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Estimation of the Abundance of Late-run Chinook Salmon in the Kenai River Based on Exploitation Rate and Harvest, 1997

by

S. L. Hammarstrom

and

James J. Hasbrouck

June 1999

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
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
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

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

Mathematics, statistics, fisheries

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

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S. L. Hammarstrom
Division of Sport Fish, Soldotna
and
James J. Hasbrouck
Division of Sport Fish, Research and Technical Services, Anchorage

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

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S .L. Hammarstrom
Alaska Department of Fish and Game, Division of Sport Fish
43961 K-Beach Road, Suite B, Soldotna, AK 99669-8367, USA

James J. Hasbrouck
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, AK 99518-1599, USA

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LIST OF APPENDICES

Appendix **Page**

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 1997. Harvest estimated by an onsite creel survey was 9,809 (SE = 704) fish. Exploitation rate was estimated by monitoring and determining fate of chinook salmon fitted with a radio transmitter. Marked chinook salmon were combined into five groups based on time of entry into the river. Exploitation rate did not differ (P > 0.05) by gender, size, or time-of-entry group. A total of 53 marked chinook salmon were harvested by the sport fishery. The estimated exploitation rate was 0.251 (SE = 0.020). The inriver return of 39,080 (SE = 4,207) fish estimated by this study was significantly (P = 0.01) less than that obtained by sonar (49,933 fish; SE = 876). These same results were observed in 1996 and indicate 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 runs. 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.

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 (Bosch and Burwen 1999).

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 chinook salmon late run is being questioned. The estimate of the return of late-run chinook salmon in 1996 from the sonar was greater than that based on estimates of harvest and exploitation rate (Hammarstrom and Hasbrouck 1998). Differences between the estimates indicated the sonar was potentially classifying some targets as chinook salmon that were actually sockeye salmon. However, results from 1996 were the first and only valid assessment of the accuracy of the sonar during the late run. Previous estimates of the inriver return from capture-recapture experiments were biased high (Bernard and Hansen 1992). 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 results from the 1996 studies has raised concerns about the accuracy of the sonar estimates of the late run.

Split-beam sonar was used in 1997 to estimate the number and direction of travel of targets, and to identify targets that were chinook salmon (Bosch and Burwen 1999). Our study was conducted to provide a second estimate of the inriver return of the late run of chinook salmon independent of the estimate based on the sonar. We then conducted a test 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 (rkm) 34, downstream to Cook Inlet. The sonar site is located at rkm 13.5. Passage of sockeye salmon is indexed by sonar at rkm 30.6 (Ruesch and Fox 1998).

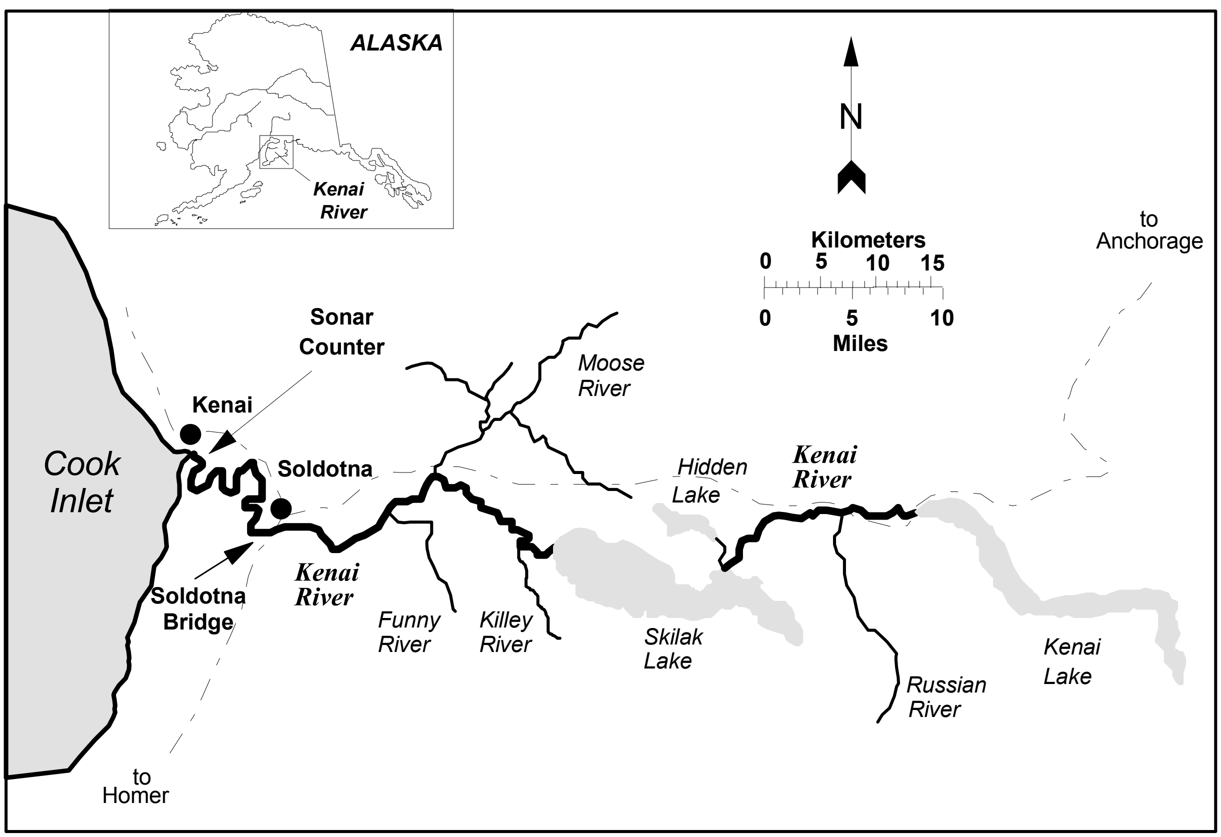


Figure 1.-Map of the Kenai River drainage.

