

Fishery Data Series No. 11-72

**Sonar Estimation of Chinook and Fall Chum Salmon
Passage in the Yukon River near Eagle, Alaska, 2010**

by

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and

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December 2011

Alaska Department of Fish and Game

Divisions of Sport Fish and Commercial Fisheries



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Weights and measures (metric)		General		Mathematics, statistics	
centimeter	cm	Alaska Administrative Code	AAC	<i>all standard mathematical signs, symbols and abbreviations</i>	
deciliter	dL	all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.	alternate hypothesis	H_A
gram	g	all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.	base of natural logarithm	e
hectare	ha	at	@	catch per unit effort	CPUE
kilogram	kg	compass directions:		coefficient of variation	CV
kilometer	km	east	E	common test statistics	(F, t, χ^2 , etc.)
liter	L	north	N	confidence interval	CI
meter	m	south	S	correlation coefficient (multiple)	R
milliliter	mL	west	W	correlation coefficient (simple)	r
millimeter	mm	copyright	©	covariance	cov
		corporate suffixes:		degree (angular)	$^\circ$
Weights and measures (English)		Company	Co.	degrees of freedom	df
cubic feet per second	ft ³ /s	Corporation	Corp.	expected value	E
foot	ft	Incorporated	Inc.	greater than	>
gallon	gal	Limited	Ltd.	greater than or equal to	≥
inch	in	District of Columbia	D.C.	harvest per unit effort	HPUE
mile	mi	et alii (and others)	et al.	less than	<
nautical mile	nmi	et cetera (and so forth)	etc.	less than or equal to	≤
ounce	oz	exempli gratia (for example)	e.g.	logarithm (natural)	ln
pound	lb	Federal Information Code	FIC	logarithm (base 10)	log
quart	qt	id est (that is)	i.e.	logarithm (specify base)	log ₂ , etc.
yard	yd	latitude or longitude	lat. or long.	minute (angular)	'
		monetary symbols (U.S.)	\$, ¢	not significant	NS
Time and temperature		months (tables and figures): first three letters	Jan, ..., Dec	null hypothesis	H_0
day	d	registered trademark	®	percent	%
degrees Celsius	°C	trademark	™	probability	P
degrees Fahrenheit	°F	United States (adjective)	U.S.	probability of a type I error (rejection of the null hypothesis when true)	α
degrees kelvin	K	United States of America (noun)	USA	probability of a type II error (acceptance of the null hypothesis when false)	β
hour	h	U.S.C.	United States Code	second (angular)	"
minute	min	U.S. state	use two-letter abbreviations (e.g., AK, WA)	standard deviation	SD
second	s			standard error	SE
Physics and chemistry				variance	
all atomic symbols				population sample	Var var
alternating current	AC				
ampere	A				
calorie	cal				
direct current	DC				
hertz	Hz				
horsepower	hp				
hydrogen ion activity (negative log of)	pH				
parts per million	ppm				
parts per thousand	ppt, ‰				
volts	V				
watts	W				

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ABSTRACT

Dual-Frequency Identification Sonar and split-beam sonar equipment were used to estimate Chinook salmon *Oncorhynchus tshawytscha* and fall chum salmon *Oncorhynchus keta* passage in the Yukon River near Eagle, Alaska from July 3 to October 6, 2010. A total of 35,074 Chinook salmon were estimated to have passed the sonar site between July 3 and August 19, and an estimated 125,547 chum salmon passed between August 20 and October 6. The sonar-estimated passage of chum salmon was subsequently expanded to a total passage estimate of 132,930 to include fish that may have passed after operations ceased. Subtracting the preliminary subsistence catch upstream of the sonar site results in an estimated border passage of 34,465 Chinook salmon, and 121,580 chum salmon. A drift gillnet sample fishery was conducted to collect age, sex, length, and genetic information. Species composition was also recorded to determine when the Chinook salmon run ended and the fall chum salmon run began. Both sonar systems functioned well with minimal interruptions to operation. Range of ensonification was considered adequate for most fish that migrated upstream. A continued long-term hydroacoustic enumeration project for Chinook and chum salmon near the United States/Canada border will help fishery managers meet conservation and management commitments made by both countries under the Yukon River Salmon Agreement.

Key words: Alaska, Yukon River, Eagle, Chinook and chum salmon, *Oncorhynchus*, DIDSON, split-beam sonar, hydroacoustics.

INTRODUCTION

The Yukon River is the largest river in Alaska, spanning 3,700 km. It flows northwesterly from its origin in northwestern British Columbia through the Yukon Territory and Central Alaska to its mouth at the Bering Sea. Commercial and subsistence fisheries harvest salmon throughout most of the drainage. These fisheries are critical to the way of life and economy of people in dozens of communities along the river, in many instances providing the largest single source of food or income. Fisheries management on the Yukon River is complex and difficult because of the number, diversity and geographic range of fish stocks and user groups. Information upon which to base management decisions comes from several sources, each of which has unique strengths and weaknesses. Gillnet test fisheries provide inseason indices of run strength, but interpretation of these data is confounded by gillnet selectivity. In addition, the functional relationship between test fishery catches and abundance is poorly defined. Mark–recapture projects provide estimates of total abundance, but the information is typically not timely enough to make day-to-day management decisions. Sonar provides timely estimates of abundance, but is limited in its ability to identify fish to species level.

Alaska is obligated to manage Yukon River salmon stocks according to precautionary, abundance–based harvest–sharing principles set by the *Yukon River Salmon Agreement* (Yukon River Panel 2004). The goal of bilateral, coordinated management of Chinook *Oncorhynchus tshawytscha* and chum *Oncorhynchus keta* salmon stocks is to meet negotiated escapement goals and also provide for subsistence and commercial harvests of surplus in both the United States and Canada. Timely estimates of abundance not only help managers adjust harvest in season, they are crucial for postseason analysis to determine whether treaty obligations were met. The Canadian Department of Fisheries and Oceans (DFO) provided estimates of mainstem salmon passage through the U.S./Canada border using mark–recapture techniques from 1980 to 2008.

Because of the highly turbid water of the Yukon River, and the width of the mainstem (roughly 400 m across at the study site), daily passage estimation methods such as counting towers and weirs are not feasible. Split-beam sonar technology has been used successfully by the Alaska Department of Fish and Game (ADF&G) to produce daily inseason estimates of salmon passage

in turbid rivers, including the lower Yukon River at Pilot Station (Carroll and McIntosh 2008) and the Kenai River (Miller and Burwen 2010). Dual-Frequency Identification Sonar¹ (DIDSON) has been used at several sites, including the Aniak River (McEwen 2010) and the Sheenjek River (Dunbar 2010) to give daily passage estimates where bottom profile and river width are appropriate for the wider beam angle and shorter range capabilities of this technology.

In 1992, ADF&G initiated a project near Eagle, Alaska (Figure 1) to examine the feasibility of using split-beam sonar to estimate the number of salmon migrating across the U.S./Canada border (Johnston et al. 1993; Huttunen and Skvorc 1994). This project was the first documented use of split-beam sonar in a riverine environment and, over the 3-year duration of the study, a number of problems were identified. Phase corruption was observed and was probably exacerbated by the highly reflective river bottom (Konte et al. 1996). The errors in the phase measurement were believed to have resulted in overly restrictive echo angle thresholds causing the removal of echoes from fish that were physically within accepted detection regions. These and other equipment issues reflected the early state of split-beam development, most of which have since been addressed.

A recommendation that came out of these studies was to find a more appropriate site with smaller rocks and a uniform bottom profile (Johnston et al. 1993). Too many large rocks or obstructions in the profile can compromise fish detection by limiting how close to the bottom the hydroacoustic beam can be aimed. Similarly, an uneven bottom profile permits fish to pass undetected by the sonar.

In 2003, ADF&G carried out a study to identify a more suitable location to deploy hydroacoustic equipment to estimate salmon passage into Canada. A 45 km section of river from the DFO mark-recapture fish wheel project at White Rock, Yukon Territory to 19 km downriver from Eagle, Alaska was explored (Pfisterer and Huttunen 2004). This area was investigated because of its proximity to the DFO project and the U.S./Canada border. Desirable characteristics included: linear bottom profiles on both sides of the river without large obstructions; a single channel; available beach above water level for topside equipment; and sufficient current, i.e., areas without eddies or slack water where fish milling behavior can occur. A total of 21 river bottom profiling transects led to a narrowing of potential project locations to an area between 9 and 19 km downriver from the town of Eagle. The 2003 study identified the two most promising sonar deployment locations at Calico Bluff and Shade Creek. Though sonar was not deployed in 2003, the bottom profiles at the preferred sites indicated that it should be possible to estimate fish passage with a combination of split-beam sonar on the longer, linear left bank and DIDSON on the shorter, steeper right bank. ADF&G carried out a 2-week study in 2004 to test sonar at the preferred sites. The two types of sonar were tested at Calico Bluff and the Shade Creek area and it was found that Six Mile Bend (11.5 km downriver from the town of Eagle, and immediately upstream of Shade Creek) was the most ideal site (Carroll et al. 2007a).

In 2005, a full-scale sonar project was conducted from July 1 to August 13 to estimate Chinook salmon passage in the Yukon River at Six Mile Bend (Carroll et al. 2007b). As suggested, DIDSON was deployed on the right bank and split-beam sonar was deployed on the left bank. The project duration was extended in 2006 to also provide an estimate of fall chum salmon

¹ Product brand names are included in this report for scientific completeness, but do not constitute product endorsement.

passage. Split-beam and DIDSON technology have since been used in subsequent years to estimate border passage for both Chinook and fall chum salmon.

STUDY AREA

The study area is a 2 km section of the mainstem Yukon River at Six Mile Bend, 11.5 km downriver from Eagle, Alaska (Figure 2). Some additional drift gillnet fishing occurs about 5 km downriver near Calico Bluff.

Average monthly discharge for the Yukon River ranges from 110,500 to 223,600 ft³/s. Flows are highest in June, with greatest variability in flow occurring in May, after which discharge and the variability in discharge decline. The upper Yukon River is turbid and silty in the summer and fall with an estimated annual suspended sediment load at Eagle of 33,000,000 tons (Brabets et al. 2000).

Hungwitchin Native Corporation owns the majority of land in the study area above the ordinary mean high water mark. Permission was granted to operate a sonar project on Hungwitchin land at Six Mile Bend. A semi-permanent field camp consisting of 6 canvas tents on plywood platforms was constructed in 2005 on the left bank (64° 51'55.70" N 141° 04'43.62" W). An additional tent platform with a 12 ft x 15 ft Weatherport portable building was constructed on the left bank 1.3 km downriver from the camp (64°52'30.84" N 141°04'52.77" W) to house computer and sonar related equipment. A portable wooden shelter was used on the right bank to house topside sonar equipment and a wireless router.

OBJECTIVES

The primary goals of this project in 2010 were to:

1. Estimate the daily and seasonal passage of Chinook and fall chum salmon using fixed-location split-beam and DIDSON sonar.
2. Use drift gillnets to estimate run timing of Chinook and fall chum salmon past the sonar site.
3. Collect a minimum of 160 Chinook salmon samples during each of 3 stratum throughout the season to characterize the age, sex and length (ASL) composition of Yukon River Chinook salmon passage, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha=0.05$ and $d=0.10$).
4. Collect a minimum of 160 fall chum salmon samples during each of 4 stratum throughout the season to characterize the age, sex and length (ASL) composition of Yukon River fall chum salmon passage, such that simultaneous 95% confidence intervals of age composition are no wider than 0.20 ($\alpha=0.05$ and $d=0.10$).
5. Collect Chinook and chum salmon tissue samples for genetic stock identification.
6. Collect daily climate and hydrologic measurements representative of the study area.

METHODS

HYDROACOUSTIC EQUIPMENT

A fixed-location, split-beam sonar developed by Kongsberg Simrad was used to estimate salmon passage on the left bank. Fish passage was monitored with a model EK60 digital echosounder, which included a general-purpose transceiver and a $2.5^\circ \times 10^\circ$ 120 kHz transducer. ER60 data acquisition software installed on a laptop computer connected to the echosounder collected raw data for processing. Digital files created by the ER60 software were examined with an echogram viewer program created in C⁺⁺ computer language to produce an estimate of fish passage.

The transducer was attached to 2 Hydroacoustic Technology Incorporated (HTI) model 662H single-axis rotators. Aiming was performed remotely using a HTI model 660 remote control unit that provides horizontal and vertical position readings.

