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Inriver Abundance, Spawning Distribution and Run Timing of Copper River Chinook Salmon in 2003

**Annual Report for Study 02-015
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**by
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Weights and measures (metric)		General		Measures (fisheries)	
centimeter	cm	Alaska Administrative Code	AAC	fork length	FL
deciliter	dL	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	mid-eye-to-fork	MEF
gram	g	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	mid-eye-to-tail-fork	METF
hectare	ha	at	@	standard length	SL
kilogram	kg	compass directions:		total length	TL
kilometer	km	east	E		
liter	L	north	N	Mathematics, statistics	
meter	m	south	S	<i>all standard mathematical signs, symbols and abbreviations</i>	
milliliter	mL	west	W	alternate hypothesis	H _A
millimeter	mm	copyright	©	base of natural logarithm	e
		corporate suffixes:		catch per unit effort	CPUE
Weights and measures (English)		Company	Co.	coefficient of variation	CV
cubic feet per second	ft ³ /s	Corporation	Corp.	common test statistics	(F, t, χ^2 , etc.)
foot	ft	Incorporated	Inc.	confidence interval	CI
gallon	gal	Limited	Ltd.	correlation coefficient (multiple)	R
inch	in	District of Columbia	D.C.	correlation coefficient (simple)	r
mile	mi	et alii (and others)	et al.	covariance	cov
nautical mile	nmi	et cetera (and so forth)	etc.	degree (angular)	°
ounce	oz	exempli gratia (for example)	e.g.	degrees of freedom	df
pound	lb	Federal Information Code	FIC	expected value	E
quart	qt	id est (that is)	i.e.	greater than	>
yard	yd	latitude or longitude	lat. or long.	greater than or equal to	≥
		monetary symbols (U.S.)	\$, ¢	harvest per unit effort	HPUE
Time and temperature		months (tables and figures): first three letters	Jan, ..., Dec	less than	<
day	d	registered trademark	®	less than or equal to	≤
degrees Celsius	°C	trademark	™	logarithm (natural)	ln
degrees Fahrenheit	°F	United States (adjective)	U.S.	logarithm (base 10)	log
degrees kelvin	K	United States of America (noun)	USA	logarithm (specify base)	log ₂ , etc.
hour	h	U.S.C.	United States Code	minute (angular)	'
minute	min	U.S. state	use two-letter abbreviations (e.g., AK, WA)	not significant	NS
second	s			null hypothesis	H ₀
Physics and chemistry				percent	%
all atomic symbols				probability	P
alternating current	AC			probability of a type I error (rejection of the null hypothesis when true)	α
ampere	A			probability of a type II error (acceptance of the null hypothesis when false)	β
calorie	cal			second (angular)	"
direct current	DC			standard deviation	SD
hertz	Hz			standard error	SE
horsepower	hp			variance	
hydrogen ion activity (negative log of)	pH			population	Var
parts per million	ppm			sample	var
parts per thousand	ppt, ‰				
volts	V				
watts	W				

FISHERY DATA REPORT NO. 04-26

**INRIVER ABUNDANCE, SPAWNING DISTRIBUTION, AND RUN
TIMING OF COPPER RIVER CHINOOK SALMON IN 2003**

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November 2004

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ABSTRACT

In 2003, radiotelemetry methods were used to estimate spawning distribution, run timing, and inriver abundance of Chinook salmon *Oncorhynchus tshawytscha* in the Copper River, Alaska. The estimated spawning proportions by major drainage were, 0.11 for the Klutina River, 0.10 for the Tonsina River, 0.17 for the Gulkana River, 0.34 for the Chitina River, 0.05 for the Tazlina River, and 0.05 for the East Fork Chistochina River. Run-timing patterns at the capture site varied among the major spawning stocks. The mean date of passage at the capture site varied from 26 May for Chinook salmon bound for the upper Copper River to 9 June for the Tonsina River mainstem spawners. In addition, the run timing of Chinook salmon bound for the tributaries of the Tonsina and Klutina rivers was earlier than their mainstem counterparts. Two-sample mark-recapture techniques were used to estimate inriver abundance at the lower boundary of the Chitina subdistrict dip net fishery. Total abundance was estimated to be 33,488 (SE=8,389) Chinook salmon ≥ 620 mm MEF for the period 15 May-30 September.

Key words: Chinook salmon, Chistochina River, Chitina River, Copper River, East Fork Chistochina River, Gulkana River, Klutina River, mark-recapture, radiotelemetry, run-timing patterns, spawning distribution, Tazlina River, Tonsina River.

INTRODUCTION

The Copper River is a large glacially fed river located in Southcentral Alaska. It flows south from the Mentasta Mountains and empties into the Gulf of Alaska, slightly east of Prince William Sound. The Copper River drainage (61,440 km²) supports spawning populations of Chinook *Oncorhynchus tshawytscha*, sockeye salmon *O. nerka*, and coho *O. kisutch* salmon as well as various resident fish species.

The Copper River Chinook salmon population supports a commercial gillnet fishery near the mouth of the river plus inriver subsistence, personal use, and sport fisheries. The average annual Chinook salmon harvest from 1999-2003 was 44,049 fish in the commercial fishery, 3,576 fish in the Glennallen subdistrict subsistence (GSS) fishery, 3,224 fish in the Chitina subdistrict dip net (CSDN) personal use fishery, and approximately 5,555 fish in the sport fishery. The GSS fishery runs from 1 June to 30 September from the north side of the Chitina-McCarthy Bridge to the village of Slana and the majority of fishers use fish wheels to harvest salmon but dip nets and rod and reel are also allowed. Federally qualified subsistence fishers can use fish wheels within the CSDN fishery and the season runs from 15 May to 30 September. The CSDN fishery is strictly a dip net fishery that typically runs from early June to the end of September. The total number of CSDN permits issued since 1984, when the fishery was declared personal use, has ranged from 10,006 in 1998 to 4,031 in 1986. Sport fishing occurs mainly in the Klutina, Tonsina, and Gulkana rivers and anglers are limited to rod and reel gear.

An accurate method for estimating the inriver abundance of Copper River Chinook salmon is required to determine if the sustainable escapement goal (SEG) of 24,000 Chinook salmon is met annually. In 2001, the Office of Subsistence Management (OSM) Fisheries Resource Monitoring Program (FRMP) funded a multi-year study titled *Feasibility of Using Fish Wheels for Long-Term Monitoring of Chinook Salmon Escapement on the Copper River* (FIS01-020). The main objective of that study was to estimate Chinook salmon inriver abundance using large fish wheels and two-event mark-recapture methodology. After a successful feasibility study (Smith et al. 2003) the FRMP decided to fund a multi-year study titled *Migratory Timing and*

Spawning Distribution of Chinook Salmon in the Copper River (FIS02-015) to supplement study FIS01-020. Estimates of abundance and distribution were determined by radio-tagging a sub sample of Chinook salmon captured for study FIS01-020. The primary emphasis of study FIS02-015 was to estimate spawning distribution and run timing, but the study design and additional Federal Aid in Fish Restoration funding also provided for an independent estimate of inriver abundance.

Copper River Chinook salmon escapement is calculated post-season by subtracting estimates of inriver harvest from an inriver abundance estimate. Inseason measures of Chinook salmon escapement are not comprehensive and include aerial counts of 9 out of 40 identified spawning streams, and enumeration of Chinook salmon at a counting tower on the Gulkana River.

Estimates of Chinook salmon spawning distribution are used to determine the proportion of the total abundance of fish in the six major Copper River tributaries. Run-timing patterns are used to determine passage of spawning stocks through the inriver fisheries and spawning tributaries, and are used to aid in determining the Chinook salmon sport fishing seasons. This report is a summary of the second year of a three-year (2002-2004) study that will annually assess the Copper River Chinook salmon spawning distribution, run timing and inriver abundance.

OBJECTIVES

The objectives of this study were to:

1. estimate the proportions of spawning Chinook salmon in the Copper River in each major spawning tributary (Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Chistochina rivers);
2. estimate the proportion of Chinook salmon spawning in the nine tributaries assessed annually during aerial surveys (Little Tonsina River, Greyling Creek, St. Anne Creek, Manker Creek, Mendeltna Creek, Kiana Creek, Gulkana River, East Fork Chistochina River, and Indian Creek);
3. describe the stock-specific run-timing patterns at the point of capture in Baird Canyon where stocks are defined as all Chinook salmon spawning in the Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Upper Copper rivers; and,
4. estimate the inriver abundance of Chinook salmon in the Copper River at the CSDN fishery.

METHODS

CAPTURE AND TAGGING

Chinook salmon were captured using two aluminum fish wheels located on the east and west banks of the Copper River in Baird Canyon from 15 May to 9 July (Figure 1). Each fish wheel had large live tanks (4.3 m long x 1.5 m deep x 0.6 m wide) on both sides and 6.1 m (20 foot) diameter baskets that fished in a minimum of 3.05 m (10 feet) of water, as described in Smith et al. (2003). Both fish wheels were intended to fish 24 hours a day and seven days per week, however there were instances where the change in water level or floating debris caused the wheel to stop fishing. Fish wheels were checked at least three times a day to ensure Chinook salmon spent a minimal amount of time in the live tanks.