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 Fisheries 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. Details of the methods and results of the creel survey are found in Marsh (1999).

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 cannot be relocated.

CAPTURE AND MARKING

Chinook salmon were captured near the sonar site (rkm 8.0–rkm 16.1) from 30 June through 31 July and fitted with radio transmitters. Four two-person crews fishing drift gillnets of 18.4 cm or 14.0 cm 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 (mideye to fork-of-tail) to the nearest millimeter and gender 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.[1] (ATS), operated in the frequency range of 150.500 mhz to 153.500 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 R4000). 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 two locations downstream of the release site of most captured chinook salmon: one at approximately rkm 9.6 and the second at approximately rkm 11.3. A third receiver and logger were placed on the river bank near the sockeye salmon sonar site at rkm 30.6. A fourth receiver and logger were placed on the river bank at rkm 33.9 just upstream of the Soldotna Bridge. The frequency and pulse code of at-large transmitters was 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 two receivers 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 rkm 0 and rkm 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 rkm 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 rkm 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 rkm. 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

[1] Use of a company's name does not constitute endorsement.

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 (Bendock and Alexandersdottir 1992, Hammarstrom and Hasbrouck 1998):

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;
9. Recapture: recaptured by the inriver netting crew; and
10. Unknown: never located after release or lost to follow-up.

Fish observed moving downstream of the two downstream data loggers 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, were recaptured, or were located in the study area but their ultimate fate was unknown. The radio transmitter was removed from recaptured chinook salmon. 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 lower 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. Inriver return of late-run chinook salmon from the sonar program (Bosch and Burwen 1999) and of harvest and exploitation rate from this study were 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 2-10 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):

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

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

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

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 $\hat{E}$ between the sonar site and Soldotna Bridge was then estimated as:

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

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 (= 2-10) 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:

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

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

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, gender, 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:

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

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 method divided fish into four length classes based on quartiles, and the second method 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 ($\alpha = 0.05$) covariate would indicate exploitation rate and harvest must be stratified by that variable.

Inriver Return

Inriver return $\hat{N}_e$ was estimated as a function of harvest $\hat{H}$ and exploitation rate by:

$$\hat{N}_e = \frac{\hat{H}}{\hat{E}}, \qquad (10)$$

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

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

where:

$\hat{H}$ and $\hat{V}\left(\hat{H}\right)$ = 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 $\hat{N}_s$ did not differ from that estimated by this project $\hat{N}_e$ was tested by:

$$z_{\alpha/2} = \frac{\hat{N}_e - \hat{N}_s}{\sqrt{\hat{V}\left(\hat{N}_e\right) + \hat{V}\left(\hat{N}_s\right)}}, \qquad (12)$$

where:

$\hat{N}_s$ and $\hat{V}\left(\hat{N}_s\right)$ = 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

The telemetry data also provided some information on migratory timing of chinook salmon. A logistic regression analysis was conducted to determine if time interval of capture, gender, or median length class differed between chinook salmon that entered the study within the day after release with those that entered the study two 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 minimum, median, and maximum 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. A Kruskal-Wallis test (Hollander and Wolfe 1973) was used to determine if the migration rate (median number of days) did not differ among groups.

RESULTS

Over 85% of the 352 chinook salmon fitted with a radio transmitter provided data to estimate exploitation rate (Table 1). The time-of-entry group, gender, and length class were determined for each of these chinook salmon (Appendix A1). Of the fish that provided failure time data, 53 (17%) were harvested by the sport fishery between the sonar site and the Soldotna Bridge, 46% were censored, and the remaining 37% survived until 1 August (Table 2). The majority (n = 92) of chinook salmon that were censored emigrated downstream from the river and were not observed inriver again. Only 11 (8%) of the censored chinook salmon were last observed between the sonar site and the Soldotna Bridge. Other causes of censoring included sport harvest upstream of the Soldotna Bridge (n = 8), recapture by the netting crew (n = 6), transmitter observed inriver upstream of the release site but on mortality mode (n = 14), last observed upstream of the Soldotna Bridge (n = 8), and known hook-and-release by the sport fishery (n = 2).

EVALUATING MODEL ASSUMPTIONS

A logistic regression analysis detected a significant (Type III likelihood ratio: χ^2 = 6.16, df = 1, P = 0.01) difference between chinook salmon that provided data and those that provided no data due to median length class (Table 3, Appendix A2): nearly 67% of the chinook salmon that provided no data were of median length or smaller. However, this does not indicate that chinook salmon providing data were a biased sample. Only 45 transmittered chinook salmon provided no data, so we had nearly an equal number of chinook salmon that provided data in both size classes. There was no effect of gender (χ^2 = 1.22, df = 1, P = 0.27) or time interval of capture (χ^2 = 5.82, df = 4, P = 0.21) 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 for transmittered chinook salmon that entered the river during the latter half of July and more curvilinear for those that entered the first half of the month. The plot of some 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 = 6.44, df = 4, P = 0.17) between a proportional

Table 1.-Number of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997.