A DIDSON long-range unit, manufactured by Sound Metrics Corporation, was deployed on the right bank. This sonar was operated at 1.2 MHz (high frequency option) for the 0 to 20 m range, and at 0.70 MHz (low frequency option) for the 20 to 40 m range, using 48 beams. Both the low and high frequency modes have a viewing angle of $29^\circ \times 14^\circ$. A 60 m cable carried power and data between the DIDSON unit in the water and a topside breakout box. A wireless router transferred data between the breakout box and a laptop computer on the opposite bank. Sampling was controlled by DIDSON software loaded on the laptop computer. All surface electronics were housed on shore in a small, wood frame shelter. Power for hydroacoustic equipment and computers was supplied separately on each bank with portable 2000-W generators running continuously.

SONAR DEPLOYMENT AND OPERATION

Several bottom-profiling transects were made in 2005 to find a suitable specific location for sonar deployment on both banks. Specific sites were selected based on a profile consisting of a steady downward sloping gradient without large dips or obstructions that can hinder full acoustic beam coverage or detection of targets, sufficient current containing no eddies, and sufficient beach above water line to house topside sonar equipment. Each season, prior to transducer deployment, bottom profiles are checked to ensure the original sites remain acceptable for ensonification. Data was collected from a total of eight transects made from bank-to-bank using a boat-mounted Lowrance LCX-15 dual-frequency transducer (down-looking sonar) with a built-in global positioning system (GPS). A bottom profile was then generated using data files uploaded to a computer and plotted with Microsoft[®] Excel (Figure 3).

The split-beam sonar was deployed July 3 on the left bank. The transducer and rotators were mounted on a freestanding frame constructed of aluminum pipe and deployed approximately 15 m from shore. The frame was secured with sandbags and the transducer height was adjusted by sliding a mounting bar up or down along riser pipes that extended above the water. The transducer was deployed at approximately 1.0 to 1.5 m in depth and aimed perpendicular to the current along the natural substrate. The transducer was deployed at a location with consistent flow and no eddy or slack water.

An artificial acoustic target was used at various distances from the transducer during deployment to verify that the transducer aim was low enough to prevent salmon from passing undetected beneath the acoustic beam and to test target detection at different ranges. The target, an airtight

250 ml weighted plastic bottle tied with monofilament line, was drifted downstream along the river bottom and through the acoustic beam. Several drifts were made with the target in an attempt to pass it through as much of the counting range as possible. Proper aim for the split-beam system was verified with visual interpretation of an echogram on a computer screen, i.e. with visible, but not overpowering return of bottom signal appearing over the majority of the ensonified range.

The split-beam system was aimed to ensonify a range of approximately 2 to 150 m when counting Chinook salmon, and 2 to 75 m when counting chum salmon. Settings for data acquisition included: 256 μ s transmit pulse lengths, 500 W power output, 5 pings per second at 150 m range, and 10 pings per second at 75 m range.

A portable tripod-style fish lead was constructed approximately 1.5 m downstream from the transducer to prevent fish passage inshore of the transducer and provide sufficient offshore distance for fish swimming upstream to be detected in the sonar beam. Sixteen freestanding lead sections constructed of 2 in diameter steel pipes connected with adjustable fittings to form tripods were used. Aluminum stringers, approximately 2.5 m long, were then attached horizontally to the upstream side of the tripods. The sections were finished with vertical lengths of aluminum conduit 3.8 cm apart. Lead sections were placed side by side in the water from shore to an initial distance of 7 m beyond the transducer. The portability of this style of fish lead was important because of the gradual slope found on the left bank. As the water level rises and falls over the duration of the summer, the transducer and lead require frequent relocation to shallower or deeper water.

The DIDSON was deployed July 3 on the right bank. It was mounted on an aluminum frame and aimed using a manual crank-style rotator. Operators adjusted the aim by viewing the video image and relaying aiming instructions to a technician on the remote bank via handheld VHF radio. Proper aim was achieved when adequate bottom features appeared over the majority of the ensonified range (0 to 40 m).

A fish lead was constructed with 2 m steel "T" stakes and 1.2 m high galvanized chain link fencing. The fish lead was less than 1 m downstream from the transducer and extended 3 m offshore beyond the transducer. This distance provided sufficient offshore diversion for fish swimming upstream to be detected in the sonar beam. A short lead was appropriate for this bank because of the steep slope and short nearfield distance (0.83 m) of the DIDSON. The right bank was ensonified to a range of 40 m from the transducer, with two sampling zones, ranging from approximately 1 to 20 m and 20 to 40 m. Sonar control parameters included:

- 1) Nearshore zone - 0.83 m window start, 20.01 m window length, high frequency mode, and 7 frames per second, and
- 2) Offshore zone - 20.84 m window start, 20.01 m window length, low frequency mode, and 4 frames per second.

SONAR DATA PROCESSING AND PASSAGE ESTIMATION

Split-beam data was collected continuously in 60 min increments and saved to an external hard drive for tracking and counting. The operator opened each data file in an echogram viewer program and marked each upstream fish track by clicking a computer mouse (Figure 4). The number of marks for each hour was saved as a text file and recorded on a count form.

DIDSON data was collected in two 30 min samples each hour of the day. For the first 30 min of every hour, the DIDSON sampled the ensonified range from 1 m to 20 m (zone 1) and the second half of each hour sampled from 20 m to 40 m (zone 2). Upstream migrating fish were counted by marking each fish track on the echogram viewer program (Figure 5). Upstream direction of travel was verified using the DIDSON video feature. These counts were saved as text files and recorded on a count form.

The actual count for each 30 min sample was expanded for the full hour, and the estimated counts from zone 1 and zone 2 were summed for a total hourly count. The daily passage \hat{y} for zone z on day d was calculated by summing the hourly passage rates for each hour as follows:

$$\hat{y}_{dz} = \sum_{p=1}^{24} \frac{y_{dzp}}{h_{dzp}} \quad (1)$$

where h_{dzp} is the fraction of the hour sampled on day d , zone z , period p and y_{dzp} is the count for the same sample.

Treating the systematically sampled sonar counts as a simple random sample would yield an over-estimate of the variance of the total, since sonar counts are highly auto-correlated. To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed. The variance for the passage estimate for zone z on day d is estimated as:

$$\hat{V}_{y_{dz}} = 24^2 \frac{1 - f_{dz}}{n_{dz}} \frac{\sum_{p=2}^{n_{dz}} \left(\frac{y_{dzp}}{h_{dzp}} - \frac{y_{dz,p-1}}{h_{dz,p-1}} \right)^2}{2(n_{dz} - 1)} \quad (2)$$

Where n_{dz} is the number of samples in the day (24), f_{dz} is the fraction of the day sampled (12/24=0.5), and y_{dzp} is the hourly count for day d in zone z for sample p . Since the passage estimates are assumed independent between zones and among days, the total variance was estimated as the sum of the variances:

$$\hat{V}ar(\hat{y}) = \sum_d \sum_z \hat{V}ar(\hat{y}_{dz}) \quad (3)$$

The reported variance reflects the sampling done on the right bank. The sampling variance for the left bank is inconsequential since the split-beam sonar sampled the entire range continuously.

The counts from each split-beam and DIDSON sample were entered into a Microsoft® Excel spreadsheet where counts were adjusted for missing samples when data collection was interrupted. Brief interruptions intermittently occurred when routine maintenance (i.e. silt removal) or relocation of a transducer was required.

Whenever a portion of a sample was missing, on either bank, passage was estimated by expansion based on the known portion of the sample. The number of minutes in a complete sample period m_s was divided by the number of minutes counted m_i , and then multiplied by the number of fish counted x in that period i . Passage y_i was estimated as:

$$\hat{y}_i = \left(m_s / m_i \right) x_i \quad (4)$$

If data from one or more complete sample periods was missing, passage for that portion of the day y_m was estimated by averaging passage from the sample periods immediately before y_b and after y_a the missing sample period(s), and then multiplying by the number of sample periods missed n :

$$\hat{y}_m = \left(\frac{y_b + y_a}{2} \right) n \quad (5)$$

If data from one or more complete days d was missing, passage for each missing day y_d was estimated using simple linear interpolation, based on the known passage y for the day immediately before x_b and the day immediately after x_a the missing day(s) x_d :

$$\hat{y}_d = y_b + (x_d - x_b) \left(\frac{y_a - y_b}{x_a - x_b} \right) \quad (6)$$

After editing was complete, an estimate of hourly, daily, and cumulative fish passage was produced and forwarded to the Fairbanks ADF&G office via satellite telephone each day. The estimates produced during the field season were further reviewed postseason and adjusted as necessary.

If a large number of chum salmon was passing on the last day of sonar operation, the estimate was expanded using a second order polynomial equation, where y_i is the i th daily passage estimate, L is the count on the last day of sonar operation, d is the total number of days expanding for, and x_i is the day number being estimated (where $i = 1$ through total number of days expanding for):

$$y_i = \frac{L}{d^2} (x_i - d)^2 \quad (7)$$

Postseason, the Chinook and chum salmon subsistence harvest from the Eagle area upstream of the sonar site was subtracted from the adjusted sonar estimate to give a border passage estimate for each species.

SPATIAL AND TEMPORAL DISTRIBUTIONS

Fish range distributions for Chinook and chum salmon were examined postseason by importing text files containing all fish track information into *R* statistical software package (R Development Core Team 2009) where the individual fish were binned by range. Microsoft[®] Excel was used to plot the binned data and investigate the spatial distribution of fish passing the sonar site. Histograms of passage by hour were created in Microsoft[®] Excel to investigate diel patterns of migration. Run timing of Chinook and chum salmon were examined inseason and postseason using information from the sonar estimate, fish range distribution, sample fishery catches, and local subsistence harvest.

SAMPLE FISHING

To monitor species composition and collect age, sex, length, and genetic samples, gillnets of mesh sizes 7.5 in and 5.25 in were drifted through three zones: left bank inshore (LBI), left bank nearshore (LBN), and left bank offshore (LBF) (Figure 2). Nets were 25 fathoms long,

approximately 25 ft deep, and hung “even” at a 2:1 ratio of web to corkline. Gillnet webbing consisted of Momoi MTC or MT, shade 11, double knot multifilament nylon twine. In 2007, it was determined that the nets being used were too deep to effectively fish the inshore zone. Consequently, more appropriate nets of shorter depth, approximately 8 ft deep, were used for the inshore drifts only, with all other specifications remaining the same as the original nets.

Fishing for species composition and sample collection was conducted once daily from August 1 to October 4 between approximately 0800 and 1200 hours on the left bank. During the sampling period, both the 5.25 in and the 7.5 in nets were drifted twice within each of 3 zones (inshore, nearshore and offshore), for a total of 12 drifts. Drifts were targeted to be 6 minutes in duration, but were occasionally shortened as necessary to avoid snags or to limit catches and thus prevent mortalities during times of high fish passage. The inshore zone drifts were referred to as “beach walks” (Fleischman et al. 1995), where one person held onto the shore end of the net and led it downstream along the beach, while a boat drifted with the offshore end. The nearshore zone was approximately one net length offshore of the inshore zone and the offshore zone was approximately one net length offshore of the nearshore zone. The order of drifts was 1) LBI, 2) LBN, and 3) LBF, with a minimum of 15 min between drifts in the same zone (Table 1). All drifts with one mesh size were completed before switching to another mesh size. Starting mesh sizes were alternated each day.

In an effort to collect more Chinook salmon age, sex, length, and genetic samples, additional fishing was conducted that targeted Chinook salmon. Between July 5 and July 31, fishing occurred twice per day from approximately 0800 to 1200 hours and again from approximately 1300 to 1700 hours to capture Chinook salmon. Between August 2 and August 15, Chinook salmon sample fishing was conducted once per day after species composition fishing was completed. Chinook salmon genetic and ASL samples were collected to estimate specific Canadian stock proportions and ASL composition of Chinook salmon entering Canada. Four different mesh sizes (5.25 in, 6.5 in, 7.5 in, and 8.5 in) were drifted in a rotating schedule over the course of the Chinook salmon run to effectively capture all size classes present (Table 1). Nets were 25 fathoms long, approximately 25 ft deep and hung “even” at a 2:1 ratio of web to corkline. Three net sizes were drifted for approximately 6 minutes each within the left bank nearshore (LBN), left bank offshore (LBF), and right bank nearshore (RBN). The right bank zone was located approximately 5 km downriver from the sonar site where river conditions were suitable for drift gillnetting on that bank (Figure 2). This resulted in a total of 9 drifts during the Chinook salmon sample fishing period.

