Fishery Data Series No. 03-03

Estimates of Chinook Salmon Abundance in the Kenai River Using Split-beam Sonar, 2001

by

James D. Miller,

Debby L. Burwen,

and

Steve J. Fleischman

February 2003

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

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

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

FISHERY DATA SERIES NO. 03-03

ESTIMATES OF CHINOOK SALMON ABUNDANCE IN THE KENAI RIVER USING SPLIT-BEAM SONAR, 2001

by

James D. Miller
and
Debby L. Burwen
Division of Sport Fish, Anchorage
and
Steve J. Fleischman
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

February 2003

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under project F-10-17, Job No. S-2-5b.

The Fishery Data Series was established in 1987 for the publication of technically-oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Fishery Data Series reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm This publication has undergone editorial and peer review.

James D. Miller, Debby L. Burwen,
Alaska Department of Fish and Game, Division of Sport Fish
and Steve J. Fleischman
Alaska Department of Fish and Game, Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska 99518-1599, USA

This document should be cited as:
Miller, J. D., D. L. Burwen, and S. J. Fleischman. 2003. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 2001. Alaska Department of Fish and Game, Fishery Data Series No. 03-03, Anchorage.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

Table **Page**

LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure **Page**

LIST OF APPENDICES

ABSTRACT

The passage of chinook salmon *Oncorhynchus tshawytscha* in the Kenai River in 2001 was estimated using side-looking split-beam sonar technology. Early (16 May-30 June) and late (1 July-10 August) runs of Kenai River chinook salmon have been monitored acoustically since 1987. A 200 kHz split-beam sonar system has been used since 1995 to estimate numbers of adult chinook salmon migrating into the Kenai River. From 1987 to 1994, a 420 kHz dual-beam sonar was used to generate similar estimates. In 2001, total upstream chinook salmon passage from 16 May through 10 August was an estimated 50,592 (SE = 633) fish, composed of 16,676 (SE = 285) fish during the early run and 33,916 (SE = 565) fish during the late run. The variability associated with these estimates reflects only sampling error and not other sources of uncertainty including target detectability, species composition, direction of travel, and target tracking. The daily peak of the early run occurred on 12 June when 50% of the run had passed by that date. The daily peak of the late run occurred on 17 July; 50% of the late run passed by 18 July.

Key words: split-beam sonar, dual-beam sonar, chinook salmon, *Oncorhynchus tshawytscha,* acoustic assessment, Kenai River, riverine sonar, early run, late run.

INTRODUCTION

Chinook salmon *Oncorhynchus tshawytscha* returning to the Kenai River (Figure 1) support one of the largest and most intensively managed recreational fisheries in Alaska (Nelson et al. 1999). Kenai River chinook salmon are among the largest in the world and have sustained in excess of 100,000 angler-days of fishing effort annually. The fishery has been politically volatile because Kenai River chinook salmon are fully allocated and are also harvested in other fisheries during July and August, including the marine commercial sockeye fishery in Upper Cook Inlet, and inriver subsistence and personal use fisheries.

Chinook salmon returning to the Kenai River are managed as two distinct runs, early and late, which typically peak in mid-June and late July, respectively (Burger et al. 1985). Early-run chinook are harvested primarily by sport anglers; late-run chinook are harvested by commercial, sport, subsistence, and personal use fisheries. These fisheries may be restricted if the projected run size falls below escapement goals set by the Alaska Board of Fisheries. From 1989 through 1998 these runs were managed for spawning escapement goals of 9,000 for early-run (16 May-30 June) and 22,300 for late-run (1 July-10 August) chinook salmon (McBride et al. 1989). In February 1999, the Alaska Board of Fisheries set new biological escapement goals based on the escapement of chinook salmon estimated by sonar and our best understanding of its biases (Hammarstrom and Hasbrouck 1998, 1999; Bosch and Burwen 1999). The new escapement goals define a range of escapement levels desired for the early run at 7,700 to 14,000 chinook (5 AAC 56.070 Kenai River Early Run Chinook Management Plan) and the late run at 23,000 to 37,000 chinook (5 AAC 21.359 Kenai River Late Run Chinook Management Plan). These escapement goal ranges should provide for a more stable fishing season without compromising either run.

Sonar estimates of inriver return provide the basis for estimating spawning escapement and implementing management plans that regulate harvest in competing sport and commercial fisheries for this stock. Implementation of these management plans has been a contentious issue for the state, one that commands much public attention. Restrictions on the sport fishery were imposed in each year from 1989 through 1992 to ensure spawning escapement goals were met. Since 1993, the 1997, 1998, and 2000 early runs, and the 1998 late run required a restriction of the sport fishery to meet escapement goals.

The first estimates of chinook salmon abundance were generated for the 1984 late run with a mark-recapture project using drift gillnets (Hammarstrom et al. 1985). The mark-recapture

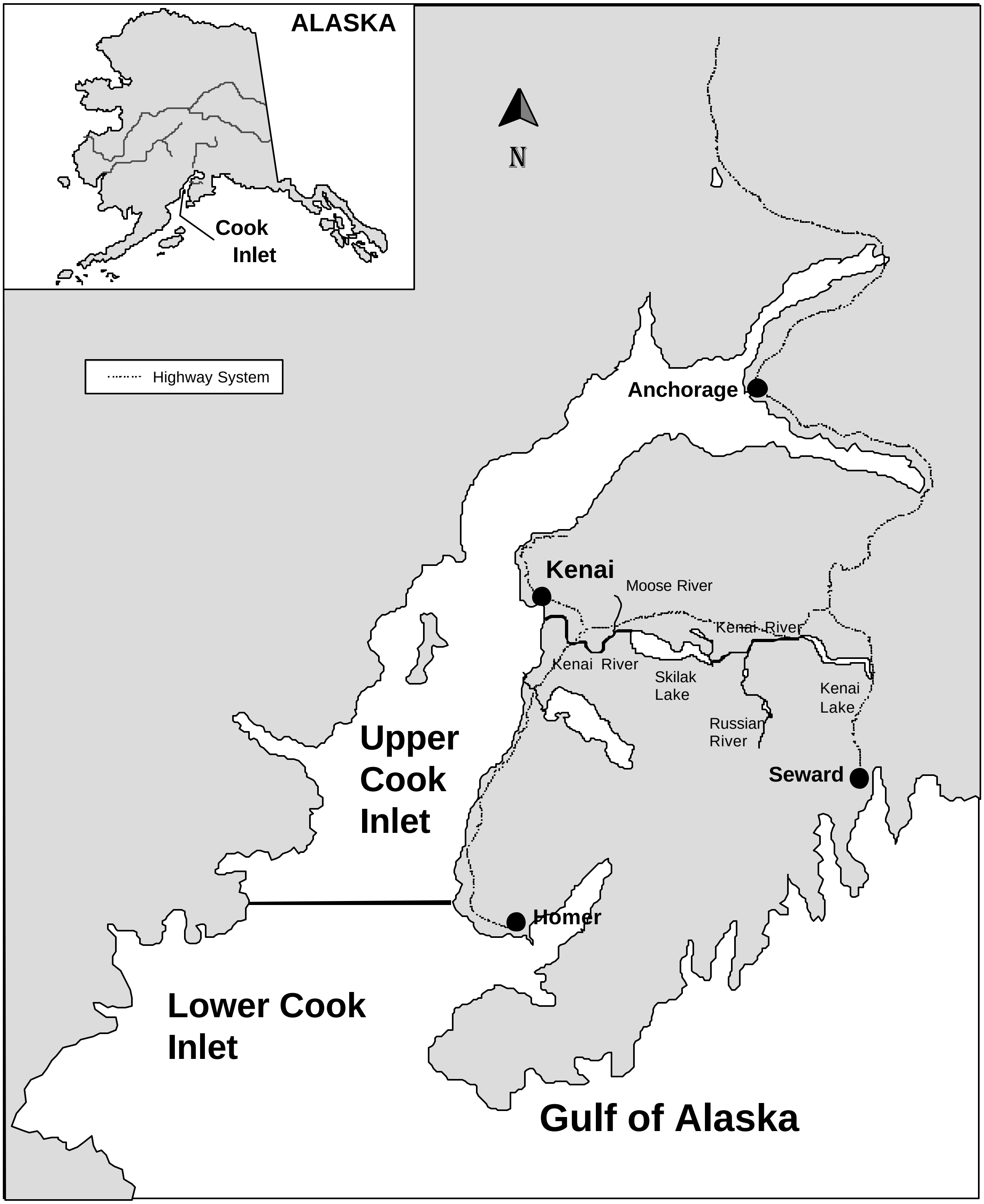


Figure 1.-Cook Inlet showing location of the Kenai River.

project produced estimates of riverine abundance through 1990 (Hammarstrom and Larson 1986; Conrad and Larson 1987; Conrad 1988; Carlon and Alexandersdottir 1989; Alexandersdottir and Marsh 1990, Sonnichsen and Alexandersdottir 1991). These estimates had low precision and were biased high (Bernard and Hansen 1992). The low precision and high bias were more apparent in the late-run estimates due to lower tagging rates and the "backing out" of marked fish. It was hypothesized that handling of marked fish resulted in a higher fraction of marked fish than unmarked fish moving back downstream into Cook Inlet where they were subsequently harvested in the commercial fishery, thus becoming unavailable for recapture.

In order to obtain timely and accurate estimates of chinook salmon passage, the department initiated studies to determine whether an acoustic assessment program could be developed to provide daily estimates of chinook salmon into the Kenai River (Eggers et al. 1995). Acoustic assessment of chinook salmon in the Kenai River is complicated by the presence of more abundant sockeye salmon *O. nerka*, which migrate concurrently with chinook salmon. Since 1987, sockeye salmon escapement estimates generated by the river mile-19 sockeye sonar project have ranged from 625,000 to 1,600,000 (Davis 2001) while late-run chinook salmon escapement estimates generated by the chinook sonar project have ranged from 29,000 to 55,000. Dual-beam sonar was initially chosen for the chinook sonar project because of its ability to estimate acoustic size (target strength), which was to serve as the discriminatory variable to systematically identify and count only large chinook salmon. Due to the considerable size difference between Kenai River chinook salmon and other species of fish present in the river, it was postulated that dual-beam sonar could be used to distinguish the larger chinook salmon from smaller fish (primarily sockeye) and estimate their numbers returning to the river.

Early studies indicated that chinook salmon could be distinguished from sockeye salmon based on target strength and spatial separation in the river. Sockeye salmon were believed to migrate near the bank and to have a smaller target strength than chinook salmon, which preferred the midchannel section of the river. A target strength threshold was established to censor “counts” based on acoustic size. A range threshold was also used when sockeye salmon were abundant, that is, targets within a designated distance from the transducer were interpreted to be sockeye salmon and not counted. These two criteria have been the basis for discriminating between species and estimating the return of chinook salmon to the Kenai River.

Daily and seasonal acoustic estimates of chinook salmon have been generated since 1987. Estimates of total passage made with sonar were consistently lower than the mark-recapture estimates for the years 1987 through 1990 (Eggers et al. 1995). The inconsistencies between sonar and mark-recapture estimates were highest during the late run presumably due to the mark-recapture biases discussed earlier.

A more advanced acoustic technology known as split-beam sonar was used to test assumptions and design parameters of the dual-beam configuration in 1994 (Burwen et al. 1995). The split-beam system provided advantages over the dual-beam system in its ability to determine the 3-dimensional position of an acoustic target in the sonar beam. Consequently, the direction of travel for each target and the spatial distribution (three-dimensional) of fish in the acoustic beam could be determined for the first time. The split-beam system operated at a lower frequency, which resulted in an improved (higher) signal-to-noise ratio (SNR). It also interfaced with improved fish-tracking software, which reduced the interference from boat wake, and improved fish-tracking capabilities (Burwen and Bosch 1996). The split-beam system was deployed side-by-side and run concurrently with the dual-beam for much of the 1994 season (Burwen et al.

1995). In a comparative study, both systems performed similarly, detecting comparable numbers of fish. The split-beam data confirmed earlier studies showing that fish were strongly oriented to the river bottom. However, experiments conducted with the split-beam system could not confirm the validity of discriminating chinook salmon from sockeye salmon based on acoustic size. These results supported modeling exercises performed by Eggers (1994) that also questioned the feasibility of discriminating between chinook and sockeye salmon using target strength. It was hypothesized that discrimination between the two species was primarily accomplished using range thresholds on the acoustic data that exploited the spatial segregation of the species (sockeye salmon migrating nearshore and chinook salmon migrating midriver; (Eggers et al. 1995; Burwen et al. 1995). In 1995, the dual-beam system was replaced with the split-beam system in order to take advantage of the additional information on direction of travel and spatial position of targets.

Two ancillary studies (Burwen et al. 1998) were conducted in 1995 directed at providing more definitive answers to remaining questions regarding: (1) the degree to which sockeye and chinook salmon are spatially separated at the site at river km 14 (river mile 8.5), and (2) the utility of using target strength and/or other acoustic parameters as discriminatory variables for species separation. Results of these studies showed the potential for including sockeye salmon in chinook salmon estimates using current methodology. The netting study found that sockeye salmon were present in the middle insonified portion of the river during the study period, and in a concurrent tethered, live-fish experiment, most sockeye salmon tethered in front of the split-beam sonar had mean target strengths exceeding the target strength threshold.

To address concerns raised by these studies, radiotelemetry projects were implemented in 1996 and 1997 to estimate the magnitude of bias introduced during periods of high sockeye passage. These studies were designed to provide an independent and accurate estimate of inriver chinook abundance during the late run when the potential to misclassify sockeye is greatest. Although the precision was similar, the use of radiotelemetry technology avoided certain biases introduced in previous mark-recapture estimates. In both 1996 and 1997, late-run sonar estimates were 21% higher than the telemetry estimates (Hammarstrom and Hasbrouck 1998, 1999).

An alternative site investigation conducted in 1999 (Burwen et al. 2000) attempted to identify alternative sites above tidal influence that might strengthen the bank orientation of sockeye salmon and thereby increase the effectiveness of range thresholds in filtering sockeye salmon from chinook salmon abundance estimates. The investigation concentrated on a site located at river km 21.2 (river mile 13.2) that was above tidal influence but below areas of major spawning activity. A netting program indicated that there were fewer sockeye salmon in the offshore area at the alternative site than there were at the current site. However, there were still relatively large numbers of sockeye salmon present in the offshore area of the alternative site during peak migration periods as well as high numbers of chinook salmon present in the nearshore area. The alternate sonar site also had several disadvantages over the current site including greater boat traffic, less acoustically favorable bottom topography, and increased background noise resulting in difficult fish tracking conditions.

We continue to pursue improved techniques for separating chinook and sockeye salmon using acoustic information. Studies with tethered and free-swimming fish indicate that there are other acoustic variables that may provide higher discriminatory power than target strength for separating sockeye and chinook salmon (Burwen and Fleischman 1998). We have also made progress in developing methods to estimate target strength more accurately (Fleischman and Burwen 2000).

Objectives for 2001 were to provide daily and seasonal estimates of chinook salmon passage into the Kenai River.

METHODS

STUDY AREA

The Kenai River drains an area of 2,150 square miles. It is glacially influenced with discharge rates lowest during winter, increasing throughout the summer and peaking in August (USDA 1992). The Kenai River has 10 major tributaries, many of which provide important spawning and/or rearing habitat for salmon. Some of these tributaries are the Russian River, Skilak River, Killey River, Moose River, and Funny River.

The Kenai River drainage is located in a transitional zone between a maritime climate and a continental climate (USDA 1992). The geographic position and local topography influence both rainfall and temperature throughout the drainage. Average annual rainfall ranges from over 101 cm in the Kenai Mountains at its source, to 46 cm in the City of Kenai at its mouth. Average summer temperatures in the drainage range from 4°C to 18°C; average winter low temperatures range from -23°C to -40°C (USDA 1992).

SITE DESCRIPTION

The 2001 sonar site was located 14 km (8.5 mi) from the mouth of the Kenai River (Figure 2). This site has been used since 1985 and was selected for its acoustic characteristics and its location relative to the sport fishery and known spawning habitat of chinook salmon.

The river bottom in this area has remained stable for the past 17 years despite a 140-year flood during September 1995 (Bosch and Burwen 1999). The slope from both banks has remained gradual and uniform, which allows a large proportion of the water column to be insonified without acoustic shadowing effects. On the right bank, the bottom is composed primarily of mud, providing an acoustically absorptive rather than reflective surface. This absorptive property improves the signal-to-noise ratio when the beam is aimed along the river bottom. The left-bank bottom gradient is steeper and consists of more acoustically reflective small rounded cobble and gravel.

The sonar site is located below the lowest suspected spawning sites of chinook salmon, yet far enough from the mouth that most of the fish counted are probably committed to the Kenai River (Alexandersdottir and Marsh 1990), reducing the incidence of chinook salmon loitering in the sonar beam or returning downstream. Initially, almost all sport fishing occurred some distance upstream of this site. However, fishing activity near the site has increased over the past several years, mostly during the late run.

ACOUSTIC SAMPLING

A Hydroacoustic Technology Inc. (HTI) split-beam sonar system was operated from 16 May through 10 August 2001. Components of the system are listed in Table 1 and further described in HTI manuals (HTI 1996, 1997). A brief explanation of the theory of split-beam sonar and its use in estimating target strength can be found in Appendix A1. A more detailed explanation can be found in Ehrenberg (1983).

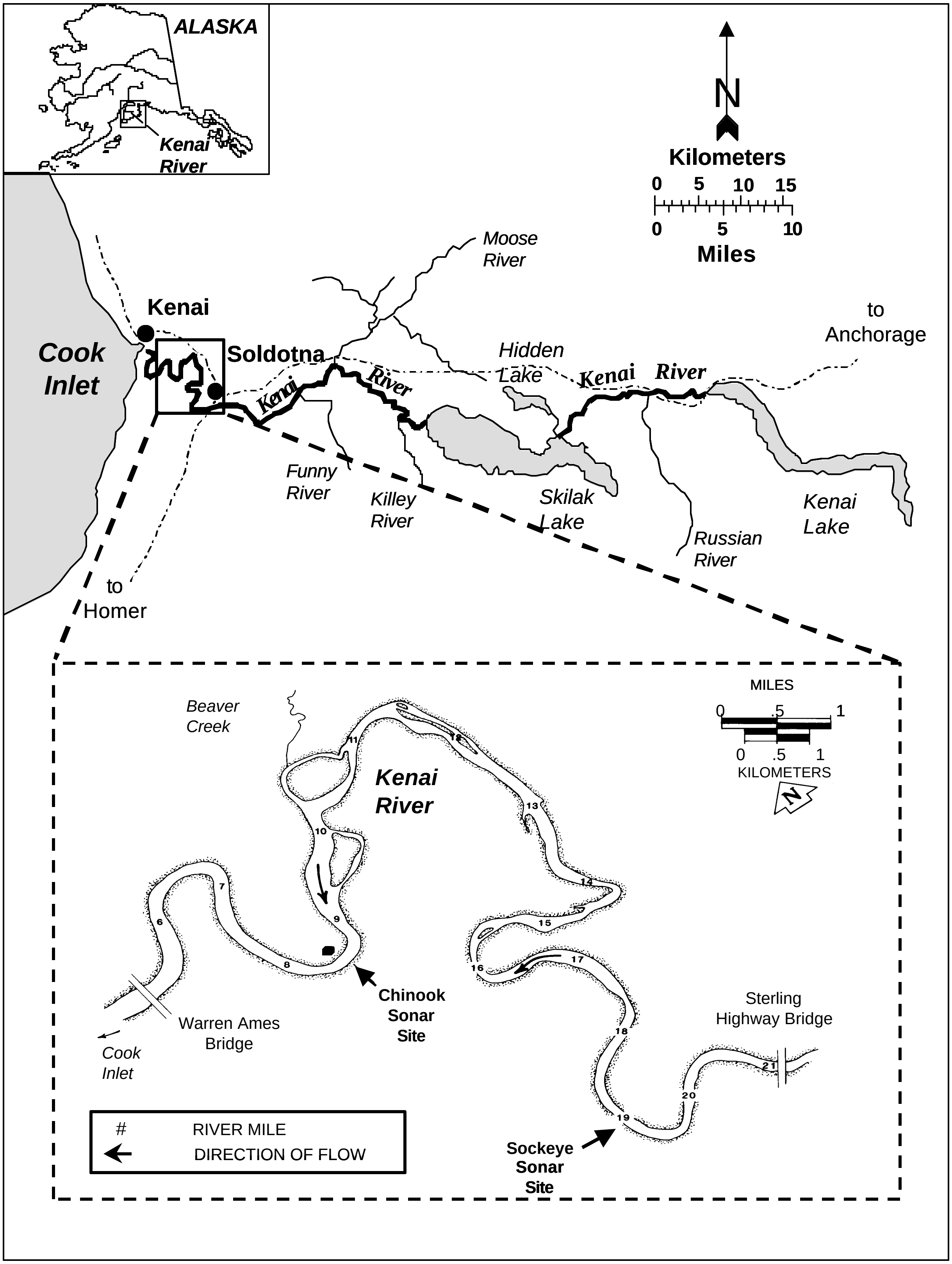


Figure 2.-The Kenai River showing location of chinook salmon sonar site, 2001.

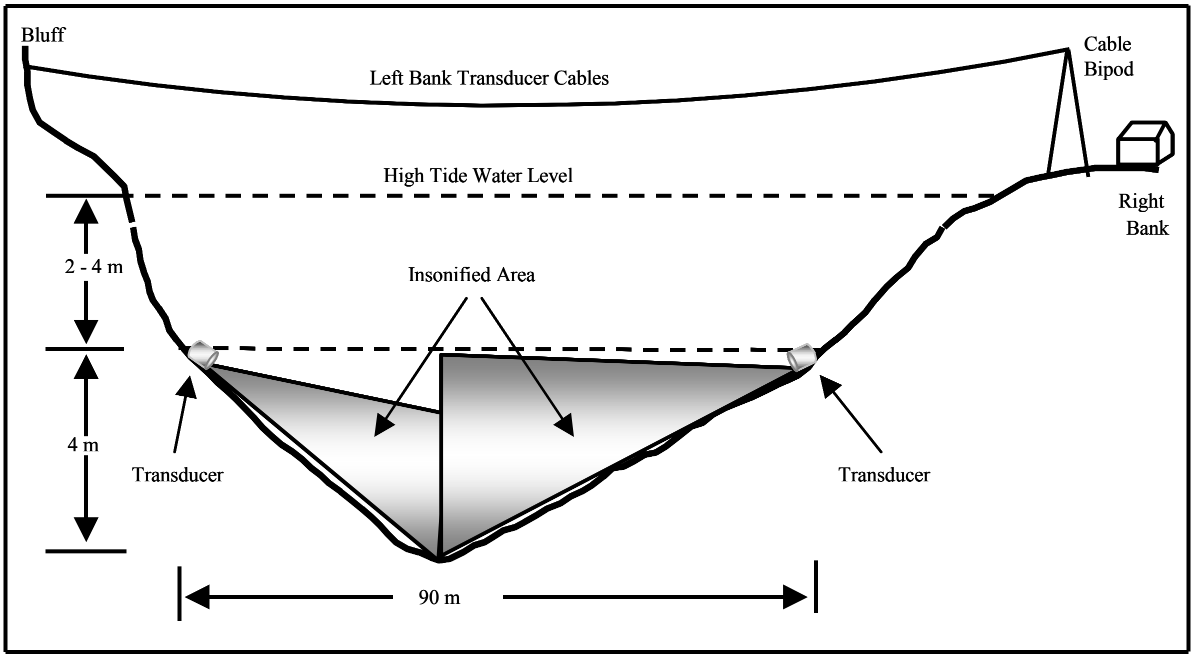
Table 1.-Principal components of the split-beam sonar system used in 2001.

System Component	Description
Sounder	Hydroacoustic Technology Inc. (HTI) Model 244 Split-Beam Echo sounder operating at 200 kHz
Signal Processor	HTI Model 340 Digital Echo Processor based in a Dell XPS T450 personal computer
Transducers	(2) HTI Split-Beam transducers: Left Bank: nominal beam widths: 2.9^{o}x10.2^o Right Bank: nominal beam widths: 2.8^{o}x10.0^o
Chart Recorder	HTI model 403 digital dual-channel chart recorder
Oscilloscope	Nicolet model 310 digital storage oscilloscope
Video Display	Hydroacoustic Assessments HARP-HC
Remote Pan and Tilt Aiming Controller	Remote Ocean Systems Model PTC-1 Pan and Tilt Controller
Remote Pan and Tilt Aiming Unit	Remote Ocean Systems Model PT-25 Remote Pan and Tilt Unit
Heading and Angular Measurement Device	JASCO Research Ltd. Uwinstru Underwater Measurement Device.

Sonar System Configuration

Sampling on both banks was controlled by electronics housed in a tent located on the right bank of the river. Communication cables led to transducers and their aiming devices on both banks. Cables leading to the left-bank equipment were suspended above the river at a height that would not impede boat traffic (Figure 3). Steel tripods were used to deploy the transducers offshore. One elliptical, split-beam transducer was mounted on each tripod. At the start of the season the transducer tripods were placed on each bank in a position close to shore but still submerged at low tide. During 16 May to 10 August, water level at low tide rose approximately 1.8 m. As the water level rose, the tripods were periodically moved closer to shore so that the total range insonified by the sonar beams increased from approximately 60 m at low water conditions (22 May) to 88 m at high water (26 June–28 June; Figure 4).

Vertical and horizontal aiming of each transducer was remotely controlled by a dual-axis electronic pan and tilt system. A digital readout indicated the aiming angle in the vertical and horizontal planes. In the vertical plane, the transducer was aimed using an oscilloscope and chart recorder to verify that the sonar beam was grazing the river bottom. In the horizontal plane, the transducer was aimed perpendicular to the flow of the river to maximize probability of insonifying fish from a lateral aspect. The range encompassed by each transducer was determined by the river bottom contour and the transducer tripod placement. Transducer tripods were placed in such a manner as to maximize counting range in an attempt to fully insonify the cross section of the river between the right- and left-bank transducers.



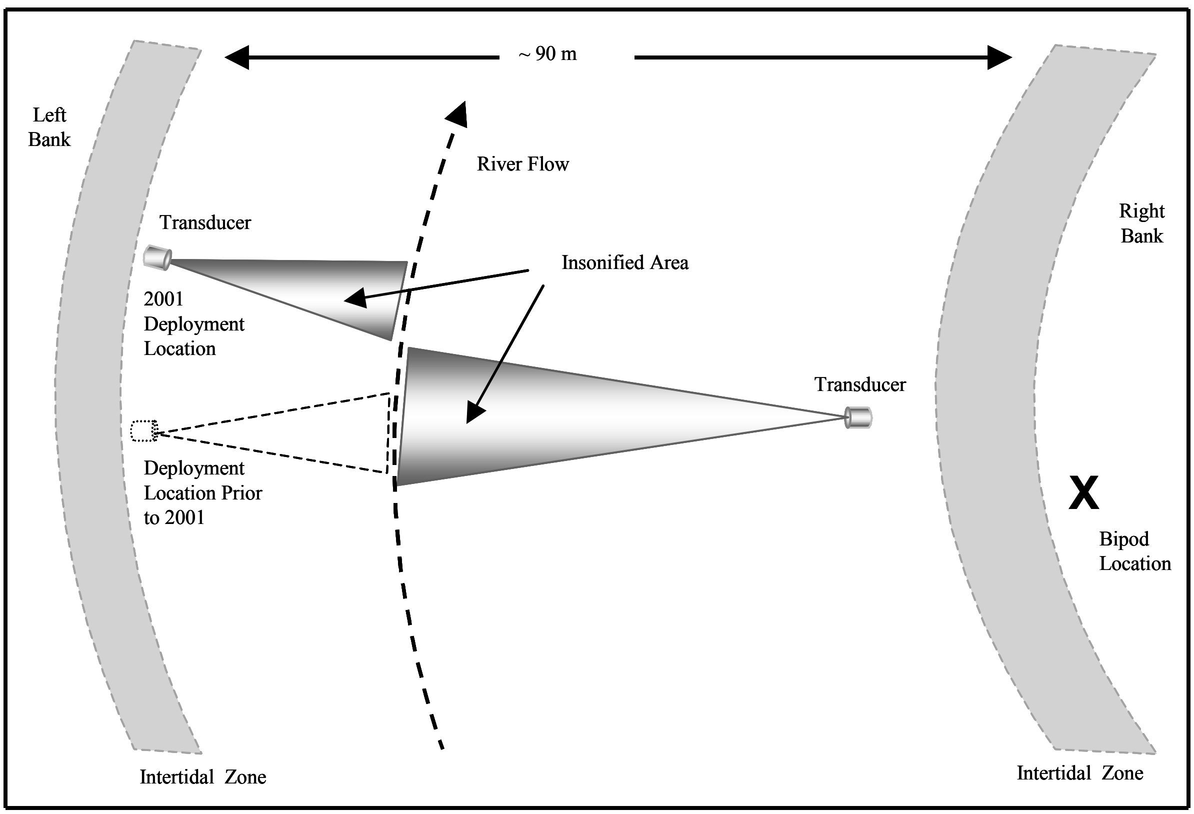


Figure 3.-Cross-sectional (top) and aerial (bottom) views of sonar site showing insonified portions of the Kenai River, 2001.