Release	Located[a]		
Date	Yes	No	Total
30-Jun	4		4
1-Jul	11	2	13
2-Jul	22	2	24
3-Jul	23		23
7-Jul	11	1	12
8-Jul	37	6	43
9-Jul	31	2	33
10-Jul	36	1	37
13-Jul	7	4	11
15-Jul	13	4	17
16-Jul	17	3	20
17-Jul	26	4	30
20-Jul	14	6	20
21-Jul	4	1	5
22-Jul	7	2	9
23-Jul	9	2	11
24-Jul	12	3	15
27-Jul	9		9
28-Jul	4	1	5
29-Jul	4	1	5
30-Jul	4		4
31-Jul	2		2
Total	307	45	352

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

Table 2.-Fate of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997.

	Fate[a]			
Dates[b]	Harvested	Censored	Survived	Total
01 - 07 July	10	29	23	62
08 - 09 July	9	34	23	66
10 - 15 July	13	33	17	63
16 - 21 July	10	35	19	64
22 - 31 July	11	10	31	52
Total	53	141	113	307

[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.

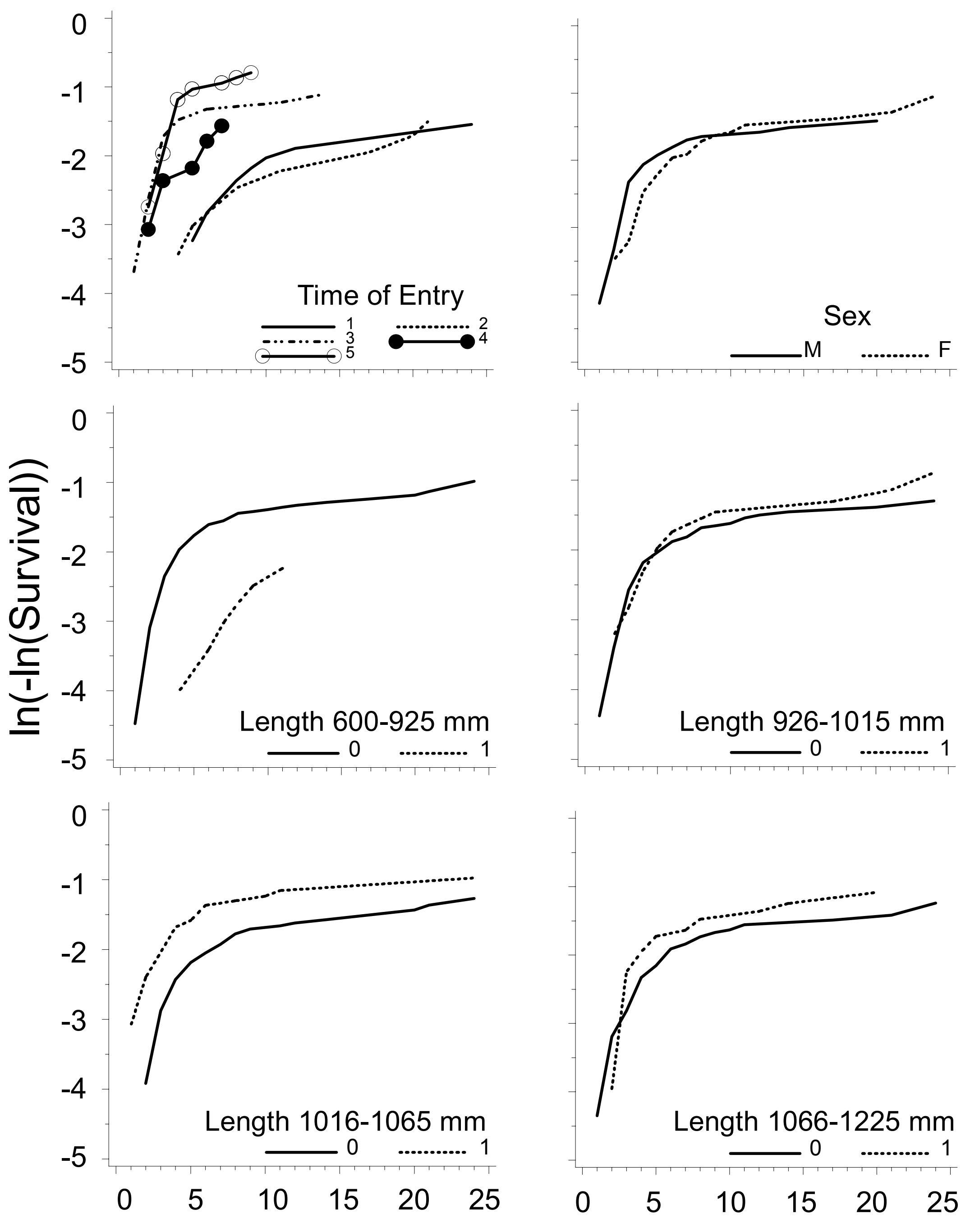
Table 3.-Status of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997 by time interval captured, gender, and length class.

		Located[a]		
Factor	Element	Yes	No	Total
Time interval captured	30 June - 07 July	71	5	76
	08 - 09 July	68	8	76
	10 - 15 July	56	9	65
	16 - 21 July	61	14	75
	22 - 31 July	51	9	60
Gender[b]	Male	146	17	163
	Female	160	28	188
Length class[c]	600 - 1,015 mm	148	31	179
	1,016 - 1,225 mm	159	14	173

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

[b] Gender not recorded for one individual with length of 1,055 mm.

[c] Based on median length (= 1,015 mm) of all chinook salmon fitted with a radio transmitter.



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: 0 = fish that were not in the length group; 1 = fish that were in the length group.

