Fishery Data Series No. 23-24

Sonar Estimation of Chinook and Fall Chum Salmon Passage in the Yukon River Near Eagle, Alaska, 2020

by

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and

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October 2023

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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SONAR ESTIMATION OF CHINOOK AND FALL CHUM SALMON PASSAGE IN THE YUKON RIVER NEAR EAGLE, ALASKA, 2020

by
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October 2023

This investigation was partially financed by the U.S./Canada Treaty Implementation funds administered by the U.S. Fish and Wildlife Service, Agreement Award F18AP00851.

ADF&G Fishery Data Series was established in 1987 for the publication of Division of Sport Fish technically oriented results for a single project or group of closely related projects, and in 2004 became a joint divisional series with the Division of Commercial Fisheries. Fishery Data Series reports are intended for fishery and other technical professionals and are available through the Alaska State Library and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

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This document should be cited as follows:
McDougall, M. J., and N. B. Brodersen. 2023. Sonar estimation of Chinook and fall chum salmon passage in the Yukon River near Eagle, Alaska, 2020. Alaska Department of Fish and Game, Fishery Data Series No. 23-24, Anchorage.

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ABSTRACT

Adaptive resolution imaging sonar (ARIS) 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 July 1 through October 6, 2020. A total of 33,550 (SE 219) Chinook salmon were estimated to have passed the sonar site from July 1 through August 27. The midpoint of the Chinook salmon migration occurred on July 29, which was 5 days later than the historical mean date. A total of 20,766 (SE 177) fall chum salmon were estimated to have passed the sonar site from August 28 through October 6. The fall chum salmon passage estimate was subsequently expanded to a total of 23,512 to include fish that may have passed after operations ceased. The midpoint of the fall chum salmon migration (based on the expanded estimate) occurred on September 24, which was 1 day later than the historical mean date. Drift gillnetting was conducted to collect age, sex, and length samples and tissue samples for genetic information. Species composition was analyzed to determine when the Chinook salmon migration ended and the fall chum salmon migration began.

Keywords: Chinook *Oncorhynchus* t*shawytscha,* fall chum salmon *Oncorhynchus keta*, adaptive resolution imaging sonar ARIS, dual-frequency identification sonar DIDSON, split-beam sonar, hydroacoustic, Eagle, Yukon River, Alaska.

INTRODUCTION

The Yukon River is the longest river in Yukon and Alaska, spanning 3,190 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 the interpretation of these data are 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 be used for day-to-day management decisions. Sonar provides timely estimates of abundance but is limited in its ability to identify fish to species.

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*. The goal of bilateral, coordinated management is to meet negotiated escapement goals and provide opportunities 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 but also 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 across the U.S./Canada border using mark–recapture techniques from 1980 to 2008 (JTC 2020). Because of the highly turbid water of the Yukon River and the width of the mainstem (approximately 400 m across at the study site), daily passage

[1] Robinson, J. Lewis. "Yukon River". Encyclopedia Britannica, July 21, 2016. https://www.britannica.com/place/Yukon-River (accessed: February 2021).

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 (Dreese and Lozori 2019). Multi-beam imaging sonar (dual-frequency identification sonar [DIDSON] and adaptive resolution imaging sonar [ARIS]) have been used at several sites, including the Anvik (Brodersen 2019) and Teslin Rivers (Mercer 2016) to give daily passage estimates where bottom profiles 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, several problems were identified. Phase corruption was observed and was probably exacerbated by the highly reflective river bottom (Konte et al. 1996). The errors in the phase measurement were believed to have resulted in overly restrictive echo angle thresholds causing the removal of echoes from fish that were physically within accepted detection regions. These and other equipment issues reflected the early state of split-beam development, most of which have since been addressed. A recommendation that came from 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 the following: 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 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 a narrowing of 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 using 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 (11.5 km downriver from the city of Eagle and immediately upriver of Shade Creek) was an ideal site (Carroll et al. 2007a).

In 2005, a full-scale sonar project was conducted from July 1 to August 13 to estimate Chinook salmon passage in the Yukon River at Six Mile Bend (Carroll et al. 2007b). As suggested, DIDSON was deployed on the right bank, and split-beam sonar was deployed on the left bank. In 2015, an ARIS replaced the DIDSON sonar (Lozori and McDougall 2016). This equipment has been used in subsequent years to estimate border passage for both Chinook and fall chum salmon.

The project duration was extended in 2006 to provide an estimate of fall chum salmon passage. There are 2 genetically distinct runs of chum salmon that enter the Yukon River: an early summer component and a later fall component (Estensen et al. 2018). Summer chum salmon spawn primarily in runoff streams in the lower 700 mi 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 Yukon River 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 and various streams in the Yukon Territory, Canada, including the mainstem Yukon River.

In 2020, the project deployed split-beam and ARIS sonar to estimate Chinook and fall chum salmon migrating across the U.S./Canada border. Sample fisheries were conducted to determine the transition between Chinook and fall chum salmon migrations as well as collect age, sex, and length (ASL) data and tissue samples for genetic stock identification. This report will describe the methods used to collect sonar and sample fishery data, as well as provide passage estimates, species distributions, and run timing, in addition to climatic and hydrologic observations.

OBJECTIVES

The goal of this project in 2020 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 sonar data collection 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 biological data from all fish captured in the sample fisheries, including species, sex, length, and scales, as applicable.
5. Collect Chinook and fall chum salmon tissue samples for genetic stock identification.
6. Collect daily climatic and hydrologic measurements representative of the study area.

METHODS

Chinook and fall chum salmon passage was estimated using split-beam sonar on the left bank and ARIS imaging sonar on the right bank. Both sonars operated continuously, 24 hours a day, and sampled 2 horizontal strata per bank, each for 30 minutes per hour (Figure 2). Data collection for the nearshore strata began at the top of the hour, whereas data collection for the offshore strata began at the bottom of the hour. Because of the low proportion of comigrating species, sonar estimates were designated as either Chinook or fall chum salmon. Although Chinook and fall chum salmon migrations are considered discrete in time, some temporal overlap does occur. The transition date between Chinook and fall chum salmon migrations was determined using daily

CPUE proportions from the species composition sample fishery, which was conducted once per day from August 1 through September 30.

Study Area

The Yukon River Basin is the fourth largest basin in North America; it has a drainage area of 857,300 km^2 and an average annual discharge of 6,400 m^3/s. Flows are highest in June, but the greatest flow variability occurs in May, after which discharge and the variability in discharge decline. The upper Yukon River is turbid and silty throughout the summer and fall, and the estimated annual suspended sediment load at Eagle is 33,000,000 tons (Brabets et al. 2000).

The study area was located on the mainstem of the Yukon River at Six Mile Bend (64°52′23.8″N, 141°04′45.12″W), approximately 11.5 km downriver from Eagle, Alaska (Figure 3). The Yukon River is approximately 400 m wide at the study site. The left-bank profile is linear, extending approximately 300 m to the thalweg with a gradual slope of approximately 3°. The right-bank profile is less linear, shorter, and steeper, extending approximately 100 m to the thalweg with a slope of approximately 9° (Figure 4). The thalweg is approximately 11 m deep, depending on the water level. 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. Both banks have been observed to have stable bottom profiles throughout the history of the project.

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 (Table 1). ER60 data acquisition software was controlled with a Simrad Controller program, software developed by ADF&G (C. T. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks), and was installed on a laptop computer and connected to the echosounder to collect raw data for processing.

An ARIS imaging sonar manufactured by Sound Metrics Corporation was deployed on the right bank. The sonar operated at 1.2 MHz (high frequency) for the nearshore stratum and at 0.70 MHz (low frequency) for the offshore stratum (Table 2). During periods of high silt, the nearshore stratum was operated at low frequency. Both the low- and high-frequency modes utilize 48 beams and have a field of view of 28°.

Digital files created by the ER60 software and the ARIS were reviewed with the echogram viewer program Echotastic (Version 3), software developed by ADF&G (C. T. Pfisterer, Commercial Fisheries Biologist, ADF&G, Fairbanks), and fish traces were marked by operators to produce an estimate of fish passage.

Sonar Deployment and Operation

River bottom profiles were checked prior to transducer deployment to ensure the sonar sites remained acceptable for ensonification. Profile data were collected using a boat-mounted Lowrance LCX-15 dual-frequency transducer (down-looking sonar) with a built-in Global Positioning System (GPS). Data files were then uploaded to a computer and used to generate bottom profile charts (Figure 4).

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 an HTI model 660 remote control unit that provided horizontal and vertical positioning. Operators adjusted the aim by viewing the echogram in either the ER60 program or Echotastic. The proper aim was achieved when adequate substrate appeared over a majority of the ensonified range.

The split-beam sonar was deployed from July 1 through October 6 on the left bank, approximately 800 m downriver from the camp (Figure 3). The transducer and rotators were mounted on a freestanding frame constructed of aluminum pipe and deployed approximately 15 m from shore (Figure 5). The transducer height was adjusted by sliding a mounting bar up or down along riser pipes that extended above the water. The transducer was deployed at a depth of approximately 1.5 m 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 configured to ensonify a range of 150 m from the transducer and sampled 2 strata (S1: 0–50 m and S2: 50–150 m; Figure 2). When counting fall chum salmon, the split-beam system was configured to ensonify a range of 75 m and sampled 2 strata (S3: 0–25 m and S4: 25–75 m).

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 upstream migrating fish to be detected in the sonar beam. Freestanding lead sections were constructed of 1.5-inch diameter steel pipes connected with adjustable fittings to form tripods. Aluminum stringers, approximately 2.5 m long, were attached horizontally to the upstream side of the tripods. Vertical lengths of aluminum conduit spaced 3.8 cm apart finished the sections. Depending upon water level, flow, and debris load, lead sections were placed side-by-side in the water from shore to approximately 3–5 m offshore 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 rose and fell over the duration of the season, the transducer and lead required frequent relocation to maintain their depth in the water column.

The ARIS was mounted to a Sound Metrics ARIS Rotator AR2 and controlled by ARIScope software, which provided horizontal and vertical positioning. Aiming was performed remotely using a laptop computer. Operators adjusted the aim by viewing the video image for each stratum. The proper aim was achieved when adequate substrate appeared over a majority of the ensonified range.

The ARIS was deployed from July 1 through October 6 on the right bank, approximately 700 m downriver from the camp. The transducer and rotator were mounted on a freestanding aluminum frame similar to the split-beam sonar and deployed approximately 4 m from shore at a depth of approximately 1.5 m (Figure 7). For the duration of the season, the ARIS was configured to ensonify approximately 40 m beginning at 0.7 m from the face of the transducer and sampled 2 strata (S5: approximately 0.7–20.7 m and S6: approximately 20.7–40.7 m; Figure 2).

A fish lead was constructed using a 1-inch heavy-duty seine mesh supported by a 1-inch PVC pipe. The seine mesh was anchored to the river bottom with a heavy chain sewn along its length, which followed the contours of the substrate. Additional flotation for the upper edge was provided by gillnet floats sewn in along the top of the mesh approximately every 1 m (Figure 6). The fish lead was located approximately 1 m downstream of the transducer and extended approximately 2 m offshore beyond the transducer. This distance provided a sufficient offshore diversion for fish migrating 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 view of the ARIS (approximately 0.7 m).

SONAR DATA PROCESSING AND PASSAGE ESTIMATION

Operators opened each data file in Echotastic and marked each upstream fish track (Figures 8 and 9). The counts were saved as text files and manually recorded on a count form. The upstream direction of travel was verified in Echotastic using the video (ARIS files only) or by the color gradation of the fish track when echoes were colored by horizontal angle (ARIS and split-beam files).

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

$$\hat{y}_{ds}=24\cdot\frac{\sum_{p-1}^{n}\frac{y_{dsp}}{h_{dsp}}}{n_{ds}} \quad , \tag{1}$$

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

Treating the systematically sampled sonar counts as a simple random sample could yield an overestimate of the variance since sonar counts can be highly autocorrelated. A variance estimator based on the squared differences of successive observations was employed to accommodate these data characteristics (Wolter 1985). The variance for the passage estimate for stratum (s) on day (d) was estimated as:

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

where n_{ds} is the number of samples in the day (typically 24), f_{ds} is the fraction of the day sampled (12/24 = 0.5 when no down time), and y_{dsp} is the hourly count for day (d) in stratum (s) for sample (p). Assuming passage estimates are independent between strata and among days, the total variance was estimated as the sum of the variances:

$$\hat{V}ar\left(\hat{y}\right)=\sum_{d}\sum_{s}\hat{V}ar\left(\hat{y}_{ds}\right) \quad . \tag{3}$$

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 entire days were missed, a daily passage was interpolated by averaging passage estimates from days before and after the missing day(s) as follows:

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

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 (i).

After data checks were performed to ensure accuracy, 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 further reviewed postseason and adjusted as necessary.

Since project operations ceased prior to the end of the fall chum salmon migration, the estimate was expanded through October 18 using a second-order polynomial equation:

$$y_i = \frac{L}{d^2}(x_i - d)^2 \quad , \tag{5}$$

where y_i is the daily passage estimate on the day (i) of expansion, L is the count on the last day of sonar operation, d is the total number of days expanded (October 18–October 6 = 12 days), and x_i is the day number being estimated.

October 18 is typically the last day of the fall chum salmon expansion. This date is based on what is considered the most likely run timing scenario derived from historical data (1982–2008) collected at the DFO mark–recapture fish wheel project near the U.S./Canada border (B. M. 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 sonar estimate to calculate the border passage estimate for both Chinook and fall chum salmon.

Spatial and Temporal Distribution

Fish range distributions for Chinook and fall chum salmon were examined by importing text files containing all fish track information into R[2] and fish counts were binned by range. The binned data were plotted to monitor the spatial distribution of fish passing the sonar site. Histograms of passage by hour were also created to investigate diel patterns of migration. Chinook and fall chum salmon run timing was examined both inseason and postseason using information from the sonar estimate, fish range distribution, sample fishery catches, and local subsistence harvest.

Sample Fishing

Sample fisheries were implemented to monitor species composition and collect ASL and genetic samples: (1) a Chinook salmon sample fishery (July 1–August 15) collected data to estimate specific Canadian stock proportions and the ASL composition of Chinook salmon entering Canada, and (2) 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 and genetic data.

Chinook salmon sampling occurred twice daily through July 31, from approximately 0800–1200 and 1300–1700 hours. The fishery specifically targeted Chinook salmon, which is the predominant species during the month of July. From August 1 through August 15, Chinook salmon sampling occurred once daily from approximately 1300 to 1700 hours.

ASL and genetic samples were collected using 4 different mesh sizes (5.25 inch, 6.5 inch, 7.5 inch, and 8.5 inch), which were drifted in a rotating schedule over the course of the Chinook salmon

[2] The R Project for statistical computing. R version 4.0.0 (Arbor Day). [released: April 24, 2020; accessed March 26, 2021]. Available for download from http://www.r-project.org/

sample fishery to effectively capture all size classes present (Table 3). Nets were 25 fathoms long, approximately 8 m 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) zones. 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 3). This resulted in 9 drifts during each Chinook salmon sample fishing period.

For each drift, 4 times were recorded to the nearest second on 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:

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

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

$$e_{dzlm}=\frac{25t_{dzlmj}}{60} \quad . \tag{7}$$

Fishing for species composition and fall chum salmon ASL data collection occurred once daily from August 1 through September 30 from approximately 0800 to 1200 hours on the left bank only. During the apportionment sampling period, both 5.25-inch and 7.5-inch 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 3) for a total of 12 drifts. Nets were hung the same as for the Chinook salmon sample fishery, with the exception of the LBI nets, which were approximately 3 m deep (Table 4). Drifts were targeted to be 6 minutes in duration but were occasionally shortened as necessary to avoid snags or limit catches to prevent mortalities during times of high fish passage. LBI drifts were referred to as beach walks (Fleischman et al. 1995) and were performed with 1 person holding onto the shore end of the net and leading 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 minutes between drifts in the same zone. All drifts using 1 mesh size were completed before switching to another mesh size. Starting mesh sizes were alternated each day (Table 3).