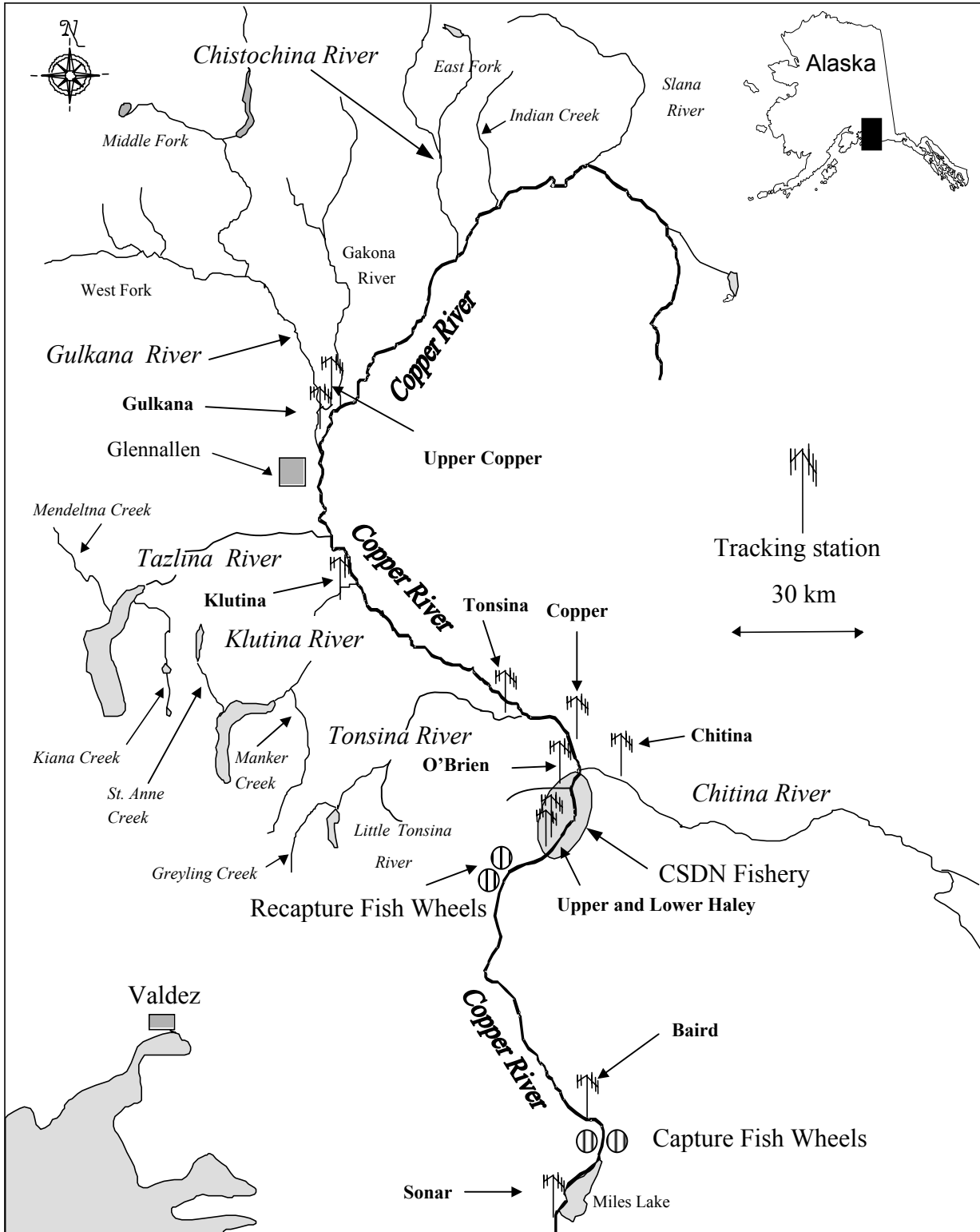


Figure 1.—Map of the Copper River drainage demarcating the capture and recapture fish wheels, boundaries of the CSDN fishery, location of eleven radio tracking stations, and nine aerial index streams, 2003.

Each time the fish wheel was checked all captured Chinook salmon were:

- 1) removed from the live tank and placed in a sampling trough;
- 2) measured to the nearest 5 mm total length (snout to tail fork); and,
- 3) sexed based on external characteristics.

A systematic approach was taken to ensure Chinook salmon were radio-tagged in proportion to run strength and timing. Initially, 1 out of every 3 Chinook salmon was radio-tagged. The tagging rate was adjusted according to total daily catches and the number of radio tags remaining.

Radio tags were inserted through the esophagus and into the upper stomach of Chinook salmon with an implant device. The device was a 45-cm piece of polyvinyl chloride (PVC) tubing with a slit on one end to seat the radio transmitter into the device. Another section of PVC that fit through the center of the first tube acted as a plunger to position the radio tag. To ensure proper radio transmitter placement, the distance between a point 1-cm posterior from the base of the pectoral fin to the tip of the snout was used to determine how far to insert the implant device into the fish.

All radio-tagged Chinook salmon also received a uniquely numbered gray spaghetti tag constructed of a 5-cm section of tubing shrunk onto a 38-cm piece of 80-lb monofilament fishing line (Pahlke and Etherton 1999). The spaghetti tag 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 of the dorsal 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 ATS¹. Each radio tag was distinguishable by its frequency and encoded pulse pattern. Twenty frequencies spaced approximately 20 kHz apart in the 149-150 MHz range with 25 encoded pulse patterns per frequency were used for a total of 500 uniquely identifiable tags. Radio-tagged Chinook salmon were tracked along the course of the Copper River using a network of twelve ground-based tracking stations (Figure 1). Each station included two deep-cycle batteries, a solar array, an antenna switch box, a steel housing box, two Yagi antennas, and either an ATS Model 5041 Data Collection Computer (DCC II) coupled with an ATS Model 4000 receiver or an ATS Model R4500 (DCC and receiver combined). The receiver and DCC were programmed to scan through the frequencies at 3-s intervals, and receive from both antennas simultaneously. When a signal of sufficient strength was encountered, the receiver paused for 12 seconds on each antenna, and then tag frequency, tag code, signal strength, date, time, and antenna number were recorded on the data logger. The relatively short cycle period minimized the chance that a radio-tagged fish swam past the receiver site without being detected. Cycling through all frequencies required 5–7 minutes depending on the number of active tags in the reception range and level of background noise. Recorded data was periodically downloaded to a laptop computer.

The first tracking station was placed at the ADF&G Miles Lake sonar site (Figure 1), approximately 20 km below the capture site. This station was used to assist with identifying any

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

radio-tagged fish that dropped out of the system. The second station was placed at the Native Village of Eyak (NVE) Baird Canyon camp, approximately 2 km upstream from the capture site. Two stations were placed on the west bank of the Copper River downstream of the CSDN fishery (below Haley Creek) to determine the total number of radio-tagged Chinook salmon that entered the fishery. One station was placed on a bluff overlooking both O'Brien Creek (a popular fish cleaning area) and the Copper River to monitor radio-tagged fish harvested in the CSDN fishery but not reported. The sixth station was placed on the north bank of the Chitina River approximately 6 km upstream from its confluence with the Copper River. The seventh station was placed on a west-side bluff of the Copper River immediately upstream from the upper boundary of CSDN fishery. The latter five stations, in combination, were used to identify all radio-tagged Chinook salmon entering and exiting the fishery. Tagged fish entering the Tonsina, Klutina, and Gulkana rivers were recorded from stations placed near the mouths of these rivers. In addition, a second station was placed on the Gulkana River at the site of the ADF&G salmon counting tower to evaluate the proportion of Gulkana River Chinook salmon that migrate past the counting tower. The twelfth station was placed on the mainstem Copper River approximately 2 km downstream from the mouth of the Gakona River. This station was used to enumerate all fish with radio tags entering the Upper Copper River drainage upstream of the Gulkana River.

The distribution of radio-tagged Chinook salmon throughout the Copper River drainage was further determined by aerial tracking from small aircraft. Three aerial-tracking surveys of the entire drainage including the mainstem Copper River were conducted from 27 June – 5 July, 23 July – 30 July, and 25 August – 3 September. Tracking flights were conducted with one aircraft and one person (in addition to the pilot) utilizing one R4500 receiver. All frequencies were loaded into the receiver prior to each flight. Dwell time on each frequency was 2 s. Flight altitude ranged from 100 to 300 m above ground. Two antennas, one on each wing strut, were mounted such that the antennas received peak signals perpendicular to the direction of travel. Once a tag was identified, its frequency, code, and GPS location was recorded. After the information was recorded, the plane circled back to the point where the signal was first heard and tracking resumed. The purpose of the aerial tracking was to locate tags in spawning tributaries other than those monitored by remote tracking stations, to locate fish that the tracking stations failed to record, and to validate that fish recorded on one of the data loggers did migrate into that particular tributary.

STUDY DESIGN

Fates of Radio-tagged Chinook Salmon

Data from the tracking stations, aerial surveys, and tag return information were used to determine the final fate assigned to each radio-tagged fish (Table 1).

Spawning Distribution

A total of eleven stationary radio-tracking stations were used to determine the proportion of total escapement and stock-specific run-timing patterns for the Chitina, Tonsina, Klutina, Tazlina, Gulkana, and Upper Copper (all waters upstream from the Gulkana River) drainages (Figure 1).

Table 1.—List of possible fates of radio-tagged Chinook salmon in the Copper River, 2003.

Fate	Description
Radio Failure	A fish that was never recorded swimming upstream into the CSDN fishery.
CSDN Recapture ^a	A fish harvested in the CSDN fishery.
Subsistence Fishery Mortality	A fish harvested in the Glennallen subdistrict subsistence fishery upstream of the McCarthy Road bridge.
Sport Fishery Mortality	A fish harvested in one of the sport fisheries.
Spawner ^b	A fish that migrated through the CSDN fishery and entered a spawning tributary of the Copper River.
Upstream migrant	A fish that migrated upstream of the CSDN 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.

^a These radio-tagged fish constituted the marked fish in the second sample of the mark-recapture experiment.

^b These radio-tagged fish were used to estimate spawning distribution and stock-specific run timing.

The distribution of Chinook salmon in the various spawning streams was estimated as the ratio of radio-tagged salmon migrating into a specific tributary to the total number of radio-tagged salmon migrating into all spawning tributaries.

Among fish that migrated past the lower two tracking stations, the proportion of fish that had fate j was estimated as:

$$\hat{P}_j = \frac{\sum_i^{\text{days}} R_{ij}}{\sum_j \sum_i R_{ij}} \quad (1)$$

where R_{ij} was the number of fish tagged on day i having fate j . Variance was estimated using bootstrap resampling techniques (Efron and Tibshirani 1993). Each bootstrap replicate drew a random sample from the total number of radio tag fates and their corresponding weights. From each replicate the proportion of spawners with spawning fate j (\hat{P}_j^*) was calculated for a total of 1,000 bootstrap data sets. The percentile method was used to estimate confidence intervals.