Four times were recorded to the nearest second onto field data sheets for each drift: net start out *SO*, net full out *FO*, net start in *SI*, and net full in *FI*. For each drift, fishing time *t*, in minutes, was approximated as:

$$t = SI - FO + \frac{FO - SO}{2} + \frac{FI - SI}{2} \quad (8)$$

Total effort e , in fathom-hours, of drift j with mesh size m during fishing period f in zone z on day d was calculated as:

$$e_{dzfmj} = \frac{25t_{dzfmj}}{60} \quad (9)$$

Captured salmon were sampled in the following ways:

For standard ASL samples, length (mid eye to tail fork to nearest 5 mm), and sex (determined by external characteristics) were recorded. Three scales from Chinook salmon and one scale from chum salmon were removed from the preferred area of the fish, on the left side approximately 2 rows above the lateral line, in an area transected by a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956). All scale samples were cleaned and mounted on gum cards to be aged by ADF&G ASL lab in Anchorage. These scale data were used to estimate the age composition of salmon that pass the Eagle sonar site.

For genetic stock identification (GSI), an axillary process was clipped from each salmon. Chinook salmon samples were stored individually in a vial of ethanol, while chum salmon samples were stored in bulk collections started weekly. All samples were sent to ADF&G genetics laboratory and from there forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, BC for processing. Non-salmon species were measured from nose to tail fork, but were not sampled for other data. Captured fish were handled in a manner that minimized mortalities. Most captured fish were quickly sampled and returned to the river. Mortalities were distributed to local residents after sampling.

SPECIES DETERMINATION

Although the Chinook and fall chum salmon runs are considered discrete in time, some temporal overlap does occur. Inseason tentative dates are chosen based on sonar counts, gillnet catches, and local harvest to represent the last day of the Chinook salmon run and the first day of the chum salmon run. After thorough examination of the sample fishery data postseason, the tentative dates used may be changed to more accurately represent the runs. Sample fishery information was used to determine the specific date after which sonar counts were classified as chum salmon. This was ascertained using reverse-cumulative Chinook catches and cumulative chum salmon catches. Chinook catch was summed in reverse from the date when the last fish was caught by calculating the total catch to date subtracted from the catch for the entire season. The date at which the chum catch surpassed the succeeding Chinook salmon catch became the species changeover date.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Climate and hydrologic data were collected daily at approximately 1800 hours. Air and water temperatures and subjective measures of wind speed and direction, cloud cover and precipitation were also recorded. Reported stream levels are taken from the U.S. Geological Survey's gaging station at Eagle, although water levels at the sonar site were carefully monitored.

RESULTS

SONAR DEPLOYMENT

On July 3 the left bank sonar was deployed approximately 800 m downriver from the camp and the right bank sonar was deployed across the river approximately 700 m downriver from the camp (Figure 2). Zones of ensonification and bottom profile of the Yukon River at the sonar site can be found in Figure 3. The left bank profile was approximately linear, extending 300 m to the thalweg at a 2.1° slope. The right bank profile was less linear, shorter and steeper, extending 100 m to the thalweg at a 6.7° slope. The substrate at Six Mile Bend was large cobble to small boulder on the right bank, and small to medium sized cobble and silt on the left bank.

CHINOOK AND CHUM SALMON PASSAGE ESTIMATION

In season, August 16 was tentatively determined to be the last day of the Chinook salmon run based on relatively low sonar counts, gillnet catches and harvest information gathered from local subsistence fishermen. Fish range distribution from the sonar also was a primary indicator that the salmon run was changing from Chinook to chum salmon. The inseason species changeover date was adjusted postseason after thorough examination of sample fishery information. Analysis of reverse-cumulative Chinook catches and cumulative chum catches showed that August 19 was the last date when the overall Chinook catch was more than the overall chum salmon catch. Figure 6 shows reverse-cumulative Chinook catch and cumulative chum catch plotted by day from just prior to the date of the first chum salmon capture. The two lines cross at the point when the number of chum caught equals the number of Chinook salmon caught subsequent to that point.

The total passage estimate at the Eagle sonar site for Chinook salmon was 35,074 from July 3 to August 19, 2010 (Table 2 and Figure 7). A peak daily passage estimate of 1,819 Chinook salmon occurred on July 22 and 164 fish passed on August 19, the last day of estimating Chinook salmon passage. Sampling time missed because of routine maintenance, system diagnostic test, system malfunction, moving and aiming the transducer, or flooding, included 110 h on the left bank, 52 h on the right bank zone 1, and 51 h on the right bank zone 2 of sampling time (Table 3). As noted in Table 3, sometimes the collection software from the split beam sonar over runs the sample time, resulting in a sample that is more than an hour long. If at the end of a day the sample time is more than 24 h (1440 min) then the time in the table may show as negative. In this case, fish may be subtracted from the estimate, resulting in a negative number of fish. Postseason, the subsistence harvest from the Eagle area upstream of the sonar site was subtracted from the sonar estimate to produce a border passage estimate of 34,465 fish (Table 4). The preliminary subsistence harvest from the Eagle area upstream of the sonar was 609 (Deena Jallen, Commercial Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication).

The total fall chum salmon passage estimate was 125,547 fish from August 20 to October 6, 2010 (Table 5 and Figure 7). Fall chum salmon passage peaked on September 20 with a daily estimate of 9,273 fish. Sampling time missed because of routine maintenance, system diagnostic test, system malfunction, moving and aiming the transducer, or flooding, included 4 h on the left bank, 13 h on the right bank zone 1, and 22 h on the right bank zone 2 of sampling time (Table 6). Although chum salmon passage was decreasing, 2,101 fish (almost 2 % of total) passed on October 6, the last day of operation. Continuing chum salmon passage when the project was terminated prompted expansion of the sonar estimate which was subsequently adjusted to

132,930 chum salmon (Table 4 and Figure 7). The expansion was calculated using a second order polynomial equation extended to October 18 (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). Postseason, the subsistence harvest from the Eagle area upstream of the sonar was subtracted from the sonar estimate to produce a border passage estimate of 121,580 fish (Table 4). The preliminary subsistence harvest from the Eagle area was 11,350 fish (Deena Jallen, Commercial Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication).

SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore oriented on both banks (Figures 8 and 9). On the left bank during the Chinook salmon run, 95% of the fish were detected within 75 m of the transducer, and 99% within 105 m. On the right bank, 94% of the fish were detected within 20 m of the transducer and 99% within 28 m. During the fall chum salmon run on the left bank, 96% of the fish were detected within 20 m of the transducer, and 99% within 30 m. On the right bank, 96% of the fish were detected within 10 m of the transducer and 99% within 14 m. The percentage of fish passage estimated by bank for the Chinook salmon season was 85% on the left bank and 15% on the right bank. During the fall chum salmon run, 61% migrated on the left bank and 39% on the right bank.

Chinook salmon passage along the left and right bank was fairly consistent during daylight hours and periods of darkness (Figure 10). More chum salmon passed along the right bank during daylight hours compared to periods of darkness while fewer chum salmon passed along the left bank during daylight hours compared to periods of darkness (Figure 11). Overall, when both banks are combined, there was very little diel fluctuation at the project site for both species.

SAMPLE FISHING

A total of 468 Chinook and 337 chum salmon were captured in drift gillnets between July 5 and October 4 (Table 7). Fishing for species composition and sample collection occurred from August 1 to October 4, and additional Chinook salmon sample fishing occurred from July 5 to August 15. Drifts during species composition fishing caught 69 Chinook and 335 chum salmon. Drifts during Chinook salmon sample fishing caught 399 Chinook and 2 chum salmon. Additionally, 8 sheefish *Stenodus leucichthys*, 2 Arctic grayling *Thymallus arcticus*, 1 whitefish *Coregoninae* spp. and 1 northern pike *Esox lucius* were captured during species composition fishing. The number of Chinook and chum salmon captured in drift gillnets by sampling purpose (species composition sampling or Chinook salmon sampling), zone and mesh size are contained in Tables 8 and 9. There were no capture mortalities. An additional 4 Chinook salmon were observed to have clipped adipose fins indicating they held coded wire tags from the hatchery in Whitehorse, YT. These fish were retained and the heads sent to the ADF&G Mark, Tag and Age Lab in Juneau, Alaska. The fish were then distributed to local area residents and added to the total subsistence harvest. No fishing occurred on July 13, July 17, July 24, August 7 and August 21 because high water and extreme debris conditions made fishing impossible.

Chinook salmon samples collected from driftnets were composed of 276 (59.0%) males and 192 (41.0%) females. Chum salmon samples from driftnets were composed of 216 (64.1%) males and 121 (35.9%) females. ASL samples from 468 Chinook and 334 chum salmon were collected and sent to the ADF&G age determination laboratory in Anchorage for processing. Genetic samples from 468 Chinook and 337 chum salmon were collected and sent to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, BC for processing.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Details of weather and water observations recorded at the sonar site are shown in Appendix A1. Water temperature decreased over the course of the season with a maximum daily recording of 21°C and a minimum of 3°C. Water level decreased over the duration of the season, with several temporary and dramatic increases following substantial rain events (Figure 12). Overall, between July 1 and October 6 the water level decreased 9.8 ft from 19.1 ft to 9.3 ft. The lowest water level recorded during the season was 9.3 ft on October 6, while the highest was 20.4 ft on July 17.

DISCUSSION

SONAR DEPLOYMENT AND OPERATION

The split-beam and DIDSON systems performed well over the entire season with no major technical difficulties or failures. Only when water levels were extremely high and large amounts of debris were floating downriver were sonar operations interrupted. July and August were characterized by heavy rains and flood events. Rapid water level fluctuations coupled with substantial debris necessitated moving the transducer(s) and fish lead(s) to deeper or shallower water. The left and right bank fish leads collapsed during extreme high water events, and both transducers had to be recovered and removed from the water on 3 occasions when the debris load compromised their stability. When silt level was exceptionally high, sonar detection ranges were diminished. Detection ranges for both sonars were reduced to approximately half of the normal counting range for 3 periods during the Chinook salmon run. In contrast, weather conditions during the chum salmon run in late August and September were very favorable for sonar operation. The DIDSON, with its wide beam angle (14°), is well suited for the right bank, where the profile is steep and slightly less linear than the left bank. The split-beam system worked without malfunction, and appeared to have satisfactory detection nearshore, while still detecting targets adequately at 150 m.

Processing procedures for both DIDSON and split-beam files worked well for estimating salmon passage at the site. All data files were easily processed in a reasonable amount of time. The improved background removal and color by angle features to the echogram viewing program used for counting fish from the split-beam data files made distinguishing fish tracks, particularly for chum passing near the transducer, easier. The updated version allowed users to simply adjust the level of background removed, depending on counting conditions.

CHINOOK AND CHUM SALMON PASSAGE ESTIMATION

The main purpose of this study was to estimate the passage of Chinook and fall chum salmon to Canada in the mainstem of the Yukon River using hydroacoustics. The Chinook salmon border passage estimate of 34,465 is 42% below the 2005 to 2009 average sonar border passage estimate of 59,381 fish. The fall chum salmon border passage estimate of 121,580 is 36% below the 2006 to 2009 average sonar border passage estimate of 189,743 fish.

SPATIAL AND TEMPORAL DISTRIBUTIONS

Based on sample fishing results and range distributions observed with the sonar, very few fish migrate upstream in the unensonified portion of the river. The majority of fish migrate within 40 m of shore on both banks. The right bank DIDSON was aimed to ensonify to a range of 40 m,

and the left bank split-beam system was aimed to ensonify to a range of 150 m. Because chum salmon tend to swim closer to shore, the range for the left bank split-beam system was reduced to 75 m on August 17 to allow faster ping rates and improved detection near shore. The diel migration pattern of chum salmon observed was similar to past years, whereas the diel migration pattern of Chinook salmon was not observed in 2010. Upstream migration was greatest in periods of darkness or suppressed light on the left bank and greatest during daylight hours on the right bank.

SAMPLE FISHING AND SPECIES DETERMINATION

Fishing was conducted with drift gillnets to capture a representative sample of fish migrating past the sonar site. If fishing effort for both species is approximately the same, this method should recognize a particular date when chum salmon compose more of the sonar count than Chinook salmon, with a minimum error due to species misclassification. However, misclassification rates are relatively insensitive to species changeover date selection because of the typically low passage rates observed around this time (Withler 2006).

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TABLES AND FIGURES

Table 1.–Species composition, and additional Chinook salmon, sample fishing schedules and drift gillnet mesh sizes for all zones, 2010.

Sampling Purpose	Day	Drift		
		1	2	3
Species Composition Sample Fishing	1	5.25"	7.50"	
	2	7.50"	5.25"	
Additional Chinook salmon Sample Fishing	1	5.25"	6.50"	7.50"
	2	7.50"	8.50"	6.50"
	3	6.50"	5.25"	8.50"
	4	8.50"	7.50"	5.25"

Table 2.—Estimated daily and cumulative Chinook salmon passage by bank, Eagle sonar, 2010.

