Fishery Data Series No. 09-30

Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River near Eagle, Alaska, 2008

by

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and

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June 2009

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
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

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
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
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye to fork	MEF
mideye to tail fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
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	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
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.
minute (angular)	'
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
variance	
population	Var
sample	var

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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 6 to October 6, 2008. A total of 38,097 Chinook were estimated to have passed the sonar site between July 6 and August 16, and an estimated 171,347 chum salmon passed between August 17 and October 6. The sonar-estimated passage of chum salmon was subsequently expanded to a total passage estimate of 193,397 to include fish that may have passed after operations ceased. By subtracting the preliminary subsistence catch above, the sonar site results in an estimated border passage of 37,407 Chinook salmon, and 180,397 chum salmon. A drift gillnet test fishery was conducted to collect age, sex, length, and genetic information. Species composition was also recorded to determine when the Chinook run ended and the fall chum 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, DIDSON, Eagle, hydroacoustics, *Oncorhynchus*, salmon, Chinook, chum, split-beam sonar, Yukon River.

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 salmon 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. Management of the fisheries on this 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 and chum 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) currently provides estimates of mainstem salmon passage through the U.S./Canada border using mark–recapture techniques.

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 (Pfisterer 2002) and the Kenai River (Miller and Burwen 2002). Dual-Frequency Identification Sonar (DIDSON)[1] has been used in the Aniak River (McEwen 2005) and the Sheenjek River (Dunbar and Pfisterer 2009) 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 resulting in 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 from the early sonar studies near the U.S./Canada border 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, uneven bottom may have permitted fish to pass undetected by the sonar, and a linear profile would alleviate this problem and allow detection of fish at longer ranges.

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. Criteria for suitable sites 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 narrowing of potential project locations to an area between 9 and 19 km downriver from the town of Eagle. The 2003 study found that the two most promising sonar deployment locations meeting the above criteria were 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 2 types of sonar were tested at Calico Bluff and the Shade Creek area and it was found that Six Mile Bend (9.7 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 *Oncorhynchus tshawytscha* 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 provide an estimate of

[1] Product names used in this report are included for scientific completeness, but do not constitute a product endorsement.

fall chum salmon *Oncorhynchus keta* 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, 9.7 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 ft^3/s. Flows are highest in June, with greatest variability in flow occurring in May, after which flow slowly declines and varies only slightly. 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 was constructed on the left bank 1.3 km downriver from 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, a wireless router, and a solar powered battery system.

OBJECTIVES

The primary goals of this project in 2008 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 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 estimate 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 (α=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 estimate 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 (α=0.05 and d=0.10).
5. Collect Chinook and chum salmon tissue samples for genetic stock identification.
6. Collect daily climate and hydrological 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° x 10° 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 *Java* 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° x 14°. 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.

Right bank power was supplied by a 12-V solar power system consisting of a four 85-W solar panel array, ten 6-V batteries, a charge controller, and an inverter. The solar power system was backed up with a portable 2000-W generator and a power converter/charger when sunlight was insufficient. Left bank hydroacoustic equipment and computers were powered with a portable 2000-W generator that ran 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. The sites chosen in 2005 were also used for deployment in 2006, 2007 and 2008. To ensure the original sites had remained acceptable for ensonification in 2008, bottom profiles were obtained after initial transducer placement. Data was collected from a total of 4 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*.

The split-beam sonar was deployed July 5 on the left bank. The transducer and rotators were mounted on a 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 in water ranging from approximately 1.0 to 1.5 m in depth and was 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 system was calibrated in-situ using a 3.8-cm tungsten carbide sphere of nominal target strength -39.5 dB at 200 kHz. The sphere was attached to a pole with monofilament line and held in the acoustic beam to verify that the target was being detected by the split-beam system within acceptable limits. 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 µs 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 weir 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 weir sections constructed of 2-inch (5.08 cm) 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 then finished with vertical lengths of aluminum conduit 1.5 in (3.8 cm) apart. Weir 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 weir 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 weir require frequent relocation to shallower or deeper water.

The DIDSON unit was deployed July 5 on the right bank. The unit was mounted on an aluminum frame and was 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 (0–40 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 2 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 by the data acquisition software in 60 minute increments each hour of the day and saved as .raw files to an external hard drive for tracking and counting. The operator opened each .raw data file in the split-beam echogram viewer program and marked each upstream fish track by clicking a computer mouse (Figure 3). 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-minute samples each hour of the day. For the first 30 minutes of every hour, the DIDSON sampled the ensonified range from 1 to 20 m (zone 1) and the second half of each hour sampled from 20 to 40 m (zone 2). Upstream migrating fish were counted by marking each fish track on a DIDSON echogram (Figure 4). 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-minute sample was expanded for the full hour, and the estimated counts from zone 1 and zone 2 were summed for a total hour estimated count for that bank. The daily passage ŷ for zone *z* on day *d* was calculated by summing the hourly passage rates for each hour as follows:

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

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:

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

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:

$$\hat{V}ar(\hat{y}) = \sum_{d}\sum_{z} \hat{V}ar(\hat{y}_{dz}) \tag{3}$$

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. When 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 was divided by the number of minutes counted and then multiplied by the number of fish counted in that period. Passage for the incomplete sample was estimated as follows:

$$P = (h_s / h_c)x \tag{4}$$

Where h_s is the number of minutes in a complete sample and h_c is the number of minutes in a sample that were actually counted, and x is the number of fish counted.

If data from one or more complete samples were missing, counts were interpolated by averaging counts from the sample immediately before and after the missing sample(s) as follows:

$$P_i = \frac{x_a + x_p}{2} \tag{5}$$

Where i is the ith missing value, x_a is the count of the sample after the missing sample(s), and x_p is the count of the sample prior to the missing sample(s).

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. High chum salmon counts at the end of the season prompted an expansion of the sonar estimate to include chum salmon that may have passed after operations ceased. The expansion used historic run timing information from the DFO mark–recapture project near the border, and a linear relationship calculated to October 18 (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). 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 the *R* statistical software package (R Development Core Team 2007) 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 was examined inseason and postseason using information from the sonar estimate, fish range distribution, test fishery catches, local subsistence harvest, and DFO mark–recapture fish wheels.

TEST FISHING AND SAMPLING

To monitor species composition and collect age, sex, length, and genetic samples, gillnets of mesh sizes 7.5 in (191 mm) and 5.25 in (133 mm) were drifted through 3 zones; left bank inshore (LBI), left bank nearshore (LBN) and left bank offshore (LBO) (Figure 5). Nets were 25 fathoms (45.7 m) long, approximately 25 ft (7.6 m) deep, constructed of Momoi MTC or MT, shade 11, double knot multifilament nylon twine and hung “even” at a 2:1 ratio of web to corkline. 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 (2.4 m) deep were used for the inshore drifts only, with all other specifications remaining the same as the original nets.

Test fishing for species composition was conducted once daily between 0800 and 1200 hours (Period 1) 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 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, 3) LBO, with a minimum of 20 minutes 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 samples, an additional fishing period was conducted between July 11 and August 15 after the normal test fishing period, from approximately 1300 to 1700 hours (Period 2). Chinook salmon genetic and ASL samples were collected to estimate specific Canadian stock proportions and ASL composition of Chinook entering Canada. Three different mesh sizes (6.5 in, 7.5 in and 8.5 in) were fished daily over the course of the Chinook salmon run to effectively capture all size classes present (Table 2). Nets were 25 fathoms (45.7 m) long, approximately 25 ft (7.6 m) deep and hung "even" at a 2:1 ratio of web to corkline. Each net was drifted for approximately 6 minutes twice daily within the left bank nearshore and offshore zones and once on the right bank (RB) approximately 5 km downriver from the sonar site where river conditions were suitable for drift gillnetting on that bank, for a total of 9 drifts (Figure 6).

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:

$$t = SI - FO + \frac{FO - SO}{2} + \frac{FI - SI}{2} \tag{6}$$

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

$$e_{dzfmj} = \frac{25\, t_{dzfmj}}{60} \tag{7}$$

Captured salmon were sampled in the following ways:

- For standard ASL samples, length (METF to nearest 5 mm), and sex (determined by inspection of external characteristics) were recorded. Three scales from Chinook salmon and one scale from chum salmon were removed from the preferred area on the left side of the fish, 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 the ADF&G ASL lab in Anchorage, Alaska. These scale data are 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, stored in a vial of ethanol, and sent to Fisheries and Oceans Canada genetics laboratory in Nanaimo, BC. 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 and any 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. Test 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 catches. Chinook catch was summed in reverse from the date when the last Chinook was caught by calculating the total Chinook catch to date subtracted from the Chinook catch for the entire season. The date at which the chum catch surpassed the succeeding Chinook catch became the species changeover date.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Climate and hydrologic data were collected daily at approximately 1800 hours at the sonar site. Air temperatures were measured, while subjective notes on wind speed and direction, cloud cover and precipitation were also recorded. Water temperatures were recorded every 4 hours with a HOBO U22 water temperature data logger suspended approximately 30 cm below the surface from a float tied to a stake about 10 m from the left bank shore. Data were transferred to a computer postseason to produce an average daily water temperature. Reported stream levels are taken from the U.S. Geological Survey’s gauging station at Eagle, although water levels at the sonar site were carefully monitored, because changes usually necessitated moving the transducer(s) and fish lead(s) to deeper or shallower water, particularly on the left bank.

RESULTS

SONAR DEPLOYMENT

On July 6 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). Figure 7 shows zones of ensonification and bottom profile of the Yukon River at the sonar site. The left bank profile is approximately linear, extending 300 m to the thalweg at a -1.8° slope. The right bank profile is less linear, shorter and steeper, extending 100 m to the thalweg at a -5.5° slope. The substrate at Six Mile Bend is large cobble to small boulder on the right bank, and small to medium sized cobble and silt on the left bank.

In 2008 there were several high water events that included large amounts of woody debris. These events sometimes necessitated removal of the weir and, on occasion, the sonar equipment from the river in order to prevent damage or loss. Sonar operations were stopped temporarily on

August 27 at 2400 because of high water and floating debris. On August 31 the left bank sonar was restarted at 0900 and the right bank sonar was restarted at 1000.