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

hazards model with no covariates and a model with gender and four length classes as covariates. Further testing showed that only chinook salmon in the smallest length class (600-925 mm) had a nearly significantly lower (Wald χ^2 = 3.20, df = 1, P = 0.07) hazard rate than those in the other length classes. There was no difference in the hazard rate among the other length classes (Wald $\chi^2 \leq 0.06$, df = 1, P $\geq$ 0.81) or due to gender (Wald χ^2 = 0.18, df = 1, P = 0.67). A model with gender, median length class, and a gender*median length class interaction was significant (likelihood ratio χ^2 = 9.42, df = 3, P = 0.02) due to a significant (Wald χ^2 = 5.77, df = 1, P = 0.02) interaction term. This result occurred because the last time-of-entry group, which had the highest estimate of exploitation rate among groups (see below), was composed primarily of females of median length or smaller and males larger than the median length (Appendix A2). We concluded there was no meaningful effect of gender or length that would require stratification of the data.

EXPLOITATION RATE

The estimated exploitation rate of late-run chinook salmon over the entire study period was 0.251 (SE = 0.020; Table 4, Appendix A3). 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 (χ^2 = 7.78, df = 4, P = 0.10) or show any trends (Table 4, Figure 3) among groups. Weighting estimates of exploitation rate of each group by CPUE data did not significantly (|z| = 0.50, P = 0.62) alter the overall estimate of exploitation rate. Estimates of exploitation rate ranged from 0.197 (SE ≤ 0.037) for chinook salmon entering the river 1-9 July to 0.379 (SE = 0.052) for chinook salmon entering the river 22-31 July.

INRIVER RETURN

Based on the estimated exploitation rate and a sport harvest of 9,809 (SE = 704) chinook salmon between the sonar site and the Soldotna Bridge, an estimated 39,080 (SE = 4,207) chinook salmon returned to the Kenai River from 1-31 July. The inriver return of 49,933 (SE = 876) chinook salmon estimated by sonar (Bosch and Burwen 1999) was significantly (|z| = 2.53, P = 0.01) greater than this estimate (Table 5).

Based on results of the proportional hazards model, we examined the effect of the potential difference in exploitation rate between chinook salmon 925 mm or smaller and those larger than 925 mm on the estimated inriver return. The creel survey and telemetry data were stratified by size class to estimate harvest and exploitation rate for each group. Inriver return of each size group was then estimated and summed to get an estimate of the total return. The stratified estimate of 43,031 (SE = 5,802) chinook salmon in the inriver return did not differ significantly (|z| = 0.55, P = 0.58) from the nonstratified estimate. Although the stratified estimate did not differ significantly (|z| = 1.18, P = 0.24) from the sonar estimate, the stratified estimate was also less precise than the nonstratified estimate and the point estimate was still nearly 7,000 chinook salmon less than that of the sonar estimate.

MIGRATORY TIMING

Capture time interval significantly (χ^2 = 28.73, df = 4, P < 0.001) affected whether transmittered chinook salmon entered the study area within 1 day after capture or entered 2 or more days after capture (Table 6, Appendix A4). Chinook salmon captured from 30 June-7 July tended to delay entry into the study area and all those captured from 22-31 July entered the study area by the day after capture. Because capture, handling, and release were similar for all chinook salmon,

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 late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997.

Dates	S_i	E_i	$SE(E_i)$	w_i [a]	E_{wi} [b]
01 - 07 July	0.803	0.197	0.037	0.323	0.064
08 - 09 July	0.803	0.197	0.036	0.138	0.027
10 - 15 July	0.710	0.290	0.058	0.282	0.082
16 - 21 July	0.808	0.192	0.039	0.155	0.030
22 - 31 July	0.621	0.379	0.052	0.103	0.039
01 - 31 July [c]	0.749	0.251	0.020	1.000	0.241

[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.

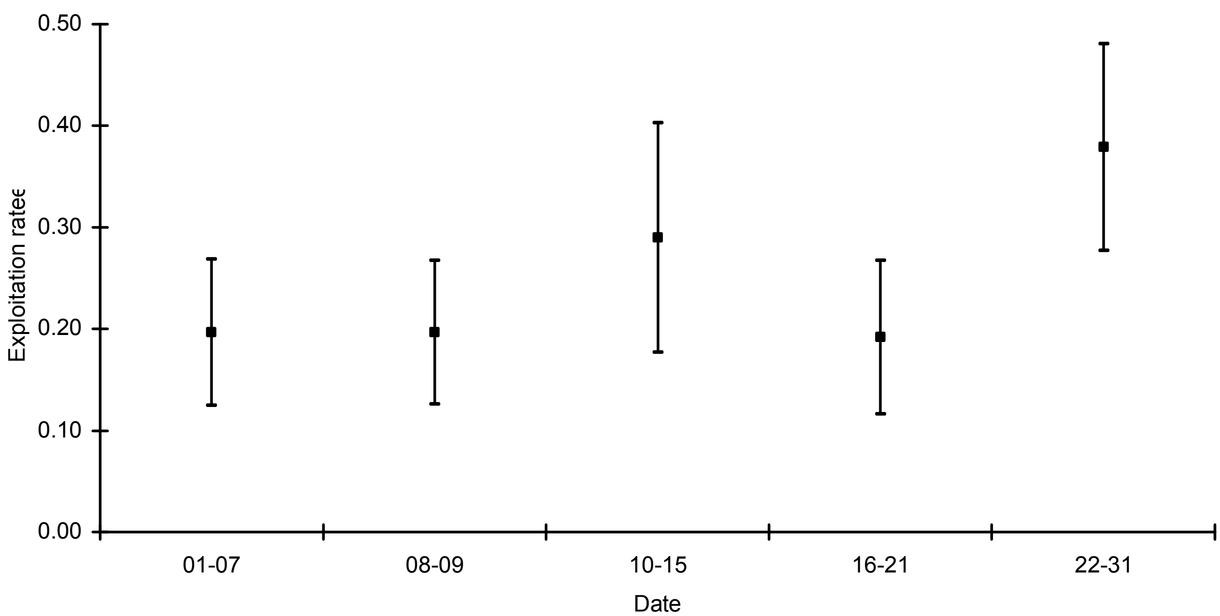


Figure 3.-Estimated exploitation rate, with 95% confidence interval estimates, of transmittered chinook salmon grouped by date of entry into the Kenai River in July 1997.

