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Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River near Eagle, Alaska, 2014

by

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and

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December 2015

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)

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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by

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ABSTRACT

Dual-frequency identification sonar (DIDSON) and split-beam sonar equipment were used to estimate Chinook salmon *Oncorhynchus tshawytscha* and fall chum salmon *O. keta* passage in the Yukon River near Eagle, Alaska from June 27 to October 6, 2014. A total of 63,482 Chinook salmon were estimated to have passed the sonar site between June 27 and August 7. The midpoint of the Chinook salmon run occurred on July 18, which was 7 days early relative to the historical mean date of July 25. An estimated 165,715 fall chum salmon passed between August 8 and October 6. The sonar-estimated passage of fall chum salmon was subsequently expanded to a total passage estimate of 172,887 to include fish that may have passed after operations ceased. The midpoint of the fall chum salmon run, with and without expansion, occurred on September 22, which is the historical mean date. Subtracting the preliminary subsistence catch upstream of the sonar site resulted in an estimated border passage of 63,431 Chinook salmon and 159,846 fall chum salmon. Drift gillnetting was conducted to collect age, sex, length, and genetic information. Species composition was 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 and the range of ensonification was considered adequate for most fish that migrated upstream.

Key words: Chinook *Oncorhynchus tshawytscha*, fall chum salmon *Oncorhynchus keta,* dual-frequency identification sonar DIDSON, split-beam sonar, hydroacoustic, Yukon River, Eagle, Alaska.

INTRODUCTION

The Yukon River is the longest river in Yukon and Alaska, spanning 3,185 km[1]. 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 Chinook salmon *Oncorhynchus tshawytscha,* chum salmon *O. keta,* and coho salmon *O. kisutch* 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 are confounded by gillnet selectivity. In addition, the functional relationship between test fishery catches and abundance are 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 Canadian-origin Yukon River Chinook and fall chum 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 is to meet negotiated escapement goals and 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 inseason, 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 (JTC 2014). Because of the highly turbid water of the Yukon River, and the width of the mainstem (approximately 400 m across at the study site),

[1] Yukoninfo. 2014. Yukon River. http://www.yukoninfo.com/yukon-river/ (Accessed: December 2014).

daily passage estimation methods that rely on visual observation, such as counting towers and weirs, are not feasible. Split-beam sonar technology is 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 (Lozori and McIntosh 2013). Dual-frequency identification sonar (DIDSON[2]) has been used at several sites, including the Anvik River (McEwen 2014) and the Sheenjek River (Dunbar 2013) 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 been addressed. A recommendation 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 consistent, downward-sloping linear bottom profiles on both sides of the river without large obstructions; a single channel; available beach above the ordinary high water mark (OHW) 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 transects led to narrowing potential project locations to an area between 9 km and 19 km downriver from the town of Eagle. The 2003 study identified the 2 most promising sonar deployment locations at Calico Bluff and Shade Creek. Although 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. These sonars 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, split-beam sonar was deployed on the left bank, and

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

this equipment has been used in subsequent years to estimate border passage for both Chinook and fall chum salmon.

In 2006, project duration was extended to provide an estimate of chum salmon passage. Genetically distinct runs of chum salmon enter the Yukon River, an early summer component and a later fall component (Estensen et al. 2013). Summer chum salmon spawn primarily in run-off streams in the lower 700 miles of the Yukon River drainage and in the Tanana River drainage. Fall chum salmon, which migrate past the Eagle sonar project, primarily spawn in the upper portion of the drainage in streams that are spring fed or have major upwelling features. Major fall chum salmon spawning areas include the Tanana, Porcupine, and Chandalar river drainages as well as various streams in the Yukon Territory, Canada, including the mainstem Yukon River.

In 2014, the project deployed split-beam and DIDSON sonar to estimate Chinook and fall chum salmon passage migrating across the U.S./Canada border. Sample fisheries were conducted to determine the transition between Chinook and fall chum salmon runs, as well as collect age, sex, and length (ASL) and tissue samples for stock identification. This report will describe in detail the methodologies used to collect sonar and test fishery data, as well as provide passage estimates, species distributions, run timing, and in addition, climate and hydrologic observations.

OBJECTIVES

The goal of this project in 2014 was to provide daily inseason estimates of Chinook and fall chum salmon migrating across the U.S./Canada border to fishery managers. Primary objectives included the following:

1. Begin field operations prior to the arrival of Chinook salmon, then operate continuously throughout the season until approximately October 6, when, historically, environmental conditions become unfavorable for field operations.
2. Operate side-looking split-beam and imaging sonar such that 95% of the migrating salmon detected are within three quarters of the ensonified range.
3. Use drift gillnets to collect species composition and catch per unit effort (CPUE) data to estimate the transition period between the Chinook and fall chum salmon migration past the sonar site.

Secondary objectives included the following:

4. Collect a minimum of 160 Chinook salmon scale samples during each of 3 stratum throughout the season to characterize the 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). Strata dates are determined by ADF&G fishery managers based on run timing, sample size, and fish pulses (DuBois 2015).
5. Collect a minimum of 160 fall chum salmon scale samples during each of 4 stratum throughout the season to characterize the 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).

6. Collect Chinook and fall chum salmon tissue samples for genetic stock identification.
7. Collect daily climatic and hydrologic measurements representative of the study area.
8. Determine the relationship between expanded nearshore split beam hourly passage rates derived from sampling at the previous standard ping rate (4.16) and a new, higher rate (8.33).

METHODS

STUDY AREA

The study area is located on the mainstem of the Yukon River at Six Mile Bend (64°52′30.8″ N, 141°04′52.8″ W), approximately 11.5 km downriver from Eagle, Alaska (Figure 2). The Yukon River Basin is the fourth largest basin in North America with a drainage area of 857,300 km^2 and an average annual discharge of 6,400 m^3/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 throughout the summer and fall, with an estimated annual suspended sediment load at Eagle of 33,000,000 tons (Brabets et al. 2000).

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 was controlled with a Simrad Controller program (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication), which was installed on a laptop computer and connected to the echosounder to collect raw data for processing.

A DIDSON long-range unit, manufactured by Sound Metrics Corporation, was deployed on the right bank. The sonar was operated at 1.2 MHz (high frequency option using 96 beams) for the nearshore strata and at 0.70 MHz (low frequency option using 48 beams) for the offshore strata. Both the low and high frequency modes have a viewing angle of 29° x 14° (Table 1).

Digital files created by the ER60 software and the DIDSON were examined with the echogram viewer program Echotastic (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication), to produce an estimate of fish passage.

SONAR DEPLOYMENT AND OPERATION

Each season, prior to transducer deployment, bottom profiles are checked to ensure the original sites remain acceptable for ensonification. Data were collected from 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 transducer was attached to 2 Hydroacoustic Technology Incorporated (HTI) model 662H single-axis rotators, configured perpendicularly to provide dual-axis rotation.

Aiming was performed remotely using a HTI model 660 remote control unit that provided horizontal and vertical positioning.

The split-beam sonar was deployed from June 28 to October 6 on the left bank, approximately 800 m downriver from the camp (Figure 2). The transducer and rotators were mounted on a freestanding frame constructed of aluminum pipe and deployed approximately 15 m from shore (Figure 4). 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 1.5 m depth and aimed perpendicular to the current, at a location with consistent flow and no slack water. When counting Chinook salmon, the split-beam system was aimed to ensonify a range of approximately 150 m from the transducer, and sampled 2 strata, (S1: approximately 0–50 m and S2: approximately 50–150 m). When counting fall chum salmon, the split-beam system was aimed to ensonify 1 stratum (S3, approximately 0–75 m; Figure 5).

Settings for data acquisition included 256 µs transmit pulse lengths and 500 W power output. During the Chinook salmon migration, the pulse repetition rate for S1 was set to 8.33 pings per second (pps), and S2 was set at 4.16 pps. The pulse repetition rate for S3 during the fall chum migration was set at 8.33 pps (Table 2).

Prior to this season, sub-sampling multiple ranges, as well as specifying file time duration with the Simrad EK60 echo sounder, was not feasible because of limitations with the ER60 software. New software (Simrad Controller) was developed to allow users the ability to collect data with more complex sampling plans (Carl Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication).

Because of occasional problems distinguishing fish traces from approximately 0 to 25 m on the left bank during the previous season (Lozori 2015), the split-beam sampling range was divided into 2 strata using the Simrad Controller software during the Chinook salmon migration. To increase the number of echoes received by fish traveling closer to the transducer, the ping rate in S1 was increased from the established rate of 4.16 pps to 8.33 pps. When sampling S2, the Simrad Controller collected echogram data for the entire 150 m range (on the bottom of the hour). Operators scrolled beyond 50 m in the echogram and enumerated the remaining range. For comparative purposes, a subsample of data collected from both the top and bottom of each hour during the Chinook salmon migration was analyzed to determine if the increased ping rate in the nearshore stratum improved fish detection close to the transducer.

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. Freestanding lead sections were constructed of 2 in diameter steel pipes connected with adjustable fittings to form tripods. 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 spaced 3.8 cm apart. Lead sections were placed side by side in the water from shore to a distance of 5 to 12 m beyond the transducer (Figure 6). 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 season, the transducer and lead require frequent relocation to maintain their depth in the water column.

The DIDSON was deployed from June 27 to October 6 on the right bank, approximately 700 m downriver from the camp (Figure 2). It was mounted on an aluminum frame and aimed using a manual crank-style rotator (Figure 7). 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 (0.83 to 40 m).

A fish lead was constructed with 2 m steel T stakes and 1.22 m plastic snow fencing with lead line strung through the bottom for weight (Figure 6). 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 shorter lead was appropriate for this bank because of the steep slope and the shorter near field of the DIDSON, because of its higher frequency, produces a usable image in this region. The right bank was ensonified over a range of approximately 40 m, beginning at 0.83 m from the face of the transducer, with 2 sampling strata (S4: 0.83–20.83 m and S5: 20.83–40.83 m) (Figure 5).

SONAR DATA PROCESSING AND PASSAGE ESTIMATION

During the Chinook salmon migration, split-beam data were collected in two 30 min samples each hour of the day and saved to an external hard drive for counting. During the top of the hour the split-beam sampled S1 (0–50 m; 8.33 pps), and sampled S2 (50–150 m; 4.16 pps) during the bottom of the hour. Throughout the fall chum salmon migration, split-beam data were collected continuously in 60 min increments and sampled S3 (0–75 m; 8.33 pps). Operators opened each data file in an echogram viewer program (Echotastic), and marked each upstream fish track with a computer mouse (Figures 8 and 9). The counts were saved as text files and recorded on a count form.

DIDSON data were collected in two 30 min samples each hour of the day. For the first 30 min of every hour, the DIDSON sampled S4 (0.83–20.83 m), and the second half of each hour it sampled S5 (20.83–40.83 m). Upstream migrating fish were counted using the Echotastic software. Upstream direction of travel was verified using the Echotastic video feature. The counts were saved as text files and recorded on a paper count form.

Similar to the hourly expansion historically used to generate the stratified DIDSON estimates (Lozori 2015), it was assumed the accuracy of the daily hourly fish passage rate for the left bank would be comparable when sub-sampling with the split-beam. Because this was the first year the left bank was stratified, analysis of the effect of the increased ping rate in S1 (8.33 pps versus 4.16 pps) on the expanded hourly passage rate was conducted by randomly sampling 15 days during the Chinook salmon migration. Nearshore salmon passage (0–50 m) from both S1 and S2 were enumerated, and a daily fish passage rate from each subset of data was generated to compare the effects of changing the ping rates (Figure 10).

The daily passage ($\hat{y}$) for stratum (s) on day (d) was calculated by averaging the hourly passage rates for the hours sampled and then multiplying as follows:

$$\hat{y}_{ds} = 24 \bullet \frac{\sum_{p=1}^{n} \frac{y_{dsp}}{f_{dsp}}}{n_{ds}}, \qquad (1)$$

where f_{dsp} is the fraction of the hour sampled on day (d), stratum (s), period (p) and y_{dsp} is the count for the same sample.

Treating the systematically sampled sonar counts as a simple random sample would yield an overestimate of the variance of the total because sonar counts are highly autocorrelated. To accommodate these data characteristics, a variance estimator based on the squared differences of successive observations was employed (Wolter 1985). The variance for the passage estimate for stratum (s) on day (d) are estimated as

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

where n_{ds} is the number of samples in the day (24), f_{ds} is the fraction of the day sampled (12/24 = 0.5), and y_{dsp} is the hourly count for day (d) in stratum (s) for sample (p). Because the passage estimates are assumed independent between strata and among days, the total variance was estimated as the sum of the variances:

$$\hat{V}ar(\hat{y}) = \sum_d \sum_s \hat{V}ar(\hat{y}_{ds}) . \tag{3}$$

MISSING DATA

Estimating daily passage by multiplying the average hourly passage rates by 24 (Equation 1) compensates for missing data (either shortened or missing periods within a day) and is reflected in the variance (Equation 2) by reducing the number of samples and the fraction of the day sampled. If 1 or multiple days were missed, the relationship of daily passage between banks was assessed. An XY scatterplot with a regression line was plotted using the observed passage from the previous days for each bank. If the regression was significant ($p < 0.05$), the linear regression equation of the line was used to calculate missing passage for each missing day (d):

$$\hat{y}_d = a + bx_d, \tag{4}$$

where a and b are the regression coefficients, x equals the passage for day (d) on the opposite bank, and $\hat{y}_d$ is the estimated passage for missing day (d).

If the regression of daily passage by bank was not significant, daily passage was interpolated by averaging passage estimates from days before and after the missing day(s) as follows:

$$\hat{y}_d = \left(1/n \sum_{i=1}^{n} x_i \right) \begin{Bmatrix} d=1, n=4 \\ d=2, n=6 \\ d=3, n=8 \end{Bmatrix}, \tag{5}$$

where d is the number of missed days, n is the number of days used for interpolation (half before and half after the missing day(s)), and x_i is the passage for each day.

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

Because project operations cease prior to the end of the fall chum salmon run, the estimate was expanded using a second order polynomial equation extended to October 18, where y_i is the daily passage estimate (i), 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):

$$y_i = \frac{L}{d^2}(x_i - d)^2 \quad (6)$$

October 18 was chosen based on what is considered the most likely run-timing scenario derived from 1982 to 2008 historical data collected at the DFO mark–recapture fish wheel project near the U.S./Canada border (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication)

Postseason, the U.S. portion of the Chinook and fall 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 fall chum salmon were examined by importing text files containing all fish track information into R (R Development Core Team 2012)[3] where the fish counts were binned by range. The binned data were plotted to investigate the spatial distribution of fish passing the sonar site. Histograms of passage by hour were created to investigate diel patterns of migration. Run timing of Chinook and fall chum salmon was examined inseason and postseason using information from the sonar estimate, fish range distribution, sample fishery catches, and local subsistence harvest.

Sample Fishing

Two specific test fisheries were implemented to monitor species composition and collect ASL and genetic samples. A Chinook salmon sample fishery (June 28–August 15) to collect data to estimate specific Canadian stock proportions and the ASL composition of Chinook salmon entering Canada, and a species composition fishery (August 1–September 30) to determine the transition date between the Chinook and fall chum salmon runs, as well as collect fall chum salmon ASL data.

From June 28 to August 1, Chinook salmon fishing occurred twice per day from approximately 0800 to 1200 hours and again from approximately 1300 to 1700 hours. The fishery specifically targeted Chinook salmon, which are the predominant species during the months of June and July.

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3 R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, available for download: http://www.R-project.org

Between August 1 and August 15, Chinook salmon sample fishing was conducted once per day between 1300 and 1700 hours.

Genetic and ASL samples were collected using 4 mesh sizes (5.25 in, 6.5 in, 7.5 in, and 8.5 in), which were drifted in a rotating schedule (Table 3) over the course of the Chinook salmon run to effectively capture all size classes present. Nets were 25 fathoms long, approximately 25 ft deep and hung "even" at a 2:1 ratio of web to corkline (Table 4). Nets 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 2.5 km upriver from the sonar site where river conditions were suitable for drift gillnetting on that bank (Figure 2). This resulted in 9 drifts during the sample fishing period.

For each drift, 4 times were recorded to the nearest second onto field data sheets: net start out (SO), net full out (FO), net start in (SI), and net full in (FI). Fishing time (t) in minutes was approximated as:

$$t = SI - FO + \frac{FO - SO}{2} + \frac{FI - SI}{2} \quad (7)$$

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

$$f_{dzlmj} = \frac{25\, t_{dzlmj}}{60} \quad (8)$$

Fishing for species composition and ASL collection was conducted once daily from August 1 to September 30, between approximately 0800 and 1200 hours on the left bank. During the sampling period, both 5.25 in and 7.5 in nets were drifted twice within each of the 3 left bank zones: left bank inshore (LBI), left bank nearshore (LBN), and left bank offshore (LBF; Figure 2) for a total of 12 drifts. Nets were hung the same as for the Chinook salmon sample fishery with the exception that the inshore nets (LBI), which were approximately 8 ft deep (Table 4). Drifts were targeted to be 6 min in duration, but were occasionally shortened as necessary to avoid snags or to limit catches and prevent mortalities during times of high fish passage. LBI drifts were referred to as beach walks (Fleischman et al. 1995), where 1 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 started approximately 1 net length from shore and the offshore zone started approximately 2 net lengths from shore. The order of drifts was 1) LBI, 2) LBN, and 3) LBF, with a minimum of 15 min between drifts in the same zone. All drifts with a specific mesh size were completed before switching to a different mesh size. The starting mesh size were alternated each day (Table 3).