Date	Daily			Cumulative			
	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	% of Total Passage
7/03 ^a	0	4	4	0	4	4	0.00
7/04	3	12	15	3	16	19	0.00
7/05	2	12	14	5	28	33	0.00
7/06	2	4	6	7	32	39	0.00
7/07	1	10	11	8	42	50	0.00
7/08	9	6	15	17	48	65	0.00
7/09	15	8	23	32	56	88	0.00
7/10	33	24	57	65	80	145	0.00
7/11	40	38	78	105	118	223	0.01
7/12	24	47	71	129	165	294	0.01
7/13 ^b	74	53	127	203	218	421	0.01
7/14 ^c	123	58	181	326	276	602	0.02
7/15	186	132	318	512	408	920	0.03
7/16	355	128	483	867	536	1,403	0.04
7/17	661	161	822	1,528	697	2,225	0.06
7/18	724	333	1,057	2,252	1,030	3,282	0.09
7/19	996	183	1,179	3,248	1,213	4,461	0.13
7/20	1,274	94	1,368	4,522	1,307	5,829	0.17
7/21	1,588	120	1,708	6,110	1,427	7,537	0.21
7/22	1,625	194	1,819	7,735	1,621	9,356	0.27
7/23	1,329 ^e	244	1,573	9,064	1,865	10,929	0.31
7/24	1,171 ^e	207	1,378	10,235	2,072	12,307	0.35
7/25	1,127	206	1,333	11,362	2,278	13,640	0.39
7/26	1,518	242	1,760	12,880	2,520	15,400	0.44
7/27	1,626	134	1,760	14,506	2,654	17,160	0.49
7/28	1,507	208	1,715	16,013	2,862	18,875	0.54
7/29	1,559	233	1,792	17,572	3,095	20,667	0.59
7/30	1,544	267	1,811	19,116	3,362	22,478	0.64
7/31	1,354	284	1,638	20,470	3,646	24,116	0.69
8/01	1,353	245	1,598	21,823	3,891	25,714	0.73
8/02	1,525	290	1,815	23,348	4,181	27,529	0.78
8/03	1,213	217	1,430	24,561	4,398	28,959	0.83
8/04	1,055	146	1,201	25,616	4,544	30,160	0.86
8/05	792	130	922	26,408	4,674	31,082	0.89
8/06	515 ^c	119	634	26,923	4,793	31,716	0.90
8/07 ^b	403	79	482	27,326	4,872	32,198	0.92
8/08 ^c	290	38	328	27,616	4,910	32,526	0.93

-continued-

Table 2.–Page 2 of 2.

Date	Daily			Cumulative			
	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	% of Total Passage
8/09	187	32	219	27,803	4,942	32,745	0.93
8/10	279	58	337	28,082	5,000	33,082	0.94
8/11	303	70	373	28,385	5,070	33,455	0.95
8/12	239	32	271	28,624	5,102	33,726	0.96
8/13	191	42	233	28,815	5,144	33,959	0.97
8/14	182	32	214	28,997	5,176	34,173	0.97
8/15	157	34	191	29,154	5,210	34,364	0.98
8/16	151	34	185	29,305	5,244	34,549	0.99
8/17	133	33	166	29,438	5,277	34,715	0.99
8/18	169	26	195	29,607	5,303	34,910	1.00
8/19	150	14	164	29,757	5,317	35,074	1.00
SE ^g		82				82	

^a Right and left bank sonar operational.

^b Counts interpolated.

^c Counts extrapolated to 24 hours based on partial counts.

^d Boxed area identifies second and third quartile of run.

^e High silt load and debris affected counts.

^f Bold box identifies median day of passage.

^g Sampling error associated with the left bank was treated as insignificant since data was collected 24 hours per day over the sampling range.

Table 3.–Number of minutes by bank and day that were adjusted, to calculate the hourly or daily Chinook salmon passage, and the resulting number of fish either added or subtracted from estimate.

Date	Left Bank (0-150m)		Right Bank (0-20m)		Right Bank (20-40m)	
	Minutes	Fish	Minutes	Fish	Minutes	Fish
7/3	9.8	0	0.0	0	0.0	0
7/4	9.5	0	30.0	0	30.0	0
7/5	8.4	0	0.0	0	0.0	0
7/6	9.0	0	30.0	0	30.0	0
7/7	9.5	0	0.0	0	0.0	0
7/8	9.4	0	0.0	0	0.0	0
7/9	9.6	0	0.0	0	0.0	0
7/10	9.1	0	15.0	0	0.0	0
7/11	8.1	0	0.0	0	0.0	0
7/12	9.5	0	30.0	3	9.0	0
7/13	1,440.0	74	720.0	53	720.0	0
7/14	605.0	51	300.0	24	300.0	0
7/15	8.4	0	0.0	0	30.0	0
7/16	8.3	0	120.0	28	120.0	0
7/17	545.7	234	330.0	77	330.0	0
7/18	127.9	78	90.0	51	60.0	0
7/19	8.4	0	7.0	1	0.0	0
7/20	8.3	0	0.0	0	0.0	0
7/21	8.9	4	0.0	0	0.0	0
7/22	8.4	5	0.0	0	0.0	0
7/23	485.8	395	30.0	19	38.5	5
7/24	545.6	441	17.0	3	0.0	0
7/25	7.6	0	18.0	6	0.0	0
7/26	8.1	4	0.0	0	0.0	0
7/27	9.9	9	0.0	0	25.0	0
7/28	10.6	5	0.0	0	0.0	0
7/29	10.2	8	11.0	1	30.0	0
7/30	20.3	15	30.0	7	10.0	0
7/31	10.5	7	15.0	2	0.0	0
8/1	10.2	4	30.0	3	5.0	0
8/2	11.2	8	0.0	0	0.0	0
8/3	10.3	1	11.0	1	0.0	0
8/4	10.2	0	0.0	0	0.0	0
8/5	10.2	0	0.0	0	0.0	0
8/6	486.8	172	70.0	9	60.0	0
8/7	1,440.0	403	720.0	79	720.0	0
8/8	554.5	109	300.0	16	300.0	0
8/9	7.0	0	5.0	0	30.0	0
8/10	7.6	0	10.0	0	10.0	0
8/11	8.3	0	0.0	0	0.0	0
8/12	7.7	0	30.0	0	47.0	0
8/13	7.2	0	0.0	0	0.0	0
8/14	9.0	0	0.0	0	0.0	0
8/15	9.0	0	120.0	0	150.0	0
8/16	9.6	0	30.0	0	0.0	0
8/17	6.7	-1	9.0	1	0.0	0
8/18	2.0	0	0.0	0	0.0	0
8/19	1.9	0	0.0	0	0.0	0
Total	6,579.2 (110 h)	2,026	3,128.0 (52 h)	384	3,054.5 (51 h)	5

Note: Negative numbers are result of collection software over running the sample period. See text, p.10 for details.

Table 4.–Eagle sonar estimate, Eagle area subsistence harvest, and U.S. and Canadian border passage estimates, 2005–2010.

Date	Sonar Estimate		Eagle Area Subsistence Harvest ^a		U.S. Sonar Mainstem Border Passage Estimate	
	Chinook	chum	Chinook	chum	Chinook	chum
2005	81,528	ND	2,566	ND	78,962	ND
2006	73,691	236,386	2,303	17,775	71,388	218,611
2007	41,697	282,670 ^b	1,999	18,691	39,698	263,979
2008	38,097	193,397 ^b	815	11,755	37,282	181,642
2009	69,957	101,734 ^b	382	6,995	69,575	94,739
2010	35,074	132,930 ^b	609	11,350	34,465	121,580

Note: Estimates for subsistence caught salmon between the sonar site and border (Eagle area) prior to 2008 include an unknown portion caught below the sonar site. This number is most likely in the hundreds for Chinook salmon, and a few thousand for chum salmon. Starting in 2008, the estimates for subsistence caught salmon only include salmon harvested between the sonar site and the U.S./Canada border.

^a Except for 2005 and 2008, subsistence estimates are preliminary.

^b Expanded sonar estimate, includes expansion for fish that may have passed after sonar operations ceased.

Table 5.—Estimated daily and cumulative chum salmon passage by bank, Eagle sonar, 2010.

Date	Daily			Cumulative			% of Total Passage
	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	
8/20	133	27	160	133	27	160	0.00
8/21 ^a	55	6	61	188	33	221	0.00
8/22	72	4	76	260	37	297	0.00
8/23	127	11	138	387	48	435	0.00
8/24	246	22	268	633	70	703	0.01
8/25	342	28	370	975	98	1,073	0.01
8/26	468	40	508	1,443	138	1,581	0.01
8/27	563	30	593	2,006	168	2,174	0.02
8/28	683	40	723	2,689	208	2,897	0.02
8/29	689	62	751	3,378	270	3,648	0.03
8/30	618	35	653	3,996	305	4,301	0.03
8/31	694	68	762	4,690	373	5,063	0.04
9/01	595	52	647	5,285	425	5,710	0.05
9/02	639	92	731	5,924	517	6,441	0.05
9/03	574	68	642	6,498	585	7,083	0.06
9/04	705	42	747	7,203	627	7,830	0.06
9/05	695	68	763	7,898	695	8,593	0.07
9/06	617	74	691	8,515	769	9,284	0.07
9/07	578	50	628	9,093	819	9,912	0.08
9/08	583	90	673	9,676	909	10,585	0.08
9/09	543	74	617	10,219	983	11,202	0.09
9/10	598	174	772	10,817	1,157	11,974	0.10
9/11	493	364	857	11,310	1,521	12,831	0.10
9/12	925	177	1,102	12,235	1,698	13,933	0.11
9/13	1,513	84	1,597	13,748	1,782	15,530	0.12
9/14	1,852	208	2,060	15,600	1,990	17,590	0.14
9/15	2,415	620	3,035	18,015	2,610	20,625	0.16
9/16	3,321	846	4,167	21,336	3,456	24,792	0.20
9/17	4,021	1,152	5,173	25,357	4,608	29,965	0.24
9/18	4,199	1,556	5,755	29,556	6,164	35,720	0.28
9/19	5,093	2,927	8,020	34,649	9,091	43,740	0.35
9/20	5,415	3,858	9,273	40,064	12,949	53,013	0.42
9/21	5,008	3,782	8,790	45,072	16,731	61,803	0.49
9/22	5,242	2,962	8,204	50,314	19,693	70,007	0.56
9/23	4,219	3,764	7,983	54,533	23,457	77,990	0.62
9/24	3,544	3,854	7,398	58,077	27,311	85,388	0.68
9/25	2,670	3,288	5,958	60,747	30,599	91,346	0.73
9/26	2,755	2,774	5,529	63,502	33,373	96,875	0.77
9/27	2,121	2,202	4,323	65,623	35,575	101,198	0.81
9/28	2,020	2,006	4,026	67,643	37,581	105,224	0.84
9/29	1,655	1,652	3,307	69,298	39,233	108,531	0.86
9/30	1,443	1,678	3,121	70,741	40,911	111,652	0.89

-continued-

Table 5.–Page 2 of 2.

Date	Daily			Cumulative			
	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	% of Total Passage
10/01	1,403	1,502	2,905	72,144	42,413	114,557	0.91
10/02	1,036	1,482	2,518	73,180	43,895	117,075	0.93
10/03	941	1,195	2,136	74,121	45,090	119,211	0.95
10/04	612	1,415	2,027	74,733	46,505	121,238	0.97
10/05	794	1,414	2,208	75,527	47,919	123,446	0.98
10/06 ^d	781	1,320	2,101	76,308	49,239	125,547	1.00
SE ^e		507				507	

^a High silt load and debris affected counts.

^b Boxed area identifies second and third quartile of run.

^c Bold box identifies median day of passage.

^d Last day of sonar operation.

^e Sampling error associated with the left bank was treated as insignificant since data was collected 24 hours per day over the sampling range.

Table 6.–Number of minutes by bank and day that were adjusted, to calculate the hourly or daily chum salmon passage, and the resulting number of fish either added or subtracted from estimate.

