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Estimation of the Abundance of Late-run Chinook Salmon in the Kenai River Based on Exploitation Rate and Harvest, 1996

by

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and

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May 1998

Alaska Department of Fish and Game **Division of Sport Fish**

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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
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

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

General

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

Mathematics, statistics, fisheries

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

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The inriver return of the late run of chinook salmon to the Kenai River was estimated to assess the accuracy of the inriver return estimate obtained with split-beam hydroacoustic (sonar) gear. In this study inriver return was estimated as a function of harvest and exploitation rate by the sport fishery between the chinook salmon sonar site and the Soldotna Bridge from 1-31 July 1996. Harvest estimated by an onsite creel survey was 5,682 (SE = 358) fish. Exploitation rate was estimated by monitoring and determining fate of chinook salmon fitted with a radio transmitter. Marked chinook salmon were combined into eight groups based on time of entry into the river. Exploitation rate did not differ ($P > 0.05$) by sex, size, or time-of-entry group. A total of 47 marked chinook salmon were harvested by the sport fishery. The estimated exploitation rate was 0.144 (SE = 0.003). The estimated inriver return of 39,356 (SE = 3,535) fish was significantly ($P = 0.005$) less than that obtained by sonar (49,755 fish; SE = 1,037). The two estimates of inriver return were not different ($P \geq 0.18$) during the period 1-13 July, when approximately 25,000 sockeye salmon entered the river, or 14-31 July, when over 600,000 sockeye salmon entered the river. However, the estimates differed by only 1% during the first period but by 13% during the second period. Differences between the estimates of the entire month and of 14-31 July indicate that the sonar gear may be classifying some targets as chinook salmon that are actually sockeye salmon. Sonar data other than that currently used to classify targets as chinook salmon should be examined to better discriminate and more accurately determine targets that are chinook salmon.

Key words: Kenai River, chinook salmon, *Oncorhynchus tshawytscha*, late run, radio telemetry, failure time, exploitation rate, harvest, inriver return, sonar.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* return to the Kenai River in two temporal migrations, termed early and late run. The early-run spawning migration enters the river from mid-May through late June or early July; the late run enters the river from late June through mid-August. Both runs support major recreational fisheries. In addition, the late run supports an incidental commercial harvest.

Growth of the recreational fisheries in the 1980s led to allocation disputes among users. In 1988 the Board of Fisheries (BOF) adopted management plans that established separate escapement goals for each run. To meet the escapement goal requirements, accurate assessment of the inriver return of chinook salmon is paramount. Since 1987, hydroacoustic gear (sonar) has provided annual estimates of the inriver return (Burwen and Bosch 1998).

Accuracy of the sonar estimates hinges mostly on the ability to distinguish chinook salmon from sockeye salmon *O. nerka*. Early studies indicated that chinook salmon could be distinguished from sockeye salmon based on target strength and spatial separation of the two species in the river channel (Eggers et al. 1995). Sockeye salmon were believed to migrate near the river banks and to have a smaller target strength than chinook salmon. Studies conducted in recent years suggest that these species cannot be distinguished based on target strength (Eggers 1994) and that some sockeye salmon migrate upstream through midchannel at the sonar site (Burwen et al. 1998).

Sonar estimates of the early run of chinook salmon are likely accurate. During 1988 and 1989 estimates of the inriver return based on sonar were compared to those based on capture-recapture experiments (Eggers et al. 1995). The estimates for the early run were not different during either year. There are also relatively few sockeye salmon that return to the Kenai River during the early run.

Accuracy of the sonar estimates of the inriver return of the late run is being questioned. Sonar estimates of the late run of chinook salmon were different than those from capture-recapture experiments; however, the capture-recapture estimates were biased high

(Bernard and Hansen 1992). The bias arose because some marked fish emigrated from the river back into Cook Inlet, and some of these marked emigrants were harvested in the commercial fishery (Alexandersdottir and Marsh 1990, Bendock and Alexandersdottir 1992); therefore, the assumed number of marked fish was biased high relative to the true number of marked fish in the population. In addition, hundreds of thousands of sockeye salmon return to the Kenai River during July and early August. The inability of the sonar gear to distinguish species and lack of independent, unbiased estimates of the inriver return that corroborates those of the sonar has raised concerns about the accuracy of the sonar estimates of the late run.

Split-beam sonar was used in 1996 to estimate the number and direction of travel of targets, and to identify targets that were chinook salmon (Burwen and Bosch 1998). This study was conducted to estimate the inriver return of the late run of chinook salmon independent of the estimate based on the sonar. A test was then conducted of the null hypothesis that these two estimates are not different. Failure to reject this hypothesis would suggest the sonar provides an unbiased estimate of the inriver return of late-run chinook salmon. If the estimates differ significantly, then additional approaches to identify targets as chinook salmon with sonar must be investigated.

METHODS

STUDY AREA

The study area was the Kenai River drainage (Figure 1). Recreational harvest and exploitation rate were estimated from the Soldotna Bridge at river kilometer (rk) 34, downstream to Cook Inlet. The sonar counter is located at rk 13.5. Passage of sockeye salmon is indexed by sonar at rk 30.6 (Ruesch and Fox 1997).

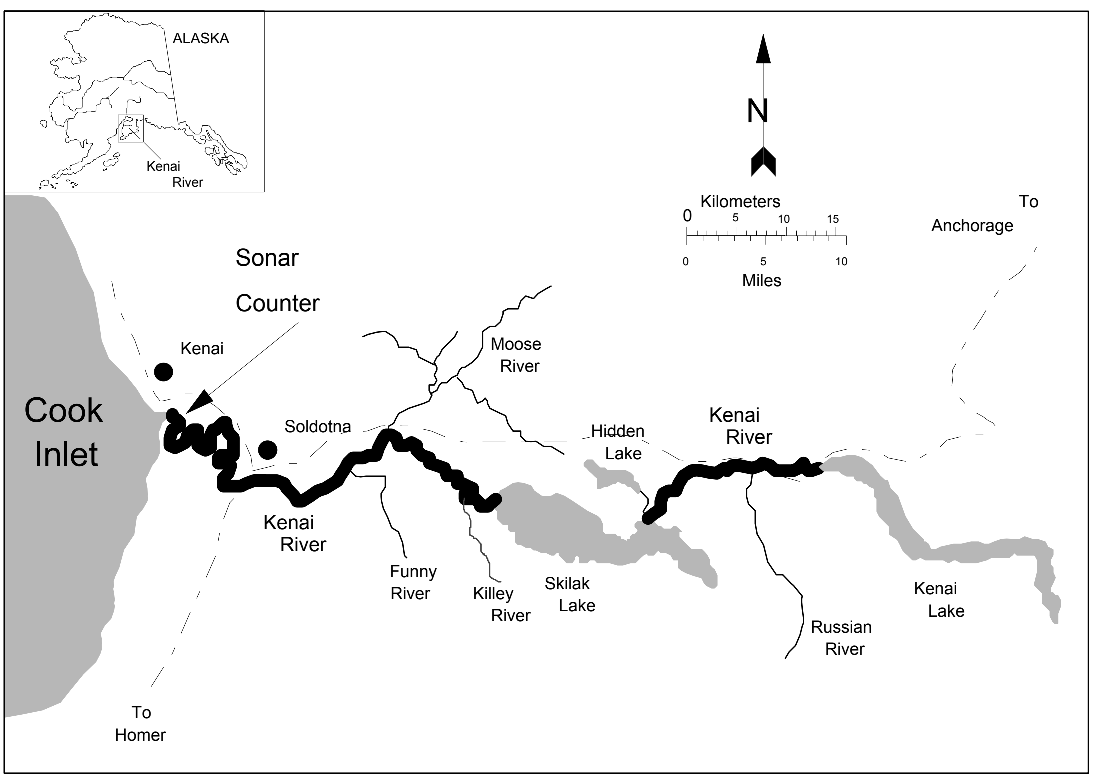


Figure 1.-Map of the Kenai River drainage.