For standard ASL samples, length was measured mideye to tail fork (METF) to the nearest 1 mm. Sex was determined by visually examining features such as development of the kype, roundness of the belly, presence or absence of an ovipositor, and overall size. This is similar to the sampling routine used on the Kuskokwim River (Molyneaux et al. 2010). There were 4 scales from Chinook salmon and 1 scale from fall chum salmon collected 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.

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 fall chum salmon samples were stored in bulk collections of up to 200 samples. All samples were sent to ADF&G genetics laboratory and, from there, forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columba 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.

SPECIES DETERMINATION

Although the Chinook and fall chum salmon runs are considered discrete in time, some temporal overlap does occur. Inseason, a tentative date is chosen based on sonar counts, gillnet catches, and local harvest to represent the last day of the Chinook salmon run, with the remainder of the sonar estimates classified as fall chum salmon. After thorough examination of the project's fishery data postseason, this tentative date may be adjusted to more accurately represent the observed run timing.

Daily catch data and CPUE from the species composition fishery were used to assess proportional abundance and as an indicator as to when the crossover date occurred. Traditional CPUE measures were calculated for each day *d* on the left bank *b* during species composition fishing using 2 specific sizes of gillnet mesh *g* regardless of catch size. Chinook salmon CPUE was calculated on the catch *c* and effort *e* (calculated in equation 8) of the large mesh gillnet (7.5 in); fall chum salmon CPUE was calculated on the catch and effort of the small mesh gillnet (5.25 in) because all nets were 25 fathoms (45.7 m) in length. CPUE estimates (in catch per fathom hour) for each species *i* were made daily for the left bank species composition test fishery:

$$CPUE_{dbi} = \frac{\sum_g c_{dbig}}{e_{dbg}} \quad .$$

CPUE data for Chinook and fall chum salmon were imported into *R* and a scatter plot from the data was smoothed using Friedman's supersmoother algorithm (Friedman 1984). The algorithm, which computes 3 separate smooth curves from the input data with symmetric spans of 0.05**n*, 0.2**n* and 0.5**n*, where *n* was the number of data points, selects the best of the 3 smooth curves for each predicted point using leave-one-out cross validation. The best spans are then smoothed by a fixed-span smoother (span = 0.2**n*) and the prediction is computed by linearly interpolating between the 3 smooth curves. This final smooth curve is then smoothed again with a fixed-span smoother (span = 0.05**n*). The crossover date is determined at the point where the 2 lines on the curve cross at the point where the CPUE for fall chum salmon equals the CPUE for Chinook salmon subsequent to that point.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Climatic and hydrologic observations were collected at approximately 1800 hours daily. Reported stream levels are taken from the U.S. Geological Survey's gaging station at Eagle[4], although water levels were monitored at the sonar site as well. Surface water temperature was measured approximately 30 cm below the surface, with a HOBO U22™ water temperature data logger. Data loggers were attached to the sonar transducer stands on each bank and set to record every half hour. Air temperature, wind velocity, and wind direction were measured daily with a handheld weather meter. Other daily observations included occurrence of precipitation and percent cloud cover.

RESULTS

SONAR DEPLOYMENT

In 2014, both the right and left bank transducers were deployed in approximately the same locations that have been used in recent years (Figure 2). The left bank profile was approximately linear, extending approximately 300 m to the thalweg at a 2.9° slope. The right bank profile was less linear, shorter and steeper, extending approximately 100 m to the thalweg at a 9.1° slope (Figure 3). 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 FALL CHUM SALMON PASSAGE ESTIMATION

Inseason, August 12 was tentatively determined to be the last day of the Chinook salmon run based on relatively low sonar counts and catches from the species composition test fishery (Figure 11). The inseason species changeover date was adjusted postseason after thorough examination of species composition drift data. Analysis of CPUE and catch data for both the large and small mesh nets (7.50 in and 5.25 in) from the species composition test fishery were plotted by day, and the relationship between the variables summarized using the Friedman's supersmoother algorithm (Figures 12 and 13, Appendix A). Both plots suggest the first day of the fall chum salmon run was August 8.

The total passage estimate at the Eagle sonar site for Chinook salmon was 63,482 from June 27 through August 7. The first quarter point was on July 11, the midpoint on July 18, and third quarter point on July 24 (Table 5). Peak daily passage estimate of 3,273 Chinook salmon occurred on July 22 and 285 fish passed on August 7 (Figure 14). Compared to historical mean run timing from 2005 to 2013, the midpoint of the Chinook salmon run occurred 7 days early (Figure 15)[5]. Sampling time missed during this period varied by strata with the strata totals ranging from 42.3 h to 59.6 h (Table 6).

The preliminary subsistence harvest from the Eagle area upstream of the sonar was 51 Chinook salmon (Deena Jallen, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Postseason, adjusting for subsistence Chinook salmon harvest produced a

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[4] USGS (U.S. Geological Survey). 2014. National Water Information System: Web Interface. USGS 15356000 Yukon River at Eagle Alaska. http://waterdata.usgs.gov/ak/nwis/inventory/?site_no=15356000&agency_cd=USGS& (Accessed: December 2014).

[5] Differences in the transition dates for species crossover confounds computation of the historical daily cumulative and mean. As a convenience, the historical daily cumulative percent and mean were computed by assuming that 100% of the run was completed on the date the Chinook salmon run transitioned to fall chum salmon.

border passage estimate of 63,431 Chinook salmon (Table 7). This estimate was above the preseason projection and the interim management escapement goal (IMEG)[6] of 42,500 to 55,000.

The total fall chum salmon passage estimate was 165,715 fish from August 8 through October 6. While the sonar was operational, the first quarter point fell on September 12, the midpoint September 22, and third quarter point on September 26 (Table 8). Fall chum salmon passage peaked on September 24, with a daily estimate of 11,450 fish (Figure 14). Compared to historical mean run timing from 2006 through 2013, the midpoint of the fall chum salmon run occurred on the historic mean date (Figure 15).

Sampling time missed during the fall chum period varied by strata, with strata totals ranging from 20.6 h to 41.4 h (Tables 6 and 9). Approximately 1.2% (2,041 fish) of the total fall chum salmon passage occurred on October 6, the last day of operation (Table 8). Because fall chum salmon passage continued after the project was terminated, the sonar estimate was expanded and adjusted to 172,887 fall chum salmon (Figure 14).

The preliminary subsistence harvest from the Eagle area was 13,041 fish (Bonnie Borba, Commercial Fisheries Biologist, ADF&G, Fairbanks; personal communication). Postseason, adjusting for subsistence fall chum salmon harvest produced a border passage estimate of 159,846 fish (Table 7). This estimate is approximately 9% below the 2006 to 2013 mean border passage estimate of 177,772. After accounting for Canadian harvest, total fall chum salmon escapement was estimated to be 157,268 fish[7], for the mainstem Yukon River in Canada. This exceeded the IMEG range of 70,000 to 104,000 fish and provided for harvest under the sharing agreement.

After reviewing echograms collected from subsampling strata S1, it was noticeable that the files sampled with the higher ping rate showed improvement in visual detection through longer, more recognizable fish traces. The relationship between the nearshore split beam hourly passage rates derived from subsampling with a ping rate of 8.33 pps and 4.16 pps was found to be significant, with a coefficient of determination $r^2 = .982$ ($P < 0.001$). Additionally, the one-to-one line is within the 95% confidence interval of the least squares regression (Figure 16). This analysis achieves objective 8.

The objectives of beginning field operations prior to the arrival of Chinook salmon, operating continuously throughout the season until approximately October 6, as well as operating side-looking split-beam and imaging sonar such that 95% of the migrating salmon are detected within three quarters of the ensonified range were achieved.

SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore-oriented on both banks (Figures 17 and 18). On the left bank, during the Chinook salmon run, approximately 95% of the fish were detected within 70 m of the transducer and 99% within 100 m. On the right bank, 95% of the fish were detected within 20 m of the transducer and 99% within 30 m. During the fall chum salmon run on the left bank, approximately 95% of the fish were detected within 20 m of the transducer and 99% within 35

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[6] The U.S./Canada Yukon River Panel agreed to a 1-year Canadian interim management escapement goal (IMEG) of 42,500–55,000 Chinook salmon based on the Eagle sonar program. In order to meet this goal, the passage at Eagle sonar must include a minimum of 42,500 fish for escapement, provide for a subsistence harvest in the community of Eagle upstream of the sonar (approximately 1,000–2,000 fish), and incorporate Canadian harvest sharing as dictated in the U.S./Canada Yukon River Treaty (20%–26% of the total allowable catch).

[7] Estimated mainstem Yukon River Canadian escapement is derived from Eagle sonar estimate (expanded through October 18; 2008 to present) minus harvest from Eagle community upstream including Canadian harvests.

m. On the right bank, approximately 95% of the fish were detected within 6 m of the transducer and 99% within 10 m. Approximately 77% of Chinook salmon and 78% of fall chum salmon passed on the left bank.

Although overall Chinook salmon migration past the sonar does not suggest a diel migration pattern, a decrease in passage on the left bank and an increase on the right bank was evident between 0900 and 1600 (Figure 19). This period corresponds with the test fishery schedule, which suggests there may be a relationship between the fishing schedule and daily Chinook salmon passage. Because the right bank test fishery occurs far upstream from the sonar (Figure 2), effectively only the left bank salmon passage would be impacted.

Similarly, fall chum salmon passage on the left bank decreased during the morning test fishery while right bank passage increased (Figure 20). It is noteworthy to mention that test fishing is not conducted on the right bank during the majority of the fall chum salmon run.

SAMPLE FISHING

A total of 720 Chinook and 1,027 fall chum salmon were captured in drift gillnets between June 28 and September 30 (Table 10). Fishing for species composition and sample collection occurred from August 1 to September 30, and additional Chinook salmon sample fishing occurred from June 28 to August 15. One sheefish *Stenodus leucichthys*, 4 Arctic grayling *Thymallus arcticus*, 2 whitefish *Coregoninae* spp., and 6 burbot *Lota lota* 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 11 and 12. There were no known Chinook or fall chum salmon capture mortalities. Thirteen Chinook salmon had 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.

Chinook salmon samples collected from driftnets were composed of 467 (65%) males and 253 (35%) females. Chinook salmon were captured in all sampling strata. Fall chum salmon samples from driftnets were composed of 669 (65%) males and 358 (35%) females. There were no fall chum salmon captured in the LBF strata. ASL samples from 714 Chinook and 939 fall chum salmon were collected and are processed at the ADF&G age determination laboratory in Anchorage. Genetic samples from 710 Chinook and 976 fall chum salmon were collected and are processed at the ADF&G genetics laboratory in Anchorage and then are forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia.

The objective to collect a minimum of 160 Chinook salmon ASL samples was met in 2 of the 3 strata, while the objective to collect 160 fall chum salmon ASL samples was met in 3 of the 4 strata (Table 13). Goals to collect Chinook and fall chum tissue samples for genetic stock identification were achieved.

CLIMATE AND HYDROLOGIC OBSERVATIONS

Weather and water observations were recorded at the sonar site daily (Appendix B). Water temperature on the left bank decreased over the course of the season, with a maximum recording of 18.3°C on July 6 and a minimum recording of 3.4°C on October 5 (Figure 21). The water level was near the historic mean upon arrival at the project site on June 26 and remained near the 1995 through 2013 historic mean the entire season, with 3 brief exceptions. Water levels rose above the mean level August 24 through September 5, September 9 through September 14, and September 28 through the end of field operations. Overall, between June 26 and October 6, the water level decreased 1.7 m from 5.8 m to 4.1 m. The lowest water level recorded during the season was 4.0 m on September 27, while the highest was 5.9 m on June 27 (Figure 22). All goals to collect climatic and hydrologic measurements were achieved this season.

DISCUSSION

Because multiple lower river run assessment projects indicated the 2014 Chinook salmon run timing was tracking earlier than historical averages, the Eagle sonar project began on June 27, which is 8 days earlier than the historical average (2007–2013) start date of July 5. The early start accounted for approximately 4,282 Chinook salmon or 7% of the total Chinook salmon passage past the sonar. Similar to the Chinook salmon run, the fall chum salmon run began 10 days early this season (August 8) based on the (2007–2013) average crossover date of August 17.

Both sonars performed well over the entire season, with no major technical difficulties or failures. There were minimal interruptions or problems with detection caused by heavy silt or high water. Rapid water level fluctuations coupled with substantial debris necessitated moving the transducers and fish leads to deeper or shallower water frequently. Heavy snowfall and cold temperatures during the last weeks of the project where unfavorable and made test fishing as well as break down uncomfortable. Icy road conditions, especially on the Alaska Highway from the Taylor highway to Fairbanks, made transporting equipment and crew by truck from Eagle to Fairbanks more difficult than usual.

We have concluded that echograms were easier to enumerate while subsampling the nearshore strata on the left bank with a higher ping rate, and there was no significant difference in daily passage rates calculated from the 2 sub-samples. Additionally, because increasing the ping rate in the nearshore stratum improved visual detection on echograms, it suggested that stratifying the sampling range during the fall chum migration could be beneficial. The Simrad controller software worked well as far as allowing users to configure the sounder to sample multiple strata.

Prior to this season, passage estimation was calculated by hand entering split-beam and DIDSON counts into a Microsoft® Excel spreadsheet. Computation in the spreadsheet expanded DIDSON counts for the full hour, adjusted counts for missing samples from both banks, and calculated the daily passage by summing the hourly passage rates for each hour (Lozori 2015). This season, the use of Excel was eliminated and text files output from Echotastic were directly imported into R. Passage estimation was calculated using an R script. This method simplified passage estimation by eliminating several calculations for missing data, as well as eliminating error from potential data entry mistakes. Additionally, the R script output provided diagnostic tables and charts, which presented daily information pertaining to hourly passage, fish distribution, and daily passage estimates by stratum. The output information provided useful inseason analysis of fish passage, which helped evaluate the accuracy of the sonar estimates.

In 2013, significant shallowing on the right bank upstream of Calico Bluff prevented Chinook salmon fishing at the traditional site. An alternative site was selected but was not effective in capturing Chinook salmon (Lozori 2015). During the 2014 season, a new site upstream of the sonar site was selected. The site had few snags, moderate current, and was a shorter distance from the sonar site than Calico Bluff. Although the total catch of Chinook salmon (both banks combined) was the highest recorded this season since 2007, right bank catches only accounted for 19% of the total catch compared to the 5-year average of 52% (2008–2012) when the fishery was conducted at Calico Bluff (Figure 23).

It is interesting to note that, considering right bank passage of Chinook salmon at the sonar site averaged approximately 20% (2007–2013) of the total run, during years the sample test fishery was conducted at Calico Bluff nearly half of the total catch was sampled on the right bank. Multiple factors may have played a role such as water levels, higher passage on the right bank at Calico Bluff, and fishing effort. Because percentages of catches and passage by bank can be disproportionate at the Eagle sonar project, researchers should be cautious pooling results from both banks when analyzing age, sex, and genetic information.

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TABLES AND FIGURES

Table 1.–Technical specifications and settings for the dual-frequency identification sonar (DIDSON LR) at the Eagle sonar site on the Yukon River, 2014.

Setting	Strata[a]	Value
Mode	S4	Identification
	S5	Detection
Frequency (MHz)	S4	1.20
	S5	0.70
Number of beams	S4	96
	S5	48
Start range (m)	S4	0.83
	S5	20.84
Frame rate	S4	7 frames/s
	S5	4 frames/s
Window length (m)	S4, S5	20.01
Range bin size	S4, S5	40 mm
Duration in minutes	S4, S5	30
Field of view	S4, S5	29°

[a] The DIDSON was aimed to ensonify a range of 40 m, beginning 0.83 m from the face of the transducer, with 2 sampling strata (S4: 0.83–20.83 m and S5: 20.83–40.83 m).

Table 2.–Split-beam sonar system settings at the Eagle sonar site on the Yukon River 2014.

Component	Setting	Strata [a]	Value
Transducer	Beam size (h x w)	All	2.5º x 10.0º
Echosounder	Power output (W)	All	500
	Pulse width (µ)	All	256
	Ping rate (pps)	S1	8.33
		S2	4.16
		S3	8.33
	Range (m)	S1	50
		S2	150
		S3	75
	Duration (min)	S1	30
		S2	30
		S3	60

[a] When counting Chinook salmon, the split-beam system was aimed to ensonify a range of approximately 150 m from the transducer, and sampled 2 strata, (S1: approximately 0–50 m and S2: approximately 50–150 m). When counting fall chum salmon, the split-beam system was aimed to ensonify 1 stratum (S3, approximately 0–75 m).

Table 3.–Net schedule of mesh sizes (in) for species composition and additional Chinook salmon samples, all zones, at the Eagle sonar project on the Yukon River, 2014.

Sampling purpose	Day	Drift 1	Drift 2	Drift 3
Species composition	1	5.25	7.50	NA
	2	7.50	5.25	NA
Additional Chinook salmon samples	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 4.–Specifications for drift gillnets used for test fishing at the Eagle sonar project on the Yukon River, 2014.

Method	Stretch mesh size (in)	Stretch mesh size (mm)	Mesh diameter (mm)	Meshes deep (MD)	Depth (m)
Drift	5.25	133	85	69	8.0
	6.50	165	105	55	7.9
	7.50	191	121	48	8.0
	8.50	216	137	43	8.1
Beach walk	5.25	133	85	26	3.0
	7.50	191	121	18	3.0

Note: Gillnet webbing consisted of Momoi MTC or MT, shade 11, double knot multifilament nylon twine.