Date	Left Bank (0-75m)		Right Bank (0-20m)		Right Bank (20-40m)	
	Minutes	Fish	Minutes	Fish	Minutes	Fish
8/20	0.3	0	98.0	5	123.0	0
8/21	-0.1	0	210.0	0	210.0	0
8/22	92.4	6	33.0	0	60.0	0
8/23	10.7	1	11.0	1	30.0	0
8/24	10.1	1	0.0	0	0.0	0
8/25	2.0	0	11.0	2	0.0	0
8/26	10.7	3	10.0	2	0.0	0
8/27	0.5	0	0.0	0	0.0	0
8/28	1	0	0.0	0	30.0	0
8/29	1	0	0.0	0	0.0	0
8/30	14.4	8	30.0	3	30.0	0
8/31	0.5	0	150.0	20	159.4	0
9/1	1.8	0	0.0	0	0.0	0
9/2	1.2	0	0.0	0	0.0	0
9/3	0.6	0	0.0	0	0.0	0
9/4	-2.8	0	0.0	0	0.0	0
9/5	1.5	1	0.0	0	0.0	0
9/6	0.5	0	0.0	0	0.0	0
9/7	1.7	0	0.0	0	0.0	0
9/8	13.8	7	0.0	0	0.0	0
9/9	0.8	0	60.0	4	48.0	0
9/10	1.3	0	0.0	0	0.0	0
9/11	-0.3	0	0.0	0	0.0	0
9/12	-0.1	0	19.0	3	30.0	0
9/13	0.4	0	0.0	0	0.0	0
9/14	-0.1	-1	0.0	0	0.0	0
9/15	-0.1	-1	0.0	0	0.0	0
9/16	4.1	4	0.0	0	0.0	0
9/17	2.2	0	30.0	80	30.0	0
9/18	2.3	0	0.0	0	0.0	0
9/19	2.2	0	4.0	11	15.0	0
9/20	2.3	1	0.0	0	0.0	0
9/21	7.2	8	0.0	0	0.0	0
9/22	2.3	1	0.0	0	0.0	0
9/23	2.3	0	0.0	0	0.0	0
9/24	2.3	0	0.0	0	0.0	0
9/25	2.3	0	0.0	0	0.0	0
9/26	2.3	0	0.0	0	0.0	0
9/27	2.2	0	0.0	0	0.0	0
9/28	2.3	0	0.0	0	0.0	0
9/29	12.1	8	10.0	16	15.0	0
9/30	2.3	0	60.0	110	270.0	0
10/1	2.3	0	0.0	0	0.0	0
10/2	2.2	0	10.0	33	30.0	1
10/3	2.3	0	55.0	91	10.0	0
10/4	2.2	0	8.0	17	210.0	0
10/5	1.3	0	0.0	0	0.0	0
10/6	2.2	0	0.0	0	0.0	0
Total	226.9 (4 h)	47	809.0 (13 h)	398	1,300.4 (22 h)	1

Note: Negative numbers are result of collection software over running sample period. See text, p.10 for details.

Table 7.–Fish caught with gillnets at the Eagle sonar project site, 2010.

Species	Species Composition Fishing	Chinook Salmon Sample Fishing	Total
Chinook	69	399	468
chum	335	2	337
sheefish	8	0	8
whitefish	1	0	1
pike	1	0	1
grayling	2	0	2
Total	416	401	817

Table 8.–Species composition fishing, effort, salmon catch, and percentage of Chinook and chum salmon catch, by zone and mesh size, Eagle sonar project site, 2010.

Zone	Mesh Size (inches)	Effort (fathom hours)	Catch		Percent of	
			Chinook	Chum	Chinook Catch	Chum Catch
LBI	5.25	334.83	1	193	1.4	57.6
	7.50	333.59	0	93	0.0	27.8
Total		668.42	1	286	1.4	85.4
LBN	5.25	350.63	26	40	37.7	11.9
	7.50	342.90	22	7	31.9	2.1
Total		693.53	48	47	69.6	14.0
LBF	5.25	343.09	11	0	15.9	0.0
	7.50	334.06	9	2	13.0	0.6
Total		677.15	20	2	29.0	0.6
Grand Total		2,039.10	69	335	100	100

Table 9.–Chinook salmon sample fishing, effort, salmon catch, and percentage of Chinook and chum salmon catch, by zone and mesh size, Eagle sonar project site, 2010.

Zone	Mesh Size (inches)	Effort (fathom hours)	Catch		Percent of	
			Chinook	Chum	Chinook Catch	Chum Catch
LBN	5.25	125.66	31	1	7.8	50.0
	6.50	128.53	58	0	14.5	0.0
	7.50	124.59	65	0	16.3	0.0
	8.50	124.06	40	0	10.0	0.0
Total		502.84	194	1	48.6	50.0
RBN	5.25	125.97	36	0	9.0	0.0
	6.50	127.45	42	0	10.5	0.0
	7.50	124.61	62	0	15.5	0.0
	8.50	122.41	34	1	8.5	50.0
Total		500.44	174	1	43.6	50.0
LBF	5.25	122.86	9	0	2.3	0.0
	6.50	136.12	12	0	3.0	0.0
	7.50	122.22	5	0	1.3	0.0
	8.50	120.66	5	0	1.3	0.0
Total		501.86	31	0	7.8	0.0
Grand Total		1,505.14	399	2	100	100

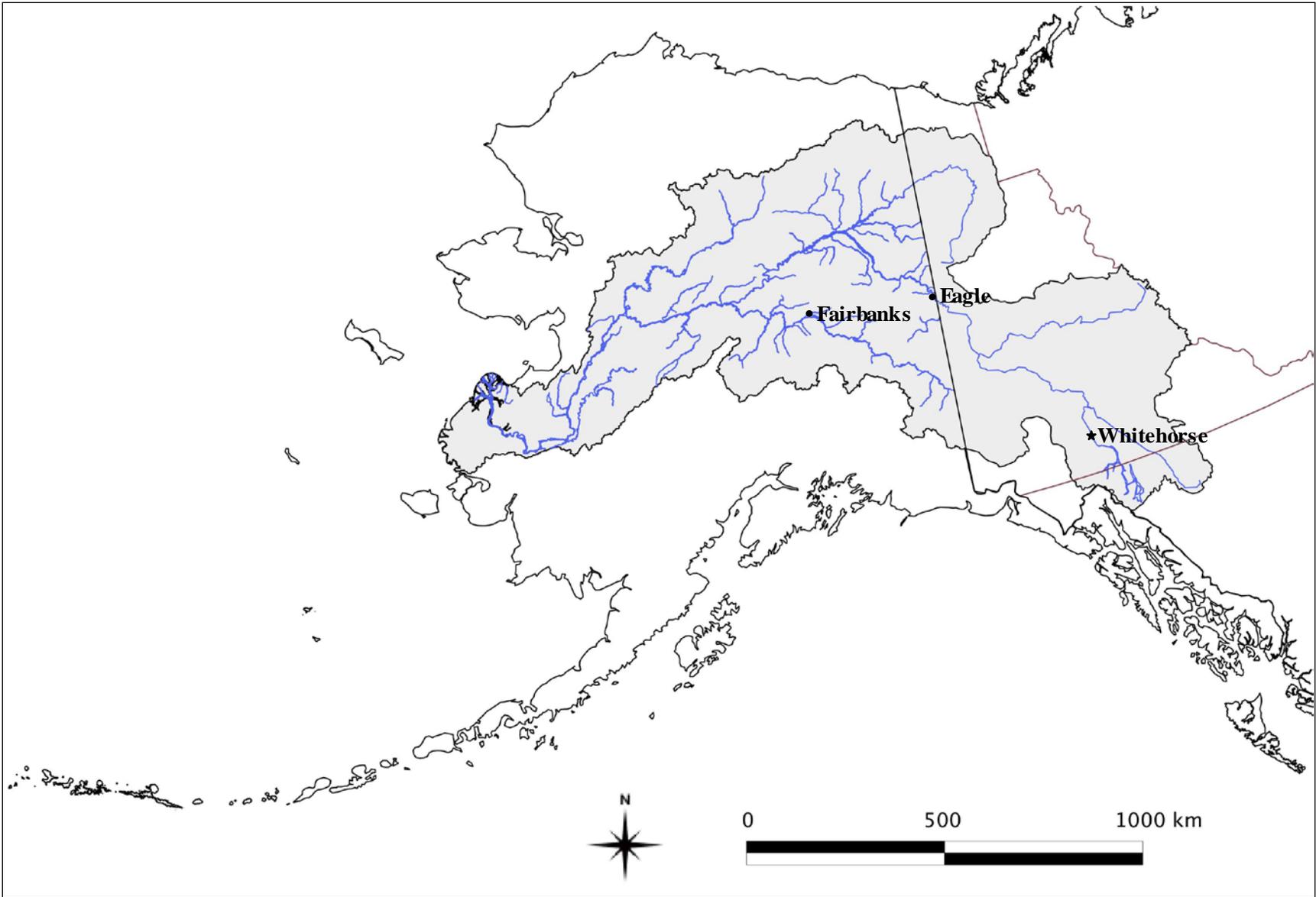


Figure 1.—Yukon River drainage.

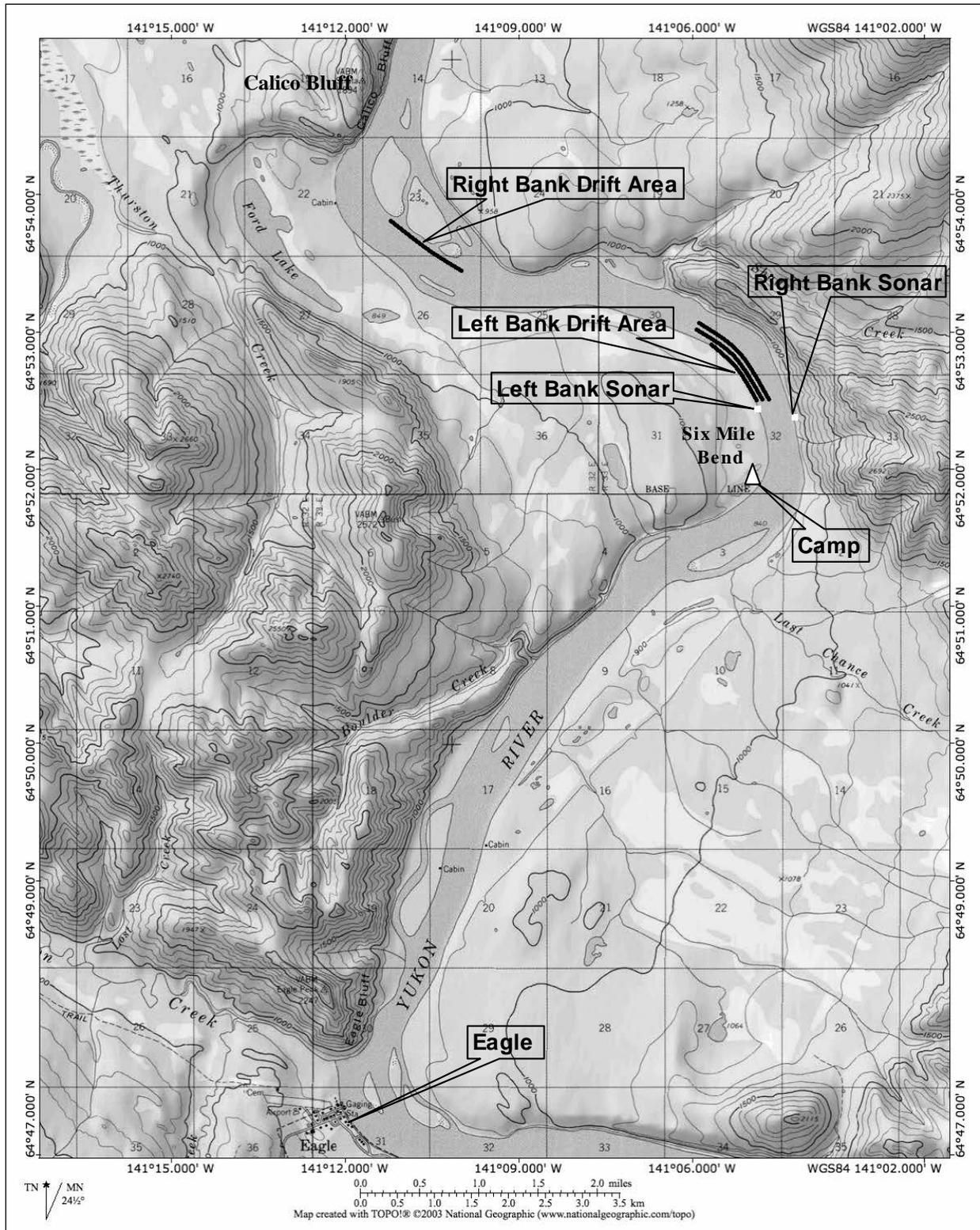


Figure 2.—Eagle sonar project site at Six Mile Bend, showing sonar and sample fishing locations.