CHINOOK AND CHUM SALMON PASSAGE ESTIMATION

Inseason, August 17 was tentatively deemed the last day of the Chinook salmon run based on relatively low sonar counts, gillnet catches, harvest information gathered from local subsistence fishers, and DFO mark–recapture fish wheel data. 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 test fishery information. Analysis of reverse-cumulative Chinook catches and cumulative chum catches showed that August 16 was the last date when the overall Chinook catch was more than the overall chum catch. Figure 8 shows reverse-cumulative Chinook catch and cumulative chum catch plotted by day from just prior to the date of the first chum capture. The 2 lines cross at the point when the number of chum caught equals the number of Chinook caught subsequent to that point.

The total passage estimate at the Eagle sonar site for Chinook salmon was 38,097 for the dates July 6 through August 16, 2008 (Table 3). A peak daily passage estimate of 1,956 Chinook salmon occurred on July 30 and 298 fish passed on August 16, the last day of estimating Chinook salmon passage. 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 37,407 (Table 4). The preliminary subsistence harvest from the Eagle area upstream of the sonar was 690 (William Busher, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication).

The total fall chum salmon passage estimate was 171,347 for the dates August 17 through October 6, 2008 (Table 5). Fall chum salmon passage peaked on September 11 with a daily estimate of 6,551 fish. Although chum salmon passage was decreasing, 4,002 fish passed on October 6, the last day of operation. Because of the high passage when the project was terminated, the sonar estimate was subsequently adjusted to 193,397 chum salmon. The expansion was calculated using historic run timing data from the DFO mark–recapture project near the Canadian border, and a linear relationship to the date October 18 (Bonnie Borba, 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 180,397 (Table 4). The preliminary subsistence harvest from the Eagle area was 13,000 (William Busher, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication).

SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore oriented on both banks (Figures 9 and 10). On the left bank during the Chinook salmon run, 93% of the fish were detected within 75 m of the transducer, and 99% within 120 m. On the right bank, 89% of the fish were detected within 26 m of the transducer and 98% within 36 m. During the fall chum salmon run on the left bank, 93% of the fish were detected within 15 m of the transducer, and 98% within 25 m. On the right bank, 95% of the fish were detected within 6 m of the transducer and 98% within 8 m. The percentage of fish passage estimated by bank for the Chinook salmon season was 78% on the left bank and 22% on the right bank. During the fall chum salmon run, 64% migrated on the left bank and 36% on the right bank.

Fewer fish passed along the left bank during daylight hours compared to periods of darkness (Figure 11 and 12). Conversely, more fish passed along the right bank during daylight hours compared to periods of darkness. Overall, when both banks are combined there was a small diel fluctuation at the project site during the Chinook run and almost none during the chum salmon run.

TEST FISHING AND SAMPLING

A total of 458 Chinook and 610 chum salmon were captured in test fish drift gillnets during the period July 11–October 4 (Table 6). Period 1 fishing occurred from July 26 through October 4, and Period 2 fishing occurred from July 11 through August 15. Test drifts during Period 1 caught 116 Chinook and 610 chum salmon, and an additional 342 Chinook were caught during Period 2. Additionally, 5 sheefish *Stenodus leucichthys*, 4 whitefish *Coregoninae* (not keyed to species) and 1 burbot *Lota lota* were captured during Period 1. The number of Chinook and chum salmon captured in drift gillnets by period, zone and mesh size are contained in Tables 7 and 8.

Chinook salmon samples collected from driftnets were composed of 290 (63.3%) males and 168 (36.7%) females. Chum salmon samples from driftnets were composed of 400 (65.6%) males and 210 (34.4%) females. Readable scale samples from 374 Chinook and 508 chum salmon collected in the drift nets were used to determine age compositions (Horne-Brine, Fisheries Biologist, ADF&G, Anchorage, Alaska; personal communication). From these samples it was determined that Chinook salmon age-1.3 fish predominated (56.7%) followed by age-1.4 (36.4%), age-1.5, age-1.2, and age 2.4 were 3.2%, 2.4% and 1.3% respectively. No other age class of Chinook was present in the catch. From the chum salmon samples it was determined that age-0.3 fish predominated (56.7%) followed by age-0.4 (40.2%), age-0.2 and age-0.5 were 2.0% and 1.2% respectively. No age-0.6 chum salmon were present in the catch. Genetic samples from 458 Chinook salmon and 350 chum salmon were collected and sent to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, BC.

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 average of 19°C and a minimum of 3°C. The water level decreased over the duration of the season, with several significant increases following substantial rain events (Figure 13). Overall, between July 1 and October 10 the water level decreased 2.4 ft from 18.2 ft to 15.8 ft. The lowest water level recorded during the season was 14.2 ft on October 4. The 2 highest peaks occurred on July 22 (21.9ft) and August 30 (23.4 ft).

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 the water level was extremely high and large amounts of debris were floating downriver were the sonar operations interrupted. The DIDSON, with its wide beam angle (29°), was the ideal system 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 marking 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 feature 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 sonar estimate of 38,097 Chinook is almost double the preliminary Canadian mark–recapture border passage estimate of 14,666 (Patrick Milligan, Stock Assessment Biologist, DFO, Whitehorse, Yukon, Canada, personal communication). When the 690 Chinook salmon harvested in the Eagle subsistence fishery in 2008 are removed from the sonar estimate, then the Canadian border passage estimate is 39% of the sonar border passage estimate. The Canadian border passage estimate was 51% of the sonar derived border passage estimate in 2005, 53% in 2006, and 56% of the sonar derived border passage estimate in 2007 (Table 4). Because the Eagle area subsistence harvest information did not exclude those fish caught below the sonar site prior to 2008 out of the data set, the exact number of salmon harvested above and below the sonar location is not known for 2005 through 2007. In 2008, Eagle subsistence harvest numbers were recorded as being above or below the sonar site, giving a better estimate of border passage.

The sonar estimate for fall chum salmon was 171,347, which is 30% greater than the preliminary Canadian mark–recapture border passage estimate of 132,048 (Patrick Milligan, Stock Assessment Biologist, DFO, Whitehorse, Yukon, Canada, personal communication). The preliminary subsistence harvest from the Eagle area was 13,000 (William Busher, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). When the Eagle area subsistence harvest was removed from the original sonar estimate (Canadian estimate was not expanded), the sonar estimated border passage was 20% more than the Canadian border passage estimate. Postseason, the sonar estimate of chum salmon was expanded to 193,397 to account for chum salmon that may have passed after sonar operations ceased (Table 4) (Bonnie Borba, Fisheries Biologist, ADF&G, Fairbanks, Alaska; personal communication). In 2007 the Canadian border passage estimate was 8% lower than the sonar border passage estimate and in 2006 it was 1% lower. Continuing to operate both the DFO and ADF&G projects simultaneously for a few years will allow managers to examine the relationship between the 2 estimation methods, determine why the Chinook estimates for the 2 projects are so different, and whether the border passage goals should be revised.

SPATIAL AND TEMPORAL DISTRIBUTIONS

Based on test 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 18 to allow faster ping rates and improved detection near shore. This season, when each bank was looked at separately, there was a pronounced diel pattern of migration during both the Chinook and chum salmon runs. Upstream migration was greatest in periods of darkness or suppressed light on the left bank and greatest during daylight hours on the right bank. Overall, when both banks are looked at together there was a small diel fluctuation during the Chinook salmon run and almost no diel fluctuation during the chum salmon run.

TEST FISHING AND SPECIES DETERMINATION

Test fishing was conducted with drift gillnets to capture a representative sample of fish migrating past the sonar site. This method seemed to be a reliable way of determining the species changeover date. The overall test fish catch composition (Period 1 only) was 16% Chinook and 84% chum salmon. This compares with the total sonar passage estimate, which was composed of 18% Chinook and 82% chum salmon. The similarity between test fish catch and sonar estimate species compositions supports the assumption that test fishing with gillnets eliminated bias between species. 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.–Period 1 (0800–1200 hrs) test fishing schedule and drift gillnet mesh sizes (inches), 2008.

Zone	Day 1	Day 2
Left Bank	5.25	7.50
Inshore	7.50	5.25
Left Bank	5.25	7.50
Nearshore	7.50	5.25
Left Bank	5.25	7.50
Offshore	7.50	5.25

Table 2.–Period 2 (1300–1700 hrs) test fishing schedule and drift gillnet mesh sizes (inches), 2008.

Zone	Day 1	Day 2	Day 3
Left Bank	6.50	7.50	8.50
Nearshore	7.50	8.50	6.50
	8.50	6.50	7.50
Right Bank	6.50	7.50	8.50
	7.50	8.50	6.50
	8.50	6.50	7.50
Left Bank	6.50	7.50	8.50
Offshore	7.50	8.50	6.50
	8.50	6.50	7.50

Table 3.–Estimated daily and cumulative Chinook salmon passage by bank, Eagle Sonar, 2008.