Table 5.–Estimated daily and cumulative Chinook salmon passage by bank at the Eagle sonar project on the Yukon River, 2014.

	Daily			Cumulative			
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
6/27 [a]	0	95	95	0	95	95	0.001
6/28 [b]	41	183	224	41	278	319	0.005
6/29	115	232	347	156	510	666	0.010
6/30	208	299	507	364	809	1,173	0.018
7/1	218	402	620	582	1,211	1,793	0.028
7/2	271	423	694	853	1,634	2,487	0.039
7/3	460	403	863	1,313	2,037	3,350	0.053
7/4	535	397	932	1,848	2,434	4,282	0.067
7/5	586	550	1,136	2,434	2,984	5,418	0.085
7/6	870	596	1,466	3,304	3,580	6,884	0.108
7/7	1,023	630	1,653	4,327	4,210	8,537	0.134
7/8	1,129	578	1,707	5,456	4,788	10,244	0.161
7/9	1,324	574	1,898	6,780	5,362	12,142	0.191
7/10	1,115	601	1,716	7,895	5,963	13,858	0.218
7/11	1,328	664	1,992	9,223	6,627	15,850	0.250 [c]
7/12	1,678	496	2,174	10,901	7,123	18,024	0.284
7/13	1,498	562	2,060	12,399	7,685	20,084	0.316
7/14	1,534	526	2,060	13,933	8,211	22,144	0.349
7/15	1,742	422	2,164	15,675	8,633	24,308	0.383
7/16	1,954	491	2,445	17,629	9,124	26,753	0.421
7/17	2,116	480	2,596	19,745	9,604	29,349	0.462
7/18	2,346	454	2,800	22,091	10,058	**32,149**	**0.506** [d]
7/19	2,189	538	2,727	24,280	10,596	34,876	0.549
7/20	2,168	594	2,762	26,448	11,190	37,638	0.593
7/21	2,038	559	2,597	28,486	11,749	40,235	0.634
7/22	2,738	535	3,273	31,224	12,284	43,508	0.685
7/23	2,415	534	2,949	33,639	12,818	46,457	0.732
7/24	2,440	424	2,864	36,079	13,242	49,321	0.777
7/25	2,184	322	2,506	38,263	13,564	51,827	0.816
7/26	1,753	232	1,985	40,016	13,796	53,812	0.848
7/27	1,216	200	1,416	41,232	13,996	55,228	0.870
7/28	838	131	969	42,070	14,127	56,197	0.885
7/29	1,262	132	1,394	43,332	14,259	57,591	0.907
7/30	1,128	176	1,304	44,460	14,435	58,895	0.928
7/31	862	158	1,020	45,322	14,593	59,915	0.944
8/1	732	92	824	46,054	14,685	60,739	0.957

-continued-

Table 5.–Page 2 of 2.

Date	Daily			Cumulative			
	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
8/2	618	84	702	46,672	14,769	61,441	0.968
8/3	538	63	601	47,210	14,832	62,042	0.977
8/4	378	108	486	47,588	14,940	62,528	0.985
8/5	288	80	368	47,876	15,020	62,896	0.991
8/6	229	72	301	48,105	15,092	63,197	0.996
8/7 [e]	244	41	285	48,349	15,133	63,482	1.000
Var			148,165	23,913	172,078		
SE	385	155	415				

[a] Right bank sonar operational.
[b] Sonar operational on both banks.
[c] Boxed area identifies second and third quartile of run.
[d] Bold identifies median day of passage.
[e] Last day of Chinook salmon estimation.

Table 6.–Sampling time, in minutes, missed by bank, zone, and date during Chinook salmon sampling at the Eagle sonar project on the Yukon River, 2014.

	Left Bank		Right Bank	
Date	0-50 m	50-150 m	0-20 m	20-40 m
6/27	1,368	630	590	661
6/28	638	390	205	332
6/29	-42	ND [a]	9	126
6/30	170	ND [a]	105	313
7/01	261	ND [a]	54	240
7/02	24	ND [a]	63	113
7/03	-63	422	42	119
7/04	-20	26	38	30
7/05	18	2	0	0
7/06	0	0	0	0
7/07	1	0	41	60
7/08	-10	30	0	30
7/09	0	0	0	0
7/10	1	0	30	37
7/11	0	0	0	0
7/12	0	0	0	0
7/13	0	0	0	0
7/14	0	0	0	0
7/15	0	0	0	0
7/16	0	0	30	30
7/17	0	0	0	0
7/18	0	0	3	0
7/19	-20	31	0	0
7/20	0	0	0	0
7/21	278	280	0	30
7/22	26	42	90	72
7/23	23	30	30	41
7/24	0	0	0	0
7/25	0	0	0	0
7/26	10	8	0	0
7/27	0	0	0	0
7/28	4	12	30	30
7/29	30	33	0	0
7/30	0	0	0	0
7/31	0	0	0	0
8/01	0	0	0	0
8/02	0	0	0	0
8/03	60	60	639	660
8/04	0	0	480	480
8/05	36	30	4	20
8/06	60	63	16	30

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Table 6.–Page 2 of 2.

Date	Left Bank 0-50 m	Left Bank 50-150 m	Right Bank 0-20 m	Right Bank 20-40 m
8/07	150	120	30	0
8/08 [b]	0	1	31	60
8/09	0	0	0	0
8/10	0	0	42	30
8/11	0	0	0	0
8/12	392	330	16	30
Total min	3,395	2,540	2,618	3,574
Total h	56.6	42.3	43.6	59.6

Note: ND indicates that data was not collected. Negative numbers are result of collection software over running the sample period.

[a] Problems with sampling software and sonar required sampling the entire range (0–150 m), until malfunctions were corrected and the range could be stratified.

[b] Crossover adjustment post season lead to the inclusion of several days of stratified sampling on the left bank.

Table 7.–Eagle sonar estimate, Eagle area subsistence harvest, and border passage estimates, 2005–2014.

	Sonar estimate		Subsistence harvest		Border passage estimate	
Date	Chinook	Fall chum	Chinook	Fall chum	Chinook	Fall 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	265,008 [a]	1,999	18,691	39,698	246,317
2008	38,097	185,409 [a]	815	11,381	37,282	174,028
2009	69,957	101,734 [a]	382	6,995	69,575	94,739
2010	35,074	133,413 [a]	604	11,432	34,470	121,498
2011	51,271	224,355 [a]	370	12,477	50,901	211,878
2012	34,747	153,248 [a]	91	11,681	34,656	141,567
2013	30,725	216,794 [a]	152	12,692	30,573	204,102
2014	63,482	172,887	51 [b]	13,041 [b]	63,431	159,846

Note: ND indicates that data was not collected. 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 fall 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] Expanded sonar estimate, includes expansion for fish that may have passed after sonar operations ceased.

[b] Subsistence estimates for 2014 are preliminary.

Table 8.–Estimated daily and cumulative fall chum salmon passage by bank at the Eagle sonar project, on the Yukon River, 2014.

	Daily			Cumulative			
Date	Left bank	Right bank	Total	Left bank	Right bank	Total	Proportion of total passage
8/08 [a]	230	38	268	230	38	268	0.002
8/09	222	50	272	452	88	540	0.003
8/10	162	48	210	614	136	750	0.005
8/11	102	42	144	716	178	894	0.005
8/12	114	32	146	830	210	1,040	0.006
8/13	104	10	114	934	220	1,154	0.007
8/14	92	36	128	1,026	256	1,282	0.008
8/15	106	66	172	1,132	322	1,454	0.009
8/16	84	44	128	1,216	366	1,582	0.010
8/17	119	26	145	1,335	392	1,727	0.010
8/18	125	32	157	1,460	424	1,884	0.011
8/19	190	42	232	1,650	466	2,116	0.013
8/20	329	58	387	1,979	524	2,503	0.015
8/21	521	78	599	2,500	602	3,102	0.019
8/22	713	178	891	3,213	780	3,993	0.024
8/23	809	212	1,021	4,022	992	5,014	0.030
8/24	982	240	1,222	5,004	1,232	6,236	0.038
8/25	1,097	292	1,389	6,101	1,524	7,625	0.046
8/26	1,200	322	1,522	7,301	1,846	9,147	0.055
8/27	1,274	395	1,669	8,575	2,241	10,816	0.065
8/28	1,263	320	1,583	9,838	2,561	12,399	0.075
8/29	1,276	398	1,674	11,114	2,959	14,073	0.085
8/30	1,108	334	1,442	12,222	3,293	15,515	0.094
8/31	1,312	276	1,588	13,534	3,569	17,103	0.103
9/01	1,522	364	1,886	15,056	3,933	18,989	0.115
9/02	1,490	278	1,768	16,546	4,211	20,757	0.125
9/03	1,349	394	1,743	17,895	4,605	22,500	0.136
9/04	1,272	418	1,690	19,167	5,023	24,190	0.146
9/05	1,214	630	1,844	20,381	5,653	26,034	0.157
9/06	1,353	610	1,963	21,734	6,263	27,997	0.169
9/07	1,588	1,018	2,606	23,322	7,281	30,603	0.185
9/08	2,016	714	2,730	25,338	7,995	33,333	0.201
9/09	2,083	534	2,617	27,421	8,529	35,950	0.217
9/10	1,712	662	2,374	29,133	9,191	38,324	0.231
9/11	1,574	562	2,136	30,707	9,753	40,460	0.244
9/12	1,517	338	1,855	32,224	10,091	42,315	0.255 [b]
9/13	1,282	200	1,482	33,506	10,291	43,797	0.264
9/14	1,282	326	1,608	34,788	10,617	45,405	0.274
9/15	1,247	1,222	2,469	36,035	11,839	47,874	0.289
9/16	1,857	1,146	3,003	37,892	12,985	50,877	0.307
9/17	1,963	1,182	3,145	39,855	14,167	54,022	0.326
9/18	3,164	946	4,110	43,019	15,113	58,132	0.351

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	Daily			Cumulative			
Date	Left Bank	Right Bank	Total	Left Bank	Right Bank	Total	Proportion of Total Passage
9/19	3,700	1,558	5,258	46,719	16,671	63,390	0.383
9/20	5,134	1,380	6,514	51,853	18,051	69,904	0.422
9/21	7,038	2,712	9,750	58,891	20,763	79,654	0.481
9/22	5,685	3,718	9,403	64,576	24,481	**89,057**	**0.537** [c]
9/23	5,735	4,290	10,025	70,311	28,771	99,082	0.598
9/24	6,722	4,728	11,450	77,033	33,499	110,532	0.667
9/25	5,228	4,072	9,300	82,261	37,571	119,832	0.723
9/26	4,099	3,966	8,065	86,360	41,537	127,897	0.772
9/27	3,817	3,018	6,835	90,177	44,555	134,732	0.813
9/28	3,149	2,602	5,751	93,326	47,157	140,483	0.848
9/29	2,478	2,410	4,888	95,804	49,567	145,371	0.877
9/30	2,276	1,662	3,938	98,080	51,229	149,309	0.901
10/01	1,828	1,952	3,780	99,908	53,181	153,089	0.924
10/02	1,840	1,400	3,240	101,748	54,581	156,329	0.943
10/03	1,580	1,166	2,746	103,328	55,747	159,075	0.960
10/04	1,241	1,222	2,463	104,569	56,969	161,538	0.975
10/05	936	1,200	2,136	105,505	58,169	163,674	0.988
10/06 [d]	1,057	984	2,041	106,562	59,153	165,715	1.000
Var				10,806	307,050	317,856	
SE				104	554	564	

Note: Median is based on inseason sonar estimates and does not include post-season expansion.

[a] First day of fall chum salmon 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.

Table 9.–Sampling time, in minutes, missed by bank, zone, and date during summer chum salmon sampling at the Eagle sonar project on the Yukon River, 2014.

	Left bank	Right bank	
Date	0-75 m	0-20 m	20-40 m
8/13 [a]	0	0	0
8/14	0	0	0
8/15	0	0	0
8/16	0	0	0
8/17	71	0	0
8/18	1	0	0
8/19	0	30	0
8/20	0	0	0
8/21	0	0	0
8/22	0	0	0
8/23	0	0	0
8/24	1	0	0
8/25	0	0	0
8/26	0	0	0
8/27	0	13	30
8/28	0	0	0
8/29	1	14	0
8/30	0	0	0
8/31	0	0	0
9/01	25	0	0
9/02	211	0	0
9/03	-1	0	0
9/04	0	0	0
9/05	60	30	0
9/06	12	0	0
9/07	0	0	0
9/08	0	0	0
9/09	0	0	0
9/10	61	0	0
9/11	0	0	0
9/12	0	0	0
9/13	0	60	30
9/14	630	300	330
9/15	642	330	330
9/16	60	0	30
9/17	0	0	0
9/18	0	0	0
9/19	0	0	0
9/20	0	0	0
9/21	0	0	0
9/22	0	0	0

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Table 9.–Page 2 of 2.

	Left bank	Right bank	
Date	0-75 m	0-20 m	20-40 m
9/23	0	0	0
9/24	0	0	0
9/25	0	0	0
9/26	1	0	0
9/27	0	0	0
9/28	0	0	0
9/29	0	0	0
9/30	0	105	68
10/01	0	14	30
10/02	0	0	0
10/03	0	0	0
10/04	0	0	0
10/05	0	0	0
10/06	709	360	386
Total min	2,484	1,256	1,234
Total h	41.4	20.9	20.6

Note: ND indicates that data were not collected. Negative numbers are result of collection software over running sample period.

[a] Crossover adjustment postseason led to the inclusion of several days of stratified sampling on the left bank.

Table 10.–Fish caught with gillnets at the Eagle sonar project, on the Yukon River, 2014.

Species	Species composition	Chinook Salmon sample	Total
Chinook salmon	26	694	720
Fall chum salmon	1,023	4	1,027
sheefish	1	0	1
whitefish	2	0	2
burbot	6	0	6
grayling	4	0	4
Total	1,062	698	1,760

Table 11.–Species composition fishing effort, catch, and percentage by zone and mesh for Chinook and fall chum salmon, at the Eagle sonar project, on the Yukon River 2014.

	Mesh size	Effort	Chinook salmon		Fall chum salmon	
Zone[a]	(inches)	(fathom hours)	Catch	Percent	Catch	Percent
LBI	5.25	345.5	5	19	533	52
	7.50	335.3	1	4	230	22
Total		680.8	6	23	763	75
LBN	5.25	355.0	4	15	166	16
	7.50	343.7	10	38	89	9
Total		698.7	14	54	255	25
LBF	5.25	333.4	2	8	1	0
	7.50	329.3	4	15	4	0
Total		662.7	6	23	5	0
Grand total		2,042.1	26	100	1,023	100

[a] Gillnets were drifted through 3 zones on the left bank; left bank inshore (LBI) which was held from shore and led downstream while a boat drifted with the offshore end; left bank nearshore (LBN) which was drifted approximately 1 net length from shore; and left bank offshore (LBF) which was drifted approximately 2 net lengths from shore.

Table 12.–Chinook salmon sample fishing effort, catch, and percentage for Chinook and fall chum salmon, Eagle sonar project, on the Yukon River 2014.

	Mesh size	Effort	Chinook salmon		Fall chum salmon	
Zone[a]	(inches)	(fathom hours)	Catch	Percent	Catch	Percent
LBN	5.25	180.7	142	20	2	50
	6.50	162.5	137	20	0	0
	7.50	165.6	105	15	1	25
	8.50	168.9	111	16	1	25
Total		677.8	495	71	4	100
RBN	5.25	172.8	40	6	0	0
	6.50	173.7	36	5	0	0
	7.50	166.1	33	5	0	0
	8.50	162.7	26	4	0	0
Total		675.2	15	19	0	0
LBF	5.25	168.1	13	2	0	0
	6.50	167.4	18	3	0	0
	7.50	163.2	21	3	0	0
	8.50	158.8	12	2	0	0
Total		657.6	64	9	0	0
Grand Total		2,010.6	694	100	4	100

[a] Gillnets were drifted through 3 zones: left bank nearshore (LBN) which was drifted approximately 1 net length from shore; left bank offshore (LBF) which was drifted approximately 2 net lengths from shore; and right bank nearshore (RBN) which was drifted approximately 1 net length from shore.

Table 13.–Number of salmon sampled for scales, by stratum dates, to characterize age, sex, and length (ASL) composition at the Eagle sonar project, on the Yukon River 2014.

Stratum Dates [a]	Chinook salmon	Fall chum salmon
6/29–7/11	184	NA
7/12–7/24	376	NA
7/25–8/07	154	NA
8/08–8/20	NA	19
8/21–9/02	NA	207
9/03–9/15	NA	181
9/16–9/30[b]	NA	613
Total	714	1,020

Note: NA indicates that data is not applicable.

[a] Stratum dates are based on the species crossover date (August 8). This table does not represent total catch or samples by species.