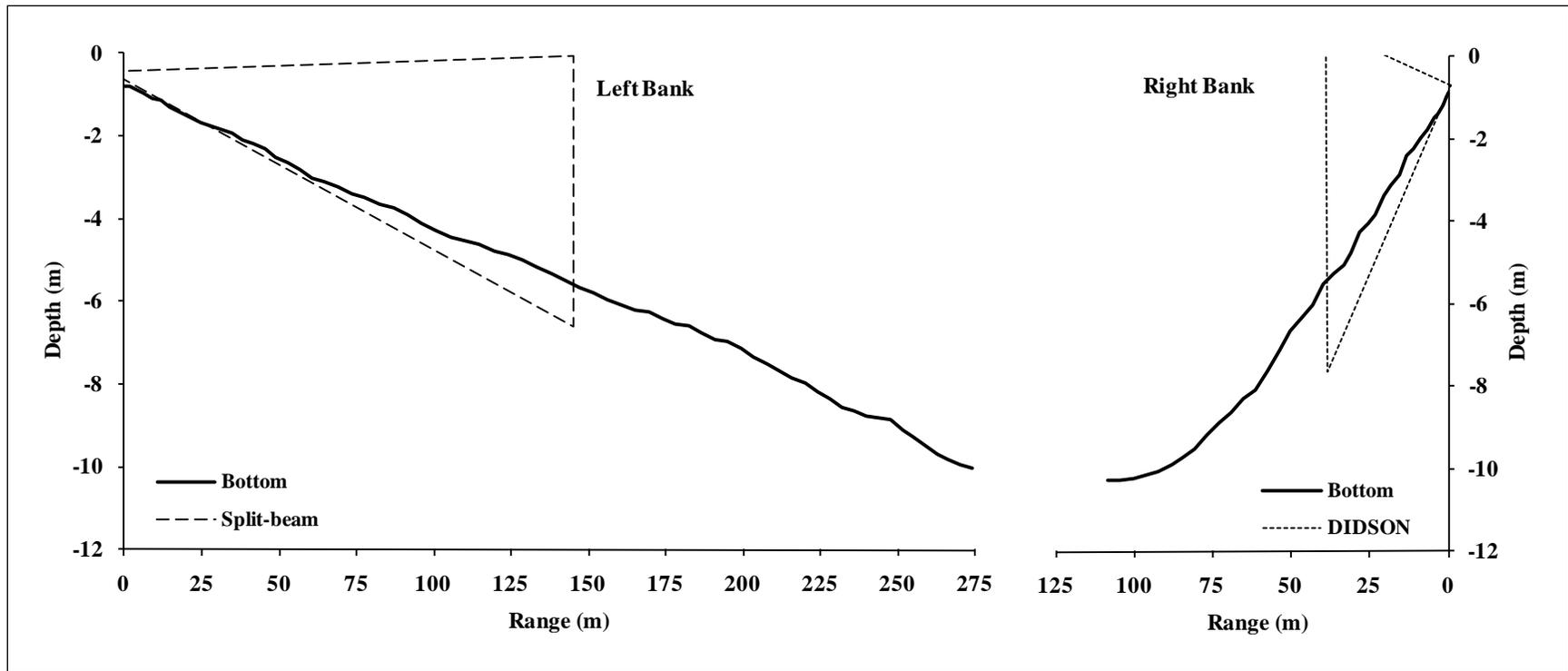
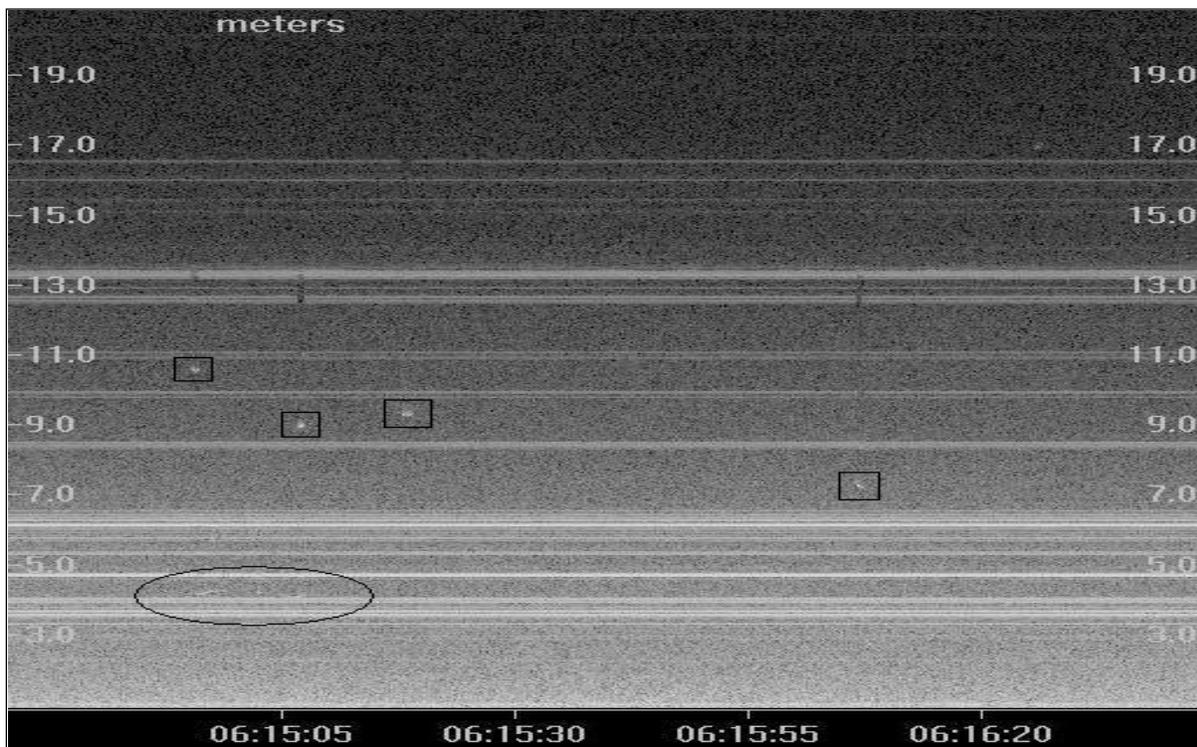


Figure 3.—Depth profile (downstream view), and ensoufied zones of Yukon River at Eagle sonar project site, 2010.



Note: Ellipse encompasses typical upstream migrating salmon.

Figure 4.—Screenshot of echogram used to count fish from split-beam sonar data files.



Note: Rectangles encompass typical migrating salmon traces and ellipse encompasses small, slow-moving non-salmon.

Figure 5.—Screenshot of echogram used to count fish from DIDSON data files.

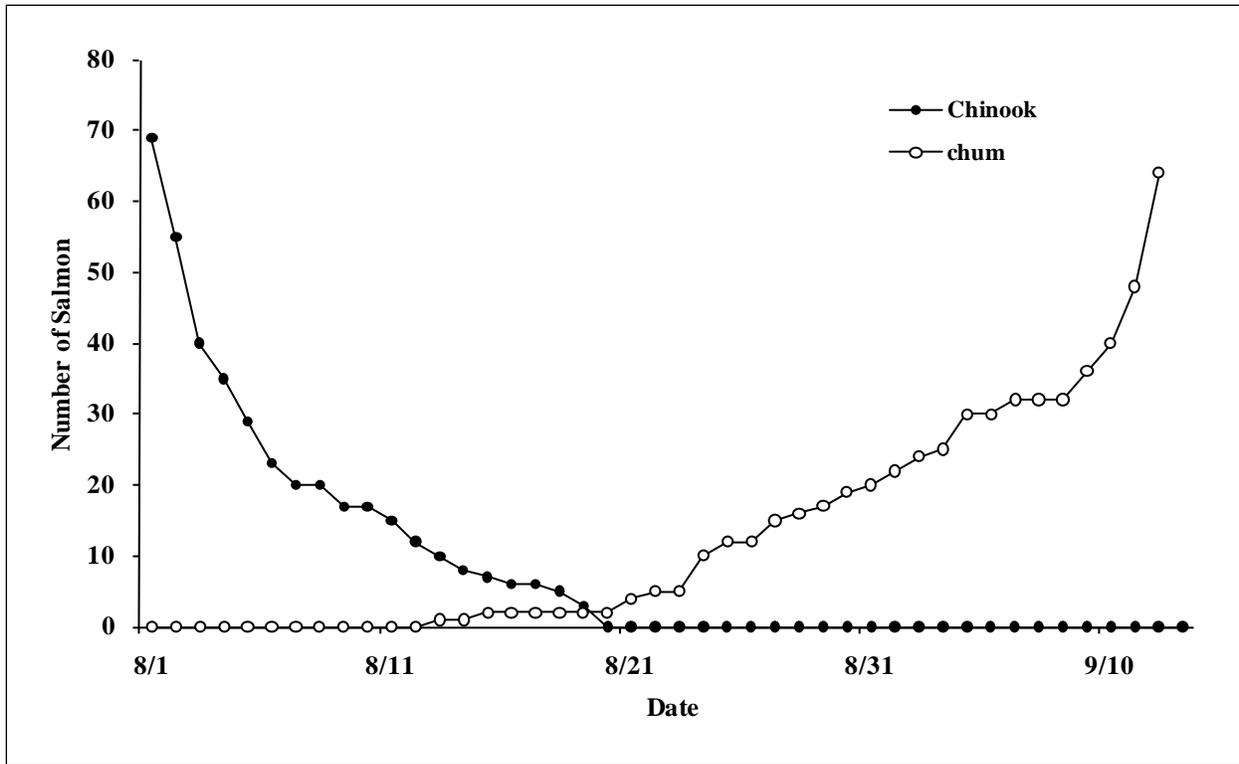


Figure 6.—Species changeover dates (August 19–20) determined from reverse cumulative Chinook and cumulative chum salmon catches at the Eagle sonar project site, 2010.

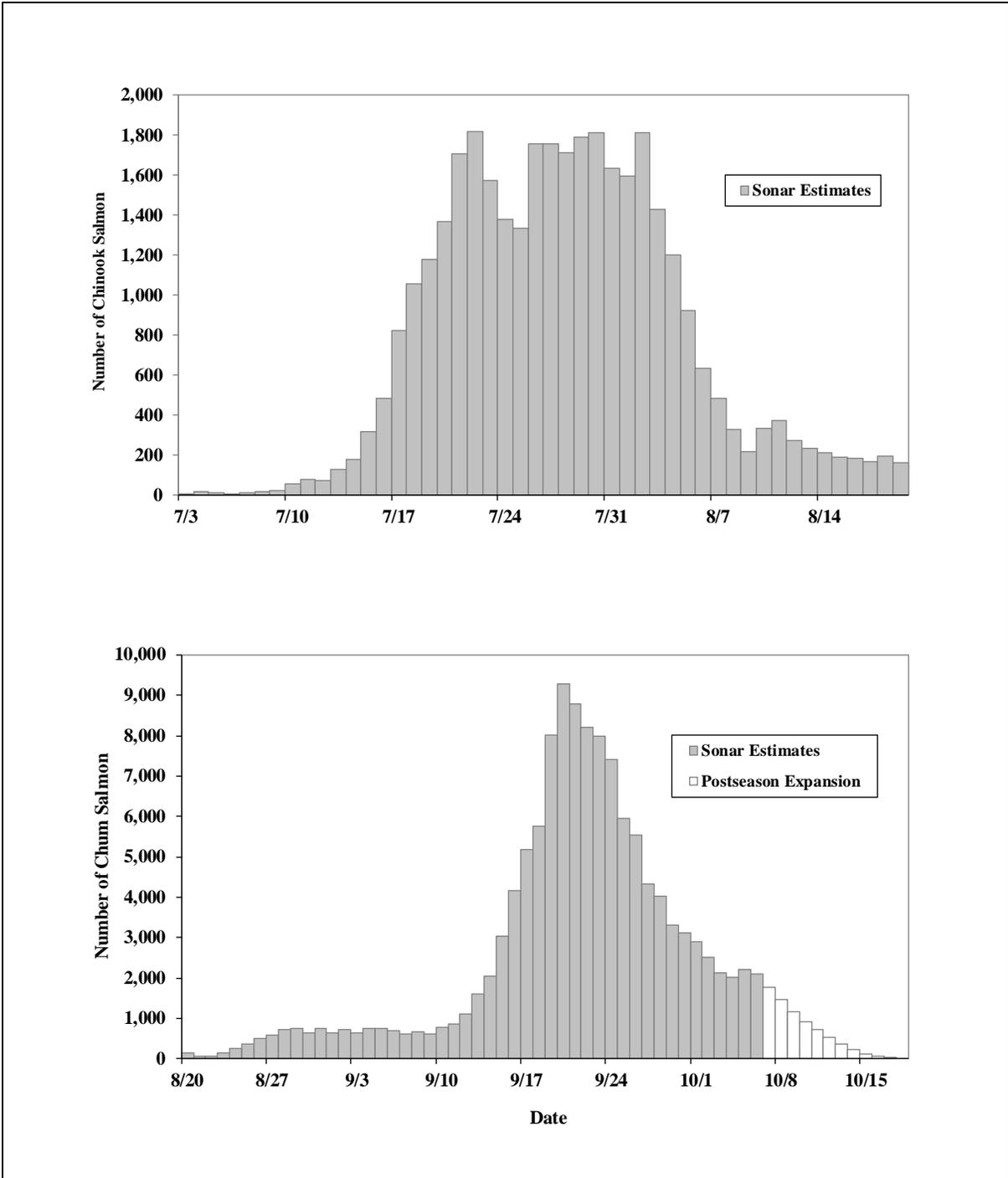


Figure 7.—Daily sonar estimates for Chinook salmon, July 3 through August 19, 2010 (top), and daily sonar estimates for chum salmon, August 20 through October 6, 2010 (bottom). Also, postseason chum salmon expansion estimates, October 7 through October 18 (bottom).