Table 5.-Estimated harvest and exploitation rate between the sonar site and the Soldotna Bridge, inriver return time interval captured, gender, and length class. Dual beam sonar (Ns), with standard errors in parentheses, of chinook salmon into the Kenai River during July 1997.

Harvest	Exploitation	$N_{f(H, E)}$	N_S	% difference[a]
9,809	0.251	39,080	49,933	28
(704)	(0.020)	(4,207)	(876)	

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

these differences were likely more indicative of fish behavior and not a result of differential handling. There was no difference in entry pattern due to gender ($\chi^2 = 0.24$, df = 1, P = 0.63) or median length class ($\chi^2 = 0.40$, df = 1, P = 0.71).

The proportion of chinook salmon that migrated upstream of the Soldotna Bridge to spawn did not differ ($\chi^2 = 1.04$, df = 4, P = 0.90) among time of capture groups (Table 7). Of the 156 transmittered chinook salmon known to be alive at the end of July or that had migrated past the upstream data logger during the month, 86% had migrated upstream of the Soldotna Bridge. For chinook salmon observed upstream of the Soldotna Bridge, the median number of days between the date captured and the date of migration past the rkm 33.9 data logger differed significantly ($\chi^2 = 15.65$, df = 4, P = 0.004) among capture groups. In general the median number of days was less for chinook salmon captured during the latter half of July than for those marked earlier in the month. However, the minimum number of days of migration was nearly identical among all groups and the maximum number of days showed no consistent pattern. This indicates there was much individual variation in migration rate among chinook salmon regardless of their time of entry into the river during July.

DISCUSSION

The split-beam sonar overestimated the inriver return of late-run chinook salmon to the Kenai River in 1997. This is consistent with results observed in 1996 (Hammarstrom and Hasbrouck 1998). In fact each program had nearly the same estimate of inriver return during both years: estimates from sonar were 49,755 chinook salmon in 1996 and 49,933 chinook salmon in 1997, while estimates calculated as a function of exploitation rate and harvest were 39,356 chinook salmon in 1996 and 39,080 chinook salmon in 1997. The biggest difference in estimation between years was a nearly doubling of the estimate of exploitation rate and of harvest in 1997 relative to those observed in 1996. The sonar estimate may be biased high because targets that are likely sockeye salmon are incorrectly classified as chinook salmon (Burwen et al. 1998, Hammarstrom and Hasbrouck 1998); however, a relatively small proportion of the sockeye salmon return is classified as chinook salmon. The point estimates from the two studies differed by 10,853 fish for the entire month, which is small relative to an estimated inriver return of over 738,700 sockeye salmon to the Kenai River during July (Ruesch and Fox 1998). This bias is also larger than the differences between "trigger points" of the projected escapement that require inseason

Table 6.-Entry timing into study after release of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997 by time interval captured, gender, and length class.

		Entry timing[a]		
Factor	Element	0-1	2+	Total
Time interval captured	30 June - 07 July	54	17	71
	08 - 09 July	63	5	68
	10 - 15 July	54	2	56
	16 - 21 July	59	2	61
	22 - 31 July	51	0	51
Gender[b]	Male	132	14	146
	Female	148	12	160
Length class[c]	600 - 1,015 mm	133	15	148
	1,016 - 1,225 mm	148	11	159

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

[b] Gender not recorded for one individual with length of 1,055 mm.

[c] Based on median length (= 1,015 mm) of all chinook salmon fitted with a radio transmitter.

Table 7.-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 the minimum, median, and maximum number of days between date captured and date that fish upstream of the Soldotna Bridge reached the bridge, for late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997.

			Number of days		
Date captured	Lower	Upper	Min	Med	Max
30 June - 07 July	7	36	2	7	23
08 - 09 July	5	27	2	9	40
10 - 15 July	2	17	3	8	31
16 - 21 July	5	26	2	5	18
22 - 31 July	3	28	3	4	24
Total	22	134			

management action to restrict the sport and potentially commercial fisheries, to meet the escapement goal for chinook salmon as described in the Kenai River late-run chinook salmon management plan (Hammarstrom and Timmons *In prep*). Regardless, this bias is rather large relative to the return of late-run chinook salmon (28%) and may overestimate the productivity of late-run chinook salmon (Hammarstrom and Timmons *In prep*). Assessment programs are being initiated or modified and sonar data other than that currently used to classify targets are being examined (Bosch and Burwen 1999) to improve the accuracy of the estimated inriver return of late-run chinook salmon to the Kenai River.

The inriver return estimated as a function of harvest and exploitation rate was relatively unbiased and precise (relative precision of 21%). The creel survey contained several strata to minimize bias and improve precision (Marsh 1999). One level of stratification, upstream vs. downstream of the sonar site, was used in this report to provide an estimate of inriver return comparable to that of the sonar gear. This level of stratification was not necessary to estimate overall levels of effort, catch, and harvest of late-run chinook salmon because it did not significantly ($P > 0.05$) improve the accuracy of these statistics (Marsh 1999). The creel survey also sampled at least 65% of all days opened to fishing during July and the entire fishing day was sampled to minimize length-of-stay bias (Pollock et al. 1994, Bernard et al. 1998). Estimated harvest was very accurate and precise with this level of sampling effort.