The same procedure was used to determine the proportions of Chinook salmon migrating into each of the nine aerial index streams: the Little Tonsina River, Greyling 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 particular stream if its radio tag was located there at least once during an aerial tracking flight or was recorded by a tracking station positioned on a tributary.

Conditions for a Consistent Spawning Distribution Estimator

To obtain unbiased estimates of the spawning distribution certain assumptions must have been met:

1. *Radio-tagging Chinook salmon did not affect their migratory behavior (final spawning destination).*

Test: There was no explicit test for this assumption because we could not observe the behavior of unhandled fish. However, we could compare recapture rates and transit times through the CSDN fishery between groups of fish affected differently by handling. In 2003, we compared the recapture rates and transit times through the fishery of fish that migrated from the tagging site to the lower boundary of the CSDN fishery in minimal (less than 11 days), moderate (11-19 days), and substantial (20 or more days) time.

2. *Captured Chinook salmon were radio-tagged in proportion to the magnitude of the run.*

Design Considerations: The tagging protocol described was designed to distribute tags over time proportional to passage of salmon past the tagging site.

Test: Marked to unmarked ratios in the second event of the NVE mark-recapture study were compared to evaluate if this condition was met. The NVE data were preferred over recapture data from this study because the recovery event covered a longer period than the fishery did. If ratios were found to vary and the tag deployment rate and fishing effort were relatively stable during the marking event, each radio-tagged fish was given a numeric weight that took into account estimated differences in the probability that an individual fish was tagged over time during the marking event. Weekly (or some alternate tagging period) salmon abundance past the tagging site was estimated using the methods of Darroch (1961). Weights for each day of tagging were computed and assigned, however weights for each day within a tagging period were computed similarly:

$$w_{i \in k} = \frac{\hat{A}_k}{x_k}. \quad (2)$$

where:

\hat{A}_k = estimated abundance of salmon past the tagging site during tagging period k ; and

x_k = the number of radio tags deployed during tagging period k .

For each day that radio tags are deployed we calculated:

$$R_{ij}^* = R_{ij} * w_i \quad (3)$$

and substituted for R_{ij} in equation (1).

Precision was estimated by constructing a bootstrap algorithm (Efron and Tibshirani 1993) for the entire experimental process (i.e., for each replicate, new weighting terms were calculated and the new weighted fates of all tags were resampled).

STOCK-SPECIFIC RUN TIMING

Run-timing patterns were described as time-density functions, where the relative abundance of stock j that entered into the fishery during time interval t was described by (Mundy 1979):

$$f_j(t) = \frac{R_{tj}}{\sum_i R_{ij}} \quad (4)$$

where:

- $f_j(t)$ = the empirical temporal probability distribution over the total span of the run for fish spawning in a tributary (or portion thereof) j ; and,
- R_{tj} = the subset of radio-tagged Chinook salmon bound for tributary j that would be caught and tagged during day t .

Those fish assigned a fate of “spawner” (Table 1) were used to determine the time-density functions.

The mean date of passage (\bar{t}_j) by the point on the river of tagging for fish spawning in tributary j was estimated as:

$$\bar{t}_j = \sum_t t f_j(t), \quad (5)$$

the variance of the run timing distribution estimated as:

$$Var(t_j) = \sum_t (t - \bar{t}_j)^2 f_j(t). \quad (6)$$

To obtain unbiased estimates of stock-specific run timing, the same two assumptions, tests, design considerations, and weighting procedures described for estimating spawning distribution also applied to estimates of run timing.

Inriver Abundance

Inriver abundance of Copper River Chinook salmon was estimated with a combination of radiotelemetry and two-event mark-recapture methods. Radio-tagging Chinook salmon in the mainstem Copper River upstream of Baird Canyon was the first event. The second event consisted of Chinook salmon harvested in the CSDN fishery from 4 June to 30 September. Marked fish in the second event were returned by CSDN fishers, or were inferred as harvested in the CSDN fishery by data collected at five automated radio tracking stations located within and on the boundaries of the CSDN fishery.

Conditions for a Consistent Abundance Estimator

To obtain an accurate estimate of abundance from a mark-recapture experiment certain conditions must be met (Seber 1982). These conditions, expressed in the circumstances of this study, along with their respective design considerations and test procedures are as follows:

1. *Handling did not make the fish more or less vulnerable to recapture than unhandled fish.*

Design Considerations: Holding time of all captured fish was minimized. Injured fish and fish that appeared to be affected by handling were not tagged. The time required for radio-tagged fish to move from the capture site to the lower tracking stations as well as transit times through the CSDN fishery was recorded by the tracking stations.

Test: There was no explicit test for this assumption because we could not observe the behavior of unhandled fish. However, as with estimates of spawning distribution and run timing, a comparison of recapture rates and transit times through the CSDN fishery between groups of fish affected differently by handling, inferred by different migration times between the capture site and the fishery, was conducted.

2. *Tagged fish were not selected for in the CSDN fishery.*

Design considerations: Selection of tagged Chinook salmon by fishers would result in an estimate of abundance biased low. Selection against tagged Chinook salmon by fishers would result in an estimate of abundance biased high.

Test: There were no explicit tests for tag selection. However, to minimize the chances of violating the assumption no reward was offered for returned radio tags. In addition, gray spaghetti tags were used to reduce the likelihood of a fisher easily identifying a tagged fish and selecting it or not selecting it for harvest. Gray tags were less identifiable at time of capture but identifiable while processing the fish.

3. *All tagged fish harvested in the CSDN fishery were accurately reported or known from information recorded on the tracking stations.*

Design considerations: To ensure accurate reporting, efforts were made to recover as many tags harvested in the CSDN fishery as possible through on-site creel sampling by encouraging fishers to return tags. Tag recovery forms and instructions were sent to ADF&G offices in Fairbanks, Delta Junction, Glennallen, Cordova, Palmer, and Anchorage. Informational bulletins were posted at all offices and at strategic positions in and around the CSDN fishery. Informational cards were distributed with CSDN permits issued at ADF&G offices encouraging tag returns. Drop boxes with envelopes requesting information on time and location of capture were posted at the primary access points (e.g., O'Brien Creek). All radio tags were labeled with information to encourage reporting of harvested tags. If only one tag was returned (either the radio tag or spaghetti tag), the CSDN fisher was contacted and queried to ensure that the fish was harvested (in past cases some tags have been removed by anglers and the fish released) and that both tags were attached. Tagged fish that were harvested in the CSDN fishery but not reported were identified using the two tracking stations located at the lower boundary of the fishery (below Haley Creek), the single station at O'Brien Creek, and the two stations at the upper boundaries of the fishery. Radio tags removed from the water have a pronounced and unquestionable increase in signal strength. Criteria for an unreported harvested fish were: 1) a pronounced and prolonged recording of a signal by a data logger at O'Brien or Haley Creek; 2) the radio tag was never recorded upstream of the CSDN fishery; and 3) no downstream movement of the radio tag was detected after the radio-tagged fish had entered the CSDN fishery.

4. *The number of radio-tagged fish that entered into the CSDN fishery was known and there was no mortality of tagged fish within the fishery other than those that were harvested.*

Design Considerations: Any tagged fish that was not identified as entering the CSDN fishery by tracking stations and aerial surveys was designated as a "failure".

Test: We assumed that any tag found only in the area of the CSDN fishery (never found upstream from the fishery) was a fish that was harvested.

5. *Marked fish mixed completely with unmarked fish across the river.*

Design Considerations: Because sampling with fish wheels and fishing in the CSDN fishery were bank-oriented capture methods, any fish swimming up only the center of the river may not have been included in the estimate. In 2002, approximately equal cross-over rates (mixing) from bank of tagging to bank of recapture were observed in the NVE fish wheel study (Smith et al. 2003). It was not known if there was a segment of the population that only migrated up the center of the river but it was assumed that if fish cross-over, then there was not a center-only segment.

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.

6. *Fish had equal probabilities of being marked or equal probabilities of being captured regardless of size or sex.*

Design Considerations: Fish wheels were used as a capture gear during the first sample. Sex and length were recorded for each radio-tagged fish. For the second sample, length data were collected from a sample of fish harvested from the CSDN fishery.

Because length measurements from the second sample were MEF and measurements from the first sample were fork length (FL; snout to fork of caudal fin), the FL measurements were converted to MEF based on a regression analysis. FL measurements were used by NVE because they found it to be an easier measurement to take from live fish. The 2002 regression analysis demonstrated that FL could be used as an accurate predictor of MEF (Figure 2). Because the slope between males and females was nearly identical, the relationship between FL and MEF length for males and females combined was used to calculate MEF length estimates of all fish tagged in the first sample.

Test: Sex-selective sampling was tested using contingency table analysis to compare ratios of recaptured and not recaptured fish of each gender. If this test indicated a significant bias, Kolmogorov-Smirnov (K-S) tests for equal capture probabilities on the cumulative length distributions were performed for males and females separately: Test (A) all fish radio-tagged during the first sampling event and radio-tagged fish captured in the second event (CSDN fishery); and Test (B) all fish radio-tagged during the first sampling event and all fish sampled in the second event (CSDN fishery). If there was no significant bias, males and females were combined and the aforementioned K-S tests performed.