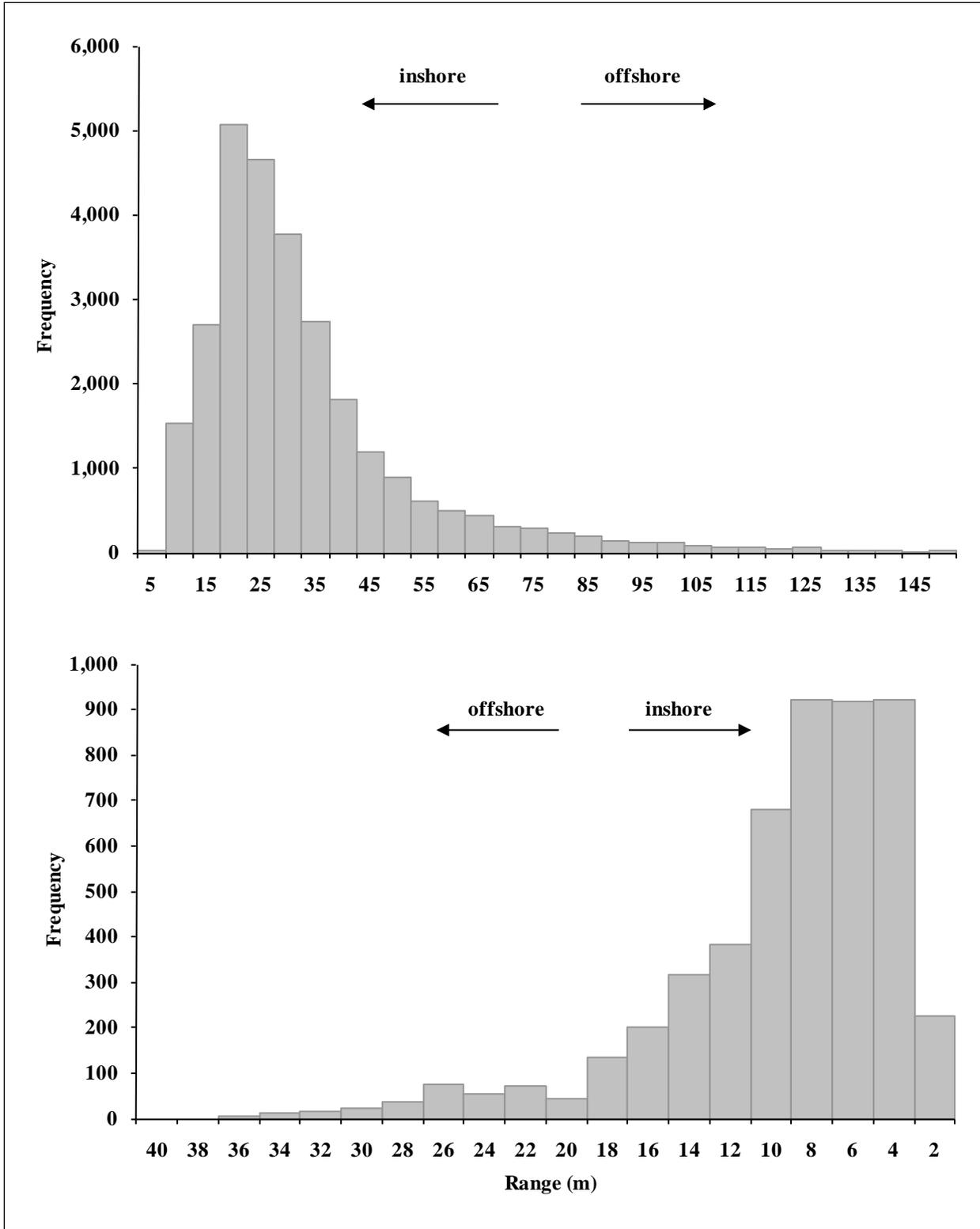


Figure 8.—Left bank (top) and right bank (bottom) horizontal distribution of upstream Chinook salmon passage in the Yukon River at Eagle sonar project site, July 3 through August 19, 2010.

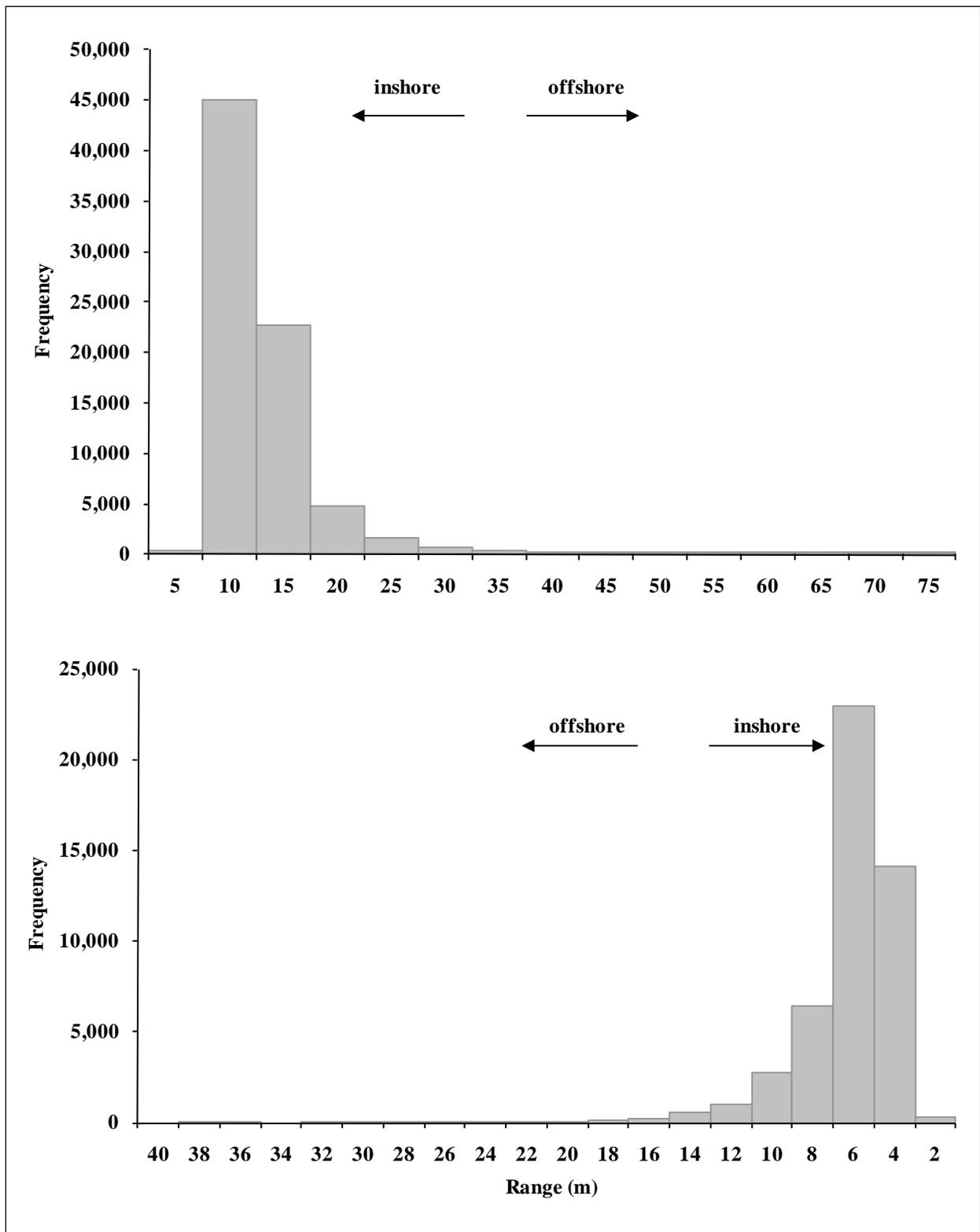


Figure 9.—Left bank (top) and right bank (bottom) horizontal distribution of upstream chum salmon passage in the Yukon River at Eagle sonar project site, August 20 through October 6, 2010.

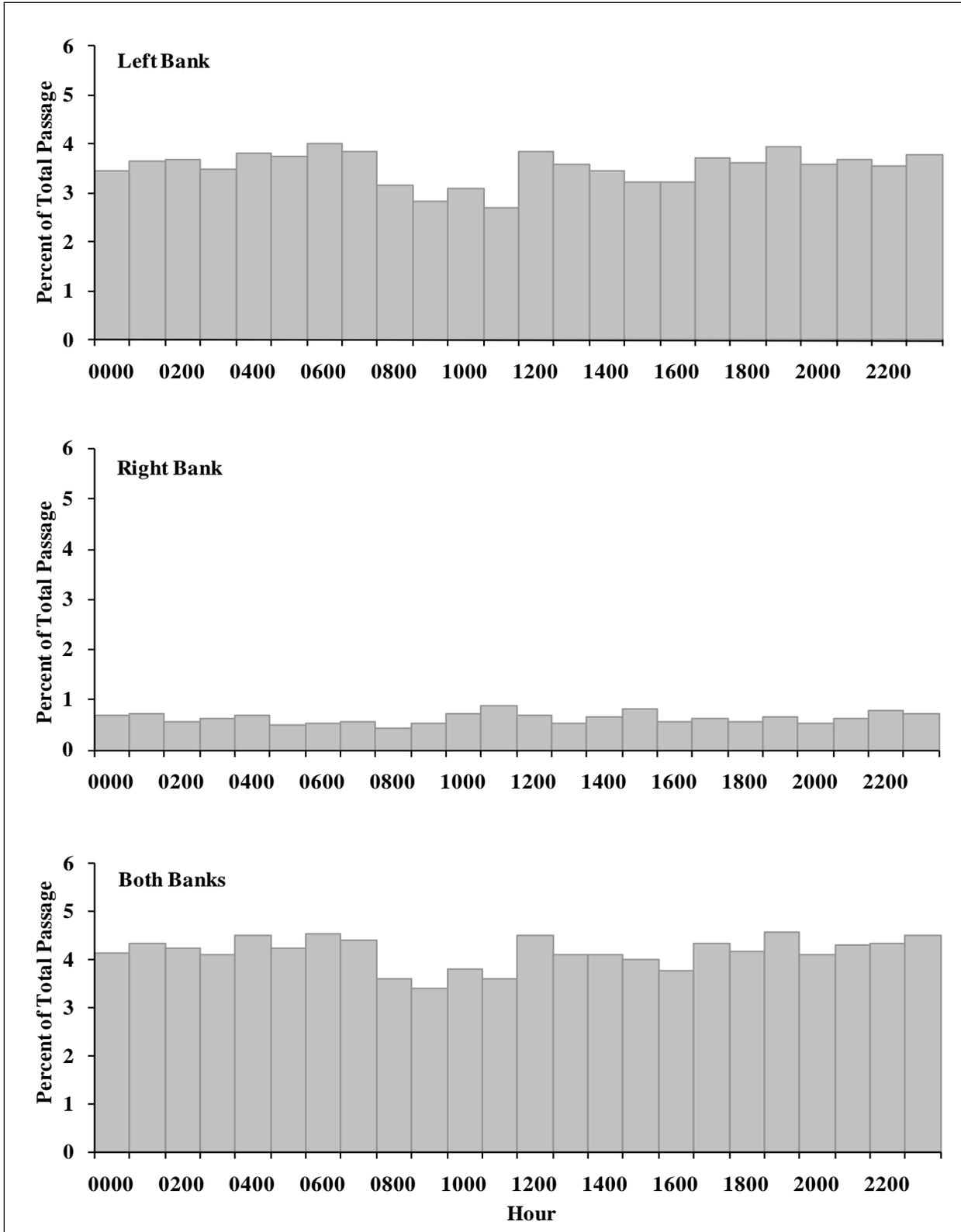


Figure 10.—Diel Chinook salmon migration pattern observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from July 3 through August 19, 2010.