STUDY DESIGN

The inriver return of late-run chinook salmon to the Kenai River was estimated as a function of harvest divided by exploitation rate. The Board of Fish defined the late run as any chinook salmon entering the Kenai River on or after 1 July. By regulation, the inriver sport fishery on late-run chinook salmon occurs from 1-31 July unless extended by emergency order into August. Inriver sport harvest upstream of the sonar site and downstream of the Soldotna Bridge was estimated by an onsite creel survey (King 1997). Details of the methods and results of the creel survey are found in King (1997).

Exploitation rate of chinook salmon was estimated upstream of the sonar site to the Soldotna Bridge by capturing a sample of fish and marking them with radio transmitters. Marked fish were monitored regularly to determine their fate. Exploitation rate and its variance were estimated by applying failure time models to the radio telemetry data (Lee 1980, Cox and Oakes 1984, Pollock et al. 1989a and b). These models are based on knowing the failure time exactly. Because the population of interest was the entire return of late-run chinook salmon, transmittered individuals were monitored throughout the Kenai River; however, we defined failure time as time-to-death occurring from sport harvest between the sonar site and the Soldotna Bridge. A special feature of these models is the presence of censored observations which occurs when exact failure time is unknown. This situation may arise because the individual survived past the end of the study, left the study area (e.g., emigrated from the Kenai River), or was lost to follow-up.

CAPTURE AND MARKING

Chinook salmon were captured near the sonar site (rk 8.0–rk 17.5) from 30 June through 2 August and fitted with radio transmitters. Four two-person crews fishing drift gillnets of 18.4 mm or 14.0 mm stretched mesh captured chinook salmon. The smaller mesh net was used during the first half of July; after mid-July the net captured too many sockeye salmon to effectively capture sufficient numbers of chinook salmon. Capturing chinook salmon near the sonar site allowed the release of fish downstream of most of the sport fishery.

Captured chinook salmon were placed in a holding cradle and fitted with a radio transmitter near the dorsal fin. Transmitters were attached to each fish using two 76 mm nickel/steel pins inserted through tabs on the transmitter, then through the dorsal area of the fish immediately ventral and slightly posterior to the anterior edge of the dorsal fin, with the antenna trailing posterior. Each pin was inserted into a 16 gauge #4 hypodermic needle. The needles were used to penetrate the flesh of the fish and, once protruding from the opposite side of the fish, were removed, exposing the pins. Yellow, uniquely numbered Petersen disk tags were placed over the protruding pins. The pins were then bent using needle-nose pliers to secure the disks tight against the flesh.

Generally only one of the four crews fitted transmitters onto captured chinook salmon. They kept the holding cradle in the river to minimize stress on captured fish. The crew also took three scales from the preferred area, on the left side of the body at a point on a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin, two rows above the lateral line (Welander 1940). Each fish was measured for length (mid-eye to fork-of-tail) to the nearest millimeter and sex identified by external characteristics. Fish were held until they visibly had recovered from capture and handling, and were then released near the location of capture. Only robust, healthy fish not visibly impacted by capture were fitted with a transmitter.

Radio transmitters, manufactured by Advanced Telemetry Systems, Inc. (ATS), operated in the frequency range of 150.000 mhz to 153.999 mhz. Each transmitter emitted a signal with a unique frequency and pulse code. Transmitters were approximately 20 mm X 45 mm in size excluding the trailing antenna and were powered by a lithium battery with an expected life of 90 days. Each transmitter was equipped with a mortality switch that activated when the tag was motionless for approximately 4 hours.

TRANSMITTER MONITORING AND RECOVERY

Receivers used to monitor and locate chinook salmon were also manufactured by ATS (Model R2100). Each receiver was interfaced with a Model DC II data logger (ATS) to decode the pulse code on each located transmitter.

Chinook salmon were monitored by a series of land- and air-based radio receivers and data loggers. A data receiver and logger were placed on the bank of the Kenai River at approximately rk 10. A second receiver and logger were placed on the river bank at rk 34 just upstream of the Soldotna Bridge. The frequency and pulse code of at-large transmitters were programmed into the memory of each receiver. This required adding the frequency and pulse code of transmitters shortly after they were placed on chinook salmon and deleting this information when a transmitter was recovered. The data loggers continually scanned the frequencies and pulse codes of all at-large transmitters throughout each day. The receiver in the downstream location detected chinook salmon that emigrated from the river after handling. The receiver upstream of the Soldotna Bridge detected chinook salmon that migrated upstream of the bridge. The data logger information was downloaded daily into a laptop computer using "Procom Plus" software.

Approximately 4 days each week during July and early August, chinook salmon were located between rk 0 and rk 38.6 from a Piper PA-18 Super Cub with a 4-element yagi antenna mounted on each wing strut. Occasionally the flight occurred or extended upstream of rk 38.6 to locate chinook salmon that migrated upstream of the Soldotna Bridge. Prior to each flight the data receiver was programmed with the frequencies of all transmitters assumed at-large. During flights a section of river approximately 2-4 rk in length was circled utilizing only the receiver in the audio mode until all frequencies in that section were located. Those frequencies were then programmed into the data logger and the section covered until all frequencies were pulse coded. Each chinook salmon was located to the nearest 0.8 rk. Any transmitter signaling in mortality mode was noted. After locating chinook salmon in one section, the flight progressed to the next river section.

Transmittered chinook salmon were also located downstream of the Soldotna Bridge from a ground vehicle or a boat. The vehicle was driven to different access locations that provided good coverage of the river. Chinook salmon were located from the boat as it was driven slowly along the river. Although monitoring from the boat was generally scheduled during periods of low boat traffic (e.g., Mondays), observations from the vehicle and by boat occurred on an opportunistic basis throughout July and early August. The procedure for locating transmittered chinook salmon was the same as that used in the plane.

The mortality switch in each transmitter doubled the pulse rate if the transmitter did not move for approximately 4 hours. Chinook salmon with transmitters in mortality mode were retrieved if possible to determine cause of death.

Alaska Department of Fish and Game personnel involved with this project, the onsite creel survey, other projects on the Kenai River, and sampling the Upper Subdistrict commercial set gillnet fishery along the east side of Upper Cook Inlet, examined harvested chinook salmon for transmitters. Date, location, Petersen disk tag number, and radio frequency of recovered chinook salmon were recorded. Effort was also directed to recover transmitters that were not returned or observed during onsite sampling.