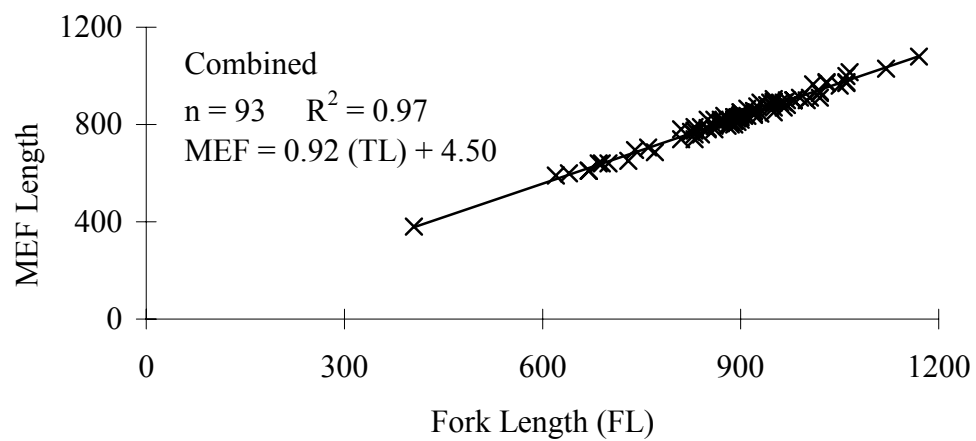
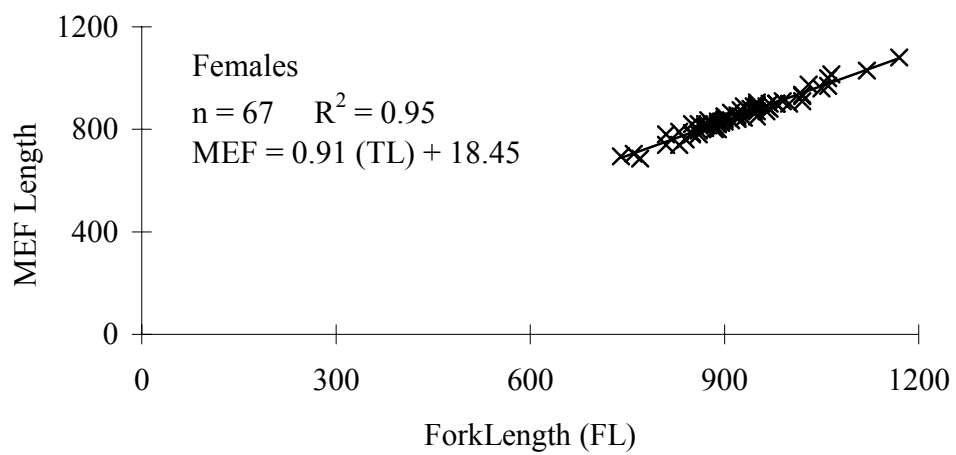
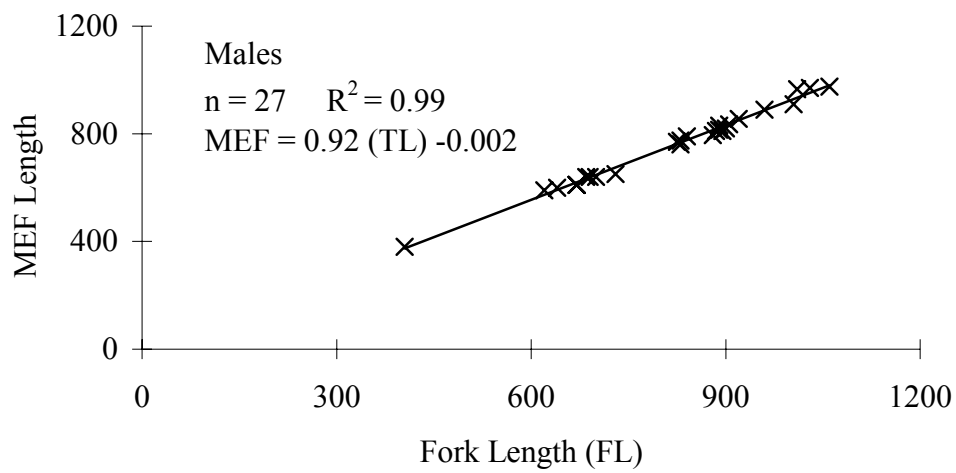


Figure 2.—The relationship between FL and MEF length of males, females, and males and females combined, 2002.

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

Design Considerations: Equal fishing effort was expended at all times over the summer during the first (marking) event. Radio tags were deployed proportional to daily catch. Date and time of capture for all fish were recorded.

Test: Marked to unmarked ratios in the second event were compared to evaluate if this condition was met. Testing of this assumption required temporal harvest data from the CSDN fishery, which was available from most returned permits. The estimated harvest from unreported permits and reported permits without date of capture information was assigned to temporal strata in proportion to the distribution of the actual reported harvest.

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

Test: Recaptured to not-recaptured ratios in the second event were compared among weeks to evaluate if this condition was met.

Estimator

A two-sample mark-recapture model was used to estimate the inriver abundance of Chinook salmon. The appropriate abundance estimator was determined based on the results of the aforementioned tests. In this experiment, temporal stratification was required and the method of Darroch (1961) was used to estimate abundance during the period of the fishery. The estimate \hat{N} was germane to the point of entry into the CSDN fishery (prior to any inriver harvest). The number of Chinook salmon examined during the second event (\hat{C}) was the estimated number of Chinook salmon harvested in the CSDN fishery. The estimated variance of \hat{N} was approximate because \hat{C} was subject to some sampling error due to the estimation of the Chinook salmon harvest from returned CSDN permits. However the estimate of CSDN harvest was very precise ($CV < 5\%$). Thus, the sampling error in \hat{C} contributed a negligible amount to the variance of \hat{N} .

To estimate the total Chinook salmon run, including those portions of the run that migrated upriver before the recovery event began and after it terminated, we divided \hat{N} by the estimated proportion of the run \hat{P} which occurred during the recovery event.

$$\hat{N}' = \hat{N}\hat{P}^{-1} \quad (7)$$

$$\text{var}(\hat{N}') = \hat{N}^2 \text{var}(\hat{P}^{-1}) + \hat{P}^{-2} \text{var}(\hat{N}) - \text{var}(\hat{P}^{-1}) \text{var}(\hat{N}) \quad (8)$$

Weekly estimates of abundance in the CSDN fishery from the partially stratified estimator (Darroch 1961) coupled with weekly cumulative CPUE data for the weeks of the fishery were used to model the uncertainty with which CPUE predicted salmon abundance during the CSDN fishery. Markov-chain Monte Carlo (MCMC) methods were used to perform a Bayesian analysis (Carlin and 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 were calculated from 1 million MCMC samples drawn from its posterior distribution:

$$\hat{P}^{-1} = \frac{\sum_{i=1}^S \tilde{P}_i^{-1}}{S} \text{ and } \hat{\text{var}}(\hat{P}^{-1}) = \frac{\sum_{i=1}^S (\tilde{P}_i^{-1} - \hat{P}^{-1})^2}{S} \quad (9)$$

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:

$$\tilde{P}_i^{-1} = \frac{\sum_{j \in B} \tilde{N}_{ij} + \sum_{j \in D} N_j^* + \sum_{j \in A} \tilde{N}_{ij}}{\sum_{j \in D} N_j^*} \quad (10)$$

where:

N_j^* were 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} was the projected number of salmon in the recovery area during week j in the i th simulation; and B , D , and A were 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 $j \in D$,

$$N_j^* = \beta^* CPUE_j + \varepsilon_j \text{ where } \varepsilon_j \sim N(0, \mathbf{D}\sigma^2) \quad (11)$$

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

$$\tilde{N}_{ij} = \hat{\beta}_i^* CPUE_j. \quad (12)$$

RESULTS

CAPTURE AND TAGGING

Chinook salmon were captured in the Baird Canyon fish wheels from 15 May to 9 July. Of the total 2,077 Chinook salmon captured in the fish wheels, 500 fish were radio-tagged and released. The daily catch of Chinook salmon ranged from zero fish on 9 July to 149 fish on 3 June. The daily radio-tagging rate varied from 3.4%-100% of all captured Chinook salmon (Figure 3).

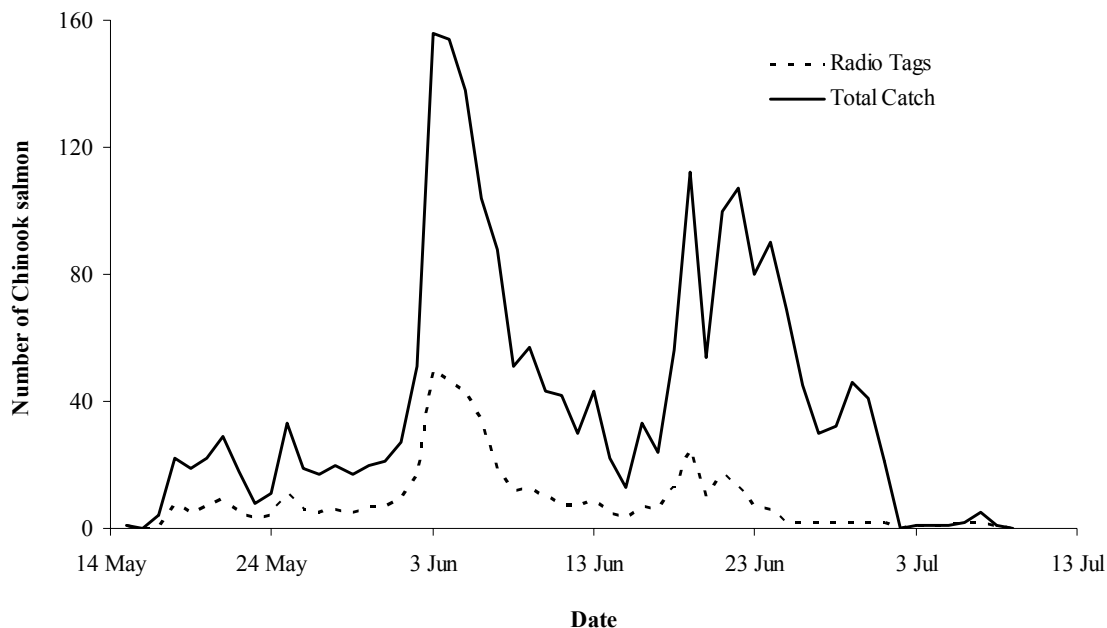


Figure 3.—Number of radio tags deployed each day and total daily catch of Chinook salmon at the Baird Canyon Copper River fish wheels, 2003.

FATES OF RADIO-TAGGED CHINOOK SALMON

Of the 500 radio-tagged Chinook salmon, 468 fish (94%) entered the CSDN fishery. Thirty-four radio tagged fish were harvested in the CSDN fishery. Four hundred twenty-one radio-tagged Chinook salmon migrated through the CSDN fishery. Fifty-three of these fish were never reported as harvested or located in a spawning tributary, 73 fish were known to be harvested in subsistence fish wheels, 32 fish were known to be harvested in sport fisheries, and 308 fish were located in spawning areas (Table 2).