	Daily			Cumulative			
Date	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	% of Total Passage
7/06 [a]		71	71	0	71	71	0.00
7/07 [b]	16	192	208	16	263	279	0.01
7/08	66	241	307	82	504	586	0.02
7/09	149	144	293	231	648	879	0.02
7/10	220	106	326	451	754	1,205	0.03
7/11	288	152	440	739	906	1,645	0.04
7/12	334	118	452	1,073	1,024	2,097	0.06
7/13	220	137	357	1,293	1,161	2,454	0.06
7/14	50	265	315	1,343	1,426	2,769	0.07
7/15	348	382	730	1,691	1,808	3,499	0.09
7/16	689	302	991	2,380	2,110	4,490	0.12
7/17	660	317	977	3,040	2,427	5,467	0.14
7/18	989	352	1,341	4,029	2,779	6,808	0.18
7/19	806	102	908	4,835	2,881	7,716	0.20
7/20	1,199	87	1,286	6,034	2,968	9,002	0.24
7/21	979	30	1,009	7,013	2,998	10,011	0.26 [c]
7/22	1,048	59	1,107	8,061	3,057	11,118	0.29
7/23	1,028	40	1,068	9,089	3,097	12,186	0.32
7/24	1,128	92	1,220	10,217	3,189	13,406	0.35
7/25	1,292	78	1,370	11,509	3,267	14,776	0.39
7/26	1,089	111	1,200	12,598	3,378	15,976	0.42
7/27	1,189	228	1,417	13,787	3,606	17,393	0.46
7/28	1,149	462	1,611	14,936	4,068	19,004	0.50 [d]
7/29	1,141	478	1,619	16,077	4,546	20,623	0.54
7/30	1,116	840	1,956	17,193	5,386	22,579	0.59
7/31	1,470	382	1,852	18,663	5,768	24,431	0.64
8/01	1,356	287	1,643	20,019	6,055	26,074	0.68
8/02	1,197	366	1,563	21,216	6,421	27,637	0.73
8/03	1,034	336	1,370	22,250	6,757	29,007	0.76
8/04	1,036	192	1,228	23,286	6,949	30,235	0.79
8/05	1,004	172	1,176	24,290	7,121	31,411	0.82
8/06	791	164	955	25,081	7,285	32,366	0.85
8/07	796	104	900	25,877	7,389	33,266	0.87
8/08	751	120	871	26,628	7,509	34,137	0.90
8/09	603	128	731	27,231	7,637	34,868	0.92
8/10	441	86	527	27,672	7,723	35,395	0.93
8/11	399	200	599	28,071	7,923	35,994	0.94
8/12	384	141	525	28,455	8,064	36,519	0.96
8/13	350	126	476	28,805	8,190	36,995	0.97
8/14	337	85	422	29,142	8,275	37,417	0.98
8/15	280	102	382	29,422	8,377	37,799	0.99
8/16	232	66	298	29,654	8,443	38,097	1.00
Total	29,654	8,443	38,097	29,654	8,443	38,097	
SE [e]		116			116	116	

[a] Right bank sonar operational.
[b] Left bank sonar operational.
[c] Boxed area identifies central half of the run.
[d] Bold box identifies median day of passage.
[e] There is no sampling error associated with left bank since data was collected 24 hrs per day over the sampling range.

Table 4.–Eagle sonar estimate, Eagle area subsistence harvest, and U.S. and Canadian border passage estimates, 2005–2008.

	Sonar Estimate		Eagle Area Subsistence Harvest[a]		U.S. Sonar Mainstem Border Passage Estimate		Canadian Mainstem Border Passage Estimate[b]	
Date	Chinook	chum	Chinook	chum	Chinook	chum	Chinook	chum
2005	81,528	NA	2,566	NA	78,962	NA	42,245	451,477
2006	73,691	236,386	2,303	17,775	71,388	218,611	36,748	217,810
2007	41,697	282,670 [c]	1,999	18,691	39,698	263,979	22,120	235,956
2008	38,097	193,397 [c]	690	13,000	37,407	180,397	14,666	132,048

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, subsistence estimates are preliminary.

[b] Canadian mainstem border passage estimates are from JTC 2008, except 2008 estimate from (Patrick Milligan, Stock Assessment Biologist, DFO, Whitehorse, Yukon, Canada, personal communication).

[c] 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, 2008.

	Daily			Cumulative			
Date	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	% of Total Passage
8/17	255	76	331	255	76	331	0.00
8/18	252	72	324	507	148	655	0.00
8/19	196	67	263	703	215	918	0.01
8/20	193	84	277	896	299	1,195	0.01
8/21	179	60	239	1,075	359	1,434	0.01
8/22	211	56	267	1,286	415	1,701	0.01
8/23	197	30	227	1,483	445	1,928	0.01
8/24	215	38	253	1,698	483	2,181	0.01
8/25	249	30	279	1,947	513	2,460	0.01
8/26	228	22	250	2,175	535	2,710	0.02
8/27	146	24	170	2,321	559	2,880	0.02
8/28	206	19	225	2,527	578	3,105	0.02
8/29	266	14	280	2,793	591	3,384	0.02
8/30	326	8	334	3,119	600	3,719	0.02
8/31	386	3	389	3,505	603	4,108	0.02
9/01	401	9	410	3,906	612	4,518	0.03
9/02	624	28	652	4,530	640	5,170	0.03
9/03	774	62	836	5,304	702	6,006	0.04
9/04	1,146	150	1,296	6,450	852	7,302	0.04
9/05	1,781	208	1,989	8,231	1,060	9,291	0.05
9/06	2,359	588	2,947	10,590	1,648	12,238	0.07
9/07	3,177	1,148	4,325	13,767	2,796	16,563	0.10
9/08	3,737	1,781	5,518	17,504	4,577	22,081	0.13
9/09	3,772	1,826	5,598	21,276	6,403	27,679	0.16
9/10	3,979	2,120	6,099	25,255	8,523	33,778	0.20
9/11	4,179	2,372	6,551	29,434	10,895	40,329	0.24
9/12	4,132	1,978	6,110	33,566	12,873	46,439	0.27 [a]
9/13	3,574	2,626	6,200	37,140	15,499	52,639	0.31
9/14	3,681	1,668	5,349	40,821	17,167	57,988	0.34
9/15	2,776	1,656	4,432	43,597	18,823	62,420	0.36
9/16	2,253	2,012	4,265	45,850	20,835	66,685	0.39
9/17	2,528	1,583	4,111	48,378	22,418	70,796	0.41
9/18	2,786	1,488	4,274	51,164	23,906	75,070	0.44
9/19	3,418	1,590	5,008	54,582	25,496	80,078	0.47
9/20	3,523	2,000	5,523	58,105	27,496	85,601	0.50 [b]
9/21	3,209	2,496	5,705	61,314	29,992	91,306	0.53
9/22	3,557	1,976	5,533	64,871	31,968	96,839	0.57
9/23	2,851	2,912	5,763	67,722	34,880	102,602	0.60
9/24	3,157	2,744	5,901	70,879	37,624	108,503	0.63
9/25	3,885	1,868	5,753	74,764	39,492	114,256	0.67
9/26	3,196	1,602	4,798	77,960	41,094	119,054	0.69
9/27	3,009	1,902	4,911	80,969	42,996	123,965	0.72
9/28	2,830	2,370	5,200	83,799	45,366	129,165	0.75

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Table 5.–Page 2 of 2.

	Daily			Cumulative			
Date	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	% of Total Passage
9/29	2,779	2,483	5,262	86,578	47,849	134,427	0.78
9/30	3,209	2,330	5,539	89,787	50,179	139,966	0.82
10/01	3,457	2,268	5,725	93,244	52,447	145,691	0.85
10/02	4,249	1,360	5,609	97,493	53,807	151,300	0.88
10/03	2,924	2,674	5,598	100,417	56,481	156,898	0.92
10/04	3,504	2,000	5,504	103,921	58,481	162,402	0.95
10/05	3,393	1,550	4,943	107,314	60,031	167,345	0.98
10/06	1,910	2,092	4,002	109,224	62,123	171,347	1.00
Total	109,224	62,123	171,347	109,224	62,123	171,347	
SE [c]		510			510	510	

[a] Boxed area identifies central half of the run.

[b] Bold box identifies median day of passage.

[c] There is no sampling error associated with left bank since data was collected 24 hrs per day over the sampling range.

Table 6.–Fish caught with gillnets at the Eagle sonar project site, 2008.

Species	Period 1	Period 2	Total
Chinook	116	342	458
chum	610	0	610
sheefish	5	0	5
whitefish	4	0	4
burbot	1	0	1
Total	736	342	1,078

Table 7.–Period 1, effort, salmon catch, and percentage of Chinook and chum catch, by zone and mesh size, Eagle sonar project site, 2008.

	Mesh Size	Effort	Catch (Period 1)		Percent of	
Zone	(inches)	(fathom hours)	Chinook	Chum	Chinook Catch	Chum Catch
LBI	5.25	354.22	9	387	7.8	63.4
	7.50	350.50	6	159	5.2	26.1
Total		704.72	15	546	12.9	89.5
LBN	5.25	376.13	43	41	37.1	6.7
	7.50	371.13	40	15	34.5	2.5
Total		747.25	83	56	71.6	9.2
LBO	5.25	370.95	13	6	11.2	1.0
	7.50	362.81	5	2	4.3	0.3
Total		733.76	18	8	15.5	1.3
Grand Total		2185.73	116	610	100	100

Table 8.–Period 2, effort, salmon catch, and percentage of Chinook and chum catch, by zone and mesh size, Eagle sonar project site, 2008.

	Mesh Size	Effort	Catch (Period 2)		Percent of	
Zone	(inches)	(fathom hours)	Chinook	Chum	Chinook Catch	Chum Catch
RB	6.50	137.33	78	0	22.8	0.0
	7.50	137.12	85	0	24.9	0.0
	8.50	139.02	50	0	14.6	0.0
Total		413.47	213	0	62.3	0.0
LBN	6.50	135.02	28	0	8.2	0.0
	7.50	136.83	48	0	14.0	0.0
	8.50	134.77	18	0	5.3	0.0
Total		406.62	94	0	27.5	0.0
LBO	6.50	135.30	7	0	2.0	0.0
	7.50	134.97	16	0	4.7	0.0
	8.50	135.59	12	0	3.5	0.0
Total		405.86	35	0	10.2	0.0
Grand Total		1225.95	342	0	100	0.0