Ultimate fates of these chinook salmon were based on the criteria established by Bendock and Alexandersdottir (1992):

1. Survivor: moved upstream after release and transmitted a radio signal in normal mode at the end of the study;
2. Mortality: harvested by the sport fishery between the sonar site and the Soldotna Bridge;
3. Handling mortality: failed to move upstream after release and either transmitted a radio signal in mortality mode or was recovered as a carcass within 5 days of release;
4. Hook-and-release mortality: recovered as a carcass with obvious signs of being hooked by the sport fishery and released (e.g. hooking wounds or scars, damaged gill filaments);
5. Personal-use mortality: harvested in the intertidal area by the personal use dip net fishery;
6. Educational mortality: harvested in the intertidal area by the Kenaitze Tribe educational fishery;
7. Commercial mortality: recovered from the harvest of the commercial drift or set gillnet fisheries of the Central District of Upper Cook Inlet;
8. Emigrant: observed at the downstream data logger and never subsequently located in the study area; and
9. Unknown: never located after release or lost to follow-up.

Fish observed by or below the downstream data logger a few hours after release were not considered at risk (part of the sample) until they re-entered the study area and proceeded upstream in a perceived normal fashion. Fish were censored if they survived beyond the end of the study, emigrated from the study area, or were located in the study area but their ultimate fate was unknown. Fish were also censored if harvested by the sport fishery downstream of the sonar site or upstream of the Soldotna Bridge to provide an estimate of exploitation rate to an area of the river where harvest was also estimated. Fish that died from handling were deleted from the analyses because these individuals were likely not representative of the chinook salmon population. Fish recovered in the personal use, educational, and commercial fisheries had emigrated from the study area prior to harvest. Although date of harvest of fish recovered from these fisheries was recorded, these individuals were censored on the date they were observed at the downstream data logger.

The exact date and location of harvest by the sport fishery or the date of censoring was known for most chinook salmon. When the exact date was unknown, the date of sport harvest or of censoring was defined as the date that encompassed 60% of the time between the date last located in the study area and the date recovered (Johnson 1979). Fish located in the study area and then lost completely were censored on the date last located in the study area.

The public was informed and educated about the project through a series of public meetings, discussions and meetings with guides, press releases and advertisements in newspapers on the Kenai Peninsula and Anchorage, and signs posted in the Kenai-Soldotna area and along the Kenai River. The public was told the objectives of the project and that some late-run chinook salmon were fitted with radio transmitters. Anglers were instructed to follow their normal behavior when deciding to release or harvest a chinook salmon regardless of the presence of the transmitter. These efforts were conducted to promote the recovery of transmitters, especially those taken by the sport fishery, without biasing the results.

DATA ANALYSIS

To estimate inriver return first required estimation of exploitation rate. Assumptions of the model used to estimate exploitation rate were also evaluated to minimize potential bias in the estimates of exploitation rate and thus of inriver return. The sonar program estimated the inriver return of late-run chinook salmon up to 31 July. After this date pink salmon spawning around the sonar site affected accurately identifying targets as chinook salmon (Burwen and Bosch 1998). Therefore, harvest and exploitation rate were also estimated for the period 1-31 July.

Exploitation Rate

To estimate exploitation rate, chinook salmon in this study were combined into groups based on date of entry into the Kenai River. Each group consisted of fish entering the river over a 2-7 day interval. Exploitation rate of each group was estimated from the first day of the interval that a transmittered chinook salmon entered the river to 31 July. Transmittered chinook salmon that entered the river during the interval were added to the group on the day of entry. Addition of individuals to a sample over time is termed left truncation (Cox and Oakes 1984) or staggered entry (Pollock et al. 1989a). Failure time models are easily extended to incorporate left truncation (Cox and Oakes 1984, Pollock et al. 1989a) by only considering these individuals at risk beginning on the day they enter the study. This assumes that all chinook salmon entering the study during the time interval have the same survival function. Thus, we combined chinook salmon into groups to maintain a similar number of fish in each group and to minimize problems that probability of survival differed among fish in a group.

The survival rate of each group after t days was estimated as the product of daily survival estimates by (Kaplan and Meier 1958):

$$\hat{S}_i(t) = \prod_{j|t_j<t} 1 - \frac{d_{ij}}{n_{ij}}, \qquad (1)$$

with variance estimated by Greenwood's formula as (Cox and Oakes 1984):

$$\hat{V}\left[\hat{S}_i(t)\right] = \frac{\left[\hat{S}_i(t)\right]^2\left[1-\hat{S}_i(t)\right]}{n_{ij}}, \qquad (2)$$

where:

d_{ij} = number of transmittered chinook salmon of group i harvested by the sport fishery between the sonar site and the Soldotna Bridge during day j, and

n_{ij} = number of transmittered chinook salmon of group i at risk throughout the Kenai River at the beginning of day j.

Exploitation rate between the sonar site and Soldotna Bridge was then estimated as:

$$\hat{E}_i(t) = 1 - \hat{S}_i(t), \qquad (3)$$

with variance estimated using equation (2) and replacing $\hat{S}_i(t)$ with $\hat{E}_i(t)$.

Catch per unit of effort (CPUE) data collected when capturing chinook salmon were used to calculate a weighted estimate of the overall exploitation rate to 31 July. During each drift each crew recorded effort as the number of minutes the net was in the river fishing. Catch and effort data from all crews were combined to estimate CPUE of each sample day. Sample days were then combined into the same time intervals as the time-of-entry groups used to estimate exploitation rate. The mean daily CPUE of each interval was estimated by:

$$\overline{CPUE_i} = \frac{\sum_{k=1}^{d_i} \widehat{CPUE}_{ik}}{d_i}, \tag{4}$$

where:

$\widehat{CPUE}_{ik}$ = estimate of CPUE of interval i on day k, and

d_i = number of days sampled by the netting crews during interval i.

The CPUE for each interval was then estimated as:

$$\widehat{CPUE}_i = D_i\left(\overline{CPUE_i}\right), \tag{5}$$

where:

D_i = total number of days (= 2-7) during interval i.

The weight of each interval was estimated as:

$$\hat{w}_i = \frac{\widehat{CPUE}_i}{\sum_{i=1}^{n} \widehat{CPUE}_i}, \tag{6}$$

where:

n = number of intervals.

The weighted estimate of exploitation rate of each group was calculated as the product of the weight and the product limit estimate of exploitation rate. The overall weighted estimate of exploitation rate and its variance were then calculated as the sum of the estimates among groups:

$$\hat{E} = \sum_{i=1}^{n} \hat{w}_i \hat{E}_i \text{, and} \tag{7}$$

$$\hat{V}(\hat{E}) = \sum_{i=1}^{n} \hat{w}_i^2 \hat{V}(\hat{E}_i)\ . \tag{8}$$

Evaluating Model Assumptions

Conditions for the accurate use of the Kaplan-Meier model are (Pollock et al. 1989a): (1) chinook salmon in the study are a random sample from the population; (2) survival times are independent among fish; (3) capturing, handling, and carrying a radio transmitter does not affect survival; and (4) censoring is a random process among fish and independent of survival. Chinook salmon in the study were likely representative of the sport catchable population because captured chinook salmon were released downstream of nearly all of the sport fishery, the drift gillnets were relatively nonselective over the size range of chinook salmon that enter the Kenai River (Carlon and Alexandersdottir 1989, Alexandersdottir and Marsh 1990), and fish were released throughout July. Independent expectation of survival among fish probably occurred because inriver migratory timing of chinook salmon is variable and because chinook salmon migrate upstream more as individuals than as schools of fish. To ensure the third assumption was met, chinook salmon were fitted with a transmitter very quickly after capture and were carefully handled to minimize stress; the transmitters were also small relative to fish size. These factors reduced effects of capture, handling, and carrying a transmitter on survival. We believe the last assumption was met because no obvious patterns or trends in censoring were observed that would indicate censoring mechanisms were related among individuals.

