement.

In addition to the fact that the aerial index streams represent a small and variable proportion of the total Copper River escapement, the stock-specific run timing curves suggest that the index streams only account for fish with early entry patterns. In both years of this study the pattern in run timing past the capture site was markedly similar (Figure 12) despite stocks being subjected to varying exploitation rates in the mixed stock commercial and subsistence fisheries. Chinook salmon bound for the upper Copper River were the first to enter the CSS fishery and fish spawning in the mainstem of the Tonsina and Klutina rivers (farthest downstream) were the last. Entry patterns where upriver stocks tend to enter a river earlier than downriver stocks have been documented in other large river systems (Koski et al. 1994; Pahlke and Bernard 1996; and McPherson et al. 1997).

The majority of radio tags located within the Klutina and Tonsina drainages in 1999 and 2000 were located in the mainstem portions of the rivers. Mainstem spawners in the two rivers combined represented a substantial proportion, 33% in 1999 and 40% in 2000, of the entire Copper River chinook salmon escapement. This component of the Copper River spawning population has never been assessed using aerial surveys or other methods. Both rivers are large, fast-flowing, and are glacially occluded making aerial surveys and other assessment techniques difficult. Continued radiotelemetry studies may be the only effective method of assessing

Table 18.-Distribution of radio-tagged chinook salmon in major spawning drainages of the Copper River, 1999 and 2000.

	Number of Radio Tags		Proportion of Spawners[a]	
Spawning Stream	1999	2000	1999	2000
Chitina River	78	41	0.22	0.13
Tonsina River	72	65	0.24	0.21
Klutina River	72	83	0.27	0.27
Tazlina River	12	9	0.04	0.03
Gulkana River	42	81	0.12	0.25
Upper Copper River Tributaries	44	39	0.11	0.12
Total	356	318	1.00	1.00

[a] Adjusted for daily tagging rates and fishing effort.