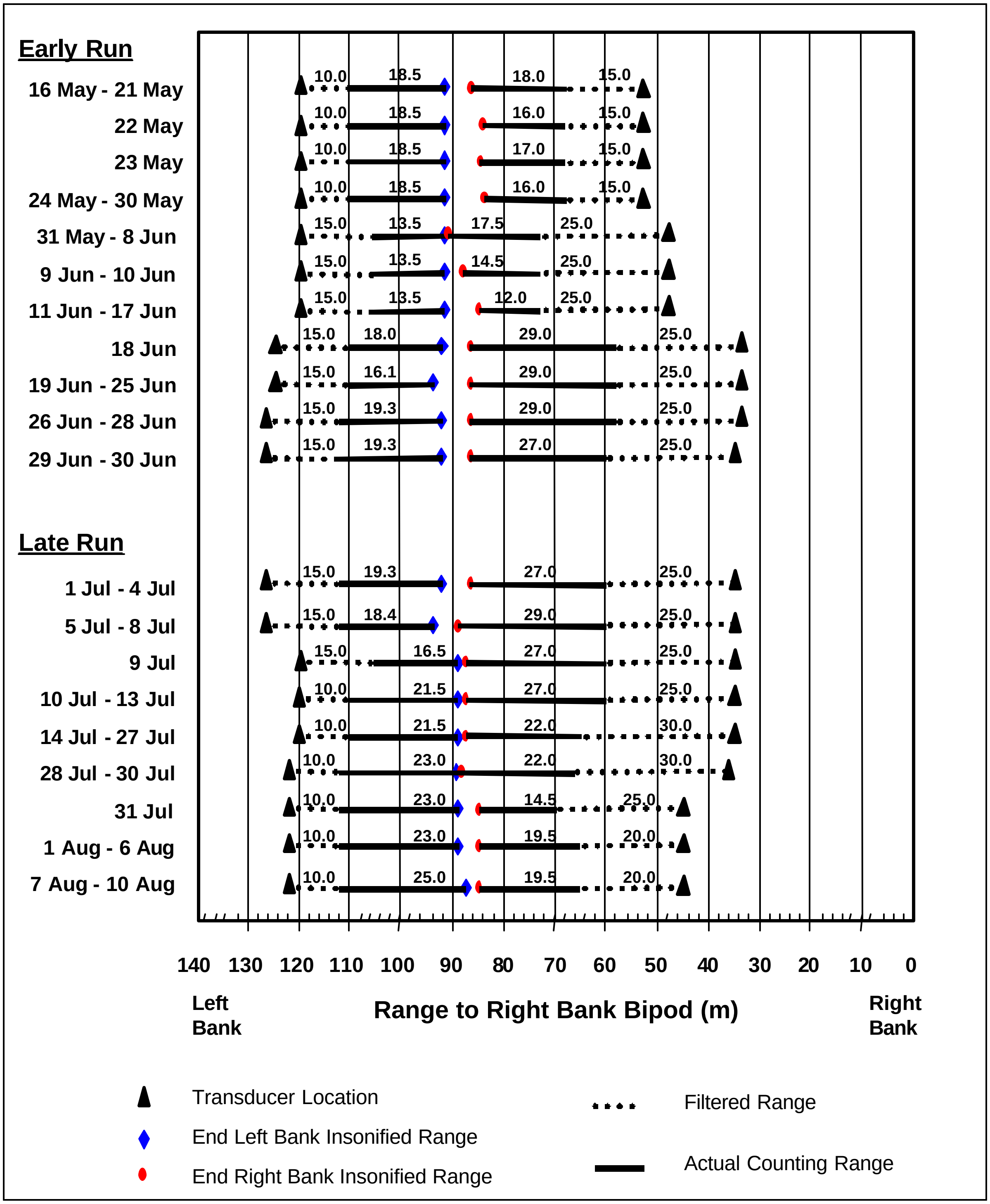


Figure 4.-Daily right- and left-bank transducer locations and counting ranges relative to bipod tower located on the right bank, Kenai River, 2001.

Bottom Mapping and Beam Coverage

A detailed profile of the river bottom and the area encompassed by the sonar beams was produced prior to acoustic sampling. Depth readings from a Lowrance X-16 were paired with range measurements from a fixed target on shore using a Bushnell Laser Ranger (±1 m accuracy). In past years, placement of transducer tripods directly across the river from each other provided optimal sonar beam aims and optimal beam coverage. River bottom profiles in 2001 indicated that an improved left-bank aim could be achieved by deploying the left-bank transducer approximately 35 m downstream from the deployment location used in past years (Figure 3). The new left-bank deployment location reduced the coverage range by a few meters, but the overall quality of the aim improved.

When detailed bottom profile information is combined with information from the attitude sensors mounted on the transducers, a detailed visualization of how well the water column above the bottom substrate was insonified by the acoustic beam could be generated (Figure 5). The attitude sensor is a more reliable indicator of the transducer position than the rotator digital readout, thus information from the attitude sensor provided a more accurate representation of beam aim and coverage than did the rotator output.

Each time the transducer was moved throughout the season, new measurements of the transducer height above the bottom substrate and its position relative to a fixed shore location were updated in an EXCEL worksheet so that beam coverage at the new location could be evaluated.

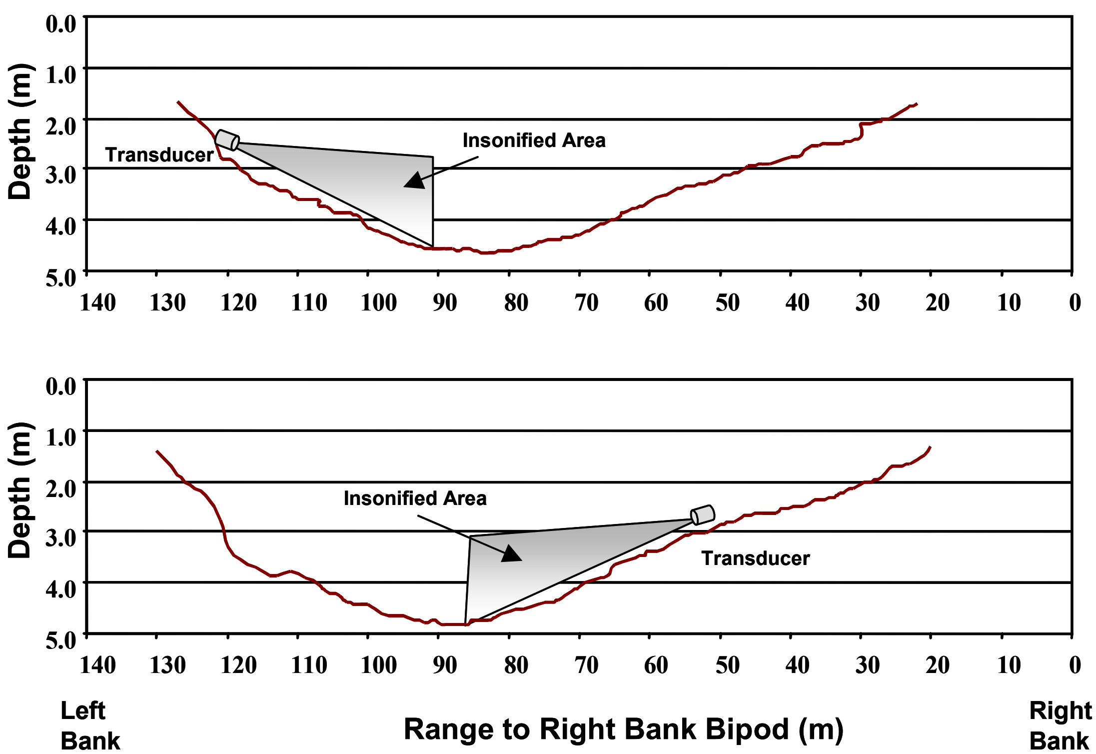


Figure 5.-Left- and right-bank bottom profiles at the Kenai River chinook sonar site with approximate transducer locations and sonar beam coverage for 16 May 2001.

System Calibration

HTI performed reciprocity calibrations with a naval standard on 14 December 2000. Calibration results were verified at the calibration facility with a 38.1-mm tungsten carbide sphere (Foote and MacLennan 1984). Further verification was obtained *in situ* by measuring the same standard sphere on 10 May, 1 August, and 9 August. For each calibration verification, we recorded the maximum background noise level and voltage threshold in addition to the data collected automatically by the onboard signal-processing software (see Data Acquisition).

Sampling Procedure

A systematic sample design (Cochran 1977) was used to sample from each bank for 20 min each hour. Although the sonar system is capable of sampling both banks continuously, data collection was restricted to 20-min samples per hour to limit the data processing time and personnel required to produce daily fish passage estimates. The equipment was automated to sample the right bank for 20 min starting at the top of each hour, followed by a 20-min left-bank sample. The system was quiescent or activated for ancillary studies during the third 20-min period. This routine was followed 24 hours per day and 7 days per week unless one or both banks were inoperable.

A test of this sample design conducted in 1999 found no significant difference between hourly estimates of chinook salmon passage obtained using full 1-hour counts and estimates obtained using expanded 20-min counts (Miller et al. 2002).

Echo Sounder Settings

Relevant echosounder settings are listed in Table 2 with a more complete summary in Appendices B1 and B2. Most echo sounder settings were identical for each bank and remained consistent throughout the sample period. High power and low gain settings were used to maximize SNR. The transmitted pulse width was set relatively low to maximize resolution of individual fish, and SNR.

Table 2.-HTI model 244 digital echo sounder settings used in 2001.

Echo Sounder Parameters	Value
Transmit Power	25 dB
System Gain (G_r)	-18 dB
TVG	$40\log_{10}R$
Transmitted Pulse Width	0.20 msec
Ping Rate Right Bank	11 pings/sec
Ping Rate Left Bank	16 pings/sec

Data Acquisition

The digital echo sounder (DES) sent data from each returned echo to the digital echo processor (DEP, Figure 6). The DEP performed the initial filtering of returned echoes based on user-selected criteria (Table 3, Appendices B1 and B2); it also recorded the start time, date and number of pings processed for each sample.

Echoes in the transducer near field (= 2.0 m) were excluded (MacLennan and Simmonds 1992). Minimum vertical and horizontal off-axis values were used to prevent consideration of unreliable data from transducer side lobes.

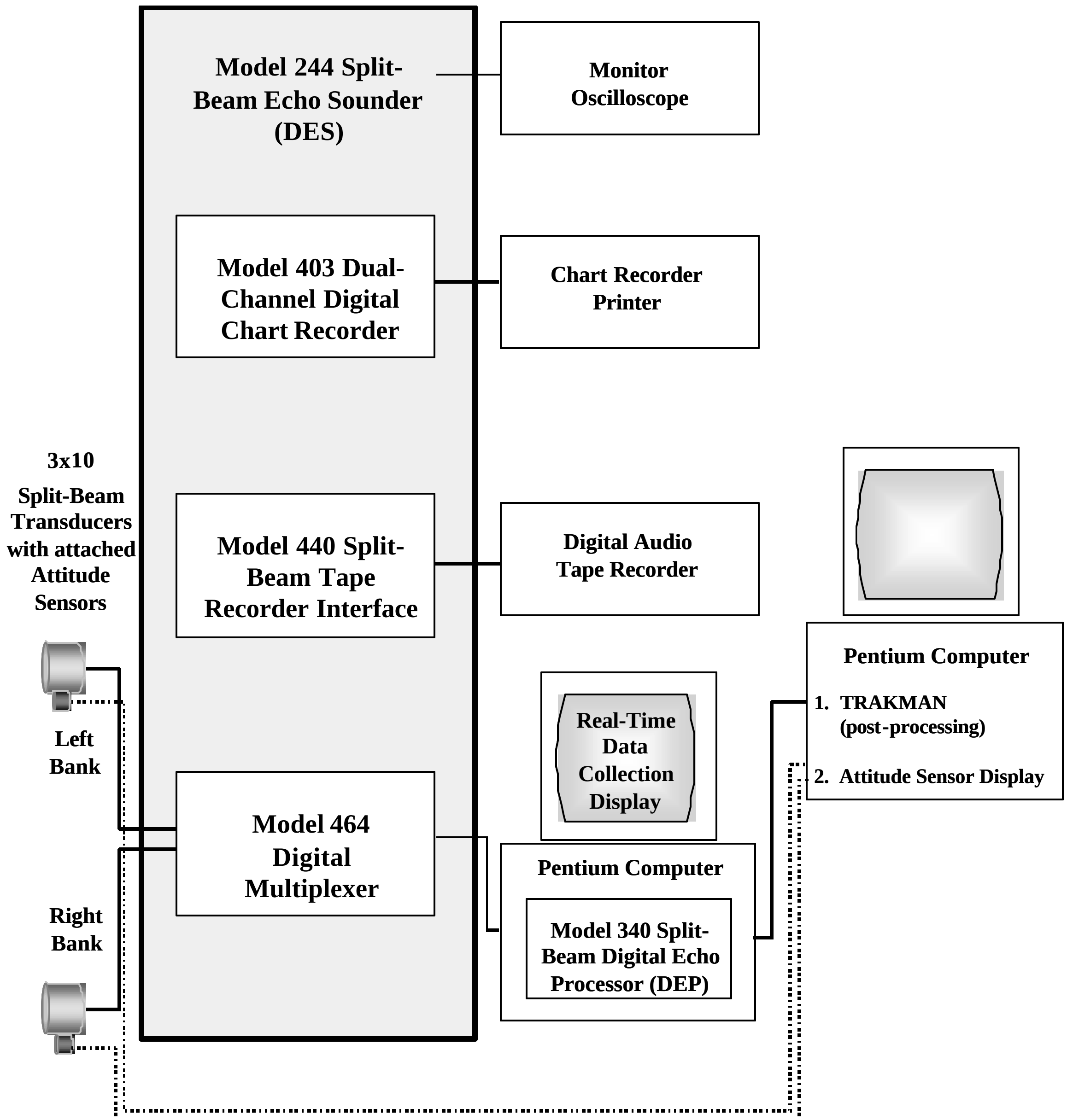


Figure 6.-Schematic diagram of 2001 split-beam sonar system configuration and data flow.

Table 3.-Echo acceptance criteria for digital echo processing, 2001.

Bank and Date	Pulse width[a] (ms) at -6 dB	Vertical angle off-axis (°)	Horizontal angle off-axis(°)	Threshold mV (dB)	Range (m)
Right					
16-May to 10-Aug	0.04 to 10.0	-2.5 to 2.5	-5.0 to 5.0	752 (-35 dB)	2.0
Left					
16- May to 10- Aug	0.04 to 10.0	-2.5 to 2.5	-5.0 to 5.0	481 (-35 dB)	2.0

[a] Pulse width filters have not been used since 1996 (Burwen and Bosch 1998a) in order to retain information potentially useful for species classification (Burwen and Fleischman *In prep*).

Voltage thresholds for data acquisition were set high enough to exclude most background noise from spurious sources such as boat wake, the river bottom, and the water surface. Collection of data from unwanted noise causes data management problems and also makes it difficult to distinguish echoes originating from valid fish targets. The amount of background noise is determined largely by the dimensions of the sonar beam in relation to the depth of the river. Since the water level at the sonar site is strongly influenced by tidal stage (vertical fluctuations of more than 4 m), the amount of background noise fluctuates periodically, with lowest noise levels during high tide and the highest levels during falling and low tides. Voltage thresholds corresponding to a -35 dB target on-axis were selected for each bank as the lowest threshold that would exclude background noise at low tide when noise was at a maximum.

For each echo passing initial filtering criteria, the DEP wrote information to the computer hard disk in ASCII file format (*.RAW files). This file provided a permanent record of all raw echo data, which could then be used by other post-processing software. A uniquely-named file was produced for each sample hour and stored the following statistics for each echo: (1) range from the transducer, (2) sum channel voltage produced by the echo, (3) pulse widths measured at -6 dB, -12 dB, and -18 dB down from the peak voltage, (4) up-down (vertical) angle, left-right (horizontal) angle, and (5) multiplexer port.

The sum channel voltage from the Model 244 DES was also output to a dot matrix printer using an HTI Model 403 Digital Chart Recorder, to a Nicolet 310[1] digital storage oscilloscope and to a Harp HC2 color chart monitor. Chart recorder output was filtered only by a voltage threshold, which was set equal to the DEP threshold. The chart recorder ran concurrently with the echo sounder and produced real-time echograms for each sample. The echograms were used for data backup and transducer aiming, and to aid in manual target tracking. Voltage output to the oscilloscope and color monitor was not filtered. Monitoring the unfiltered color echogram ensured that subthreshold targets were not being unintentionally filtered. Advanced features on the digital oscilloscope aided in performing field calibrations with a standard target and in monitoring the background noise level relative to the voltage threshold level.

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

FISH TRACKING AND ECHO COUNTING

A diagram illustrating inseason data flow can be found in Appendix C1. Echoes in the *.RAW files were manually grouped (tracked) into fish using HTI proprietary software called TRAKMAN. TRAKMAN produces an electronic chart recording for all valid echoes collected during a 20-min sample on the computer monitor. Selected segments of the chart can be enlarged and echoes viewed on a Cartesian grid. Echoes following a sequential progression through the beam were selected by the user and classified into fish traces. TRAKMAN then produced three output files. The first file contained each echo that was tracked in a valid target (*.MEC file) and included the following data for each echo: estimated X (left-right), Y (up-down), and Z (distance from the transducer) coordinates in meters, where the transducer face is the origin of the coordinate system, pulse widths measured at -6 dB, -12 dB, and -18 dB amplitude levels, combined beam pattern factor in dB, and target strength in dB. The second fixed-record ASCII file (*.MFS file) summarized data from all echoes associated with an individual tracked target and output the following fields by target: total number of echoes tracked, starting X, Y, and Z coordinates, distance traveled (meters) in the X, Y, and Z directions, mean velocity (m/sec), and mean target strength (dB). The third file was identical to the *.RAW file described earlier except that it contained only those echoes combined into tracked targets. Direction of travel was determined using information from the echo coordinates of individually tracked targets. A target was classified as upstream if its ending (X-axis) position in the acoustic beam was located upriver from its starting position and downstream if its ending position was downriver from its starting position.

Downstream targets (and occasionally upstream targets during a strong flood tide) were further classified as fish or debris primarily by looking at the angle of passage and degree of movement in the Z-axis (range from transducer) as the target transited the acoustic beam. For debris, the angle of passage through the beam is constant with little change in the range as it passes through the beam. Consequently, debris resembles a line drawn on the echogram with a straight-edge. A fish typically leaves a meandering trace that reflects some level of active movement as it passes through the acoustic beam. Obvious debris-like downstream targets were excluded from consideration as valid fish targets during the tracking procedure and the remainder of downstream targets was retained to adjust the total estimate of fish passage. Separate summary files were generated for tracked targets classified as debris (i.e. *.DEC and *.DFS files). Except for debris, only targets comprising echoes displaying fish-like behavior were tracked. Echoes from structure, boat wake and sport-fishing tackle were ignored.

DATA ANALYSES

Tidal and Temporal Distribution

Fish passage rates have been shown to be related to tidal stage (Eggers et al. 1995). Therefore tide stage was determined throughout the season using water level measurements taken at the top of each hour and at 20 minutes past each hour from a staff gauge located at the site. For the purpose of this study, falling tide was defined as the period of decreasing staff gauge readings, low tide as the period of low static readings, and rising tide as the period of both increasing readings and high static readings (i.e. high slack tide). The rising and high slack tides were combined into one category due to the very short duration of high slack tide. Data from both banks were combined to summarize fish passage by tide stage (falling, low, and rising) for both upstream and downstream traveling fish. Data were first filtered using target strength and range criteria (see section below on species discrimination).

Spatial Distribution

Knowledge of the spatial distribution of fish is desirable for developing strategies for insonifying a specific area, for determining appropriate transducer beam dimensions, and for evaluating the probability of detecting fish near the edge of the acoustic beam (Mulligan and Kieser 1996).

Inseason range (z-axis) distributions for each bank were plotted separately for upstream and downstream fish. Range distributions were calculated using the midpoint range for each target as follows:

$$z_m = z_s + \left(\frac{d_z}{2}\right), \tag{1}$$

where:

z_m = midpoint range (in meters),

z_s = starting range (in meters), and

d_z = distance traveled in the range z direction.

Prior to 2000, range distribution comparisons were made using z_m, the distance from the face of the transducer to the target location (Miller et al. 2002). These comparisons provided information on distribution of fish targets from the face of the transducer, but because tripod/transducer locations change throughout the season the comparisons were poor descriptors of actual fish range distributions across the river. For 2001, range estimates by bank were standardized to the nearest shore transducer deployment for that bank based on distances to a fixed point (cable bipod) on the right bank (Figures 3 and 4):

$$z_a = z_m + \left|z_t - z_n\right|, \tag{2}$$

where:

z_a = adjusted range (in meters),

z_t = distance (in meters) from right bank bipod to transducer, and

z_n = distance (in meters) from right bank bipod to nearest shore (right bank or left bank) deployment location.

Range distribution plots were produced postseason with the adjusted (standardized) range estimates allowing for comparisons of actual fish target locations across the river. The end range in these range distribution graphs was the maximum distance covered (generally to the thalweg) by the sonar beam on that particular bank.

Vertical distributions were plotted by direction of travel (upstream and downstream) and tide stage. Vertical distributions were calculated from the midpoint angle off-axis in the vertical plane as follows:

$$\theta_y = \arcsin \frac{y_s + \left(\frac{d_y}{2}\right)}{z_m}, \tag{3}$$

where:

θ_y = vertical angle-off-axis midpoint (degrees),

y_s = starting vertical coordinate (in meters), and

d_y = distance traveled in vertical direction (in meters).

Target Strength Distribution

Target strength was calculated for individual echoes (Appendix A1) and averaged for each tracked fish. Inseason target strength distributions were plotted separately for early- and late-run fish and for upstream and downstream fish.

Species Discrimination

Tracked fish were filtered using criteria intended to minimize the number of sockeye salmon counted. Two parameters have been used historically on this project to separate large chinook salmon from smaller species: target strength and distance from the transducer (range). Although studies have questioned the ability of these filters to exclude sufficient numbers of sockeye salmon (Eggers 1994, Burwen et al. 1995), we continued their use in 2001 to ensure comparability of passage estimates with those of past years, while continuing to investigate other means of discriminating between fish sizes (see Discussion).

Tracked fish with mean target strength less than -28 dB were assumed to be species other than chinook salmon and excluded from further analysis. The majority of fish within the nearshore area were assumed to be smaller species such as sockeye, pink *O. gorbuscha*, and coho *O. kisutch* salmon, so all targets within a particular threshold range were filtered out regardless of target strength. Several range thresholds were applied on the right and left bank, all associated with either moving the transducer tripods closer to shore and increasing the range to maintain mid-channel coverage, or with extending the range thresholds during periods of high sockeye salmon passage to avoid misclassifying offshore-distributed sockeye as chinook. Adjustments to the early-run range thresholds were made postseason after reviewing daily target range distributions. Late-run thresholds remained unchanged from those used inseason. Final early-run range thresholds were 10 m (16 May-30 May) and 15 m (31 May-30 June) on the left bank and 15 m (16 May-30 May) and 25 m (31 May-30 June) on the right bank (Figure 4). Final late-run range thresholds were 15 m (1 July-9 July) and 10 m (10 July-10 August) on the left bank and 25 m (1 July-13 July and 31 July), 30 m (14 July-30 July), and 20 m (1 August-10 August) on the right bank (Figure 4).

Passage Estimates

Estimates of chinook salmon passage for day i were generated as follows:

$$\hat{y}_i = 24 \sum_{k=1}^{2} \bar{y}_{ik} \,, \qquad (4)$$

where the mean hourly passage past bank k during day i was:

$$\bar{y}_{ik} = \frac{1}{n_{ik}} \sum_{j}^{n_{ik}} \hat{y}_{ijk} \,, \qquad (5)$$

where n_{ik} was the number of hours during which passage was estimated (or imputed) on bank k for day i. When the sonar was functional on bank k during hour j of day i, then hourly chinook salmon passage was estimated as follows:

$$\hat{y}_{ijk} = \frac{60}{t_{ijk}} c_{ijk} , \tag{6}$$

where:

t_{ijk} = number of minutes (usually 20) sampled from bank k during hour j of day i, and

c_{ijk} = number of upstream-bound fish on bank k meeting range and target-strength criteria during t_{ijk}.

When the sonar system was functional on one bank but not the other, we imputed the passage estimate on the non-functional bank k from passage on the functional bank k' with a ratio estimator:

$$\hat{y}_{ijk} = \hat{R}_{ikt}\, \hat{y}_{ijk'}, \tag{7}$$

where the estimated bank-to-bank ratio $\hat{R}_{ikt}$ for day i and tide stage t was calculated by pooling counts from all hours during the previous 2 days with tide stage t:

$$\hat{R}_{ikt} = \frac{\sum_{j \in J_t} \hat{y}_{(i-2)jk} + \sum_{j \in J_t} \hat{y}_{(i-1)jk}}{\sum_{j \in J_t} \hat{y}_{(i-2)jk'} + \sum_{j \in J_t} \hat{y}_{(i-1)jk'}} . \tag{8}$$

An unusual circumstance encountered during the late run necessitated the use of the ratio estimator to estimate several days of missing data on one bank. A suboptimal aim experienced on the right bank from 26 July-30 July resulted in an undercount during this time. We used the average left to right bank ratios from 21 July-25 July and 31 July-4 August and the left-bank passage estimates from 26 July-30 July to estimate right bank passage for the days the undercount occurred (26 July-30 July).

Because the bottom profile of the river is not a perfect “V”, but rather is rounded at the thalweg, there is generally a small gap in coverage between the right- and left-bank beams. This gap in beam coverage was larger in 2001 than in past years due to the new location of the left bank transducer and the resulting transducer aim (see Bottom Mapping and Beam Coverage). Therefore, for the first time, daily passage estimates were expanded postseason in 2001 to account for incomplete spatial coverage. Expanded passage for day i was:

$$\hat{z}_i = \hat{S}_i \hat{y}_i . \tag{9}$$

The spatial expansion factor was:

$$\hat{S}_i = 1 + \frac{\hat{D}_i G_i}{\sum_m c_{im}} , \tag{10}$$

where $\hat{D}_i$ was the fish passage density (meter^{-1}) in the gap, G_i was the width of the gap (in meters) on day i, c_{im} was the total number of qualifying fish counted in range bin m (1 meter wide) during day i, and m was distance (rounded to the nearest meter) from a reference point located on the right bank. Density $\hat{D}_i$ was estimated by fitting a local-regression (LOESS) smoother to fish densities (c_{im}) across the river channel, then averaging fitted densities for all range bins that fell in the gap. The denominator in Equation 10 is the total number of qualifying targets actually counted during day i (i.e., it does not include fitted values of c_{im} in the gap). "Qualifying" targets are upstream fish that met range and target-strength criteria.

The variance of the expanded passage estimate z for day i was estimated as:

$$\hat{V}[\hat{z}_i] = \hat{s}_i^2 \hat{V}[\hat{y}_i], \quad (11)$$

where the variance of estimates of y, due to systematic sampling in time, was approximated (successive difference model; Wolter 1985), with adjustments for missing data, as:

$$\hat{V}[\hat{y}_i] \cong 24^2(1-f)\sum_{k=1}^{2}\frac{\sum_{j=2}^{24}\phi_{ijk}\phi_{i(j-1)k}\left(\hat{y}_{ijk}-\hat{y}_{i(j-1)k}\right)^2}{2\sum_{j=1}^{24}\phi_{ijk}\sum_{j=2}^{24}\phi_{ijk}\phi_{i(j-1)k}}, \quad (12)$$

where f was the sampling fraction (approximately 0.33), and ϕ_{ijk} was 1 if the sonar was operating on bank k during hour j, or 0 if not. Uncertainty due to imperfect detection of fish, imperfect discrimination of species, missing hourly counts, and spatial expansion was not estimated. Therefore variance estimates were biased low.

The cumulative estimate of chinook salmon abundance, and its variance, was the sum of the daily estimates:

$$\hat{Z} = \sum_i \hat{z}_i \text{ , and} \quad (13)$$

$$\hat{V}\left[\hat{Z}\right] = \sum_i \hat{V}[\hat{z}_i]. \quad (14)$$

Unfiltered[2] daily passage estimates for day i, were calculated by following Equations 4-12 after substituting unfiltered counts c'_{jk} for c_{jk}, where:

c'_{jk} = number of upstream-bound fish greater than 15 m from the right-bank transducer and greater than 10 m from the left-bank transducer, for bank k and hour j.

The "alternative" daily estimate of chinook salmon abundance was calculated by multiplying the unfiltered sonar passage estimate by the proportion $\hat{p}_i$ of chinook salmon in drift gillnet catches near the sonar site (Reimer et al. 2002):

$$\hat{z}'_i = \hat{x}_i \hat{p}_i . \quad (15)$$

---

[2] Unfiltered with respect to target strength, but restricted to upstream-bound targets passing at a distance greater than the smallest range thresholds used during the season (15 m on right bank, 10 m on left bank).