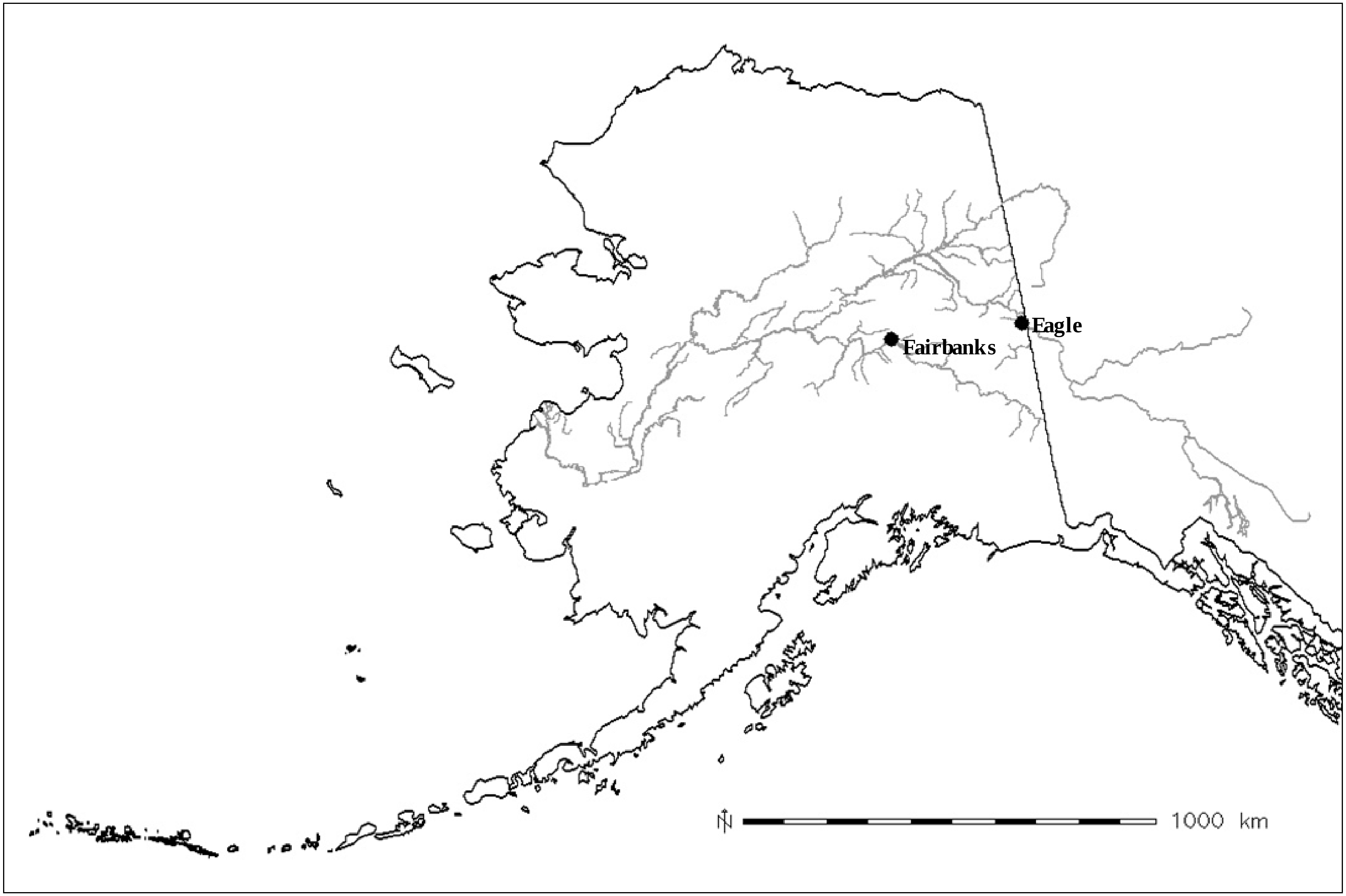


Figure 1.–Yukon River drainage.

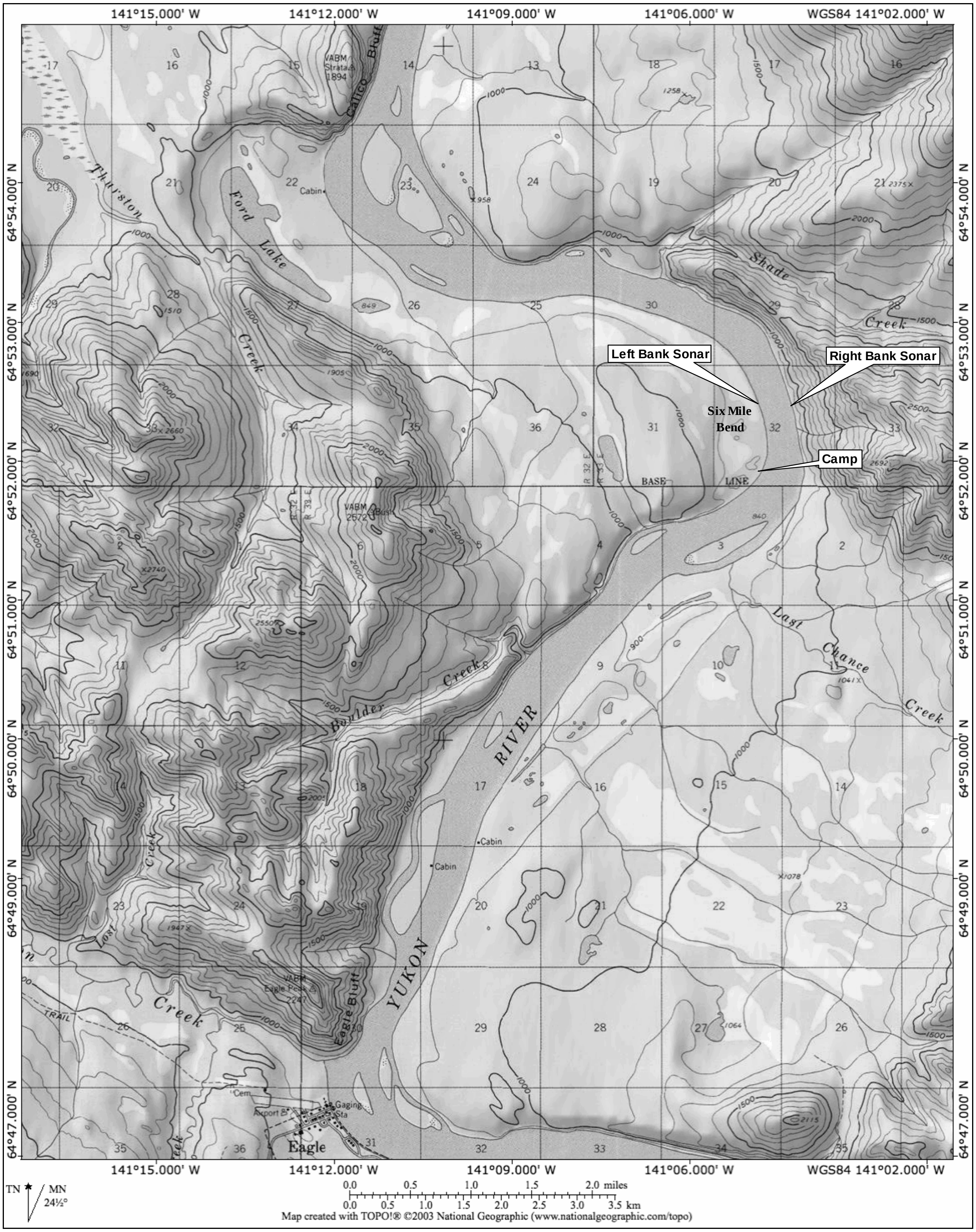


Figure 2.–Eagle sonar project site at Six Mile Bend.

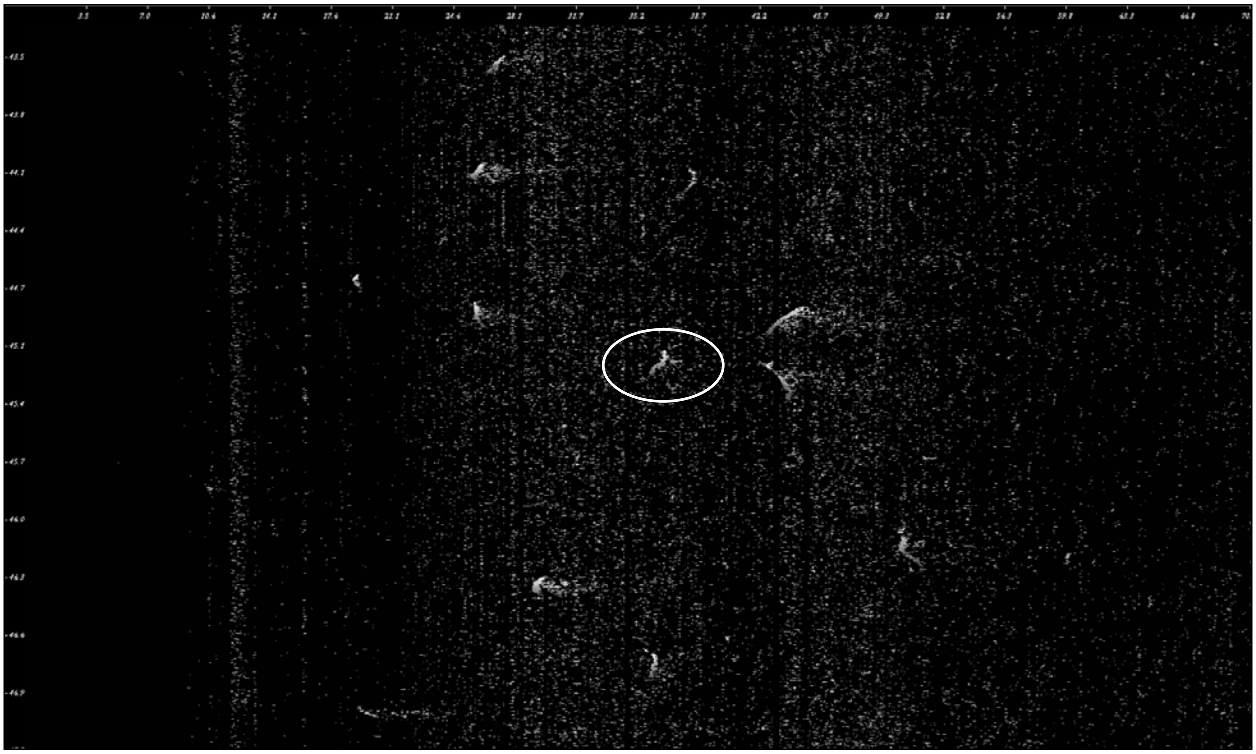


Figure 3.–Screenshot of echogram used to count fish from split-beam sonar data files. Ellipse encompasses typical upstream migrating salmon.