[b] Last day of sample fishing

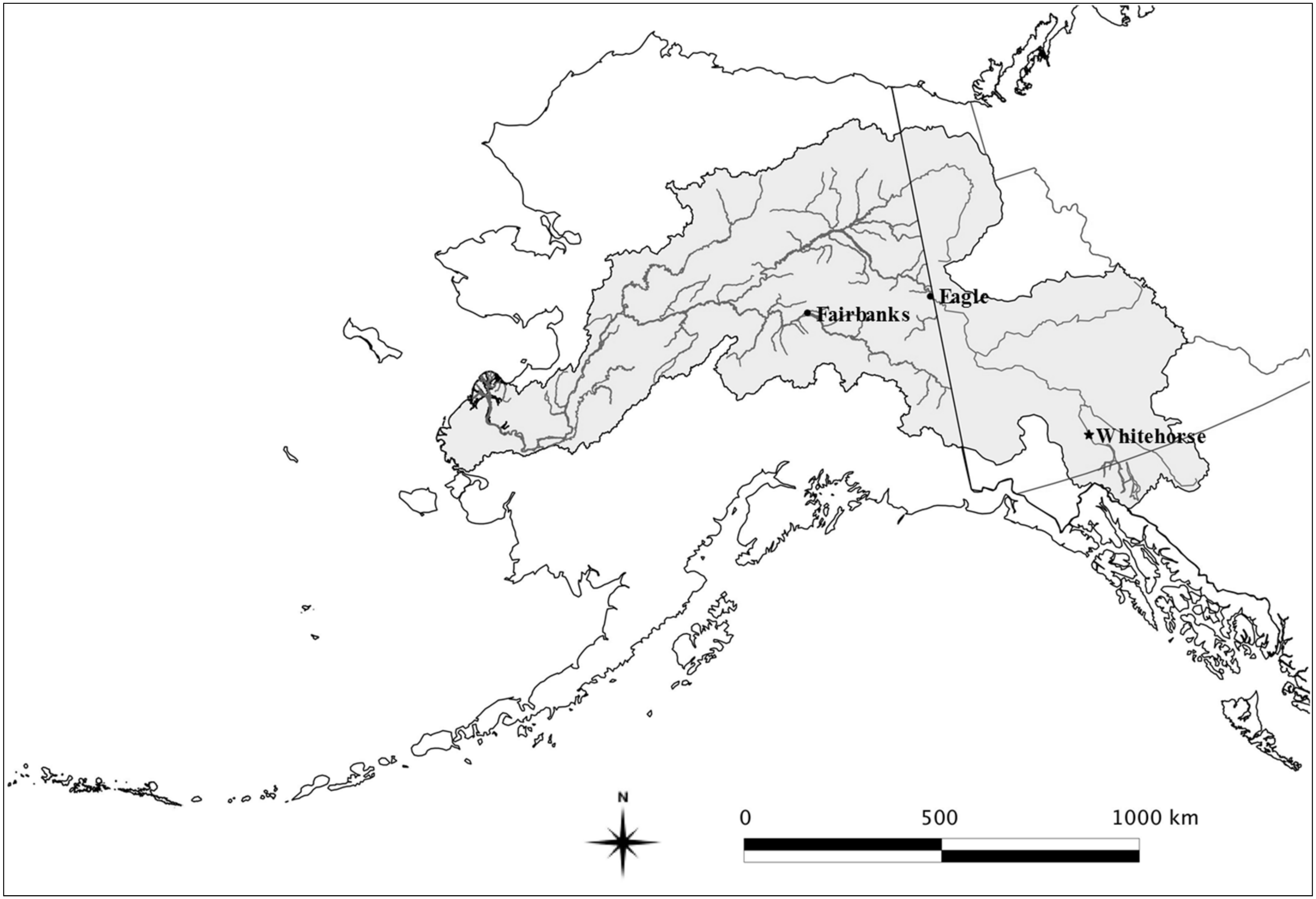


Figure 1.–Yukon River drainage.

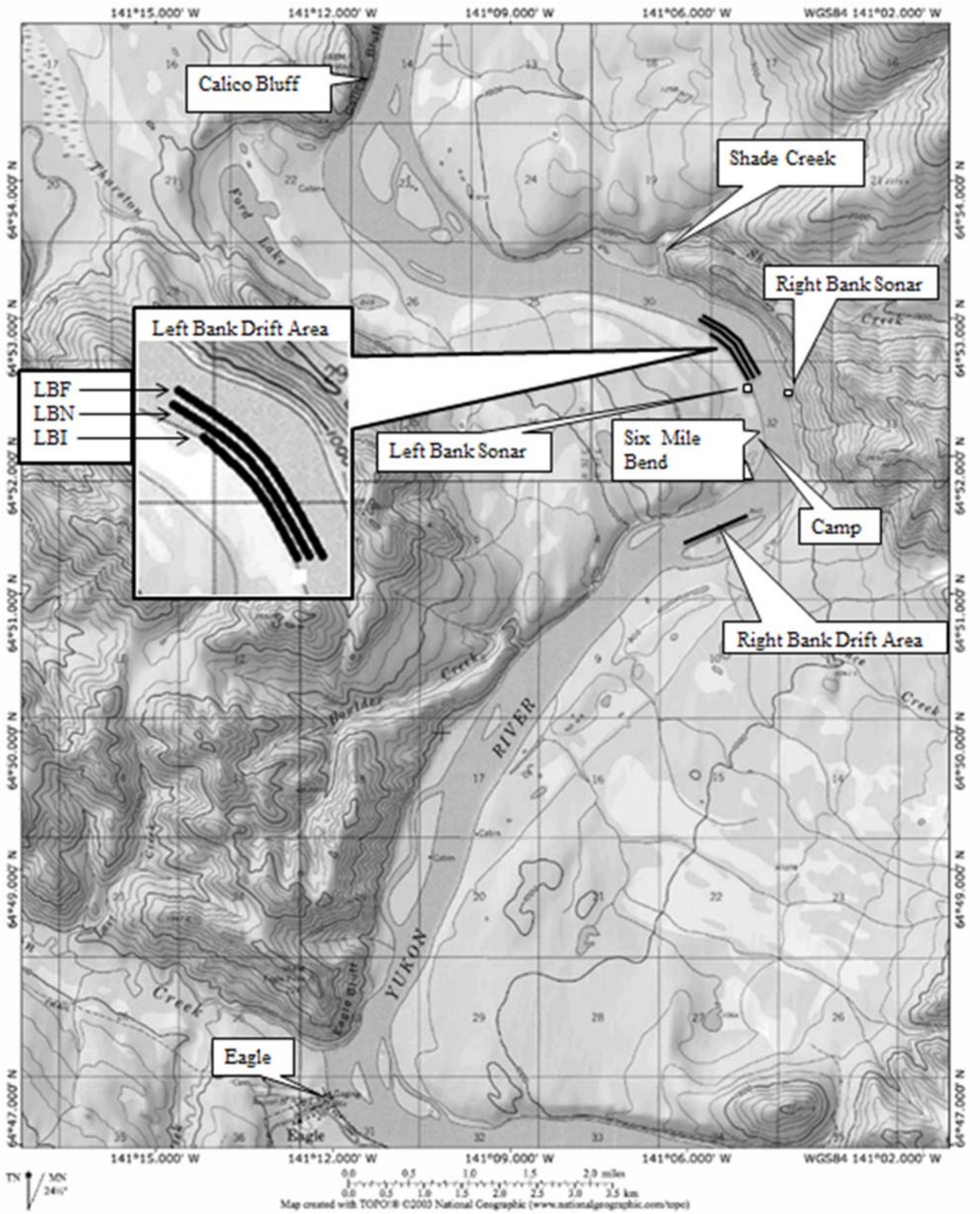


Figure 2.–Eagle sonar project site at Six Mile Bend on the Yukon River, showing sonar and drift gillnet fishing locations, 2014.

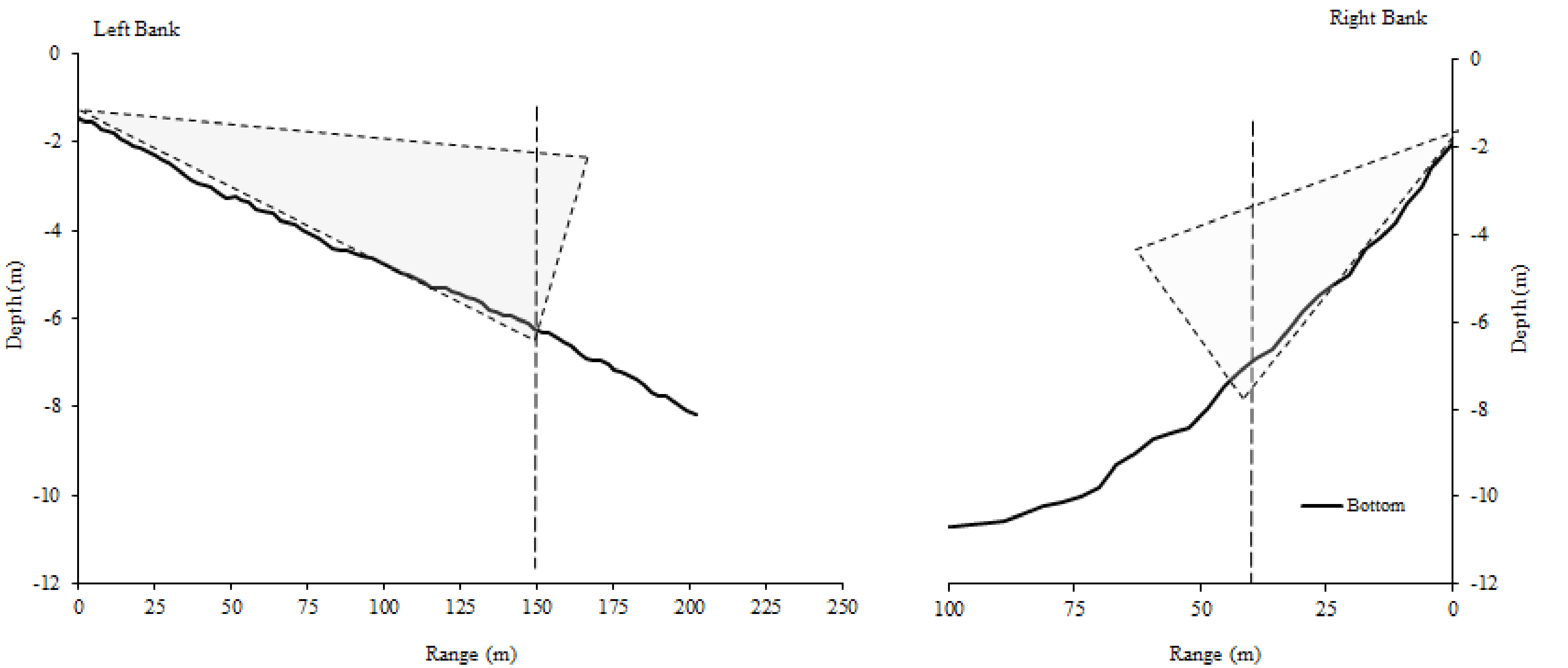


Figure 3.–Depth profile of Yukon River in front of transducers (downstream view), and approximate sonar coverage (not to scale) at the Eagle sonar project.

Note: To avoid damage to the outboard motor and transducer, bathymetric data collection began offshore at a depth of approximately 2 m. Data collected in 2013.

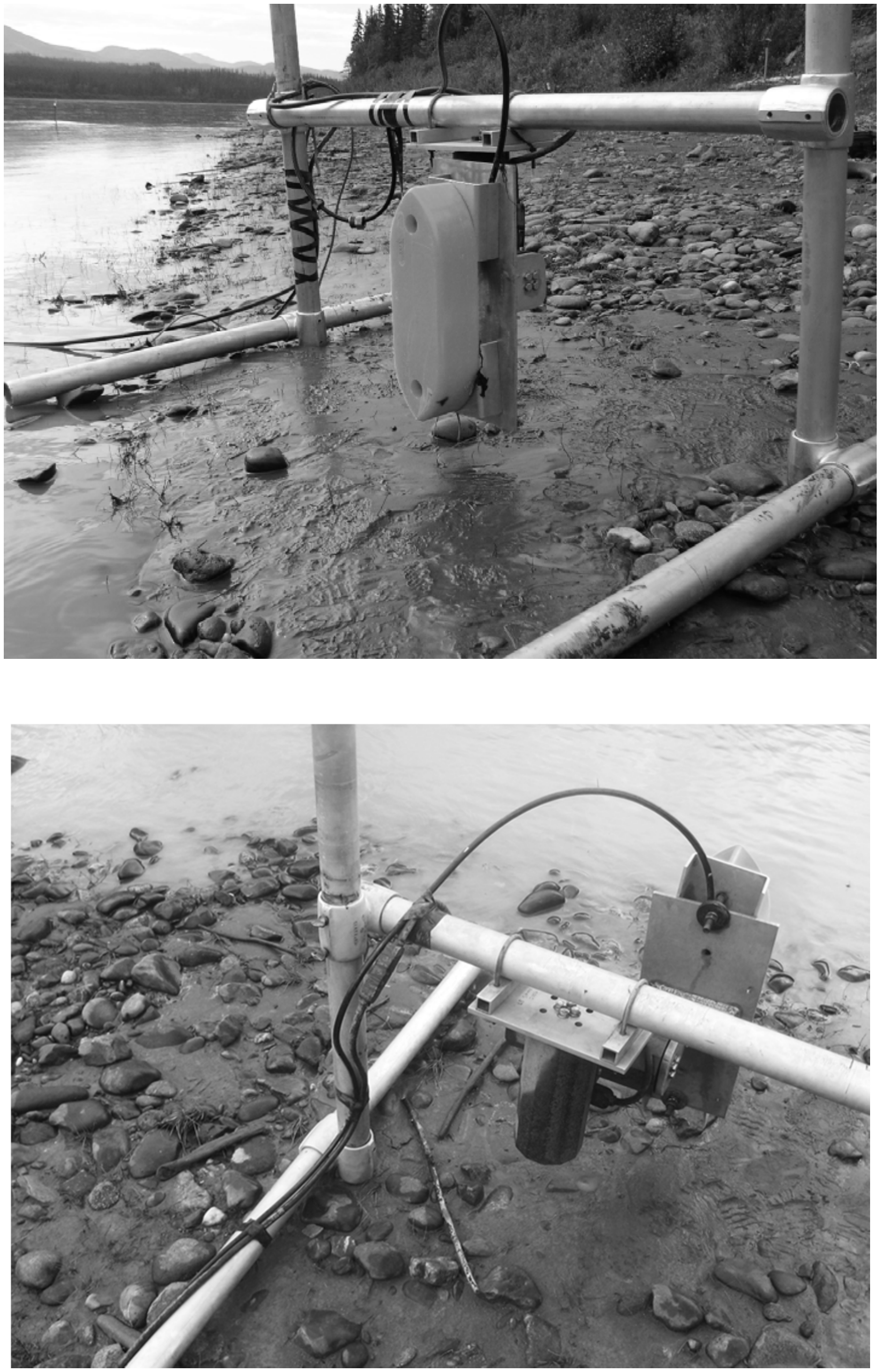


Figure 4.–Split-beam transducer mounted to an aluminum H-mount (top) and the same transducer mounted to 2 single-axis automated rotators (bottom), used on the left bank at the Eagle sonar project, on the Yukon River, 2014.

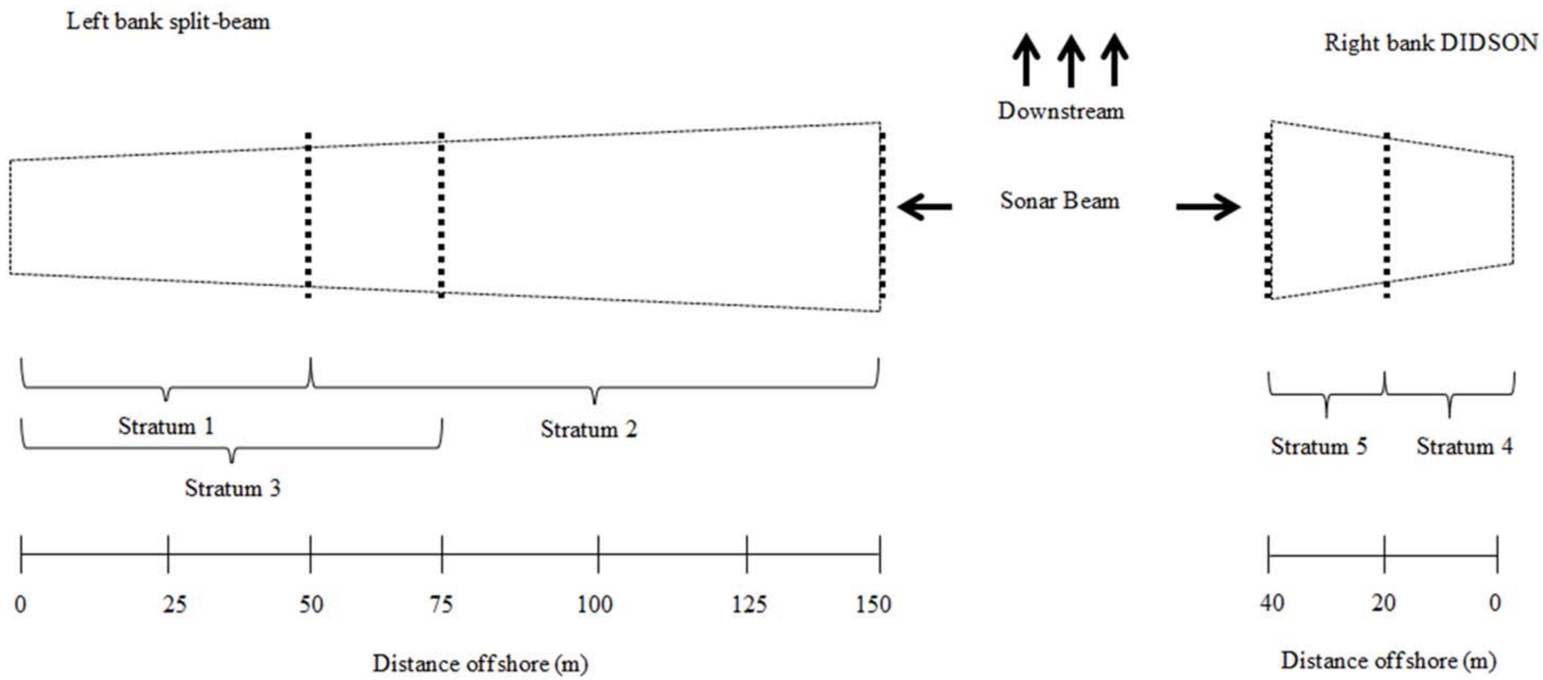


Figure 5.–Illustration of strata and approximate sonar ranges (not to scale) at the Eagle sonar project, on the Yukon River 2014.