The variance estimate of the alternative estimate follows Goodman (1960):

$$\hat{\text{var}}(\hat{z}_i') = \hat{x}_i^2\, \hat{\text{var}}(\hat{p}_i) + \hat{p}_i^2\, \hat{\text{var}}(\hat{x}_i) - \hat{\text{var}}(\hat{p}_i)\, \hat{\text{var}}(\hat{x}_i). \quad (16)$$

Note that variance of sonar estimates presented in this report reflects only the uncertainty associated with sampling error, as this is the only uncertainty we are currently able to quantify. Other sources of uncertainty associated with this type of project include target detectability, species composition, direction of travel, and target tracking. Because we are only able to account for sampling error related to the systematic sample design, our approach has been to keep the methods as consistent as possible from year to year so that whatever bias is present will also be consistent.

NET-APPORTIONED ESTIMATES

Starting in 1998, the inriver chinook salmon age, weight and length (AWL) netting program, originally designed to collect age, sex and length (ASL) samples, was modified to assess the feasibility of using catch per unit effort (CPUE) from the drift gillnets as an alternative index of chinook salmon abundance (Reimer et al. 2002). A standardized drift zone was defined just downstream from the sonar site and crews fished a standard drift period relative to the tide cycles. In addition, the schedule was intensified so that CPUE estimates could be generated daily.

Our objective was to use the netting CPUE to detect periods when chinook salmon passage estimates were biased high due to inclusion of sockeye salmon (or other species). It was anticipated that in the absence of high levels of sockeye passage (or other species), sonar estimates and CPUE would track reasonably well. Conversely, during periods of high sockeye passage, we expected the two to diverge. If a sufficient number of days of paired CPUE and sonar data were collected where the two estimates tracked closely, the relationship between the two could be exploited to generate adjusted estimates of chinook passage when needed.

After three seasons (1998-2000) of standardized CPUE data were collected, we concluded that CPUE was a relatively poor predictor of abundance, because the magnitude of gillnet catches was quite variable and dependent on river conditions (Reimer et al. 2002). CPUE often tracked the sonar estimates for the short term, but the relationship between the sonar and CPUE data changed over time. Netting efficiency generally declined over the season, and was affected by water volume and turbidity. Gillnets were most efficient when the river was low and turbid, and least efficient when the river was high and clear. The effects of water volume and turbidity changed among years.

On the other hand, there was some evidence that chinook and sockeye salmon were caught with similar efficiency by the gillnets, and that the gillnet catches might provide useful estimates of species composition (Reimer et al. 2002). Thus gillnet catches were used experimentally in 2001 to apportion sonar passage estimates to species. Net-apportioned estimates of chinook salmon abundance were the product of unfiltered sonar passage estimates and the proportion of chinook salmon in the drift gillnets (Equation 15). Proportions of chinook salmon in drift gillnets were taken from Reimer (2003).

RESULTS

System Calibration

During system calibration at the HTI calibration facility, the target strength of a 38.1-mm tungsten carbide standard sphere was measured at -39.61 dB and -38.84 dB with the right- and left-bank transducers, respectively (HTI 2000; Table 4). The theoretical value for the sphere is -39.5 dB (MacLennan and Simmonds 1992). During subsequent *in situ* calibration checks using the same sphere, mean target strength varied from -37.69 dB to -38.17 dB on the right bank and from -37.75 dB to -39.47 dB on the left bank (Table 4). Small fluctuations in mean target strength are expected throughout the season as target strength can vary with water temperature, depth, conductivity and other factors. However, right-bank *in situ* calibration checks produced relatively low mean target strength values (up to 2 dB less than mean target strengths produced during reciprocity calibrations). Although we were not able to determine the cause of the low values inseason, further analyses conducted postseason revealed that an incorrect calibration parameter entered at the beginning of the season resulted in incorrect target strength calculations throughout the season for all right-bank targets, and that mean target strength values for all right-bank targets were 1.3 dB higher than they should have been. Mean target strength for all right-bank targets and for the standard target data was adjusted postseason by -1.3 dB. After corrections were made, mean target strength of the standard target sphere on the right bank varied from -38.99 dB to -39.47 dB (Table 4). Right-bank mean target strength values presented throughout the remainder of this report have been adjusted by -1.3 dB.

Beam Coverage

Successful beam coverage in the middle of the river was dependent on the river bottom contour, transducer deployment locations, and transducer aiming. The gap in beam coverage in the middle of the river varied throughout the season dependant upon these factors. Throughout much of the early run and part of the late run, the mid-river gap in coverage ranged from 4-7 m (Figure 4). During the middle portion of the late run (9 July-30 July), which encompassed peak late-run chinook passage, the gap in beam coverage was less than 2 m (Figure 4).

Target Tracking

In 2001, 54,186 targets were manually tracked, 9,472 during the early run and 44,714 during the late run. After filtering for range and target strength criteria and making temporal expansions, the proportion of upstream fish was 97.8% for the early run and 96.7% for the late run (Appendices D1 and D2).

The number of acquired echoes per fish varied by run, bank, and direction of travel. During the early run, upstream fish averaged 61 (SD = 36) and 63 (SD = 47) echoes per fish on the left and right banks, respectively. Downstream fish averaged 59 echoes (SD = 53) on the left bank and 77 echoes (SD = 79) on the right bank. Upstream fish during the late run averaged 78 (SD = 49) echoes on the left bank and 81 (SD = 53) echoes on the right bank. Downstream fish averaged 88 (SD = 79) echoes on the left bank and 79 (SD = 74) echoes per fish on the right bank.

Tidal and Temporal Distribution

Upstream passage during the early run occurred mostly during the falling tide (57.4%); the falling and rising tide were about equally important during the late run (43.7% and 42.0% respectively; Tables 5 and 6, Figure 7). Most downstream passage occurred during the falling tide for both the early (51.3%) and late (53.2%) runs.

Table 4.-Results of 2001 *in situ* calibration verifications using a 38.1 mm tungsten carbide standard sphere.

Location	Date	Mean Target Strength (dB)	SD	Corrected Mean Target Strength (dB)[a]	N	Range (m)	Noise (mV)	Threshold (mV)
Right Bank								
HTI[b]	14 Dec	-39.61	1.82	N/A[c]	996	6.2	N/A[c]	N/A[c]
Kenai River	10 May	-38.17	1.70	-39.47	2,209	16.2	150	200
Kenai River	1 August	-37.69	2.42	-38.99	3,633	33.0	160	175
Kenai River	9 August	-37.83	1.71	-39.13	1,686	23.8	200	250
Left Bank								
HTI[b]	14 Dec	-38.84	0.51	N/A[c]	728	6.2	N/A[c]	N/A[c]
Kenai River	10 May	-38.84	1.56	N/A[c]	4,445	19.2	100	150
Kenai River	1 August	-39.47	2.48	N/A[c]	2,588	22.1	96	100
Kenai River	9 August	-37.75	1.81	N/A[c]	564	23.9	200	250

[a] Right bank mean target strength values obtained during *in situ* calibration verifications were adjusted by -1.3 dB to account for incorrect calibration parameters used throughout the season on the right bank.

[b] Measurements taken at Hydroacoustic Technology Inc. facility during system calibration.

[c] Not available or not applicable.

SPATIAL DISTRIBUTION

Vertical Distribution

Fish were bottom oriented during both runs, although vertical distribution did vary somewhat by direction of travel, tide stage, and season (Appendices E1 and E2). During the early run, 96% of the upstream fish (chinook targets) on the left bank and 89% on the right bank were on or below the acoustic axis (Figure 8). Downstream fish were less bottom oriented (Appendices E1 and E2). Seventy percent of downstream fish on each bank were below the acoustic axis (Figure 8). Upstream fish (chinook targets) on the left bank (mean = -0.75°, SD = 0.38, n = 3,523) were on average significantly lower ($t = 5.91$, $P \ll 0.001$) in the water column than downstream fish (mean = -0.19°, SD = 0.64, n = 47). On the right bank, upstream fish (mean = -0.49°, SD = 0.48, n = 1,210) were also significantly lower in the water column ($t = 2.12$, $P = 0.019$) than downstream fish (mean = -0.33°, SD = 0.57, n = 55). Upstream traveling fish on both banks were bottom oriented during all tide phases, but were distributed slightly higher in the water column during the rising tide phase (Figure 9).

Late-run fish also showed a tendency to travel along the river bottom, although to a lesser degree than early-run fish (Figure 10 and Appendix E2). Sixty-five percent of upstream fish on the left bank and 79% of upstream fish on the right bank were on or below the acoustic axis. Fifty-four percent of downstream fish on the left bank and 46% of downstream fish on the right bank were on or below the acoustic axis. Upstream fish on the left bank (mean = -0.28°, SD = 0.56, n = 7,513) traveled lower ($t = 5.74$, $P \ll 0.001$) in the insonified water column than downstream fish

Table 5.-Estimates of chinook salmon passage by tide stage and direction of travel for the 2001 early run (16 May to 30 June).

2001 Early Run	Total Number of Fish	Rising	Falling	Low
Upstream	16,676	3,664	9,568	3,445
Row %	100.0%	22.0%	57.4%	20.6%
Column %	97.8%	97.1%	98.1%	98.0%
Downstream	369	110	189	70
Row %	100.0%	29.8%	51.3%	18.9%
Column %	2.2%	2.9%	1.9%	2.0%

Test for Independence: Chi-square = 11.04, df = 2, P = 0.004

Table 6.-Estimates of chinook salmon passage by tide stage and direction of travel for the 2001 late run (1 July to 10 August).

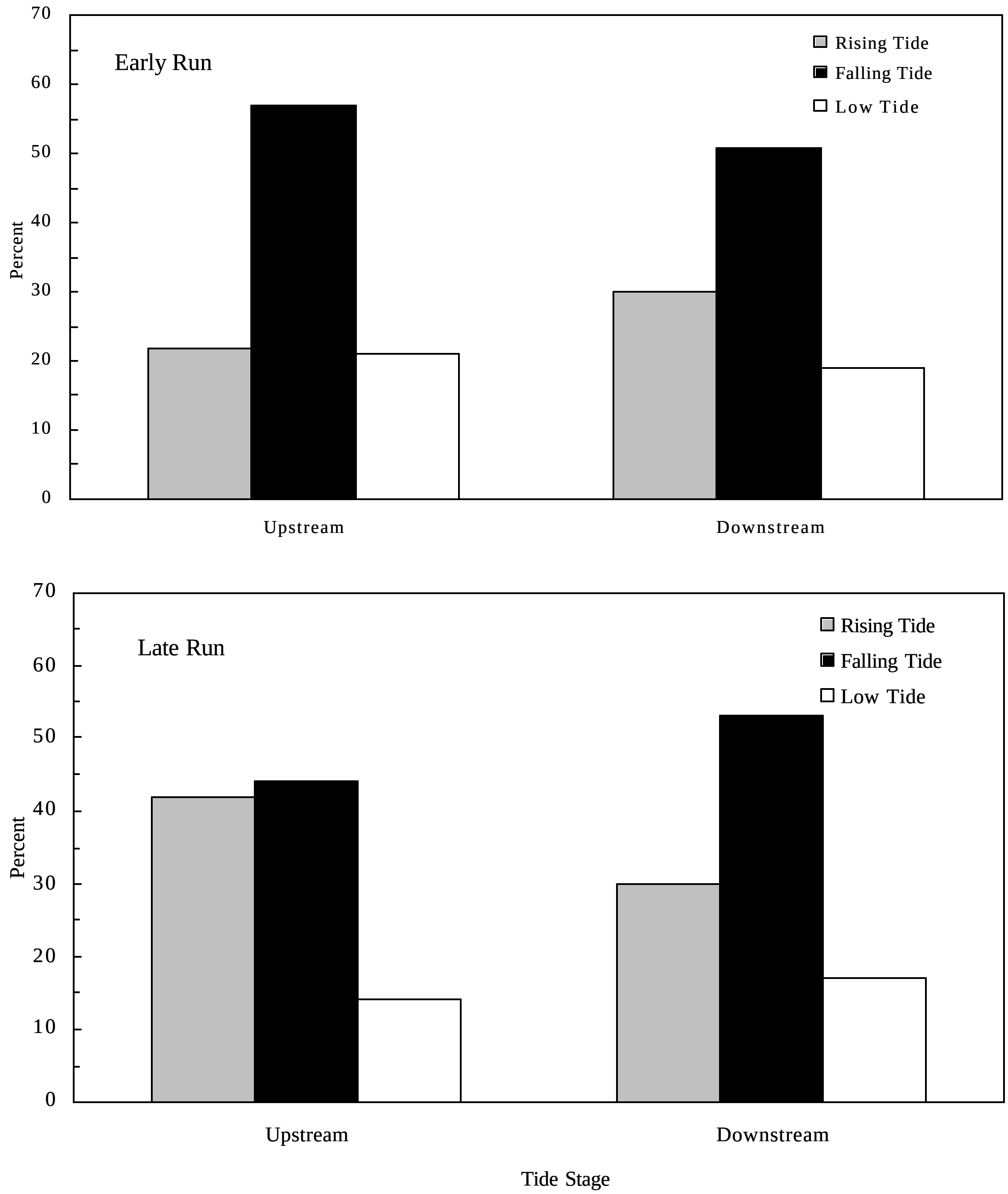
2001 Late Run	Total Number of Fish	Rising	Falling	Low
Upstream	33,916	14,233	14,805	4,878
Row %	100.0%	42.0%	43.7%	14.4%
Column %	96.7%	97.7%	96.0%	96.1%
Downstream	1,149	341	611	196
Row %	100.0%	29.7%	53.2%	17.1%
Column %	3.3%	2.3%	4.0%	3.9%

Test for Independence: Chi-square = 64.80, df = 2, P <<<0.0001

(mean = -0.08°, SD = 0.47, n = 203). Similarly, upstream fish on the right bank (mean = -0.04°, SD = 0.39, n = 2,706) traveled lower (t = 2.84, P = 0.002) in the insonified water column than downstream fish (mean = -0.06°, SD = 0.40, n = 158). Upstream traveling fish on both banks were distributed slightly higher in the water column during the rising tide stage (Figure 11).

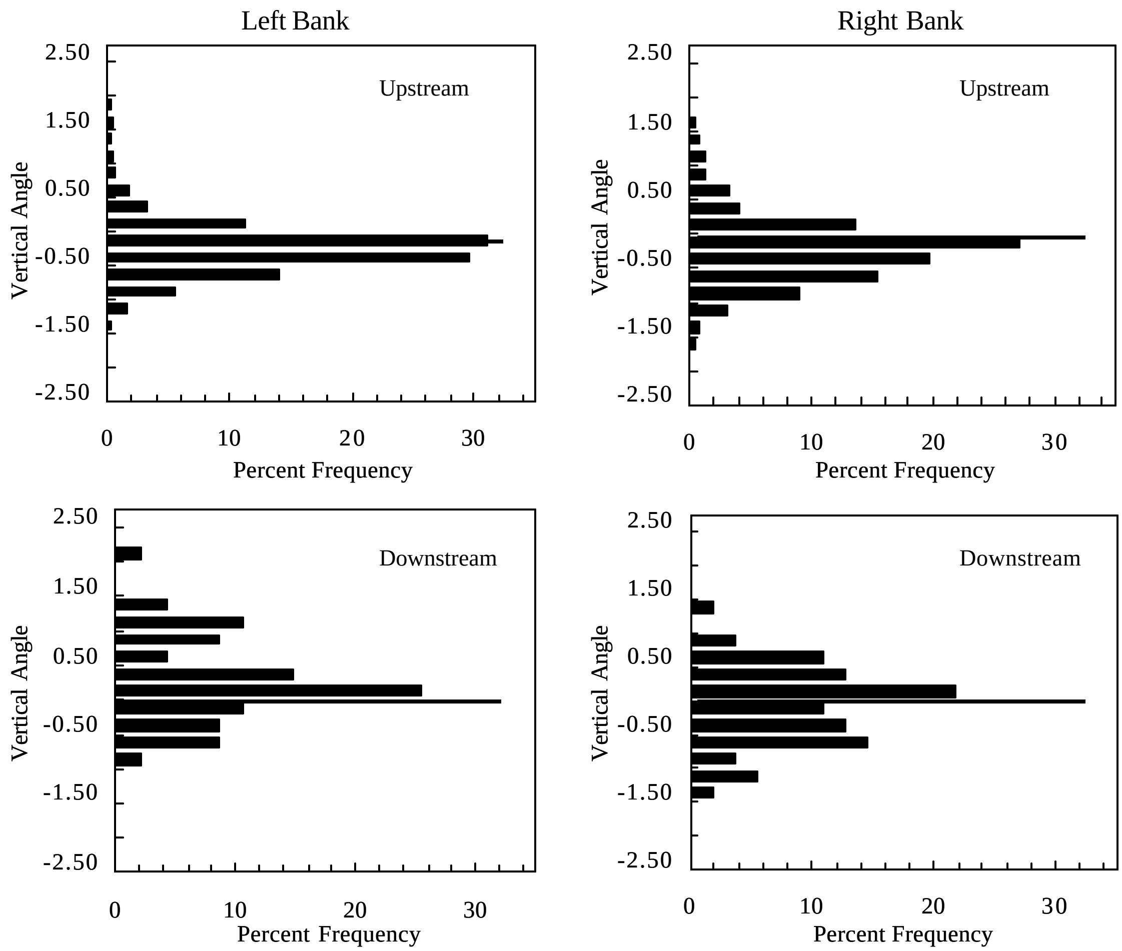
Range Distribution

During the early run, upstream fish on the left bank were distributed throughout the offshore ranges but right-bank fish exhibited a slightly bimodal distribution (Figure 12). Upstream range distributions during the early run were significantly different from downstream distributions for both left (Anderson-Darling, P << 0.001) and right (Anderson-Darling, P << 0.001) banks (Figure 12). Range distributions were similar among the three tide stages for both banks (Figure 13).



Note: Data have been filtered by range and target strength criteria.

Figure 7.-Distribution of upstream and downstream fish by tide stage during the early and late runs, Kenai River, 2001.

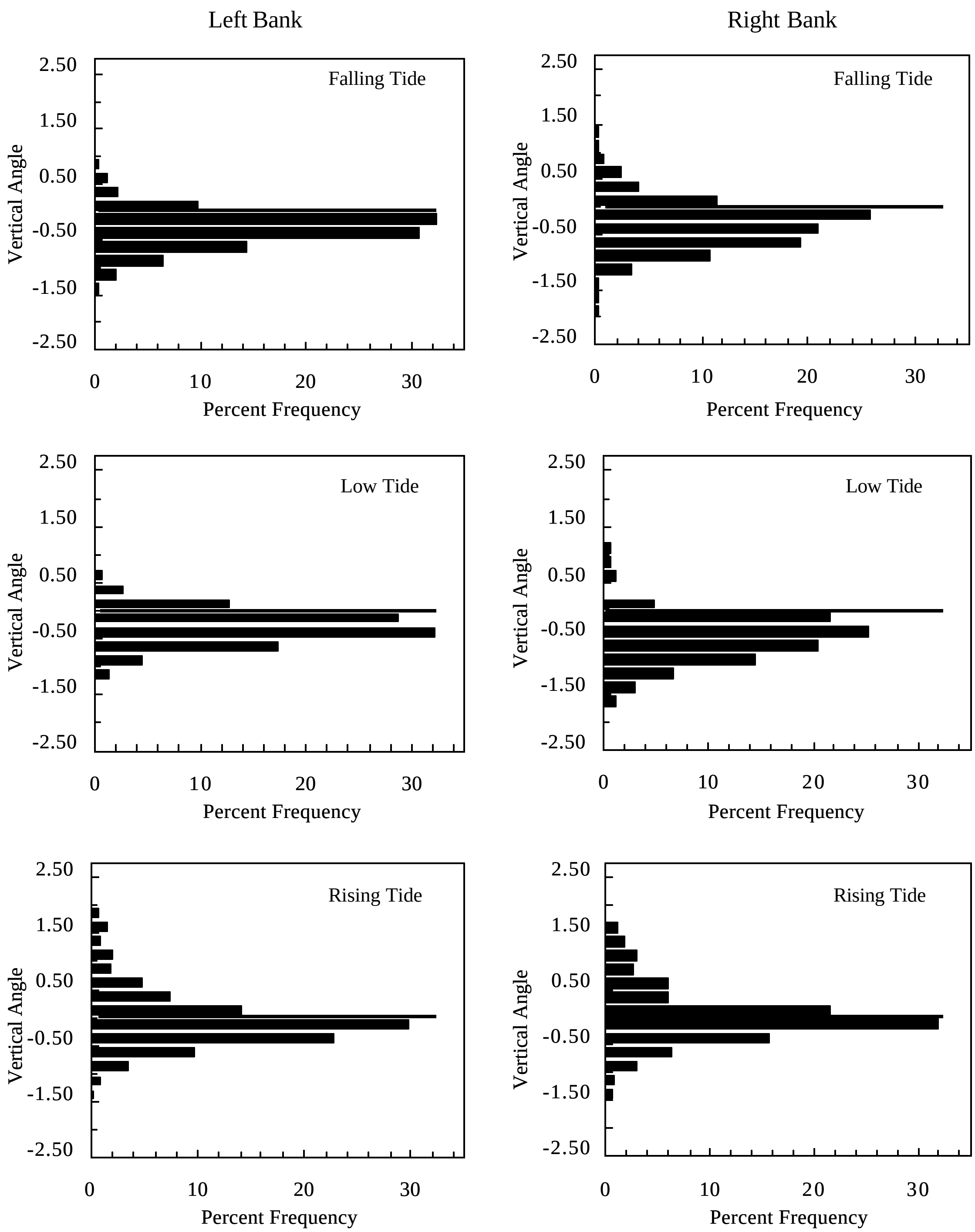


Note: Data have been filtered by range and target strength criteria.

Figure 8.-Vertical distributions of early-run upstream and downstream fish on the left and right banks, Kenai River, 2001.

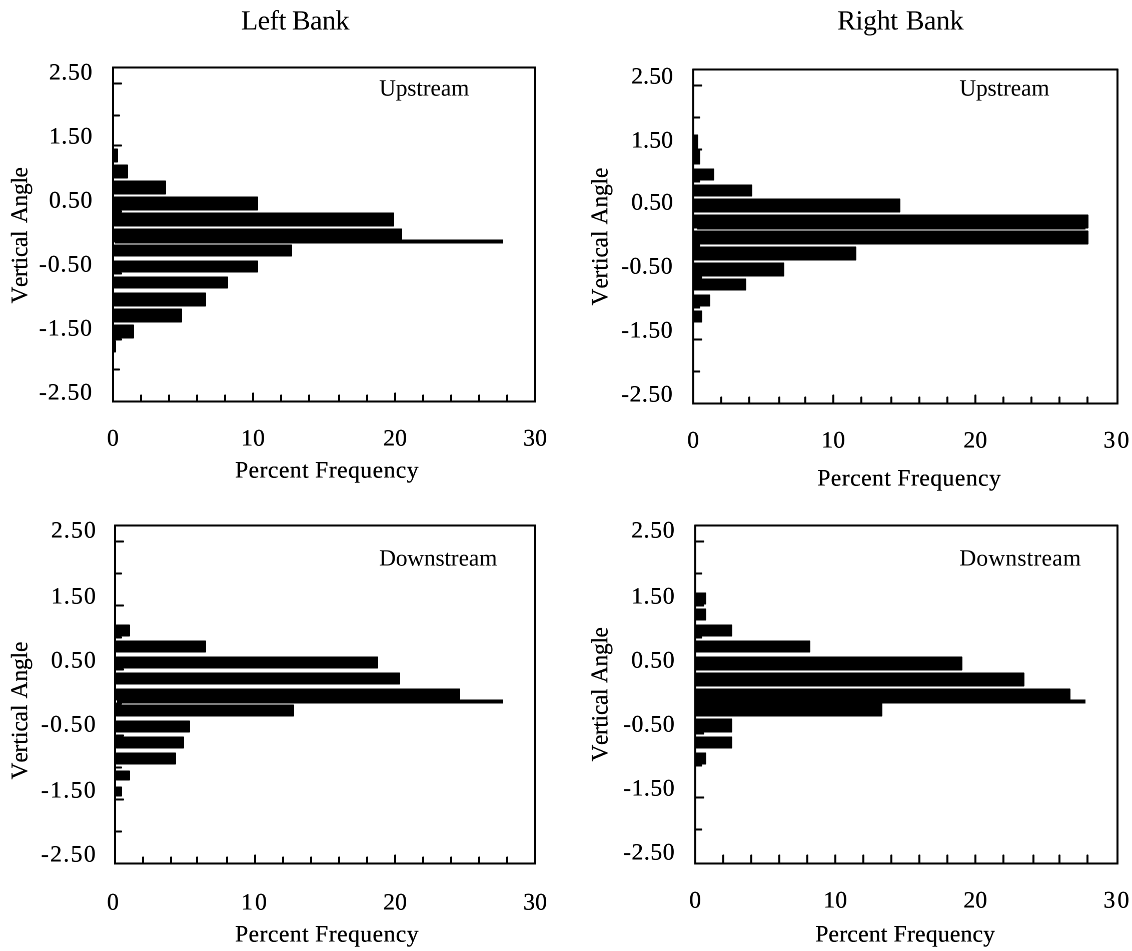
During the late run, upstream fish on the left bank were evenly distributed throughout the range; upstream-moving fish on the right bank exhibited a bimodal range distribution (Figure 14). Range distributions were significantly different between upstream- and downstream-moving fish on both the left (Anderson-Darling, P <<< 0.001) and right (Anderson-Darling, P <<< 0.001) banks; downstream fish exhibited a stronger offshore distribution on each bank (Figure 14). Left- and right-bank range distributions remained relatively unchanged throughout the falling, low and rising tide stages (Figure 15).

Estimates of upstream fish passage by bank were higher for the left bank during both the early and late run (Tables 7 and 8). During the early run 64.7% of the estimated upstream inriver return passed on the left bank while 22.6% of the upstream passage estimate passed by on the right bank (Table 7). Similarly, during the late run 66.9% of the upstream-moving fish passed on the left bank and 26.9% passed on the right bank (Table 8). Passage beyond the insonified range in the mid-river gap area was estimated at 12.7% during the early run and 6.2% during the late run (Tables 7 and 8).



Note: Data have been filtered by range and target strength criteria.

Figure 9.-Vertical distributions of early-run upstream fish during falling, low, and rising tide stages on the left and right banks, Kenai River, 2001.



Note: Data have been filtered by range and target strength criteria.

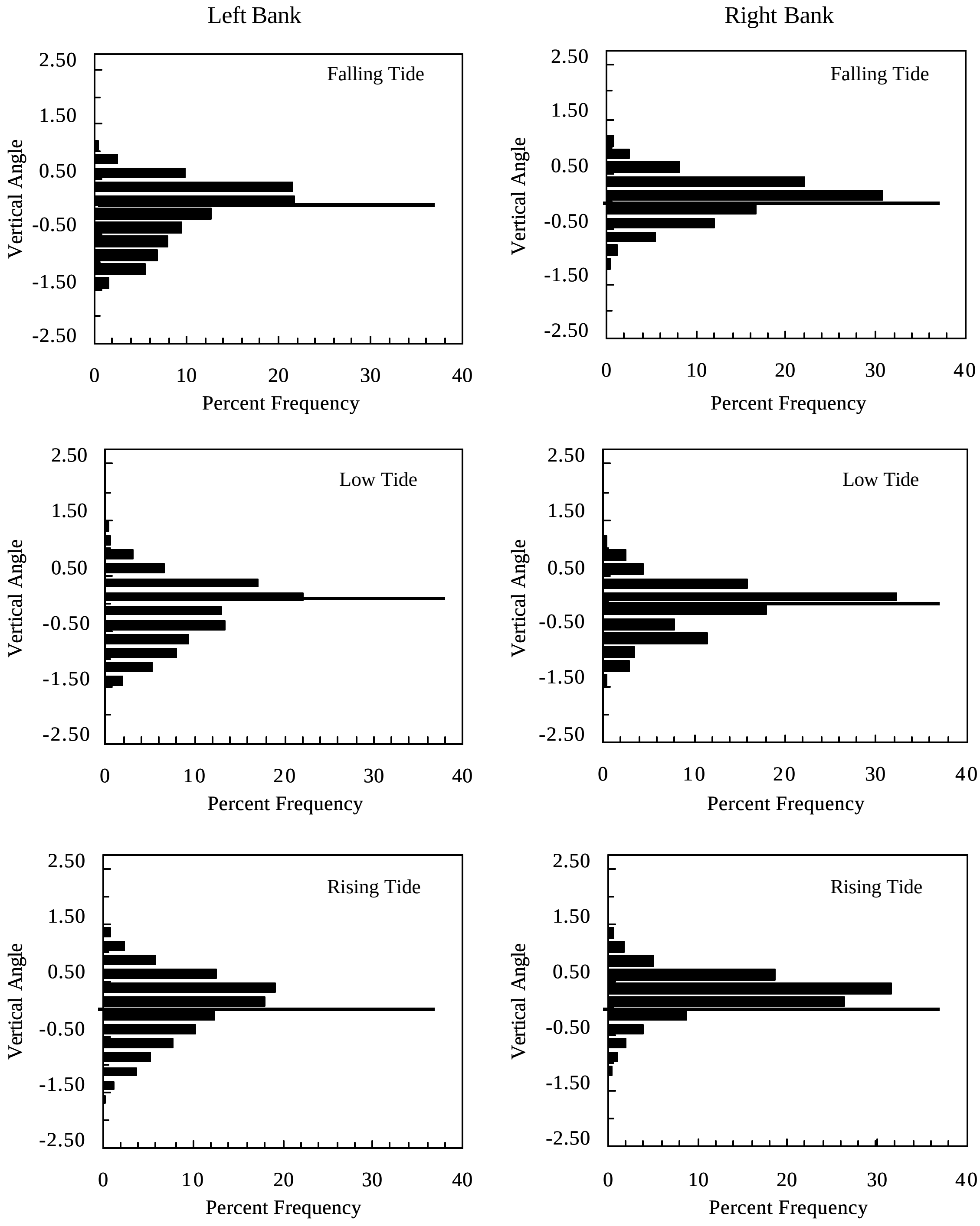
Figure 10.-Vertical distributions of late-run upstream and downstream fish on the left and right banks, Kenai River, 2001.