Captured fish were identified to species, and length was measured to the nearest 1 mm. Salmon species were measured from the middle of the eye to the fork of tail (METF); nonsalmon species were measured from tip of snout to fork of tail (FL). Sex was recorded only for salmon species and was determined by visual examination of external features, such as the 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 (Froning and Smith 2020). A total of 4 scales from Chinook salmon and 1 scale from fall chum salmon were removed from the preferred area of the fish on the left side approximately 2 rows above the lateral line in an area transected by a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin (Clutter and Whitesel 1956). All scale samples were cleaned, mounted on gum cards, and sent to the ADF&G age determination laboratory in Anchorage for processing.

For genetic stock identification (GSI), an approximately 1 cm^2 section of pelvic fin tissue was collected from each Chinook and fall chum salmon and stored on Whatman cards. All samples were sent to the ADF&G genetics laboratory for cataloging and, from there, forwarded to the Fisheries and Oceans Canada genetics laboratory in Nanaimo, British Columbia, for processing. ASL and GSI data were paired, and all sampling data were recorded on field data sheets and entered into a Microsoft Access database. Captured fish were handled in a manner that minimized mortalities.

SPECIES DETERMINATION

In season, the daily proportions of Chinook and fall chum salmon CPUE from the species composition sample fishery were used to determine the last day of the Chinook salmon migration. The remainder of the passage estimates for the season were then classified as fall chum salmon.

Catch per unit effort calculations

CPUE was 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 using the catch (c) and effort (e; calculated in Equation 7) of the large mesh gillnet (7.5 in); fall chum salmon CPUE was calculated using 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 species composition sample fishery:

$$CPUE_{dbi}=\frac{\sum_g c_{dbig}}{\sum_g e_{dbg}} \quad . \qquad (8)$$

Determination of Chinook and fall chum salmon transition date

The transition from Chinook to fall chum salmon was determined using daily left-bank CPUE values for Chinook and fall chum salmon captured in the species composition fishery. The daily CPUE values were smoothed using the function *supsmu* in *R* with the default span (Friedman 1984). The smoothed values were used to compute the estimated daily (d) proportions ($\hat{p}$) for the 2 species (i):

$$\hat{p}_{di}=\frac{CPUE_{di}}{\sum_i CPUE_{di}} \quad . \qquad (9)$$

The species transition date was defined as the day on which the proportion of fall chum salmon was greater than or equal to 0.5 and was designated as the first day of fall chum salmon estimation.

CLIMATIC AND HYDROLOGIC OBSERVATIONS

Climatic and hydrologic observations were collected at approximately 1800 daily. Reported stream levels were taken from the U.S. Geological Survey's gauging station at Eagle[3], although relative 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 pods on each bank and set to record every hour. Air temperature, wind velocity, and wind direction were measured daily using a thermometer and Kestrel handheld wind meter. Other daily observations included the occurrence of precipitation and percent cloud cover.

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[3] USGS (U.S. Geological Survey). 2021. 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&amp (accessed: February 2021).

RESULTS AND DISCUSSION

SONAR DEPLOYMENT

In 2020, both the right- and left-bank transducers were deployed in approximately the same locations that have been used in recent years (Figure 3). Occasionally, water level fluctuations and debris made it necessary to move the transducers and fish leads to deeper or shallower water; however, this is not uncommon and did not affect sonar operation. With the exception of 1 day missed on the right bank, as described below, there were no significant problems with project operations. The left-bank sonar operated from approximately 1300 on July 1 to 1200 on October 6. The right-bank sonar operated from approximately 1900 on July 1 to 1200 on October 6. The primary project objective of estimating Chinook and fall chum salmon passage through October 6 was achieved.

Inseason, August 24 was determined to be the last day of the Chinook salmon migration based on CPUE from the species composition sample fishery (Figures 10 and 11; Appendix A1). This was adjusted postseason using the full catch data set with the last day of the Chinook salmon migration occurring August 27 (Figures 10 and 11; Appendix A1). The total passage estimate for Chinook salmon was 33,550 (SE 219) from July 1 through August 27 (Table 5). The first quarter point of the run fell on July 21, the midpoint on July 29, and the third quarter point on August 5 (Table 6). The midpoint of the Chinook salmon run occurred 5 days late compared to the 2005–2019[4] mean run timing (Figure 12). Chinook salmon passage peaked on July 30 with a daily estimate of 1,343 fish, and a total of 98 Chinook salmon were estimated to have passed the sonar on August 27, the last day of the Chinook salmon season (Figure 13).

Sonar sampling time missed during the Chinook salmon migration varied by strata, and totals ranged from 14.7 hours to 46.3 hours (Table 7). Most time missed was due to an ARIS malfunction on the right bank from approximately 1500 on August 8 to 1000 on August 13. A DIDSON was deployed from 1600 on August 10 to 0900 on August 13 and collected data in place of the ARIS; however, no data were collected on the right bank on August 9. The passage estimate for August 9 was interpolated by averaging passage estimates from days before and after the missing day (Equation 4) and accounted for 628 Chinook salmon. Other causes of missed time included generator failures and routine moving and re-aiming of the sonar because of changes in water level.

The total passage estimate for fall chum salmon was 20,766 (SE 177) fish from August 28 through October 6 (Table 5). Because the fall chum salmon migration continued after project operations ceased, the passage estimate was expanded through October 18 to a total of 23,512 fish. Based on the expanded passage estimate, the first quarter point of the run fell on September 15, the midpoint on September 24, and the third quarter point on October 2 (Table 8). The midpoint of the fall chum salmon run occurred 1 day late compared to the 2006–2019[4] mean run timing (Figure 12). Fall chum salmon passage peaked on October 3 with a daily estimate of 858 fish, and a total of 781 fall chum salmon were estimated to have passed the sonar on October 6, the last day of sonar operation (Figure 13). Sonar sampling time missed during the fall chum salmon migration varied by strata, and totals ranged from 7.6 hours to 13.2 hours (Table 9). Most time missed was due to generator

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[4] Differences in the species transition date from year to year confound 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 Chinook run was completed on the date the Chinook salmon run transitioned to fall chum salmon.

failures, routine moving and re-aiming of the ARIS because of changes in water level, and routine cleaning of the ARIS.

The river bottom profile remained similar to previous seasons and was acceptable for fish detection throughout the 2020 season. Water levels and silt did not affect fish detection, and overall, the project ran smoothly with few breaks in operation.

SPATIAL AND TEMPORAL DISTRIBUTION

Fish were shore-oriented on both banks (Figures 14 and 15). During the Chinook salmon migration, on the left bank, 95% of fish were detected within 70 m of the transducer, and on the right bank, 95% of fish were detected within 20 m of the transducer. During the fall chum salmon migration, on the left bank, 95% of fish were detected within 15 m of the transducer, and on the right bank, 95% of fish were detected within 10 m of the transducer. The objective of operating side-looking split-beam and imaging sonar such that 95% of the migrating salmon were detected within three-quarters of the ensonified range was achieved during both the Chinook and fall chum salmon migrations. Approximately 60% (20,062) of Chinook salmon and 69% (14,393) of fall chum salmon passed on the left bank.

Analysis of hourly sonar passage rates during the Chinook salmon migration did not show any distinct diel migration patterns (Figure 16). However, a diel migration pattern was observed for fall chum salmon, with a decrease midday on the left bank coupled with an increase midday on the right bank (Figure 17). When both banks were combined, the patterns were no longer evident.

SAMPLE FISHING

Chinook salmon sample fishing occurred from July 1 through August 15. Species composition and fall chum salmon sample fishing occurred from August 1 through September 30, except on September 23, due to motor issues. A total of 514 Chinook salmon and 165 fall chum salmon were captured in drift gillnets between July 1 and September 30 (Table 10). A total of 5 sheefish *Stenodus leucichthys*, 5 broad whitefish *Coregonus nasus*, 1 Bering cisco *Coregonus laurettae*, and 1 arctic grayling *Thymallus arcticus* were also captured in the sample fisheries.

A total of 1,920 fathom-hours were fished in the Chinook salmon sample fishery, and 2,056 fathom-hours were fished in the species composition and fall chum salmon sample fishery (Tables 11 and 12). The cumulative CPUE for Chinook salmon was slightly below the 2007–2019 mean and the cumulative CPUE for fall chum salmon was well below the 2007–2019 mean (Figure 18).

Chinook salmon sampled were made up of 236 (46%) males and 278 females. Fall chum salmon sampled were made up of 89 (54%) males and 76 females. Clipped adipose fins, an indication that fish hold coded wire tags from the hatchery in Whitehorse, Yukon Territory, were not observed on any Chinook salmon.

A total of 513 Chinook and 165 fall chum salmon were sampled for complete ASL and genetic data. Of the scales collected, 427 (83%) Chinook and 142 (86%) fall chum salmon were analyzed as ageable (AYKDBMS[5]). Goals to collect biological data from all fish captured in the sample

[5] Arctic–Yukon–Kuskokwim Database Management System (AYKDBMS). 2006– . Alaska Department of Fish and Game, Division of Commercial Fisheries. Juneau, AK. https://www.adfg.alaska.gov/CF_R3/external/sites/aykdbms_website/Default.aspx (accessed: February 2021).

fisheries, including species and ASL as applicable, and GSI tissue samples for Chinook and fall chum salmon were achieved.

Climatic and Hydrologic Observations

Weather and water observations were recorded at the sonar site daily beginning July 2 (Appendix B1). The water temperature on the left bank fluctuated in July and August but generally decreased over the latter third of the season (Figure 19). The maximum water temperature observed was 16.2°C on July 20, and the minimum was 6.0°C on October 6. The water level was above the historical median (1995 to 2019) for the entire season and rose above the historical maximum from August 19 through August 24 and September 7 through September 11 (Figure 20). All goals to collect climatic and hydrologic measurements were achieved this season.

ACKNOWLEDGMENTS

The authors wish to acknowledge the field camp personnel: ADF&G technicians Allison Brooking, Maureen Chambrone, Adonis Cole, Dave Fish, A.J. Hytry, Mark Jackson, Cole Larsen, and Matt Stoller, as well as ADF&G biologists Deena Jallen and Keela Wiglesworth, for collecting most of the data used in this report, which contributed to the successful operation of the project this season. Due to restraints resulting from the COVID-19 pandemic, DFO personnel were not able to work at the Eagle sonar project in 2020; however, the bilateral collaboration is greatly appreciated, and we hope it will continue in the future. We are especially grateful to the Hungwitchin Native Corporation for the use of their land and to the community of Eagle for their support and hospitality. Thanks to the Department of Transportation in Eagle for allowing us to store project equipment and boats at their facility, as well as Toshihide Hamazaki (ADF&G Commercial Fisheries Biometrician), Jody Lozori (ADF&G Commercial Fisheries Sonar Biologist), and Carl Pfisterer (ADF&G Commercial Fisheries Sonar Coordinator) for their review and editorial comments on this manuscript and for their technical support. This investigation was partially funded by U.S./Canada treaty implementation funds administered by the U.S. Fish and Wildlife Service, Agreement Award F18AP00851, and ADF&G general funds.

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TABLES AND FIGURES

Table 1.–Split-beam sonar system settings at the Eagle sonar project on the Yukon River, 2020.

Component	Setting	Stratum [a]	Value
Transducer	Beam size (h x w)	All	2.5° x 10.0°
Echosounder	Power output (W)	All	500
	Pulse width (μ)	All	256
	Ping rate (pps)	S1	8.33
		S2	4.16
		S3	16.66
		S4	8.33
	Range (m)	S1	50
		S2	150
		S3	25
		S4	75
	Duration (min)	S1	30
		S2	30
		S3	30
		S4	30

[a] When counting Chinook salmon, the split-beam system ensonified a range of 150 m and sampled 2 strata (S1: 0–50 m and S2: 50–150 m). When counting fall chum salmon, the split-beam system ensonified a range of 75 m and sampled 2 strata (S3: 0–25 and S4: 25–75 m).

Table 2.–Technical specifications and settings for the adaptive resolution imaging sonar (ARIS) at the Eagle sonar project on the Yukon River, 2020.

Setting	Stratum [a]	Value
Mode	S5	Identification
	S6	Detection
Frequency (MHz)	S5	1.2
	S6	0.7
Number of beams	S5	48
	S6	48
Start range (m)	S5	0.7
	S6	20.7
End range (m)	S5	20.7
	S6	40.7
Frame rate (frames/s)	S5	6
	S6	4
Duration (min)	S5, S6	30
Field of view (degrees)	S5, S6	28

[a] The 2 ARIS sampling strata (S5: 0.7–20.7 m and S6: 20.7–40.7 m) were independently aimed using a Sound Metrics ARIS Rotator AR2 and ARIScope software.

Table 3.–Net schedule of mesh sizes (in) used for Chinook salmon sample fishing and species composition and fall chum salmon sample fishing for all zones at the Eagle sonar project on the Yukon River, 2020.

		Stretch mesh size in inches		
		Drift		
Sampling purpose	Day	1	2	3
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
Species composition and fall chum salmon samples	1	5.25	7.50	NA
	2	7.50	5.25	NA

Table 4.–Specifications for drift gillnets used for sample fishing at the Eagle sonar project on the Yukon River, 2020.

	Stretch mesh size		Mesh diameter	Meshes deep	Depth
Method	(in)	(mm)	(mm)	(md)	(m)
Drift	5.25	133	85	69	8.00
	6.50	165	105	55	7.90
	7.50	191	121	48	8.00
	8.50	216	137	43	8.10
Beach walk	5.25	133	85	26	3.00
	7.50	191	121	18	3.00

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

Table 5.–Cumulative fish passage estimates by bank and species with standard errors (SE) and 95% confidence intervals (CI), at the Eagle sonar project on the Yukon River, 2020.

					95% CI	
Species	Left bank	Right bank	Total passage	SE	Lower	Upper
Chinook	20,062	13,488	33,550	219	33,121	33,979
Fall chum (excluding expansion[a])	14,393	6,373	20,766	177	20,419	21,113
Fall chum (including expansion[a])	16,534	6,978	23,512	177	23,165	23,859

Note: Standard errors (SE) are only computed for the estimates during the period of sonar operation.

[a] The last day of sonar operation was October 6. Because sonar operations ceased before the end of the fall chum salmon migration, estimates were expanded through October 18.

Table 6.–Estimated daily and cumulative Chinook salmon passage by bank at the Eagle sonar project on the Yukon River, 2020.

	Daily				Cumulative			
Date	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
07/01[a]	0	19	19	12	0	19	19	0.001
07/02	4	14	18	5	4	33	37	0.001
07/03	6	8	14	4	10	41	51	0.002
07/04	6	25	31	6	16	66	82	0.002
07/05	14	26	40	6	30	92	122	0.004
07/06	24	68	92	8	54	160	214	0.006
07/07	42	106	148	13	96	266	362	0.011
07/08	140	158	298	14	236	424	660	0.020
07/09	210	225	435	27	446	649	1,095	0.033
07/10	262	246	508	22	708	895	1,603	0.048
07/11	342	231	573	30	1,050	1,126	2,176	0.065
07/12	472	276	748	33	1,522	1,402	2,924	0.087
07/13	385	274	659	30	1,907	1,676	3,583	0.107
07/14	328	354	682	35	2,235	2,030	4,265	0.127
07/15	334	312	646	28	2,569	2,342	4,911	0.146
07/16	288	341	629	30	2,857	2,683	5,540	0.165
07/17	310	328	638	29	3,167	3,011	6,178	0.184
07/18	330	282	612	26	3,497	3,293	6,790	0.202
07/19	288	258	546	20	3,785	3,551	7,336	0.219
07/20	336	319	655	29	4,121	3,870	7,991	0.238
07/21	299	404	703	29	4,420	4,274	8,694	0.259
07/22	444	448	892	41	4,864	4,722	9,586	0.286
07/23	560	390	950	36	5,424	5,112	10,536	0.314
07/24	584	378	962	33	6,008	5,490	11,498	0.343
07/25	741	336	1,077	34	6,749	5,826	12,575	0.375
07/26	842	362	1,204	38	7,591	6,188	13,779	0.411
07/27	699	563	1,262	38	8,290	6,751	15,041	0.448
07/28	855	424	1,279	36	9,145	7,175	16,320	0.486
07/29	**850**	**400**	**1,250**	**51**	**9,995**	**7,575**	**17,570**	**0.524**
07/30	907	436	1,343	47	10,902	8,011	18,913	0.564
07/31	851	406	1,257	48	11,753	8,417	20,170	0.601
08/01	801	348	1,149	36	12,554	8,765	21,319	0.635
08/02	687	412	1,099	49	13,241	9,177	22,418	0.668
08/03	771	376	1,147	42	14,012	9,553	23,565	0.702
08/04	749	396	1,145	40	14,761	9,949	24,710	0.737
08/05	688	308	996	43	15,449	10,257	25,706	0.766
08/06	626	314	940	37	16,075	10,571	26,646	0.794
08/07	536	282	818	34	16,611	10,853	27,464	0.819

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Table 6.–Page 2 of 2.