Figure 6.–Portable tripod-style fish lead used on the left bank (top) and plastic snow fencing used on the right bank at the Eagle sonar project, on the Yukon River, 2014.

Figure 7.–View of a DIDSON mounted to aluminum H-mount with manual crank-style rotator at the Sheenjek sonar project. This mount is comparable to the one used at the Eagle sonar project, on the Yukon River.

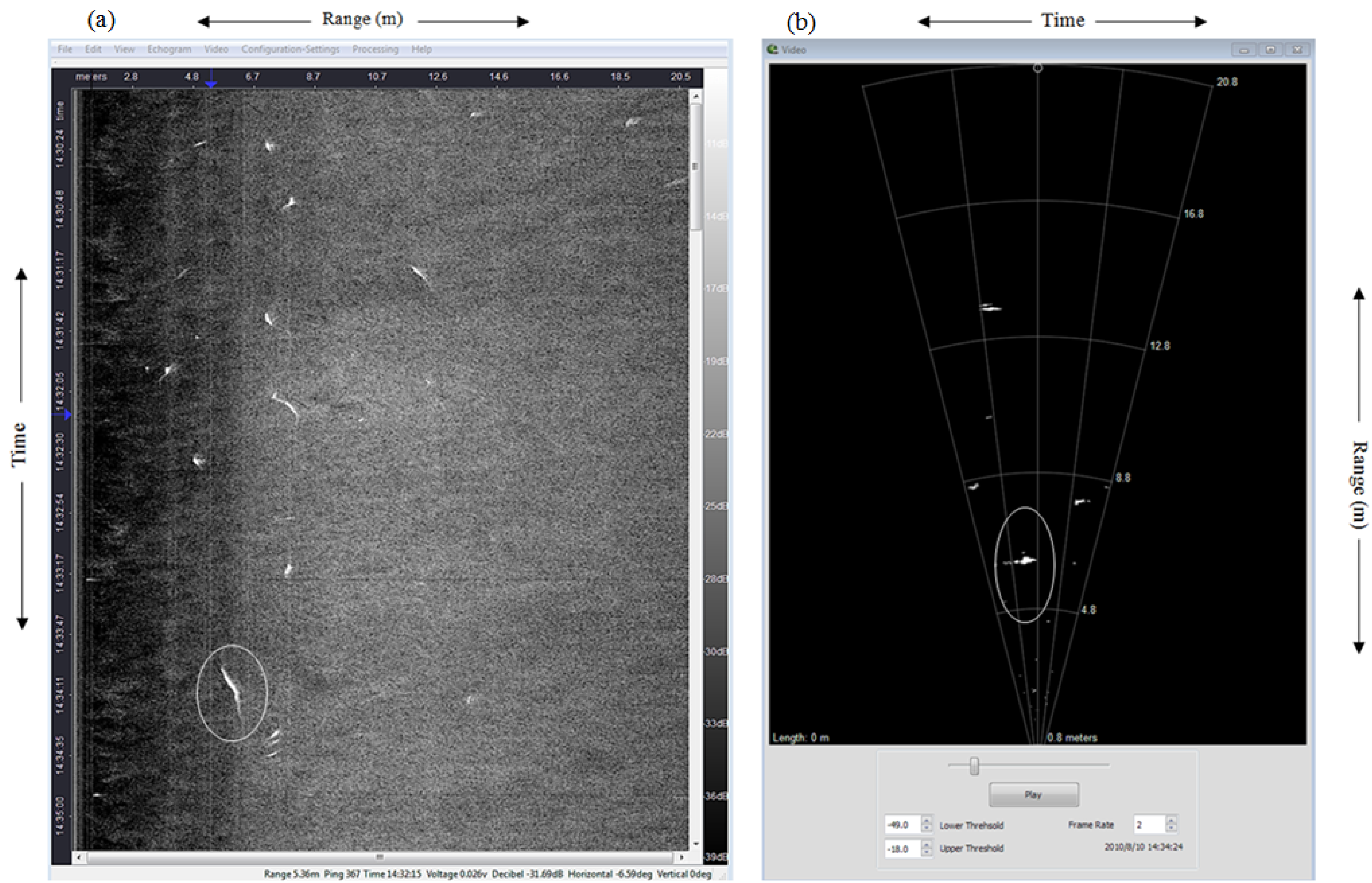


Figure 8.–Screenshots of echogram (a) and video (b) used to count and determine direction of travel from DIDSON data files at the Eagle sonar project on the Yukon River, 2014.

Note: Ellipse encompasses typical upstream migrating salmon.

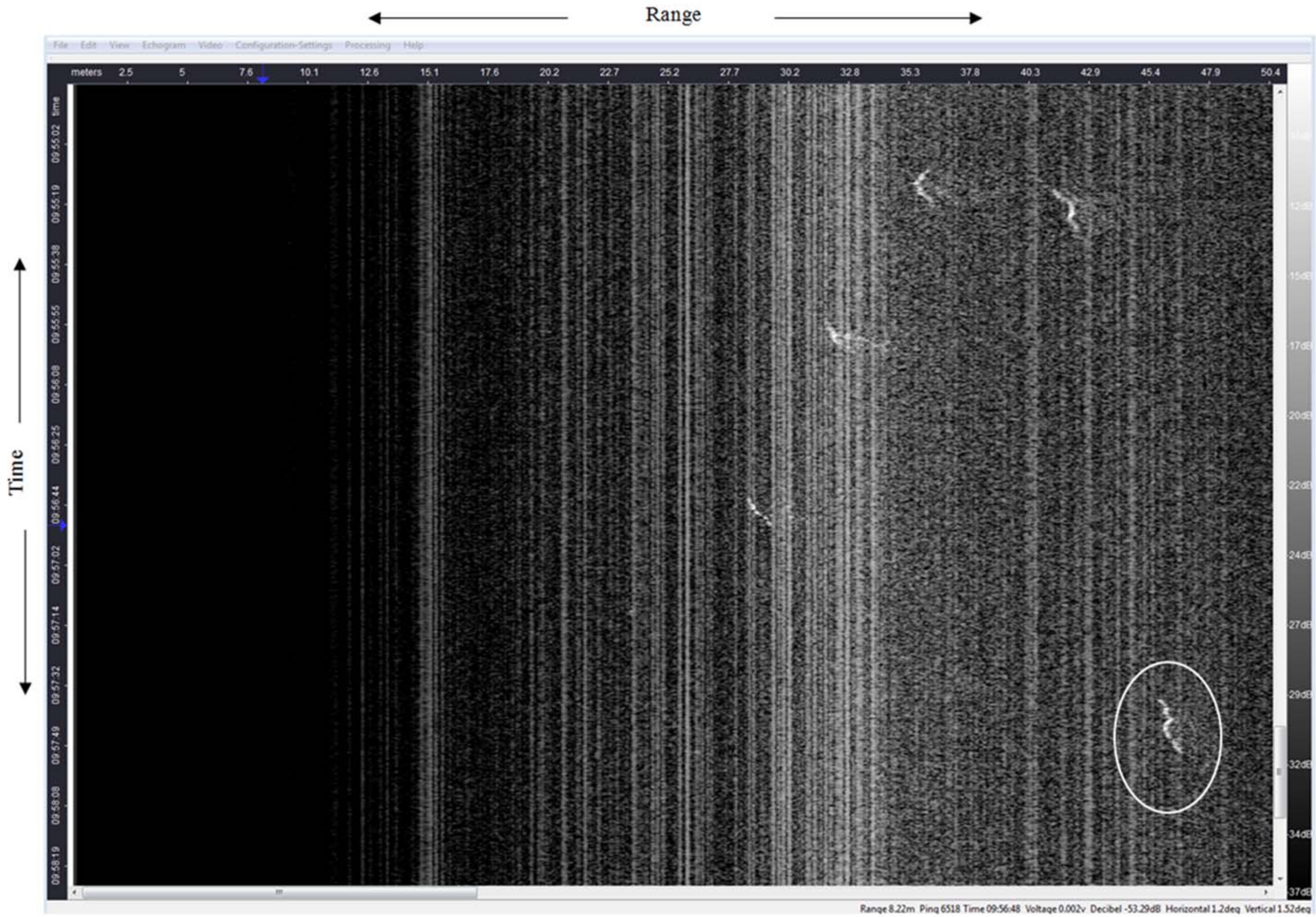


Figure 9.–Screenshot of echogram used to count and determine direction of travel from split-beam sonar data files at the Eagle sonar project on the Yukon River, 2014.

Note: Ellipse encompasses typical upstream migrating salmon.

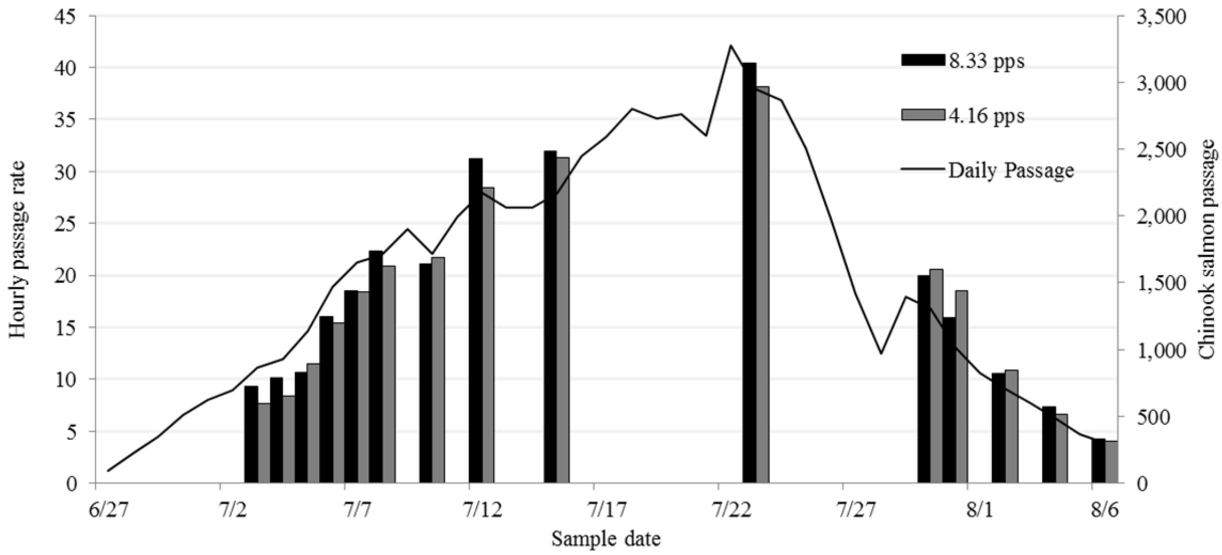


Figure 10.–Comparison of mean hourly left bank nearshore (0–50m) passage rates derived from sampling at 8.33 and 4.16 pps on randomly selected days, at the Eagle sonar project on the Yukon River, 2014.

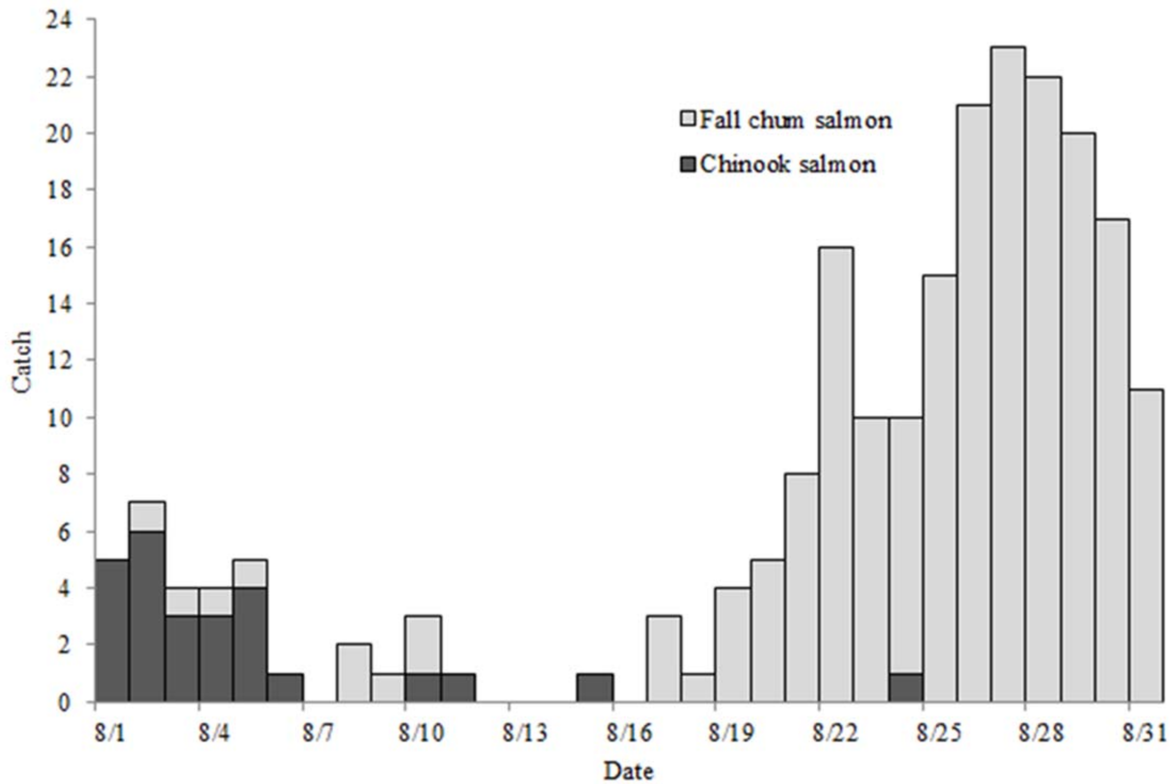


Figure 11.–Daily catch during species composition fishing at the Eagle sonar project, on the Yukon River, 2014.

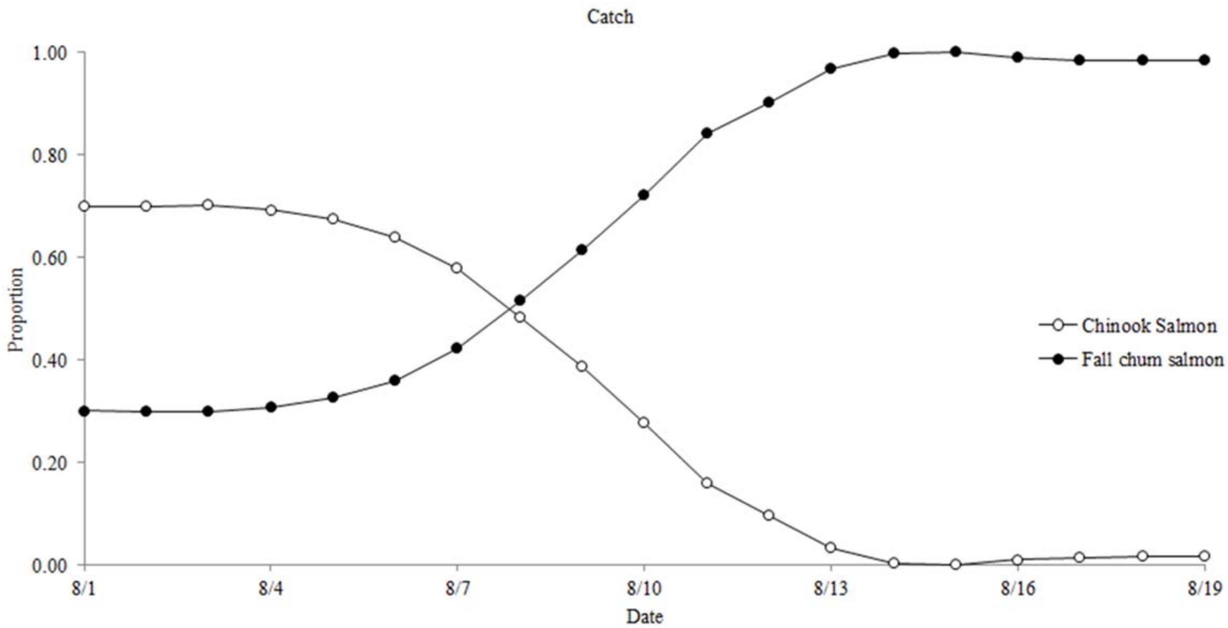


Figure 12.–Results of applying smoothing algorithm to Chinook and fall chum salmon species composition test fishery catch data at the Eagle sonar project, on the Yukon River, 2014. Species changeover date (August 8) determined at the point the curves intersect.