Target Strength

Target strength distributions varied by bank, direction of travel, and run. Table 9 shows target strength statistics for fish that met minimum range and target strength criteria, whereas Figures 16 and 17 show target strength distributions and statistics that include all tracked targets.

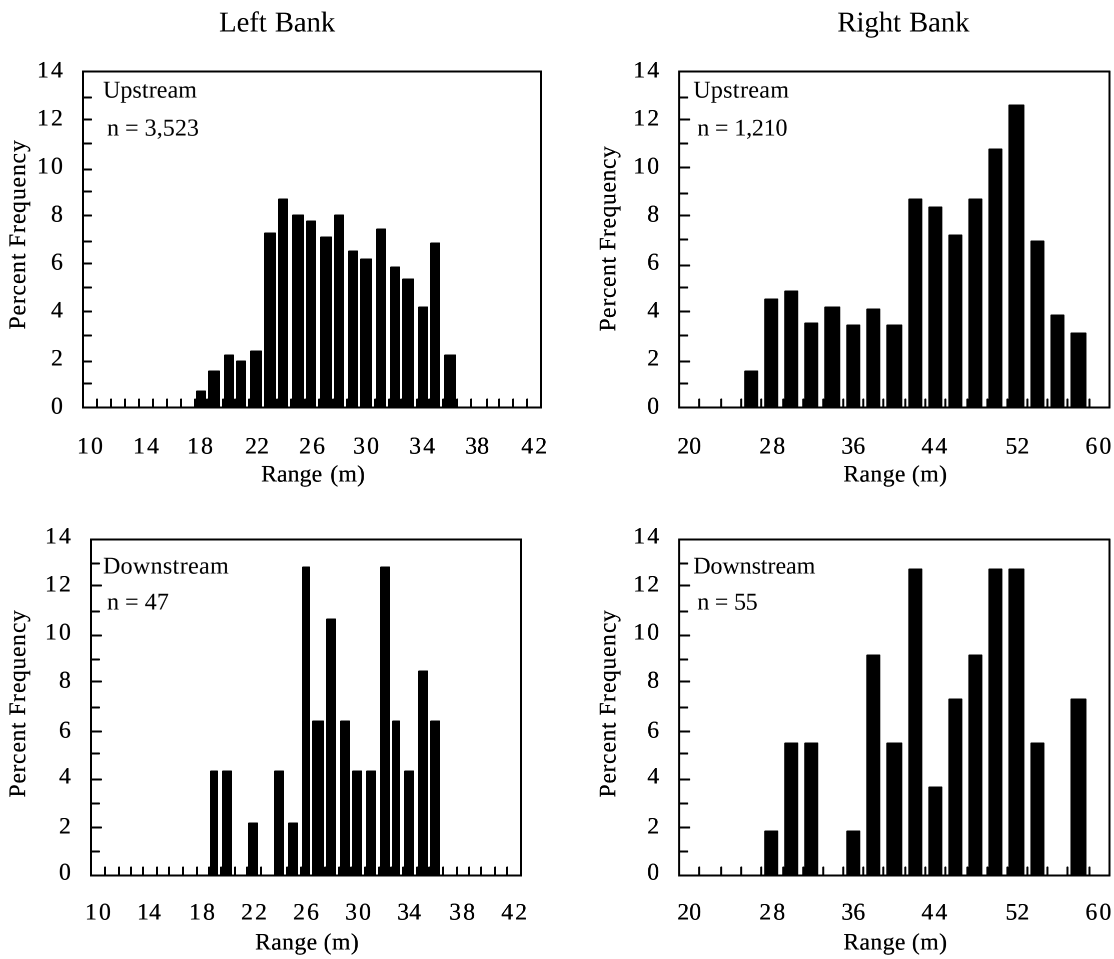
Mean target strength estimates for all upstream targets were similar between banks for both the early and late run, with right bank mean target strength estimates exhibiting slightly more variation (Figures 16 and 17). Mean target strength estimates for all downstream targets were also similar between banks and in general were more variable than upstream targets (Figures 16 and 17).

During the early run on the left bank, mean target strength of chinook salmon was higher ($t = -2.40$, $P < 0.01$) among upstream traveling fish than among downstream traveling fish, but variability was similar ($F = 1.29$, $P = 0.09$; Table 9). On the right bank, mean target strength for



Note: Data have been filtered by range and target strength criteria.

Figure 11.-Vertical distributions of late-run upstream fish during falling, low, and rising tide stages on the left and right banks, Kenai River, 2001.

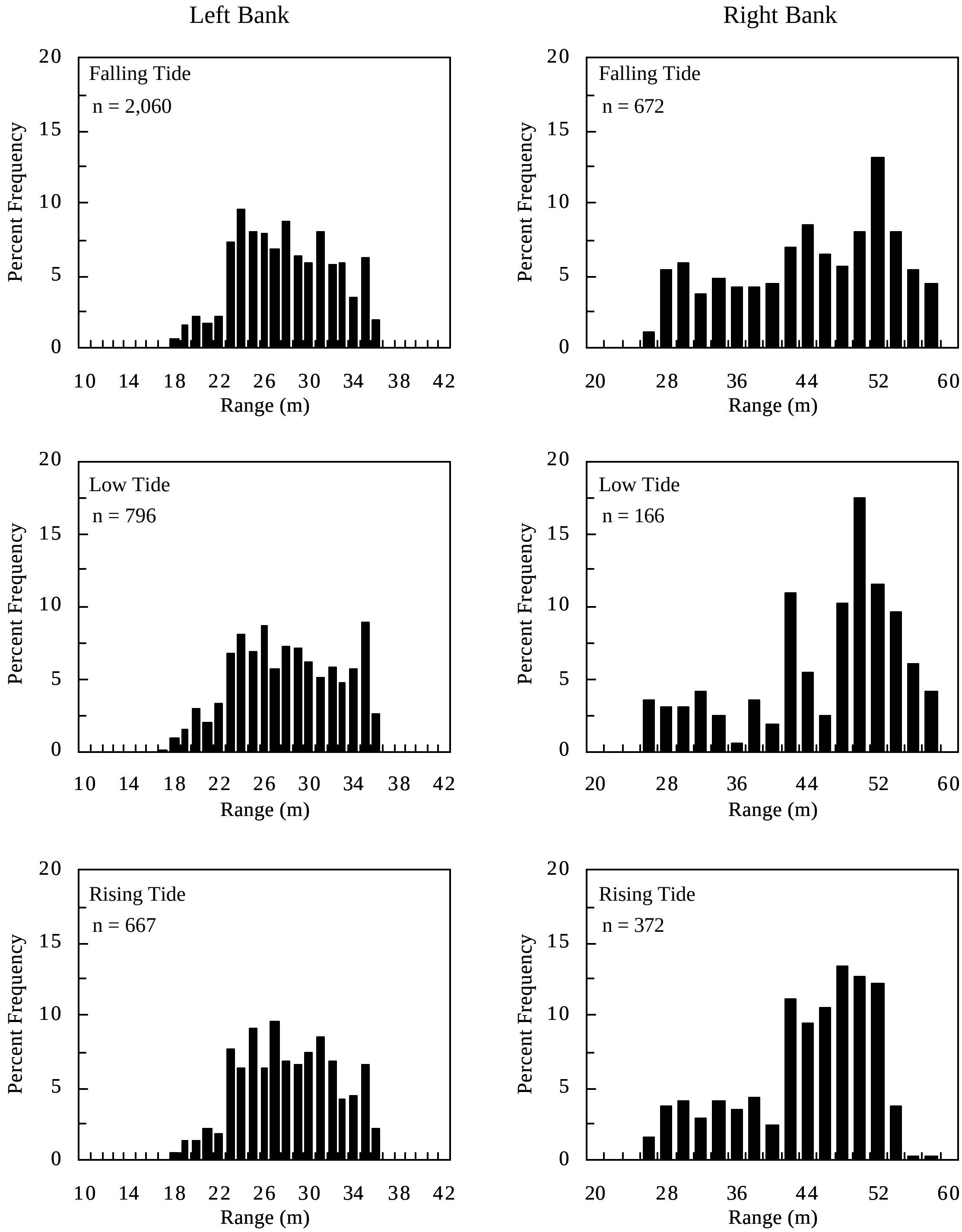


Note: Data have been filtered by range and target strength criteria.

Figure 12.-Range distributions of early-run upstream and downstream fish on the left and right banks, Kenai River, 2001.

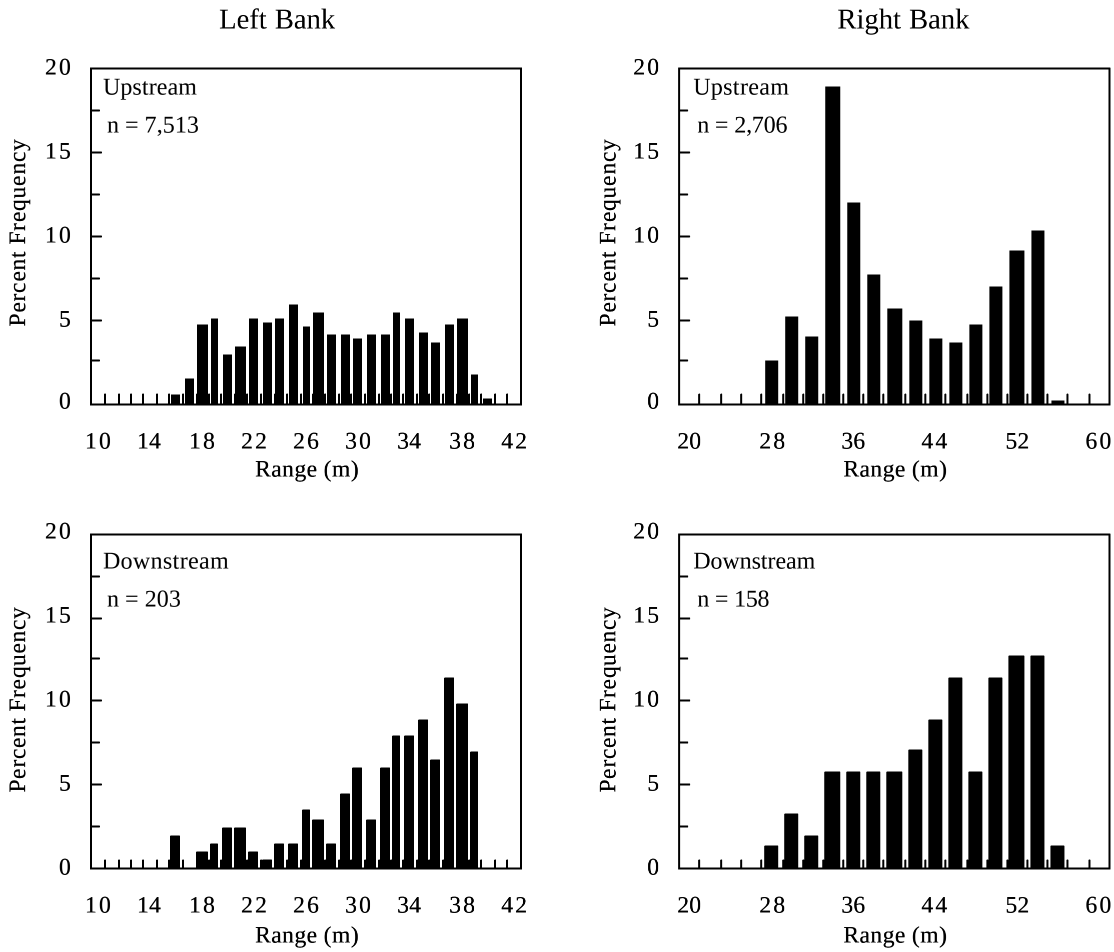
upstream traveling fish was also slightly higher (t = -1.89, P = 0.03), and variability was greater (F = 0.50, P << 0.01; Table 9). The statistical significance of the difference in mean target strength between upstream and downstream traveling fish on both banks was likely an artifact of sample size rather than a meaningful difference in mean target strength.

During the late run on the left bank, mean target strength of chinook salmon was similar (t = -0.44, P = 0.33) among upstream and downstream traveling fish as was the variability in mean target strength (F = 1.06, P = 0.27, Table 9). On the right bank during the late run, mean target strength was again similar (t = -1.14, P = 0.13) among upstream and downstream traveling fish and there was no statistical difference (F = 1.02, P = 0.42) in variability of mean target strength among upstream and downstream traveling fish (Table 9).



Note: Data have been filtered by range and target strength criteria.

Figure 13.-Range distributions of early-run upstream fish during falling, low, and rising tide stages on the left and right banks, Kenai River, 2001.



Note: Data have been filtered by range and target strength criteria.

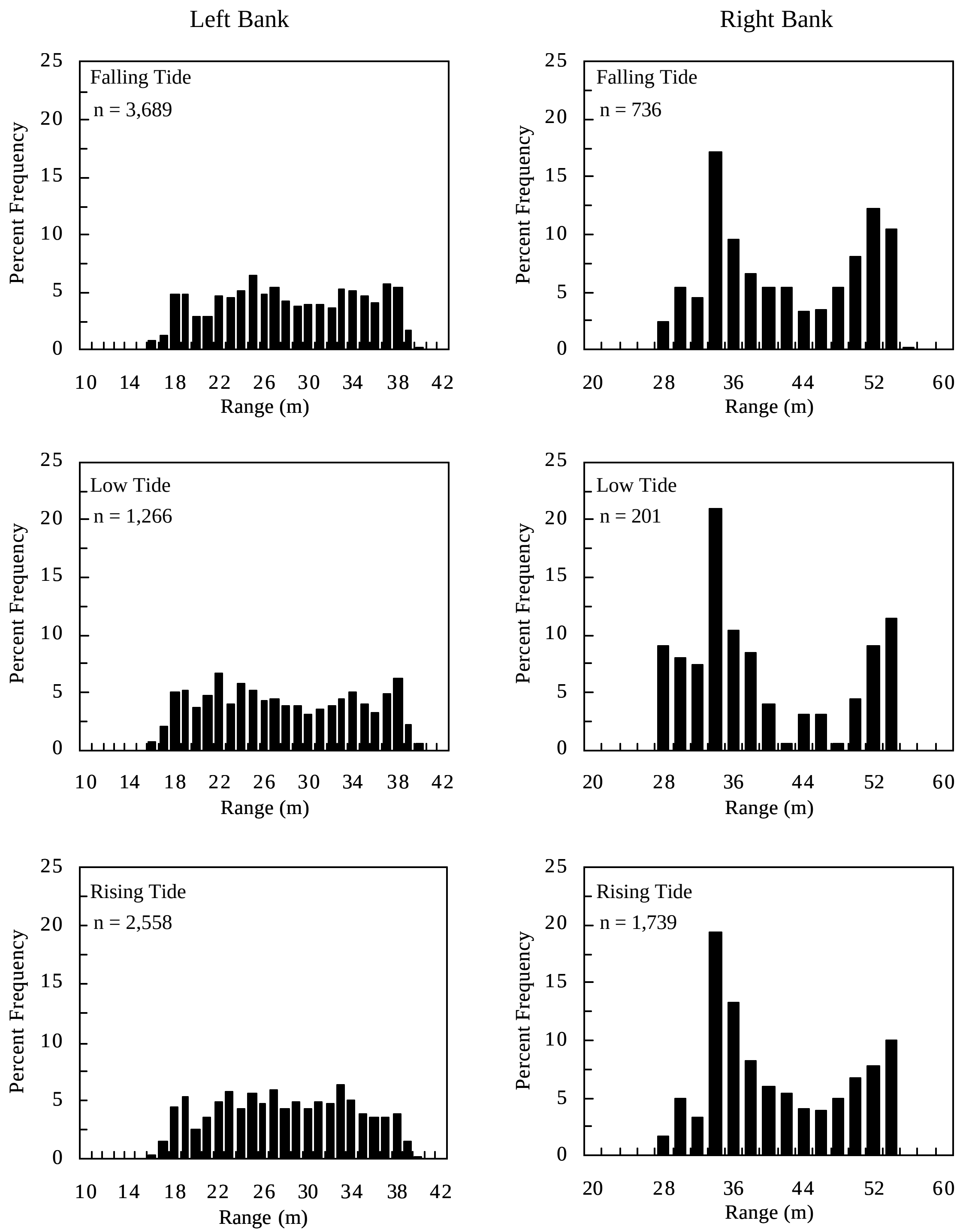
Figure 14.-Range distributions of late-run upstream and downstream fish on the left and right banks, Kenai River, 2001.

Passage Estimates

Daily estimates of chinook salmon passage were generated for 16 May-10 August. Sampling was terminated at 2240 hours on 10 August. During the 87-day season, a total of 641 hours of acoustic data were processed from the right bank and 682 hours from the left bank. This represented 31% of the total available sample time on the right bank and 33% on the left bank.

Final passage estimates differed slightly from those generated inseason after adjustments were made for a calibration error, a late-season suboptimal aim, a gap in mid river coverage, and range threshold corrections (see Methods). Adjustments resulted in a 7% decrease in total passage during the early run and a 6% decrease in total passage during the late run.

Final upstream chinook salmon passage from 16 May through 10 August was estimated at 50,592 (SE = 633) fish, composed of 16,676 (SE = 285) during the early run and 33,916 (SE = 565) during the late run (Tables 7, 8, 10, and 11). The daily peak of the early run occurred on 12 June when 50% of the run had passed by that date (Figure 18). When compared with historic



Note: Data have been filtered by range and target strength criteria.

Figure 15.-Range distributions of late-run upstream fish during falling, low, and rising tide stages on the left and right banks, Kenai River, 2001.

Table 7.-Estimates of early-run fish passage by direction of travel, 2001.

Bank	Estimate of Upstream Component	Estimate of Downstream Component	Estimate of Total Fish Passage[a]
Right Bank	3,763	152	3,915
Left Bank	10,787	167	10,954
Mid-River	2,126	50	2,176
Total	16,676	369	17,045

[a] Total passage (upstream component plus downstream component) is provided to maintain comparability between recent (1995-2001) fish passage estimates derived from split-beam sonar and composed of only upstream targets, and past (1987-1994) estimates generated by dual-beam sonar and composed of both upstream and downstream targets. Dual-beam sonar was not capable of determining direction of travel, so prior to 1995 all targets were assumed to be upstream targets.

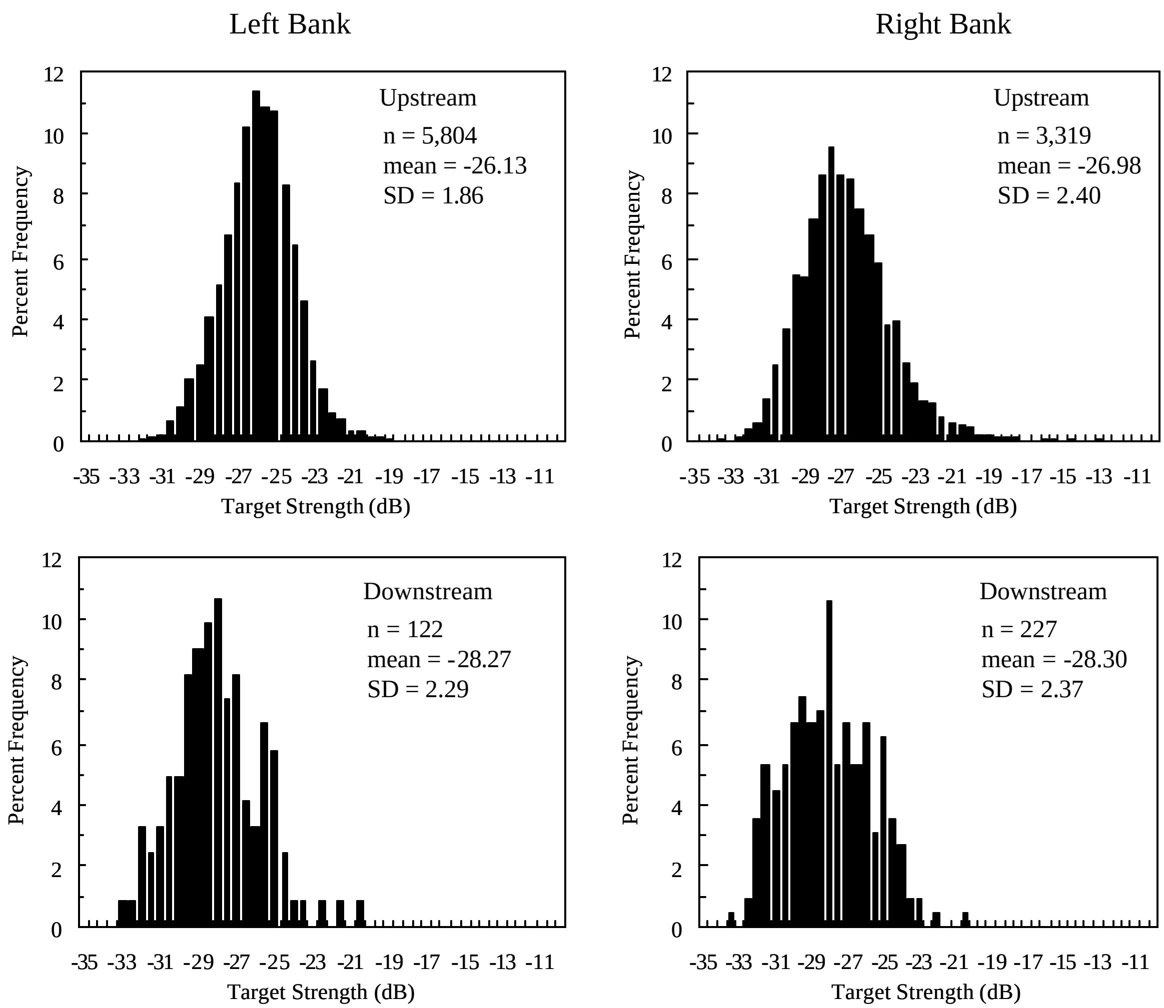
Table 8.-Estimates of late-run fish passage by direction of travel, 2001.

Bank	Estimate of Upstream Component	Estimate of Downstream Component	Estimate of Total Fish Passage
Right Bank	9,126	584	9,710
Left Bank	22,683	498	23,181
Mid-River	2,107	67	2,174
Total	33,916	1,149	35,065

[a] Total passage (upstream component plus downstream component) is provided to maintain comparability between recent (1995-2001) fish passage estimates derived from split-beam sonar and composed of only upstream targets, and past (1987-1994) estimates generated by dual-beam sonar and composed of both upstream and downstream targets. Dual-beam sonar was not capable of determining direction of travel, so prior to 1995 all targets were assumed to be upstream targets.

Table 9.-Mean target strength (dB) for upstream and downstream targets by bank (chinook only) during the early (16 May-30 June) and late (1 July-10 August) runs, 2001.

Location	Upstream Mean Target Strength (dB)	SD	N	Downstream Mean Target Strength (dB)	SD	N
Early Run						
Left Bank	-25.67	1.39	3,523	-26.14	1.58	47
Right Bank	-25.71	1.93	1,861	-25.99	1.37	91
Late Run						
Left Bank	-26.37	1.26	7,513	-26.41	1.30	203
Right Bank	-26.17	1.52	2,706	-26.31	1.54	158



Note: Data have not been filtered by range or target strength criteria.

Figure 16.-Early-run target strength distributions for all upstream and downstream targets on the left and right banks, Kenai River, 2001.

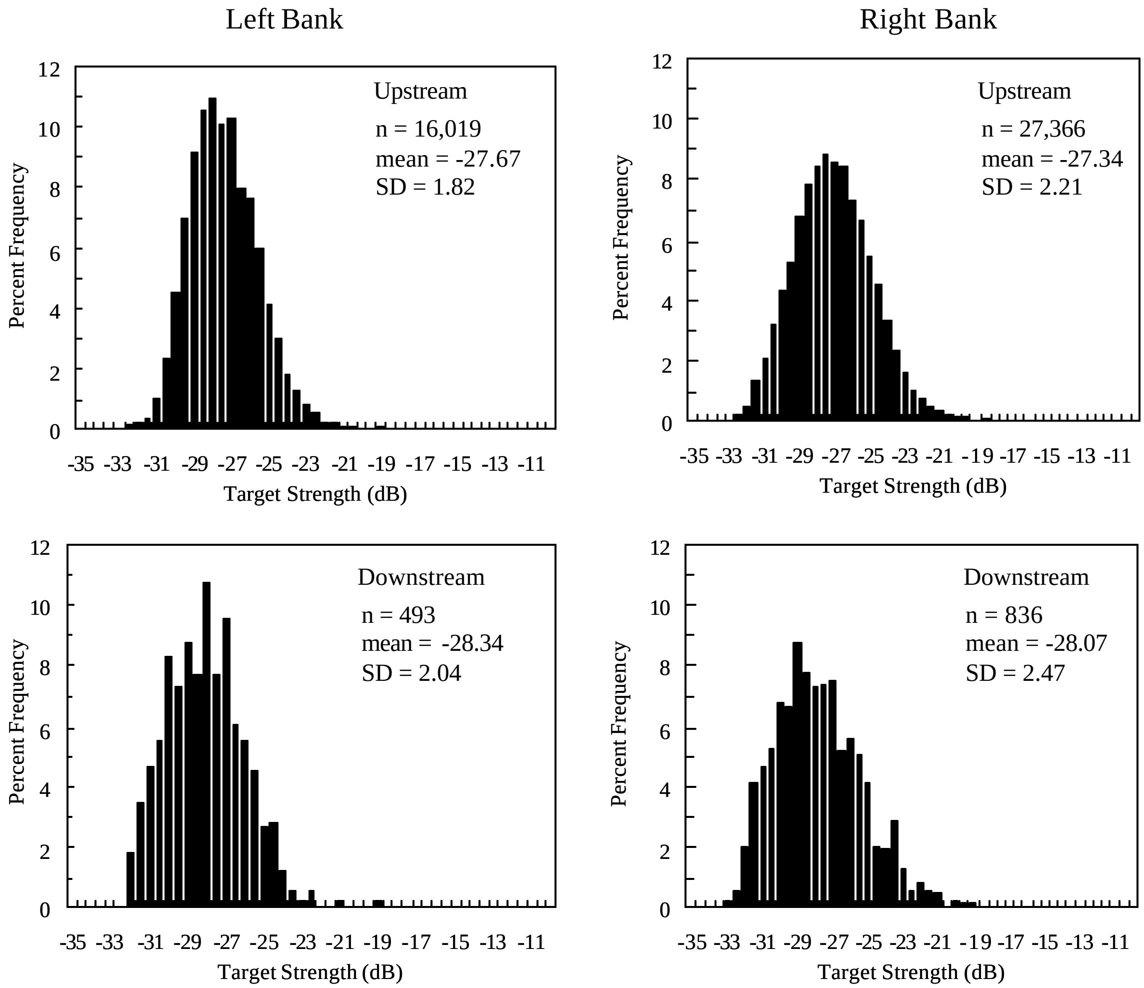
mean escapement timing, the 2001 early run experienced average run timing through May and early run timing beginning in mid June when passage rates increased (Figure 18 and Appendix F1). The daily peak of the late run occurred on 17 July; 50% of the late run passed by 18 July (Figure 19). When compared with historic mean escapement timing, the late run experienced early migratory timing in early July, but became more average as the season progressed (Figure 19 and Appendix F2).

DISCUSSION

SPATIAL DISTRIBUTION

Bank Preference

Historically, the right bank has been heavily favored by migrating fish during both the early and late runs, but the proportion of fish traveling up the right bank has increased as the season



Note: Data have not been filtered by range or target strength criteria.

Figure 17.-Late-run target strength distributions for all upstream and downstream targets on the left and right banks, Kenai River, 2001.

progressed (Burwen and Bosch 1995a; 1995b; 1996; 1998b; Eggers et al. 1995; Bosch and Burwen 1999; Miller and Burwen 2002). During the 2001 early and late runs, however, approximately two-thirds of upstream fish passed on the left bank during each run (Tables 10 and 11). A similar pattern was observed in 1999 when over 50% of upstream passage occurred on the left bank during both runs (Miller et al. 2002). The 1996 and 1997 early runs also experienced heavy left-bank passage: almost half the early-run upstream passage occurred on the left bank during those years (Burwen and Bosch 1998b; Bosch and Burwen 1999). The apparent changes in bank preference do not appear to be related to a changing bottom contour, as the bottom profile at the site has remained relatively stable over the past several years. Bosch and Burwen (1999) pointed out that below average discharge rates during the early runs of 1996 and 1997 might have influenced bank preference. Below average discharge rates also occurred in 1999 (Miller et al. 2002). Discharge rates in 2001, however, were average during much of the early run and well above average throughout the late run (USGS 2002). Relocation of the

Table 10.-Estimated daily upstream passage of chinook salmon, Kenai River sonar, early run, 2001.