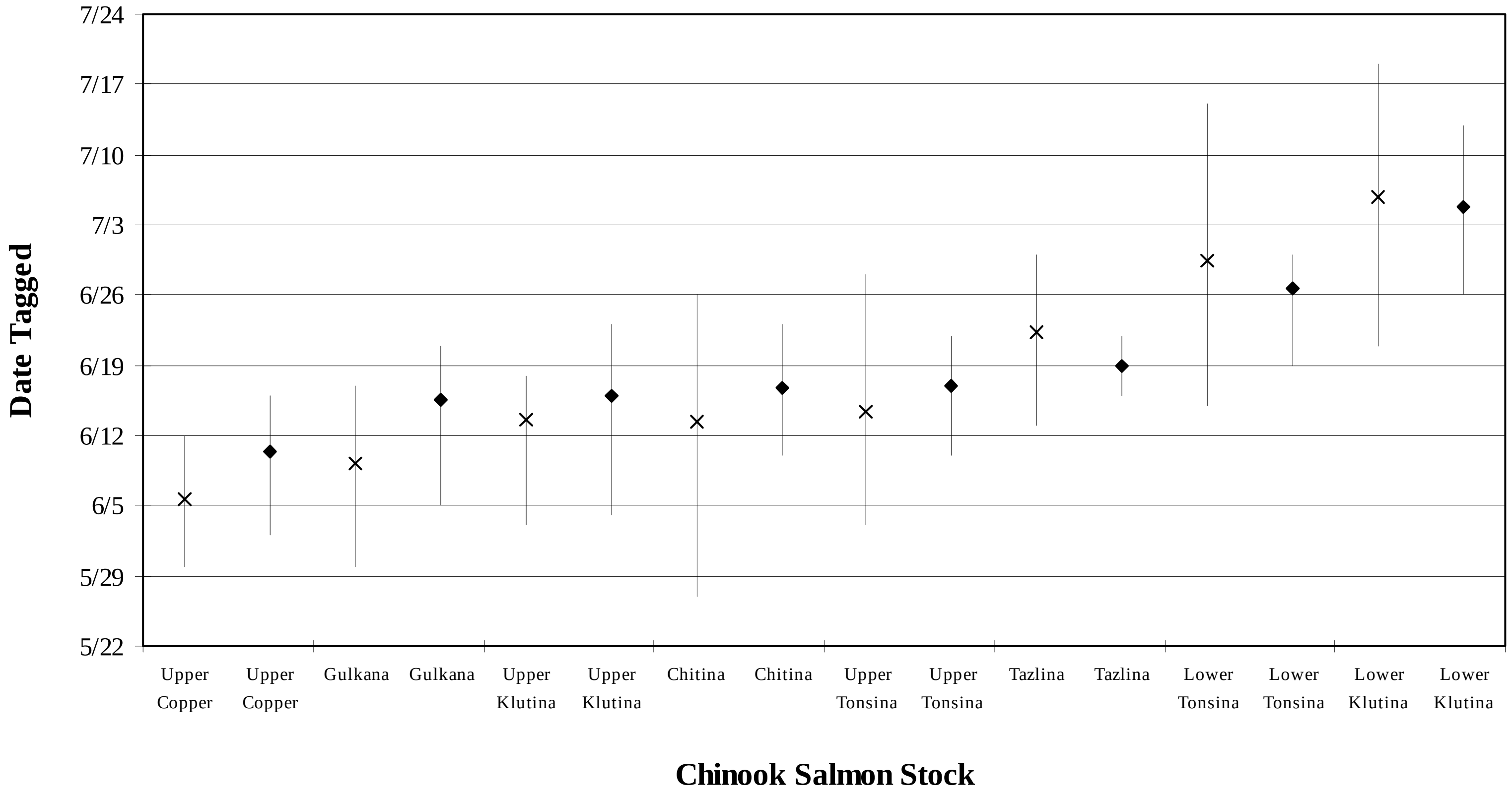

Figure 12.-Mean passage date (symbol) and 80% range (vertical lines) of Copper River chinook salmon stocks at the capture site in 1999 and 2000.

relative escapement in these systems. It should be noted that the proportions of spawners in the tributary streams are minimum estimates. Some of the radio tags located in the mainstem Klutina and Tonsina rivers may have been associated with fish that were ultimately bound for tributary streams, but failed to complete their upstream migration as a result of either natural or handling mortality, or were tags that were regurgitated. In the Unalakleet River, four of six chinook salmon reported hooked by sport fishers regurgitated their tags when captured (Wuttig 1998). Both the Tonsina and Klutina rivers support sport fisheries that may have captured tagged fish.

The differences in run timing between tributary and mainstem spawners in the Klutina and Tonsina rivers are analogous to the early and late-run stocks on the Kenai River (Burger et al. 1985). The late-run stocks in the Kenai River spawn in the mainstem that has effluent from large lakes (Kenai and Skilak lakes), whereas early-run stocks spawn in run-off tributaries. Both the mainstem Klutina and Tonsina rivers originate from large lakes (Klutina and Tonsina lakes), while tributaries are run-off streams. The mainstem Kenai, Klutina and, Tonsina systems are all buffered by large lakes that reduce the turbidity and extreme summer flows that occur in the mainstem river. Burger et al. (1985) hypothesized that these behavioral differences in run timing are a result of warmer water temperatures in the lake-fed tributaries, which enable eggs to incubate faster than in the cooler run-off tributaries.

CONCLUSIONS AND RECOMMENDATIONS

The greatest concern for the mark-recapture component of the study is the likelihood of limited CSS fishery openings during June. Upriver gillnetting and sampling of fish wheels during June is recommended as a remedy for this problem. This would provide the information needed to directly estimate abundance with mark-recapture methods for the entire run and would not require expanding a periodic estimate based on CPUE data as was done in this study.

In future years of the study, there exists a potential that public interest in this project may erode and the reliability of tag return information may become more suspect. Starting in 2001, CSS fishing permits will be issued from private vendors, and informing the public about the study and encouraging tag returns will become more difficult. Highly visible informational signs, flyers, and tag return boxes should be placed at access points throughout the CSS fishery. In addition, a tracking station should again be placed at O’Brien Creek to help identify radio tags that are removed from the water.

To provide a better understanding of the factors that may increase handling delay or cause failed migrations, relationships between various physical attributes of radio tagged chinook salmon and these delays or failed migrations should be investigated. These data should include brightness or coloration of the fish, presence of lesions, scrapes or net marks, and damage or splitting of fins, and should be assessed and recorded at the time of marking.

To minimize handling stress on captured chinook salmon, smaller mesh dip net bags should be used. This would likely reduce the frequency of injury to chinook salmon such as splitting caudal fins when landing them into the boat. As an additional measure of reducing stress, captured chinook salmon should be tagged and released immediately, as opposed to waiting until the drift is completed.

Additional aerial tracking surveys of the Tonsina and Klutina rivers are recommended to accurately designate radio tagged chinook salmon as mainstem or tributary spawners. Although, no signs of mainstem spawning in the Copper River were observed in 2000, ground-based assessments of radio tags located in the mainstem river should be repeated for two reasons. First, to continue to investigate the possibility that there is mainstem spawning in this area, and second, to locate radio tags that are not found during aerial survey flights.

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APPENDIX A
DAILY CATCH STATISTICS

Appendix A1.-Daily fishing effort, water level, catch, CPUE, and number of radio tags deployed for chinook salmon in the Copper River, 2000.