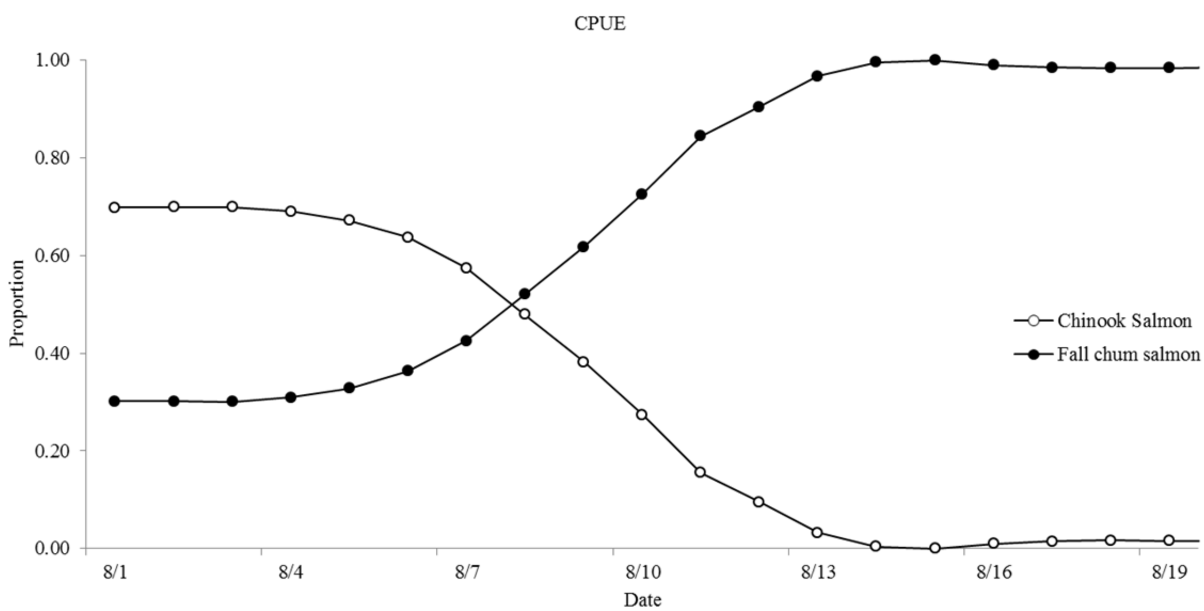
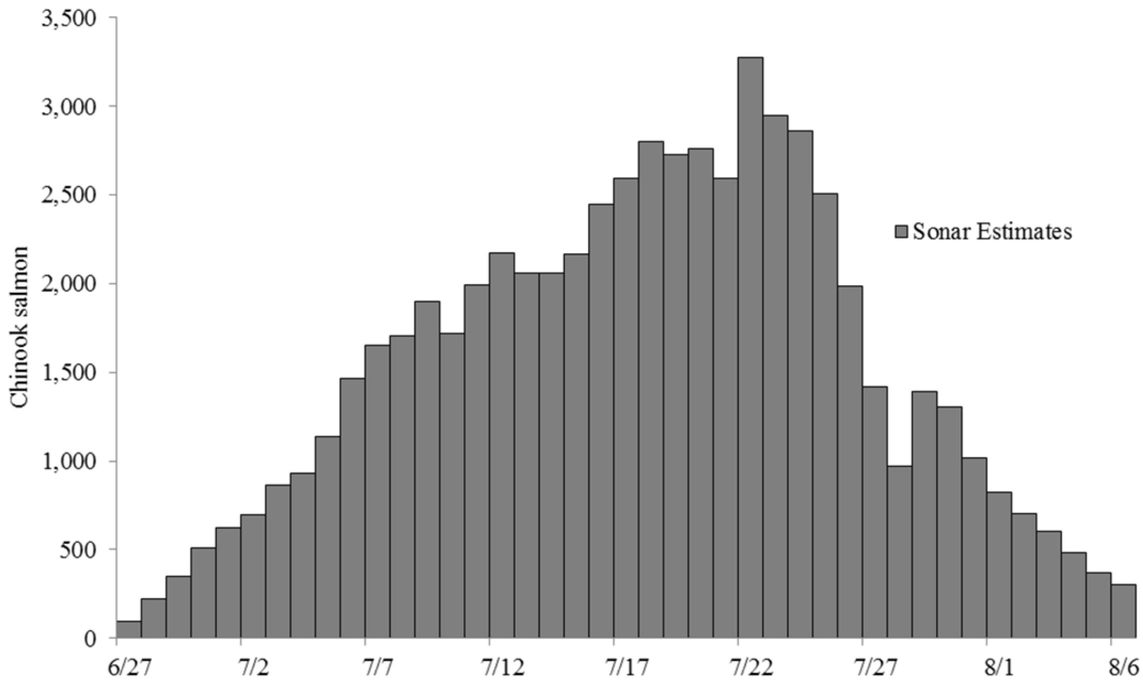


Figure 13.–Species changeover date of August 8, determined by applying smoothing algorithm to Chinook and fall chum salmon species composition test fishery CPUE data at the Eagle sonar project, on the Yukon River, 2014.



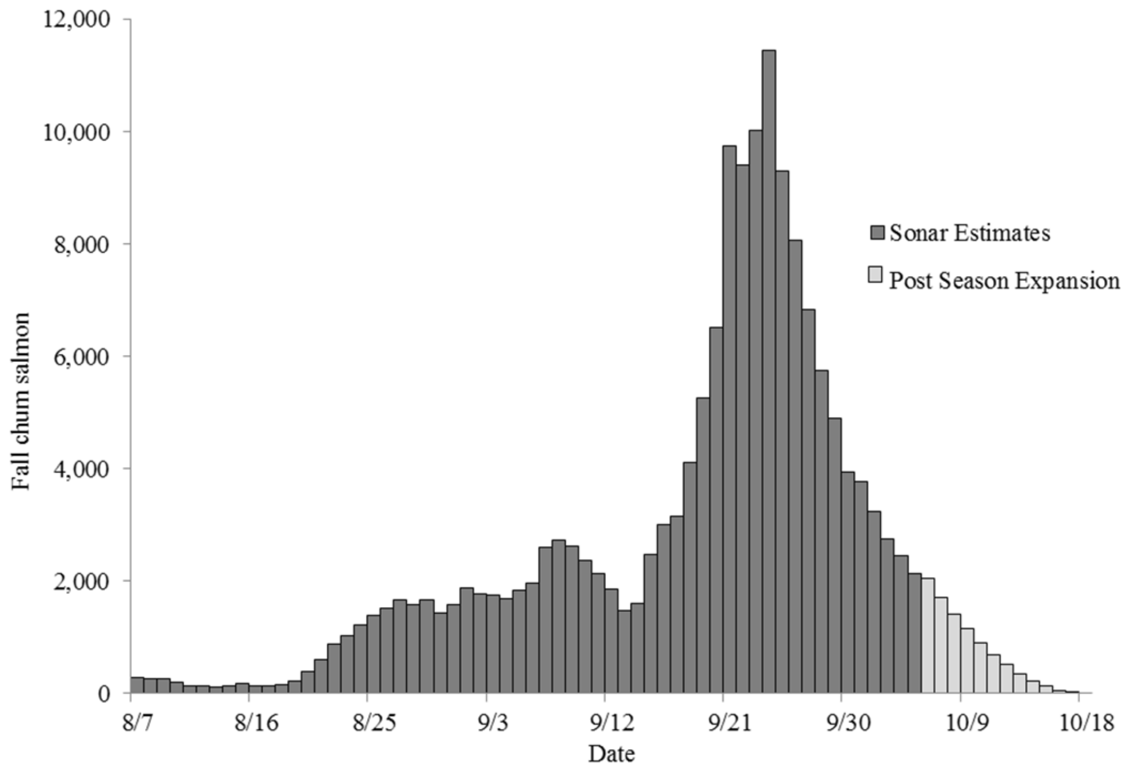
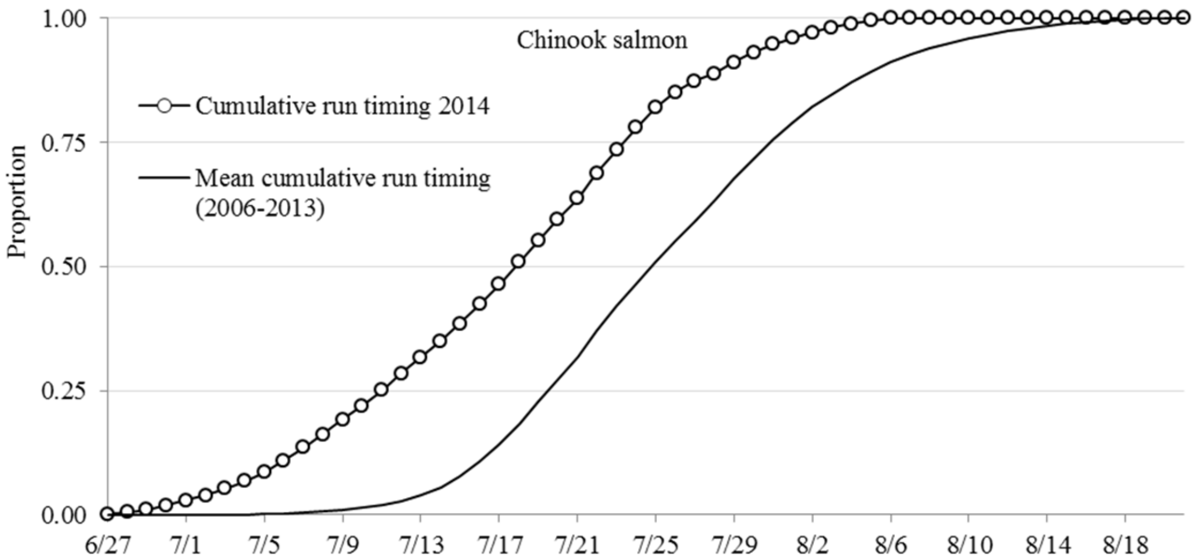


Figure 14.–Daily sonar estimates for Chinook salmon, June 27 through August 7, 2014 (top), and daily sonar estimates with postseason fall chum salmon expansion estimates for fall chum salmon, August 8 through October 18 (bottom).



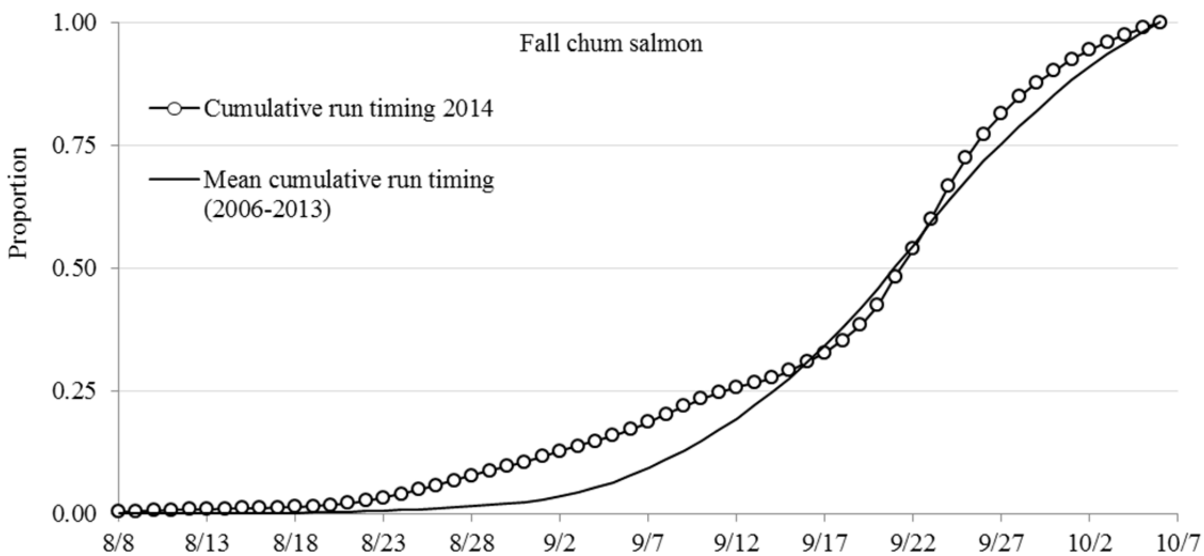


Figure 15.–2014 Chinook and fall chum salmon daily cumulative passage timing, compared to the 2005–2013 mean passage timing at the Eagle sonar project, on the Yukon River.

Note: Fall chum salmon cumulative passage timing does not include postseason expansion estimates.

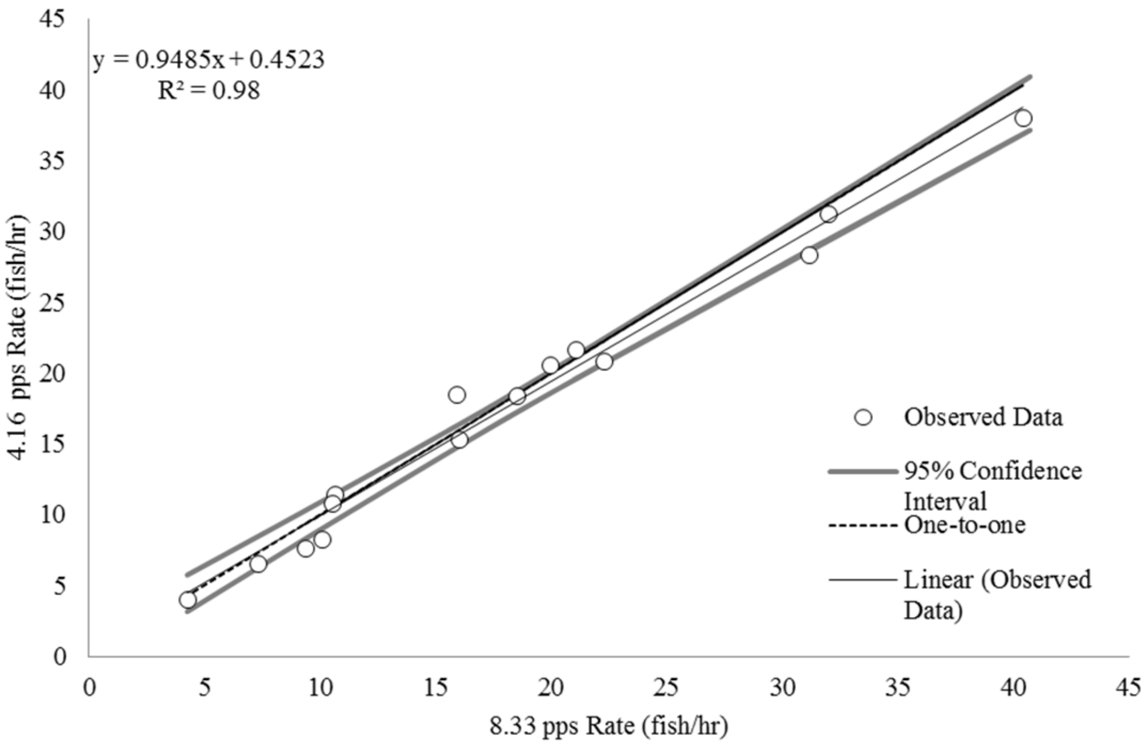


Figure 16.–Scatter plot of hourly passage rates on randomly selected days, from left bank nearshore (0–50 m) files sampled with 8.33 and 4.16 pings per second (pps) at the Eagle sonar project on the Yukon River, 2014.

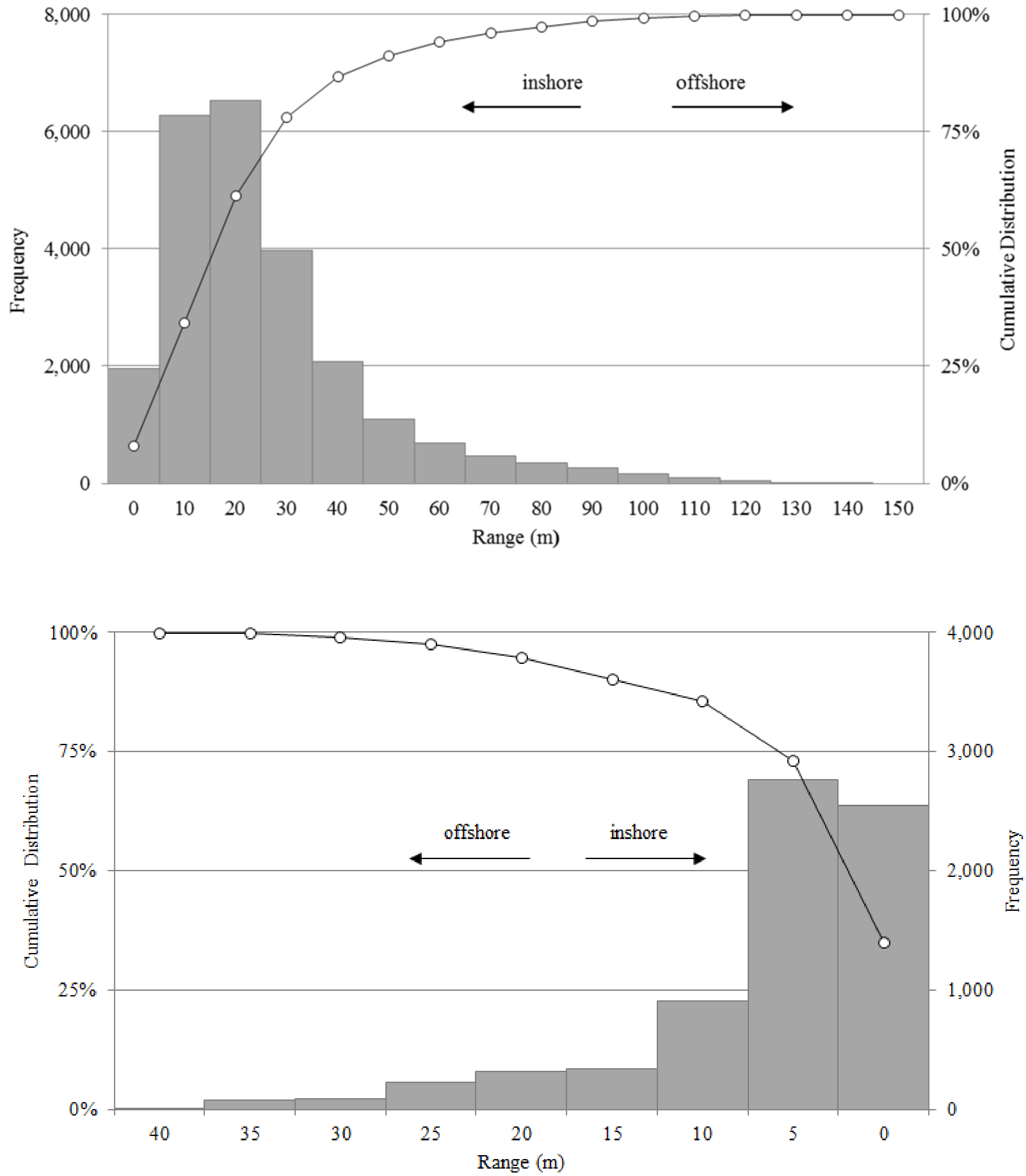


Figure 17.–Left bank (top) and right bank (bottom) horizontal distribution of upstream migrating Chinook salmon in the Yukon River at Eagle sonar project site, June 26 through August 7, 2014.