	Daily					Cumulative			
Date	Left bank	Right bank	Total	SE		Left bank	Right bank	Total	Proportion
08/08	418	266	684	35		17,029	11,119	28,148	0.839
08/09	399	229	628	21	b	17,428	11,348	28,776	0.858
08/10	381	187	568	42		17,809	11,535	29,344	0.875
08/11	372	179	551	23		18,181	11,714	29,895	0.891
08/12	272	215	487	25		18,453	11,929	30,382	0.906
08/13	242	221	463	22		18,695	12,150	30,845	0.919
08/14	196	246	442	25		18,891	12,396	31,287	0.933
08/15	186	212	398	22		19,077	12,608	31,685	0.944
08/16	136	190	326	16		19,213	12,798	32,011	0.954
08/17	158	73	231	12		19,371	12,871	32,242	0.961
08/18	100	77	177	15		19,471	12,948	32,419	0.966
08/19	120	80	200	12		19,591	13,028	32,619	0.972
08/20	86	68	154	15		19,677	13,096	32,773	0.977
08/21	78	39	117	11		19,755	13,135	32,890	0.980
08/22	63	49	112	10		19,818	13,184	33,002	0.984
08/23	46	66	112	8		19,864	13,250	33,114	0.987
08/24	54	66	120	9		19,918	13,316	33,234	0.991
08/25	50	78	128	13		19,968	13,394	33,362	0.994
08/26	34	56	90	9		20,002	13,450	33,452	0.997
08/27[c]	60	38	98	10		20,062	13,488	33,550	1.000
Total	20,062	13,488	33,550						
Var	29,498	18,439	47,937						
SE	172	136	219						

Note: The upper portion of the outlined box identifies the second quartile of the run and the lower portion of the outlined box identifies the third quartile of the run. The bold box identifies the median day of passage. including the expanded estimate.

[a] Sonar operational on both banks.

[b] Standard error (SE) calculated on the left bank only.

[c] Last day of Chinook salmon estimation.

Table 7.–Sampling time, in minutes, missed by bank, stratum, and date during Chinook salmon sampling at the Eagle sonar project on the Yukon River, 2020.

	Left bank		Right bank	
	Stratum 1	Stratum 2	Stratum 5	Stratum 6
Date	(0–50 m)	(50–150 m)	(0.7–20.7 m)	(20.7–40.7 m)
07/01	408	396	570	558
07/02	0	18	18	6
07/03	0	0	36	42
07/04	12	0	30	30
07/05	0	0	0	12
07/06	0	0	0	0
07/07	0	0	0	0
07/08	0	0	0	0
07/09	78	78	90	72
07/10	0	0	0	0
07/11	0	0	12	0
07/12	0	0	0	0
07/13	0	30	0	0
07/14	0	0	0	0
07/15	0	0	0	0
07/16	0	0	12	0
07/17	0	0	0	0
07/18	0	0	0	0
07/19	0	0	0	0
07/20	0	0	120	60
07/21	30	30	0	0
07/22	0	0	0	0
07/23	0	0	0	0
07/24	0	0	0	0
07/25	0	0	0	0
07/26	6	0	0	0
07/27	0	0	0	0
07/28	0	0	0	0
07/29	72	96	0	0
07/30	0	0	0	0
07/31	0	0	0	0
08/01	0	0	0	0
08/02	0	0	0	0
08/03	0	0	0	0
08/04	0	0	0	0

-continued-

Table 7.–Page 2 of 2.

	Left bank		Right bank	
	Stratum 1	Stratum 2	Stratum 5	Stratum 6
Date	(0–50 m)	(50–150 m)	(0.7–20.7 m)	(20.7–40.7 m)
08/05	150	150	0	0
08/06	0	0	0	0
08/07	0	0	0	0
08/08	0	0	270	300
08/09	30	48	720	720
08/10	0	0	480	480
08/11	0	0	0	0
08/12	0	0	0	0
08/13	0	0	12	90
08/14	0	0	30	18
08/15	0	0	6	0
08/16	0	0	0	0
08/17	0	0	12	108
08/18	48	24	114	96
08/19	0	0	0	0
08/20	12	6	54	42
08/21	6	42	90	114
08/22	30	0	36	30
08/23	0	0	0	0
08/24	0	0	0	0
08/25	0	0	0	0
08/26	0	0	0	0
08/27	0	0	0	0
Total (min)	882	918	2,712	2,778
Total (h)	14.7	15.3	45.2	46.3

Table 8.–Estimated daily and cumulative fall chum salmon passage by bank at the Eagle sonar project on the Yukon River, 2020.

	Daily				Cumulative			
Date	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
08/28[a]	34	42	76	9	34	42	76	0.003
08/29	68	17	85	13	102	59	161	0.007
08/30	48	32	80	10	150	91	241	0.010
08/31	56	24	80	12	206	115	321	0.014
09/01	60	60	120	9	266	175	441	0.019
09/02	84	52	136	14	350	227	577	0.025
09/03	68	52	120	12	418	279	697	0.030
09/04	192	68	260	20	610	347	957	0.041
09/05	212	86	298	19	822	433	1,255	0.053
09/06	220	110	330	18	1,042	543	1,585	0.067
09/07	260	82	342	20	1,302	625	1,927	0.082
09/08	346	144	490	23	1,648	769	2,417	0.103
09/09	370	114	484	26	2,018	883	2,901	0.123
09/10	307	110	417	26	2,325	993	3,318	0.141
09/11	352	118	470	25	2,677	1,111	3,788	0.161
09/12	366	138	504	28	3,043	1,249	4,292	0.183
09/13	389	96	485	23	3,432	1,345	4,777	0.203
09/14	484	134	618	29	3,916	1,479	5,395	0.229
09/15	442	152	594	29	4,358	1,631	5,989	0.255
09/16	454	131	585	19	4,812	1,762	6,574	0.280
09/17	516	160	676	26	5,328	1,922	7,250	0.308
09/18	506	265	771	32	5,834	2,187	8,021	0.341
09/19	639	186	825	28	6,473	2,373	8,846	0.376
09/20	478	198	676	25	6,951	2,571	9,522	0.405
09/21	428	134	562	31	7,379	2,705	10,084	0.429
09/22	526	222	748	27	7,905	2,927	10,832	0.461
09/23	503	159	662	34	8,408	3,086	11,494	0.489
09/24	**413**	**237**	**650**	**23**	**8,821**	**3,323**	**12,144**	**0.517**
09/25	431	272	703	27	9,252	3,595	12,847	0.546
09/26	390	190	580	28	9,642	3,785	13,427	0.571
09/27	360	240	600	23	10,002	4,025	14,027	0.597
09/28	440	206	646	27	10,442	4,231	14,673	0.624
09/29	392	294	686	41	10,834	4,525	15,359	0.653
09/30	429	244	673	37	11,263	4,769	16,032	0.682
10/01	541	258	799	33	11,804	5,027	16,831	0.716
10/02	533	294	827	37	12,337	5,321	17,658	0.751
10/03	522	336	858	49	12,859	5,657	18,516	0.788
10/04	525	288	813	36	13,384	5,945	19,329	0.822

-continued-

Table 8.–Page 2 of 2.

	Daily				Cumulative			
Date	Left bank	Right bank	Total	SE	Left bank	Right bank	Total	Proportion
10/05	400	256	656	27	13,784	6,201	19,985	0.850
10/06[b]	609	172	781	63	14,393	6,373	20,766	0.883
10/07[c]	512	145	657	NA	14,905	6,518	21,423	0.911
10/08[c]	423	119	542	NA	15,328	6,637	21,965	0.934
10/09[c]	343	97	440	NA	15,671	6,734	22,405	0.953
10/10[c]	271	76	347	NA	15,942	6,810	22,752	0.968
10/11[c]	207	59	266	NA	16,149	6,869	23,018	0.979
10/12[c]	152	43	195	NA	16,301	6,912	23,213	0.987
10/13[c]	106	30	136	NA	16,407	6,942	23,349	0.993
10/14[c]	68	19	87	NA	16,475	6,961	23,436	0.997
10/15[c]	38	11	49	NA	16,513	6,972	23,485	0.999
10/16[c]	17	5	22	NA	16,530	6,977	23,507	1.000
10/17[c,d]	4	1	5	NA	16,534	6,978	23,512	1.000
Total	16,534	6,978	23,512					
Var[e]	20,163	11,328	31,491					
SE[e]	142	106	177					

Note: The upper portion of the outlined box identifies the second quartile of the run and the lower portion of the outlined box identifies the third quartile of the run. The bold box identifies the median day of passage, including the expanded estimate.

[a] First day of fall chum salmon estimation.

[b] Last day of sonar operation.

[c] Expanded passage estimate.

[d] The last day of the expanded passage was October 18; however, the estimate for that day was 0 and was excluded from this table.

[e] Variance and standard error calculations include data through October 6, the last day of sonar operation.

Table 9.–Sampling time, in minutes, missed by bank, stratum, and date during fall chum salmon sampling at the Eagle sonar project on the Yukon River, 2020.

	Left bank		Right bank	
Date	Stratum 3 (0–25 m)	Stratum 4 (25–75 m)	Stratum 5 (0.7–20.7 m)	Stratum 6 (20.7–40.7 m)
08/28	0	0	0	0
08/29	60	30	48	30
08/30	6	0	0	0
08/31	0	0	0	0
09/01	0	0	0	0
09/02	0	0	0	0
09/03	0	0	0	0
09/04	0	0	0	0
09/05	0	0	0	0
09/06	0	0	0	0
09/07	0	0	0	0
09/08	0	0	0	0
09/09	0	0	0	0
09/10	6	0	0	0
09/11	0	0	0	0
09/12	30	30	0	0
09/13	66	132	0	186
09/14	0	0	0	0
09/15	0	0	0	0
09/16	0	0	6	0
09/17	0	0	0	0
09/18	24	0	30	6
09/19	0	0	0	30
09/20	0	0	0	0
09/21	0	0	0	0
09/22	0	0	0	0
09/23	0	6	6	30
09/24	30	0	6	0
09/25	0	0	0	0
09/26	0	0	0	0
09/27	0	0	0	0
09/28	0	0	0	0
09/29	0	0	0	0
09/30	210	180	0	0
10/01	0	0	0	0
10/02	0	0	0	0
10/03	0	0	0	0
10/04	0	0	0	0
10/05	0	0	0	0
10/06	360	360	360	360
Total (min)	792	738	456	642
Total (h)	13.2	12.3	7.6	10.7

Table 10.–Fish caught with gillnets at the Eagle sonar project on the Yukon River, 2020.

	Sampling purpose		
Species	Species composition and fall chum salmon samples	Chinook salmon samples	Total
Chinook salmon	157	357	514
Fall chum salmon	165	0	165
Sheefish	5	0	5
Broad whitefish	5	0	5
Bering cisco	1	0	1
Arctic grayling	1	0	1
Total	334	357	691

Table 11.–Fishing effort, catch, and proportion by zone and mesh size for Chinook and fall chum salmon in the Chinook salmon sample fishery at the Eagle sonar project on the Yukon River, 2020.

	Mesh size	Fishing effort	Chinook salmon		Fall chum salmon	
Zone[a]	(in)	(fathom-hours)	Catch	Proportion	Catch	Proportion
LBN	5.25	166	68	0.190	0	0.000
	6.50	171	78	0.218	0	0.000
	7.50	169	73	0.204	0	0.000
	8.50	161	52	0.146	0	0.000
Total		668	271	0.759	0	0.000
RBN	5.25	161	12	0.034	0	0.000
	6.50	160	24	0.067	0	0.000
	7.50	164	17	0.048	0	0.000
	8.50	154	6	0.017	0	0.000
Total		639	59	0.165	0	0.000
LBF	5.25	157	10	0.028	0	0.000
	6.50	153	4	0.011	0	0.000
	7.50	154	10	0.028	0	0.000
	8.50	149	3	0.008	0	0.000
Total		613	27	0.076	0	0.000
Grand total		1,920	357	1.000	0	0.000

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

Table 12.–Fishing effort, catch, and proportion by zone and mesh size for Chinook and fall chum salmon in the species composition and fall chum salmon sample fishery at the Eagle sonar project on the Yukon River, 2020.

	Mesh size	Fishing effort	Chinook salmon		Fall chum salmon	
Zone[a]	(in)	(fathom-hours)	Catch	Proportion	Catch	Proportion
LBI	5.25	355	30	0.191	108	0.655
	7.50	341	20	0.127	9	0.055
Total		696	50	0.318	117	0.709
LBN	5.25	344	42	0.268	36	0.218
	7.50	343	54	0.344	11	0.067
Total		687	96	0.611	47	0.285
LBF	5.25	337	4	0.025	1	0.006
	7.50	336	7	0.045	0	0.000
Total		673	11	0.070	1	0.006
Grand total		2,056	157	1.000	165	1.000

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

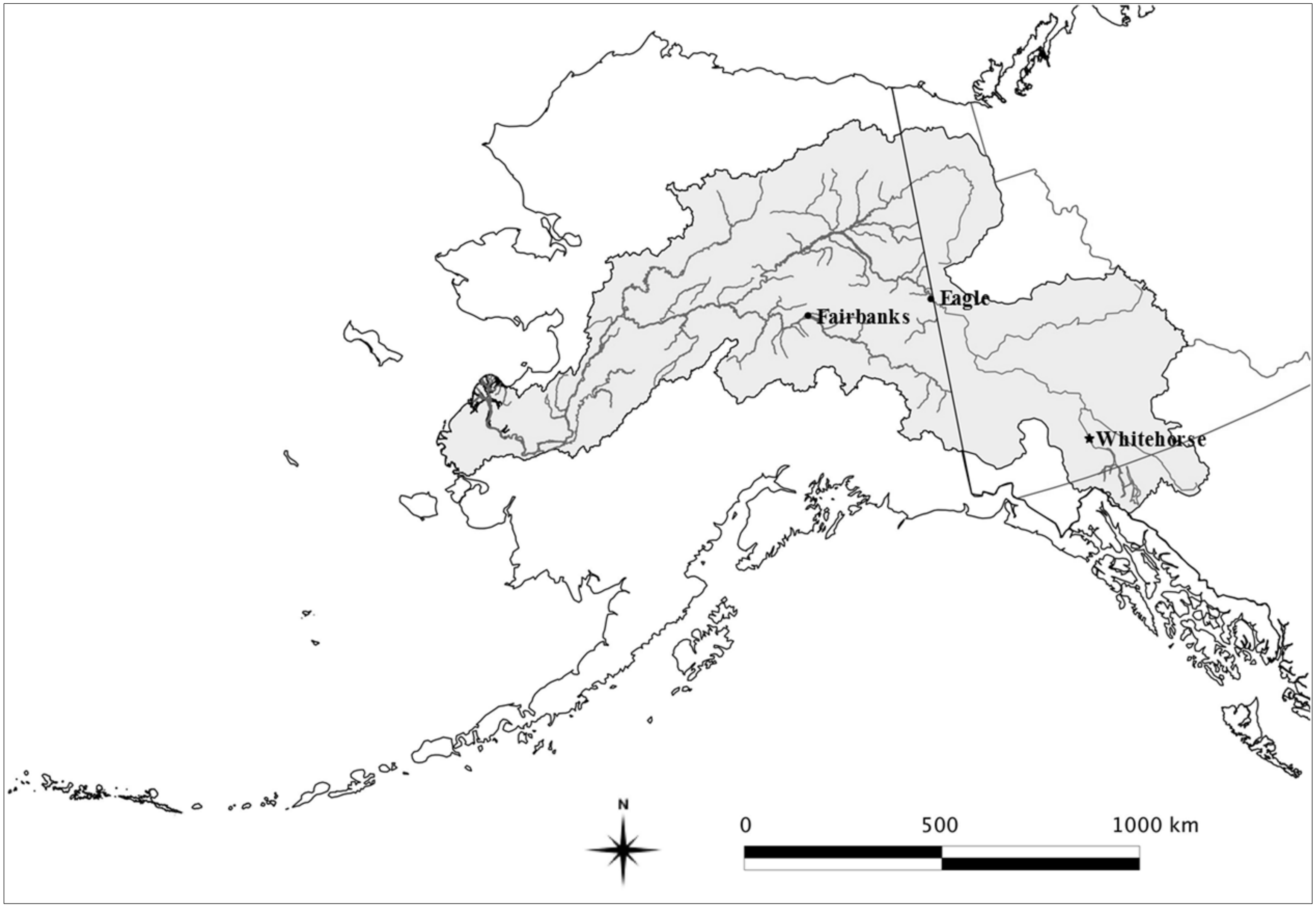

Figure 1.–Yukon River drainage.