This project appeared well received among guides and anglers, and the public information program helped minimize potential problems of incorrectly censoring a chinook salmon that was harvested by the sport fishery.

The proportional hazards model (Cox and Oakes 1984) was used to investigate whether time-of-entry, sex, or size were associated with expectation of survival from the sport fishery. This nonparametric multiple regression model related these explanatory variables, or covariates, to the hazard rate as:

$$\ln\left[h_m(\tau \mid \mathbf{x}_m) / h_0(\tau)\right] = \sum_{a=1}^{q} \beta_a x_{am}, \tag{9}$$

where:

- $h_m(\tau|\mathbf{x}_m)$ = hazard rate of fish m,
- $h_0(\tau)$ = baseline hazard rate when the value of all covariates of fish m equals 0,
- β_a = regression coefficient of covariate a,
- $\mathbf{x}_m$ = vector of covariates of fish m, and
- τ = failure time (days) after entry into the river.

Covariates with a positive coefficient, β_a, increase the hazard rate and thus the exploitation rate. Size was modeled in two different ways. The first divided fish into four length classes based on quartiles, and the second classified individuals into two classes based on the median of the length measurement of all transmittered chinook salmon. All covariates except time-of-entry were coded as binary variables. A significant (α = 0.05) covariate would indicate exploitation rate and harvest must be stratified by that variable.

Inriver Return

Inriver return was estimated as a function of harvest and exploitation rate by:

$$\hat{N}_e = \frac{\hat{H}}{\hat{E}}, \tag{10}$$

and its variance estimated as the quotient of two independent random variables by (Lindgren 1976:140):

$$\hat{V}(\hat{N}_e) = \hat{N}_e^2\left[\frac{\hat{V}(\hat{H})}{\hat{H}^2} + \frac{\hat{V}(\hat{E})}{\hat{E}^2}\right], \tag{11}$$

where:

- $\hat{H}$ and $\hat{V}(\hat{H})$ = sport harvest of late-run chinook salmon between the sonar site and the Soldotna Bridge and its variance, both estimated by the creel survey.

The null hypothesis that the inriver return of late-run chinook salmon estimated by sonar did not differ from that estimated by this project was tested by:

$$z = \frac{\hat{N}_e - \hat{N}_s}{\sqrt{\hat{V}(\hat{N}_e) + \hat{V}(\hat{N}_s)}}, \tag{12}$$

where:

- $\hat{N}_s$ and $\hat{V}(\hat{N}_s)$ = inriver return and its variance estimated by sonar.

A two-tailed test was conducted because there was no *a priori* idea of the direction of potential bias of inriver return estimated by the sonar. If the sonar counted targets of other species as chinook salmon then the estimate would be biased high. If the sonar did not count targets of other species as chinook salmon and missed targets of chinook salmon, then the estimate could be biased low.

MIGRATORY TIMING

Although not a focus of this study, radio telemetry data provided some information on migratory timing of chinook salmon. A logistic regression analysis was conducted to determine if time interval of capture, sex, or

Table 1.-Number of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996.

Release Date	Located[a] Yes	No	Total
1	7		7
2	13	1	14
3	5	3	8
7	31	1	32
8	19	3	22
9	18	4	22
10	13	4	17
11	14	8	22
14	23	5	28
15	37	4	41
16	46	7	53
17	27	5	32
21	18	2	20
22	41	6	47
23	21	5	26
24	34	3	37
25	40	9	49
28	8	7	15
29	11	2	13
30	5	3	8
31		1	1
Total	431	83	514

[a] Located chinook salmon entered the river and were considered at risk to the sport fishery. Chinook salmon not located were never observed inriver or were observed at a downstream data logger a few hours after release, indicating the fish emigrated from the river, and never observed inriver again.

median length class differed between chinook salmon that entered the study within the day after release with those that entered the study 2 or more days after release. Date of capture was used in the analysis with dates combined into the same intervals as time-of-entry to maintain some consistency in the overall analyses. The median number of days between date of capture and date of upstream migration past the Soldotna Bridge was also estimated for each time-of-capture group.

RESULTS

Over 80% of the 514 chinook salmon fitted with a radio transmitter during July provided data to estimate exploitation rate (Table 1). The time-of-entry group, sex, and length class were determined for each of these chinook salmon (Appendix A1). Of the fish that provided failure time data, 47 (10%) were harvested by the sport fishery between the sonar site and the Soldotna Bridge, 30% were censored, and the remaining 60% survived until 1 August (Table 2). Thirty-three fish observed at the downstream data logger and censored as emigrants subsequently re-entered the river and were monitored a second time. This accounts for the discrepancy between the 431 fish that provided data (Table 1) and the 464 fates (Table 2).

EVALUATING MODEL ASSUMPTIONS

A logistic regression analysis detected a significant (Type III likelihood ratio: χ^2 = 15.28, df = 7, P = 0.03) difference between chinook salmon that provided data and those that provided no data due to time interval of capture (Table 3, Appendix A2). This occurred because a number of chinook salmon captured 26-31 July provided no data. However, this does not indicate that chinook salmon providing data were a biased sample. Nine of the 13 fish captured during this interval that provided no data were observed inriver after 31 July and there was no significant difference (χ^2 = 6.88, df = 6, P = 0.33) among the other seven groups. There was no effect of sex (χ^2 = 0.45, df = 1, P = 0.50) or median length class (χ^2 = 1.49, df = 1, P = 0.22) on whether a chinook salmon provided data.

The proportional hazards model showed that only time-of-entry was useful to stratify estimates of exploitation rate. Plots of ln(-ln $S[\tau|x_a]$) against time for each covariate (Figure 2) indicated only time-of-entry seriously violated the assumption of proportionality (Kalbfleisch and Prentice 1980:91-95). The plot was relatively steep the first few days after entry into the river for all but the first group. The plot of several groups crossed each other rather than showing a constant difference, which indicates that the hazard rate, similar to an instantaneous mortality rate (White and Garrott 1990), was not constant among groups. There was no significant difference (likelihood ratio χ^2 = 3.50, df = 4, P = 0.48) between a proportional hazards model with no covariates and a model with sex and four length classes as covariates. Further testing showed that neither sex (Wald χ^2 = 0.15, df = 1, P = 0.69) nor any of the length classes (range Wald χ^2 = 0.003-1.752, df = 1, range P = 0.18-0.96) significantly affected exploitation rate. Similarly, a model with sex, median length class, and a sex*median length class interaction was not significant (likelihood ratio χ^2 = 1.81, df = 3, P = 0.61).