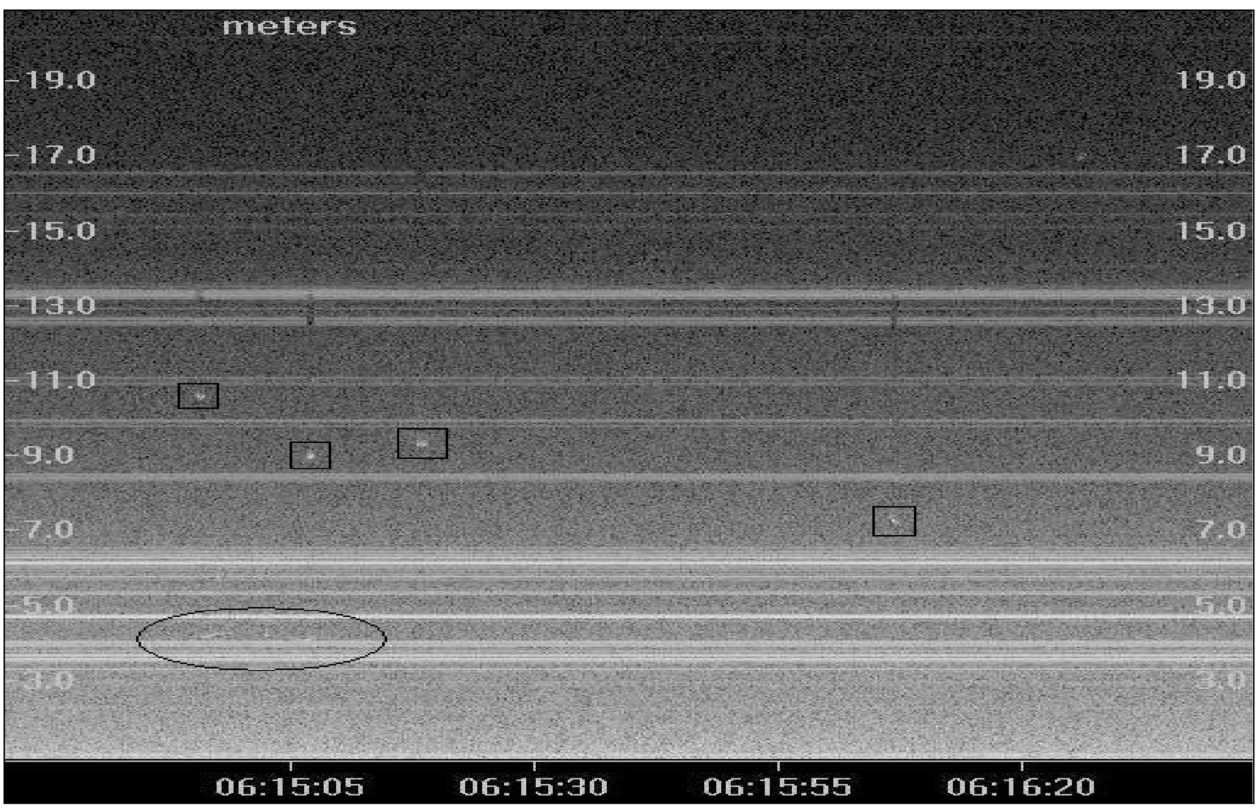


Figure 4.–Screenshot of echogram used to count fish from DIDSON data files. Rectangles encompass typical migrating salmon traces and ellipse encompasses small, slow non-salmon.

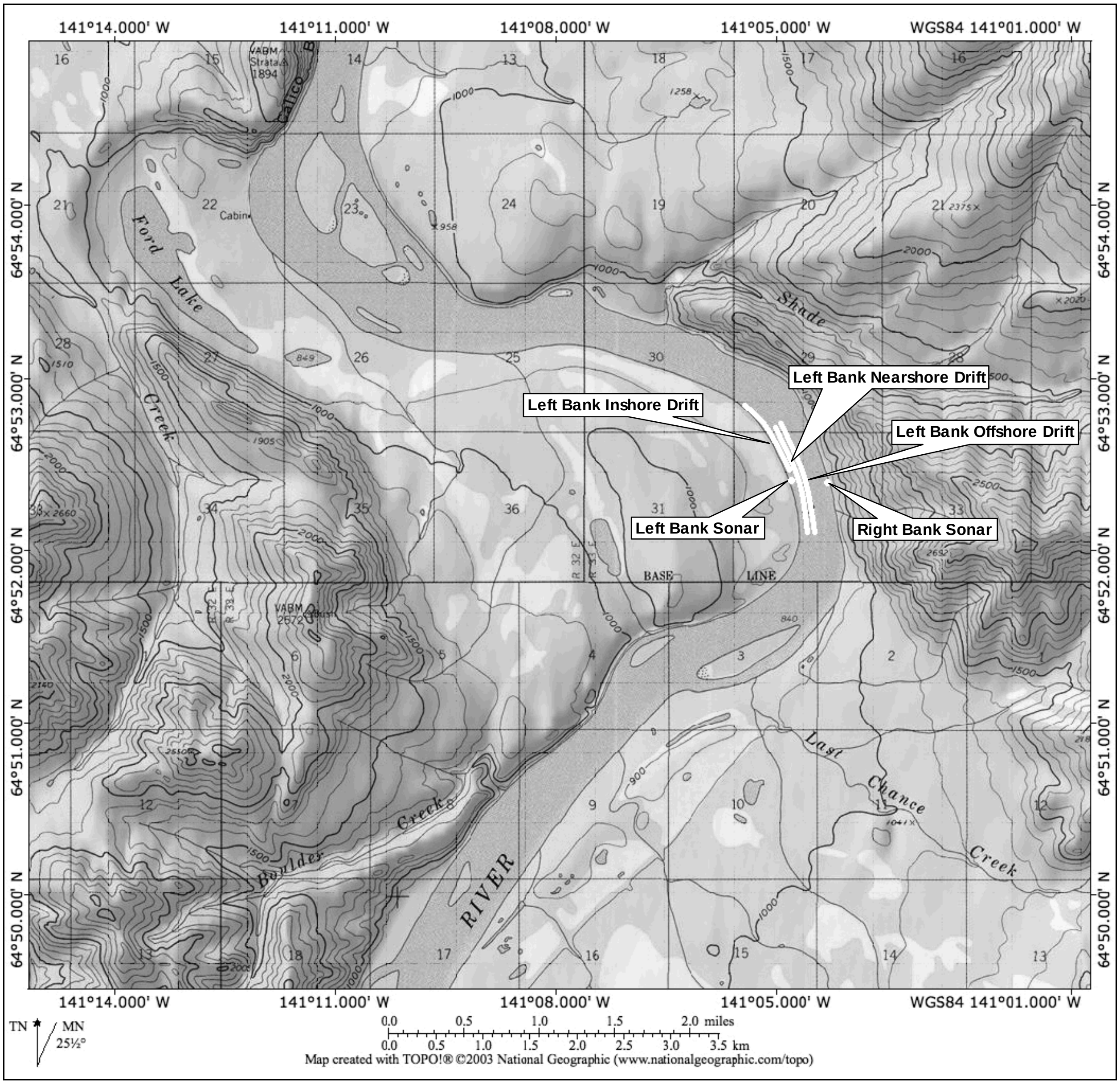


Figure 5.–Period 1 gillnet drift locations.

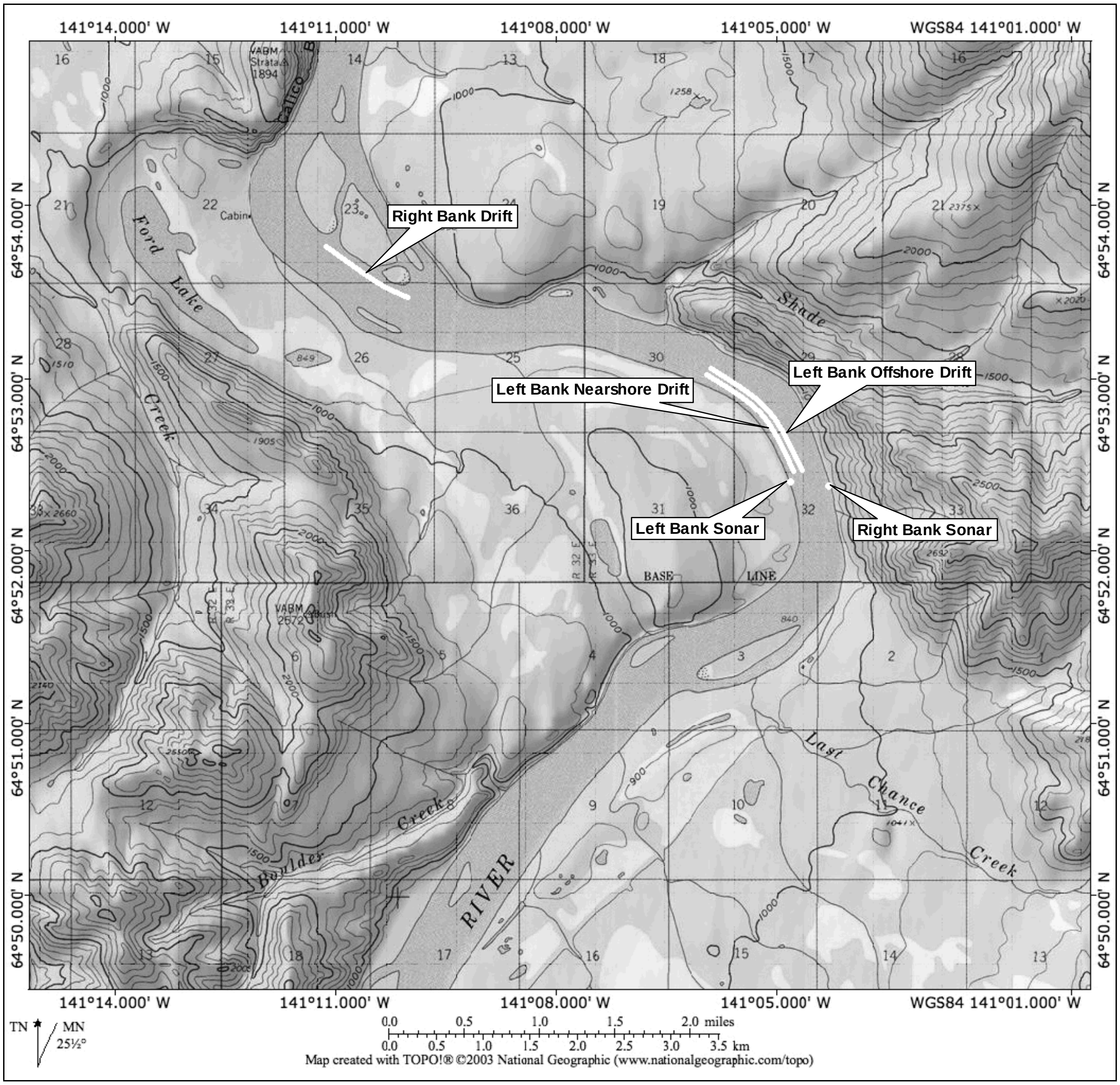


Figure 6.–Period 2 gillnet drift locations.