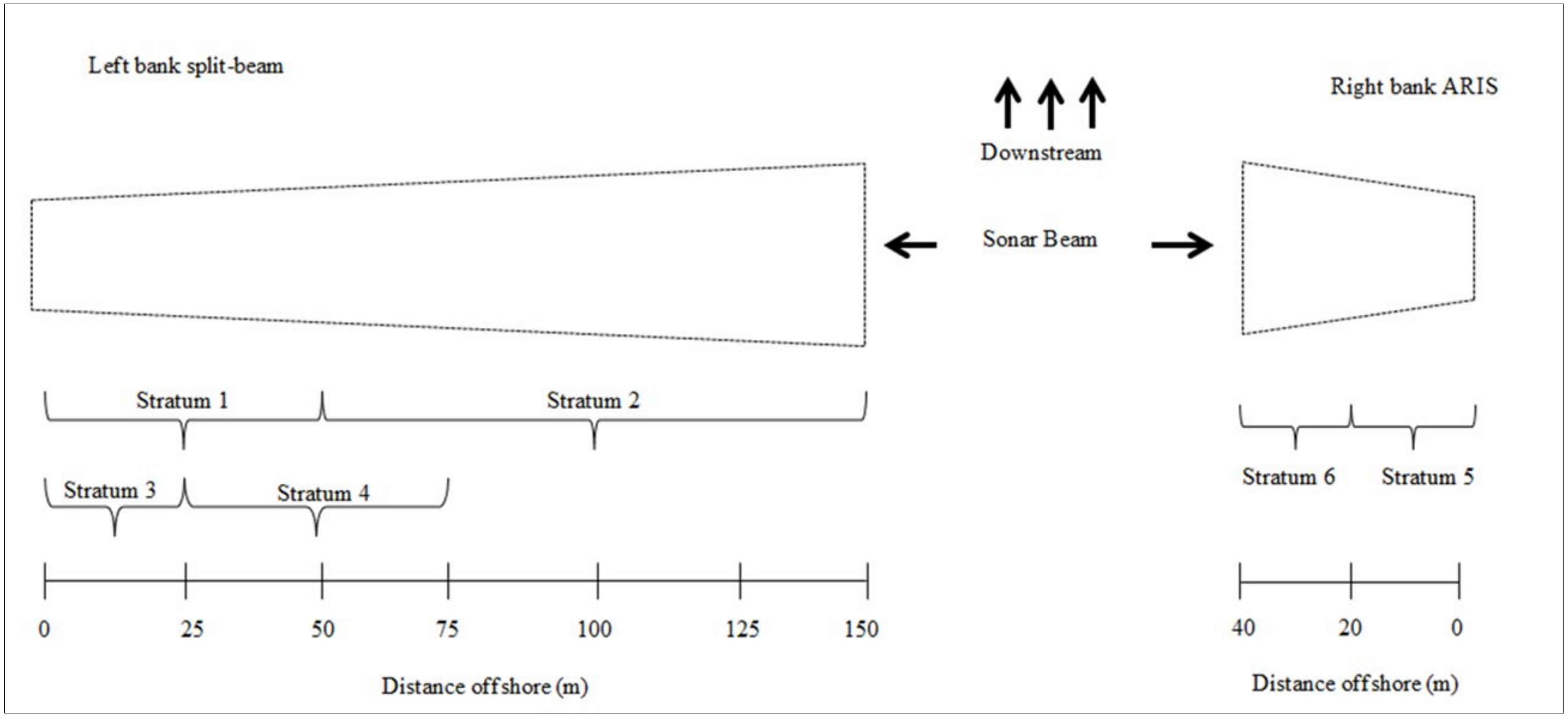

Figure 2.–Illustration of strata and approximate sonar ranges (not to scale) at the Eagle sonar project on the Yukon River, 2020.

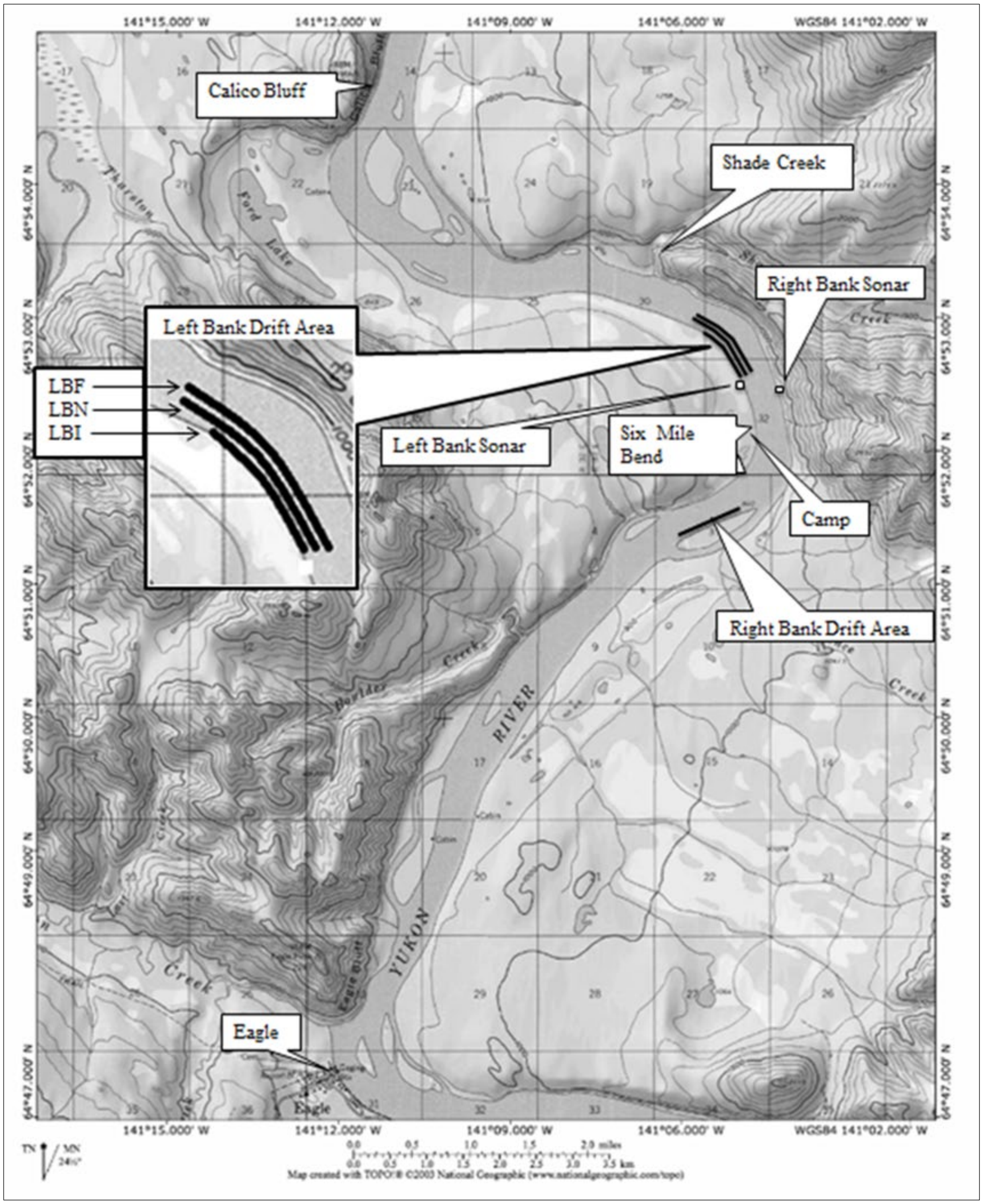

Figure 3.–Eagle sonar project site at Six Mile Bend on the Yukon River showing sonar and drift gillnet fishing locations, 2020.

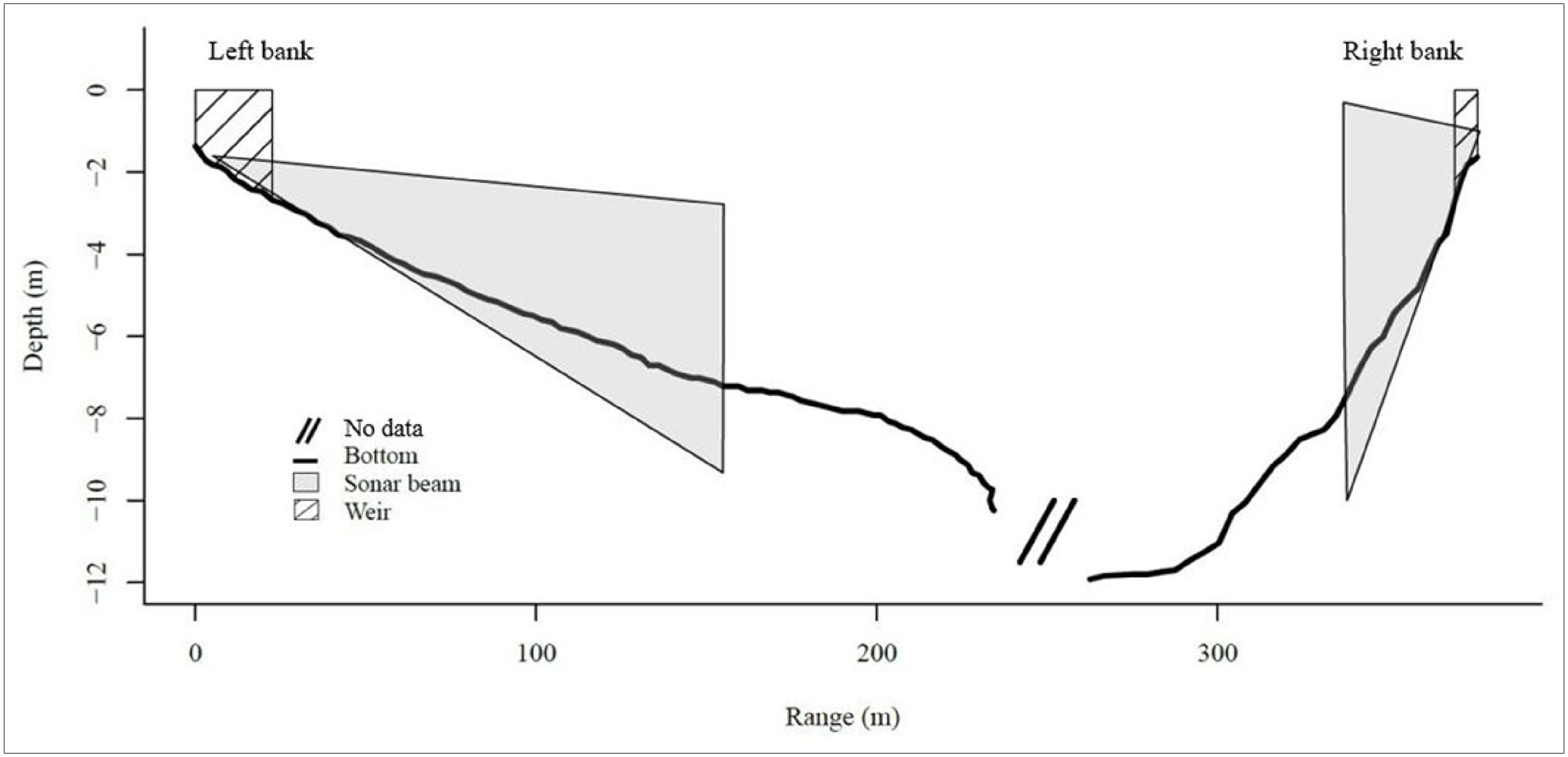

Figure 4.–Depth profile of the Yukon River in front of transducers (looking downstream) and approximate sonar coverage at the Eagle sonar project, 2020.

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

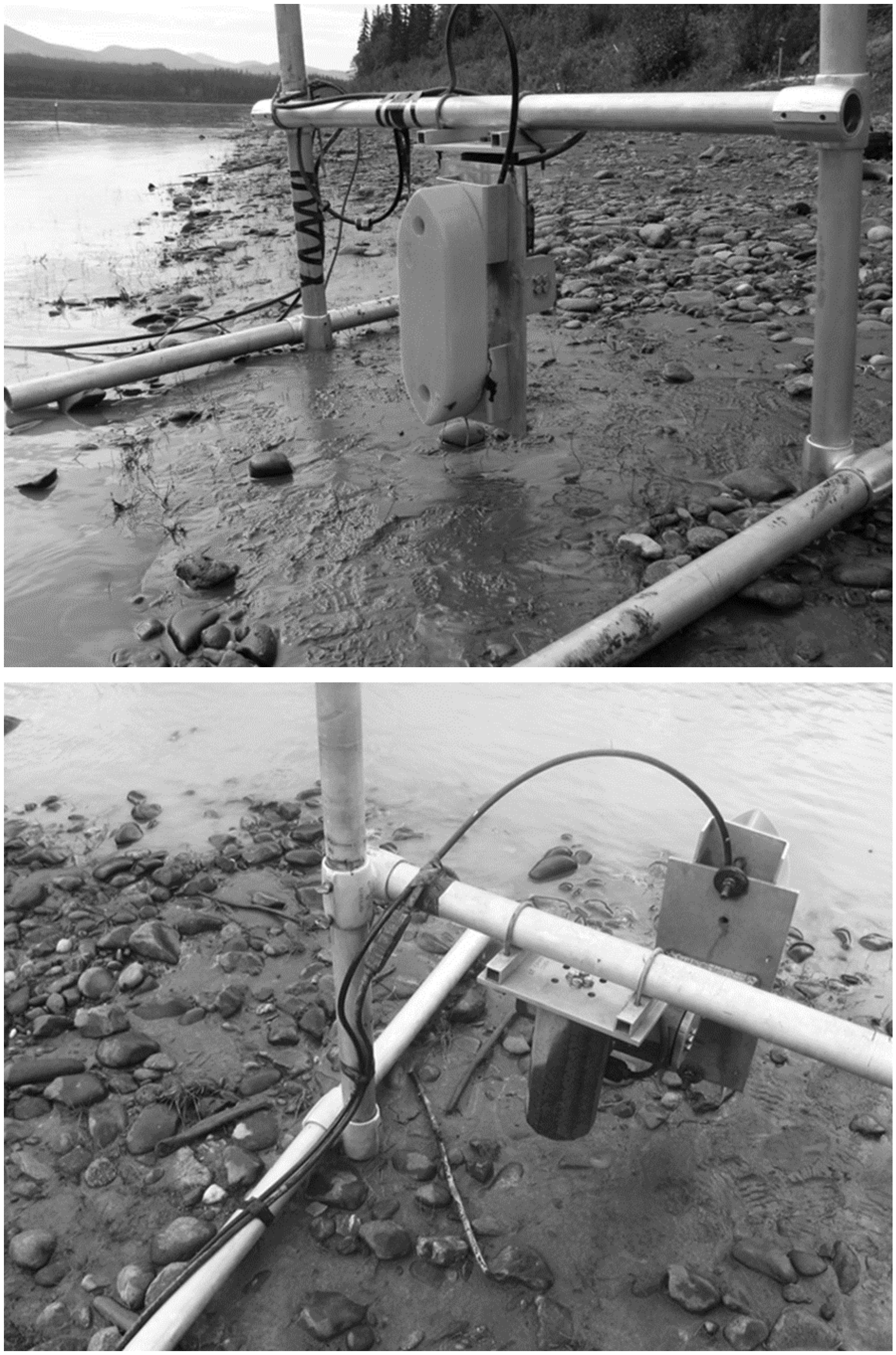

Figure 5.–Split-beam transducer mounted to an aluminum H-mount (top) and the same transducer mounted to 2 single-axis automated rotators (bottom) used on the left bank at the Eagle sonar project on the Yukon River, 2020.