Table 2.—Fates of radio-tagged Chinook salmon in the Copper River, 2003.

Fate ^a	Number of Tags
Total Deployed	500
Radio Failure	32
Total Entering CSDN Fishery	468
CSDN Fishery Recapture Mortality	34
Total Fish Passing Through CSDN fishery	434
Upstream Migrant ^b	53
Subsistence Fishery Mortality	73
Spawner	308
Sport Fishery Mortality	32

^a Refer to Table 1 for definition of fates.

^b Includes 26 tags that passed through the CSDN fishery and drifted back downstream and 27 fish that were found in the mainstem of the Copper River upstream of the CSDN fishery.

Boat tracking surveys in previous studies were completed to determine if radio-tagged fish found in the mainstem of the Copper River were mainstem spawners. The surveys found no active Chinook salmon spawning in areas where the radio tags were located. Based on these boat surveys radio-tagged fish found in the mainstem Copper River are assumed to be mortalities or radio tag losses and are not included in the estimates of spawning distribution or run timing.

SPAWNING DISTRIBUTION

A total of 296 Chinook salmon were recorded entering the CSDN fishery by the Haley Creek tracking stations. Out of the 296 fish recorded moving between the Baird Canyon and Haley Creek tracking stations 65% reached the CSDN fishery in 12 days or less and 90% migrated

through the CSDN fishery in 5 days or less (Figure 4). Recaptured to not recaptured ratios of fish exhibiting minimal (<11 d), moderate (11-19 d), and substantial (>19 d) time to migrate into the fishery after handling implied that radio-tagging Chinook salmon had little influence on their migratory behavior (Table 3). In addition, transit times through the CSDN fishery for fish affected differently by handling were similar (Figure 4).

The probability of capture at the Baird Canyon fish wheels varied over two distinct time periods (Table 4). Therefore, equation 2 was used to calculate weights for radio tagged fish in each period and equation 3 was used to estimate the number of fish tagged on day i with fate j . This estimator provided adjustments based on estimated passage during each period. Estimated passage, rather than CPUE, was preferred for weighting because CPUE may not have varied in proportion to passage due to fluctuations in gear efficiency resulting from changes in river water levels and fish wheel placement.

Radio-tagged Chinook salmon were located in 32 separate streams within all six major tributaries of the Copper River. The smallest proportion of spawners returned to the Tazlina River (0.05) and the largest proportion returned to the Chitina River (0.34; Figure 5).

Spawning distribution estimates from 2002 are provided in this report for comparison purposes (Table 5 and Figure 5). These estimates changed when the 2003 weighting methodology was applied to the 2002 data and are therefore different than what was reported in Savereide (2003).

The proportion of Chinook salmon detected in the nine aerial index streams accounted for 0.34 (SE=0.05) of Chinook salmon in all spawning tributaries. The Gulkana River accounted for the largest proportion of spawners in the nine index streams (Table 6). Mainstem spawners accounted for 0.86 (SE=0.061) of all Chinook salmon in the Tonsina River and 0.55 (SE=0.11) of those in the Klutina River.

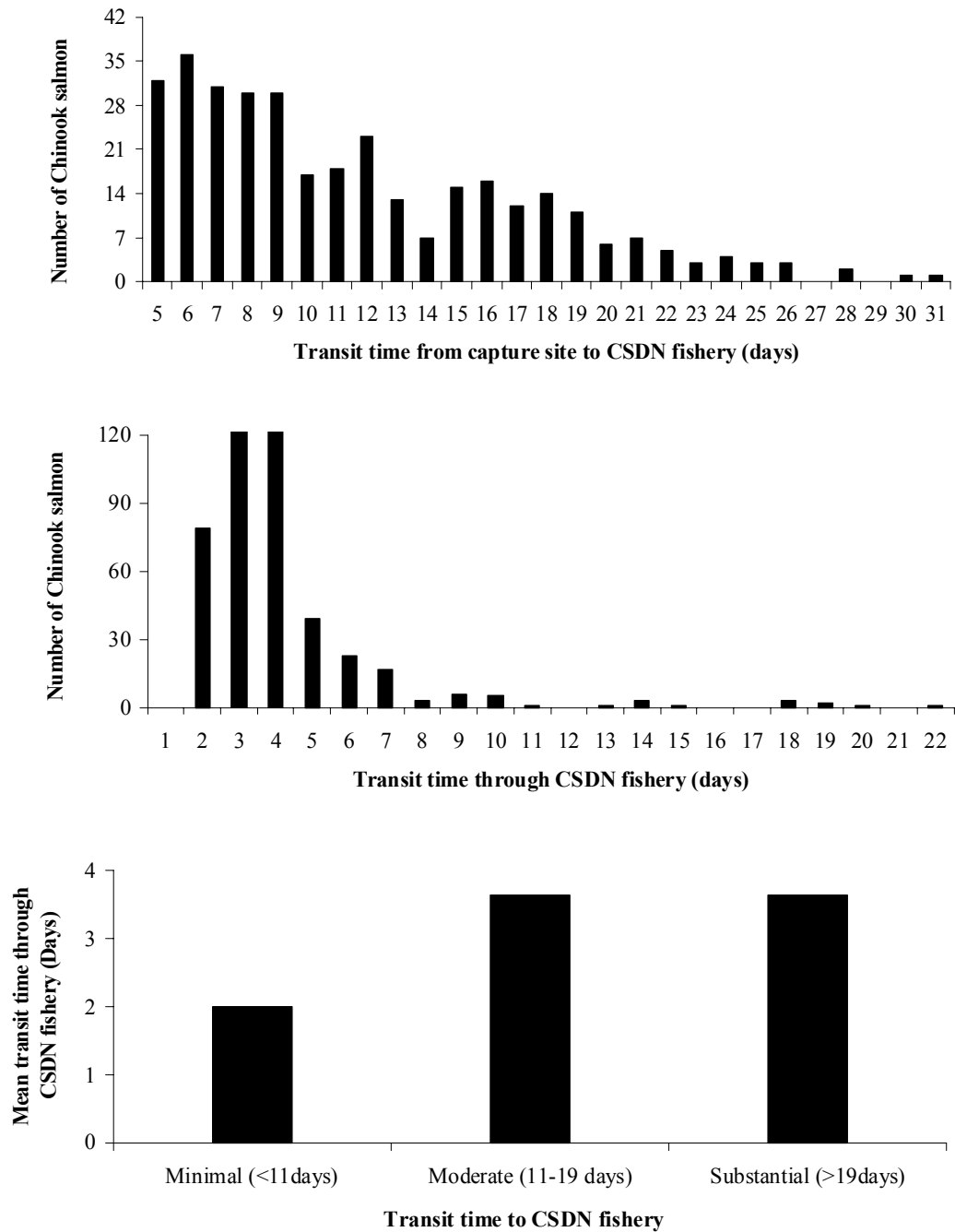


Figure 4.—Migratory times from capture site to the CSDN fishery (top panel), transit times through the CSDN fishery (middle panel), and a comparison of mean transit times through the CSDN fishery of fish that exhibited minimal, moderate, and substantial migratory times (bottom panel) for radio-tagged Chinook salmon in the Copper River, 2003.

Table 3.—Recapture rates for Chinook salmon exhibiting minimal (<11 d), moderate (11-19 d), and substantial (>19 d) time to migrate from capture site into the CSDN fishery after handling, 2003.

	Migratory Time to CSDN Fishery After Handling			Total
	< 11 days	11-19 days	> 19 days	
Recaptured	11	8	3	22
Not Recaptured	183	103	33	319
Total	194	111	36	341
Recapture Rate ^a	0.06	0.08	0.09	

^a Chi-square test for heterogeneity in recapture rates was performed for cells with bold numbers ($\chi^2=0.51$; $df=2$; $P=0.77$).

Table 4.—Contingency table analysis comparing marked:unmarked ratios in the second event of the NVE fish wheel mark-recapture study.

Period of Marking	Period of Recapture	
	21 May – 10 June	11 June – 20 July
Marked (17 May–3 June)	5	7
Marked (4 June–1 July)	1	84
Marked (Total)	6	91
Unmarked	461	1,072
Marked:Unmarked	0.01	0.08
Total Examined	467	1,163

^a Chi-square tests for heterogeneity in marked:unmarked ratios ($\chi^2=25.46$; $df=1$; $P<0.01$) were performed for cells with bold numbers.

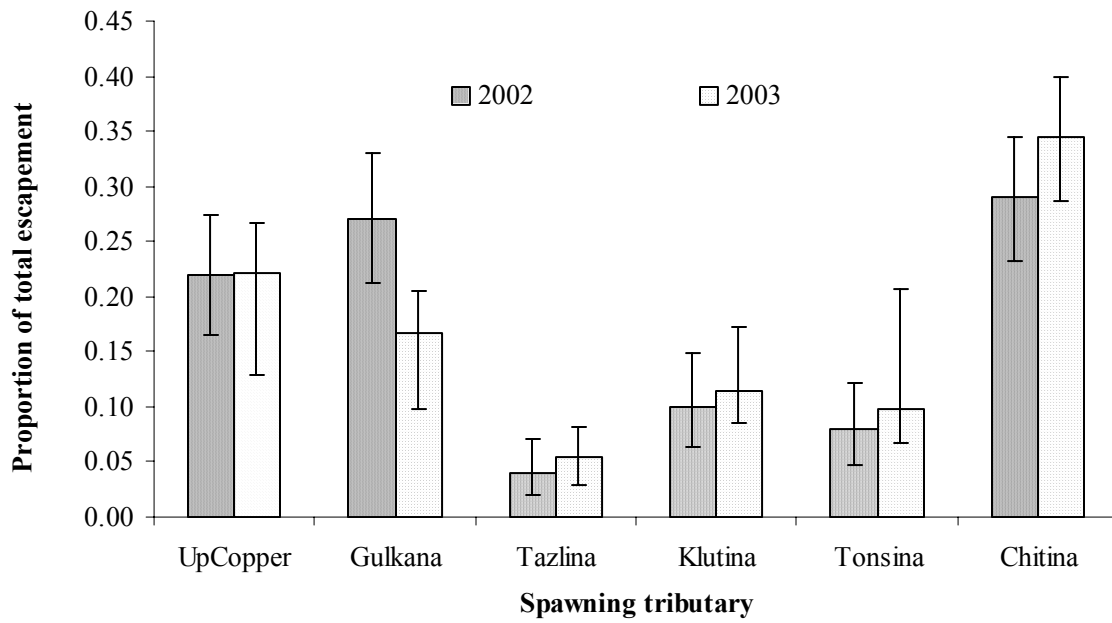


Figure 5.—Spawning distribution and 95% confidence intervals of Copper River Chinook salmon by major drainage, 2002-2003.