EXPLOITATION RATE

The estimated exploitation rate of late-run chinook salmon over the entire study period was 0.144 (SE = 0.003; Table 4). Exploitation rate of the entire study was estimated as the average of the exploitation rate among time-of-entry groups because survival rates did not differ (logrank χ^2 = 5.20, df = 7, P = 0.64) among groups. Weighting estimates of exploitation rate of each group by CPUE data did not significantly (|z| = 3.10, P = 0.99) alter the overall estimate of exploitation rate. Estimates of exploitation rate ranged from 0.066 (SE = 0.011) for chinook salmon entering the river 22-23 July to 0.255 (SE = 0.051) for chinook salmon entering the river 1-7 July. Exploitation rate appeared to steadily decline among the four groups entering the river between 1 and 17 July (Figure 3). However, most of the transmittered chinook salmon entered the river between 12 and 31 July and exploitation rate of these fish had no consistent trend.

The estimate of exploitation rate did not change significantly (|z| = 0.28, P = 0.78) if we ignored the first time line of the 33 chinook salmon censored as emigrants from the study area that subsequently re-entered the

Table 2.-Fate of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996.

	Fate[a]			
Dates[b]	Harvested	Censored	Survived	Total
01-07 July	7	25	18	50
08-11 July	7	14	32	53
12-15 July	6	19	35	60
16-17 July	4	14	39	57
18-21 July	6	12	36	54
22-23 July	3	22	33	58
24-25 July	9	29	45	83
26-31 July	5	4	40	49
Total	47	139	278	464

[a] Harvested individuals were harvested by the sport fishery between the sonar site and the Soldotna Bridge, censored individuals were lost to follow-up due to emigration from the river or to some other cause, and chinook salmon that survived were alive in the river at the end of July.

[b] Range of dates that transmittered chinook salmon entered the river.

study area (Table 5). If censoring these fish arose from handling then including the first time line could bias the estimate. We were conservative when designating days-at-risk: if presence in the study area was questionable then the fish was censored or the day excluded from estimation. If individuals at risk were incorrectly censored or days deleted this would bias the estimate. However, making a less conservative determination of the days at risk did not significantly ($|z| = 0.53$, $P = 0.60$) change the estimated exploitation rate. Therefore, the average exploitation rate among groups provided a relatively unbiased estimate of the overall exploitation rate.

INRIVER RETURN

Based on the estimated sport harvest (King 1997) and exploitation rate, an estimated 39,356 (SE = 3,535) chinook salmon returned to the Kenai River from 1-31 July (Table 6). The inriver return of 49,755 (SE = 1,037) chinook salmon estimated by sonar (Burwen and Bosch 1998) was significantly ($|z| = 2.82$, $P = 0.005$) greater than this estimate.

Table 3.-Status of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996 by time interval captured, sex, and length class.

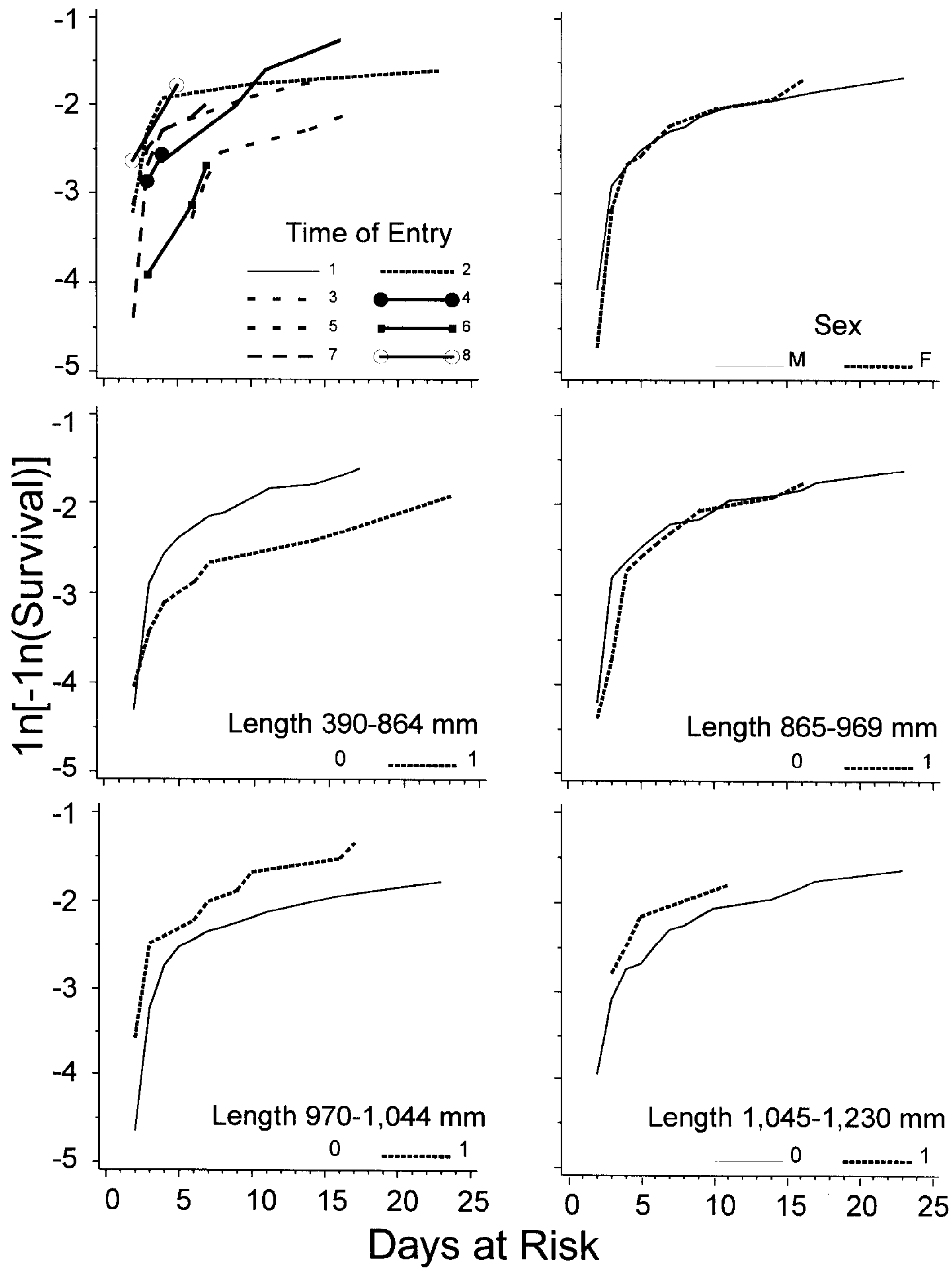
		Located[a]		
Factor	Element	Yes	No	Total
Time interval captured	01-07 July	56	5	61
	08-11 July	64	19	83
	12-15 July	60	9	69
	16-17 July	73	12	85
	18-21 July	18	2	20
	22-23 July	62	11	73
	24-25 July	74	12	86
	26-31 July	24	13	37
Sex	Male	258	46	304
	Female	173	37	210
Length class[b]	390-970 mm	221	49	270
	971-1,230 mm	210	34	244

[a] Located chinook salmon entered the river and were considered at risk to the inriver sport fishery. Chinook salmon not located were never observed inriver or were observed at a downstream data logger a few hours after release, indicating the fish emigrated from the river, and never observed inriver again.

[b] Based on median length (= 970 mm) of all chinook salmon fitted with a radio transmitter.