Figure 6.–Portable tripod-style fish lead used on the left bank (top) and seine mesh fish lead used on the right bank (bottom) at the Eagle sonar project on the Yukon River, 2020.

Figure 7.–ARIS imaging sonar and ARIS Rotator AR2 mounted to an aluminum H-mount (top) and close-up view of rotator mount (bottom) at the Eagle sonar project on the Yukon River, 2020.

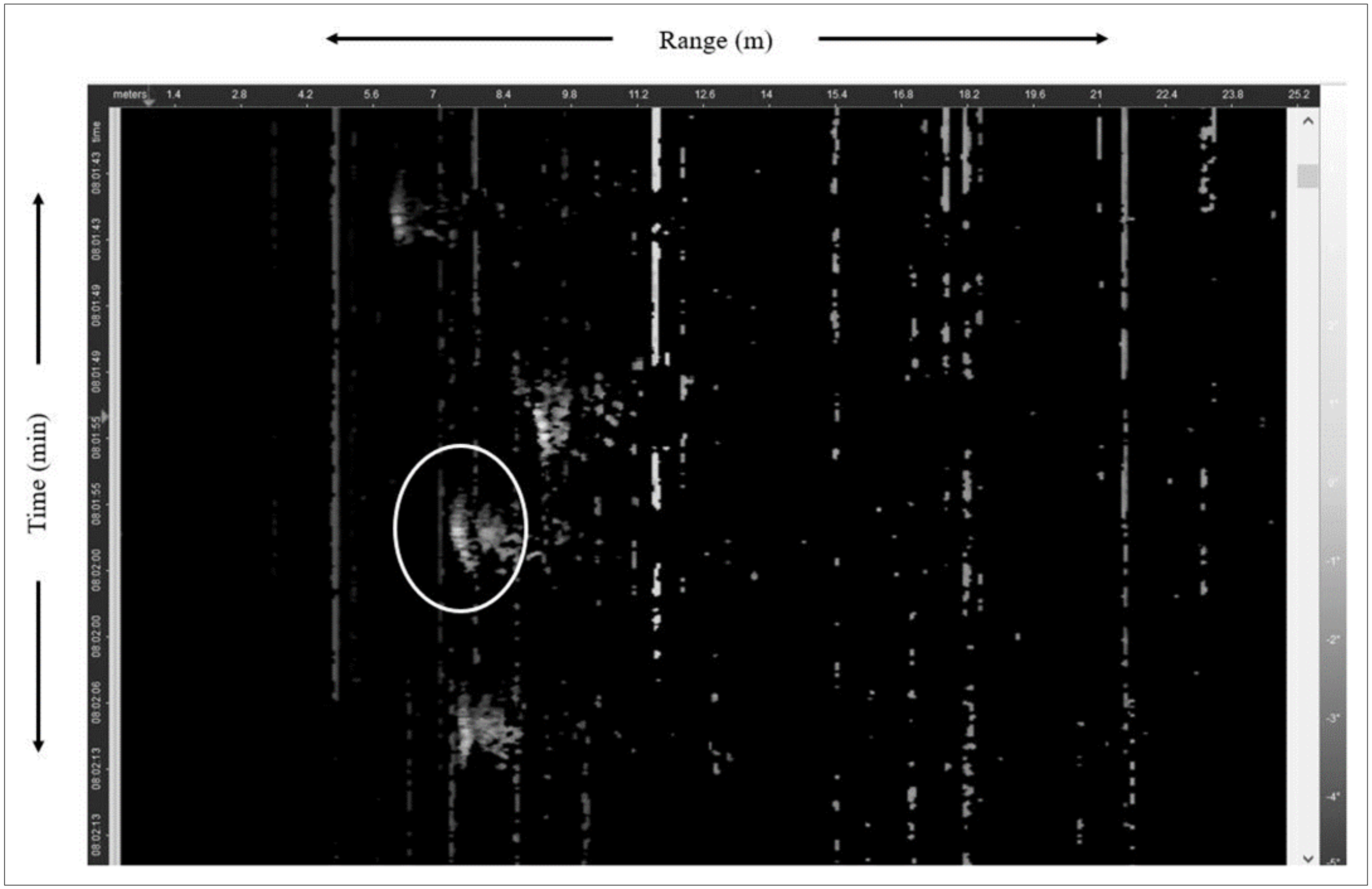

Figure 8.–Screenshot of an echogram from a split-beam sonar data file used to count fish and determine direction of travel at the Eagle sonar project on the Yukon River.

Note: Ellipse encompasses typical upstream migrating salmon.

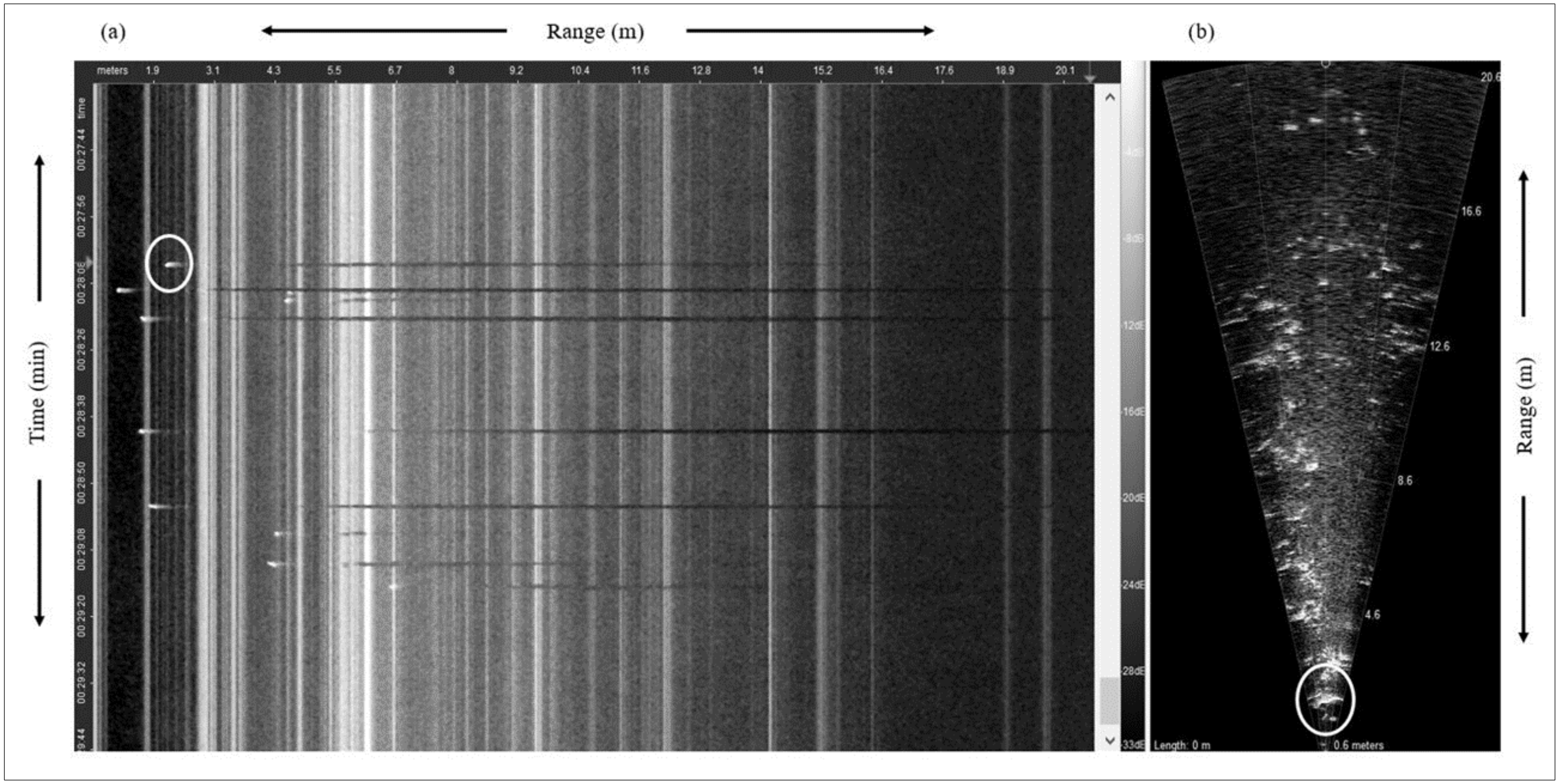

Figure 9.–Screenshots of (a) an echogram and (b) video from an ARIS data file used to count fish and determine direction of travel at the Eagle sonar project on the Yukon River.

Note: Ellipse encompasses typical upstream migrating salmon.

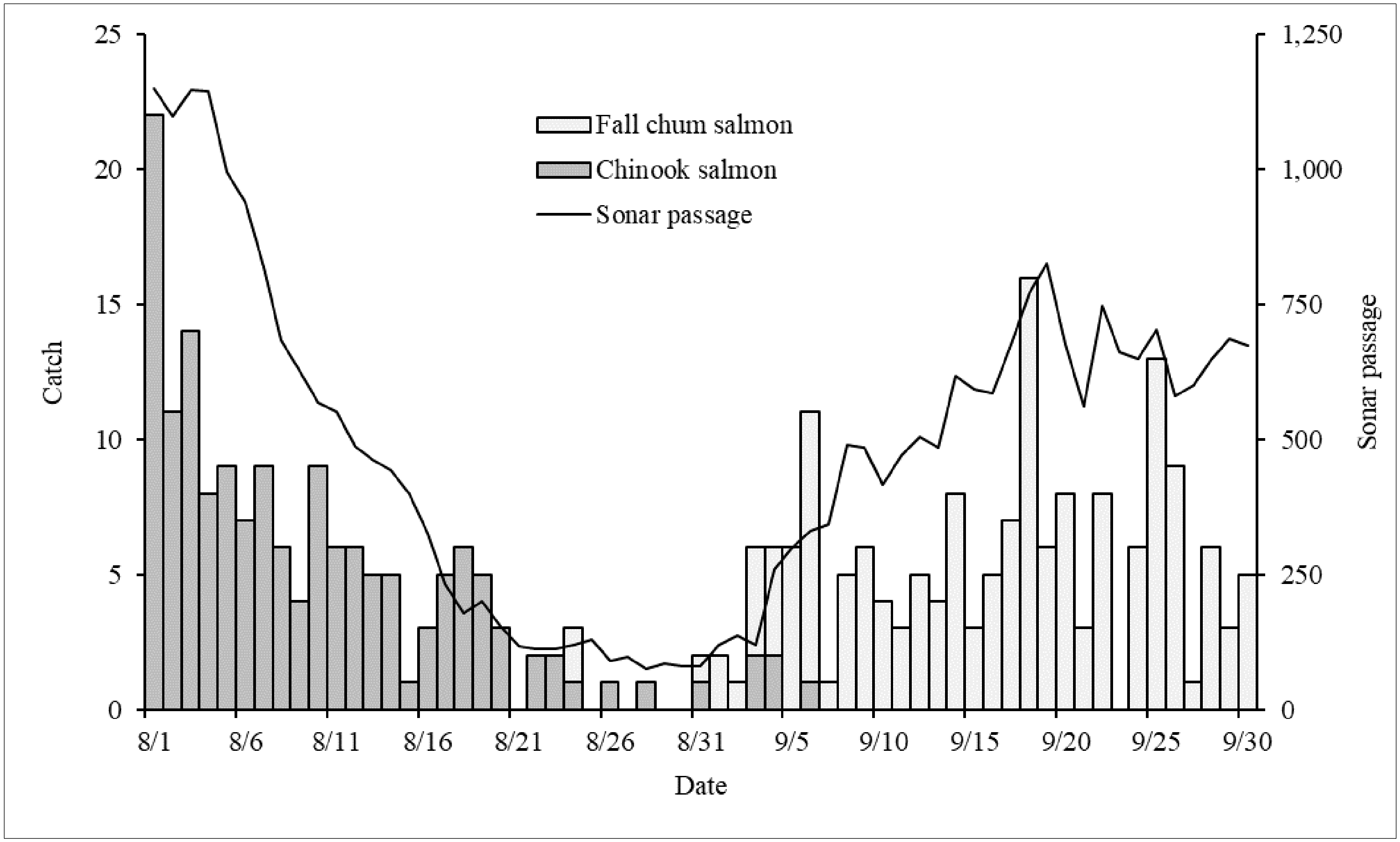

Figure 10.–Daily catch during species composition fishing and sonar passage estimates at the Eagle sonar project on the Yukon River, 2020.

Note: The sample fishery did not operate on September 23 due to motor issues.

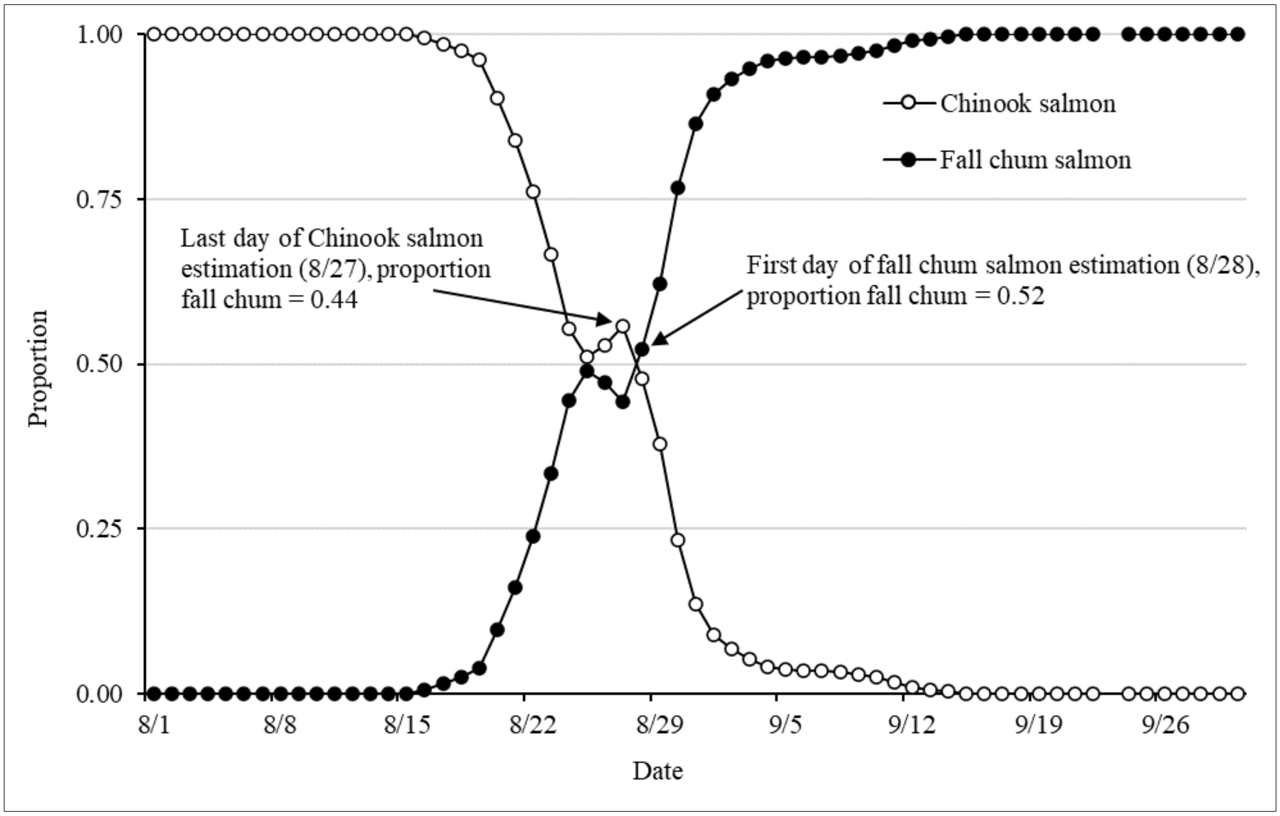

Figure 11.–Proportion of catch based on smoothed Chinook and fall chum salmon species composition catch per unit effort (CPUE) data at the Eagle sonar project on the Yukon River, 2020.