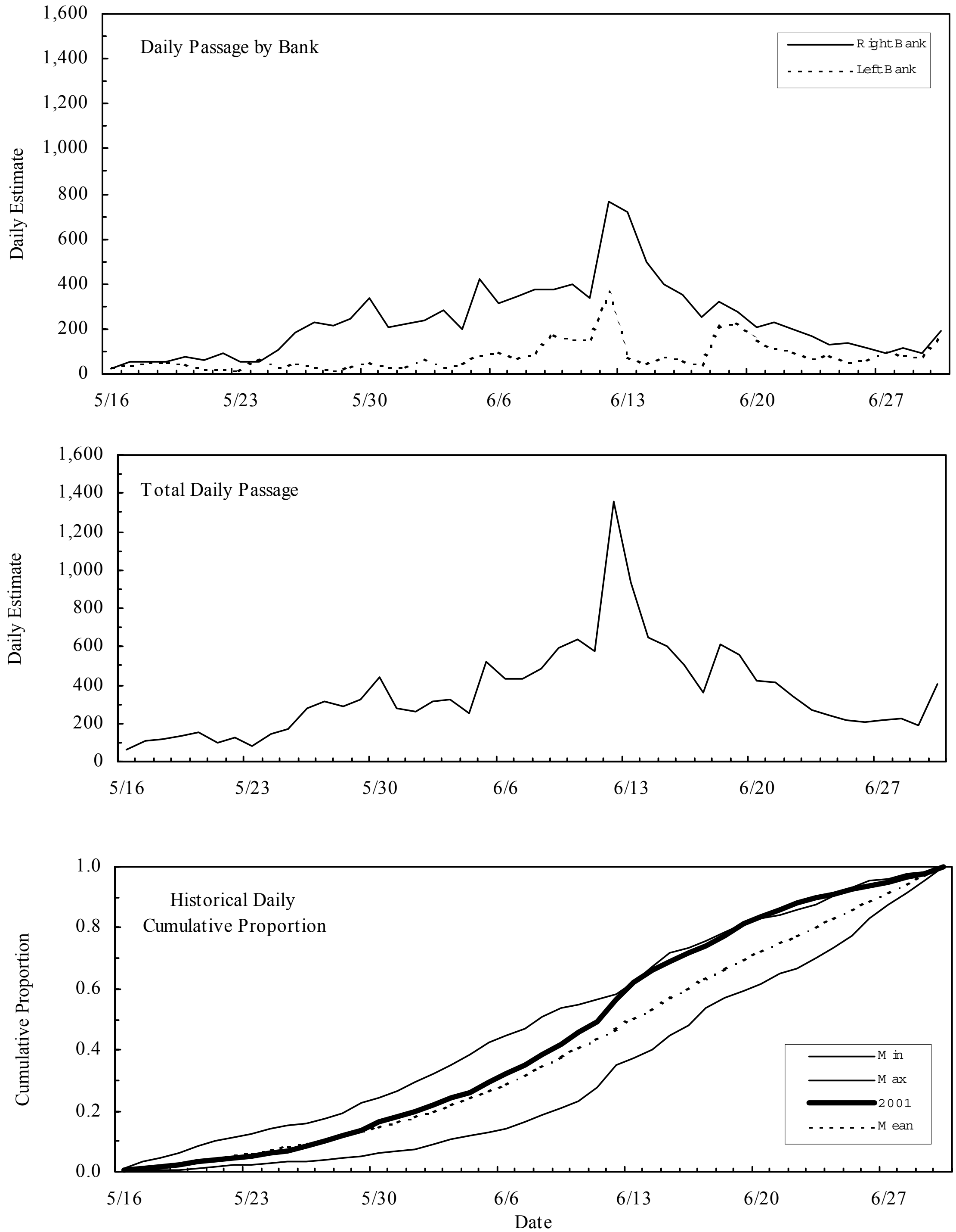
Date	Left Bank	Right Bank	Mid-River[a]	Daily Total	Cumulative Total
16-May	21	30	11	62	62
17-May	54	41	16	111	173
18-May	51	54	12	117	290
19-May	57	51	25	133	423
20-May	78	45	33	156	579
21-May	63	21	17	101	680
22-May	90	24	14	128	808
23-May	51	18	12	81	889
24-May	50	72	25	147	1,036
25-May	105	33	37	175	1,211
26-May	186	48	44	278	1,489
27-May	226	27	61	314	1,803
28-May	216	15	60	291	2,094
29-May	242	33	48	323	2,417
30-May	338	51	51	440	2,857
31-May	207	31	38	276	3,133
1-Jun	219	32	8	259	3,392
2-Jun	240	66	10	316	3,708
3-Jun	281	33	14	328	4,036
4-Jun	201	43	11	255	4,291
5-Jun	420	83	16	519	4,810
6-Jun	315	103	15	433	5,243
7-Jun	344	70	13	427	5,670
8-Jun	377	93	16	486	6,156
9-Jun	374	179	37	590	6,746
10-Jun	396	155	88	639	7,385
11-Jun	336	151	89	576	7,961
12-Jun	762	363	230	1,355	9,316
13-Jun	718	75	146	939	10,255
14-Jun	494	45	108	647	10,902
15-Jun	395	75	130	600	11,502
16-Jun	350	60	89	499	12,001
17-Jun	249	40	75	364	12,365
18-Jun	324	208	75	607	12,972
19-Jun	274	231	53	558	13,530
20-Jun	203	154	61	418	13,948
21-Jun	232	118	67	417	14,365
22-Jun	198	99	49	346	14,711
23-Jun	171	66	35	272	14,983
24-Jun	129	87	24	240	15,223
25-Jun	135	53	25	213	15,436
26-Jun	118	64	21	203	15,639
27-Jun	91	103	26	220	15,859
28-Jun	117	84	23	224	16,083
29-Jun	94	74	22	190	16,273
30-Jun	195	162	46	403	16,676
Total	10,787	3,763	2,126	16,676	

[a] Throughout the early run, approximately 1 to 7.5 m of range in the middle of the river was not insonified by sonar equipment located on either bank. An expansion was used to estimate passage for this portion of the river.

Table 11.-Estimated daily upstream passage of chinook salmon, Kenai River sonar, late run, 2001.

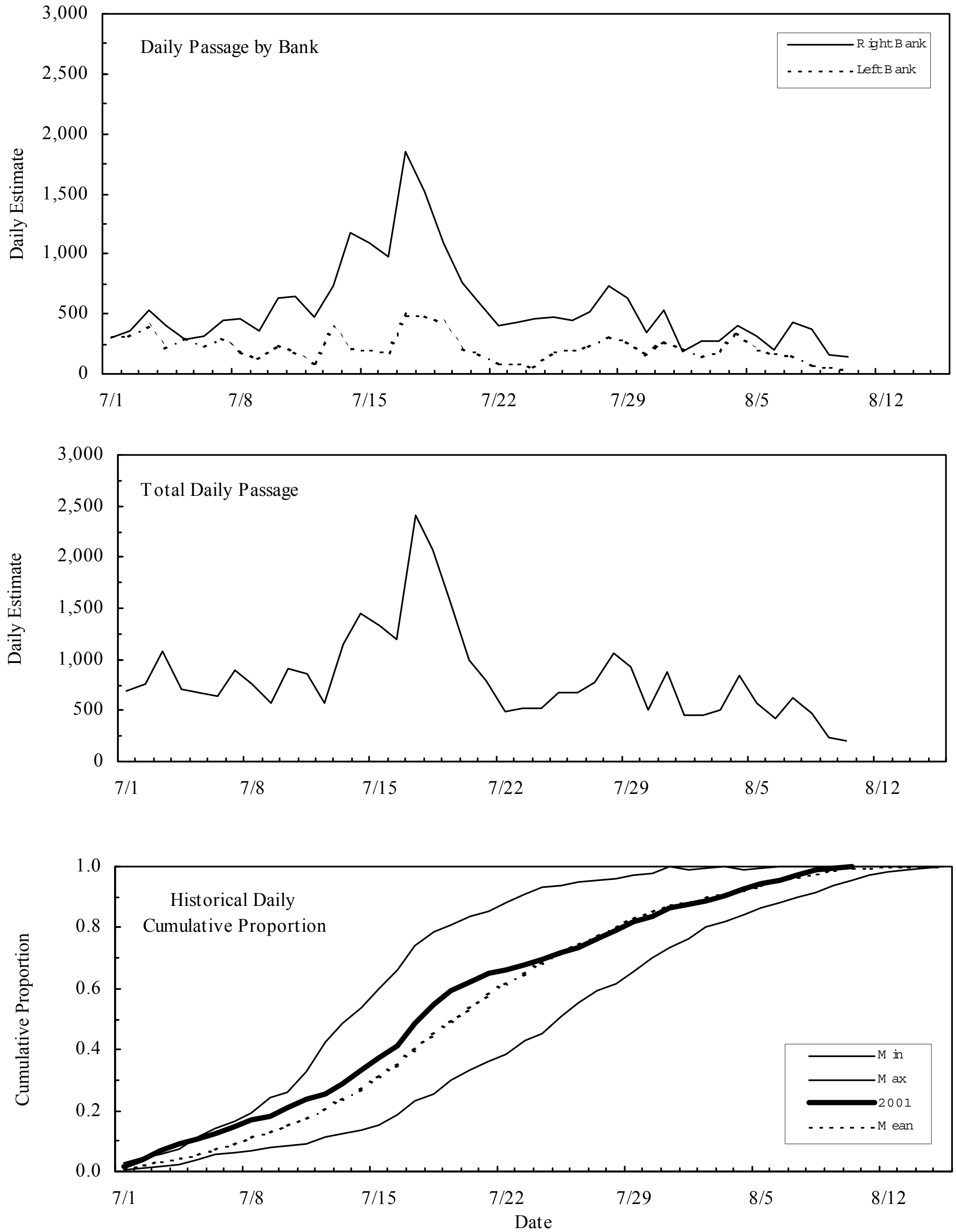
Date	Left Bank	Right Bank	Mid-River[a]	Daily Total	Cumulative Total
1-Jul	303	313	81	697	697
2-Jul	356	309	101	766	1,463
3-Jul	530	396	149	1,075	2,538
4-Jul	401	222	91	714	3,252
5-Jul	287	297	92	676	3,928
6-Jul	311	231	103	645	4,573
7-Jul	440	297	150	887	5,460
8-Jul	455	180	116	751	6,211
9-Jul	365	132	71	568	6,779
10-Jul	629	247	32	908	7,687
11-Jul	647	180	31	858	8,545
12-Jul	467	90	18	575	9,120
13-Jul	731	382	35	1,148	10,268
14-Jul	1,171	219	58	1,448	11,716
15-Jul	1,093	195	50	1,338	13,054
16-Jul	978	177	46	1,201	14,255
17-Jul	1,853	489	73	2,415	16,670
18-Jul	1,515	486	64	2,065	18,735
19-Jul	1,087	428	53	1,568	20,303
20-Jul	757	210	27	994	21,297
21-Jul	587	174	25	786	22,083
22-Jul	395	87	15	497	22,580
23-Jul	428	81	17	526	23,106
24-Jul	461	57	11	529	23,635
25-Jul	476	180	20	676	24,311
26-Jul	447	196	24	667	24,978
27-Jul	520	228	28	776	25,754
28-Jul	726	317	26	1,069	26,823
29-Jul	629	276	24	929	27,752
30-Jul	344	151	13	508	28,260
31-Jul	536	279	68	883	29,143
1-Aug	190	220	45	455	29,598
2-Aug	267	144	48	459	30,057
3-Aug	266	188	50	504	30,561
4-Aug	407	348	85	840	31,401
5-Aug	317	207	57	581	31,982
6-Aug	198	177	42	417	32,399
7-Aug	425	165	28	618	33,017
8-Aug	376	69	22	467	33,484
9-Aug	162	61	9	232	33,716
10-Aug	150	41	9	200	33,916
Total	22,683	9,126	2,107	33,916	

[a] Throughout the late run, approximately 1 to 6.6 m of range in the middle of the river was not insonified by sonar equipment located on either bank. An expansion was used to estimate passage for this portion of the river.



Note: Total estimates (center panel) include mid-river expansion. Mean in bottom panel is based on estimates of total passage for 1988-1997 and upstream passage for 1998-2000.

Figure 18.-Daily sonar estimates of passage by bank (top panel), total passage (center panel), and historical cumulative proportions for the early run of chinook salmon returning to the Kenai River, 2001.



Note: Total estimates (center panel) include mid-river expansion. Mean in bottom panel is based on estimates of total passage for 1987-1997 and upstream passage for 1998-2000.

Figure 19.-Daily sonar estimates of passage by bank (top panel), total passage (center panel), and historical cumulative proportions for the late run of chinook salmon returning to the Kenai River, 2001.

left-bank transducer several meters downstream of its historic location during the 2001 season, and the subsequent improved aim, may have contributed to the higher left-bank passage estimate in that the improved aim was able to detect fish that would not have been detected with the old aim. Increased left-bank preferences observed in previous years, however, suggest that the increased left-bank proportions in 2001 may have resulted from factors other than or in addition to increased fish detectability.

Vertical Distribution

Monitoring the spatial distribution of fish is particularly important at the present site, where tide-induced changes in water level have been shown to affect fish distribution. A primary concern is that fish may swim over the beam during rising and falling tide stages. Because the site experiences extreme semidiurnal tidal fluctuations that average 4 m and are as high as 7 m (Figure 3), it is not possible to insonify the entire cross-sectional area of the river that can potentially be used by migrating chinook salmon. Fish position data suggest that most upstream fish are within the insonified zone. When sockeye are not present in large numbers, most fish prefer the offshore, bottom section of the river where beam coverage is maximized. Although there were slightly more fish in the upper half of the beam during the rising tide stage on both banks during the 2001 early and late runs (Figures 9 and 11), very few fish occupied the upper half of the beam overall. Data collected in previous years showed that fish have maintained a strong bottom orientation during all three tide stages during both the early and late runs (Eggers et al. 1995; Burwen et al. 1995).

Because the vast majority of fish travel close to the river bottom (Figures 8 and 10), our greatest concern is missing fish passing under the sonar beam. Relatively few fish were detected below the -2.0° beam angle (Figures 8 and 10). Even with the decreased ability to detect targets on the edge of the beam, we assume there would be larger numbers of targets detected in this region if substantial numbers of fish were traveling below the effective beam, given the large acoustic size of chinook salmon.

Range Distribution

Because transducer deployment locations varied throughout the season (Figure 4) due to changing water levels, fish range distributions by bank and run were standardized based on the most nearshore deployment locations within that run. Hence, fish range distributions for a given bank and the distances mentioned below reflect distance from the most nearshore deployment location for that bank.

The range distribution of upstream-moving fish on the left bank indicates that fish were dispersed throughout the insonified range during both the early and late runs. The offshore truncation of the left-bank early-run range distribution was the result of the transducer location and river bottom contour restricting the left-bank early-run maximum insonified range to 36 m (Figure 12). Low passage inside of 24 m during the early run (Figure 12) and inside 18 m during the late run (Figure 14) was the result of using range thresholds to eliminate nearshore sockeye salmon from chinook salmon counts. The nearshore range distribution was partially influenced by varying range thresholds and by tripod relocations closer to shore as the water level rose.

The right-bank range distribution also exhibited nearshore truncation during both the early and late runs due to range filters eliminating nearshore targets (Figures 12 and 14). This was very evident during the late run. The apparent large increase in passage from 32 m to 34 m during the late run was an artifact of the range thresholds eliminating most of the targets inside of 34 m

(Figure 14). Varying range thresholds used throughout the late run resulted in some passage inside of 34 m, but the threshold used during peak passage (14 July-19 July) eliminated a substantial number of nearshore targets and resulted in the apparent large increase in passage just beyond the threshold range.

TARGET STRENGTH

Historically, the left bank has consistently produced higher mean target strength estimates than has the right bank (Burwen and Bosch 1998b; Bosch and Burwen 1999, 2000; Miller et al. 2002; Miller and Burwen 2002). The higher mean target strength observed on the left bank was attributed to threshold-induced bias rather than actual differences in fish size. It was concluded that the acoustically reflective gravel substrate on the left bank prevented the sonar beam from being aimed as close to the river bottom on that bank as it was on the right. Because left-bank fish were, on average, farther from the acoustic axis than right-bank fish, a greater proportion of small echoes from left-bank fish failed to meet the voltage threshold, thus biasing target strength estimates upward. In addition, the higher background noise experienced on the left bank resulted in higher variability in positional estimates, which also resulted in a positive target strength bias.

In 2001, the relocation of the left-bank transducer approximately 35 m downstream of the historical location resulted in an improved sonar beam aim. Although the substrate type was similar at the new location, the more favorable bottom contour allowed for the left-bank sonar beam to be aimed closer to the river bottom throughout its range resulting in more on-axis targets. The improved left-bank aim was evident in both the early- and late-run left-bank mean target strength distributions for unfiltered targets (Figures 16 and 17). Mean target strength of all upstream targets was very similar between banks for both runs, with mean target strengths of left-bank targets exhibiting smaller standard deviations than those of right-bank targets.

Downstream unfiltered targets were smaller (1 dB on the right bank, 2 dB on the left bank) than upstream unfiltered targets during the early run (Figure 16). The proportion of downstream targets was also slightly larger in the unfiltered data set than in the filtered data set during the early run (4% vs. 3%; Table 9 and Figure 16). Smaller downstream unfiltered targets and a larger proportion of downstream targets in the unfiltered data set indicates that the target strength threshold is most likely filtering out downstream traveling debris that were incorrectly classified as downstream swimming fish, or that smaller fish were more likely to travel downstream. During the late run, downstream targets were only slightly smaller (less than 1 dB on each bank) than upstream targets and the proportion of downstream targets was similar (~3%) for filtered and unfiltered data (Table 9 and Figure 17). The tendency for downstream traveling targets to have smaller average target strengths than upstream-traveling targets has been documented in prior years (Bosch and Burwen 1999, 2000; Miller et al. 2002; Miller and Burwen 2002). Discerning between debris-like traces and a fish traveling downstream can be difficult, and crewmembers are instructed to include downstream targets as valid fish traces when in doubt. Some misclassification of downstream-traveling debris as fish is inevitable. This is the reason that this project and many others choose to ignore downstream targets rather than subtract them from upstream estimates even when direction of travel is known. Typically, the proportion of downstream targets is small, and the potential error that would be introduced by misclassifying debris as downstream traveling fish is of greater concern.

After applying range and target strength filters to both the early and late runs, average target strength of upstream and downstream traveling chinook salmon on each bank differed by less than 1 dB (Table 9). This suggests that at least in the data set used to generate chinook salmon estimates, most downstream targets were correctly classified as fish rather than debris.

DIRECTION OF TRAVEL

All tracked targets have been classified by direction of travel since 1995, when split-beam technology was first implemented. Since then, the downstream component of the early run has varied from 6% to 12% and averaged 8%, while the downstream component of the late run has ranged from 4% to 14% and has averaged 6% (Burwen and Bosch 1996, 1998b; Bosch and Burwen 1999, 2000; Miller et al. 2002; Miller and Burwen 2002). The downstream component of the late run during 5 of the past 6 years has equaled 6% or less with the exception of the 14% anomaly estimated in 1998 (Bosch and Burwen 2000). Downstream passage in 2001 averaged 2% during the early run and 3% during the late run (Tables 5 and 6).

The proportion of downstream targets in 2001 was relatively large during the first few days of the early run and also appeared to increase slightly during the last 2 weeks of the late run (Appendices D1 and D2). The late-run downstream component averaged 3% before 29 July, but averaged 7% after that date. A similar late-season trend was observed in 1998 and 2000 (Bosch and Burwen 2000; Miller and Burwen 2002) and may be attributed to mainstem spawners lingering in the sonar beam and slowly swimming upstream and then back downstream, thus increasing the downstream count.

COMPARISON OF PASSAGE ESTIMATES WITH OTHER INDICES

Based on many years of research, we no longer assume that sonar estimates of chinook abundance are equally reliable under all circumstances. Recent research efforts have focused on identifying conditions when sonar estimates may not be reliable. Our foremost concern is that we may be including substantial numbers of sockeye in chinook estimates during periods of high sockeye passage. Therefore, sonar estimates of chinook abundance were compared with several other indices of chinook and sockeye abundance to aid in evaluating the sonar's accuracy with respect to both species apportionment and run magnitude.

As mentioned above (see Methods), chinook gillnet CPUE and net-apportioned sonar estimates were compared with chinook sonar passage estimates to determine periods when the chinook passage estimate was likely biased high due to presence of sockeye. We should emphasize that the net-apportioned sonar estimate is experimental, and although within-year comparisons with the chinook passage estimate may be useful, year-to-year comparisons should not be made because the methods used in the netting program continue to evolve and change.

In addition to comparing gillnet CPUE and the net-apportioned sonar estimates to chinook sonar passage estimates, we also compared the chinook sonar estimate with sport fish catch rates and with upriver sockeye sonar estimates.

Inriver sport fish CPUE is monitored by an intensive creel program (Reimer 2003) and may be a useful index of chinook salmon abundance. But like gillnet CPUE, its performance varies under changing water clarity and discharge conditions. It may also vary with changes in how the sport fishery is prosecuted with respect to bait restrictions and/or closures.

The river mile-19 sockeye sonar site, located upriver of the chinook sonar site, provides an index of inriver sockeye salmon abundance. This sonar project is conducted from 1 July through mid August by the Commercial Fisheries Division and targets only nearshore sockeye salmon (Davis 2001). Although travel time between the mile-8.6 chinook sonar site and the river mile-19 sockeye sonar site undoubtedly varies, we believe it averages 1 to 2 days. Information from this project aids in determining periods when chinook estimates are most likely to be biased high.

Early Run

The 2001 early-run inriver return estimate of 16,676 chinook salmon was average compared to past years (Appendix F1), while presence of sockeye salmon during the 2001 chinook salmon early run was likely greater than in past years. Early-run sockeye salmon escapement to the Russian River, a tributary to the Kenai River and a major contributor to early-run Kenai River sockeye salmon escapement, was 78,255 fish in 2001 based on weir counts, which together with catch estimates composed a near record return (Larry Marsh, Alaska Department of Fish and Game, Soldotna, personal communication). Gillnet CPUE estimates confirm the presence of sockeye salmon at the chinook sonar site during much of June, with peak sockeye gillnet CPUE occurring during the first 2 weeks of June (Figure 20). The presence of sockeye salmon in the gillnets and the large escapement of early-run Russian River sockeye salmon leads one to question what influence sockeye passage may have had on chinook passage estimates.

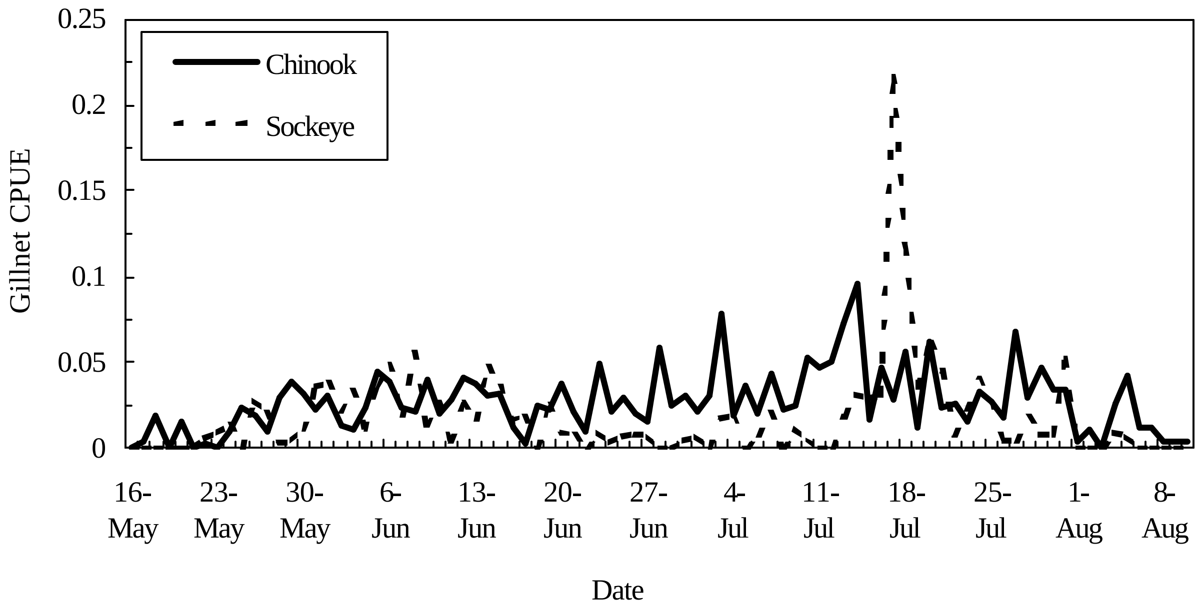


Figure 20.-Daily CPUE of chinook and sockeye salmon from inriver gillnetting, 16 May-10 August, 2001.

The range distribution of unfiltered upstream targets during the early run reveals that the distribution of passage shifted closer to shore (i.e., 15-19 m on the left bank and 22-40 m on the right bank) during the first 2 weeks of June (Figure 21). The shift in passage was more obvious on the right bank than on the left bank where fish were more evenly distributed throughout the range. Possible explanations for the shift in passage include increased sockeye passage, increased discharge rates (Figure 22) forcing chinook closer to shore, or a combination of both.

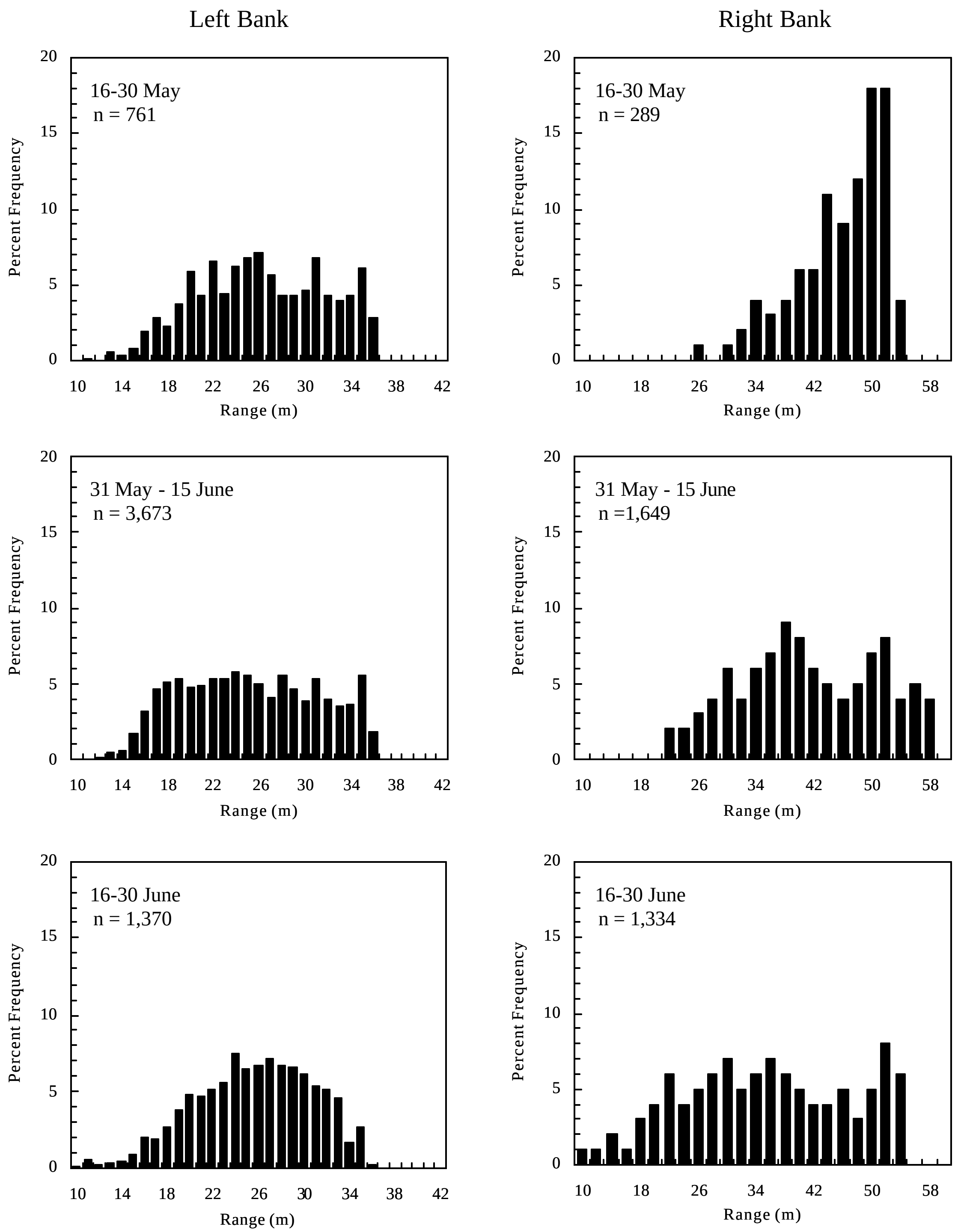


Figure 21.-Range distribution of all (unfiltered) upstream targets on the left and right banks during the early run, 16-30 May, 31 May-15 June, and 16-30 June, Kenai River, 2001.