Date	Fishing Effort (hr)	Water Level (cm)	Catch	CPUE (catch/hr)	Cumulative CPUE (catch/hr)	Radio Tags Deployed	Tagging Rate
19-May	0.0	0	0	0.00	0.00	0	0.00
20-May	4.0	56	0	0.00	0.00	0	0.00
21-May	4.8	51	0	0.00	0.00	0	0.00
22-May	4.0	46	0	0.00	0.00	0	0.00
23-May	5.0	38	0	0.00	0.00	0	0.00
24-May	4.9	33	3	0.61	0.61	2	0.67
25-May	5.0	38	2	0.40	1.01	2	1.00
26-May	5.2	43	5	0.97	1.98	3	0.60
27-May	5.0	51	10	1.99	3.97	7	0.70
28-May	4.9	56	2	0.41	4.38	1	0.50
29-May	5.0	64	11	2.21	6.58	8	0.73
30-May	5.0	76	8	1.60	8.18	5	0.63
31-May	5.1	84	8	1.57	9.76	5	0.63
1-Jun	5.0	91	14	2.83	12.59	9	0.64
2-Jun	4.9	94	35	7.17	19.75	24	0.69
3-Jun	5.1	104	19	3.75	23.50	13	0.68
4-Jun	4.9	119	33	6.71	30.22	22	0.67
5-Jun	5.0	140	33	6.58	36.79	22	0.67
6-Jun	4.9	160	16	3.30	40.09	12	0.75
7-Jun	4.6	191	17	3.67	43.76	11	0.65
8-Jun	5.2	206	8	1.53	45.29	5	0.63
9-Jun	5.1	178	14	2.76	48.05	10	0.71
10-Jun	5.0	185	19	3.79	51.84	13	0.68
11-Jun	5.2	191	19	3.67	55.51	13	0.68
12-Jun	5.0	196	14	2.80	58.31	9	0.64
13-Jun	5.0	206	13	2.60	60.91	9	0.69

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Appendix A1.-Page 2 of 3.

Date	Fishing Effort (hr)	Water Level (cm)	Catch	CPUE (catch/hr)	Cumulative CPUE (catch/hr)	Radio Tags Deployed	Tagging Rate
14-Jun	2.7	221	3	1.13	62.04	1	0.33
15-Jun	4.2	224	3	0.71	62.75	2	0.67
16-Jun	3.1	218	14	4.57	67.32	10	0.71
17-Jun	3.9	211	7	1.79	69.11	5	0.71
18-Jun	5.0	203	10	1.99	71.11	7	0.70
19-Jun	5.0	198	16	3.22	74.33	11	0.69
20-Jun	4.9	193	17	3.48	77.81	12	0.71
21-Jun	5.1	180	15	2.97	80.78	10	0.67
22-Jun	5.1	163	9	1.78	82.56	6	0.67
23-Jun	5.0	180	6	1.20	83.76	4	0.67
24-Jun	5.0	188	10	2.00	85.76	7	0.70
25-Jun	5.0	213	14	2.80	88.56	9	0.64
26-Jun	5.0	231	31	6.16	94.71	21	0.68
27-Jun	5.0	249	20	3.99	98.70	10	0.50
28-Jun	5.0	272	19	3.77	102.48	10	0.53
29-Jun	5.0	302	6	1.21	103.68	4	0.67
30-Jun	4.2	307	10	2.41	106.09	5	0.50
1-Jul	4.1	315	19	4.62	110.71	10	0.53
2-Jul	2.5	318	4	1.61	112.32	2	0.50
3-Jul	5.1	320	7	1.39	113.71	4	0.57
4-Jul	5.0	320	15	3.00	116.71	10	0.67
5-Jul	5.1	328	13	2.55	119.26	9	0.69
6-Jul	5.1	328	10	1.97	121.23	7	0.70
7-Jul	4.9	320	15	3.05	124.28	10	0.67
8-Jul	5.1	320	14	2.75	127.03	9	0.64
9-Jul	5.1	328	10	1.97	129.00	7	0.70
10-Jul	5.1	318	16	3.13	132.13	11	0.69

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Appendix A1.-Page 3 of 3.

Date	Fishing Effort (hr)	Water Level (cm)	Catch	CPUE (catch/hr)	Cumulative CPUE (catch/hr)	Radio Tags Deployed	Tagging Rate
11-Jul	5.0	310	17	3.40	135.53	12	0.71
12-Jul	5.0	297	19	3.81	139.34	14	0.74
13-Jul	5.0	305	12	2.42	141.76	9	0.75
14-Jul	3.0	300	8	2.65	144.41	6	0.75
15-Jul	4.9	300	9	1.82	146.23	7	0.78
16-Jul	4.9	312	16	3.28	149.51	12	0.75
17-Jul	5.1	310	4	0.78	150.29	3	0.75
18-Jul	5.0	312	6	1.19	151.49	5	0.83
19-Jul	5.0	315	3	0.60	152.08	3	1.00
20-Jul	5.0	302	6	1.20	153.28	5	0.83
21-Jul	5.0	295	5	1.01	154.29	4	0.80
22-Jul	5.0	284	15	2.98	157.27	11	0.73
23-Jul	5.0	272	7	1.40	158.66	5	0.71
24-Jul	5.1	274	8	1.58	160.25	6	0.75
25-Jul	5.0	264	6	1.20	161.45	5	0.83
26-Jul	5.0	254	2	0.40	161.85	1	0.50
27-Jul	4.0	254	4	0.99	162.84	3	0.75
28-Jul	5.0	274	2	0.40	163.24	2	1.00
29-Jul	4.6	251	2	0.43	163.68	2	1.00
30-Jul	5.0	244	1	0.20	163.88	1	1.00
31-Jul	4.6	236	0	0.00	163.88	0	0.00
1-Aug	4.0	234	2	0.50	164.38	2	1.00
2-Aug	3.4	234	0	0.00	164.38	0	0.00
3-Aug	4.0	234	0	0.00	164.38	0	0.00