Note: Species transition date (August 28) defined as the day on which the proportion of fall chum salmon was greater than or equal to 0.5 and is designated as the first day of fall chum salmon estimation. The sample fishery did not operate on September 23 due to motor issues.

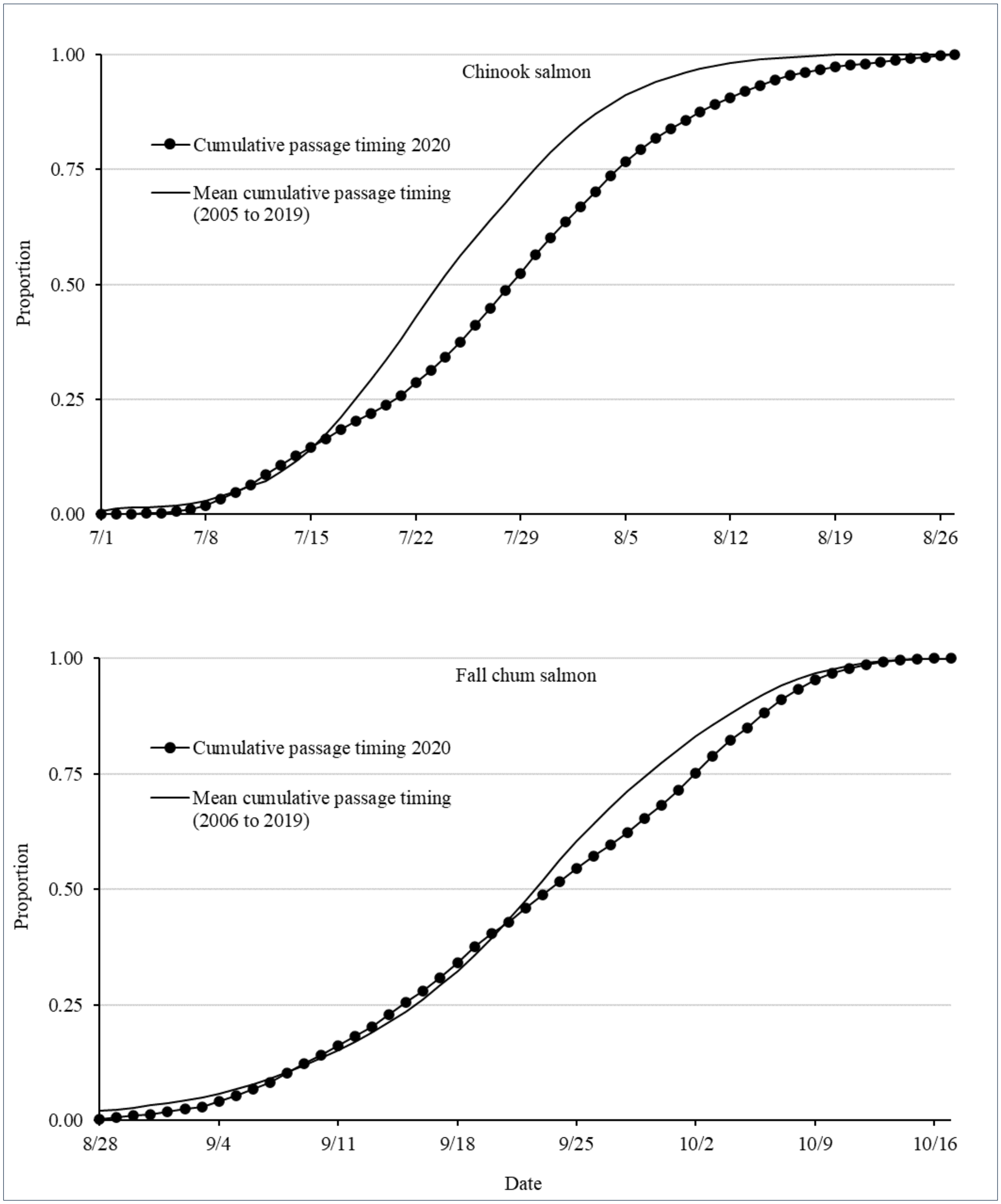

Figure 12.–2020 Chinook (top) and fall chum (bottom) salmon daily cumulative passage timing compared to the 2005–2019 (Chinook salmon) and 2006–2019 (fall chum salmon) mean passage timing at the Eagle sonar project on the Yukon River.

Note: Fall chum salmon cumulative passage timing includes postseason expansion estimates through October 17. The expansion estimate on October 18 was 0 and was excluded from this figure.

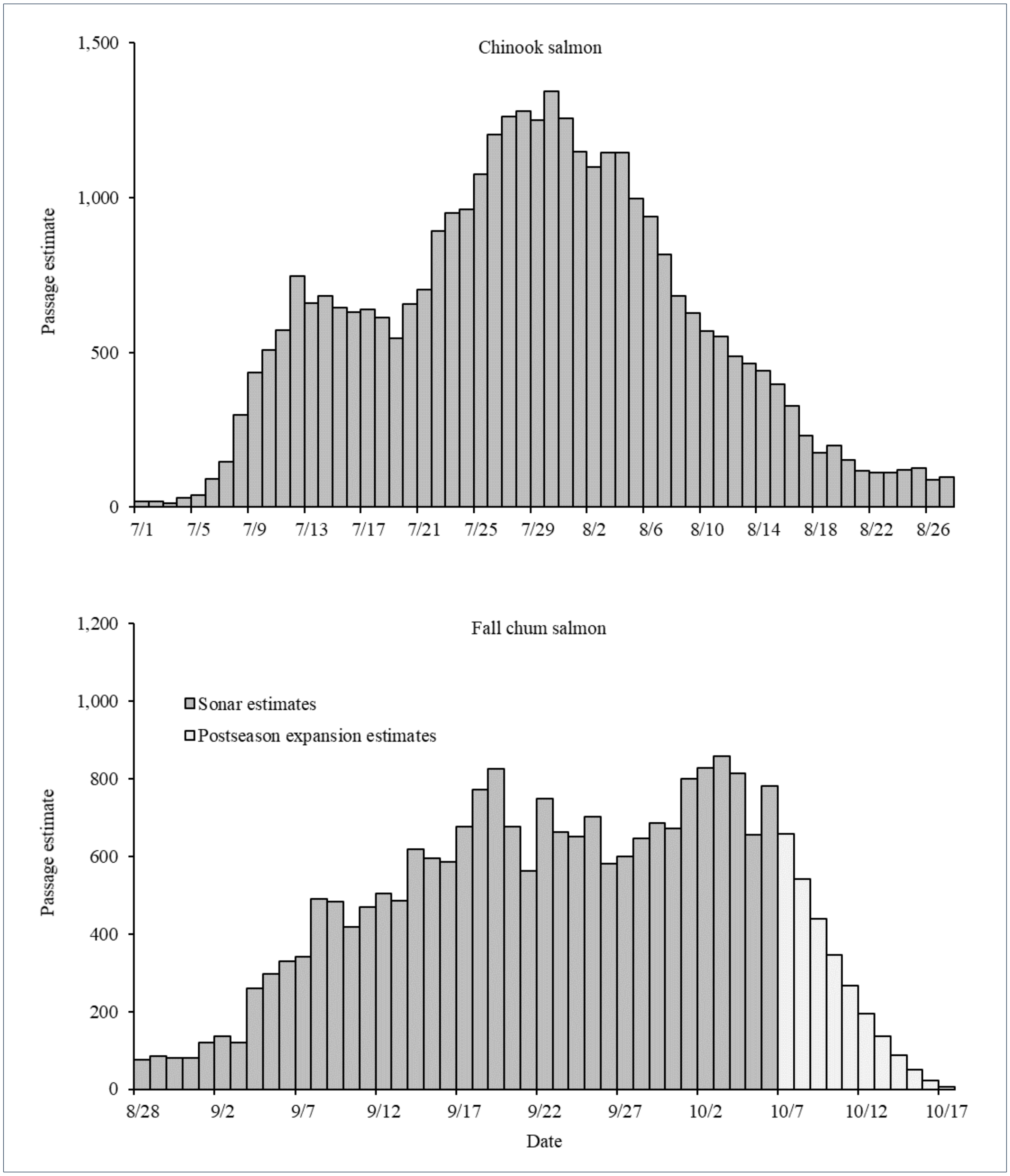

Figure 13.–Daily sonar passage estimates for Chinook salmon (top) from July 1 through August 27 and fall chum salmon (bottom) from August 28 through October 17 at the Eagle sonar project on the Yukon River, 2020.

Note: Postseason expansion estimates were calculated from October 7 through 18. The expansion estimate on October 18 was 0 and was excluded from this figure.

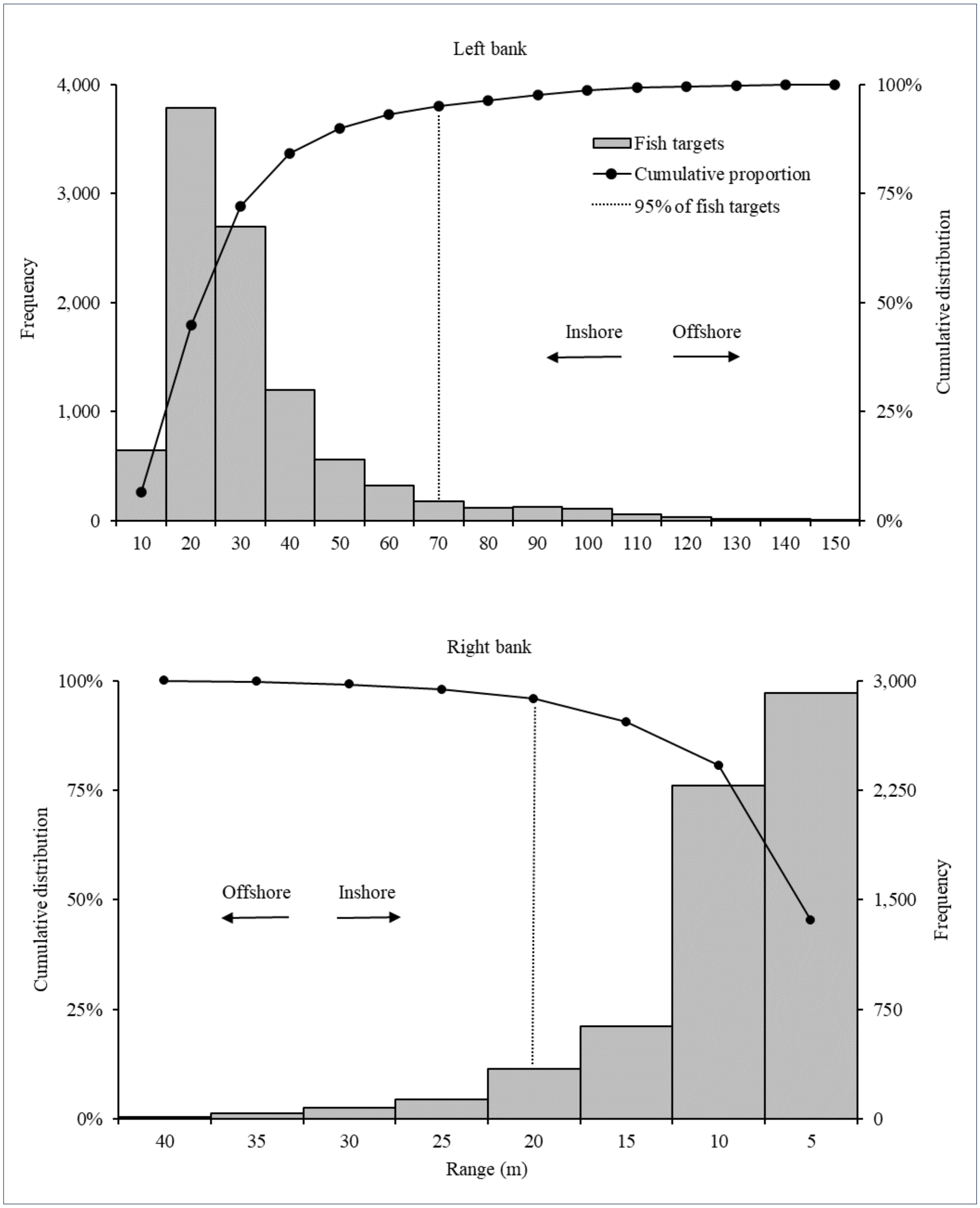

Figure 14.–Left- and right-bank horizontal distribution of upstream migrating Chinook salmon from July 1 through August 27 at the Eagle sonar project on the Yukon River, 2020.

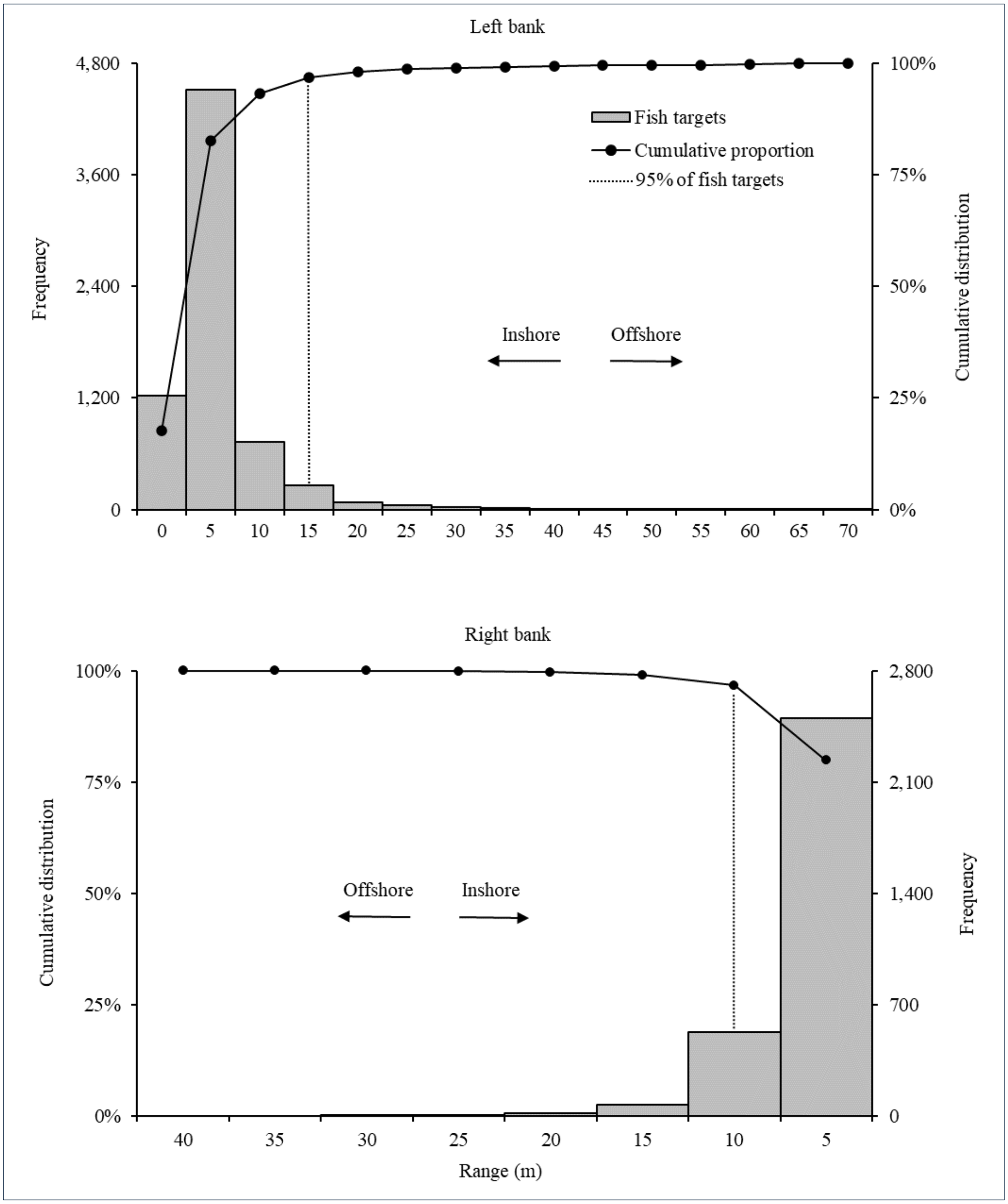

Figure 15.–Left- and right-bank horizontal distribution of upstream migrating fall chum salmon from August 28 through October 6 at the Eagle sonar project on the Yukon River, 2020.