To further examine this result we compared estimates of inriver return from this project and from the sonar during the portion of the late run when the Kenai River had relatively few sockeye salmon (e.g., estimated daily passage of less than a few thousand targets at the sockeye salmon sonar site) and that portion of the run when the river had many sockeye salmon. Estimates of daily passage at the sockeye salmon sonar site were fewer than 3,500 sockeye salmon from 1-13 July (Ruesch and Fox 1997). On 14 July the estimated passage was over 26,000 sockeye salmon, and on 15 and 16 July over 107,000 sockeye salmon passed the site each day. Daily estimates then exceeded 14,500 sockeye salmon until 28 July.

Based on this information, harvest, exploitation rate, and inriver return were estimated for the periods 1–13 July and 14–31 July (Table 6). Exploitation rate from 1-13 July was 0.163 (SE = 0.020) and from 14-31 July was 0.114 (SE = 0.007). Only the first two time-of-entry groups were used to estimate exploitation rate from 1-13 July. Too few transmittered chinook salmon entered the study area on 12 or 13 July to accurately estimate exploitation rate for this group. To estimate exploitation rate from 14-31 July, transmittered chinook salmon that entered the study area prior to 14 July and



For Time of Entry: 1 = 1–7 July; 2 = 8–11 July; 3 = 12–15 July; 4 = 16–17 July; 5 = 18–21 July; 6 = 22–23 July; 7 = 24–25 July; 8 = 26–31 July. For length graphs, 0 designates fish that were not in the length group; 1 designates fish that were in the length group.

Figure 2.-Plots of different covariates to examine assumption of proportionality in the proportional hazards model.

Table 4.-Kaplan-Meier estimates of survival (S_i) and exploitation (E_i), and estimated weights (w_i) and weighted estimates of exploitation (E_{wi}), by time interval of entry into the study for chinook salmon fitted with a radio transmitter in the Kenai River during July 1996.

Dates	S_i	E_i	$SE(E_i)$	w_i [a]	E_{wi} [b]
01-07 July	0.745	0.255	0.051	0.167	0.042
08-11 July	0.814	0.186	0.030	0.096	0.018
12-15 July	0.880	0.120	0.019	0.170	0.020
16-17 July	0.924	0.076	0.012	0.124	0.009
18-21 July	0.838	0.162	0.024	0.194	0.031
22-23 July	0.934	0.066	0.011	0.059	0.004
24-25 July	0.870	0.130	0.017	0.099	0.013
26-31 July	0.840	0.160	0.023	0.091	0.015
01-31 July [c]	0.856	0.144	0.009	1.000	0.153

[a] Based on CPUE data of chinook salmon captured with drift gillnets in the lower Kenai River.

[b] Interval estimates are the product of the Kaplan-Meier estimate of exploitation of chinook salmon that entered the river during the interval and the weight of the interval.

[c] The average of the interval estimates for survival and exploitation, and the sum of the interval estimates for weighted exploitation.

were still alive on 14 July were combined with fish that entered the study area on 14-15 July. Exploitation rate of groups entering the study area after 16 July was not changed.

The estimates of inriver return from this project and from sonar (Table 6) were not significantly different for the period 1-13 July ($|z| = 0.05$, $P = 0.96$) or for the period 14-31 July ($|z| = 1.33$, $P = 0.18$). Estimates for the second time period require careful interpretation. The sonar estimates the number of chinook salmon that entered the river, while the estimate from this project is the abundance of chinook salmon in the river, during the period.

MIGRATORY TIMING

Capture time interval ($\chi^2 = 22.57$, df = 7, $P = 0.002$) and length class ($\chi^2 = 3.79$, df = 1, $P = 0.05$) had significant effects on whether a chinook salmon entered the study area within 1 day after capture or entered 2 or more days after capture (Table 7, Appendix 3). Chinook salmon captured from 1-11 July tended to delay entry into the study area and those captured from 24-31 July tended to enter the study area quickly. Fish smaller than the median length tended to delay entry into the river after capture and those larger than the median length tended to enter quickly after capture. Because capture, handling, and release were similar for all chinook salmon, these differences were likely more indicative of individual fish behavior and not a result of differential handling. There was no difference ($\chi^2 = 2.19$, df = 1, $P = 0.14$) in entry pattern between the sexes.

Chinook salmon that entered the Kenai River in early July tended to migrate upstream of the Soldotna Bridge to spawn whereas those that entered the river in late July tended to spawn downstream of the bridge (Table 8). Three hundred six transmittered chinook salmon were known to be alive at the end of July or had migrated past the upstream data logger during the month. Nearly 61% of these 306 fish had migrated upstream of the Soldotna Bridge. The median number of days between the date captured and the date of migration past the upstream data logger steadily declined from 10 days for fish captured 1-7 July to 4 days for the groups of fish captured 18-31 July. These results imply that as the return of chinook salmon progresses through July, the fish that spawn upstream of the bridge migrate through the lower river at a faster rate. Unfortunately the study ended 31 July so data collected after this date were not included. This may bias these results, especially of chinook salmon captured during the last half to one-third of July.

DISCUSSION

The split-beam sonar overestimated the inriver return of late-run chinook salmon to the Kenai River in 1996. The sonar estimate appears biased high because targets that are likely sockeye salmon are incorrectly classified as chinook salmon; however, a relatively small proportion of the sockeye salmon return is classified as chinook salmon. When daily passage of sockeye salmon numbered a few thousand during early July there was little if any bias. For the entire month of July the point estimates from the two studies differed by 10,400 fish, which is small relative to an estimated total sockeye salmon return to the Kenai River of over