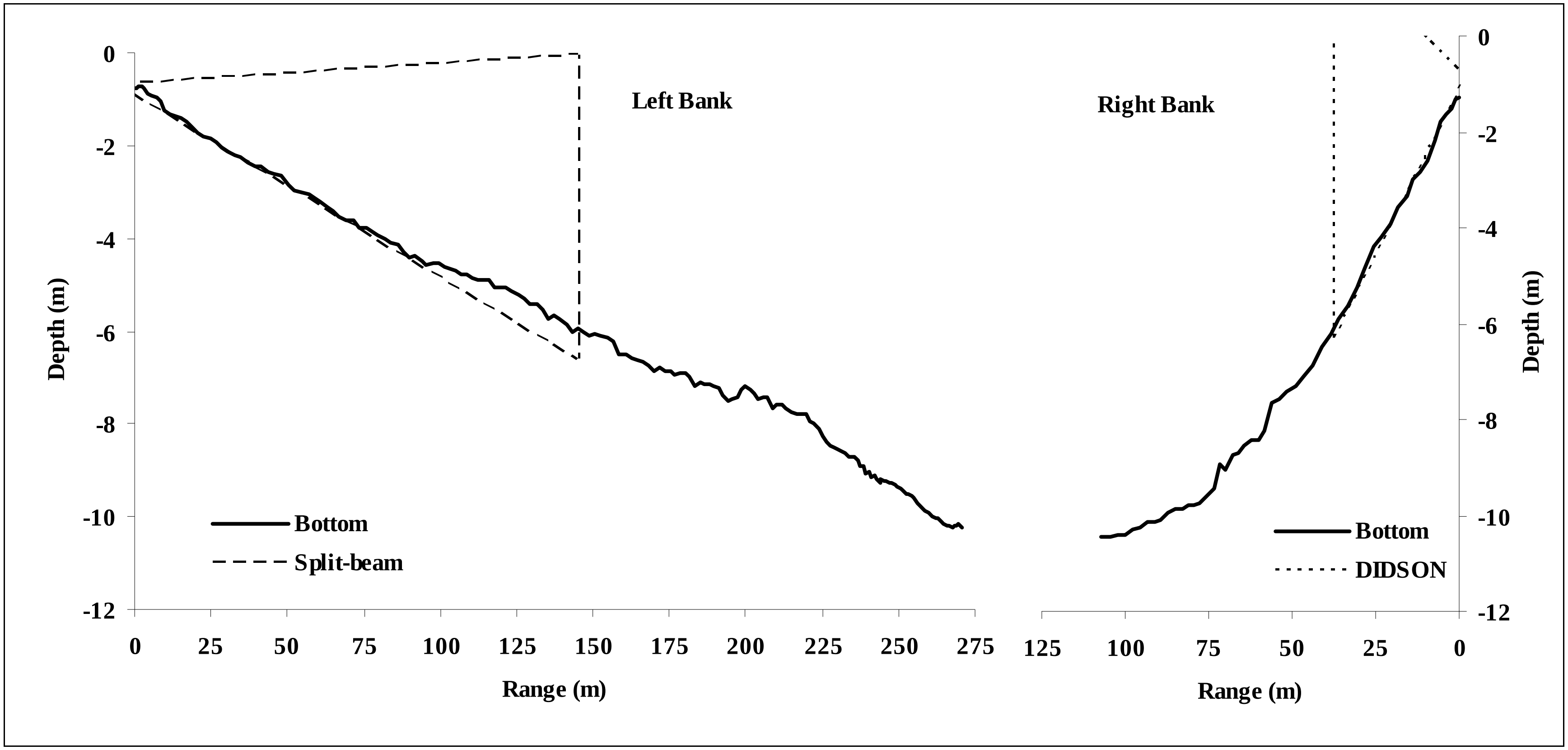


Figure 7.–Depth profile (downstream view), and ensonified zones of Yukon River at Eagle sonar project site, 2008.

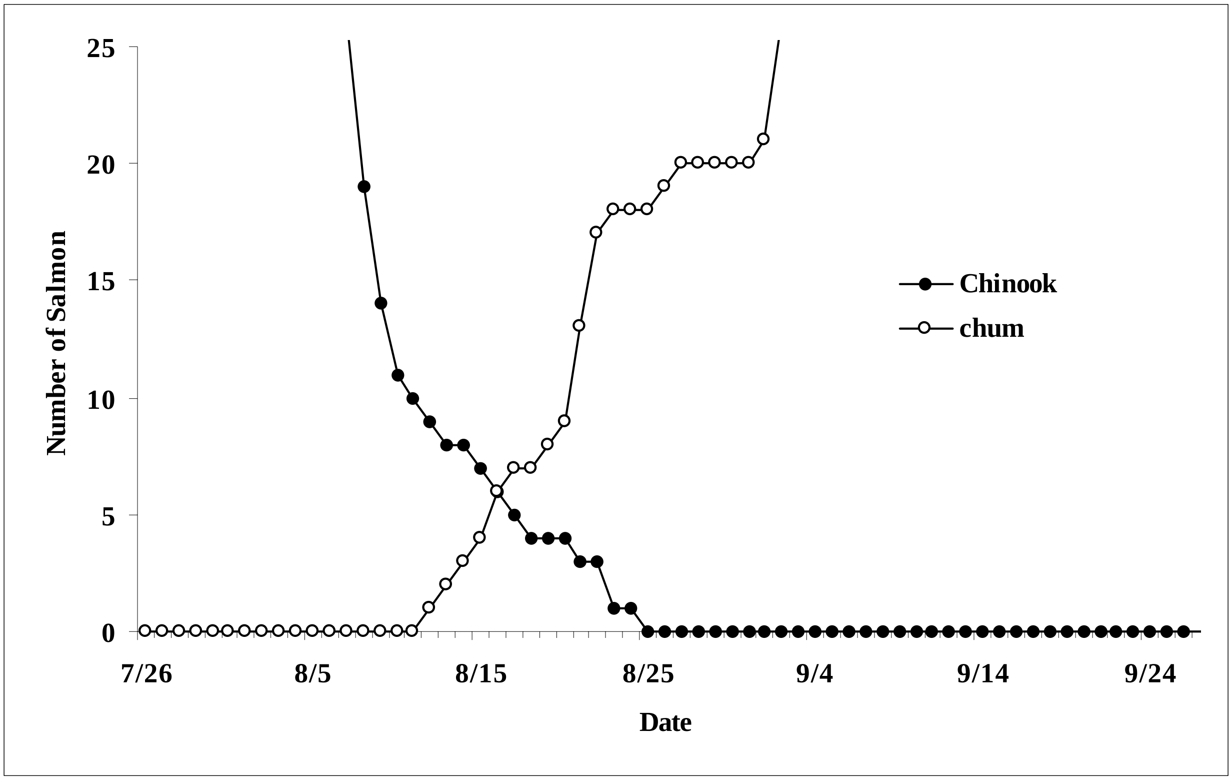


Figure 8.–Species changeover date determined from reverse cumulative Chinook and cumulative chum salmon catches at the Eagle sonar project site, 2008.

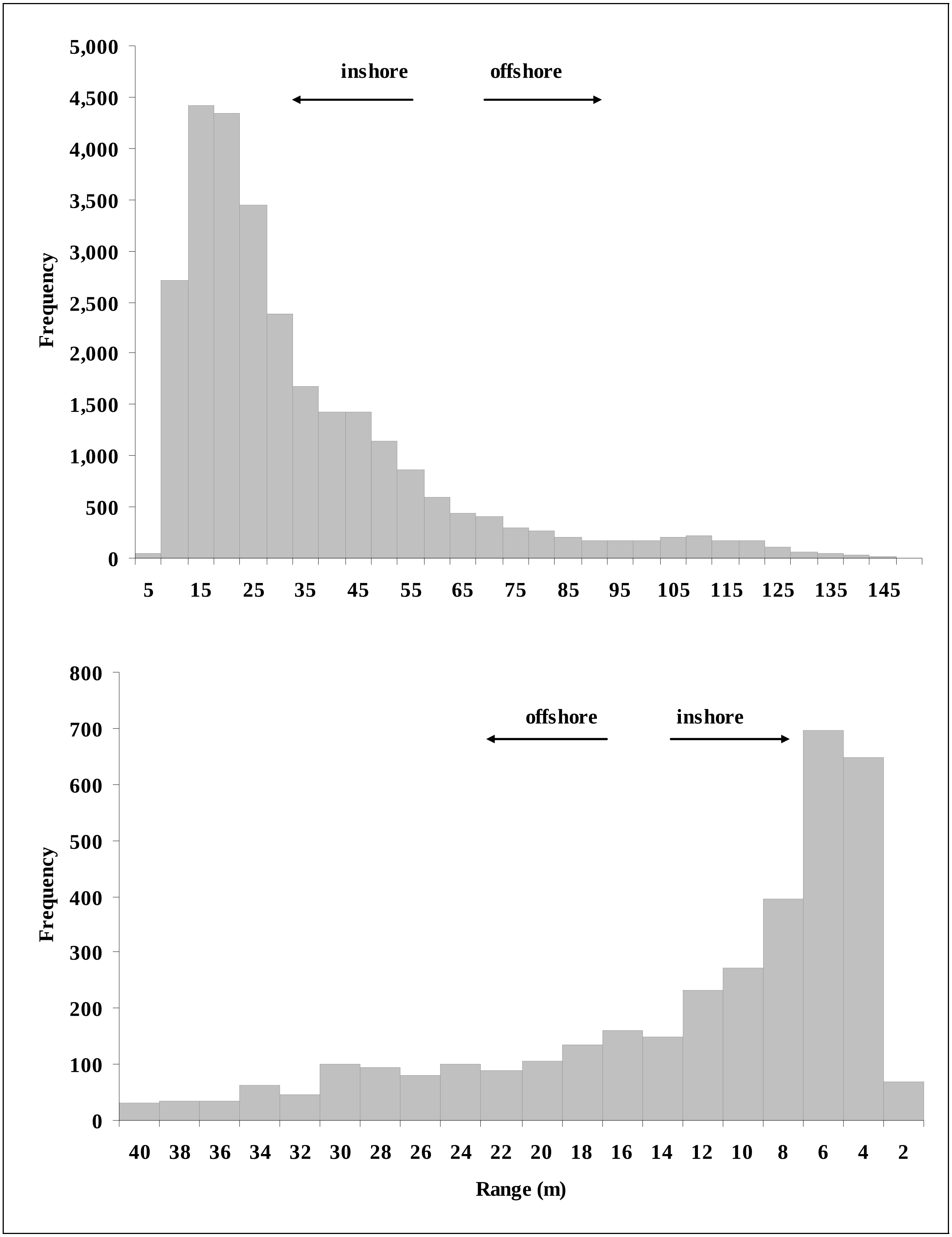


Figure 9.–Left bank (top) and right bank (bottom) horizontal distribution of upstream Chinook salmon passage in the Yukon River at Eagle sonar project site, July 6 through August 16, 2008.