No obvious violation of model assumptions or other sources of bias were detected in the estimate of exploitation rate. Stratification by size did not significantly improve accuracy of the estimated inriver return, provided an estimate that was less precise (relative precision = 26%), and did not alter our overall result of bias in the sonar estimate of inriver return. Weighted estimates of exploitation rate did not dramatically improve the accuracy of the overall estimate of exploitation rate. It is possible the exploitation rate of the 22-31 July entry group differed from other groups but our statistical power was too low to detect a difference. However, catch rate of chinook salmon by the netting crew was so low during this interval that it appears a relatively low proportion of the overall return entered the river during this time interval. Some chinook salmon that were censored or that provided no data were perhaps harvested in the sport fishery, but so few transmittered chinook salmon were lost entirely that this source of error should create little bias. The inriver migratory behavior of individual chinook salmon, release of a large number of fish with a transmitter throughout the month, vigilant monitoring and recovery program, and good cooperation from the angling public and guides all helped provide a relatively accurate, precise estimate of exploitation.

Our estimate of inriver return was slightly less precise than that obtained in 1996 (Hammarstrom and Hasbrouck 1998). This is due to a combination of reduced precision in the estimates of both harvest and exploitation rate. The estimate of harvest was likely less precise in 1997 because there was more angler effort, and more variation in angler effort, than in 1996. The estimate of exploitation rate was less precise in 1997 because we captured fewer chinook salmon for marking than in 1996. We tried to capture 150-200 chinook salmon during the last 10 days of July each year. We attained our sample goal in 1996 but did not in 1997 because catch rate declined dramatically during this time interval.

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).

The addition of two data loggers along the river bank and conducting aerial surveys on Mondays and during evenings, as recommended by Hammarstrom and Hasbrouck (1998), improved our ability to determine the location and status of transmittered chinook salmon. In 1996, with only two data loggers present, it was difficult to determine the status of a number of fish; whether the chinook salmon was alive and present in the river on any given day. The additional data loggers and better aerial survey data in 1997 minimized assigning an incorrect fate to transmittered chinook salmon.

In 1997 we could not compare estimates of inriver return from this project with that of the sonar during the portion of July when the river had relatively few sockeye salmon and the remainder of July when several hundred thousand sockeye salmon entered the river. Hammarstrom and Hasbrouck (1998) found that when daily passage of sockeye salmon numbered a few thousand during early July 1996, there was little bias in the sonar estimate of the inriver return of chinook salmon. We believe this comparison was not possible in 1997 for at least two reasons: (1) distribution of transmittered chinook salmon in the sport fishery, and (2) characteristics of the fishery itself. It is likely that the sample of transmittered chinook salmon was not distributed throughout the river downstream of the Soldotna Bridge during the first few days of July. Thus, the sample during the first few days was probably not representative of the chinook salmon present downstream of the bridge during this time. This sampling problem also occurred in 1996 but the dynamics of the fishery were such that this problem caused little bias. In 1996 the fishery was opened to use of bait on 9 June, and angler effort and catch rate were relatively low throughout June and July (King 1997). The fishery in 1997 was restricted the last two weeks of June to "trophy" fishing, which also reduced angler effort. On 1 July use of bait was allowed, catch rate was more typical in early July 1997 than that observed in 1996, and effort increased dramatically in early July relative to that observed in late June (Marsh 1999).

The less restrictive fishery prior to July and the low effort and catch rates observed in 1996 meant that relatively few chinook salmon were harvested the first few days of July. The few days that it took the initial group of transmittered chinook salmon to distribute themselves throughout the fishery downstream of the Soldotna Bridge likely also introduced little bias in the estimate of exploitation rate during this time. Restrictions to the fishery in June 1997 allowed the population of chinook salmon present downstream of the bridge to gradually grow, and in early July, with the dramatic increase in angler effort and use of bait that increased catch rates, several hundred chinook salmon were harvested. Because transmittered chinook salmon were largely still downstream of where most of the fishery occurred in early July, the estimate of exploitation was biased low relative to the true exploitation rate of chinook salmon in the fishery, and the estimate of inriver return was biased high. Over the entire month of July

1997 this bias likely becomes negligible because the harvest of chinook salmon that entered the Kenai River prior to 1 July (i.e., individuals not represented by the transmittered sample) is small relative to the entire harvest during the month.

In general the migratory patterns observed in 1996 were also seen in 1997. A greater proportion of chinook salmon transmittered early in July delayed entry into the river relative to those transmittered later in the month. In addition, chinook salmon that migrated upstream of the Soldotna Bridge on average migrated more quickly during the latter portion of the month than those entering the river early in the month. Chinook salmon of median length or smaller tended to delay entry into the river in 1996, which was not observed in 1997; however, a greater proportion of fish of median length or smaller provided no data in 1997. Hammarstrom and Hasbrouck (1998) found that chinook salmon that entered the river in early July 1996 tended to migrate upstream of the Soldotna Bridge to spawn while those that entered later in the month tended to remain downstream of the bridge. In 1997 this was not so: the same proportion of chinook salmon migrated upstream of the bridge regardless of their time of entry during the month. These differences between the years may reflect natural annual variation or arise because the data analyzed for migratory behavior was truncated on 1 August in 1996 but went until 18 August in 1997.