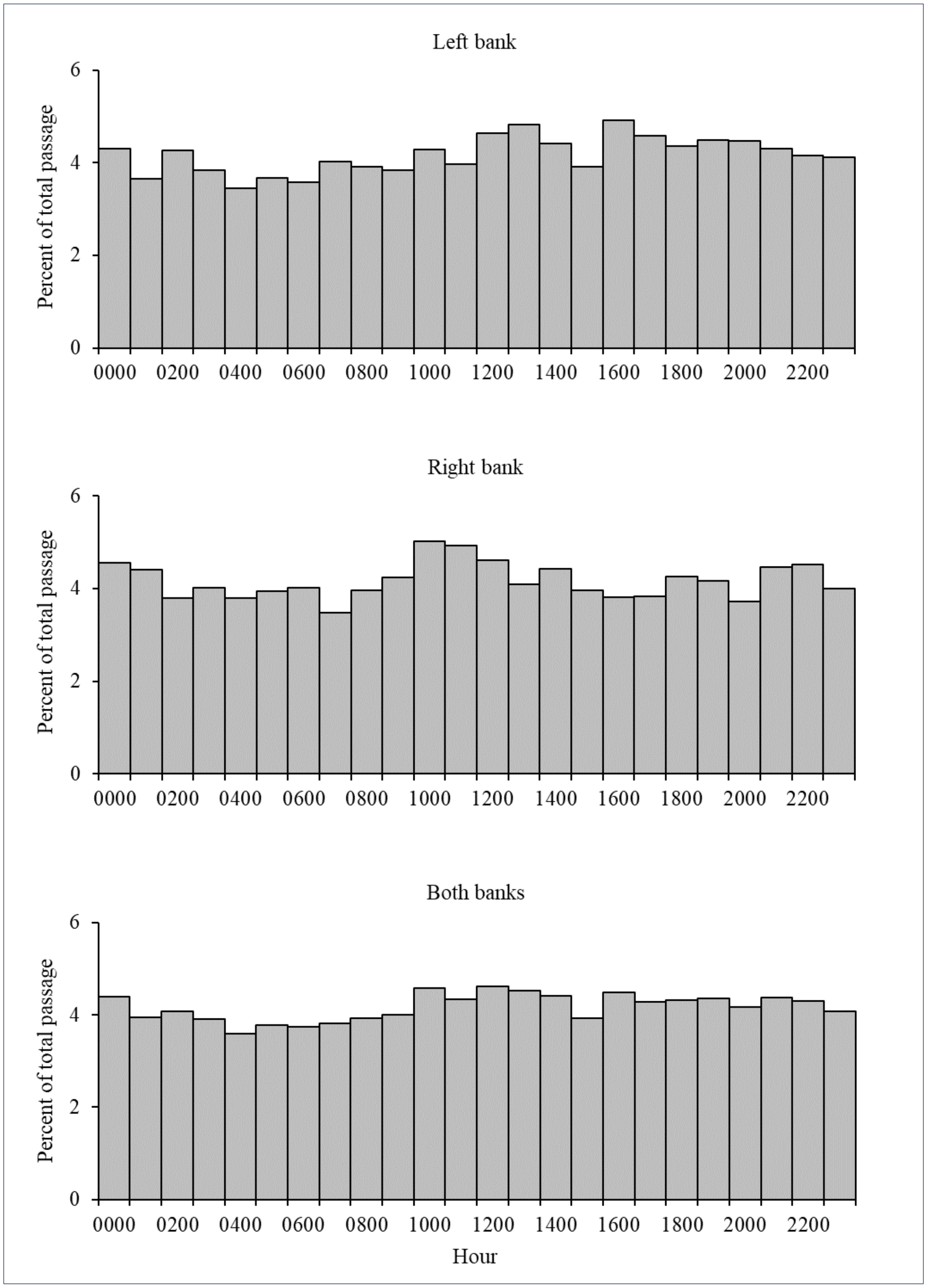

Figure 16.–Percent of total Chinook salmon passage, by hour, observed on the left bank, right bank, and both banks combined from July 1 through August 27 at the Eagle sonar project on the Yukon River, 2020.

Note: Days with missing hourly passage rates were included in the calculations.

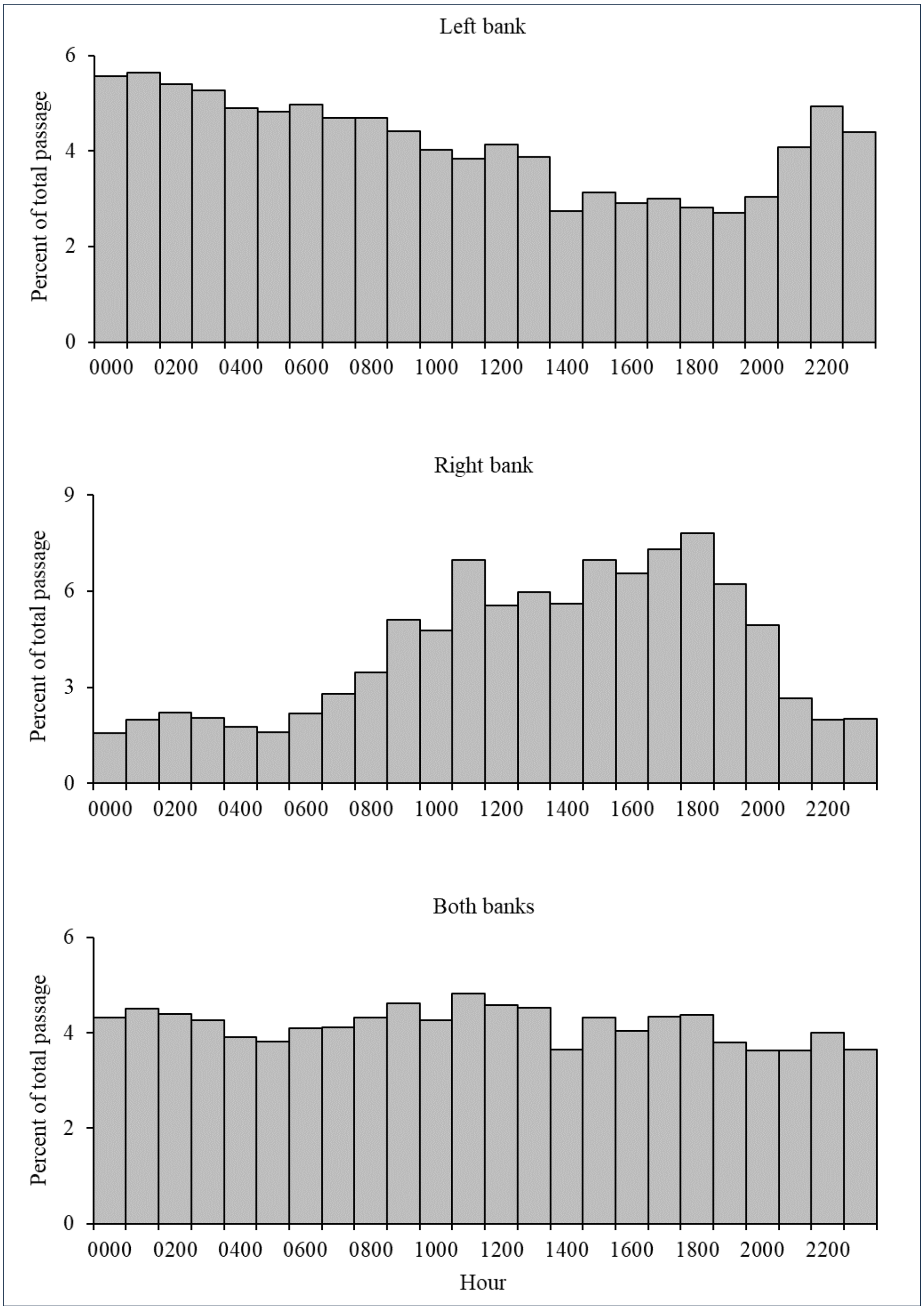

Figure 17.–Percent of total fall chum salmon passage, by hour, observed on the left bank, right bank, and both banks combined from August 28 through October 6 at the Eagle sonar project on the Yukon River, 2020.

Note: Days with missing hourly passage rates were included in the calculations.

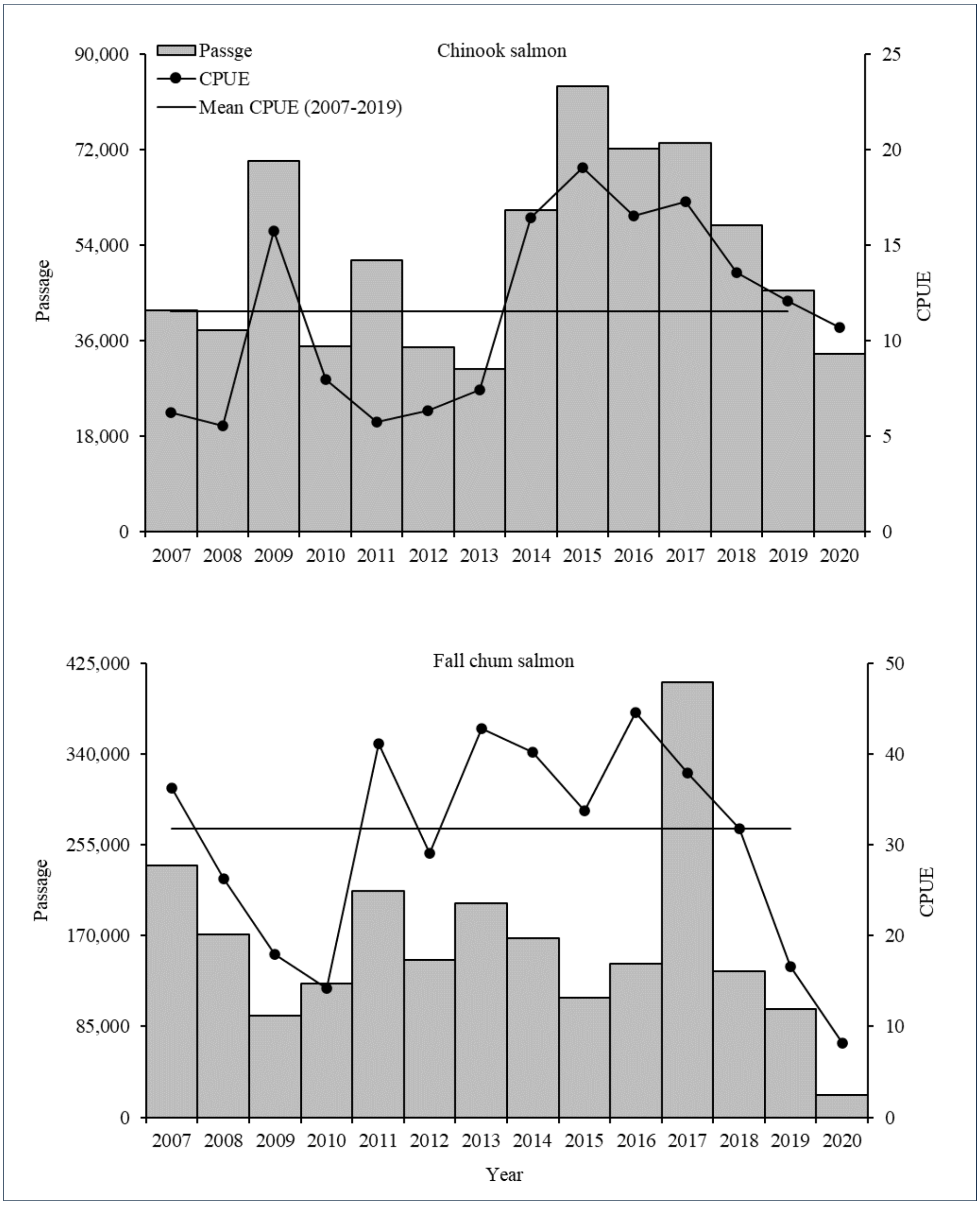

Figure 18.–Chinook and fall chum salmon passage, total cumulative catch per unit effort (CPUE) by year, and mean total cumulative CPUE (2007–2019) at the Eagle sonar project on the Yukon River, 2020.

Note: Because test fishing sites on the right bank have changed several times throughout the project history, CPUE calculations are derived from the left bank test fishery only. Prior to 2013, fish were occasionally released without being sampled to avoid mortalities. For these years, the CPUE only represents fish sampled.

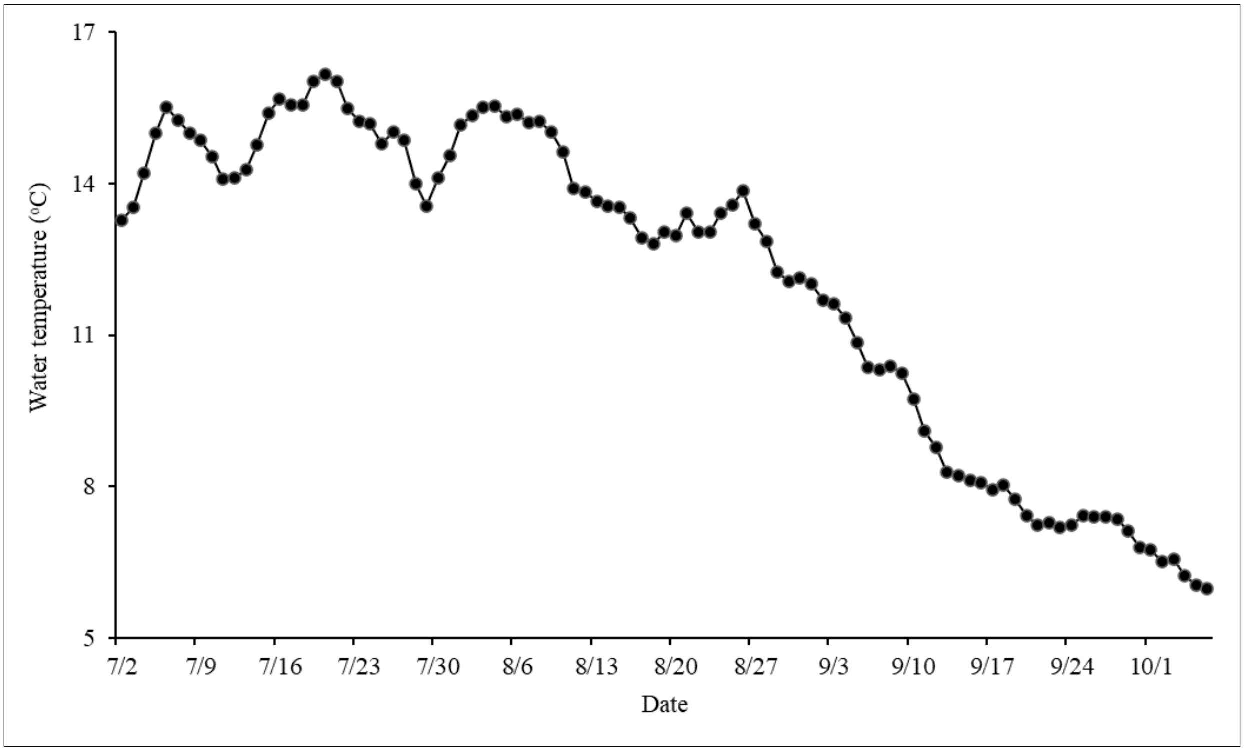

Figure 19.–Median daily water temperature recorded from July 2 through October 6 on the left bank at the Eagle sonar project on the Yukon River, 2020.