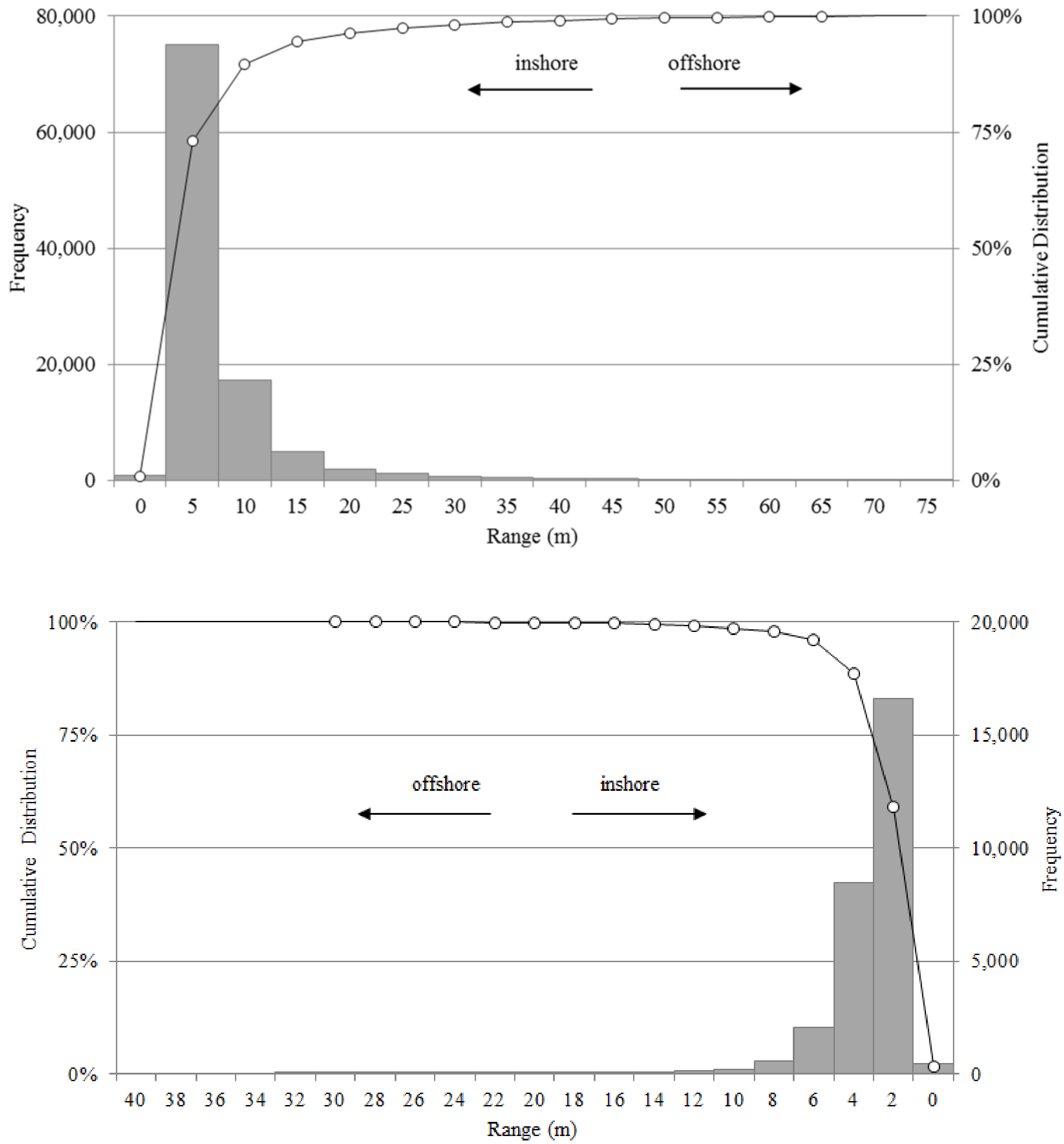


Figure 18.–Left bank (top) and right bank (bottom) horizontal distribution of upstream migrating fall chum salmon in the Yukon River at Eagle sonar project site, August 8 through October 6, 2014.

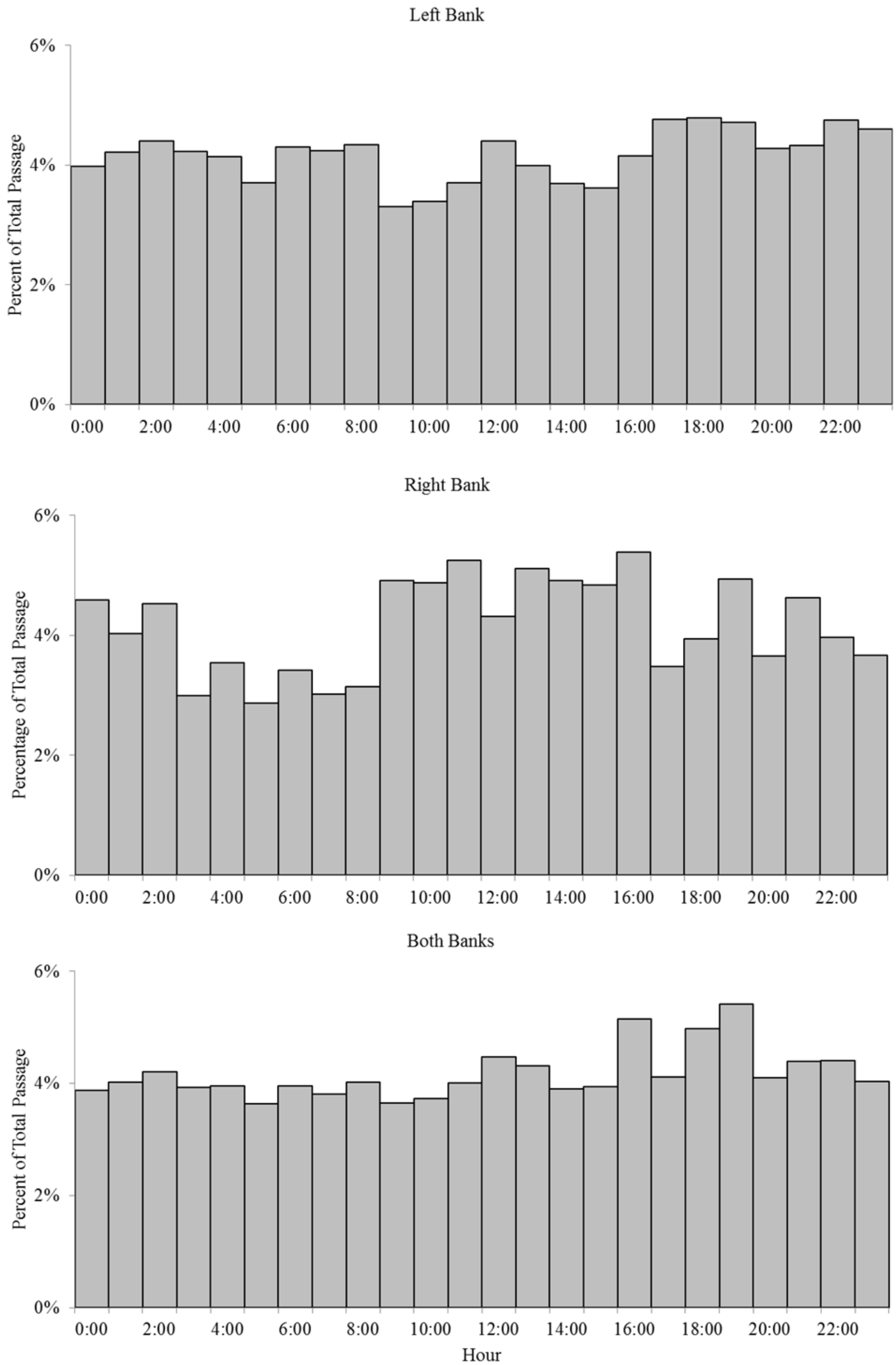


Figure 19.–Percentage of total Chinook salmon passage, by hour, observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from June 27 through August 7, 2014.

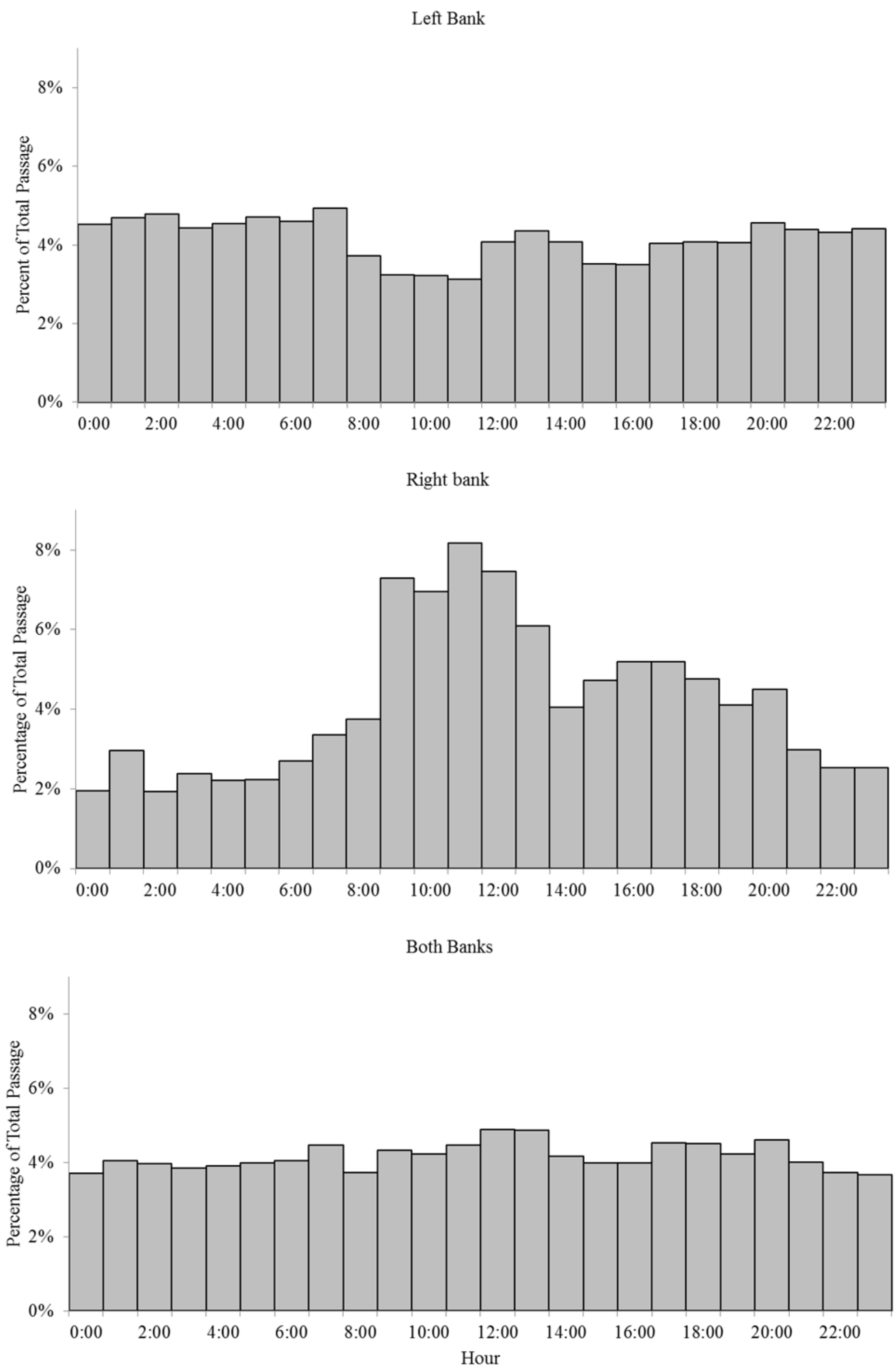


Figure 20.–Percentage of total fall chum salmon passage, by hour, observed on the left bank (top), right bank (middle), and both banks combined (bottom) of the Yukon River at the Eagle sonar project site from August 8 through October 6, 2014.

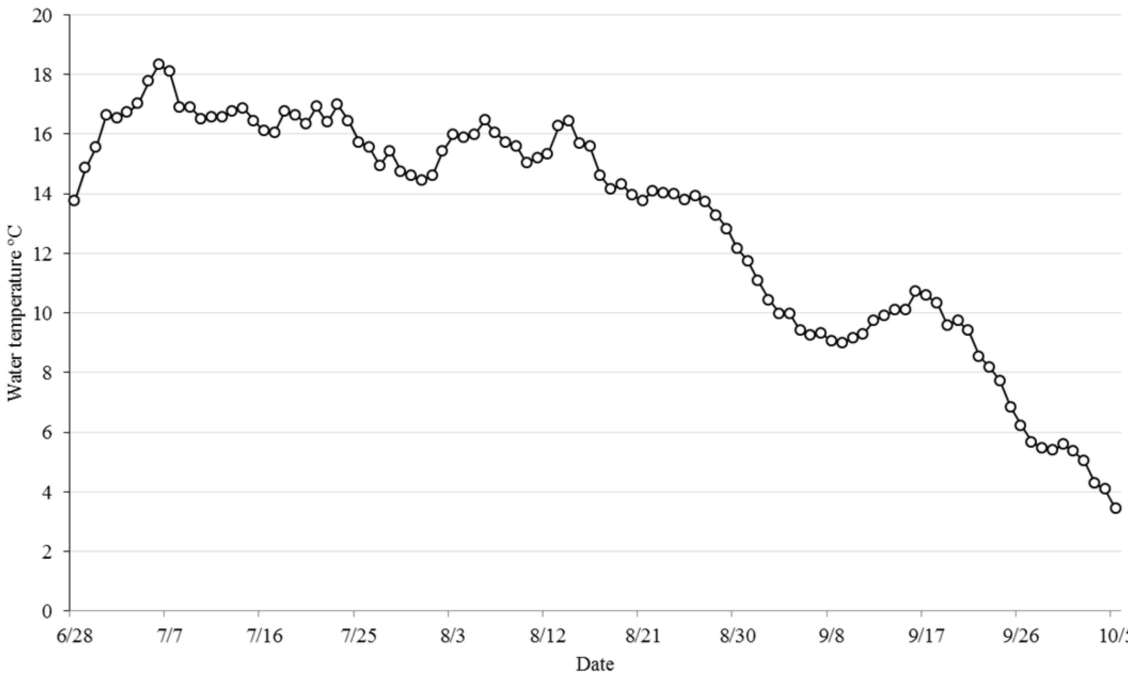


Figure 21.–Mean daily water temperatures recorded on the left bank at the Eagle sonar project on the Yukon River, 2014.

Note: Because of minimal variation between water temperatures on both banks, only the left bank has been plotted.