Capture and handling of chinook salmon, at least in intertidal areas of a river, appears to affect their migratory behavior (Hammarstrom and Hasbrouck 1998, Bernard et al. *In press*). Of the 113 chinook salmon captured and handled from 1-8 July, 40 (35%) went downstream and were observed at or below the downstream data loggers within 3 days of release. During these same dates, a time period when the sonar likely provided unbiased estimates of chinook salmon because relatively few sockeye salmon were present, only 462 (8%) of 6,025 chinook salmon targets at the sonar site were considered moving downstream (Bosch and Burwen 1999). This indicates the downstream movement of chinook salmon was not equal between marked and unmarked fish. We also found that the time period when a chinook salmon was captured impacted the number of days it took for the fish to actually enter the study. These results are consistent with those observed in 1996 (Hammarstrom and Hasbrouck 1998) and have important implications for capture-recapture studies designed to estimate inriver return or migratory timing of chinook salmon.

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.

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APPENDIX A. SUPPORTING STATISTICS

Appendix A1.-Fate (H, C, or S) of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997 by time interval of entry into the study, gender, and length class.

		Length class[a]															
		600-925 mm			926-1,015 mm			1,016-1,065 mm			1,066-1,225 mm			Total			Grand
Dates	Sex	H[b]	C	S	H	C	S	H	C	S	H	C	S	H	C	S	Total
01 - 07 July	F		2	2	3	5	2	2	5	5	2	1	1	7	13	10	30
	M	1	9	3		2	2			3	2	5	5	3	16	13	32
08 - 09 July[c]	F	2	4	2	3	6	3	2	9	5		3		7	22	10	39
	M		5	6		1	1		2	1	2	4	4	2	12	12	26
10 - 15 July	F	1	3	1	2	10	5	3	8	2		3		6	24	8	38
	M		2	1	1	2	2	3			3	5	6	7	9	9	25
16 - 21 July	F		1	5	2	5	3	2	6			1	2	4	13	10	27
	M	1	8	5	1	6	1		4	2	4	4	1	6	22	9	37
22 - 31 July	F	1	2	2	3		3	2	1	6		2	4	6	5	15	26
	M			4		1		2		2	3	4	10	5	5	16	26
Total		6	36	31	15	38	22	16	35	26	16	32	33	53	141	112	306

[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.

[c] Gender not recorded for one individual with length of 1,055 mm.

Appendix A2.-Status of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997 by gender and length class within each time interval of capture.

		Length class[a]					
		600-1,015 mm		1,016-1,225 mm		Total	
Date Captured	Gender	No[b]	Yes	No	Yes	No	Yes
30 June - 07 July	F	2	17	1	16	3	33
	M	1	18	1	20	2	38
08 - 09 July[c]	F	5	21	1	20	6	41
	M	1	13	1	13	2	26
10 - 15 July	F	3	20		15	3	35
	M	3	8	3	13	6	21
16 - 21 July	F	7	14	3	11	10	25
	M	3	22	1	14	4	36
22 - 31 July	F	3	11	3	15	6	26
	M	3	4		21	3	25
Total	F	20	83	8	77	28	160
	M	11	65	6	81	17	146
Grand Total		31	148	14	158	45	306

[a] Based on median length (= 1,015 mm) of all chinook salmon fitted with a radio transmitter.

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

[c] Gender not recorded for one individual with length of 1,055 mm.

Appendix A3.-Number at risk (n_{ij}), harvested by the inriver sport fishery (d_{ij}), or censored (c_{ij}); and cumulative estimates of survival rate (S_i), exploitation rate (E_i), and standard error of exploitation rate [$SE(E_i)$], on day j for chinook salmon in time interval of entry group i fitted with a radio transmitter in the Kenai River during July 1997.

01 - 07 July

Date	n_{ij} [a]	d_{ij}	c_{ij}	S_i	E_i	$SE(E_i)$
1-Jul	12			1.000	0.000	0.000
2-Jul	28			1.000	0.000	0.000
3-Jul	45			1.000	0.000	0.000
4-Jul	48			1.000	0.000	0.000
5-Jul	50	2		0.960	0.040	0.006
6-Jul	50	1	1	0.941	0.059	0.008
7-Jul	58		1	0.941	0.059	0.008
8-Jul	57	2	1	0.908	0.092	0.012
9-Jul	54	1		0.891	0.109	0.014
10-Jul	53	1	1	0.874	0.126	0.016
11-Jul	51			0.874	0.126	0.016
12-Jul	51	1	2	0.857	0.143	0.019
13-Jul	48			0.857	0.143	0.019
14-Jul	48		1	0.857	0.143	0.019
15-Jul	47		2	0.857	0.143	0.019
16-Jul	45		6	0.857	0.143	0.020
17-Jul	39		0	0.857	0.143	0.021
18-Jul	39		1	0.857	0.143	0.021
19-Jul	38		2	0.857	0.143	0.021
20-Jul	36		2	0.857	0.143	0.022
21-Jul	34		2	0.857	0.143	0.023
22-Jul	32			0.857	0.143	0.023
23-Jul	32			0.857	0.143	0.023
24-Jul	32	2	1	0.803	0.197	0.031
25-Jul	29		3	0.803	0.197	0.033
26-Jul	26			0.803	0.197	0.035
27-Jul	26		1	0.803	0.197	0.035
28-Jul	25		1	0.803	0.197	0.035
29-Jul	24		1	0.803	0.197	0.036
30-Jul	23			0.803	0.197	0.037
31-Jul	23			0.803	0.197	0.037