Table 5.—Distribution of Chinook salmon in major spawning drainages in the Copper River, 2002-2003.

Spawning Tributary	2002 ^a		2003	
	Proportion	SE	Proportion	SE
Chitina River	0.29	0.03	0.34	0.03
Gulkana River	0.27	0.04	0.17	0.03
Klutina River	0.15	0.03	0.11	0.03
Tazlina River	0.04	0.02	0.05	0.01
Tonsina River	0.08	0.02	0.10	0.04
Upper Copper Drainage	0.22	0.03	0.22	0.04

^a 2003 weighting methodology was applied to the 2002 data.

Table 6.—Proportions of Chinook salmon located in nine aerial survey index streams in the Copper River drainage, 2002-2003.

Spawning Stream	2002 ^a		2003	
	Proportion	SE	Proportion	SE
Gulkana River	0.27	0.04	0.17	0.03
E. Fork Chistochina River	0.05	0.02	0.05	0.02
Manker Creek	0.05	0.02	0.04	0.02
St. Anne Creek	0.01	0.01	0.01	0.01
Little Tonsina River	0.01	0.01	0.01	0.01
Greyling Creek	0.01	0.01	0.00	<0.01
Indian Creek	0.02	0.01	0.02	0.01
Kiana Creek	0.02	0.01	0.01	0.01
Mendeltna Creek	0.02	0.01	0.04	0.01
Proportion of Total in Index Streams	0.46	0.04	0.34	0.05

^a 2003 weighting methodology was applied to the 2002 data.

RUN TIMING

As with estimates of spawning distribution, weighted observations for individual fish (equations 2 and 3) were used because the marked to unmarked ratios in the second event of the NVE fish wheel study varied significantly.

Run-timing patterns at the capture site varied among the individual spawning stocks (Figure 6). The mean date of passage at the Baird Canyon fish wheels for all Chinook salmon captured in 2003 was 31 May (SE=8.6 days) and ranged from 26 May (SE=6.1 days) for the upper Copper River drainage stock to 6 June (SE=9.2 days) for the Tonsina River stock (Table 7). The mean date of passage varied for all stocks in both years of the study, but individual stocks displayed similar patterns between years (Figure 7). In general, migratory timing of Chinook salmon bound for tributaries of the Tonsina and Klutina rivers was earlier than their mainstem spawning counterparts (Table 7).

INRIVER ABUNDANCE

Conditions for a Consistent Abundance Estimator

The probability of capture for Chinook salmon in the CSDN fishery did not appear to be altered by tagging or handling techniques. The majority (90%) of radio-tagged fish entering the CSDN fishery migrated through the fishery in less than five days (Figure 4). The tracking stations located at the lower end of the CSDN fishery detected 65% of the radio-tagged fish within 12 days of capture and only 13% required 19 days or more (Figure 4). Furthermore, recapture rates were independent of the amount of time fish took to migrate upstream ($\chi^2=1.70$; $df=2$, $P=0.43$; Table 3).

There was no tag loss or natural mortality between the first and second samples. Thirty-two of the 500 radio-tagged Chinook salmon were removed from the analysis because they never entered the CSDN fishery. The remaining 468 radio-tagged fish either successfully migrated through, or were harvested in the CSDN fishery.

Movements of radio-tagged fish between banks in the NVE mark-recapture study indicated that marked fish mixed with unmarked fish between sampling events (Smith 2004). The NVE data were used to evaluate this assumption because bank of capture information was generally lacking from fish harvested in the CSDN fishery (recovery event for this experiment). In the NVE study, Chinook salmon were radio-tagged and released from both banks and examined for marks from both banks very near the fishery, so contingency tests comparing recapture rates and movements between the east and west banks could be performed and were appropriate for making inferences for this study.

The probability of a Chinook salmon being recaptured was not influenced by its gender or size. Recapture rates of males (0.12) and females (0.11) in the CSDN fishery were not significantly different ($\chi^2=0.11$; $df=1$; $P=0.73$). Cumulative length frequency distributions of fish marked during the first event and fish recaptured during the second event in the CSDN fishery were not significantly different ($DN=0.10$; $P=0.70$; Figure 8). In addition, cumulative length frequency distributions of marked fish during the first event and sampled fish during the second event were not significantly different ($DN=0.08$; $P=0.11$; Figure 8). Results of these tests indicated that stratification of the data by length, age, or sex was not warranted and data from both events could be pooled to estimate composition proportions.

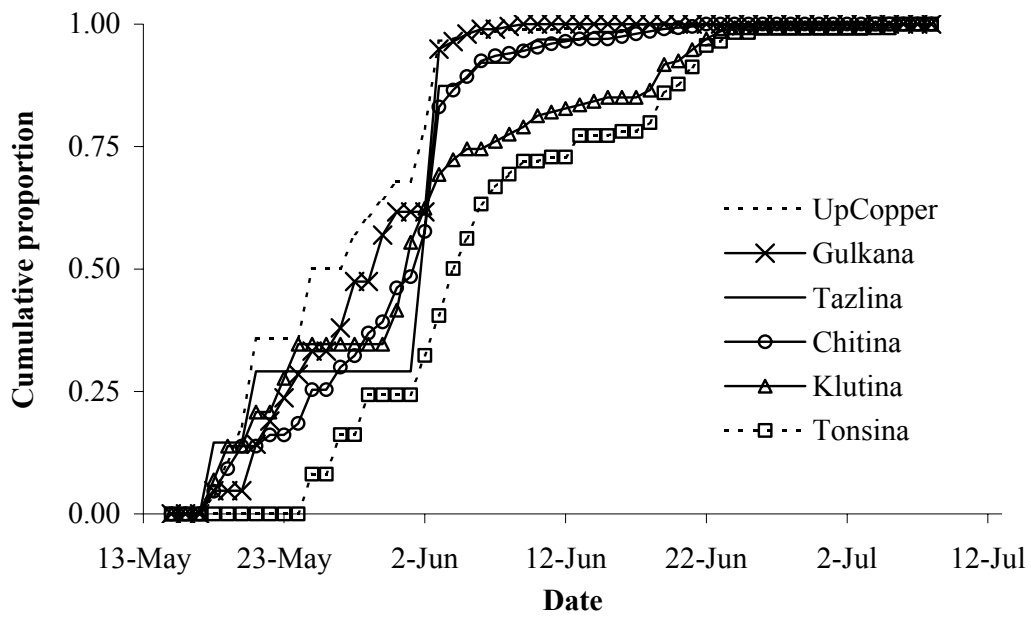


Figure 6.—Run-timing patterns of Chinook salmon at the capture site for the major stocks in the Copper River, 2003.

Table 7.—Statistics regarding the run timing past the capture site in Baird Canyon of the major Chinook salmon spawning stocks in the Copper River, 2003.

Spawning Stock	Duration (No. of Days)	Mean Date of Passage (\bar{t})	SE (\bar{t})
Upper Copper River	5/18-6/14 (27)	5/26	6.1
Gulkana River	5/18-6/9 (22)	5/28	5.5
Chitina River	5/18-6/22 (35)	5/30	6.8
Tazlina River	5/18-6/17 (30)	5/30	7.5
Tonsina River (All)	5/25-7/4 (40)	6/6	9.2
Mainstem	5/25-7/4 (40)	6/9	9.4
Tributaries	5/27-6/8 (12)	5/31	3.6
Klutina River (All)	5/18-7/6 (49)	6/1	10.8
Mainstem	5/23-7/6 (44)	6/6	11.7
Tributaries	5/18-6/10 (23)	5/27	7.0

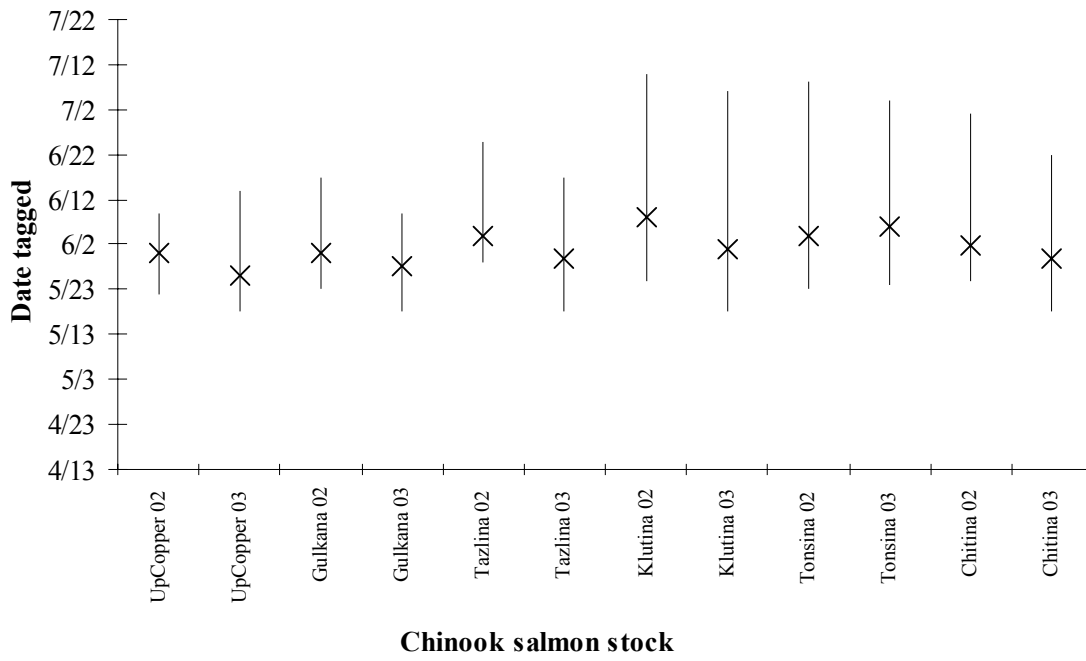


Figure 7.—Mean passage date (symbol) and 80% range (vertical lines) of Copper River Chinook salmon stocks at the capture site in 2002-2003.