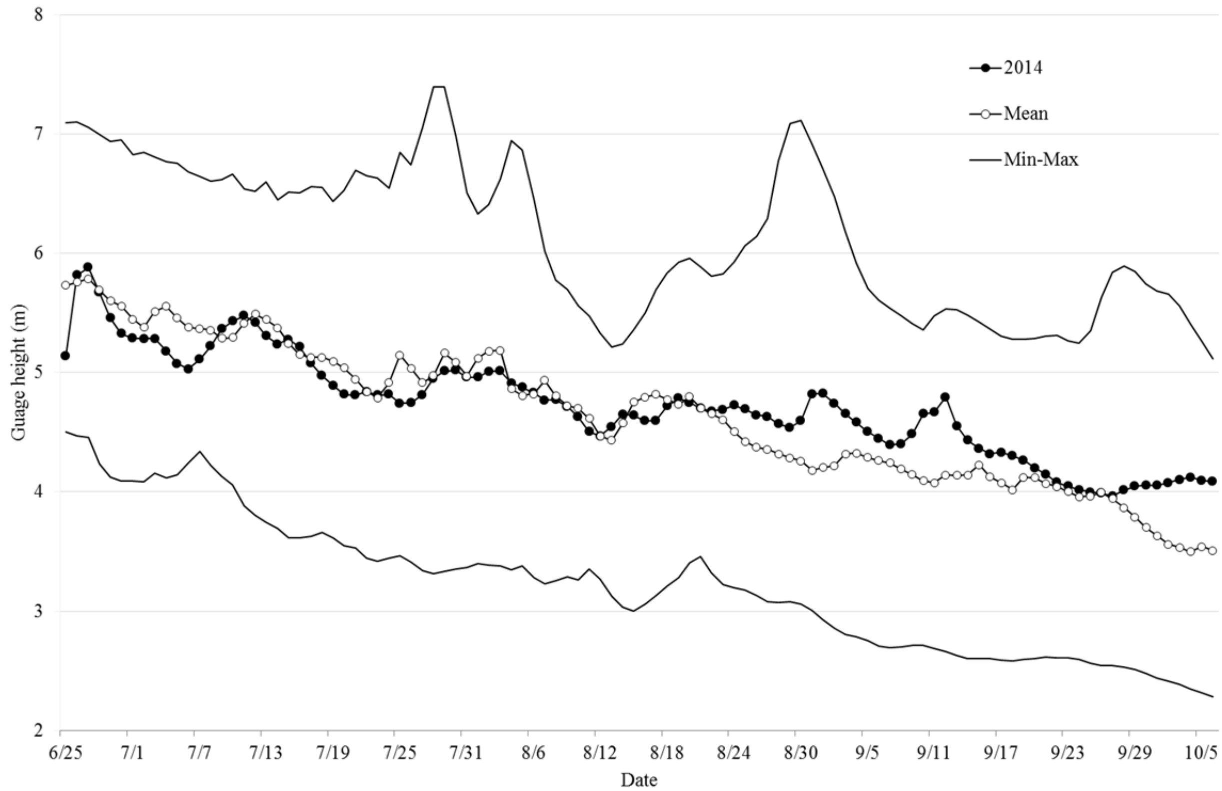


Figure 22.–Yukon River daily water level during the 2014 season at the Eagle water gage compared to minimum, maximum, and mean gage height 1995 to 2013.

Source: United States Geological Survey.

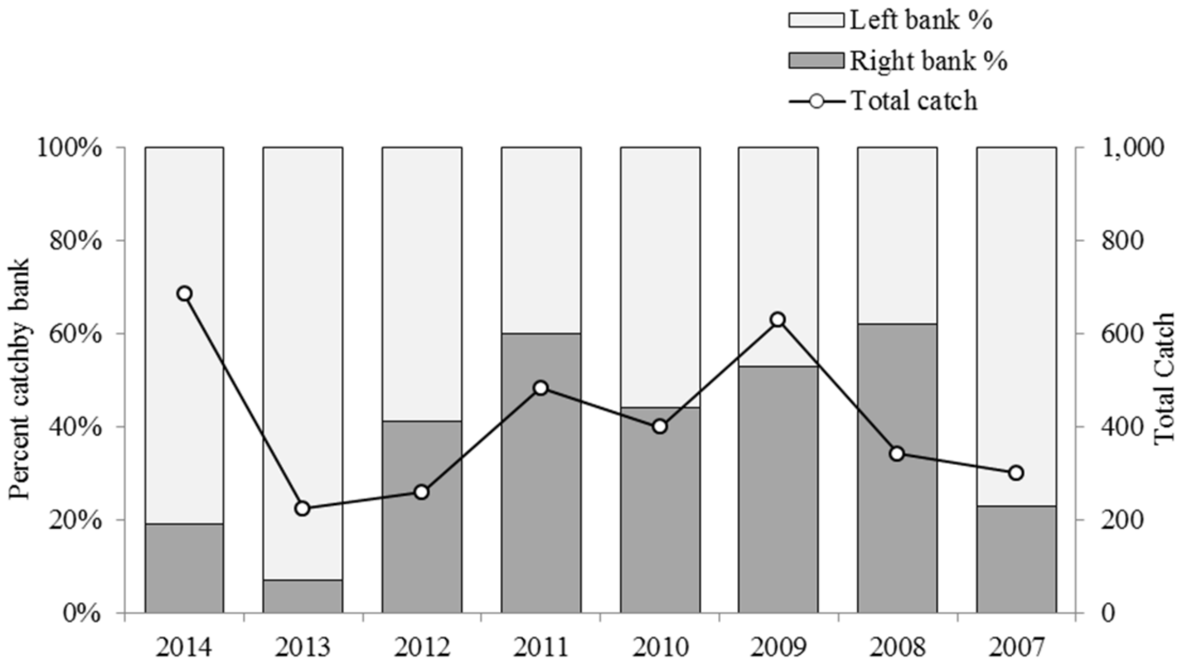


Figure 23.–Total Chinook salmon catch and percent catch by bank from the ASL and genetic sample test fishery at the Eagle sonar project on the Yukon River, 2014.

Note: Test fishing on the right bank at Calico Bluff occurred from 2008 to 2012. In 2007, 2013, and 2014 fishing on the right bank was conducted near the sonar site, upstream of Calico Bluff.

APPENDIX A: SPECIES COMPOSITION TEST FISHERY CATCH, CPUE, AND SMOOTHED DATA BY DAY AND SALMON SPECIES

Appendix A1.–Species composition test fishery catch, CPUE, and smoothed data by day and salmon species at the Eagle sonar project, on the Yukon River, 2014.

	Chinook salmon					Fall chum salmon				
Date	Large mesh fathom hours	Catch	CPUE	Catch smoothed	CPUE smoothed	Small mesh fathom hours	Catch	CPUE	Catch smoothed	CPUE smoothed
8/01	16.83	2	0.12	1.86	0.11	17.25	0	0.00	0.80	0.05
8/02	16.80	5	0.30	1.81	0.11	16.75	1	0.06	0.77	0.05
8/03	16.69	1	0.06	1.75	0.10	17.25	1	0.06	0.75	0.04
8/04	17.17	3	0.18	1.67	0.10	16.56	1	0.06	0.74	0.04
8/05	17.30	2	0.12	1.51	0.09	16.75	1	0.06	0.73	0.04
8/06	15.99	1	0.06	1.28	0.08	15.67	0	0.00	0.72	0.04
8/07	15.92	0	0.00	0.99	0.06	15.84	0	0.00	0.72	0.04
8/08	16.06	0	0.00	0.69	0.04	16.34	2	0.12	0.74	0.04
8/09	16.03	0	0.00	0.43	0.03	16.65	1	0.06	0.68	0.04
8/10	16.64	0	0.00	0.22	0.01	16.37	1	0.06	0.57	0.03
8/11	15.81	0	0.00	0.08	0.00	16.46	0	0.00	0.42	0.03
8/12	16.26	0	0.00	0.03	0.00	16.60	0	0.00	0.27	0.02
8/13	16.36	0	0.00	0.01	0.00	16.43	0	0.00	0.24	0.01
8/14	16.30	0	0.00	0.00	0.00	16.49	0	0.00	0.32	0.02
8/15	16.30	0	0.00	0.00	0.00	16.96	0	0.00	0.56	0.03
8/16	15.94	0	0.00	0.01	0.00	16.33	0	0.00	0.92	0.06
8/17	16.57	0	0.00	0.02	0.00	16.73	3	0.18	1.44	0.09
8/18	16.15	0	0.00	0.04	0.00	16.53	1	0.06	2.20	0.13
8/19	16.37	0	0.00	0.05	0.00	16.80	3	0.18	3.17	0.19
8/20	16.82	0	0.00	0.07	0.00	16.37	2	0.12	4.17	0.25
8/21	16.70	0	0.00	0.07	0.00	16.92	4	0.24	5.47	0.32
8/22	17.03	0	0.00	0.07	0.00	18.23	12	0.66	6.99	0.40
8/23	16.25	0	0.00	0.06	0.00	17.39	7	0.40	8.30	0.47
8/24	17.55	1	0.06	0.06	0.00	16.81	6	0.36	9.52	0.53
8/25	16.40	0	0.00	0.05	0.00	17.63	12	0.68	10.81	0.59
8/26	16.94	0	0.00	0.05	0.00	17.65	16	0.91	11.79	0.64
8/27	17.00	0	0.00	0.05	0.00	18.81	18	0.96	12.18	0.67
8/28	17.08	0	0.00	0.05	0.00	18.72	14	0.75	12.39	0.69
8/29	16.95	0	0.00	0.05	0.00	17.32	12	0.69	12.51	0.70
8/30	16.54	0	0.00	0.04	0.00	17.84	14	0.79	12.38	0.70
8/31	17.05	0	0.00	0.03	0.00	13.91	5	0.36	12.18	0.70

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	Chinook salmon					Fall chum salmon				
Date	Large mesh fathom hours	Catch	CPUE	Catch smoothed	CPUE smoothed	Small mesh fathom hours	Catch	CPUE	Catch smoothed	CPUE smoothed
9/01	15.43	0	0.00	0.02	0.00	16.86	9	0.53	12.09	0.70
9/02	15.97	0	0.00	0.01	0.00	17.57	21	1.20	11.96	0.69
9/03	16.02	0	0.00	0.00	0.00	16.84	12	0.71	11.81	0.68
9/04	16.47	0	0.00	0.00	0.00	17.07	9	0.53	11.57	0.67
9/05	16.28	0	0.00	0.00	0.00	17.27	13	0.75	11.37	0.66
9/06	16.32	0	0.00	0.00	0.00	16.52	6	0.36	11.17	0.65
9/07	16.41	0	0.00	0.00	0.00	16.93	10	0.59	11.27	0.66
9/08	16.16	0	0.00	0.00	0.00	17.27	15	0.87	11.20	0.65
9/09	16.41	0	0.00	0.00	0.00	17.09	11	0.64	11.00	0.64
9/10	16.49	0	0.00	0.00	0.00	17.05	9	0.53	10.72	0.62
9/11	16.01	0	0.00	0.00	0.00	18.09	23	1.27	10.46	0.60
9/12	17.08	0	0.00	0.00	0.00	16.78	3	0.18	9.48	0.55
9/13	16.11	0	0.00	0.00	0.00	16.34	5	0.31	8.62	0.50
9/14	17.65	0	0.00	0.00	0.00	17.07	8	0.47	8.66	0.50
9/15	16.77	0	0.00	0.00	0.00	16.66	4	0.24	10.47	0.59
9/16	17.72	0	0.00	0.00	0.00	17.10	11	0.64	13.87	0.77
9/17	16.46	0	0.00	0.00	0.00	16.63	7	0.42	19.24	1.05
9/18	17.46	0	0.00	0.00	0.00	18.00	21	1.17	25.56	1.40
9/19	17.51	0	0.00	0.00	0.00	19.64	51	2.60	30.65	1.68
9/20	18.10	0	0.00	0.00	0.00	19.09	42	2.20	33.24	1.85
9/21	17.44	0	0.00	0.00	0.00	17.08	48	2.81	33.63	1.90
9/22	15.52	0	0.00	0.00	0.00	16.40	31	1.89	32.76	1.87
9/23	16.77	0	0.00	0.00	0.00	15.59	22	1.41	30.67	1.77
9/24	15.36	0	0.00	0.00	0.00	17.28	37	2.14	28.95	1.68
9/25	11.18	0	0.00	0.00	0.00	15.29	17	1.11	27.90	1.62
9/26	15.81	0	0.00	0.00	0.00	15.16	21	1.39	27.57	1.60
9/27	17.93	0	0.00	0.00	0.00	16.36	14	0.86	27.16	1.58
9/28	17.13	0	0.00	0.00	0.00	17.02	27	1.59	27.29	1.59
9/29	14.76	0	0.00	0.00	0.00	16.26	15	0.92	27.75	1.61
9/30	17.06	0	0.00	0.00	0.00	19.22	41	2.13	28.20	1.64

APPENDIX B: CLIMATE AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climate and hydrologic observations recorded daily at 1800 hours, at the Eagle sonar project site on the Yukon River, 2014.

	Precipitation	Wind		Sky	Temperature (°C)	
Date	(code)[a]	Direction	Speed (mph)	(code)[b]	Air	Water[c]
6/28	A	W	3.0	S	23.6	13.8
6/29	A	Calm	0.0	S	24.3	14.9
6/30	B	E	1.0	B	23.1	15.6
7/01	B	N	1.2	S	24.7	16.6
7/02	A	Calm	0.0	C	25.7	16.5
7/03	A	S	2.7	C	17.5	16.7
7/04	A	W	2.2	S	27.7	17.0
7/05	A	W	1.6	C	26.9	17.8
7/06	A	S	4.5	C	26.6	18.3
7/07	A	S	2.9	S	23.5	18.1
7/08	C	Calm	0.0	O	20.2	16.9
7/09	A	N	0.9	S	23.9	16.9
7/10	A	N	0.7	S	23.2	16.5
7/11	A	Calm	0.0	C	21.3	16.6
7/12	A	NW	1.9	B	21.2	16.6
7/13	B	S	1.9	B	18.0	16.7
7/14	A	S	1.5	S	24.6	16.9
7/15	B	N	2.4	B	15.0	16.4
7/16	B	S	2.3	B	18.0	16.1
7/17	A	S	1.0	B	18.0	16.1
7/18	A	N	4.0	B	21.0	16.8
7/19	B	Calm	0.0	B	16.0	16.6
7/20	B	E	9.7	B	15.4	16.3
7/21	A	E	3.5	C	19.0	16.9
7/22	A	W	7.5	B	23.4	16.4
7/23	A	SE	1.8	B	20.2	17.0
7/24	B	S	3.0	B	15.4	16.4
7/25	C	SE	8.0	O	12.5	15.7
7/26	A	SE	3.4	B	15.1	15.6
7/27	B	NW	1.6	B	14.8	14.9
7/28	B	NW	2.1	B	18.8	15.4
7/29	A	SE	0.8	S	19.5	14.7
7/30	A	Calm	0.0	C	24.0	14.6
7/31	A	Calm	0.0	S	20.7	14.4
8/01	B	Calm	0.0	B	20.1	14.6
8/02	A	Calm	0.0	S	22.7	15.4
8/03	A	Calm	0.0	S	20.5	16.0
8/04	A	SE	1.7	S	23.7	15.9
8/05	B	N	1.2	S	17.0	16.0
8/06	A	NW	1.9	S	19.5	16.5
8/07	C	NW	1.2	O	20.0	16.0
8/08	A	Calm	0.0	B	20.0	15.7
8/09	A	NE	7.3	S	20.0	15.6
8/10	A	SW	1.2	B	20.2	15.0

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Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (°C) Air	Temperature (°C) Water[c]
8/11	A	NE	3.3	S	21.3	15.2
8/12	A	SE	3.0	B	17.7	15.3
8/13	A	S	4.8	B	18.8	16.3
8/14	A	S	3.7	S	22.0	16.4
8/15	C	S	2.5	O	14.0	15.7
8/16	A	SE	4.0	O	18.0	15.6
8/17	A	SE	2.0	B	18.0	14.6
8/18	B	W	1.0	O	14.0	14.1
8/19	A	N	1.0	S	21.0	14.3
8/20	A	N	8.0	S	18.0	14.0
8/21	B	E	1.0	B	18.0	13.8
8/22	A	W	2.0	S	25.0	14.1
8/23	B	NW	1.0	B	17.0	14.0
8/24	A	NW	2.0	B	19.0	14.0
8/25	B	SE	2.0	B	15.0	13.8
8/26	B	E	1.0	B	16.0	13.9
8/27	B	Calm	0.0	B	18.0	13.7
8/28	A	SE	2.0	B	19.0	13.3
8/29	B	N	1.0	B	13.0	12.8
8/30	B	Calm	0.0	B	13.0	12.2
8/31	B	NNW	3.0	A	12.0	11.7
9/01	B	SSE	2.0	A	12.0	11.1
9/02	S	NW	6.0	A	12.0	10.4
9/03	B	NW	5.0	A	8.0	10.0
9/04	S	Calm	0.0	A	15.0	10.0
9/05	A	WSW	1.0	B	12.0	9.4
9/06	A	NNW	5.0	B	12.0	9.2
9/07	A	NW	1.0	C	15.0	9.3
9/08	A	SSE	2.0	C	16.0	9.0
9/09	A	SE	8.0	B	15.0	9.0
9/10	A	SSE	2.0	S	17.0	9.2
9/11	A	NNE	1.0	S	20.0	9.3
9/12	A	SE	3.0	B	17.0	9.8
9/13	A	S	4.0	B	17.0	9.9
9/14	A	S	2.0	S	21.0	10.1
9/15	A	Calm	0.0	O	17.0	10.1
9/16	A	W	2.0	B	14.0	10.7
9/17	A	S	4.0	S	14.0	10.6
9/18	A	S	3.0	S	17.0	10.3
9/19	A	NE	9.0	B	15.0	9.6
9/20	A	SE	2.0	S	16.0	9.7

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Date	Precipitation (code)[a]	Wind Direction	Wind Speed (mph)	Sky (code)[b]	Temperature (°C) Air	Temperature (°C) Water[c]
9/21	A	W	1.0	S	12.0	9.4
9/22	B	Calm	0.0	O	4.0	8.5
9/23	A	Calm	0.0	B	8.0	8.2
9/24	A	NW	1.0	C	5.0	7.7
9/25	A	Calm	0.0	C	5.0	6.8
9/26	A	N	17.0	S	8.0	6.2
9/27	A	NW	1.0	O	6.0	5.7
9/28	A	NNW	2.0	B	5.0	5.5
9/29	A	NNE	4.0	B	3.0	5.4
9/30	B	Calm	0.0	B	3.0	5.6
10/01	A	Calm	0.0	O	5.0	5.4
10/02	A	N	2.0	B	5.0	5.0
10/03	A	NE	2.0	O	4.0	4.3
10/04	A	Calm	0.0	B	6.0	4.1
10/05	F	Calm	0.0	O	-1.0	3.4

[a] Precipitation code for the preceding 24 hour 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 Hobo U22™ Data logger.