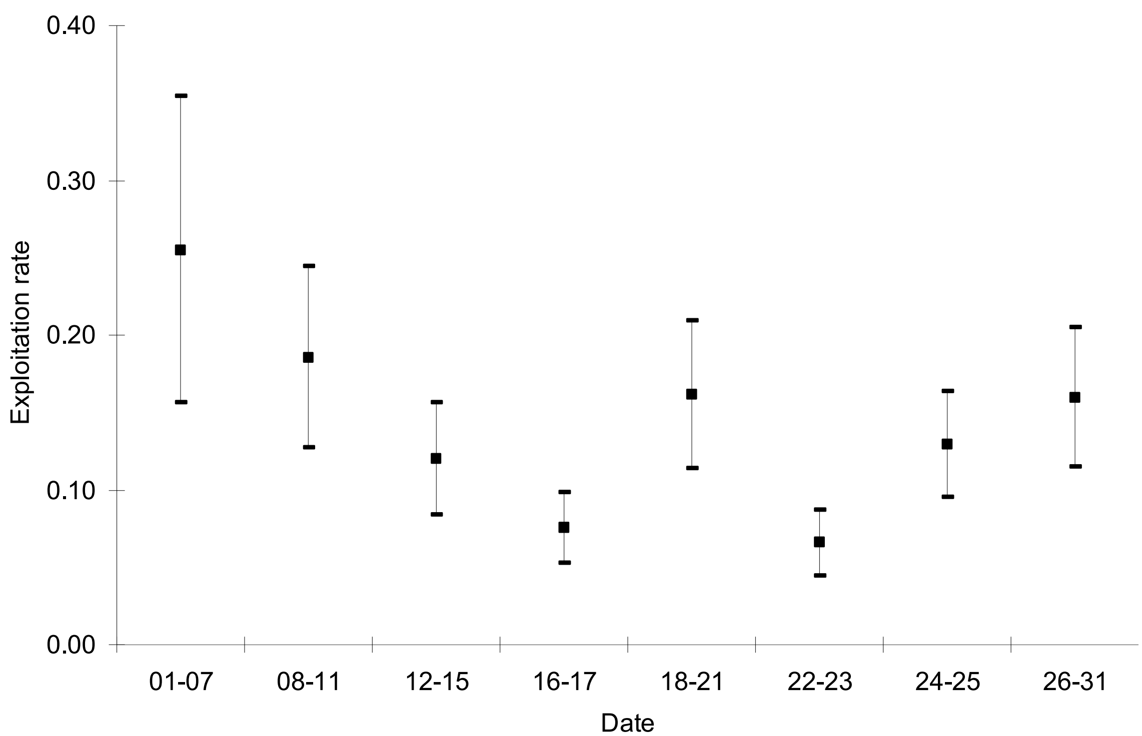


Figure 3.-Estimated exploitation rate, with 95% confidence interval estimates, of transmittered chinook salmon grouped by date of entry into the Kenai River in July 1996.

Table 5.-Kaplan-Meier estimates of exploitation (E_i) and associated standard error by time interval of entry into the study, based on three scenarios of days at risk for chinook salmon fitted with a radio transmitter in the Kenai River during July 1996.

	Scenario[a]					
	Initial		Delete re-entries		Less conservative	
Dates	E_i	$SE(E_i)$	E_i	$SE(E_i)$	E_i	$SE(E_i)$
01-07 July	0.255	0.051	0.268	0.053	0.249	0.048
08-11 July	0.186	0.030	0.190	0.030	0.173	0.028
12-15 July	0.120	0.019	0.120	0.019	0.106	0.016
16-17 July	0.076	0.012	0.077	0.012	0.078	0.012
18-21 July	0.162	0.024	0.162	0.024	0.172	0.026
22-23 July	0.066	0.011	0.067	0.011	0.095	0.014
24-25 July	0.130	0.017	0.133	0.018	0.102	0.013
26-31 July	0.160	0.023	0.160	0.023	0.222	0.034
01-31 July[b]	0.144	0.009	0.147	0.009	0.150	0.009

[a] Initial designates initial determination of fate and days at risk of each transmittered chinook salmon. Delete re-entries designates deletion of first time line of fish censored when observed at or below the downstream data logger that later re-entered the river. Days at risk after re-entry is included in estimation. Less conservative designates a less conservative determination of days at risk: chinook salmon observed at the downstream data logger and others of questionable status on any given day were assumed to be in the river.

[b] Estimates are the average of the estimates of each time-of-entry group and standard errors measure variability of the estimates among the groups.

640,000 fish during the month. Regardless, this bias is rather large relative to the return of late-run chinook salmon (26%) and may overestimate the productivity and forecasted returns of late-run chinook salmon (Hammarstrom 1997). Sonar data other than that currently used to classify targets are being examined to improve identification of chinook salmon from other targets (Burwen and Bosch 1998).

The inriver return estimated as a function of harvest and exploitation rate was relatively unbiased and precise (relative precision of 18%). The creel survey contained several strata to minimize bias and improve precision (King 1997). Harvest estimates from the creel survey downstream of the Soldotna Bridge also do not differ from harvest estimated by the Statewide Harvest Survey (Howe et al. 1996). No obvious violation of model assumptions or other sources of bias were detected in the estimate of exploitation rate. Weighted estimates of exploitation rate did not dramatically improve accuracy because exploitation rate did not differ among groups. In addition it appeared that the entry of transmittered chinook salmon into the study was fairly proportional to the overall return of chinook salmon: weights among entry groups were similar. The inriver migratory behavior of chinook salmon, release of a large number of fish with a transmitter throughout the

Table 6.-Estimated harvest and exploitation rate between the sonar site and the Soldotna Bridge, inriver return estimated as a function of harvest and exploitation rate [$N_{f(H,E)}$], and inriver return estimated with dual beam sonar (N_s), with standard errors in parentheses, of chinook salmon in the Kenai River during three time periods of July 1996.

	Time period[a]					
Statistic	01-13 July		14-31 July		1-31 July	
Harvest	1,340	(186)	4,178	(306)	5,682	(358)
Exploitation	0.163	(0.020)	0.114	(0.007)	0.144	(0.009)
$N_{f(H, E)}$	8,246	(1,511)	36,596	(3,491)	39,356	(3,535)
N_S	8,318	(255)	41,437	(1,011)	49,755	(1,037)
% difference[b]	1		13		26	

[a] From 01-13 July relatively few sockeye salmon entered the Kenai River, from 14-31 July hundreds of thousands of sockeye salmon entered the Kenai River, and 01-31 July are estimates of the entire study.

[b] Percentage difference between the two estimates of inriver return relative to the estimate as a function of harvest and exploitation.

month, vigilant monitoring and recovery program, and good cooperation from the public all helped provide relatively accurate, precise estimates of exploitation. Although it is possible that some chinook salmon that were censored or that provided no data were actually harvested in the sport fishery, the apparent acceptance of this program by the angling public and guides likely minimized any problems of incorrectly censoring a fish that was actually harvested in the fishery.

Previous estimates of the return of late-run chinook salmon based on capture-recapture experiments suffered from both bias and imprecision (Alexandersdottir and Marsh 1990). Lack of precision was caused by marking and recapturing too few fish. Bias resulted from size-selective sampling and marking non-Kenai chinook salmon. In addition, marked chinook salmon emigrated, or "backed out", of the river (Bendock and Alexandersdottir 1992). Size-selective sampling and backing out were observed in other capture-recapture experiments involving chinook salmon (Johnson et al. 1993, McPherson et al. 1996).

Capture and handling of chinook salmon, at least in intertidal areas of a river, appears to affect their migratory behavior. Of the 141 chinook salmon captured and handled from 1-11 July, 65 (46%) went downstream and were observed at or below the downstream data logger within 3 days of release. During these same dates, a time period when the sonar provided unbiased estimates of chinook salmon, only 609 (8%) of 7,807 chinook salmon targets at the sonar site were considered moving downstream (Burwen and Bosch 1998). This indicates the downstream movement of chinook salmon was not equal

Table 7.-Entry timing into study after release of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996 by time interval captured, sex, and length class.

		Entry timing[a]		
Factor	Element	0-1	2+	Total
Time interval captured	01-07 July	36	20	56
	08-11 July	39	25	64
	12-15 July	49	11	60
	16-17 July	52	21	73
	18-21 July	16	2	18
	22-23 July	48	14	62
	24-25 July	66	8	74
	26-31 July	23	1	24
Sex	Male	187	71	258
	Female	142	31	173
Length class[b]	390-970 mm	156	65	221
	971-1,230 mm	173	37	210

[a] Entered the study within 1 day after release or took at least 2 days to enter the study after release.

[b] Based on median length (= 970 mm) of all chinook salmon fitted with a radio transmitter.

Table 8.-Number of transmittered chinook salmon that migrated upstream of the Soldotna Bridge (Upper) or were known alive at the end of study downstream of the bridge (Lower), and median number of days between date captured and date that fish upstream of the Soldotna Bridge reached the bridge, for chinook salmon fitted with a radio transmitter in the Kenai River during July 1996.