08 - 09 July

Date	n_{ij} [a]	d_{ij}	c_{ij}	S_i	E_i	$SE(E_i)$
8-Jul	34			1.000	0.000	0.000
9-Jul	66		2	1.000	0.000	0.000
10-Jul	64		1	1.000	0.000	0.000
11-Jul	63	2	2	0.968	0.032	0.004
12-Jul	59	1		0.952	0.048	0.006
13-Jul	58		1	0.952	0.048	0.006
14-Jul	57		1	0.952	0.048	0.006
15-Jul	56	2	2	0.918	0.082	0.011
16-Jul	52		5	0.918	0.082	0.011
17-Jul	47		4	0.918	0.082	0.011
18-Jul	43	1	2	0.897	0.103	0.015
19-Jul	40			0.897	0.103	0.015
20-Jul	40		4	0.897	0.103	0.015
21-Jul	36		1	0.897	0.103	0.016
22-Jul	35		2	0.897	0.103	0.017
23-Jul	33		2	0.897	0.103	0.017
24-Jul	31	1	2	0.868	0.132	0.022
25-Jul	28		1	0.868	0.132	0.023
26-Jul	27			0.868	0.132	0.024
27-Jul	27	1		0.835	0.165	0.029
28-Jul	26	1		0.803	0.197	0.035
29-Jul	25		1	0.803	0.197	0.035
30-Jul	24			0.803	0.197	0.036
31-Jul	24			0.803	0.197	0.036

10 - 15 July

Date	n_{ij} [a]	d_{ij}	c_{ij}	S_i	E_i	$SE(E_i)$
10-Jul	41	1		0.976	0.024	0.004
11-Jul	42	2	2	0.929	0.071	0.011
12-Jul	38	4		0.831	0.169	0.025
13-Jul	40	2	1	0.790	0.210	0.030
14-Jul	37		1	0.790	0.210	0.031
15-Jul	50	2	1	0.758	0.242	0.030
16-Jul	47		4	0.758	0.242	0.031
17-Jul	43		1	0.758	0.242	0.032
18-Jul	42		1	0.758	0.242	0.032
19-Jul	41		4	0.758	0.242	0.033
20-Jul	37	1	3	0.738	0.262	0.037
21-Jul	33		4	0.738	0.262	0.039
22-Jul	29		2	0.738	0.262	0.042
23-Jul	27	1	1	0.710	0.290	0.047
24-Jul	25		1	0.710	0.290	0.049
25-Jul	24		3	0.710	0.290	0.050
26-Jul	21			0.710	0.290	0.053
27-Jul	21			0.710	0.290	0.053
28-Jul	21		1	0.710	0.290	0.053
29-Jul	20		1	0.710	0.290	0.055
30-Jul	19		1	0.710	0.290	0.056
31-Jul	18			0.710	0.290	0.058

16 - 21 July

Date	n_{ij} [a]	d_{ij}	c_{ij}	S_i	E_i	$SE(E_i)$
16-Jul	19			1.000	0.000	0.000
17-Jul	44	2		0.955	0.045	0.007
18-Jul	43	2	3	0.910	0.090	0.013
19-Jul	38			0.910	0.090	0.014
20-Jul	53	1	2	0.893	0.107	0.014
21-Jul	54	3	3	0.843	0.157	0.020
22-Jul	48	2	4	0.808	0.192	0.025
23-Jul	42		3	0.808	0.192	0.027
24-Jul	39		2	0.808	0.192	0.028
25-Jul	37		3	0.808	0.192	0.028
26-Jul	34		3	0.808	0.192	0.030
27-Jul	31		2	0.808	0.192	0.031
28-Jul	29		2	0.808	0.192	0.032
29-Jul	27		6	0.808	0.192	0.033
30-Jul	21		1	0.808	0.192	0.038
31-Jul	20			0.808	0.192	0.039

22 - 31 July

Date	n_{ij} [a]	d_{ij}	c_{ij}	S_i	E_i	$SE(E_i)$
22-Jul	7		1	1.000	0.000	0.000
23-Jul	16	1		0.938	0.063	0.015
24-Jul	27	2	1	0.868	0.132	0.024
25-Jul	24	4		0.723	0.277	0.048
26-Jul	20	1		0.687	0.313	0.058
27-Jul	28		3	0.687	0.313	0.049
28-Jul	29	1	2	0.664	0.336	0.051
29-Jul	30	1	1	0.641	0.359	0.052
30-Jul	32	1		0.621	0.379	0.053
31-Jul	33			0.621	0.379	0.052

[a] Number at risk also changes due to chinook salmon captured and fitted with a radio transmitter on days during the interval of entry into the study.

Appendix A4.-Entry timing into study after release of late-run chinook salmon fitted with a radio transmitter in the Kenai River during 1997 by time interval captured, gender, and length class.

		Length class[a]					
		600-1,015 mm		1,016-1,225 mm		Total	
Date Captured	Gender	0-1[b]	2+	0-1	2+	0-1	2+
30 June - 07 July	F	14	3	13	3	27	6
	M	13	5	14	6	27	11
08 - 09 July[c]	F	18	3	19	1	37	4
	M	12	1	13		25	1
10 - 15 July	F	19	1	15		34	1
	M	8		12	1	20	1
16 - 21 July	F	13	1	11		24	1
	M	21	1	14		35	1
22 - 31 July	F	11		15		26	0
	M	4		21		25	0
Total	F	75	8	73	4	148	12
	M	58	7	74	7	132	14
Grand Total		133	15	147	11	280	26

[a] Based on median length (= 1,015 mm) of all chinook salmon fitted with a radio transmitter.

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

[c] Gender not recorded for one individual with length of 1,055 mm.