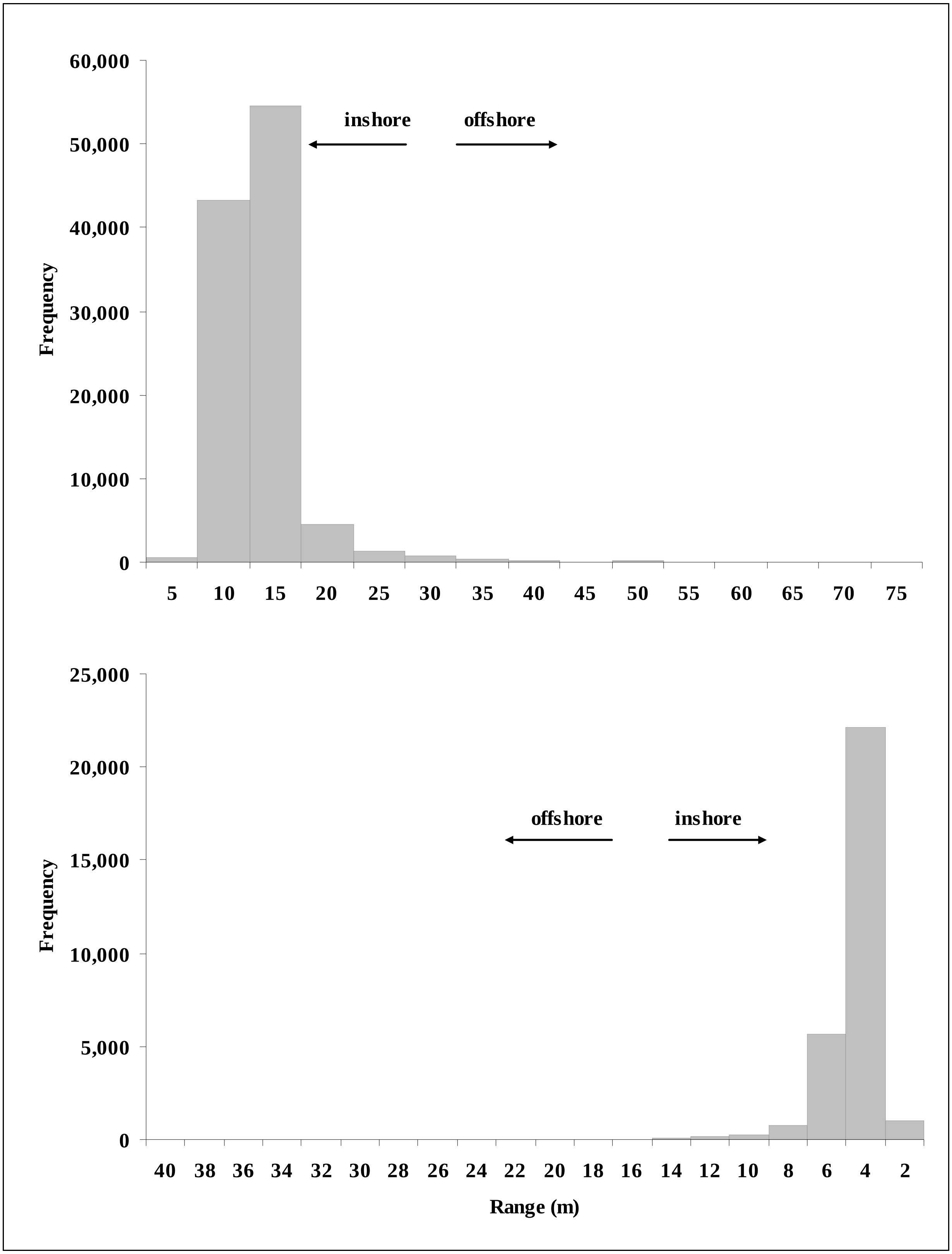


Figure 10.–Left bank (top) and right bank (bottom) horizontal distribution of upstream chum salmon passage in the Yukon River at Eagle sonar project site, August 17 through October 6, 2008.

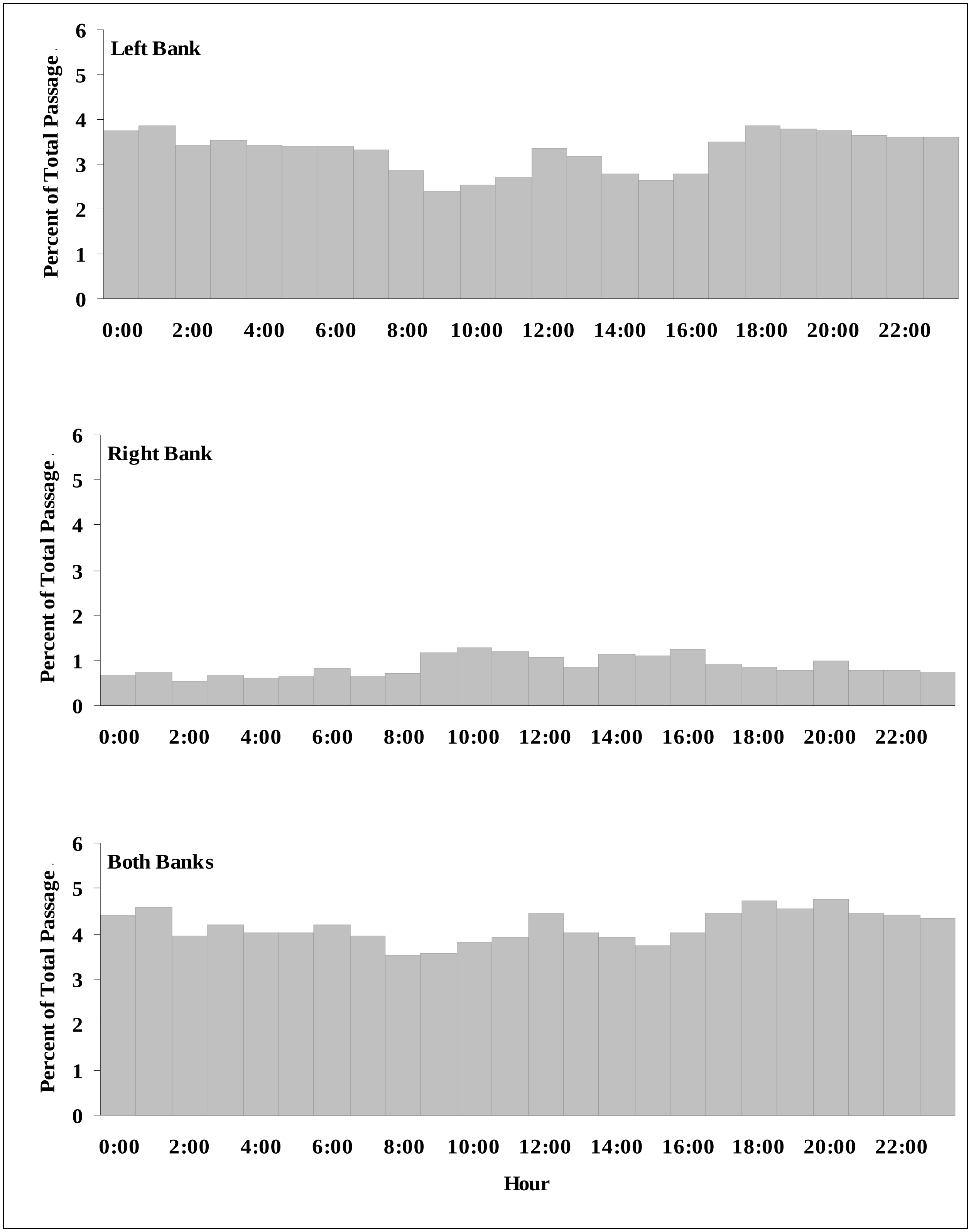


Figure 11.–Diel Chinook salmon migration pattern observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from July 7 through August 16, 2008.