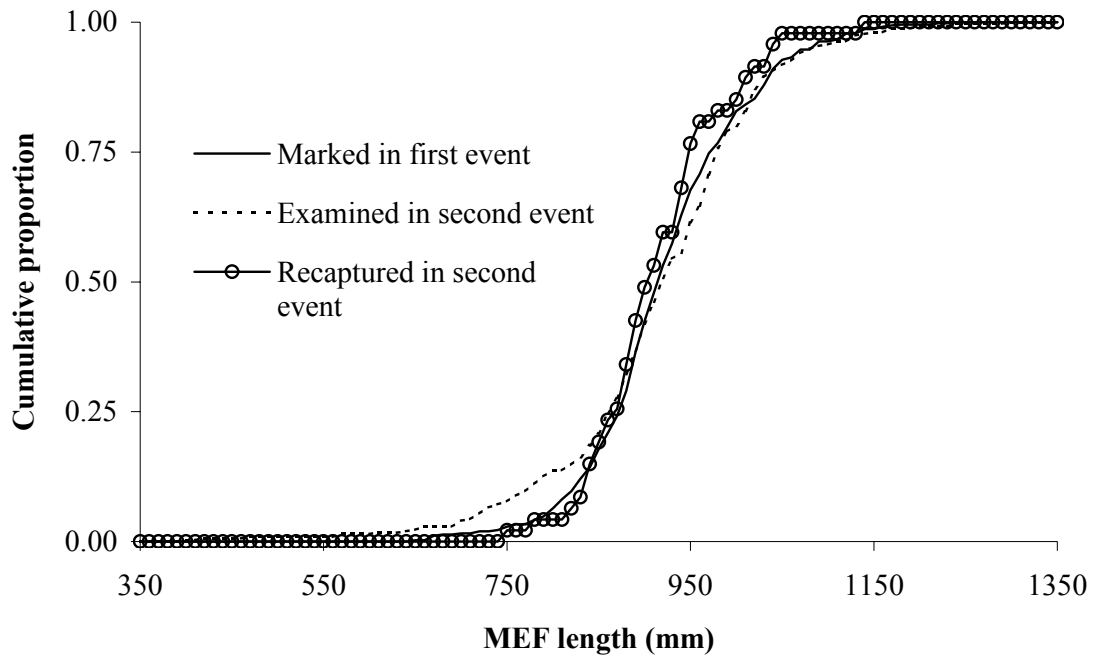


Figure 8.—Cumulative length frequency distributions of all fish marked with radio tags during the first event, all fish examined in the second event, and all radio-tagged fish recaptured during the second event, 2003.

The probability of a Chinook salmon being marked was dependent on the time of capture. Marked to unmarked ratios were significantly different among four recapture periods ($\chi^2=8.67$; $df=3$; $P=0.03$; Table 8). The probability of a Chinook salmon being recaptured was also dependent on their entry time into the CSDN fishery. Recapture rates were significantly different between tagging periods ($\chi^2=11.12$; $df=3$; $P=0.01$; Table 8).

Table 8.—Contingency table analyses comparing weekly marked:unmarked and recaptured:not recaptured ratios for radio-tagged Chinook salmon, 2003.

Test for Equal Marked: Unmarked Proportions in the Second Event

Period	June 4- June14	June 15- June 21	June 22- July 5	July 6- Sept. 30
Marked	3	13	10	8
Unmarked	340	317	640	572
Marked:Unmarked	0.01	0.04	0.02	0.01

$\chi^2=8.67$; $df=3$; $P=0.03$

Test for Complete Mixing between the First and Second Events

Period	June 4- June14	June 15- June 21	June 22- July 5	July 6- Sept. 30
Recaptured	4	16	9	5
Not Recaptured	90	102	155	40
Recapture Rate	0.04	0.14	0.05	0.11

$\chi^2=11.12$; $df=3$; $P=0.01$

Estimator

A partially stratified estimator (Darroch 1961) was used to estimate inriver abundance of Chinook salmon because the tests of consistency indicated that the probability of Chinook salmon being marked and recaptured was dependent on their time of capture and entry into the CSDN fishery. The 2003 estimated inriver abundance was 29,662 (SE=7,327) Chinook salmon ≥ 620 mm MEF for the period 4 June-30 September. To account for the proportion of the run that passed prior to the opening of the CSDN fishery on 4 June, the estimate was expanded using the relationship between abundance and CPUE during the first sample (Figure 9). The estimated proportion of the total run that migrated through the fishery from 4 June to 30 September was 0.90 (SE=0.42). Therefore, total estimated abundance entering the CSDN fishery was 33,488 (SE=8,389) Chinook salmon ≥ 620 mm MEF.

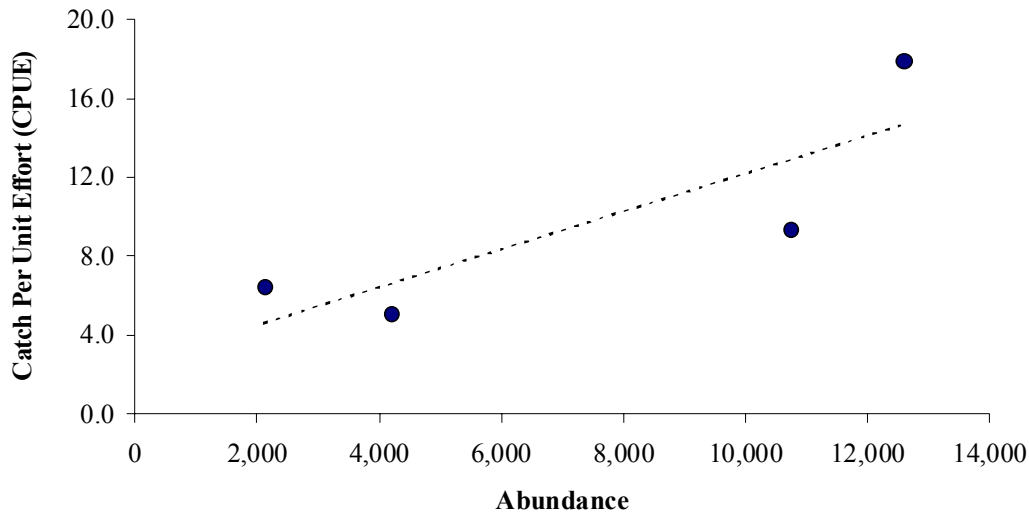


Figure 9.—Periodic estimates of abundance of Chinook salmon and cumulative periodic CPUE, 2003. Periodic refers to a single week or pooled weeks. Dashed line is a linear trendline.

DISCUSSION

The parameters in this study were estimated making the assumptions that the population was tagged in a representative manner and that tagging did not alter the fish's behavior. The effects of inserting radio tags into Chinook salmon on survival, migratory behavior, and catchability are not fully understood. The proportion of radio-tagged Chinook salmon that failed to migrate upstream varied from 8% (n=36) in 2002 to 6% (n=32) in 2003 (Savereide 2003). Comparable studies on Chinook salmon in the Stikine and Taku rivers in Southeast Alaska have observed similar failure or retreat rates (Pahlke and Bernard 1996; Bernard et al. 1999). Even though the failure rates observed in this study are not uncommon, the central question of whether handling affects the probability of capture in the second event still remains. Handling effect was examined in this study by comparing recapture rates and transit times through the CSDN fishery for radio-tagged fish that exhibited varying migration times from the tagging site to the fishery. The assumption was that migration time was a relative measure of stress, and stressed fish may have migrated upstream in nearshore waters with lower velocities. A radio-tagged Chinook salmon exhibiting these characteristics would be more vulnerable to capture by shore-positioned dip net fishermen and fish wheels. Similar recapture rates between fish that exhibited minimal, moderate, and substantial time to migrate between the fish wheels and the fishery, coupled with comparable transit times through the CSDN fishery suggested that any handling-induced changes in migratory behavior did not affect their probability of capture.

Previous studies have provided varying theories on the effects of radio tags on salmon migration. Monan and Liscom (1975) suggested that spring and fall run Chinook salmon can successfully migrate to their spawning grounds when fitted with internal radio tags. In contrast, Gray and Haynes (1979) found that the proportion of Chinook salmon fitted with

internal radio tags that returned to their spawning grounds was significantly less than fish tagged with only spaghetti tags. The latter study concluded that the majority of unsuccessful migrations were caused by placing the radio tag into the posterior stomach instead of just behind the esophageal sphincter in the anterior stomach. In this study radio tags were placed in the anterior stomach of Chinook salmon. Of the radio-tagged fish that migrated through the CSDN fishery 73% were located in a spawning tributary. These results imply that correctly placed internal radio tags improve the chance that tagging will not negatively affect migratory behavior Chinook salmon. Because only fish that successfully migrated into spawning streams were used to estimate spawning distribution and run timing, the assumption made in this study was that the probability that a tagged fish successfully migrated to a spawning stream did not vary by spawning stock.