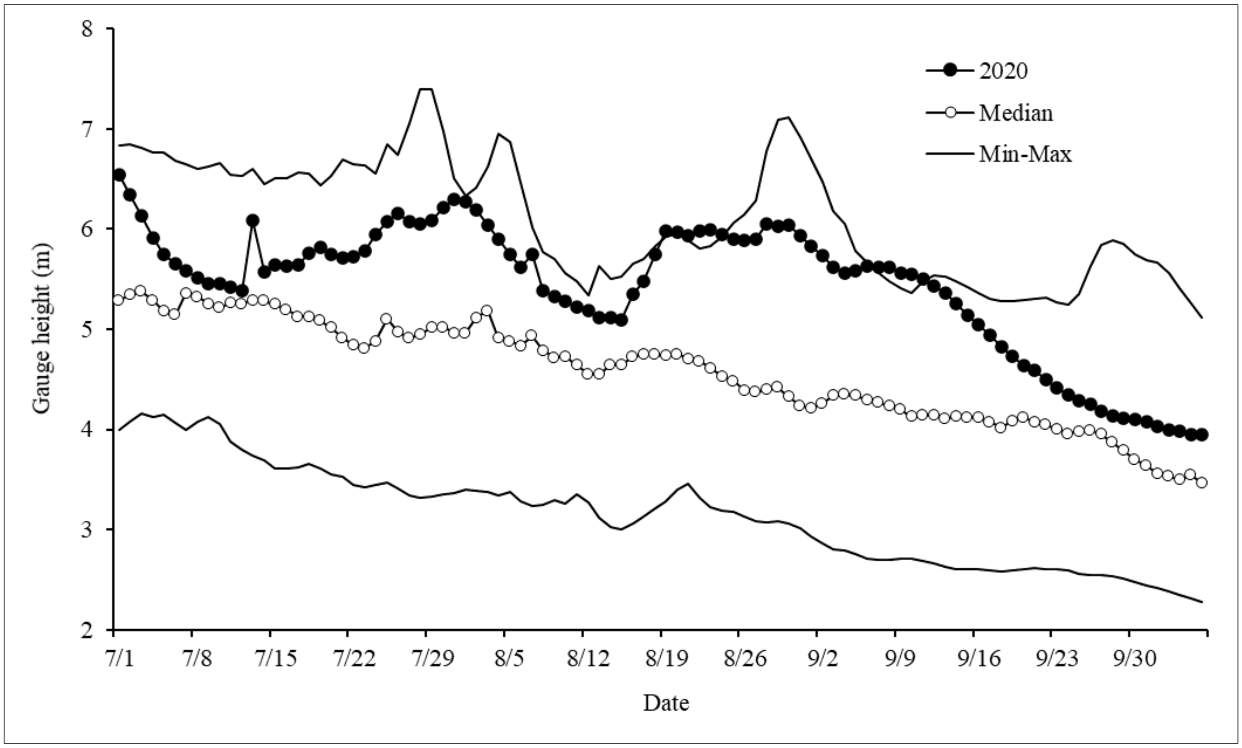

Figure 20.–Yukon River water level recorded daily at 1800 during the 2020 season at the city of Eagle, compared to minimum, maximum, and median gauge height from 1995 to 2019.

Source: United States Geological Survey (USGS gauge (15356000 YUKON R AT EAGLE AK).

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

Appendix A1.–Species composition test fishery catch, catch per unit effort (CPUE), and smoothed data by day and salmon species at the Eagle sonar project on the Yukon River, 2020.

	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
08/01	19.20	12	0.63	8.74	0.48	17.88	0	0.00	0.00	0.00
08/02	17.83	6	0.34	8.13	0.45	17.47	0	0.00	0.00	0.00
08/03	18.32	8	0.44	7.52	0.41	17.23	0	0.00	0.00	0.00
08/04	17.99	6	0.33	6.91	0.38	14.26	0	0.00	0.00	0.00
08/05	17.50	7	0.40	6.30	0.35	16.63	0	0.00	0.00	0.00
08/06	17.88	6	0.34	5.64	0.31	17.24	0	0.00	0.00	0.00
08/07	17.15	6	0.35	5.03	0.28	17.55	0	0.00	0.00	0.00
08/08	16.69	1	0.06	4.45	0.25	16.94	0	0.00	0.00	0.00
08/09	17.49	1	0.06	3.94	0.22	17.68	0	0.00	0.00	0.00
08/10	17.79	3	0.17	3.46	0.20	18.36	0	0.00	0.00	0.00
08/11	17.30	3	0.17	3.08	0.18	16.94	0	0.00	0.00	0.00
08/12	17.94	5	0.28	2.72	0.16	16.60	0	0.00	0.00	0.00
08/13	16.98	2	0.12	2.45	0.14	17.52	0	0.00	0.00	0.00
08/14	16.80	1	0.06	2.20	0.13	17.34	0	0.00	0.00	0.00
08/15	17.84	1	0.06	2.00	0.12	16.87	0	0.00	0.00	0.00
08/16	16.75	2	0.12	1.83	0.11	16.76	0	0.00	0.01	0.00
08/17	17.55	3	0.17	1.64	0.09	17.66	0	0.00	0.02	0.00
08/18	16.77	1	0.06	1.44	0.08	17.14	0	0.00	0.03	0.00
08/19	16.94	1	0.06	1.23	0.07	17.38	0	0.00	0.04	0.00
08/20	18.02	3	0.17	1.05	0.06	17.13	0	0.00	0.10	0.01
08/21	17.02	0	0.00	0.84	0.05	16.42	0	0.00	0.16	0.01
08/22	13.88	0	0.00	0.69	0.04	16.62	0	0.00	0.22	0.01
08/23	16.75	0	0.00	0.55	0.03	17.32	0	0.00	0.28	0.02
08/24	13.81	0	0.00	0.43	0.02	16.58	2	0.12	0.34	0.02
08/25	16.67	0	0.00	0.30	0.02	16.75	0	0.00	0.29	0.02

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Appendix A1.–Page 2 of 3.

	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
08/26	17.18	1	0.06	0.25	0.01	16.66	0	0.00	0.22	0.01
08/27	16.84	0	0.00	0.19	0.01	16.64	0	0.00	0.15	0.01
08/28	16.83	0	0.00	0.15	0.01	17.04	0	0.00	0.16	0.01
08/29	16.73	0	0.00	0.13	0.01	16.75	0	0.00	0.21	0.01
08/30	16.54	0	0.00	0.15	0.01	16.69	0	0.00	0.48	0.03
08/31	16.42	0	0.00	0.14	0.01	16.84	0	0.00	0.93	0.05
09/01	16.52	0	0.00	0.16	0.01	17.24	2	0.12	1.59	0.09
09/02	16.42	0	0.00	0.17	0.01	17.58	1	0.06	2.33	0.14
09/03	17.28	1	0.06	0.17	0.01	16.91	4	0.24	2.97	0.18
09/04	16.66	0	0.00	0.15	0.01	17.15	4	0.23	3.45	0.21
09/05	16.68	0	0.00	0.15	0.01	17.08	6	0.35	3.75	0.23
09/06	16.79	1	0.06	0.15	0.01	17.48	9	0.52	3.90	0.24
09/07	16.93	0	0.00	0.15	0.01	16.73	1	0.06	3.92	0.24
09/08	16.73	0	0.00	0.13	0.01	17.04	5	0.29	4.01	0.24
09/09	16.59	0	0.00	0.12	0.01	17.67	6	0.34	4.11	0.24
09/10	16.50	0	0.00	0.10	0.01	17.51	4	0.23	4.29	0.25
09/11	17.13	0	0.00	0.08	0.00	16.74	2	0.12	4.38	0.25
09/12	16.83	0	0.00	0.05	0.00	17.98	4	0.22	4.48	0.26
09/13	17.33	0	0.00	0.03	0.00	16.64	1	0.06	4.57	0.26
09/14	16.95	0	0.00	0.01	0.00	17.69	7	0.40	4.68	0.27
09/15	16.30	0	0.00	0.00	0.00	18.34	3	0.16	4.76	0.27
09/16	16.73	0	0.00	0.00	0.00	17.87	5	0.28	4.90	0.28
09/17	17.38	0	0.00	0.00	0.00	18.90	5	0.27	5.06	0.29
09/18	17.30	0	0.00	0.00	0.00	18.52	15	0.81	5.24	0.30
09/19	16.68	0	0.00	0.00	0.00	17.56	5	0.29	5.41	0.30

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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
09/20	16.82	0	0.00	0.00	0.00	18.42	8	0.43	5.58	0.31
09/21	17.40	0	0.00	0.00	0.00	16.66	1	0.06	5.69	0.32
09/22	17.00	0	0.00	0.00	0.00	17.17	8	0.47	5.75	0.32
09/23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
09/24	17.58	0	0.00	0.00	0.00	18.63	5	0.27	5.69	0.32
09/25	17.35	0	0.00	0.00	0.00	18.30	10	0.55	5.55	0.31
09/26	18.22	0	0.00	0.00	0.00	17.89	8	0.45	5.34	0.30
09/27	16.44	0	0.00	0.00	0.00	16.96	1	0.06	5.01	0.28
09/28	16.89	0	0.00	0.00	0.00	18.50	5	0.27	4.64	0.26
09/29	16.37	0	0.00	0.00	0.00	16.89	3	0.18	4.24	0.24
09/30	16.74	0	0.00	0.00	0.00	17.39	5	0.29	3.85	0.22

Note: ND means no data.

APPENDIX B: CLIMATIC AND HYDROLOGIC OBSERVATIONS

Appendix B1.–Climatic and hydrologic observations recorded daily at 1800 at the Eagle sonar project site on the Yukon River, 2020.

	Precipitation	Wind		Sky	Temperature (°C)	
Date	(code)[a]	Direction[b]	Velocity (kph)	(code)[c]	Air	Water[d]
07/02	A	NW	6.9	S	16.3	13.3
07/03	A	NA	0.0	B	19.9	13.5
07/04	A	NE	4.0	B	23.8	14.2
07/05	A	SW	1.2	B	21.7	15.0
07/06	A	NW	5.4	S	21.7	15.5
07/07	A	NW	5.4	C	25.4	15.3
07/08	A	N	1.7	C	23.2	15.0
07/09	A	SW	5.4	S	22.1	14.9
07/10	B	SSW	4.1	O	13.0	14.5
07/11	A	SSE	0.8	B	17.9	14.1
07/12	B	NA	0.0	O	19.1	14.1
07/13	B	NE	2.0	S	16.6	14.3
07/14	A	W	3.2	S	25.9	14.8
07/15	A	NW	4.8	C	23.8	15.4
07/16	B	E	1.4	B	16.8	15.7
07/17	B	NW	1.2	B	20.5	15.6
07/18	B	W	1.5	B	18.4	15.5
07/19	A	NW	4.4	S	19.8	16.0
07/20	A	NW	3.8	S	22.6	16.2
07/21	ND	ND	ND	ND	ND	16.0
07/22	B	N	1.4	O	16.0	15.5
07/23	B	NW	1.3	B	19.7	15.2
07/24	B	NA	0.0	B	20.6	15.2
07/25	B	NE	2.4	B	21.9	14.8
07/26	B	NE	0.7	B	18.6	15.0
07/27	C	NA	0.0	F	16.9	14.9
07/28	A	NA	0.0	O	17.6	14.0
07/29	A	NA	0.0	S	20.4	13.6
07/30	A	SE	4.9	F	24.0	14.1
07/31	A	NA	0.0	S	25.3	14.6
08/01	A	SE	5.0	O	21.4	15.2
08/02	B	SE	2.8	B	18.5	15.4
08/03	A	N	0.9	B	22.8	15.5
08/04	A	NA	0.0	S	27.0	15.5
08/05	A	W	0.8	S	22.2	15.3
08/06	A	NA	0.0	C	24.7	15.4
08/07	A	W	0.8	S	20.4	15.2

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Date	Precipitation (code)[a]	Wind Direction[b]	Wind Velocity (kph)	Sky (code)[c]	Temperature (°C) Air	Temperature (°C) Water[d]
08/08	A	NA	0.0	C	20.7	15.2
08/09	B	NW	1.6	B	18.8	15.0
08/10	A	NNW	2.7	B	17.6	14.6
08/11	A	S	3.2	B	18.6	13.9
08/12	A	SW	4.6	B	17.0	13.8
08/13	C	N	2.1	O	16.7	13.6
08/14	A	S	3.5	C	21.9	13.6
08/15	A	NA	0.0	C	19.5	13.5
08/16	A	S	2.3	C	19.4	13.3
08/17	A	NW	1.7	C	20.9	12.9
08/18	B	E	9.0	S	19.3	12.8
08/19	A	NW	3.9	S	21.1	13.0
08/20	A	NA	0.0	B	18.5	13.0
08/21	B	NW	1.9	B	19.1	13.4
08/22	A	E	4.0	B	17.7	13.0
08/23	A	NA	0.0	S	21.8	13.0
08/24	A	NW	5.4	B	20.4	13.4
08/25	A	NW	1.2	O	17.3	13.6
08/26	A	NE	0.7	B	19.2	13.8
08/27	A	SE	3.5	B	15.3	13.2
08/28	A	SE	3.3	S	15.8	12.9
08/29	A	SE	4.0	S	18.0	12.3
08/30	A	SE	2.7	C	17.1	12.1
08/31	A	NA	0.0	O	15.7	12.1
09/01	B	SE	9.0	O	17.4	12.0
09/02	B	S	1.3	O	16.8	11.7
09/03	A	E	6.9	B	13.6	11.6
09/04	B	NA	0.0	O	11.1	11.3
09/05	A	NW	2.1	B	12.5	10.9
09/06	A	SE	10.0	C	15.4	10.4
09/07	A	SE	1.7	S	16.6	10.3
09/08	B	SE	0.4	B	12.2	10.4
09/09	A	NW	0.7	O	13.7	10.2
09/10	A	NW	0.8	S	12.9	9.7
09/11	B	NW	1.9	O	9.8	9.1
09/12	A	NA	0.0	B	13.5	8.8
09/13	A	SE	2.4	C	12.0	8.3
09/14	A	SE	1.4	B	13.1	8.2
09/15	A	SE	2.7	B	13.5	8.1
09/16	A	NA	0.0	S	16.3	8.1

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	Precipitation	Wind		Sky	Temperature (°C)	
Date	(code)[a]	Direction[b]	Velocity (kph)	(code)[c]	Air	Water[d]
09/17	B	SE	9.5	O	16.4	7.9
09/18	A	SE	3.0	B	17.3	8.0
09/19	B	NW	4.4	S	9.1	7.8
09/20	A	SE	3.8	S	8.8	7.4
09/21	A	S	1.8	O	9.3	7.2
09/22	A	SE	3.4	S	10.9	7.3
09/23	A	E	0.8	B	10.2	7.2
09/24	A	SE	6.1	B	9.4	7.2
09/25	A	E	1.1	O	9.6	7.4
09/26	A	SE	0.6	O	9.3	7.4
09/27	B	SE	5.3	O	9.7	7.4
09/28	C	NA	0.0	O	9.1	7.3
09/29	A	NA	0.0	C	12.5	7.1
09/30	A	E	4.5	B	11.3	6.8
10/01	A	SE	3.9	C	14.6	6.7
10/02	A	SE	5.1	S	15.7	6.5
10/03	A	NA	0.0	B	13.3	6.6
10/04	A	SW	1.3	S	9.7	6.2
10/05	C	NA	0.0	B	7.8	6.1
10/06	A	NW	3.8	C	4.7	6.0

Note: ND means no data.

[a] Precipitation code for the preceding 24-h period: A = none; B = intermittent rain; C = continuous rain; D = snow and rain mixed; E = light snowfall; F = continuous snowfall; G = thunderstorm with or without precipitation.

[b] Wind direction code: N = North; S = South; E = East; W = West; V = Variable; NA = Not applicable (no wind).

[c] 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.

[d] Water temperature collected approximately 30 cm below surface with Hobo U22 data logger.