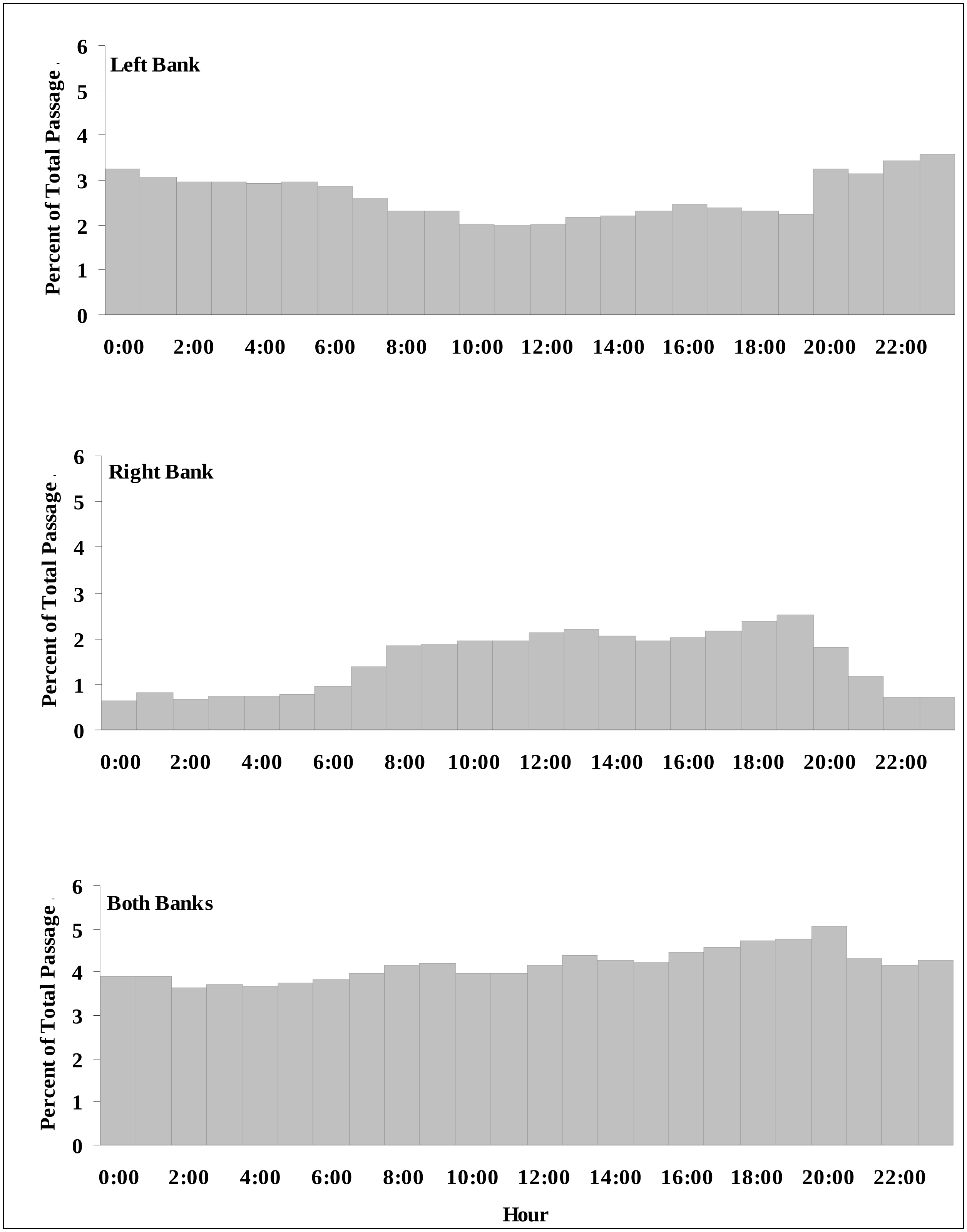
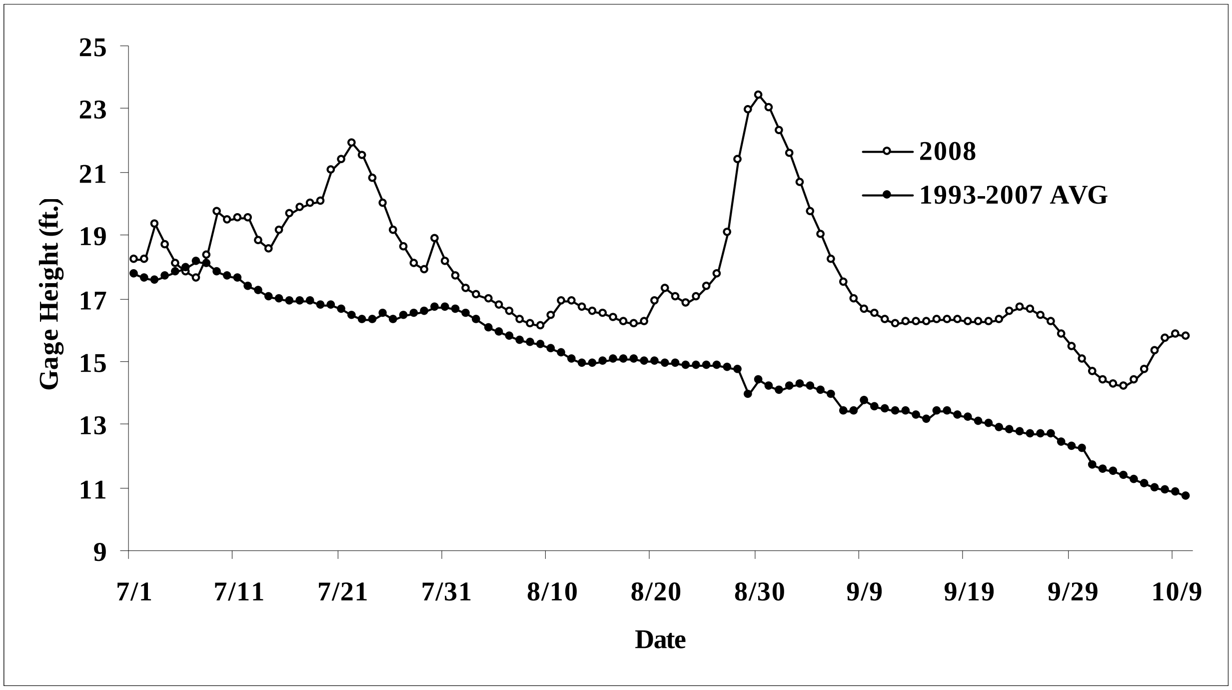


Figure 12.–Diel chum salmon migration pattern observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from August 17 through October 6, 2008.



Source: United States Geological Survey.

Figure 13.–Daily water elevation measured at Eagle, July 1 through October 10, 2008, and average water level from 1993 through 2007.

APPENDIX A. CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix A1.–Climate and hydrologic observations recorded daily at 1800 hours at the Eagle sonar project site, 2008.

	Precipitation	Wind		Sky	Temperature (C°)	
Date	(code)[a]	Direction	Speed (mph)	(code)[b]	Air	Water
7/8	A	calm	calm	B	18.4	15
7/9	A	calm	calm	B	19.5	15
7/10	B	S	10	B	17.8	15
7/11	B	W	5	S	23.4	14
7/12	B	calm	calm	S	23.9	15
7/13	A	calm	calm	S	27.8	15
7/14	B	calm	calm	B	13.9	15
7/15	A	calm	calm	S	26.7	16
7/16	A	E	5	B	27.2	16
7/17	A	calm	calm	O	18.9	15
7/18	C	E	5	O	11.1	15
7/19	B	calm	calm	O	12.8	14
7/20	C	calm	calm	O	11.7	13
7/21	A	E	1	B	15.8	12
7/22	B	calm	calm	B	10.5	11
7/23	B	E	10	O	11.8	11
7/24	A	E	2	C	19.5	13
7/25	B	E	10	O	14.9	13
7/26	A	calm	calm	B	20.4	13
7/27	A	E	1	S	27.7	14
7/28	B	E	<5	S	19.9	14
7/29	A	W	<5	B	14.5	14
7/30	A	W	5	C	12.0	13
7/31	B	W	5	O	12.6	12
8/1	A	calm	calm	B	16.9	13
8/2	B	E	<5	O	14.6	13
8/3	A	E	<5	S	9.8	12
8/4	A	calm	calm	B	12.7	13
8/5	B	calm	calm	O	11.7	13
8/6	A	calm	calm	S	19.3	16
8/7	B	N	5	O	9.9	12
8/8	B	S	2	O	11.1	12
8/9	A	calm	calm	S	12.9	13
8/10	B	S	5-10	B	11.7	12
8/11	B	calm	calm	B	17.8	12
8/12	A	calm	calm	B	23.9	14
8/13	A	calm	calm	O	17.2	14
8/14	B	calm	calm	O	12.8	12
8/15	B	calm	calm	B	16.7	14
8/16	B	calm	calm	B	15.6	14
8/17	A	W	5	B	16.7	14
8/18	A	W	calm	S	15.6	14
8/19	A	S	gusty	C	11.1	13
8/20	A	S	20	C	21.1	12
8/21	A	S	10	C	14.2	12
8/22	A	S	5	C	14.1	12
8/23	A	S	15	C	17.6	12
8/24	A	S	5	B	10.8	12
8/25	A	W	5	O	14.4	12
8/26	A	calm	calm	O	16.2	12

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Appendix A1.–Page 2 of 2.

Date	Precipitation (code)[a]	Wind Direction	Speed (mph)	Sky (code)[b]	Temperature (C°)	Date	Precipitation (code)[a]
8/27	A	calm	calm	O		11.9	11
8/28	A	W	5	C		17.0	10
8/29	No Data						
8/30	No Data						
8/31	A	calm	calm	C		17.0	9
9/1	A	calm	calm	C		23.0	9
9/2	A	calm	calm	S		18.0	9
9/3	A	calm	calm	S		21.0	10
9/4	A	calm	calm	S		21.0	10
9/5	A	calm	calm	S		19.0	10
9/6	A	calm	calm	S		19.0	10
9/7	C	calm	calm	O		13.0	10
9/8	B	calm	calm	O		11.0	10
9/9	A	E	>5	O		12.7	10
9/10	B	calm	calm	O		12.3	10
9/11	A	calm	calm	S		13.2	10
9/12	B	E	5	O		14.3	10
9/13	B	calm	calm	O		8.6	9
9/14	A	calm	calm	B		9.6	9
9/15	A	calm	calm	O		8.0	9
9/16	B	calm	calm	B		7.0	9
9/17	A	W	10	O		5.0	8
9/18	A	calm	calm	O		6.0	9
9/19	A	E	5	O		5.9	8
9/20	A	E	5	S		6.9	8
9/21	No Data						
9/22	A	calm	calm	C		4.2	8
9/23	A	calm	0	C		5.7	7
9/24	A	S	0	S		4.1	7
9/25	A	N	3	C		3.8	6
9/26	A	N	0-3	B		3.0	5
9/27	A	calm	0	C		3.1	4
9/28	A	N	0-3	C		-0.1	4
9/29	A	calm	0	C		-0.1	4
9/30	E	calm	0	O		0.1	4
10/1	A	S	0-3	C		-0.2	4
10/2	F	W	0-3	O		0.0	3
10/3	A	calm	0	B		-0.2	3
10/4	A	calm	0	B		-0.3	3
10/5	A	calm	0	C		-0.2	3
10/6	A	N	1	C		-0.2	3
Average						13.0	10.8

[a] Precipitation code for the preceding 24 hr 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.