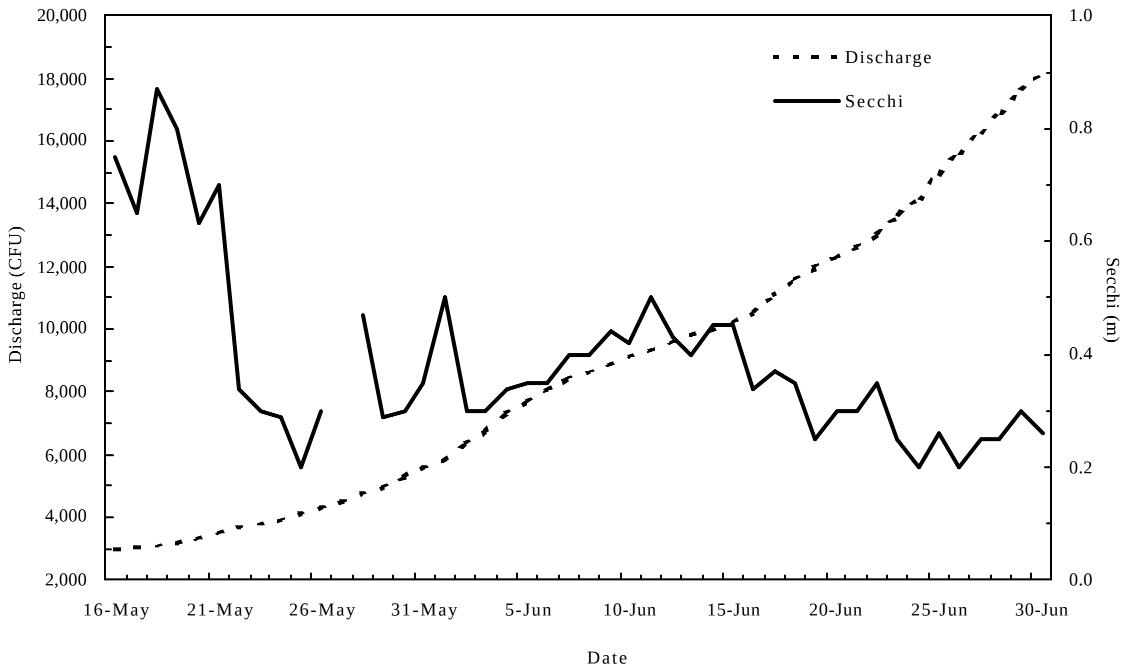


Figure 22.-Daily discharge rates at the Soldotna Bridge and Secchi depth readings in front of the sonar site, Kenai River, early run (16 May–30 June), 2001.

CPUE estimates of chinook salmon from inriver gillnetting tracked early-run sonar estimates fairly well until about 20 June (Figure 23). During the last 10 days of June, sonar estimates declined and CPUE generally increased. In the past, such discrepancies could be explained by changing river conditions; e.g., increased net efficiency was often associated with decreasing water clarity and/or decreasing water volume (Reimer et al. 2002). However, river conditions cannot explain the increased net efficiency in late June 2001. During this time period, discharge was increasing and Secchi readings were relatively stable (Figure 22).

Net apportioned estimates, which are the product of unfiltered sonar estimates and proportion of chinook salmon in the net catches (Equation 13), tracked the sonar estimates quite well during the early run (Figure 24, Appendix G1). During late June, the net-apportioned estimates were slightly higher than the conventional sonar estimates, but the difference was relatively small and both estimates exhibited the same trend.

In general, CPUE of sport-caught chinook salmon exhibited a trend similar to sonar estimates, with chinook CPUE peaking in early to mid June and decreasing after that (Figure 25). Elevated sport CPUE in early to mid June confirms an increased chinook presence during the period of increased sockeye passage, suggesting that elevated chinook sonar counts during this time cannot be attributed solely to sockeye misclassification. As with gillnet CPUE data, sport CPUE can be influenced by several factors including river discharge and water clarity. No obvious correlation existed between sport CPUE and river discharge or water clarity during the early run (Figures 22 and 25).

Although daily sockeye gillnet CPUE and large Russian River weir counts suggest the presence of sockeye throughout much of the early run, indices discussed above suggest that filters were

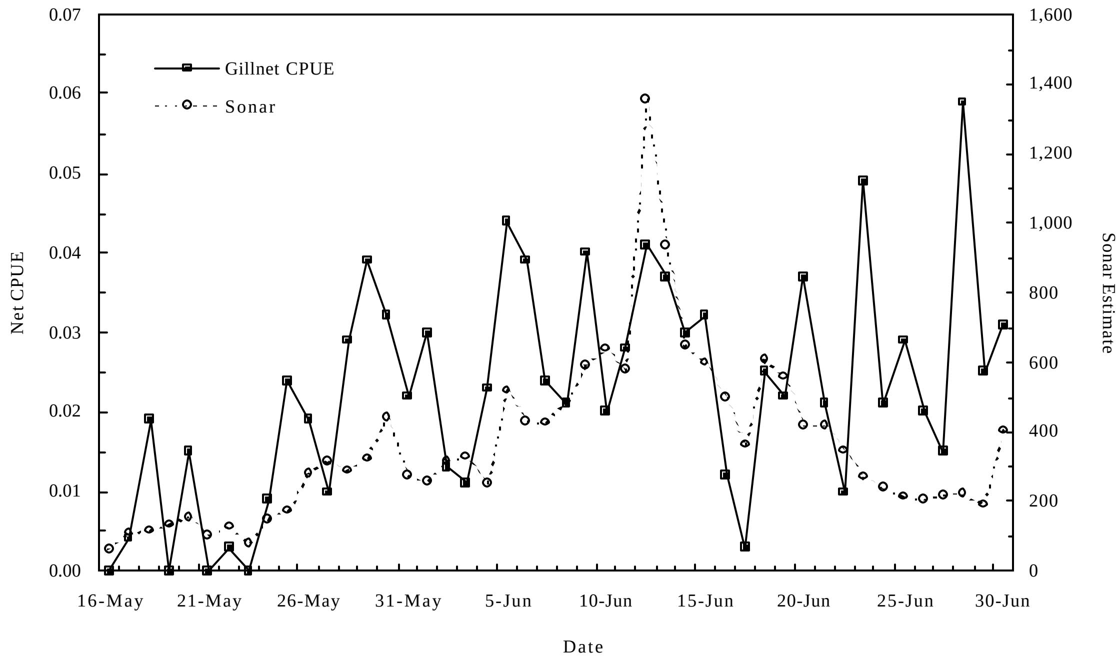


Figure 23.-Daily sonar estimates and inriver gillnet CPUE of chinook salmon during the early run (16 May–30 June), Kenai River, 2001.

successful at removing most of these targets and that inflation of early-run chinook estimates was minimal.

Late Run

The 2001 late-run inriver return of 33,916 chinook salmon was below average (Appendix F2), as was the river mile-19 sockeye salmon escapement estimate of 650,036 (Davis *In prep*). As with the early run, there were no indications that sockeye salmon passage severely affected late-run chinook passage estimates. However, some misclassification was possible and may have occurred in mid July.

Based on gillnet CPUE of sockeye salmon (Figure 20) and river mile-19 sockeye salmon sonar estimates (Figure 26), substantial numbers of sockeye salmon were likely present at the chinook sonar site throughout much of July and into August. Gillnet CPUE data show a peak in sockeye passage at the chinook sonar site on 17-18 July that was of a large magnitude compared to chinook gillnet CPUE data (Figure 20). The river mile-19 sockeye salmon sonar site also experienced a large peak in sockeye passage on 18 July, as well as a second large peak on 28 July (Figure 26). The second peak in sockeye passage at the sockeye sonar site was likely not evident in the netting data because these sockeye may have traveled inshore of where the gillnets were fished, whereas during the earlier peak sockeye may have traveled further offshore within range of the gillnets.

Range distributions based on sonar counts confirm a shift in passage closer to shore (i.e., 13-19 m on the left bank and 20-30 m on the right bank) in mid to late July (Figure 27). The shift in passage was more pronounced on the right bank than on the left bank, with left-bank targets

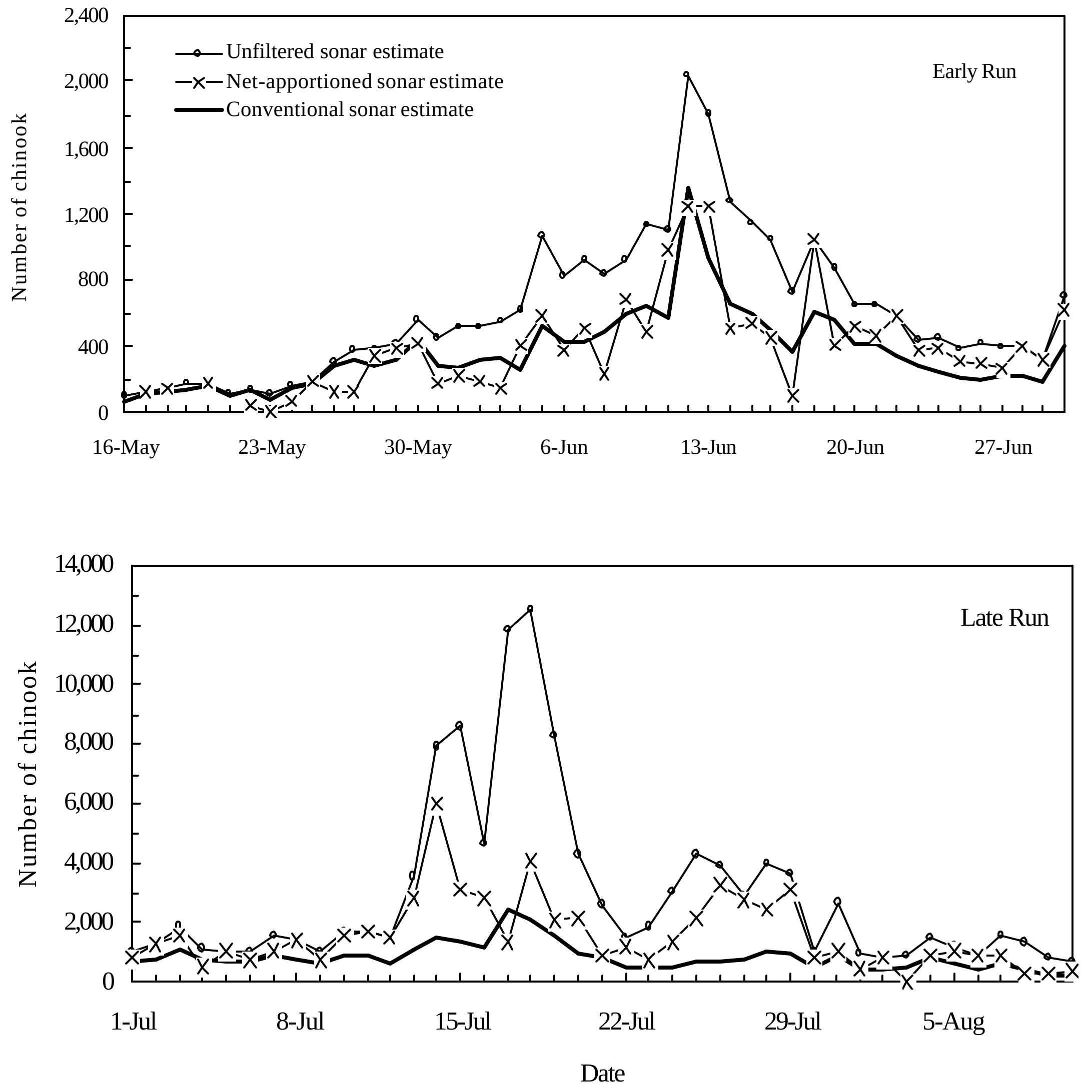
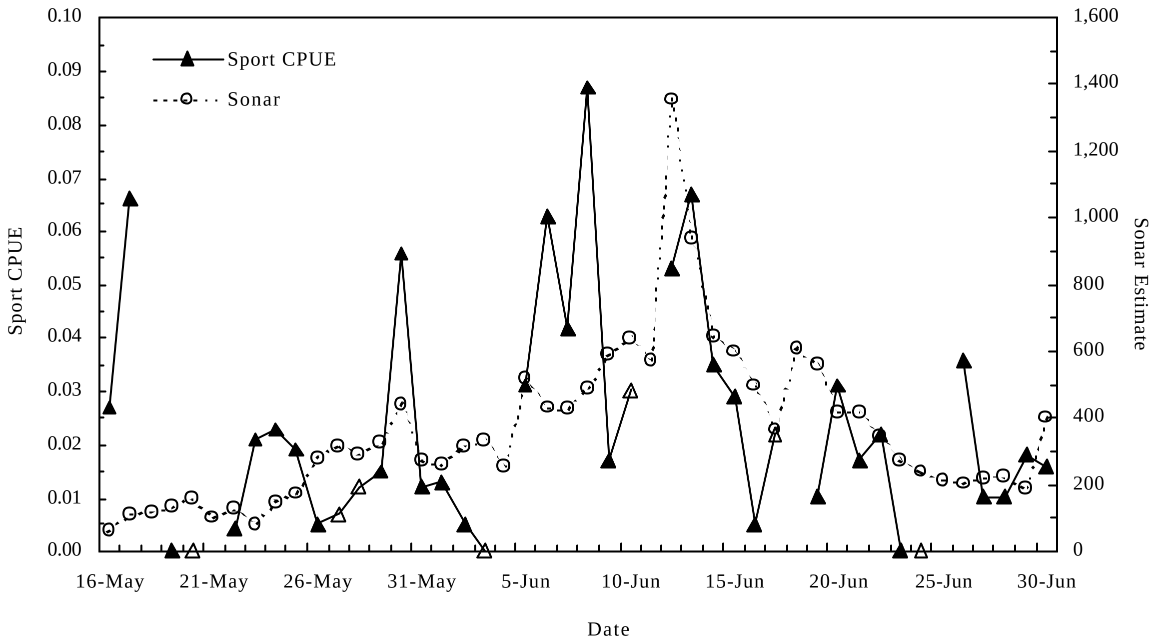


Figure 24.-Filtered (conventional), unfiltered, and net-apportioned estimates of chinook salmon passage, for the early and late runs, Kenai River sonar, 2001.

more evenly distributed throughout the range than right-bank targets. Fluctuating discharge rates during the late run (Figure 28) fail to explain the shift in passage distribution.

A comparison of daily chinook sonar estimates with river mile-19 sockeye sonar estimates (Figure 26) suggests that daily chinook estimates in July were not severely influenced by sockeye salmon passage. From 15 July to 18 July the river mile-19 sonar project recorded a 12-fold increase in sockeye passage, while estimated chinook passage at the chinook sonar project during the same period experienced a 4-fold increase (Figure 26). The second peak at the river mile-19 sockeye sonar site that occurred 28 July was even larger than the first peak, but chinook passage at the downriver site during this same time period was less than half the passage experienced at the downriver site during the 17 July peak. If sockeye passage influenced chinook estimates, the influence was greater in mid-July than in late July.

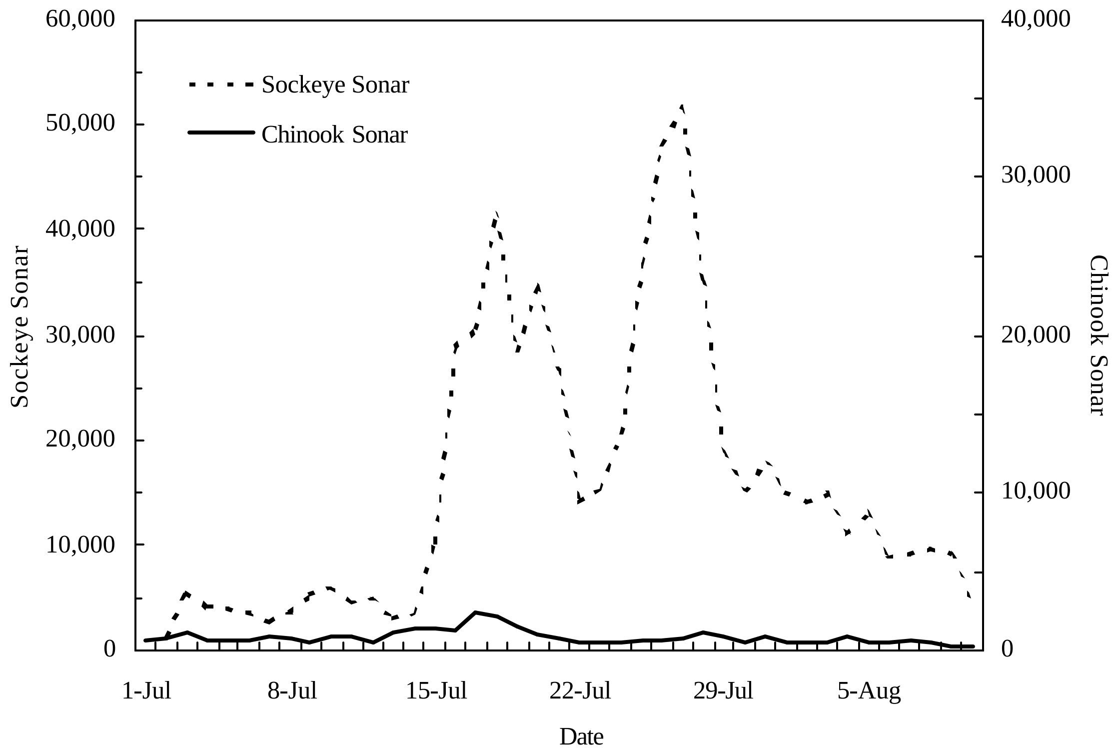


Note: Sport fish CPUE for 18 May was 0.543. This day was excluded from the graph for scaling purposes, but is included in CPUE data presented by Reimer (2003).

Figure 25.-Daily chinook salmon sonar estimates with chinook salmon sport fish CPUE (open triangles represent days on which only unguided anglers were allowed to fish), early run (16 May-30 June), 2001.

In general, late-run sonar estimates for chinook tracked net CPUE chinook estimates fairly well (Figures 29 and 30). The largest disparity occurred on 17-19 July, during the first peak in sockeye abundance. Chinook CPUE was low relative to the chinook sonar estimates during this time period, suggesting that some sockeye contamination may have occurred. Water clarity was relatively high during this time period also (Figure 28) which may have resulted in more net avoidance by chinook and thus fewer chinook caught. However the increase in water clarity did not appear large enough to fully explain the disparity between net CPUE estimates and sonar estimates.

Chinook sport fish CPUE estimates also tracked sonar estimates fairly well with a few exceptions (Figure 31). Sport CPUE estimates suggest that overestimation of chinook passage by the sonar may have occurred in mid July, and that underestimation was likely in late July. It is important to note the increased chinook sport CPUE in mid July as this might imply increased chinook passage on days when increased sockeye passage was suspected. Thus, the elevated chinook estimates during peak sockeye passage cannot be fully attributed to sockeye misclassification. Varying river discharge and water clarity during the late run (Figure 28) may have influenced sport CPUE estimates.



Note: River mile-19 sockeye salmon sonar estimates taken from (Davis *In prep*).

Figure 26.-Daily chinook sonar estimates and river mile-19 sockeye sonar estimates lagged one day, late run (1 July–10 August), 2001.

Net-apportioned estimates were substantially higher than the conventional sonar estimates during the late run, especially during the second half of July when sockeye were abundant (Figure 24; Appendix G2). This and other evidence indicates that sockeye salmon were underrepresented in the gillnet catches (Reimer 2003). Therefore we consider the net-apportioned estimates of chinook salmon abundance to be biased high, especially during the late run. Changes to the netting project are recommended for 2002, including use of more than one mesh size to obtain less biased estimates of species composition (Reimer 2003).

In summary, based on the above-mentioned indicators, the chinook sonar project may have overestimated chinook salmon passage in mid July due to heavy passage of sockeye salmon. However, underestimation by the sonar project was also likely on other days in July, and based on available data (i.e. chinook and sockeye net CPUE data and chinook and sockeye sonar data) we believe the magnitude of the overestimation during the late run was relatively small.

OUTLOOK

Substantial progress has been made been made in the past year toward developing new, more accurate estimates of chinook salmon abundance. At present, three avenues of investigation are being pursued.

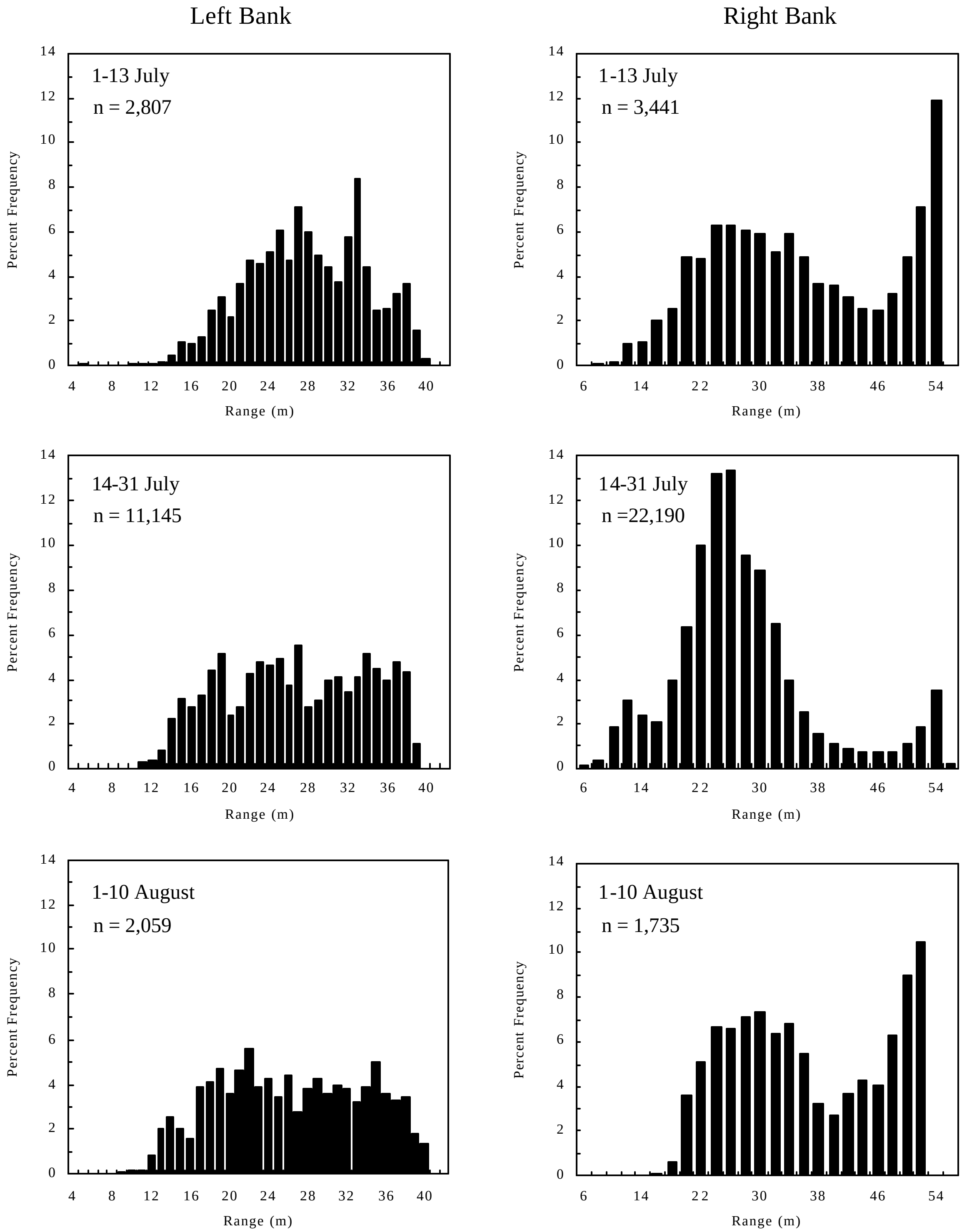


Figure 27.-Range distribution of all (unfiltered) upstream targets on the left and right banks during the late run, 1-13 July, 14-31 July, and 1-10 August, Kenai River, 2001.

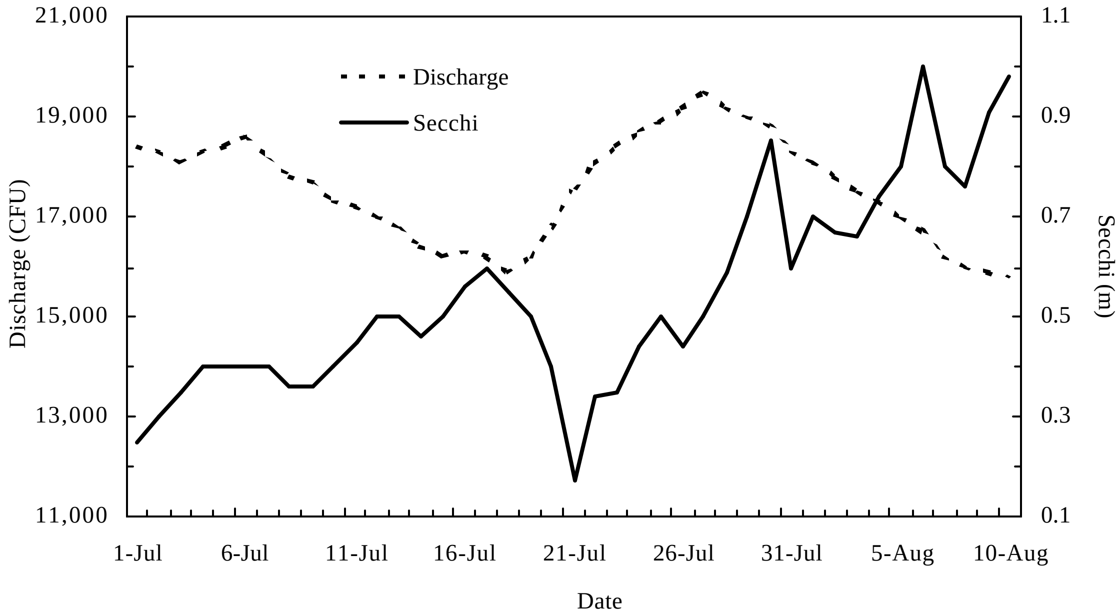
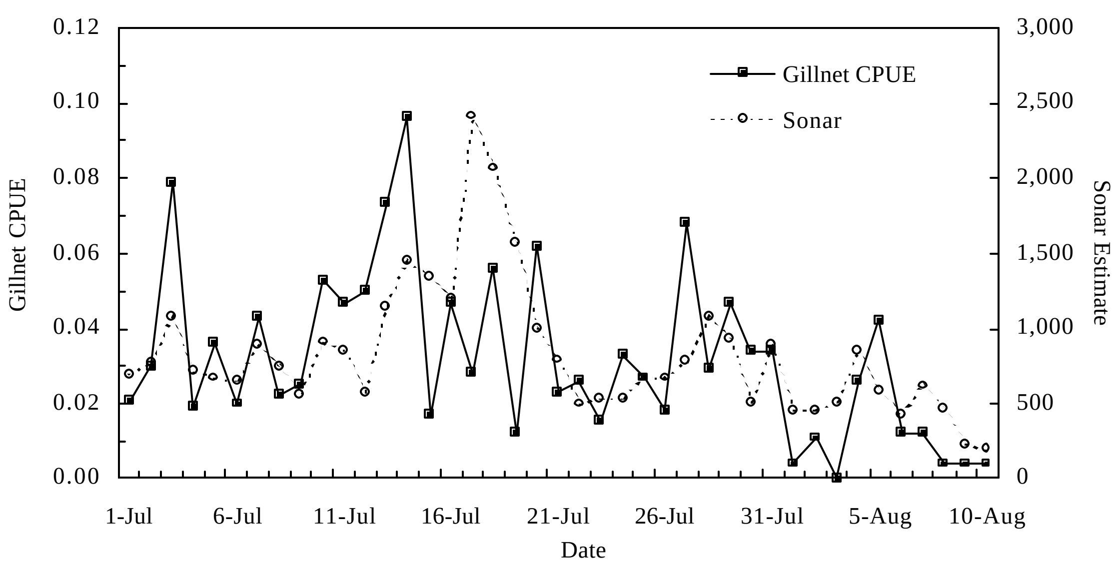


Figure 28.-Daily discharge rates at the Soldotna Bridge and Secchi depth readings in front of the sonar site, Kenai River, late run (1 July–10 August), 2001.



Note: Gillnet CPUE from Reimer 2003.

Figure 29.-Daily sonar estimates and inriver gillnet CPUE for chinook salmon during the late run (1 July–10 August), 2001.