Date captured	Lower	Upper	Median days
01-07 July	6	29	10
08-11 July	10	33	7
12-15 July	11	39	5
16-17 July	25	33	5
18-21 July	7	4	4
22-23 July	21	24	4
24-25 July	26	21	4
26-31 July	14	3	4
Total	120	186	

between marked and unmarked fish. We also found that the time period when a chinook salmon was captured and size of the fish impacted the number of days it took for the fish to actually enter the study. These results have important implications for capture-recapture studies designed to estimate inriver return or migratory timing of chinook salmon.

Harvest of late-run chinook salmon, and likely exploitation rate, was low in 1996 (Hammarstrom 1997, King 1997). A 100-year flood occurred in the Kenai River in September 1995 followed by a winter of low snow pack. The resultant changes to portions of the river channel, poor water clarity, and low water conditions caused a reduction in both angler effort and catch rate (King 1997). This perhaps explains why, in a fishery size-selective for larger fish (Alexandersdottir and Marsh 1990), size did not significantly affect the hazard rate due to sport harvest because anglers tended to harvest chinook salmon that they caught rather than releasing smaller fish in hopes of harvesting a larger fish. Even so there was some indication that mortality due to sport harvest perhaps increased with increasing size. Although not statistically significant, point estimates of the regression coefficients and the estimated risk ratio indicate that the hazard rate increased with increasing size category.

The fact that survival rate did not differ among time-of-entry groups does not indicate that exploitation rate was relatively constant during July. The estimates are for the group of fish that enter the river in a time interval and not the exploitation rate during that interval. Exploitation rate of each group was affected both by the migratory timing of chinook salmon of each group between the sonar site and the Soldotna Bridge and the daily exploitation rate (instantaneous mortality rate due to sport harvest) during that migratory time interval. Chinook salmon that entered the river early in July had a relatively low daily exploitation rate but also tended to migrate more slowly, whereas fish that entered later in July were exposed to a relatively higher daily exploitation rate but tended to migrate more quickly through the lower river.

We recommend at least two modifications to this study in 1997 to improve monitoring of transmittered chinook salmon. First, additional data loggers should be placed along the river to improve locating fish. This will be especially important downstream of release of handled chinook salmon to better determine if a fish emigrated from the river or remained at risk to the sport fishery in the lower portion of the river. Second, aerial monitoring should be conducted on Mondays and during evenings. Aerial tracking downstream of the Soldotna Bridge was difficult in 1996 due to noise from boats, cellular phones, and other sources. There was less background noise on Mondays and during evenings when there were fewer people on the river. We also recommend that the level of sample effort and public contact/education be maintained in 1997 to minimize problems of bias and imprecision.

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APPENDIX A

Appendix A1.-Fate (H, C, or S) of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996 by time interval of entry into the study, sex, and length class.

		Length class[a]															
		390-865 mm			866-970 mm			971-1,045 mm			1,046-1,230 mm			Total			Grand
Dates	Sex	H[b]	C[b]	S[b]	H	C	S	H	C	S	H	C	S	H	C	S	Total
1-7 July	F		1	2	2	1	3	1	1	2		2		3	5	7	15
	M		10	5	1	4	1	1	4	4	2	2	1	4	20	11	35
8-11 July	F		1			1	4	1		2		1	2	1	3	8	12
	M	1	10	10			5	2	1	5	3		4	6	11	24	41
12-15 July	F	1	1	2	1	2	5		5	7		1	3	2	9	17	28
	M	1	3	5	1		3	2	3	2		4	8	4	10	18	32
16-17 July	F				1	1	10		1	3	1	1	2	2	3	15	20
	M	1	6	8		1	7			3	1	4	6	2	11	24	37
18-21 July	F				2	1	7	1	3	3		1		3	5	10	18
	M	1	2	12	1	1	2	1	1	4		3	8	3	7	26	36
22-23 July	F					7	7	2	4	3			1	2	11	11	24
	M		2	6		2	4		4	4	1	3	8	1	11	22	34
24-25 July	F			3	2	7	6	2	7	7		2	5	4	16	21	41
	M	2	2	4	1	2	4	1	4	3	1	5	13	5	13	24	42
26-31 July	F			2		3	7	1	1	6	1		3	2	4	18	24
	M			11	1		3			2	2		6	3	0	22	25
Total		7	38	70	13	33	78	15	39	60	12	29	70	47	139	278	464

[a] Based on quartiles of length measurement of all chinook salmon fitted with a radio transmitter.

[b] H = sport harvest mortality, C = censored, and S = survived to end of study.

Appendix A2.-Status of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996 by sex and length class within each time interval of capture.

		Length class[a]					
		390-970 mm		971-1,230 m		Total	
Date Captured	Sex	No[b]	Yes	No	Yes	No	Yes
1-7 July	F	3	9		5	3	14
	M	2	27		15	2	42
8-11 July	F	4	8	2	10	6	18
	M	11	30	2	16	13	46
12-15 July	F	1	12	4	13	5	25
	M	2	14	2	21	4	35
16-17 July	F	5	18	1	13	6	31
	M	4	28	2	14	6	42
18-21 July	F	1	2	1	5	2	7
	M		2		9	0	11
22-23 July	F	3	18	1	8	4	26
	M	3	16	4	20	7	36
24-25 July	F	2	15	4	23	6	38
	M	1	10	5	26	6	36
26-31 July	F	3	6	2	8	5	14
	M	4	6	4	4	8	10
Total	F	22	88	15	85	37	173
	M	27	133	19	125	46	258
Grand Total		49	221	34	210	83	431

[a] Based on median length (= 970 mm) of all chinook salmon fitted with a radio transmitter.

[b] Located chinook salmon entered the river and were considered at risk to the inriver sport fishery. Chinook salmon not located were never observed inriver or were observed at a downstream data logger a few hours after release, indicating the fish emigrated from the river, and never observed inriver again.

Appendix A3.-Entry timing into study after release of chinook salmon fitted with a radio transmitter in the Kenai River during July 1996 by time interval captured, sex and length class.

		Length class[a]					
		390-970 mm		971-1,230 m		Total	
Date Captured	Sex	0-1[b]	2+[b]	0-1	2+	0-1	2+
01-07 July	F	9		3	2	12	2
	M	15	12	9	6	24	18
08-11 July	F	5	3	6	4	11	7
	M	16	14	12	4	28	18
12-15 July	F	11	1	12	1	23	2
	M	8	6	18	3	26	9
16-17 July	F	13	5	8	5	21	10
	M	21	7	10	4	31	11
18-21 July	F	2		5		7	0
	M	2		7	2	9	2
22-23 July	F	12	6	8		20	6
	M	11	5	17	3	28	8
24-25 July	F	12	3	22	1	34	4
	M	8	2	24	2	32	4
26-31 July	F	6		8		14	0
	M	5	1	4		9	1
Total	F	70	18	72	13	142	31
	M	86	47	101	24	187	71
Grand Total		156	65	173	37	329	102

[a] Based on median length (= 970 mm) of all chinook salmon fitted with a radio transmitter.

[b] Entered the study within 1 day after release or took at least 2 days to enter the study after release.