It is important to report that the 2002 spawning distribution estimates presented in Savereide (2003) have changed because the 2003 radio tag weighting procedure described in equations (1) and (2) was applied to data from 2002. The diagnostic tests from 2002 indicated that there were no significant differences in the marked to unmarked ratios of Chinook salmon in the second event (Savereide 2003). However, these tests used temporal harvest information from the CSDN fishery, which were determined from the voluntary return of harvest permits that in many instances did not provide date of capture information. The NVE mark-recapture data (Smith 2004; FIS01-020) provided more accurate and precise estimates of capture probabilities over time and indicated that a weighting scheme based on relative passage was appropriate. In addition, information from a Chinook salmon counting tower on the Gulkana River in 2002 suggested the proportion estimate for the Gulkana River may have been biased low. In 2003, the new weighting procedure was developed incorporating information from the second event of the NVE fish wheel study. When fishing effort and the tagging rate are relatively stable this weighting procedure provides a better representation of the spawning distribution because it incorporates the variable catchability of migrating fish. The only caveat is that the period estimates of salmon abundance past the tagging site in 2002 were based on sporadic recapture information. This problem was remedied in 2003 with the addition of a second recapture fish wheel.

The distribution of spawning Chinook salmon was similar between 2002 and 2003 (Figure 5). The Tazlina River consistently exhibited a small proportion of the total escapement because there are only two relatively small spawning streams used by Chinook salmon in this drainage. The Upper Copper drainage was also consistent across years and exhibited a larger proportion of the total escapement because the area is fairly large and numerous spawning streams are available. The Tonsina and Klutina rivers, which exhibit both early and late runs of Chinook salmon, were consistent with very little annual variation. In contrast, the Gulkana River exhibited relatively large changes in the annual distribution of Chinook salmon. The pronounced differences in run timing of the various stocks and the probability that exploitation of stocks in the commercial and inriver fisheries varies annually is a likely explanation for some of the variability noted in the spawning distribution.

The spawning distribution of Chinook salmon in the Copper River drainage from 2002-2003 indicated that the nine spawning streams that are aerial surveyed annually for an index of escapement represent a sizeable proportion of the total drainage-wide escapement. Previous studies have determined the estimated proportion to be as high as 40% (Evenson and Wuttig 2000) and low as 26% (Wuttig and Evenson 2001). Chinook salmon located in the nine index

streams accounted for 46% (2002) and 34% (2003) of all spawning fish in the Copper River drainage. The largest contributor to the total escapement count was the Gulkana River, which accounted for 59% of the escapement in the index streams in 2002 and 48% in 2003. However, escapement in the Gulkana River represented only 27% and 17% respectively, of the total drainage-wide escapement. The interannual variation in the proportion of the total escapement represented by these nine streams and the fact that a majority of these streams support stocks with early run-timing patterns suggest that the aerial escapement index that has been conducted since the late 1960s to assess Chinook spawning abundance during peak spawning is neither a consistent nor reliable measure of total escapement.

In 2002 and 2003 the run timing of Chinook salmon at the Baird Canyon capture site revealed that upriver stocks, such as the Upper Copper River and Gulkana River stocks, were the first to enter the CSDN fishery and downriver stocks, such as the Klutina River and Tonsina River stocks, were the last. This type of run-timing pattern where upriver salmon stocks enter first inriver and downriver stocks enter last has been observed in other large river systems (Koski et al. 1994; Pahlke and Bernard 1996). If this run timing holds true at the mouth of the Copper River, where fish are vulnerable to the commercial fishery, then it is probable that individual stocks are subject to varying levels of exploitation.

One characteristic shared by the Chinook salmon stocks in the Tonsina and Klutina rivers was the different run timings of mainstem and tributary spawners. In 2003, tributary spawners were the first to arrive inriver and mainstem spawners arrived a measurable time later (Table 7). In addition, mainstem spawners accounted for a majority (69%) of all spawning Chinook salmon in both rivers. These run-timing patterns were also noted in all previous year's of this study and are analogous to the early and late-run Chinook salmon stocks of the Kenai River. Burger et al. (1985) suggested that Kenai and Skilak lakes contribute to increased fall and winter temperatures of downstream waters in the Kenai River, enabling successful reproduction for late-run mainstem spawners. Both the Klutina and Tonsina rivers have large lakes at their headwaters that may produce the warmer water temperatures needed for late-run spawners.

A partially stratified mark-recapture model (Darroch 1961) was used to estimate the abundance of Chinook salmon at the point of entry into the CSDN fishery. Experimental assumptions such as tag loss, emigration, and mortality were explicitly tested because the fates of all radio-tagged fish were known. However, potential bias from factors such as unreported harvest, illegal harvest, selection for tagged fish, inability to detect radio-tagged fish that were harvested, and removal of tags could not be explicitly tested.

Unreported harvest in the CSDN fishery, defined as harvest by permitted CSDN fishers who did not return their permit, would bias the abundance estimate low because these fish were not accounted for in the total harvest estimate. The number of Chinook salmon harvested by CSDN fishers who did not return their permits was estimated based on harvest rate trends from CSDN fishers that returned their permits after multiple reminder letters. The high return rate of permits (84%) suggested that the unreported harvest was negligible.

Illegal harvest in the CSDN fishery, defined as harvest without a permit, would also bias the abundance estimate low because radio-tagged fish that were harvested were used in the estimation whether they were reported or not, whereas unmarked fish that were harvested and not reported were not. For this reason, the estimate of Chinook salmon abundance is only

affected if a radio-tagged Chinook salmon was illegally harvested. In this study there was little evidence to suggest that radio-tagged Chinook salmon were illegally harvested. All 34 radio-tagged fish harvested in the CSDN fishery were returned by fishers holding a permit.

Failure to detect radio-tagged Chinook salmon harvested in the CSDN fishery would have biased the estimate of Chinook salmon abundance high. The probability that this situation occurred was low because tracking stations located at the upper and lower boundaries of the CSDN fishery and at O'Brien Creek were able to detect all but 8 out of the 468 of the radio-tagged fish that entered and exited the fishery.

CSDN fishers that selected for radio-tagged Chinook salmon or removed and returned radio tags from Chinook salmon that were not harvested would bias the abundance estimate low because the marked (radio-tagged) to unmarked (not radio-tagged) ratio of captured Chinook salmon in the harvest would be larger than the marked to unmarked ratio in the population. Selection for radio-tagged Chinook salmon was assumed negligible because there was no reward offered for returned tags and gray-colored spaghetti tags that were difficult to detect while dip-netting fish were used. In fact, several CSDN fishers stated they did not notice the spaghetti or radio tag until they had processed their fish. When possible, fishers who returned tags were asked whether the tagged fish was harvested or released. None of the 25 CSDN fishers that were queried indicated that they had removed a tag and released a fish.

The design of the mark-recapture experiment incorporated the harvest of Chinook salmon in the CSDN fishery for the second event. The advantages of this were that a relatively large number of fish were examined for marks, the additional cost to the experiment was minimal, and relatively few fish needed to be handled and marked. However, frequent and prolonged fishery openings were required to estimate Chinook salmon abundance, especially in June when a large portion of the run was passing through the study area. Even with early fishery openings (by regulation the fishery cannot open before 1 June), a portion of the early run typically has already migrated through the study area.

In 2003, the CSDN fishery opened on 4 June and there were relatively few closures thereafter. Therefore the CSDN harvest was used to estimate abundance for an estimated 90% of the run. Prior to the opening of the fishery on 4 June, marked fish from the first event passed through the fishery area, but their probability of capture was zero. Therefore, to estimate abundance for the period prior to 4 June, the mark-recapture estimate of abundance for the period during the fishery was expanded by the proportion of the total run it represented. The relationship between periodic estimates of CPUE in the marking event and their corresponding estimate of abundance was determined for periods when the fishery was open and applied to the estimate of CPUE when the fishery was closed to estimate abundance and model uncertainty in the estimate.

The estimated proportion of the run accounted for by the mark-recapture study incorporated two sources of uncertainty because the variation in the relationship between periodic CPUE (process error) and abundance estimates (measurement error) is characteristic of the uncertainty in estimating total abundance (Figure 9). The variation associated with this method of estimation was greater than the variation associated with the mark-recapture model. Therefore, active sampling in late May and early June, prior to the opening of the fishery would be preferable to the expansion technique.

In addition to the potential sources of bias previously discussed, the results of the NVE fish wheel study (FIS01-020) suggest that this study's inriver abundance estimate could be biased low. Smith (2004) reported an inriver abundance estimate of 44,764 Chinook salmon (SE=12,385), this was approximately 11,000 fish greater than the abundance estimate generated in this study. A likely explanation for the difference in the two estimates is given by results of the Smith (2004) study that estimated that the probability of a Chinook salmon being captured and tagged in late May and early June (the period prior to the opening of the fishery) was substantially less than later on during the run. This implies that using the relationship between CPUE and abundance during the period of the fishery to expand for the portion of the run prior to the fishery yields an expanded abundance estimate that is biased low because the relationship changed as the run progressed. The rising water levels during break-up may explain this change in catchability because fish wheel catches tend to be stronger during periods of stable or dropping water levels.

CONCLUSIONS

This project was successful in meeting all project objectives in 2003.

Estimates of stock-specific run-timing patterns over the span of this study (1999-2003) have indicated that although there is considerable overlap in run timing among stocks, there has been a consistent pattern of passage through the CSDN fishery where upriver stocks tend to pass early and lower stocks tend to pass late.

Estimates of spawning distribution have shown that proportions of the total drainage escapement spawning in the six major drainages have remained relatively consistent over the span of the study with the Gulkana and Chitina stocks showing the most variability. The variability in spawning proportions may, in part, be explained by varying levels of exploitation in the commercial and inriver fisheries.

The modification of the procedure for estimating spawning distribution and run timing by weighting radio tags based on estimated probabilities of capture by time from the NVE mark-recapture study provided improved estimates and the new procedure should be used in the analysis of the 2004 data.

Evidence suggests the estimate of total inriver abundance provided in this study may be biased low as a result of the expansion of the mark-recapture estimate to account for the fraction of the run that passed prior to the opening of the fishery. The expansion was based on the assumption that catchability remained constant throughout the run. However, data from the NVE mark-recapture study suggested that catchability during the early part of the run was lower than during the period of the mark-recapture study.

RECOMMENDATIONS

It is recommended that the Federal Office of Subsistence Management and ADF&G support:

1. continued efforts to estimate the inriver abundance or total escapement of Chinook salmon; and,
2. studies that estimate the exploitation rates of the major spawning stocks.

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