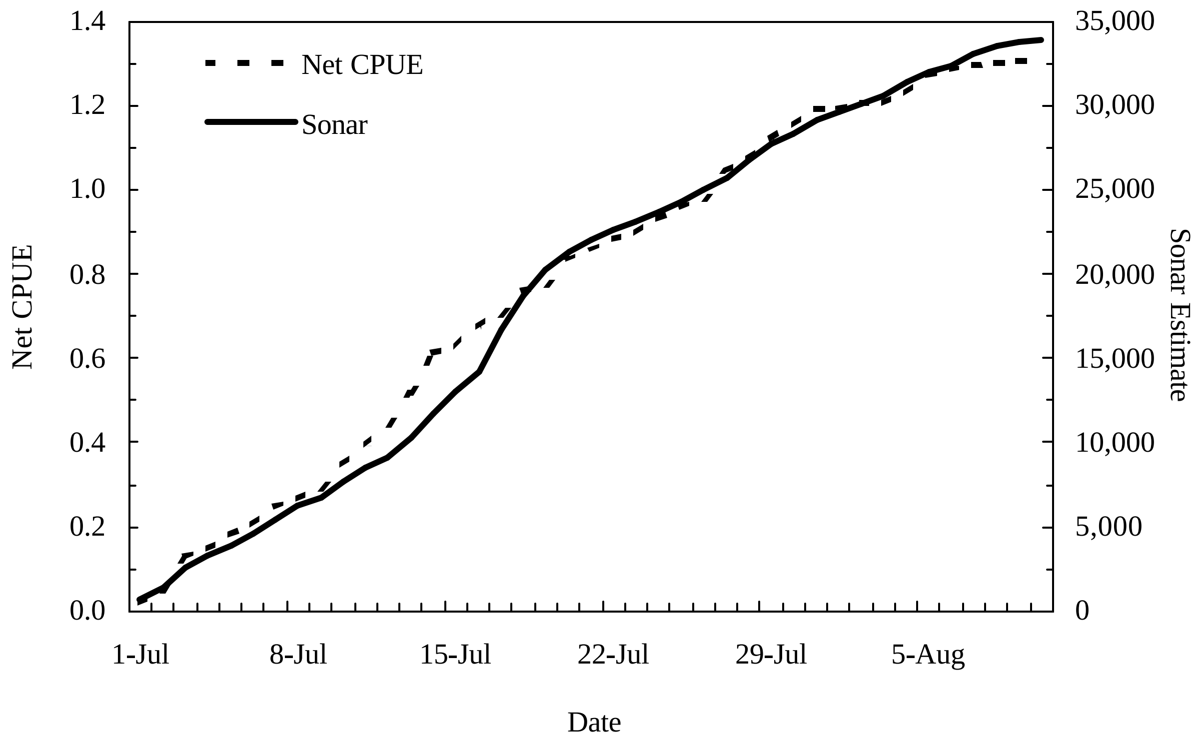


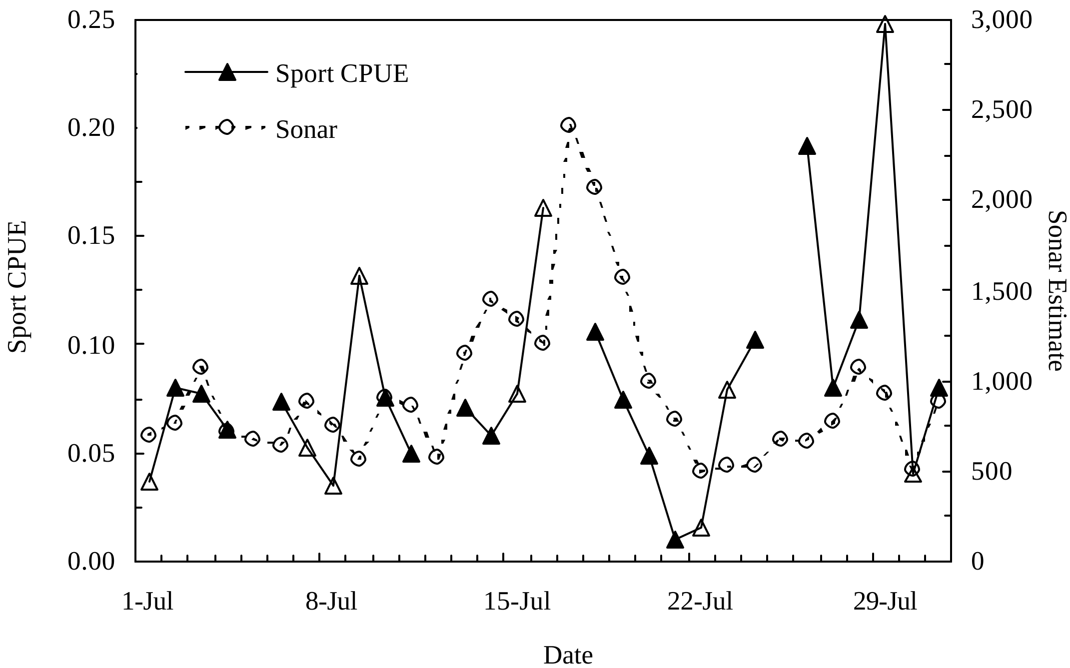
Figure 30.-Cumulative sonar estimates with cumulative inriver net CPUE, late-run chinook salmon (1 July–10 August), 2001.

Inriver Netting

Recent analyses have indicated that the netting data are better utilized to index species composition than to index fish abundance (Reimer et al. 2002). Consequently, several changes are slated for the inriver netting program in 2002 to improve estimates of species composition (Reimer et al. 2002). Nets will be constructed from material of different color and construction to increase catches, two mesh sizes (7.5”, 5.0”) will be drifted to reduce bias, and drifts will be shortened to get better spatial correspondence between the netting and sonar data. We expect that better accuracy and precision of species composition estimates will result, yielding net-apportioned estimates that will be a useful alternative index of chinook abundance.

Pulse Width

We have long known that measures of echo envelope width were related to fish size among tethered fish (Burwen and Fleischman 1998). Recently, we have become more confident that this relationship holds for free-swimming fish also, at least at low fish densities (Burwen and Fleischman *In prep*). We are currently developing statistical methodology for exploiting this information to estimate species composition from pulse-width data alone (Fleischman and Burwen *In prep*). Although such methods may not be useful during periods of very high sockeye passage, we do expect them to be useful during low-density situations, which would include most or all of the early run and portions of the late run.



Note: Sport fish CPUE data taken from Reimer 2003.

Figure 31.-Daily chinook salmon sonar estimates with chinook salmon sport fish CPUE (open triangles represent days on which only unguided anglers were allowed to fish), late run (1 July-31 July), 2001.

It is also possible that current pulse width measurements can be improved to provide more precise estimates of fish size. We are currently funding a graduate student at the University of Washington who is concentrating on some of the details of echo envelope measurement.

Imaging Sonar

Finally, we have obtained access to a new, experimental imaging sonar for several weeks in 2002. This equipment is capable of producing video-like images of fish, but has the drawback of being limited to relatively short ranges. In 2002, we hope to test the feasibility of using the imaging sonar to measure fish size, and to delineate the range limitations in the Kenai River.

ACKNOWLEDGMENTS

We would like to thank Mark Jensen for his assistance in overseeing the day-to-day operation of the project, for providing inseason computer programming and networking support, and for his assistance in reducing and analyzing the inseason data. We would also like to thank Linda Lowder, Sarah Donchi, Mike Hopp, and Brian Jones for meticulously collecting the sonar data and for their high motivation throughout a long field season. Special thanks, also, to the members of the Sport Fish staff in Soldotna who provided logistical support whenever needed.

LITERATURE CITED

Alexandersdottir, M., and L. Marsh. 1990. Abundance estimates of the escapement of chinook salmon into the Kenai River, Alaska, by analysis of tagging data, 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-55, Anchorage.

Bernard, D. R., and P. A. Hansen. 1992. Mark-recapture experiments to estimate the abundance of fish: a short course given by the Division of Sport Fish, Alaska Department of Fish and Game in 1991. Alaska Department of Fish and Game, Special Publication No. 92-4, Anchorage.

Bosch, D., and D. Burwen. 1999. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 99-3, Anchorage.

Bosch, D., and D. Burwen. 2000. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 1998. Alaska Department of Fish and Game, Fishery Data Series No. 00-12, Anchorage.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of chinook salmon (Oncorhynchus tshawytscha) in the Kenai River, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 42(4):693-700.

Burwen, D. L., and D. E. Bosch. 1995a. Estimates of chinook salmon abundance in the Kenai River using dual-beam sonar, 1993. Alaska Department of Fish and Game, Fishery Data Series No. 95-31, Anchorage.

Burwen, D. L., and D. E. Bosch. 1995b. Estimates of chinook salmon abundance in the Kenai River using dual-beam sonar, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-38, Anchorage.

Burwen, D. L., and D. E. Bosch. 1996. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-9, Anchorage.

Burwen, D. L., and D. E. Bosch. 1998. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 98-2, Anchorage.

Burwen, D. L., D. E. Bosch, and S. J. Fleischman. 1995. Evaluation of hydroacoustic assessment techniques for chinook salmon on the Kenai River using split- beam sonar. Alaska Department of Fish and Game, Fishery Data Series No. 95-45, Anchorage.

Burwen, D. L., D. E. Bosch, and S. J. Fleischman. 1998. Evaluation of hydroacoustic assessment techniques for chinook salmon on the Kenai River, 1995. Alaska Department of Fish and Game, Fishery Data Series No. 98-3, Anchorage.

Burwen, D., J. Hasbrouck, and D. Bosch. 2000. Investigations of alternate sites for chinook salmon sonar on the Kenai River. Alaska Department of Fish and Game, Fishery Data Series No. 00-43, Anchorage.

Burwen, D. L., and S. J. Fleischman. 1998. Evaluation of side-aspect target strength and pulse width as hydroacoustic discriminators of fish species in rivers. Canadian Journal of Fisheries and Aquatic Sciences 55:2492-2502.

Burwen, D. L., and S. J. Fleischman. In prep. Evaluation of multifrequency fm-slide sonar for estimating fish size in the Kenai River. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Carlon, J. A., and M. Alexandersdottir. 1989. Abundance estimates of the escapement of chinook salmon into the Kenai River, Alaska, by analysis of tagging data, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 107, Juneau.

Cochran, W. G. 1977. Sampling techniques. Third Edition. John Wiley & Sons, New York.

Conrad, R. H. 1988. Abundance estimates of the escapement of chinook salmon into the Kenai River, Alaska, by analysis of tagging data, 1987. Alaska Department of Fish and Game, Fishery Data Series No. 67, Juneau.

Conrad, R. H., and L. L. Larson. 1987. Abundance estimates for chinook salmon (Oncorhynchus tshawytscha) in the escapement into the Kenai River, Alaska, by analysis of tagging data, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 34, Juneau.

Davis, R. Z. 2001. Upper Cook Inlet salmon escapement studies, 2000. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 2A01-22, Anchorage.

Davis, R. Z. In prep. Upper Cook Inlet salmon escapement studies, 2001. Alaska Department of Fish and Game, Commercial Fisheries Division, Regional Information Report, Anchorage.

Eggers, D. M. 1994. On the discrimination of sockeye and chinook salmon in the Kenai River based on target strength determined with 420 kHz dual-beam sonar. Alaska Fishery Research Bulletin 1(2):125-139.

Eggers, D. E., P. A. Skvorc, and D. L. Burwen. 1995. Abundance estimate for chinook salmon in the Kenai River using dual-beam sonar. Alaska Fishery Research Bulletin 2(1):1-22.

Ehrenberg, J. E. 1983. A review of in situ target strength estimation techniques. FAO (Food and Agriculture Organization of the United Nations) Fisheries Report 300:85-90.

Fleischman, S. J., and D. L. Burwen. 2000. Correcting for position-related bias in estimates of the acoustic backscattering cross-section. Aquatic Living Resources 13:283-290.

Fleischman, S. J., and D. L. Burwen. In press. Mixture models for species apportionment of hydroacoustic data, with echo envelope length as the discriminatory variable. ICES Journal of Marine Science, XXX: 000 - 000.

Foote, K. G., and D. N. MacLennan. 1984. Comparison of copper and tungsten carbide calibration spheres. Journal of the Acoustical Society of America 75:612-616.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association 55:708-713.

Hammarstrom, S. L., and J. J. Hasbrouck. 1998. Estimation of the abundance of late-run chinook salmon in the Kenai River based on exploitation rate and harvest, 1996. Alaska Department of Fish and Game, Fishery Data Series No. 98-6, Anchorage.

Hammarstrom, S. L., and J. J. Hasbrouck. 1999. Estimation of the abundance of late-run chinook salmon in the Kenai River based on exploitation rate and harvest, 1997. Alaska Department of Fish and Game, Fishery Data Series No. 99-8, Anchorage.

Hammarstrom, S. L., and L. L. Larson. 1986. Kenai River salmon escapement. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27(S-32-2), Juneau.

Hammarstrom, S. L., L. Larson, M. Wenger, and J. Carlon. 1985. Kenai Peninsula chinook and coho salmon studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration. Annual Performance Report, 1984-1985, Project F-9-17, 26(G-II-L), Juneau.

HTI (Hydroacoustic Technology, Inc.). 1996. Model 340 digital echo processor (split-beam) operator's manual, version 1.6. Hydroacoustic Technology Inc., Seattle, WA.

HTI (Hydroacoustic Technology Inc.). 1997. Model 241/243/244 split-beam digital echo sounder system operator's manual, version 1.6. Hydroacoustic Technology Inc, Seattle, WA.

HTI (Hydroacoustic Technology Inc.). 2000. Transducer calibration for HTI Model 244 split-beam system, December 14, 2000. Report of Hydroacoustic Technology, Inc. to Alaska Department of Fish and Game, Sport Fish Division, Anchorage.

MacLennan, D. N., and E. J. Simmonds. 1992. Fisheries acoustics. Chapman & Hall, London, UK.

McBride, D. N., M. Alexandersdottir, S. Hammarstrom, and D. Vincent-Lang. 1989. Development and implementation of an escapement goal policy for the return of chinook salmon to the Kenai River. Alaska Department of Fish and Game, Fishery Manuscript No. 8, Juneau.

Miller, J. D., D. Bosch, and D. Burwen. 2002. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 1999. Alaska Department of Fish and Game, Fishery Data Series No. 02-24, Anchorage.

Miller, J. D., and D. Burwen. 2002. Estimates of chinook salmon abundance in the Kenai River using split-beam sonar, 2000. Alaska Department of Fish and Game, Fishery Data Series No. 02-09, Anchorage.

LITERATURE CITED (Continued)

Mulligan, T. J., and R. Kieser. 1996. A split-beam echo-counting model for riverine use. International Council for the Exploration of the Sea Journal of Marine Science 53:403-406.

Nelson, D. C., D. Athons, P. Berkhahn, and S. Sonnichsen. 1999. Area management report for the recreational fisheries of the Kenai Peninsula, 1995-1997. Alaska Department of Fish and Game, Fishery Management Report No. 99-3, Anchorage.

Reimer, A. 2003. Chinook salmon creel survey and inriver gillnetting study, Lower Kenai River, Alaska, 2001. Alaska Department of Fish and Game, Fishery Data Series No. 03-01. Anchorage.

Reimer, A. M., W. W. Jones, and L. E. Marsh. 2002. Chinook salmon creel survey and inriver gillnetting study, lower Kenai River, Alaska, 1999 and 2000. Alaska Department of Fish and Game, Fishery Data Series No. 02-25, Anchorage.

Sonnichsen, S. and M. Alexandersdottir. 1991. Estimates of total return by age for Kenai River chinook salmon, 1986-1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-69, Anchorage.

USDA (United States Department of Agriculture). 1992. Kenai River landowner's guide. Prepared by the U. S. Department of Agriculture, Soil conservation Service (SCS) for the Kenai Soil and Water Conservation District. Kenai, Alaska.

USGS (United States Geological Survey). 2002. Water resources data, Alaska, water year 2001. Website Daily Streamflow for Alaska, Soldotna gauging station, site #15266300, accessed January 4, 2002. http://water.usgs.gov/ak/nwis/discharge

Wolter, K. M. 1985. Introduction to variance estimation. Springer-Verlag, New York.

APPENDIX A. TARGET STRENGTH ESTIMATION

Appendix A1.-Using the sonar equation to estimate target strength with dual- and split-beam applications.

Target strength (TS), in decibels (dB), of an acoustic target located at range R (in meters), θ degrees from the maximum response axis (MRA) in one plane and ϕ degrees from the MRA in the other plane is estimated as:

$$TS = 20 \log_{10}(V_o) - SL - G_r + 40 \log_{10}(R) + 2\alpha R - G_{TVG} - 2B(\theta,\phi),$$

where:

V_o	=	voltage of the returned echo, output by the echo sounder;
SL	=	source level of transmitted signal in dB;
G_r	=	receiver gain in dB;
$40\log_{10}(R)$	=	two-way spherical spreading loss in dB;
$2\alpha R$	=	two-way absorption loss in dB;
G_{TVG}	=	time-varied-gain correction of the echo sounder; and
$2B(\theta,\phi)$	=	two-way loss due to position of the target off of the MRA.

The source level and gain are measured during calibration and confirmed using *in situ* standard sphere measurements. The time-varied-gain correction compensates for spherical spreading loss. Absorption loss ($2\alpha R$) was ignored in this study.

In practice, the location of the target in the beam (θ and ϕ) is not known, so $B(\theta,\phi)$ must be estimated in order to estimate target strength. Dual-beam and split-beam sonar differ in how they estimate $B(\theta,\phi)$, also called the beam pattern factor.

Dual-beam sonar (Ehrenberg 1983) uses one wide and one narrow beam. The system transmits on the narrow beam only and receives on both. The ratio between the voltages of the received signals is used to estimate beam pattern factor:

$$B(\theta,\phi) = 20 \log(V_N/V_W) \bullet WBDO,$$

where V_N is the voltage of the returned echo on the narrow beam, V_W is the voltage of the echo on the wide beam, WBDO is the wide beam drop-off correction, specific to each transducer, and estimated at calibration.

Split-beam sonar (MacLennan and Simmonds 1992) estimates target location (angles θ and ϕ of the target from the MRA) directly, not just the beam pattern factor ($B(\theta,\phi)$). Split-beam transducers are divided into four quadrants, and θ and ϕ are estimated by comparing the phases of signals received by opposing pairs of adjacent quadrants. The beam pattern factor is a function of θ and ϕ, determined during laboratory calibration.

APPENDIX B. SYSTEM PARAMETERS

Appendix B1.-Example of system parameters used for data collection on the right bank (transducer 733).

* Start Processing at Port 1 -FILE_PARAMETERS- Sun July 1 06:00:07 2001

* Data processing parameters used in collecting this file for Port 1

100	-1		1	MUX argument #1 - multiplexer port to activate
101	-1		0	percent - sync pulse switch, ping rate determiner NUS
102	-1		13200	maxp - maximum number of pings in a block NUS
103	-1		32767	maxbott - maximum bottom range in samples NUS
104	-1		76	N_th_layer - number of threshold layers
105	-1		5	max_tbp - maximum time between pings in pings
106	-1		5	min_pings - minimum number of pings per fish
507	-1	FED5		timval - 0xFED5 corresponds to about 20 kHz NUS
108	-1		1	mux_on - means multiplexing enabled on board NUS
109	-1		200	mux_delay - samples delay between sync and switching NUS
110	-1		0	decimate_mask - decimate input samples flag NUS
112	-1		1	echogram_on - flag for DEP echogram enable 0=off, 1=on
113	-1		1	Hourly Sampling flag 1=On 0=Off
118	-1		5	maxmiss - maximum number of missed pings in auto bottom
119	-1		0	bottom-0=fix,1=man,2=scope,3=acq_chan1,4=acq_chan2,5=auto_1,6=auto_chan2
120	-1		1	sb_int_code - sb only=0, sb-int: 40log a bot=1, 20log=2
121	-1		0	sb_int_code2 - sb only=0, sb-int 40log eg=0, 20log=2
122	-1		76	N_int_layers-number of integration strata
123	-1		76	N_int_th_layers - number of integration threshold strata
124	-1		0	int_print - print integrator interval results to printer
125	-1		0	circular element transducer flag for bpf calculation
126	-1		80	grid spacing for Model 404 DCR (in samples, 16 s/m)
127	-1		1	TRIG argument #1 - trigger source
128	-1		0	TRIG argument #2 - digital data routing
130	-1		0	TVG Blank (0=Both Start/End,1=Stop Only,2=Start Only,3=None)
200	-1		20	sigma flag 0.0 = no sigma, else sigma is output
201	-1		220	sl - transducer source level
202	-1		-170.8	gn - transducer through system gain at one meter
203	-1		-18	rg - receiver gain used to collect data
204	-1		5.5	narr_ax_bw - vertical nominal beam width
205	-1		10	wide_ax_bw - horizontal axis nominal beam width
206	-1		0	narr_ ax_corr - vertical axis phase correction
207	-1		0	wide_ax_corr - horizontal axis phase correction
208	-1		11	ping_rate - pulses per second
209	-1		0	echogram start range in meters
210	-1		58	echogram stop range in meters
211	-1		653	echogram threshold in millivolts
212	-1		13.2	print width in inches
213	-1		0	Chirp Bandwidth (0.0 = CHIRP OFF)
214	-1		20	Sampling within Hour Ending Time (in Decimal Minutes)
215	-1		1500	Speed of Sound (m/s)
216	-1		200	The Transducer's Frequency (kHz)
217	-1		-2.5	min_angoff_v - minimum angle off axis vertical
218	-1		2	max_angoff_v - maximum angle off axis vertical
219	-1		-5	min_angoff_h - minimum angle off axis horiz.

-continued-

220	-1	5	max_angoff_ h - maximum angle off axis horiz.
221	-1	-24	max_dB_off - maximum angle off in dB
222	-1	-15.9921	ux - horizontal electrical to mechanical angle ratio
223	-1	-33.0589	uy - vertical electrical to mechanical angle ratio
224	-1	0	ud_coef_a - a coeff. for up-down beam pattern eq.
225	-1	-0.0033	ud_coef_b - b coeff. for up-down beam pattern eq.
226	-1	-2.5114	ud_coef_c - c coeff. for up-down beam pattern eq.
227	-1	0.1056	ud_coef_d - d coeff. for up-down beam pattern eq.
228	-1	-0.1621	ud_coef_e - e coeff. for up-down beam pattern eq.
229	-1	0	lr_coef_a - a coeff. for left-rt beam pattern eq.
230	-1	-0.0001	lr_coef_b - b coeff. for left-rt beam pattern eq.
231	-1	-0.2134	lr_coef_c - c coeff . for left-rt beam pattern eq.
232	-1	0.0007	lr_coef_d - d coeff. for left-rt beam pattern eq.
233	-1	-0.0002	lr_coef_e - ecoeff. for left-rt beam pattern eq.
234	-1	4	maximum fish velocity in meters per second
235	-1	1	Echo Scope Bottom Location
236	-1	0.4	maxpw - pulse width search window size
238	-1	52	bottom - bottom depth in meters
239	-1	0	init_slope - initial slope for tracking in m/ping
240	-1	0.2	exp_cont - exponent for expanding tracking window
241	-1	0.2	max_ch_rng - maximum change in range in m/ping
242	-1	0.04	pw_criteria->min_pw_6-min -6 dB pulse width
243	-1	10	pw_criteria->max_pw_6-max -6 dB pulse width
244	-1	0.04	pw_criteria->min_pw_12 - min -12 dB pulse width
245	-1	10	pw_criteria->max_pw_12 - max -12 dB pulse width
246	-1	0.04	pw_criteria->min_pw_18 - min -18 dB pulse width
247	-1	10	pw_criteria->max_pw_18 - max -18 dB pulse width
249	-1	10	maximum voltage to allow in .RAW file
250	-1	0.2	TX argument #1 - pulse width in milliseconds
251	-1	25	TX argument #2 - transmit power in dB-watts
252	-1	-12	RX argument #1 - receiver gain
253	-1	90.9	REP argument #1 - ping rate in ms per ping
254	-1	10	REP argument #2 - pulsed cal tone separation
255	-1	1	TVG argument #1 - TVG start range in meters
256	-1	100	TVG argument #2 - TVG end range in meters
257	-1	40	TVG argument #3 - TVG function (XX Log Range)
258	-1	-6	TVG argument #4 - TVG gain
259	-1	0	TVG argument #5 - alpha (spreading loss) in dB/Km
260	-1	0.2	minimum absolute distance fish must travel in x plane
261	-1	0.2	minimum absolute distance fish must travel in y plane
262	-1	0.2	minimum absolute distance fish must travel in z plane
263	-1	2	bottom_window - auto tracking bottom window (m)
264	-1	3	bottom_threshold - auto tracking bottom threshold (V)
265	-1	11.2	TVG argument #7 - 20/40 log crossover (meters)
266	-1	0	rotator - which rotator to aim
267	-1	0	aim_pan - transducer aiming angle in pan (x, lf/rt)
268	-1	0	aim_tilt - transducer aiming angle in tilt (y, u/d)
401	0-75	1 to 76	th_layer[0-74], bottom of 1st threshold layer - bottom of 76th threshold layer (m)
			(i.e. 76 threshold layers in 1 m increments and numbered 0 through 75)

-continued-

Appendix B1.-Page 3 of 3.

402	0-74	752	th_val[0-74], threshold for 1st through 75th layers in millivolts
402	75	9999	th_val[75], threshold for 76th layer in millivolts
405	0-74	1	Integration threshold value for layers 1-75 (mV)
405	75	9999	Integration threshold value for layer 76 (mV)
602	-1	1017536	Echo sounder serial number
604	-1	306733	Transducer serial number
605	-1	Spd-3	Echogram paper speed
606	-1	9_pin	Echogram resolution
607	-1	Board_External	Trigger option
608	-1	LeftToRight	River flow direction

Appendix B2.-Example of system parameters used for data collection on the left bank (transducer 738).

* Start Processing at Port 2 -FILE_PARAMETERS- Sun Jul 1 06:20:00 2001

* Data processing parameters used in collecting this file for Port 2

100	-1		2	MUX argument #1 - multiplexer port to activate
101	-1		0	percent - sync pulse switch, ping rate determiner NUS
102	-1		19200	maxp - maximum number of pings in a block NUS
103	-1		32767	maxbott - maximum bottom range in samples NUS
104	-1		61	N_th_layer - number of threshold layers
105	-1		5	max_tbp - maximum time between pings in pings
106	-1		5	min_pings - minimum number of pings per fish
507	-1	FED5		timval - 0xFED5 corresponds to about 20 kHz NUS
108	-1		1	mux_on - means multiplexing enabled on board NUS
109	-1		200	mux_delay - samples delay between sync and switching NUS
110	-1		0	decimate_mask - decimate input samples flag NUS
112	-1		1	echogram_on - flag for DEP echogram enable 0=off, 1=on
113	-1		1	Hourly Sampling flag 1=On 0=Off
118	-1		5	maxmiss - maximum number of missed pings in auto bottom
119	-1		0	bottom-0=fix,1=man,2=scope,3=acq_chan1,4=acq_chan2,5=auto_1,6=auto_chan2
120	-1		1	sb_int_code - sb only=0, sb-int: 40log a bot=1, 20log=2
121	-1		0	sb_int_code2 - sb only=0, sb-int 40log eg=0, 20log=2
122	-1		61	N_int_layers-number of integration strata
123	-1		61	N_int_th_layers - number of integration threshold strata
124	-1		0	int_print - print integrator interval results to printer
125	-1		0	circular element transducer flag for bpf calculation
126	-1		80	grid spacing for Model 404 DCR (in samples, 16 s/m)
127	-1		1	TRIG argument #1 - trigger source
128	-1		0	TRIG argument #2 - digital data routing
130	-1		0	TVG Blank (0=Both Start/End,1=Stop Only,2=Start Only,3=None)
200	-1		20	sigma flag 0.0 = no sigma, else sigma is output
201	-1		218.34	sl - transducer source level
202	-1		-171.7	gn - transducer through system gain at one meter
203	-1		-18	rg - receiver gain used to collect data
204	-1		5.5	narr_ax_bw - vertical nominal beam width
205	-1		10	wide_ax_bw - horizontal axis nominal beam width
206	-1		0	narr_ ax_corr - vertical axis phase correction
207	-1		0	wide_ax_corr - horizontal axis phase correction
208	-1		16	ping_rate - pulses per second
209	-1		0	echogram start range in meters
210	-1		40	echogram stop range in meters
211	-1		481	echogram threshold in millivolts
212	-1		13.2	print width in inches
213	-1		0	Chirp Bandwith (0.0 = CHIRP OFF)
214	-1		40	Sampling within Hour Ending Time (in Decimal Minutes)
215	-1		1500	Speed of Sound (m/s)
216	-1		200	The Transducer's Frequency (kHz)
217	-1		-2.5	min_angoff_v - minimum angle off axis vertical
218	-1		2	max_angoff_v - maximum angle off axis vertical
219	-1		-5	min_angoff_h - minimum angle off axis horiz.

-continued-

Appendix B2.-Page 2 of 3.