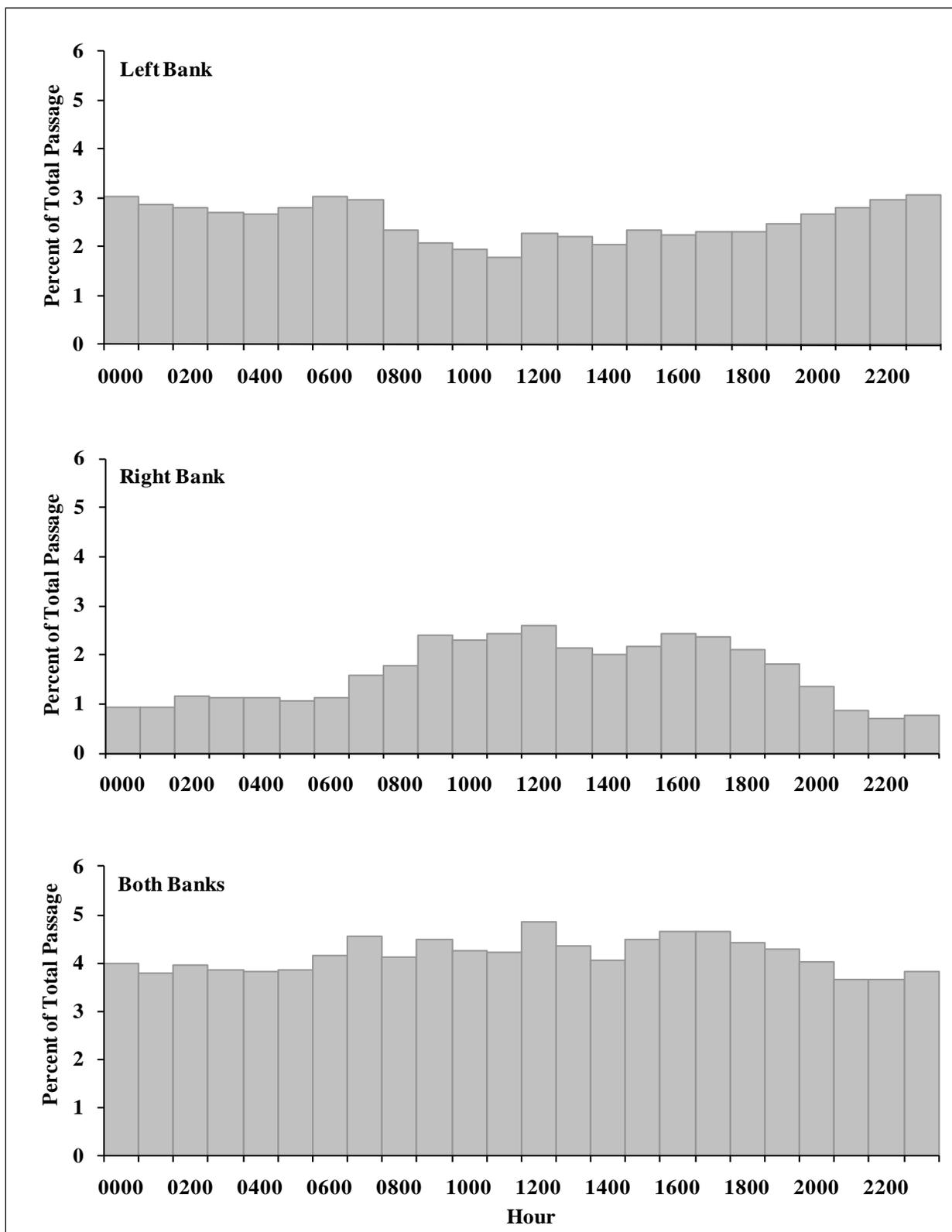
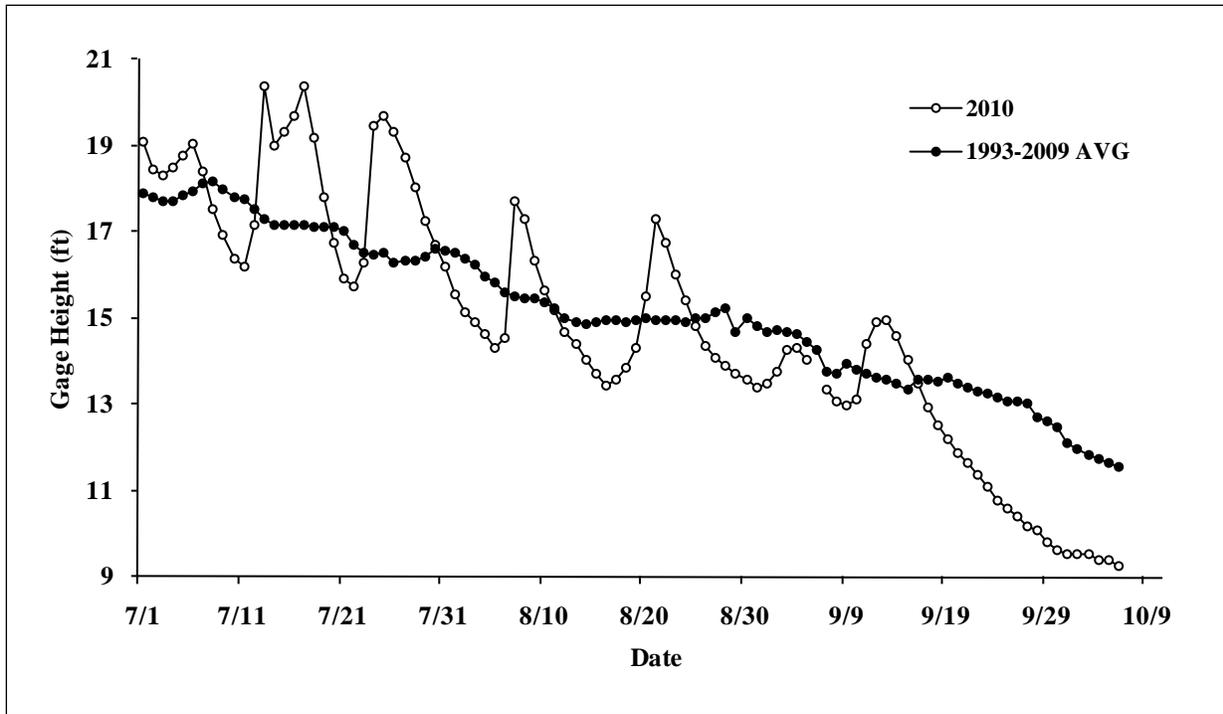


Figure 11.—Diel chum salmon migration pattern observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from August 20 through October 6, 2010.



Source: United States Geological Survey

Figure 12.—Daily water elevation measured at Eagle, July 1 through October 6, 2010, and average water level from 1993 through 2009.

APPENDIX A. CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.—Climate and hydrologic observations recorded daily at 1800 hours at the Eagle sonar project site, 2010.

Date	Precipitation	Wind		Sky	Temperature (C°)	
	(code) ^a	Direction	Speed (mph)	(code) ^b	Air	Water ^c
7/03	B	N	<5	B	23	16
7/04	B	E	<5	B	21	16
7/05	A	E	5	O	20	15
7/06	A	E	<5	B	23	15
7/07	A	N	<5	S	22	15
7/08	A	calm	calm	S	25	16
7/09	A	SE	5	S	31	17
7/10	A	E	<5	O	24	16
7/11	B	E	<5	O	15	16
7/12	A	calm	calm	S	22	16
7/13	A	N	<5	B	19	14
7/14	A	N	<5	S	20	14
7/15	A	N	<5	B	18	14
7/16	A	NW	<5	S	19	14
7/17	A	S	<5	B	19	13
7/18	A	S	6	B	18	15
7/19	A	calm	calm	B	20	15
7/20	A	SE	<5	O	22	16
7/21	B	NW	<5	O	19	15
7/22	A	NW	<5	O	18	15
7/23	C	calm	calm	O	18	15
7/24	B	calm	calm	B	21	13
7/25	A	calm	calm	B	21	13
7/26	A	SE	5	B	25	15
7/27	C	calm	calm	O	15	14
7/28	A	calm	calm	B	17	15
7/29	A	N	<5	C	19	15
7/30	A	N	<5	B	20	16
7/31	A	N	<5	C	23	17
8/01	A	N	<5	S	27	18
8/02	A	N	>5	S	28	18
8/03	A	S	>5	S	30	20
8/04	A	S	<5	S	34	21
8/05	B	S	<5	B	18	17
8/06	C	S	<5	O	14	10
8/07	ND	ND	ND	ND	ND	ND
8/08	A	calm	<5	S	20	15
8/09	A	SE	<5	B	19	14
8/10	A	SE	<5	B	22	15
8/11	A	S	<5	B	19	14
8/12	A	S	<5	B	21	15
8/13	A	calm	calm	B	20	16
8/14	A	S	<5	S	26	16
8/15	A	S	6	C	30	15
8/16	A	S	<5	S	27	15
8/17	A	N	9	B	15	15

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Date	Precipitation	Wind		Sky	Temperature (C°)	
	(code) ^a	Direction	Speed (mph)	(code) ^b	Air	Water ^c
8/18	B	N	<5	O	12	14
8/19	A	N	6	O	12	13
8/20	A	N	<5	S	17	12
8/21	A	N	5	S	18	12
8/22	A	N	<5	B	18	11
8/23	B	N	5	B	14	12
8/24	B	N	6	O	14	12
8/25	B	N	6	S	14	12
8/26	A	N	<5	S	17	13
8/27	B	N	<5	B	13	13
8/28	B	calm	calm	O	14	12
8/29	B	N	<5	B	12	13
8/30	A	calm	calm	S	17	12
8/31	A	calm	calm	B	14	12
9/01	A	calm	calm	B	14	12
9/02	A	N	6	S	16	12
9/03	A	S	<5	S	11	12
9/04	A	S	5	O	15	11
9/05	A	calm	calm	O	14	11
9/06	A	calm	calm	C	18	11
9/07	A	S	<5	O	15	10
9/08	B	calm	calm	O	13	10
9/09	A	N	8	O	14	10
9/10	A	S	<5	B	15	10
9/11	A	N	5	C	17	10
9/12	A	S	<5	C	17	10
9/13	A	S	calm	C	12	10
9/14	A	N	<5	C	16	10
9/15	A	N	6	C	17	10
9/16	A	N	calm	C	16	10
9/17	A	N	6	C	17	10
9/18	A	calm	calm	C	15	9
9/19	A	calm	calm	C	15	9
9/20	A	calm	calm	C	15	8
9/21	A	S	5+	O	10	8
9/22	A	S	5 gust to 20	S	4	8
9/23	A	S	5 gust to 20	C	4	5
9/24	A	S	5 gust to 20	C	2	4
9/25	A	S	<5	S	2	4
9/26	E	S	<5	O	0	4
9/27	A	N	9	B	0	4

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Appendix A1.–Page 3 of 3.

Date	Precipitation	Wind		Sky	Temperature (C°)	
	(code) ^a	Direction	Speed (mph)	(code) ^b	Air	Water ^c
9/28	A	calm	calm	B	-1	4
9/29	A	calm	calm	O	5	4
9/30	A	S	5	O	10	6
10/1	A	SE	10	O	14	6
10/2	A	S	<5	B	10	6
10/3	A	S	8	B	10	6
10/4	A	S	<5	C	9	4
10/5	A	calm	calm	B	1	3
10/6	A	SE	7	B	6	4
Average					16	12

^a Precipitation code for the preceding 24 h period: A = none; B = intermittent rain; C = continuous rain; D = snow and rain mixed; E = light snowfall; F = continuous snowfall; G = thunderstorm w/ or w/o precipitation.

^b Instantaneous cloud cover code: C = clear, cloud cover < 10% of sky; S = cloud cover < 60% of sky; B = cloud cover 60–90% of sky; O = overcast (100%); F = fog, thick haze or smoke.

^c Water temperature collected approximately 30 cm below surface with pocket thermometer.