220	-1	5	max_angoff_ h - maximum angle off axis horiz.
221	-1	-24	max_dB_off - maximum angle off in dB
222	-1	-15.7629	ux - horizontal electrical to mechanical angle ratio
223	-1	-54.6434	uy - vertical electrical to mechanical angle ratio
224	-1	0	ud_coef_a - a coeff. for up-down beam pattern eq.
225	-1	-0.0012	ud_coef_b - b coeff. for up-down beam pattern eq.
226	-1	-2.7392	ud_coef_c - c coeff. for up-down beam pattern eq.
227	-1	-0.0864	ud_coef_d - d coeff. for up-down beam pattern eq.
228	-1	-0.1515	ud_coef_e - e coeff. for up-down beam pattern eq.
229	-1	0	lr_coef_a - a coeff. for left-rt beam pattern eq.
230	-1	0	lr_coef_b - b coeff. for left-rt beam pattem eq.
231	-1	-0.2157	lr_coef_c - c coeff . for left-rt beam pattern eq.
232	-1	0.0001	lr_coef_d - d coeff. for left-rt beam pattern eq.
233	-1	-0.0002	lr_coef_e - ecoeff. for left-rt beam pattern eq.
234	-1	4	maximum fish velocity in meters per second
235	-1	1	Echo Scope Bottom Location
236	-1	0.4	maxpw - pulse width search window size
238	-1	34.3	bottom - bottom depth in meters
239	-1	0	init_slope - initial slope for tracking in m/ping
240	-1	0.2	exp_cont - exponent for expanding tracking window
241	-1	0.2	max_ch_rng - maximum change in range in m/ping
242	-1	0.04	pw_criteria->min_pw_6-min -6 dB pulse width
243	-1	10	pw_criteria->max_pw_6-max -6 dB pulse width
244	-1	0.04	pw_criteria->min_pw_12 - min -12 dB pulse width
245	-1	10	pw_criteria->max_pw_12 - max -12 dB pulse width
246	-1	0.04	pw_criteria->min_pw_18 - min -18 dB pulse width
247	-1	10	pw_criteria->max_pw_18 - max -18 dB pulse width
249	-1	10	maximum voltage to allow in .RAW file
250	-1	0.2	TX argument #1 - pulse width in milliseconds
251	-1	25	TX argument #2 - transmit power in dB-watts
252	-1	-12	RX argument #1 - receiver gain
253	-1	62.5	REP argument #1 - ping rate in ms per ping
254	-1	10	REP argument #2 - pulsed cal tone separation
255	-1	1	TVG argument #1 - TVG start range in meters
256	-1	100	TVG argument #2 - TVG end range in meters
257	-1	40	TVG argument #3 - TVG function (XX Log Range)
258	-1	-6	TVG argument #4 - TVG gain
259	-1	0	TVG argument #5 - alpha (spreading loss) in dB/Km
260	-1	0.2	minimum absolute distance fish must travel in x plane
261	-1	0.2	minimum absolute distance fish must travel in y plane
262	-1	0.2	minimum absolute distance fish must travel in z plane
263	-1	2	bottom_window - auto tracking bottom window (m)
264	-1	3	bottom_threshold - auto tracking bottom threshold (V)
265	-1	11.2	TVG argument #7 - 20/40 log crossover (meters)
266	-1	0	rotator - which rotator to aim
267	-1	0	aim_pan - transducer aiming angle in pan (x, lf/rt)
268	-1	0	aim_tilt - transducer aiming angle in tilt (y, u/d)
401	0-60	1 to 61	th_layer[0-60], bottom of 1st threshold layer - bottom of 61st threshold layer (m) (i.e. 61 threshold layers in 1 m increments and numbered 0 through 60)

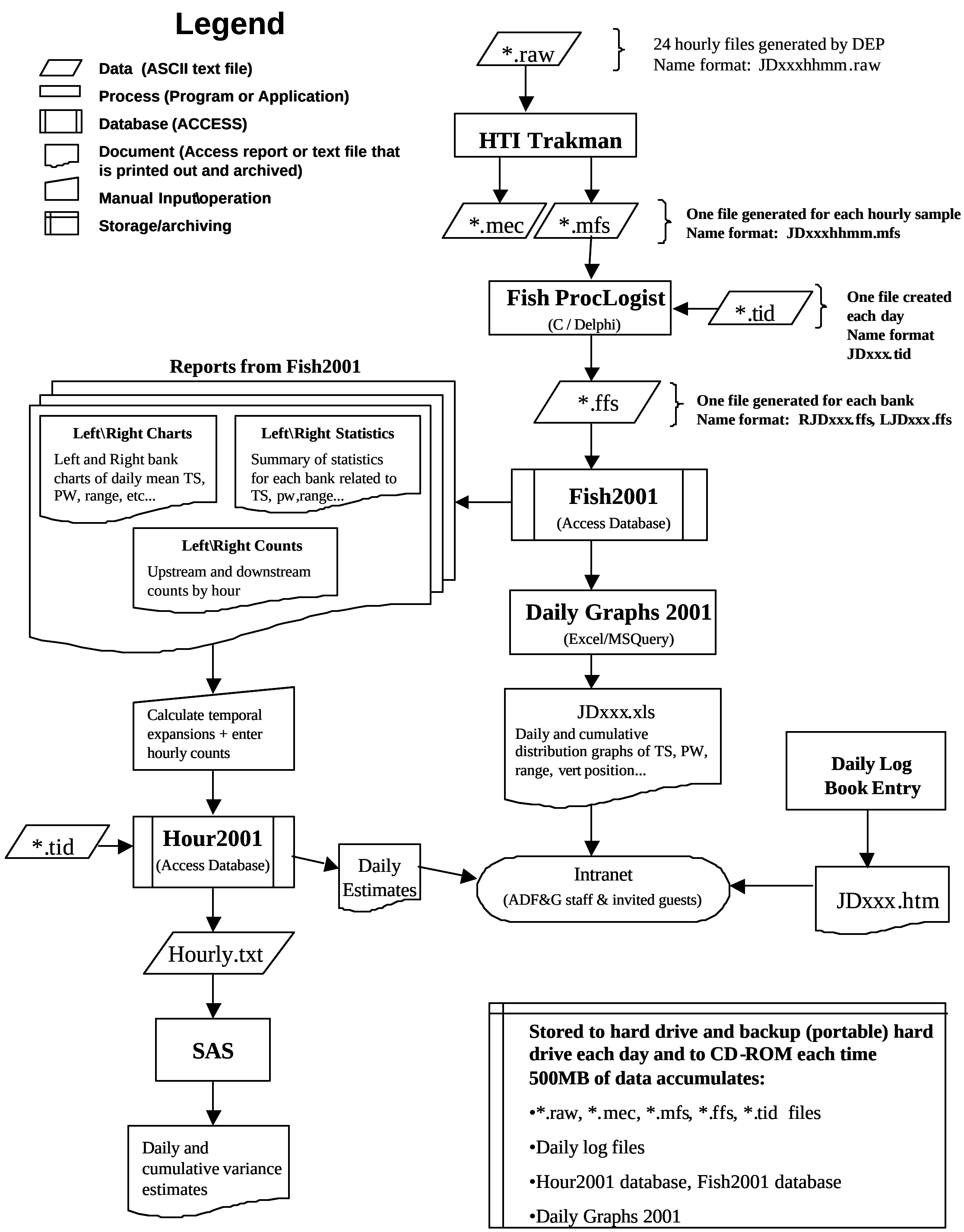
-continued-

Appendix B2.-Page 3 of 3.

402	0-59	481	th_val[0-59], threshold for 1st through 60th layers in millivolts
402	60	9999	th_val[60], threshold for 61st layer in millivolts
405	0-59	1	Integration threshold value for layers 1-60 (mV)
405	60	9999	Integration threshold value for layer 61 (mV)
602	-1	1017536	Echo sounder serial number
604	-1	306738	Transducer serial number
605	-1	Spd-5	Echogram paper speed
606	-1	9_pin	Echogram resolution
607	-1	Board_External	Trigger option
608	-1	LeftToRight	River flow direction

APPENDIX C. DATA FLOW

Appendix C1.-Inseason data flow diagram for the Kenai River chinook salmon sonar project, 2001.



APPENDIX D. DAILY PROPORTIONS OF UPSTREAM AND DOWNSTREAM FISH FOR THE 2001 EARLY AND LATE KENAI RIVER CHINOOK SALMON RUNS

Appendix D1.-Daily proportions of upstream and downstream fish for the 2001 Kenai River early chinook run.

Date	Downstream Estimate	Upstream Estimate	Daily Total	% Downstream	% Upstream
16 May	25	62	87	29.1%	70.9%
17 May	11	111	122	8.7%	91.3%
18 May	7	117	124	5.4%	94.6%
19 May	11	133	144	7.7%	92.3%
20 May	30	156	186	16.3%	83.7%
21 May	7	101	108	6.7%	93.3%
22 May	7	128	135	5.0%	95.0%
23 May	4	81	85	4.2%	95.8%
24 May	8	147	154	4.9%	95.1%
25 May	8	175	182	4.2%	95.8%
26 May	7	278	286	2.5%	97.5%
27 May	7	314	322	2.3%	97.7%
28 May	11	291	303	3.7%	96.3%
29 May	0	323	323	0.0%	100.0%
30 May	3	440	444	0.8%	99.2%
31 May	7	276	283	2.5%	97.5%
1 June	0	259	259	0.0%	100.0%
2 June	9	316	325	2.9%	97.1%
3 June	6	328	334	1.9%	98.1%
4 June	0	255	255	0.0%	100.0%
5 June	6	519	525	1.2%	98.8%
6 June	29	432	462	6.4%	93.6%
7 June	10	427	437	2.2%	97.8%
8 June	0	486	486	0.0%	100.0%
9 June	3	591	594	0.5%	99.5%
10 June	7	639	646	1.1%	98.9%
11 June	0	575	575	0.0%	100.0%
12 June	8	1,357	1,364	0.6%	99.4%
13 June	4	939	942	0.4%	99.6%
14 June	0	647	647	0.0%	100.0%
15 June	4	600	604	0.6%	99.4%
16 June	11	499	510	2.1%	97.9%
17 June	9	364	374	2.5%	97.5%
18 June	0	607	607	0.0%	100.0%
19 June	4	559	562	0.6%	99.4%
20 June	11	418	429	2.6%	97.4%
21 June	4	417	421	0.9%	99.1%
22 June	14	345	359	3.9%	96.1%
23 June	7	272	279	2.5%	97.5%
24 June	13	240	254	5.3%	94.7%
25 June	9	213	222	4.3%	95.7%
26 June	9	203	212	4.3%	95.7%
27 June	0	220	220	0.0%	100.0%
28 June	13	224	237	5.6%	94.4%
29 June	8	191	199	3.8%	96.2%
30 June	17	403	420	4.0%	96.0%
Total	369	16,676	17,045	2.2%	97.8%

Appendix D2.-Daily proportions of upstream and downstream fish for the 2001 Kenai River late chinook run.

Date	Downstream Estimate	Upstream Estimate	Daily Total	% Downstream	% Upstream
1 July	39	697	736	5.3%	94.7%
2 July	21	766	787	2.6%	97.4%
3 July	17	1,075	1,093	1.6%	98.4%
4 July	14	714	728	1.9%	98.1%
5 July	21	676	697	3.0%	97.0%
6 July	4	645	649	0.6%	99.4%
7 July	18	887	905	2.0%	98.0%
8 July	7	751	758	0.9%	99.1%
9 July	3	568	572	0.6%	99.4%
10 July	39	908	946	4.1%	95.9%
11 July	12	858	871	1.4%	98.6%
12 July	25	575	600	4.1%	95.9%
13 July	19	1,148	1,166	1.6%	98.4%
14 July	25	1,448	1,474	1.7%	98.3%
15 July	50	1,338	1,388	3.6%	96.4%
16 July	6	1,201	1,207	0.5%	99.5%
17 July	59	2,415	2,473	2.4%	97.6%
18 July	40	2,065	2,105	1.9%	98.1%
19 July	25	1,568	1,593	1.6%	98.4%
20 July	37	994	1,031	3.6%	96.4%
21 July	22	786	808	2.7%	97.3%
22 July	9	497	507	1.8%	98.2%
23 July	6	526	532	1.2%	98.8%
24 July	34	529	563	6.0%	94.0%
25 July	46	676	722	6.4%	93.6%
26 July	13	667	680	2.0%	98.0%
27 July	22	775	798	2.8%	97.2%
28 July	64	1,070	1,134	5.7%	94.3%
29 July	40	928	968	4.1%	95.9%
30 July	71	508	579	12.2%	87.8%
31 July	23	883	906	2.5%	97.5%
1 August	33	455	488	6.7%	93.3%
2 August	30	459	489	6.2%	93.8%
3 August	47	504	551	8.5%	91.5%
4 August	23	840	864	2.7%	97.3%
5 August	56	581	637	8.9%	91.1%
6 August	13	417	431	3.1%	96.9%
7 August	63	618	680	9.2%	90.8%
8 August	20	467	488	4.2%	95.8%
9 August	17	232	249	6.7%	93.3%
10 August	14	200	214	6.8%	93.2%
Total	1,149	33,916	35,065	3.3%	96.7%

APPENDIX E. AVERAGE VERTICAL ANGLE BY TIDE STAGE, RUN, BANK, AND FISH ORIENTATION (UPSTREAM OR DOWNSTREAM) FOR THE 2001 KENAI RIVER CHINOOK SALMON RUNS

Appendix E1.-Average vertical angle by tide stage and orientation for the 2001 Kenai River early chinook run, 2001.

Tide Stage / Fish Orientation	Average Vertical Angle	Standard Deviation	Sample Size
Left Bank			
Falling			
Downstream	-0.30	0.56	26
Upstream	-0.79	0.34	2,060
Tide Stage Total	-0.78	0.35	2,086
Downstream	0.29	0.44	4
Upstream	-0.78	0.30	796
Tide Stage Total	-0.78	0.31	800
Downstream	-0.14	0.77	17
Upstream	-0.56	0.52	667
Tide Stage Total	-0.55	0.53	684
Left Bank Total	-0.73	0.39	3,570
Right Bank			
Falling			
Downstream	-0.25	0.49	29
Upstream	-0.57	0.43	672
Tide Stage Total	-0.55	0.44	701
Downstream	-0.63	0.47	15
Upstream	-0.74	0.44	166
Tide Stage Total	-0.73	0.44	181
Downstream	-0.12	0.75	11
Upstream	-0.25	0.49	372
Tide Stage Total	-0.24	0.49	383
Right Bank Total	-0.48	0.49	1,265

Appendix E2.-Average vertical angle by tide stage and orientation for the 2001 Kenai River late chinook run.

Tide Stage / Fish Orientation	Average Vertical Angle	Standard Deviation	Sample Size
Left Bank			
Falling			
Downstream	-0.03	0.41	123
Upstream	-0.30	0.54	3,689
Tide Stage Total	-0.29	0.54	3,812
Downstream	-0.13	0.48	37
Upstream	-0.36	0.54	1,266
Tide Stage Total	-0.35	0.54	1,303
Downstream	-0.20	0.56	43
Upstream	-0.20	0.58	2,558
Tide Stage Total	-0.20	0.58	2.601
Left Bank Total	-0.27	0.55	7,716
Right Bank			
Falling			
Downstream	0.13	0.39	80
Upstream	-0.16	0.38	736
Tide Stage Total	-0.13	0.39	816
Downstream	-0.12	0.42	29
Upstream	-0.30	0.44	201
Tide Stage Total	-0.28	0.44	230
Downstream	0.04	0.38	49
Upstream	0.05	0.37	1,769
Tide Stage Total	0.05	0.37	1,818
Right Bank Total	-0.03	0.39	2,864

APPENDIX F. HISTORIC ESTIMATES OF INRIVER RETURN BY YEAR AND DATE (1987–2001).

Appendix F1.-Kenai River early-run chinook salmon sonar estimates of inriver return, 1987-2001.

Date/Year	1987	1988	1989	**1990**	**1991**	**1992**	1993	1994	1995	1996	**1997**	**1998[a]**	1999[a]	**2000[a]**	2001[a]
7 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6	NA	NA	NA
8 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	18	NA	NA	NA
9 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	NA	NA	NA
10 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	NA	NA	NA
11 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	12	NA	NA	NA
12 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	12	NA	NA	NA
13 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	27	NA	NA	NA
14 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	43	NA	NA	NA
15 May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	63	NA	NA	NA
16 May	NA	188	180	78	30	54	64	238	98	60	114	48	33	18	62
17 May	NA	415	319	57	12	48	85	342	99	91	99	45	63	49	111
18 May	NA	259	264	93	65	88	91	260	78	63	93	57	66	54	117
19 May	NA	260	180	136	55	40	66	302	149	96	165	36	39	84	133
20 May	NA	406	147	93	68	78	69	369	228	177	84	54	116	64	156
21 May	NA	184	245	69	51	90	165	327	465	165	129	33	186	84	101
22 May	NA	182	164	75	111	108	117	246	265	156	114	15	192	123	128
23 May	NA	231	186	63	66	150	160	212	286	159	162	12	243	132	81
24 May	NA	288	279	51	66	126	141	303	265	159	138	33	159	147	147
25 May	NA	351	300	76	57	79	150	170	198	153	165	81	141	234	175
26 May	NA	393	270	70	81	93	168	150	189	240	220	43	330	186	278
27 May	NA	387	419	87	81	66	150	267	165	204	325	60	342	177	314
28 May	NA	483	357	61	78	78	361	258	159	330	317	63	402	84	291
29 May	NA	713	269	221	51	45	538	347	222	512	288	63	378	204	323
30 May	NA	333	164	154	51	111	388	321	351	348	350	129	273	105	440
31 May	NA	501	157	175	69	114	266	369	282	474	318	93	459	117	276
1 June	NA	556	258	153	150	106	187	321	357	603	213	111	633	192	259
2 June	NA	545	194	294	240	107	412	266	369	741	241	189	444	250	316
3 June	NA	598	233	225	362	232	324	298	549	873	376	192	540	282	328
4 June	NA	755	246	178	177	190	255	304	693	1,051	324	186	924	266	255
5 June	NA	782	280	192	316	166	276	351	429	943	427	**162**	876	139	519
6 June	NA	493	384	156	**296**	319	327	198	807	741	327	**150**	807	186	432
7 June	NA	506	545	**304**	**215**	515	198	384	843	773	591	**283**	672	237	427
8 June	NA	771	890	**414**	**243**	375	297	306	999	918	441	**300**	609	108	486
9 June	NA	569	912	**339**	**444**	**486**	378	462	789	1,140	391	**234**	504	135	591
10 June	NA	333	913	**272**	**275**	**264**	453	432	876	684	527	**327**	439	207	639
11 June	NA	320	710	**453**	**334**	**234**	549	423	774	882	512	**600**	596	315	575
12 June	NA	302	577	**568**	**400**	**394**	600	329	417	864	537	**1,168**	723	165	1,357
13 June	NA	188	599	**445**	**369**	**236**	951	376	492	1,071	681	**719**	393	**337**	939
14 June	NA	289	458	**330**	**268**	**174**	811	514	691	1,111	424	**912**	610	**309**	647
15 June	NA	510	335	**658**	**441**	**312**	407	306	636	1,116	318	**951**	436	**571**	600
16 June	NA	808	397	**485**	**615**	**239**	616	453	648	420	348	**770**	696	**441**	499
17 June	NA	535	514	**267**	**330**	**339**	567	315	750	495	**405**	**675**	807	**765**	364
18 June	NA	533	464	**238**	**493**	**320**	606	435	808	697	**315**	**498**	742	**591**	607
19 June	NA	200	295	**331**	**437**	**390**	422	636	419	657	**399**	**510**	771	**348**	559
20 June	NA	175	498	**369**	**314**	**548**	504	402	594	315	**408**	**351**	1,247	**319**	418
21 June	NA	373	520	**257**	**457**	**372**	621	570	438	351	**252**	**309**	1,192	**522**	417
22 June	NA	312	614	**267**	**433**	**297**	399	366	375	396	**390**	**273**	819	**456**	345
23 June	NA	375	547	**240**	**396**	**213**	607	550	178	401	**225**	**294**	935	**462**	272
24 June	NA	674	564	**322**	**251**	**337**	720	696	450	573	**285**	**288**	1,151	**408**	240
25 June	NA	582	374	**258**	**235**	**362**	808	734	429	684	**332**	**228**	1,292	**186**	213
26 June	NA	436	369	**322**	**261**	**330**	1,051	597	334	504	**381**	**219**	731	**359**	203
27 June	NA	549	309	**231**	**340**	**291**	1,158	639	946	228	**363**	**207**	678	615	220
28 June	NA	827	425	**240**	**327**	**253**	798	681	696	303	**297**	**308**	537	489	224
29 June	NA	495	376	**208**	**258**	**121**	728	929	984	234	**570**	**363**	753	516	191
30 June	NA	915	292	**193**	**270**	**197**	660	649	615	351	**582**	**276**	687	441	403
Total		20,880	17,992	**10,768**	**10,939**	**10,087**	19,669	18,403	21,884	23,505	**14,963**	**13,103**	25,666	**12,479**	16,676

Note: Bold and shaded numbers represent the dates that the chinook fishery was restricted to catch and release due to low inriver return.

[a] Upstream moving fish only reported.

Appendix E2.-Kenai River late-run chinook salmon sonar estimates of inriver return, 1987-2001.

Date/Year	1987	1988	1989	**1990**	1991	**1992**	1993	1994	1995	1996	1997	**1998[a]**	1999[a]	2000[a]	2001[a]
1 July	507	526	769	578	267	364	539	663	350	341	486	491	453	461	697
2 July	429	404	489	305	300	297	432	342	398	240	642	597	612	373	766
3 July	405	398	353	486	333	320	325	625	353	303	600	480	486	370	1,075
4 July	628	292	566	436	519	198	397	858	439	393	633	450	396	488	714
5 July	596	482	1,106	853	316	225	429	705	667	1,067	657	606	369	787	676
6 July	523	654	879	795	242	331	884	1,069	720	879	627	612	683	778	645
7 July	769	379	680	929	186	247	1,572	1,050	931	780	1,158	660	936	1,020	887
8 July	483	725	776	432	139	170	1,855	655	417	867	1,221	462	1,030	1,713	751
9 July	384	471	1,404	309	393	205	1,876	744	519	768	1,618	480	1,047	1,632	568
10 July	314	1,732	560	359	481	221	820	1,275	450	1,023	3,486	450	717	1,461	908
11 July	340	1,507	2,010	778	403	143	1,238	509	325	1,146	5,649	171	1,059	1,038	858
12 July	751	1,087	2,763	557	330	1,027	676	828	276	714	4,497	192	560	1,506	575
13 July	747	2,251	910	1,175	308	605	3,345	1,066	570	1,128	5,373	262	401	2,327	1,148
14 July	761	2,370	2,284	1,481	572	689	3,177	1,332	714	4,437	2,031	368	969	2,709	1,448
15 July	913	2,405	1,111	1,149	542	745	2,233	2,211	750	3,222	4,042	1,118	636	2,808	1,338
16 July	1,466	1,259	1,344	1,011	1,029	703	2,329	3,825	1,962	3,494	3,420	1,416	927	2,264	1,201
17 July	1,353	1,520	963	2,395	2,052	570	2,037	4,692	1,128	2,253	4,584	1,424	3,558	1,915	2,415
18 July	841	2,180	1,382	2,113	3,114	853	1,438	2,157	3,942	2,820	2,334	1,638	2,784	2,154	2,065
19 July	2,071	1,724	425	1,363	1,999	1,128	715	3,493	4,692	2,236	1,146	1,146	1,869	1,919	1,568
20 July	3,709	2,670	820	1,499	1,422	1,144	1,348	2,317	4,779	2,609	1,578	741	3,471	1,155	994
21 July	3,737	3,170	916	787	1,030	799	981	1,695	3,132	3,435	894	1,608	3,354	933	786
22 July	1,835	1,302	583	573	1,050	619	1,166	1,386	3,465	2,250	1,840	1,411	1,998	702	497
23 July	1,700	1,502	756	642	2,632	1,449	1,163	1,050	2,421	3,050	1,441	808	1,875	760	526
24 July	2,998	1,386	783	1,106	2,204	**711**	1,344	1,232	831	3,634	1,080	933	1,748	1,868	529
25 July	1,915	999	495	810	1,306	**1,713**	2,245	1,412	840	3,240	532	542	1,937	1,761	676
26 July	1,968	924	432	671	1,216	**1,296**	1,421	1,378	1,683	2,319	519	723	1,098	1,034	667
27 July	1,523	960	618	755	1,195	**1,561**	1,952	1,244	1,806	1,782	438	807	3,066	992	775
28 July	2,101	1,398	538	**603**	1,901	**1,957**	1,915	2,180	789	861	333	**954**	1,358	999	1,070
29 July	1,923	1,400	441	**546**	1,146	**1,533**	1,363	1,327	558	474	401	**1,255**	1,185	1,029	928
30 July	2,595	1,158	391	**382**	791	**1,198**	1,628	1,776	510	621	450	**1,556**	969	577	508
31 July	2,372	910	383	**316**	974	**951**	862	1,808	480	1,548	420	**1,344**	1,308	549	883
1 August	470	925	351	**393**	897	**921**	767	1,037	474		247	**909**	591	695	455
2 August	314	781	201	**388**	867	**1,018**	613	1,226	369		291	**1,512**	468	421	459
3 August	263	989	132	**533**	392	**837**	337	1,081	447		213	**1,006**	642	294	504
4 August	835	1,524	142	**717**	331	**862**	463	658	519			**1,131**	444	453	840
5 August	904	1,091	107	**723**	174	**861**	711	536	404			**1,094**	436	489	581
6 August	648	1,333	107	**552**	343	**654**	1,079	1,042	408			**864**	654	504	417
7 August	694	1,186	65	**516**	618	**558**	656	797	279			**843**	678	366	618
8 August	658	1,449		**682**	600	**217**	669		267			**750**	804	417	467
9 August	368	1,132		**679**		**165**	422		272			**570**	328	399	232
10 August	312	755		**678**		**249**	252					**496**	165	397	200
11 August		698		**547**											
12 August				**362**											
13 August				**221**											
14 August				**139**											
15 August				**150**											
Total	48,123	52,008	29,035	**33,474**	34,614	**30,314**	49,674	53,281	44,336	53,934	54,881	**34,878**	48,069	44,517	33,916

Note: Shaded numbers represent dates when the chinook fishery was restricted to catch and release due to low inriver return.

[a] Upstream fish only reported.

APPENDIX G. FILTERED (CONVENTIONAL), UNFILTERED, AND NET-APPORTIONED CHINOOK PASSAGE ESTIMATES, KENAI RIVER SONAR, EARLY AND LATE RUNS, 2001.

Appendix G1.-Filtered (conventional), unfiltered, and net-apportioned chinook passage estimates, Kenai River sonar, early run, 2001.

Date	Filtered (Conventional)	Unfiltered	Net-Apportioned
16-May	62	104	[a]
17-May	111	125	125
18-May	117	143	143
19-May	133	172	[a]
20-May	156	180	180
21-May	101	115	[a]
22-May	128	136	45
23-May	81	112	0
24-May	147	169	68
25-May	175	183	183
26-May	278	314	125
27-May	314	377	126
28-May	291	383	345
29-May	323	418	380
30-May	440	564	423
31-May	276	453	174
1-Jun	259	515	225
2-Jun	316	513	192
3-Jun	328	555	139
4-Jun	255	619	412
5-Jun	519	1,065	581
6-Jun	433	830	369
7-Jun	427	921	512
8-Jun	486	842	230
9-Jun	590	930	682
10-Jun	639	1,139	488
11-Jun	576	1,104	981
12-Jun	1,355	2,037	1,245
13-Jun	939	1,807	1,243
14-Jun	647	1,280	501
15-Jun	600	1,148	540
16-Jun	499	1,050	450
17-Jun	364	728	104
18-Jun	607	1,050	1,050
19-Jun	558	874	403
20-Jun	418	651	521
21-Jun	417	647	462
22-Jun	346	586	586
23-Jun	272	436	369
24-Jun	240	451	387
25-Jun	213	381	305
26-Jun	203	421	301
27-Jun	220	393	262
28-Jun	224	401	401
29-Jun	190	317	317
30-Jun	403	704	616
Total	16,676	28,347	17,193

[a] No fish were caught in drift gillnets on these dates.

Appendix G2.-Filtered (conventional), unfiltered, and net-apportioned chinook passage estimates, Kenai River sonar, late run, 2001.

Date	Filtered (Conventional)	Unfiltered	Net-Apportioned
1-Jul	697	1,048	786
2-Jul	766	1,222	1,222
3-Jul	1,075	1,864	1,540
4-Jul	714	1,088	544
5-Jul	676	1,014	1,014
6-Jul	645	1,003	716
7-Jul	887	1,557	1,038
8-Jul	751	1,431	1,431
9-Jul	568	1,050	735
10-Jul	908	1,688	1,547
11-Jul	858	1,714	1,714
12-Jul	575	1,472	1,472
13-Jul	1,148	3,549	2,809
14-Jul	1,448	7,906	5,998
15-Jul	1,338	8,602	3,128
16-Jul	1,201	4,673	2,804
17-Jul	2,415	11,876	1,341
18-Jul	2,065	12,523	4,040
19-Jul	1,568	8,299	2,075
20-Jul	994	4,309	2,154
21-Jul	786	2,574	858
22-Jul	497	1,507	1,172
23-Jul	526	1,856	742
24-Jul	529	3,005	1,336
25-Jul	676	4,305	2,152
26-Jul	667	3,932	3,277
27-Jul	776	2,917	2,746
28-Jul	1,069	3,998	2,461
29-Jul	929	3,599	3,085
30-Jul	508	1,040	851
31-Jul	883	2,646	1,008
1-Aug	455	943	471
2-Aug	459	802	802
3-Aug	504	855	0
4-Aug	840	1,462	877
5-Aug	581	1,216	1,043
6-Aug	417	896	896
7-Aug	618	1,529	918
8-Aug	467	1,317	329
9-Aug	232	849	283
10-Aug	200	696	348
Total	33,916	119,833	63,763